Serbian Society of Soil Science
University of Belgrade, Faculty of Agriculture

BOOK OF PROCEEDINGS

3rd International and 15th National Congress

SOILS FOR FUTURE UNDER GLOBAL CHALLENGES

21–24 September 2021
Sokobanja, Serbia

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FOREWORD

The Serbian Society of Soil Science continues its tradition of hosting conferences, which is one of its primary activities. It organized the 3rd International and 15th National Congress – Soils for Future Under Global Challenges in the International Decade of Soils 2015–2024, collaborating with the University of Belgrade Faculty of Agriculture and under the auspices of the Ministry of Education, Science and Technological Development of the Republic of Serbia, along with sponsors and numerous contributors of papers. Namely, the International Union of Soil Sciences (IUSS) proclaimed the International Decade of Soils 2015-2024. In the Vienna Soil Declaration of 7 December 2015, IUSS recognized the key roles soils play in addressing major resource, environmental, health and social challenges currently facing humanity.

Due to the COVID-19 pandemic, the Congress was held as an online event, in combination with limited physical presence of international and domestic participants who observed the prescribed epidemiological measures and recommendations of the Serbian Government.

The topics of the Congress were grouped into the following four sessions: (i) Soil fundamentals, (ii) Soil-water-plant-atmosphere continuum, (iii) Soil degradation and soil and water conservation, and (iv) Soil and water future socio-economic pathways. The thematic areas were selected to support the distinct efforts of agriculture, and humankind in general, to deal with current resource, environmental, health and social issues.

Growing population pressures, industrialization and intensive use of soil exhaust natural resources and limit the performance of soil functions, such as biomass production, water purification, carbon sequestration, and the like. The additional impacts of climate change, land use changes and the above-mentioned global changes affect the ability of soils to regenerate and even lead to degradation. The future capacity of soils to support life on Earth is in question.

A number of conferences on soil and global changes have been held worldwide over the past several years. Continuing these efforts, we need to keep in mind that the study of soils has changed rapidly. Previously, soil science was seen as supporting agriculture and forestry, and justified by increased soil productivity. However, the focus has recently expanded considerably. Soil science is now a major component of each environmental science course, given that soil plays a key role in elementary natural cycles. Soil pollution is also extremely important, often more persistent than air or water pollution. The impacts of global changes on soils are viewed from a much broader perspective than only several decades ago. However, despite the interest in new fields, the agricultural imperative must not be forgotten. Agriculture remains the main economic purpose of the use of soils and hunger is certainly among the most serious potential disasters set off by global changes.

Ninety-eight contributions were accepted for presentation at the Congress. More than 320 authors and co-authors from 18 countries participated. Fourty contributions from the Congress and included in this Book of Proceedings. They reflect the outcomes of the most recent research of 154 authors and co-authors from 15 countries worldwide. This shows that most of the presentations were a result of teamwork, which not only guarantees a comprehensive approach, but also quality.

Seven distinguished domestic and international professors and scientists prepared the keynote speeches. The submitted papers are available on the website of the Serbian Society of Soil Science (https://congress.sdpz.rs). The contributions contained in this Book of Proceedings have been reviewed by international peers.

An excursion completed the program and content of the Congress. It included showing of four soil profiles of the dominant soil types in the Sokobanja area, including Calcomelanosol, Brownized Calcomelanosol, Calcocambisol and Vertisol, under different land uses (native meadow, devastated native pasture, native forest and intensive apple orchard).
It is our wish to see all the positive outcomes of the Congress implemented in due course, along with recommendations of scientists and professionals. This would fulfil the objective of the Congress in the best possible way. The permanent legacy of the Congress should be the inclusion of soil in the core of policies that support environmental protection and sustainable development.
In closing, I wish to express once again my sincerest gratitude to all who contributed to the publication of this Book of Proceedings.

September 2021 in Sokobanja

Prof. Dr. Boško Gajić

President of the Serbian Society of Soil Science
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PLENARY LECTURES

CONTENT AND SCOPE OF PEDOLOGICAL RESEARCH FOR FOREST SITES MAPPING

Olivera Košanin*, Rade Cvjetićanin, Marko Perović, Janko Ljubičić, Milan Knežević

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Abstract

Forest sites mapping is an innovative concept of forest division in Serbia, although this method has been used in Western Europe for decades. It is based on the selection of types of forest sites, which represent homogeneous units in terms of ecological and production characteristics, which are exposed to approximately the same hazards and risks and to which the same management treatments are applied. The mapping method itself is based on the overlap of digitalized thematic maps: geological, pedological, maps of climatic conditions (temperature, precipitation, etc.), maps of soil properties (water and nutrient regime), geomorphological maps, maps of current and potential vegetation, etc. Given the sectoral inconsistency and the unavailability of appropriate digital maps, the primary sites mapping method used in Germany could not be implemented in Serbia. Having in mind the insufficient study of forest soils in Serbia, an integral and at the same time the most important part of the methodology, are detailed pedological studies. The methodology used was developed by the joint work of a team of Serbian and German experts and included existing available maps and data, but also the results of detailed field studies of land, sites and vegetation. In forest soils, in contrast to agricultural lands, physical properties (depth, mechanical composition, porosity, etc.) are of much greater importance for the survival of tree species, because the water regime of the soil depends on these characteristics. Serbia is a moderately-forested country, with a forest cover of 29.1%, which is close to the world average but significantly below the average European forest cover (46%). In the next 70 to 100 years, great changes are expected in Serbia, primarily in the composition of tree species and the appearance of new types of forests. However, what is a big problem today is the speed and intensity of climate change. Forests simply do not have enough time to adapt, which leads to their drying and decay. Precisely one of the basic goals of forest sites mapping is to create a database on water balance and soil nutrient regime. Based on soil characteristics, it is possible to predict changes in accordance with projected estimates of climate change (temperature and precipitation). This method of assessment gives the possibility of timely selection of species whose ecological conditions correspond to the projected climate conditions. The characteristics of the soil of an area are placed in the center of the division, because the properties of the soil, primarily its ability to retain water, have been singled out as a key factor in the survival of a certain type of vegetation. The trend of climate change in our country, according to most scenarios, is changing in the direction of increasing the average annual temperature, uneven distribution of precipitation during the year, more frequent and longer dry periods and more. This concept has been implemented and tested in the area of the Mt. Boranja massif located in NW Serbia. The

study covered the belt of hilly and mountain beech forests, on three geological substrates: granodiorite, phyllite and limestone.

Keywords: Mapping, Mt. Boranja, Soil, Vegetation, Site types

INTRODUCTION

Forest sites mapping is an innovative concept of forest division, and first version of the methodology was developed by the joint work of experts dealing with forest sites in Germany and Serbia, while implementation, testing and improvement are still going. In Serbia, for several decades, as a basis for the division and planning of forest management, a classification based on forest types has been used: Jović et al. (1990, 1991, 1996); Jović and Medarević (1991); Banković et al. (2003); Medarević et al. (2003), Medarević and Milošević (2005) and others. The typological classification of forest area is performed in two phases. The first phase consists of ecological-biological studies, while the second phase consists of production studies of forest stands. To single out forest types, it is necessary to hire highly qualified staff, which is considered a disadvantage of this method for wider application.

The concept of forest sites mapping is based on the recommendations of the German Forest Mapping Working Group of the German Forest Management Planning Agency „AG Standortskartierung in der Arbeitsgemeinschaft Forsteinrichtung (Forstliche Standortskartierung, 6. Auflage, 2003)", implemented and tested methodology used for mapping forest sites in Montenegro (Reif et al., 2016) as well as a recommendation of the mapping system used in Hesse (Grüneklee, 2016).

The main goal of mapping forest sites in the proposed way is to develop, test and implement a modern, innovative methodological approach to improve the ecological database for sustainable forest management and conservation of forest ecosystems with special focus on scarce data and development of guidelines for mapping forest habitats (Košanin et al., 2017). The concept is based on the use of GIS tools, and the mapping itself has two dimensions: scientific and practical. The scientific dimension refers to the methodology of studying, collecting and classifying data on habitat factors. Most importantly, the mapping system should be simple and applicable to non-scientific staff, in other words to be clear and easily applicable to the forestry profession and forest management companies (e.g. PE „Srbijašume", PE „Vojvodinašume", National parks, etc.). The method in its original form, in the conditions of Germany, is based on the overlap of digitalized thematic maps: position (exposure, slope, altitude, relief), climate (temperature and precipitation), vegetation (current and potential) and soil- geology. In the conditions of Serbia, where there is no digital map of all site factors in the available form (missing or expensive), as well as systematized ecological studies of most forest complexes, detailed research and formation of available databases are a very important segment.

The basic unit in mapping is the site type that represents an area that is characterized by approximately the same: ecological conditions, risk exposure, as well as economic and production values. Existing habitat classifications (EUNIS Habitat Classification; Natura

2000 European Union Habitats; Corine Land Cover Classification, etc.), give a rather rough division of site units. For example, in the Corine Land Cover Classification, forest sites are divided into: Broad-leaved forest, Coniferous forest and Mixed forest, which represents a very rough division of forest ecosystems. Stevanovic et al. (1995), provide site classification from a theoretical point of view for the needs of biologists, relying primarily on vegetation characteristics. It is similar with the EUNIS classification, which, although it singles out a larger number of forest sites, is based on the characteristics of vegetation. Forest sites mapping is a method of detailed study of forest sites, which includes a large number of replications and includes the study of all ecological conditions on one type of geological base. Also, this method includes a whole set of important data on the site and is intended for the needs of solving practical problems in forestry. At the same time, it is a kind of database that can be corrected, supplemented and available to different users.

Site type is the result of the mutual influence and action of climate, relief, soil and vegetation. Sites belonging to the same type are exposed to the same risks, are approximately the same profitability, e.g. productivity, and approximately the same forest-breeding options are applied to them. The concept was tested for the first time in the Republic of Serbia on Mount Boranja, more precisely on the management unit (MU) „Istočna Boranja" on a relatively small and ecologically homogeneous area of 254.76 ha, on a granodiorite geological base (Košanin et al., 2017). The implementation of the concept on the same mountain massif is in progress, but the research includes forests on phyllites and a complex consisting of limestone, sandstone and clay shale. One of the basic goals and tasks is to improve information on the characteristics of forest land, to develop a publicly available database of ecological geo-data on forests, to improve the methodology itself and the existing mapping guidelines (Košanin et al., 2017).

For the purpose of mapping forest sites, it is favorable if there are digitalized maps of: basic climate elements, potential and current vegetation, geological material, soil types, soil reactions, soil water and other soil properties. For forest areas of Serbia, especially mountainous ones, there are generally no detailed and systematized soil studies. Monitoring of forest health in the Republic of Serbia in the 16x16 km network (Kadović et al., 2004) is the first systematized study, which enabled the formation of a significant platform for the exchange of expert knowledge, which included the collection of detailed data on soil and forest ecosystem health.

A very important segment in the mapping of forest sites are edaphic characteristics. Today, pedological maps made for the needs of agriculture during the second half of the 20^{th} century are used in Serbia, because little was known about soil as a habitat for agricultural crops after the end of World War II. Forest areas are much less explored, ie mapping was performed on the basis of a small number of profiles and has an orientational character (Manojlović et al., 1997). Also, in general, in Serbia there are only maps of soil types, although for the purpose of mapping forest sites as well as for assessing soil functions and providing support to decision makers, it would be very important to have an available database of soil ecosystem properties and appropriate soil properties maps, for example pH value, soil organic carbon, cation exchange capacity, etc (Costa et al., 2020).

IMPLEMENTATION OF FOREST SITES MAPPING METHODOLOGY IN THE REPUBLIC OF SERBIA

The implementation of the forest sites mapping methodology was performed, in two phases, in the pilot area located on the Mount Boranja, the MU „Istočna Boranja”, whose total area is 4,103.73ha (Figure 1). The first phase of the study, which was realized in the period 2016-2017, included a part of the MU on granitoid rocks. The second phase of the study includes shale sites and a complex consisting of limestone, sandstone and clay shale, and is still in progress.

Mount Boranja belongs to a group of low mountains located in the area of northwestern Serbia and represents the northernmost mountain of the Dinaric system towards the Pannonian Plain (Cvijić, 1924). The formation of the Mount Boranja relief was greatly influenced by the abrasion by the waves of the Pannonian Sea, and later by intensive erosion processes. The highest peak is the Košutnja stop (939m), and the lowest point is at 200m. The terrain is intersected by numerous streams and slopes. Steep terrains prevail, especially in the northern and northwestern part of the complex, while the southern part of the complex is mostly of a milder slope.

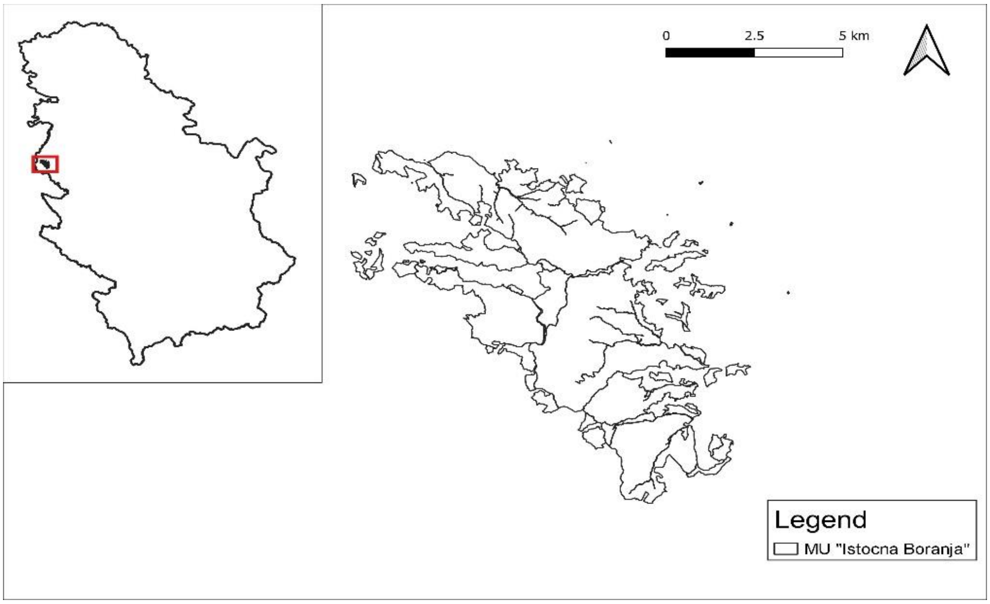

Figure 1. Geographical position of the research site of the MU „Istočna Boranja”

Most of the terrain is exposed to the north. The main mass of Boranje consists of granitoid rocks, and around them there is a zone of contact-metamorphic rocks: diabase-corneas, limestones, quartz conglomerates, shales, sandstones, dacites and in the vicinity of Mali Zvornik (Voljevica river basin), a narrow zone of serpentines and serpentinites (Milovanović and Ćirić, 1968). In the area of the Mount Boranja massif, more than 1000mm of water sediments fall annually. In the pluvimetric regime, two maxima are clearly distinguished, the first is in May, and the second in October. The least precipitation is during the winter months (January and February). During the summer months (June, July and August), an average of 300 to 450 mm of water sediments fall. The studies were conducted in one of the most productive and best preserved mountain beech forest complexes in Serbia, which was a key factor in the selection of the MU „Istočna Boranja“, for testing and implementation of forest sites mapping methodology.

CONCEPTUAL SCHEME FOR SITE MAPPING

The conceptual scheme which is used as a basis for data collection and mapping, should also include all relevant data and enable the system of landscape units to be as homogeneous as possible in terms of its characteristics. It is very important that the choice of the conceptual scheme is adjusted to the available data. Thus, for example, in the area of lowland forests of Vojvodina, it is more appropriate to use a conceptual scheme based on the combined Hessen principle (Figure 2.) (Grüneklee, 2016). The following are used as input data for the scheme: climate, vegetation and soil, where the conceptual scheme does not include the influence of the relief, because the relief is flat.

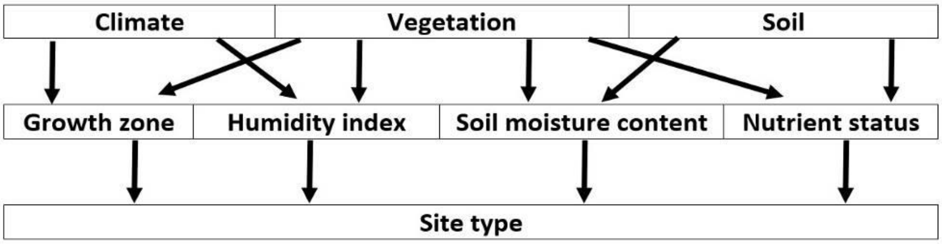

Figure 2. Relationship between site factors in lowland terrain

The impact of relief on forest ecosystems located in hilly and mountainous areas is very important, so the conceptual scheme shown in Figure 3 is used in the mapping process.

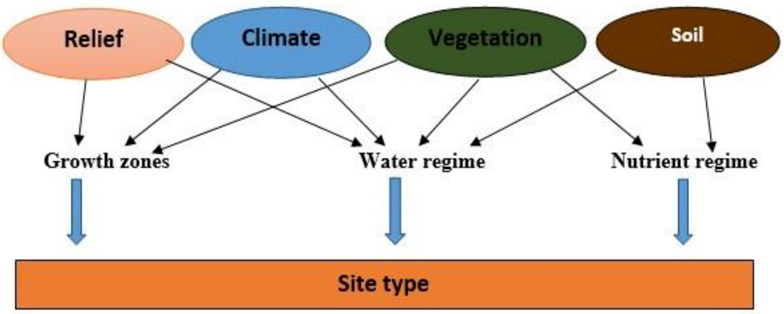

Figure 3. Relationship between habitat factors in a hilly-mountainous area

The integrated concept of forest habitat mapping in Serbia includes the following phases of work:

1. preparation of initial thematic maps and their digitalization;
2. defining representative sites for field studies and sampling;

3. detailed field studies of soil, vegetation and site;
4. laboratory tests (preferably if possible);
5. integrating study data;
6. identification of site types;
7. efficient spatial prediction.

PREPARATION OF INITIAL THEMATIC MAPS

For the purpose of mapping forest sites, thematic maps in digital form are necessary: geological materials, climatograms (temperature, precipitation, relative humidity, etc.), digital terrain model (30m), soil types, soil reactions, water and other soil properties. However, having in mind the fact that in Serbia there are certain problems related to obtaining digital thematic maps, as well as inter-institutional asynchrony, the mapping methodology solves this problem in the way shown in the conceptual scheme presented in Figure 3.

As a starting point for the selection of forest sites types, it is necessary to create 3 maps with the help of GIS tools: a map of growth zones, a map of water balance and a map of the nutrient regime. By overlapping the obtained layers, their analysis, drawing boundaries and applying appropriate classifications, the types of forest sites are distinguished. Growth zones are conditioned by climate and relief, and are allocated on the basis of the available amount of heat in one site, based on the average annual temperature and the average temperature in the vegetation period. Soil water balance is a very complex property that is conditioned by the relationships between climate, soil and relief, while the nutritional regime largely depends on soil characteristics, type of plant community and their mutual interaction.

DEFINING REPRESENTATIVE LOCALITIES

Creating statistical models of soil maps with acceptable accuracy requires a large number of samples. In order to achieve high accuracy, it is necessary to open a minimum of 4 soil profiles per each change (Reif et al., 2016): relief- geomorphone shape (10 classes) Schoeneberger et al., (2002), Wysocki et al., (2011), Jasiewicz and Stepinski (2013), exposure (3 classes: warm, cold and transitional), terrain slope (3 classes: flat, ≤30°,>30°), parent material. Distance and accessibility for field studies and sampling can be a major problem (Costa et al., 2020), but the level of implementation costs should not be neglected either. In the case of very steep and difficult terrain, field studies and sampling can be realized by the method of transect- movement in a straight line along a predefined azimuth. In order to achieve both goals, a scheme of collecting samples with non-overlapping fields measuring 500x500m was developed, while the selection of fields is done using an Excel table by random selection of samples using GIS.

DETAILED FIELD STUDIES OF SOIL AND SITES

National soil survey manuals can be used primarily for soil classification and determination. In Germany, soil description and classification are done by:

Bodenkundliche Kartieranleitung „KA5“ (Ad-hoc-AG Boden, 2005), Forstliche Standortsaufnahme (AK Standortskartierung, 2003, Bodenzustandserhebung im Wald (BZE II), Chapter V (BMELV, 2006). In Serbia, manuals are used for the description and study of soil: Chemical methods of soil testing (Bogdanović et al., 1966), Methodology of field soil testing and production of pedological maps (Filipovski et al., 1967) and Methods of research and determination of physical properties of soil (Bošnjak et al., 1997). The Soil Classification of Yugoslavia (Škorić et al., 1985) and the IUSS Working Group WRB (FAO, 2006) were used for land classification. The field guide used to map forest sites is a synthesis of several field guides, but is mostly based on FAO documents. Pedological studies can be realized through field and/or laboratory studies. It is important that the description of the soil in the field is done in detail. A good description of the soil and the acquired knowledge about the genesis of the soil and its ecological characteristics, can largely replace the extensive and expensive laboratory work, and can also prevent errors in soil sampling. The soil is studied with a minimum set of parameters. For field studies of soil and description of site conditions, the following are used: Field guide (Caspari and Schack-Kirchner, 2008), which was created by synthesizing several field guides, but is mostly based on guidelines for soil description (FAO, 2006) as well as the Methodology of field soil testing and production of pedological maps (1967), which was accepted by the Serbian Society for the Study of Soil and is used in Serbia.
The experimental area on which data on site, soil and vegetation are collected is rectangular in shape with dimensions of 5x20 m. The longer side of the rectangle is placed on the ground parallel to the isohypses of the terrain. The pedological profile is opened from the lower side of the experimental area, in the middle of the longer side (Figure 4.).

Figure 4. Experimental area

The description of the soil is best done using a freshly opened soil profile, approximately 1m wide and 1m deep (or until the parent material appears). If the profile is dry, it must be moistened before the description with a spray bottle. The following accessories are required for field scientific work on soil: field guide, data entry manual, Munsell color atlas, topographic and geological maps, profile digging tool, knife, meter, field pH meter or pH indicator paper, 10% hydrochloric acid solution, water spray bottle, camera, altimeter, GPS and magnifier.
Field studies include a description of the site and the profile itself. Site description includes determination of: GPS coordinates, profile number (ID), date, location in the field, geographical name of the locality, altitude, exposure, slope, surface stiffness (%), karst relief (%) and soil type. Profile description includes determination of: morphogenetic structure of profiles, horizon powers (cm), O_l, O_f, O_h layer powers, physiological depths,

soil textures, Munssel Soil Color Charts, geological substrate type, soil bulk density, skeletal content (%), pH value in water, humus content (%), calcium carbonate content (%). The results of field research are entered in the appropriate manual.

In order to achieve greater accuracy of the results, soil sampling by genetic horizons can also be performed. The following properties are determined: the content of hygroscopic water (drying in an oven at a temperature of 105°C for 6 to 8 hours); granulometric composition (treatment of samples with sodium pyrophosphate, soil fractionation was performed by combining pipette method and elutration method using Atterberg sieve, with the determination of the percentage of fractions of: 2-0.2mm, 0.2-0.06mm, 0.06-0.02mm, 0.02-0.006mm, 0.006-0.002mm and less than 0.002mm); the triangle of the American Pedological Society is used to determine the textural classes of soil; active and substitution acidity (pH in H_2O and in 0.01M $CaCl_2$, electrometrically using pH meter); hydrolytic acidity (Y1 cm^3, after Kappen); the sum of adsorbed base cations (S in $cmol*kg^{-1}$, after Kappen); total adsorption capacity for cations (T in $cmol*kg^{-1}$, calculated); sum of acid cations (T-S in $cmol*kg^{-1}$, calculated via hydrolytic acidity); degree of soil saturation bases (%, after Hissink); humus content (%, Tyurin method in Simakov modification); total nitrogen (%, after Kjeldahl); carbon to nitrogen ratio (C:N, calculated) and readily available P_2O_5 and K_2O (mg/100 grams of soil, after Al method).

The properties of the soil, which are described in the field phase of the work and examined in the laboratory, aim to better understand the genesis, define the properties and determine the type of soil in the form of quantitative values.

INTEGRATION OF DATA OBTAINED BY THE STUDY

Pedological studies play a very important role in forest sites mapping. According to the existing soil map (Tanasijević et al, 1961), which was made on the basis of the basic geological map, the area of the Mount Boranja massif is dominated by Dystric Cambisol, while very small areas have podzolic and leached subtypes, as well as only leached soil-Luvisol (Figure 5).

Soil properties are of great influence and importance for the production of maps of water balance and nutritional regime of soil. Soil water content and plant water availability are the result of water balance resulting from the hydrological cycle within a particular ecosystem (Armbruster et al., 2004). The individual components of the water balance (Kutílek, 1978) are subject to external influences, mainly climate and topography, and internal influences which are conditioned by the composition and properties of the soil as well as the characteristics of the vegetation. A large number of tables and diagrams for assessing the ability of soil to retain water, based on certain physical characteristics of the soil, for the purposes of mapping are found in the work of Dehner et al. (2015).

Based on the results of field studies, the amount of water available to the soil in the zone of the root system of plants is estimated, ie the available water capacity- AWC. AWC is highly dependent on soil texture which is a key element of the assessment. Only a person with extensive experience can assess the available water capacity in the field. To obtain high reliability results, it is desirable to determine the granulometric composition of the soil by laboratory analysis. Soil properties that can also be determined by laboratory analyses are: skeletal content, humus content and soil bulk density.

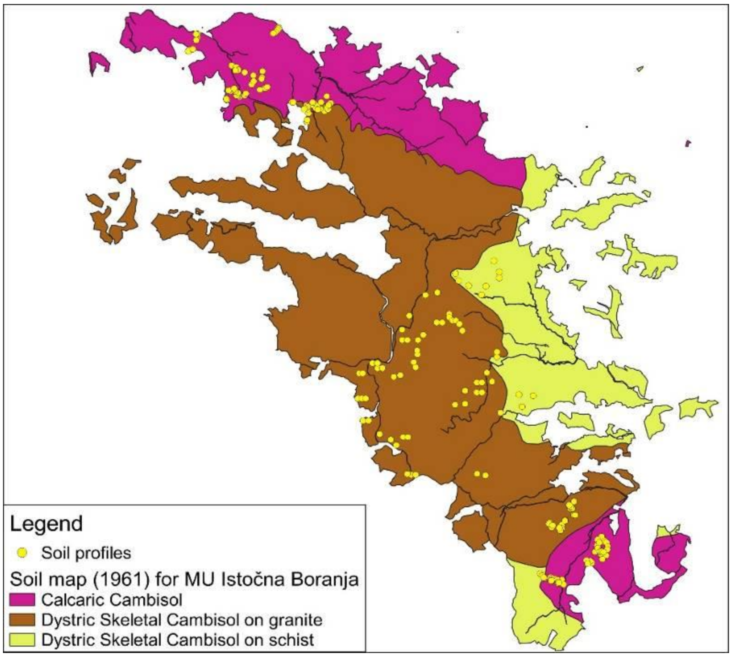

Figure 5. Pedological map of MU „Istočna Boranja“ with the position of the profiles

AWC is determined for each horizon based on: texture, skeletal content, soil density, and humus content (Caspari and Schack-Kirchner, 2008). If the determination of AWC is performed in the field, the texture class is estimated by „finger test” in the dry state of the soil (according to Kaczynski's field method), and by the method shown in Figure 6, it translates into texture classes used in the German classification. German texture classes are used as an input to Table 1 (assuming the bulk density of the soil ranges from 0.8 to 1.4 g/cm^3) from which the AWC value is read which is then corrected with the values for humus content (h2, h3, h4, h5), whose classes are assessed in the field based on color.
AWC values (Table 1) are corrected by skeletal content and horizon depth by the following functions (Caspari and Schack-Kirchner, 2008):

$$AWChorizon = AWCtab * \left(1 - \frac{skeletal\ content(\%)}{100}\right) * depth$$

To the obtained AWC values, tabular readings of corrections for humus content calculated on the horizon capacity are added. Finally, the obtained AWC values are summed by horizons and the AWC profile is obtained.

$$AWCprofile = AWChorizon_{n1} + AWChorizon_{n2} + \cdots AWChorizon_{n}$$

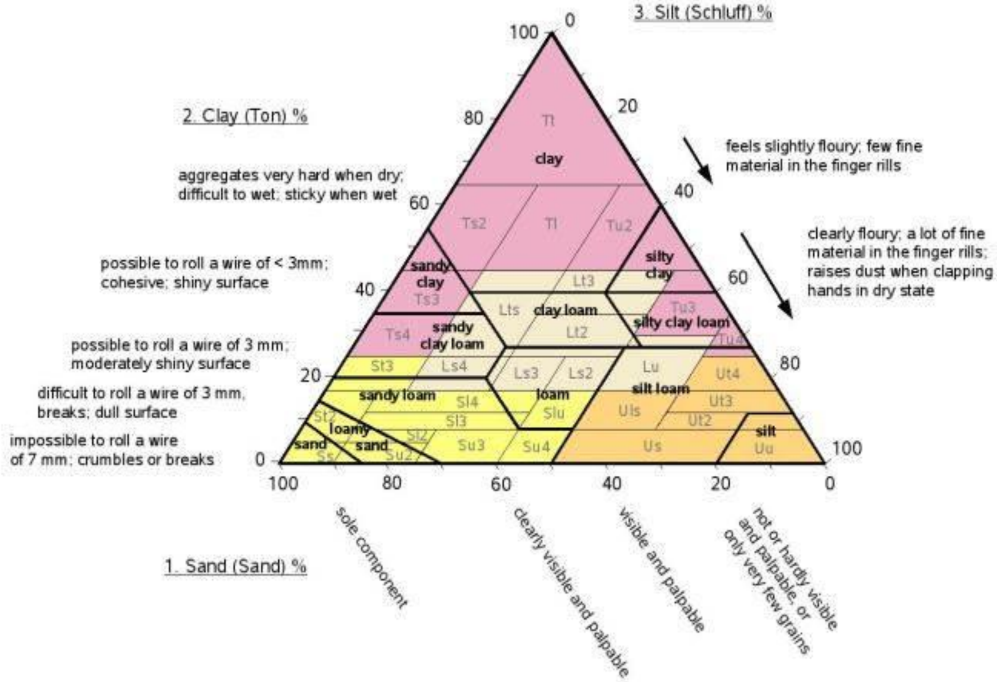

Figure 6. Soil texture triangle with FAO (black line) and German (gray line) texture classes. In the German system S (s) = sand, U (u) = silt and T (t) = clay (clay)

Soils of light mechanical composition, rich in skeletal fraction, have a smaller field water capacity, because they have a high share of non-capillary pores from which water is subject to free drainage. Soils rich in silt and clay fraction, with a fine texture, have a larger volume of capillary pores that retain water against the influence of gravitational force, which results in a relatively higher value of field water capacity. However, compared to well-aggregated loam and silt loam, the available field water capacity in heavy clay soils is lower, so the amount of available and available water to plants is lower (AWC).

The skeletal fraction reduces the available soil water capacity in proportion to its volume, unless the rocks are porous. The depth of the soil and the layers that limit the development of the root system affect the total AWC, because they can limit the volume of soil available for root growth (restrictive layers, they can be of natural or anthropogenic origin). Humus also acts as a permeable filter with high hydraulic conductivity after being soaked with water. One of the specifics of forest ecosystems is the formation of forest mats or litter, which has a key and irreplaceable role in terms of nutrient supply and which has a great impact on the water regime (Miderman, 1960), because it absorbs several times more water than mineral horizons below and at the same time reduces water losses in the soil. Indirectly, organic matter improves soil structure and aggregate stability, resulting in increased pore size and total volume, also improving soil quality by increasing infiltration, soil water movement, and available water capacity. Humus is characterized by the ability to retain water better compared to mineral soil, which largely depends on the type of plant community (Hao et al, 2019). According to Gajić et al., (2008) forest lands have 2.5 times higher infiltration rate compared to meadow and 6 times higher than cultivated lands, and they can also accept and store more available water than meadow and cultivated lands in surface 45cm. The values of volume specific mass are significantly lower under forest in relation to lands that are cultivated or used as meadows.

Table 1. Estimation of total air capacity (AC), available water capacity (AWC), field water capacity (FC) and dead water (DW) based on soil texture classes; table simplified for bulk density ranging from 0.8 to 1.4 g/cm^3

Texture Class (see Fig.6)	Air capacity (AC) in Vol.% pores > 50 µm pF < 1.8	Available water capacity (AWC) in Vol.% pores 0.2-50 µm pF=1.8-4.2	Field capacity (FC) in Vol.% pores ≤50 µm pF ≥1.8	Dead water (DW) in Vol.% pores ≤0.2 µm pF ≥ 4.2	Correction of AWC based on humus content (Add these numbers to your AWC result)			
					h2	h3	h4	h5
Ss	36	9	14	5	1	3	4	5
Sl2	23	20	28	8	2	3	4	6
S13	18	22	34	12	1	3	4	6
S14	18	22	36	14	2	4	5	6
Slu	14	23	38	15	1	2	4	6
St2	24	18	26	8	3	4	5	7
St3	18	18	35	17	2	4	6	9
Su2	24	20	26	6	2	3	4	6
Su3	17	25	35	10	1	3	3	4
Su4	14	27	39	12	1	2	3	4
Ls2	13	21	40	19	1	3	5	8
Ls3	15	21	39	18	1	3	5	8
Ls4	15	20	39	19	2	4	6	8
Lt2	11	18	42	24	3	5	8	10
Lt3	8	17	45	28	2	4	8	11
Lts	10	17	44	27	3	5	7	9
Lu	12	21	41	20	3	5	7	8
Uu	10	30	43	13	1	2	3	4
Uls	13	24	39	15	3	4	4	7
Us	11	28	41	13	1	2	3	4
Ut2	10	28	40	12	1	1	2	4
Ut3	11	26	39	13	1	1	2	4
Ut4	12	23	39	16	2	3	4	6
Tt	4	15	51	36	2	4	5	7
Ti	5	15	48	33	2	4	6	8
Tu2	5	16	47	31	1	3	5	8
Tu3	8	17	45	28	2	4	7	9
Tu4	10	19	41	22	3	5	6	8
Ts2	5	16	47	31	2	4	6	8
Ts3	7	16	45	29	2	5	7	9
Ts4	13	17	43	26	2	4	7	9

Based on the obtained AWC values (mm), soils are classified into 7 classes (Table 2). However, good water properties of the soil at the same time do not mean that the plants will have enough water during the vegetation period. Namely, the soil water balance (WBL) is greatly influenced by other site factors, primarily the amount and distribution of precipitation, exposure, slope, etc. The obtained AWC values, which are determined in field conditions, must be corrected by applying the appropriate transformation tables: frequency table, median value transfer table and WBL transfer table (Steinrücken and Behrenes, 2017; Košanin et al., 2017; Košanin et al., 2021). The obtained transfer table for WBL serves as the basis for making a WBL map.

Table 2. AWC classes

AWC (mm)	AWC class
1-10	1
10-25	2
25-45	3
45-65	4
65-95	5
95-130	6
> 130	7

The nutrient regime (NR) is crucial for plant growth and is conditioned by chemical and biochemical processes in the soil. Available data on the basis of which the NR can be assessed or determined are: parent material (geological map or field research) which affects the degree of soil saturation with bases (%); pH values of soil samples and vegetation analysis (herbaceous indicators of soil acidity and security nutrients) (Table 3). The classification of the NR can be performed on the basis of the type of humus which is estimated on the basis of the thickness of the layers (Ol, Of, Oh) in the field or on the calculation of the C/N ratio, which is an indicator of the intensity and relationship of humification and mineralization. Mull type of humus is an indicator of eutrophic, moder humus- mesotrophic, and mor humus- oligotrophic soils. In the area of Boranje, there is a predominantly moder to mull moder type of humus. Based on the collected data in the field and on specific parameters (Table 3), the analysis of the NR is performed (Reif et al., 2017).

The most common parameters used to determine the NR are the degree of base saturation or pH value in H_2O. Based on these parameters, which were determined by laboratory testing or estimated on the basis of a geological map, the NR is assessed through the scheme for classifying the NR (Reif et al., 2016) (Table 3).

Table 3. Parameters for determining the NR

Class			
1. Parent material			
Class			
0	Not available		
1	High	Rich in bases	
2	Medium	Poor to rich in bases	
3	Low	Poor in bases	
2. Potential of supplying bases by horizons			
0	No horizon with > 25% skeletal content for base-rich parent substrate or > 50% for base-poor substrate		
1	High: substrate rich in bases, skeletal content > 25%		
2	Moderate: substrate poor to rich in bases, skeletal content > 50%		
3	Low: substrate poor in bases, skeletal content > 50%		
3. pH value for different depths			
Class	pH 0-60cm	pH > 60cm	
0			No data
1	> 6.5	> 6.5	Rich in bases
	* whole profile > 6.5		Rich in bases
2	< 6.5	> 6.5	In depth rich in bases
3	> 5.0	6.5 – 5.1	Rich in bases
	* whole profile 5 – 6.5		Rich in bases
4	< 5.1	5.1 – 6.5	In depth rich in bases
5	> 5.0	< 5.1	At the top rich in bases
6	< 5.1	< 5.1	Poor in bases
	* whole profile < 5.1		Poor in bases
4. Trophic level based on vegetation analysis			
0	Not available		
1	Eutrophic		
2	Mesotrophic		
3	Oligotrophic		

Table 4. Nutritional regime classification scheme

Coarse fraction	< 50%	> 50%		
		alkalinity of bedrock		
pH class		high	medium	low
1	rich	rich	rich-medium	rich-medium
2	rich-medium	rich-medium	rich-medium	medium
3	medium	rich-medium	medium	medium
4	medium	medium	medium	medium-poor
5	medium-poor	medium	medium-poor	medium-poor
6	poor	medium-poor	medium-poor	poor

On the basis of certain values of the NR, a table of frequency classes of base saturation in relation to the forms of relief is made, which serves as a basis for making a map of the NR. The term „trophic level" characterizes the soil nutritional status- the impact of soil biological activity, the intensity of decomposition, the emergence of demanding/undemanding plants and biodiversity. Sites can be classified into three levels of trophic: carbonate eutrophic/eutrophic, mesotrophic and oligotrophic.

IDENTIFICATION OF SITE TYPES

The final map of forest sites was obtained by overlapping the WBL map and the NR map. By adding a temperature layer, differences in growth zones can be determined. The obtained site types are defined by the amount of water and the NR. Sites are classified into 9 WBL classes, and according to the values of the NR into 3 classes (Košanin et al., 2017). For example, in the area of MU „Istočna Boranja", five site types have been identified on granitoid rocks (Figure 7) (Košanin et al., 2021):

1. **Moderate humid- medium** site of *Fagetum montanum* B. Jovanović 1953; Syn. *Asperulo odoratae-Fagetum* B. Jovanović 1973;
2. **Humid- medium** site of *Fagetum montanum* B. Jovanović 1953; Syn. *Asperulo odoratae-Fagetum* B. Jovanović 1973;
3. **Very humid- medium** site of *Fagetum montanum* B. Jovanović 1953; Syn. *Asperulo odoratae-Fagetum* B. Jovanović 1973;
4. **Very humid- poor** site of *Fagetum montanum* B. Jovanović 1953; Syn. *Asperulo odoratae-Fagetum* B. Jovanović 1973;
5. **Extremely humid- poor to medium** site of *Fagetum montanum* B. Jovanović 1953; Syn. *Asperulo odoratae-Fagetum* B. Jovanović 1973.

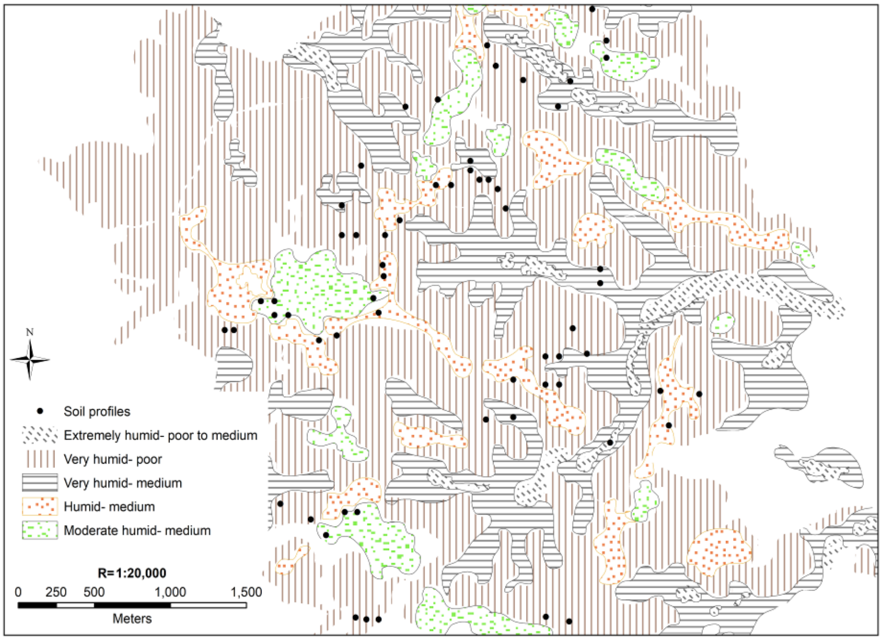

Figure 7. Site types in the area of MU „Istočna Boranja" on granitoid rocks

EFFICIENT SPATIAL FORECASTING

Given the current scarcity and insufficient systematicity in data collection, the importance of forest sites mapping is reflected in the formation of a database with basic ecological data on forest ecosystems, which are relevant to forestry, ecology and nature protection. A single database, which would be available to different institutions, would provide a simple and easy access for the exchange of relevant information related to forestry and nature protection between the institutions. Also, this approach enables constant collection and updating of data in the database, by various stakeholders.

The importance of forest sites mapping is also reflected in the isolation of zones with a potential risk of lack of water or nutrients. We are witnessing evident climate change, where the separation of zones with a potential risk of lack of water can be of great importance for sustainable forest management, timely change of tree species. Also, knowledge of site characteristics is the starting point for mapping forest functions and risk prediction.

Forest site maps have a great practical application in forestry. Based on the knowledge of the types of forest sites, the risk for certain types of trees and the classes of benefits are determined. Namely, climate scenarios predict changes in the average annual air temperature. By introducing the predicted values into the temperature layer, the growth zones change, and thus the WBL. By changing the WBL of a site, the ecological conditions change, and thus potentially the possibility of the survival of certain types of trees on it. The concept of forest habitat mapping enables users of forest ecosystem services to react in a timely manner by choosing species that can survive in the changed climatic conditions of the habitat.

The provision of a site with water depends primarily on the characteristics of the soil but also the climate, more precisely the temperature and the amount of precipitation both on an annual level and during the vegetation period. For the forestry, water can be considered a key factor of production and its sustainability, and at the same time contributes to stability for the forest ecosystem, since water is necessary not only for nutrition, but also for the growth and development of stands. Liquid groundwater has its deflocculating, dissolving, hydrolytic and translocation effects. The soil loses water through processes of infiltration, surface runoff and evapotranspiration. Surface runoff is significantly regulated by forest stands, both in the period rich in precipitation (runoff is less compared to unforested land) and in drought (runoff is greater compared to unforested land). The character of surface runoff and water flow through the soil depends on many factors, especially on the slope, amount and intensity of precipitation, soil permeability, depth of freezing and vegetation coverage.

It should be emphasized that the methodology of the concept of mapping forest sites is still quite „rough" and is still in the phase of testing, supplementation and design, but it certainly has great practical potential and importance for the forestry profession.

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SOIL QUALITY FOR PLUM PRODUCTION IN THE ŠUMADIJA REGION

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Abstract

The total plum growing surface in Serbia amounted to 72,316 ha in 2019, listing Serbia the topmost plum grower in Europe. Plum trees are grown across the whole territory of Serbia, but the most important areas of plum cultivation are central (Šumadija region) and western Serbia.
The study investigated the fertility of agricultural soils under plum orchards, as well as the soils planned for the establishment of new orchards. A total of 102 samples were taken at two depths (0-30 and 30-60 cm) and analyzed thereafter. Parameters of soil fertility (the main chemical properties), the content of available DTPA (diethylenetriaminepentaacetic acid) extractable microelements (Fe, Mn, Zn, and Cu) and the content of available B (H_2O extraction) were examined in the scope of the research.
Soil quality in the studied area is primarily determined by the processes of pedogenesis, as well as cultivation practices, i.e. the applied system of cultivation and fertilization. On average, an acidic soil reaction with a very low content of carbonates and readily available phosphorus was found in all the analyzed samples. The content of humus, total nitrogen and readily available potassium were at a moderate level. According to the research results, 71% of the total number of samples were carbonate-free in the surface and sub-surface soil layers. Regarding the content of readily available phosphorus, at both investigated depths 0-30 and 30-60 cm, most of the examined soil samples (66% and 91%) had a very low content of available phosphorus (<4 mg/100 g). Availability of microelements (copper, iron and manganese) was at the satisfactory level in all studied soils. The analysis of available boron (B) showed insufficient boron supply in 70% of the analyzed samples, especially in deeper soil layers. Similar situation, although less pronounced, was found in the analysis of available zinc content in deeper soil layers.
Šumadija has great natural potentials which provide a solid basis for future development and regional leadership in the production of traditional plum products. Variations in plum production results and soil quality confirm that the optimization of soil fertility and water-air regime are the main requirements to achieve full yield potential.

Keywords: Šumadija region, plum production, soil quality

INTRODUCTION

Considering that plums were among the first Serbian export products, plum production was one of the important pillars of Serbian economy in modern history (Matković, 2015).

Domestic or European plum (*Prunus domestica* L.) commonly known as "Shljiva" is a leading fruit species in Serbia and traditionally one of the most important plant species. It can even be said that plum is one of the symbols of Serbia (a national brand). With 558 930 t in plum production, Serbia was ranked second in Europe and third in the world in 2019, having been surpassed only by China and Romania) FAOSTAT (2019).
Main problem in cultivation of plum trees in Serbia is extensive production, which characterize low level of agricultural techniques and low yield (Keserović et al., 2012). More than 50% of plum orchards are grown extensively. Plum trees are grown across the whole territory of Serbia, but the most important areas of plum cultivation are central (Šumadija region) and western Serbia, where the growing surface is mainly situated at higher altitudes, with suitable exposure of the slopes for the production of the fruit species. According to the official data of the Regional Agency for Development of Šumadija and Pomoravlje, 11,000 ha of orchards have been recorded in the Šumadija district, of which 6,500 ha are under plum orchards. Of the total area under plums, 60% is the intensive plantation type of production, while the remaining areas are in the extensive mode of production (REDA, 2011). Šumadija is rich in natural potentials which provide a good basis for the future development of plum production. The Šumadija region is relatively unpolluted land, with favorable climate conditions, abundant water resources and preserved biodiversity (Brković et. al, 2016). However, limiting factor for intensive plant production in this region could be low soil quality (pronounced acidity, disturbed structure, compaction, soil exhaustion, presence of beneficial microorganisms, etc.) and the absence of appropriate agro-technical operation and ameliorative measures. In these areas, acidic soils with deficiency of organic matter and inadequate major nutrients availability are the main limiting factors for intensive plum production (Milosevic et al., 2013). Absence of fertilization and ameliorative measures before planting could result in deterioration of soil chemical, physical and biological properties, nutrient deficiencies and disorders of macronutrients in plants. Therefore, limited vegetative growth, low productivity and poor fruit quality are often seen in Serbian orchards (Milosevic and Milosevic, 2010).
Organic fertilizers, such as cattle manure, have been known to improve soil fertility (physical, chemical and biological properties of soils), particularly by increasing the humus content, availability of nutrients and acidity (Power and Prasad, 1997; Sharpley et al. 2004; Lal, 2006; Milić et al., 2019a). However, due to a drastic livestock reduction in Serbia during the last 30 years (Arsić et al. 2012), the use of high-quality organic fertilizer in plum production areas has decreased. The research of Bogdanović et al. (1993), conducted in intensive agricultural production, reported a decrease in humus content as compared to the previous research, and the negative trend continues. Decreased humus content is most often caused by intensive tillage, omission of organic fertilizers and burning of crop residues.
Consequently, a decrease of organic matter can lead to drastic impairment of soil physical and chemical properties, with negative impacts on soil nutrient cycling mechanisms (Bauer and Black, 1994, Loveland, 2003). Moreover, in the project study conducted by Milic et al (2019b) based on a survey of plum producers in the Šumadija region was determined that the application of ameliorative quantities of organic or mineral fertilizers was done only at 61% of the plots while calcification was performed only at 21% investigated parcels which

is not satisfactory considering the characteristics of the examined soil and the conditions required for the cultivation of this plant species.
The subject of the study was to evaluate fertility of agricultural soils under plum orchards, as well as the soils planned for the establishment of new orchards in the Šumadija region. The general aim was to provide guidelines for better land use and production of this highly productive plant species.

MATERIALS AND METHODS

Study area

Šumadija is the largest sub region in central Serbia. Its territory in a broader sense includes the areas between the three large rivers Sava and Danube in the north, Velika Morava in the east and Zapadna Morava in the south (Marković and Pavlović, 1995). This area is located between 43º 35' 39" and 44º 50' 32" N and 20° 13' 36" and 21º 24' 34" E. The climate in Šumadija is moderate continental with significant microclimate differences that arise due to the size of the region and the differences in the altitude. The average annual air temperature is 11.3 °C and the average annual precipitation is about 610 mm. The sampling plan and selection of locations was conducted on the basis of presence and distribution of plum orchards, plots planned for the establishment of plantations, as well as spatial distribution of the soil types in the Šumadija region (Figure 1).

Soil analysis

All laboratory analyses were performed at the Laboratory for Soil and Agroecology of the Institute of Field and Vegetable Crops, accredited according to the standard ISO/IEC 17025:2017.
Soil samples were collected in September 2019 at two depths (0-30 and 30-60 cm). The analysed data set comprised of a total of 102 samples pertaining to 51 analysed plots divided into two main groups: 1. Agricultural soils under plum orchards - PO (39), and 2. The soils planned for the establishment of new orchards - ENO (12). The collected soil samples were naturally air-dried, milled and passed through a 0.2 mm sieve, according to ISO 11464:2006. Soil pH value was determined by potentiometric method according to ISO 10390:2005, in 1:5 suspension of soil in 1 M KCl using Mettler Toledo Seven Compact pH meter with glass electrode. The carbonate content (as $CaCO_3$) was determined according to ISO 10693:1995 volumetric method.
The soil organic matter (OM) content was determined by Turyn's method based on oxidation by potassium dichromate (Kaurichev, 1980). Readily available phosphorus in soil was determined by extraction of ammonium lactate (Egner et al., 1960), whereby detection was performed spectrophotometrically at the wavelength of 830 nm in a UV/VIS spectrophotometer using the phospho-molybdate-blue-method (Murphy and Riley, 1962). Readily available potassium in soil was determined also by extraction of ammonium lactate using flame photometer. Determination of available microelements, DTPA (Fe; Mn; Zn; Cu) - method SRPSISO 14870: 2004 and available boron (B) - hot-water extraction was performed on the apparatus "Vista Pro" - Varian; by the method of induced coupled plasma ICP - OES (Inductively Coupled Plasma-Optical Emission Spectroscopy).

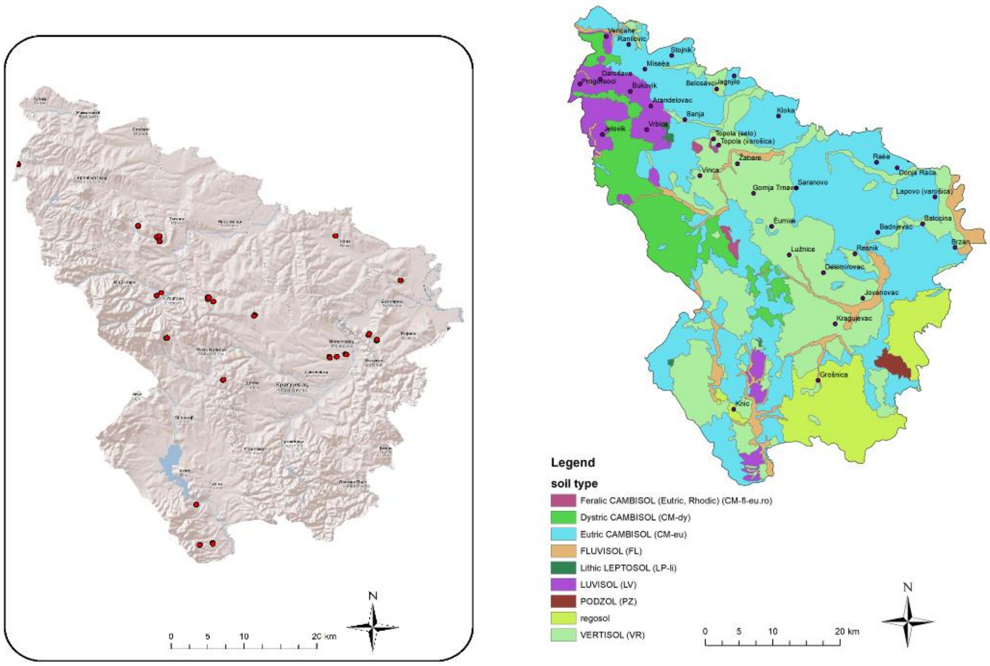

Figure 1. Distribution of sampling localities and soil types (pedological map) of the Šumadija region

A two-way analysis of variance (ANOVA) was conducted for descriptive statistics and estimation of main effects between two analyzed groups and sampling depth. The least significant difference (Fisher's test) was used to determine whether means differed significantly. For statistical analyses, Microsoft Excel (Microsoft Corporation, USA) and Statistica 13 (StatSoft, Germany) commercial software packages were used. Unless otherwise stated, the level of significance referred to in the results is $P < 0.05$.

RESULTS AND DISCUSSION

Agrochemical soil properties of the examined area were primarily determined by the processes of pedogenesis and cultivation practices, i.e. tillage and fertilization. The intensity of the change of the properties depended on the initial supply in the examined plots, the duration of anthropogenic impact, as well as the type and manner of fertilization. Chemical properties of soil, both directly and indirectly, determine the level and dynamics of soil nutrients. Therefore, changes in soil chemical properties are one of the most important indicators of soil fertility.

Soil fertility is largely determined by soil reaction. Availability and dynamics of nutrients (Duogherty, 2012), intensity of soil microbiological activity (Oliver et al., 2013), mineralization of organic matter, decomposition of soil minerals, and dissolution of sparingly soluble compounds, coagulation and peptization of colloids, as well as other physical and chemical processes, depend on soil pH value (Jakšić et al., 2013).

The average values of soil fertility parameters are given in table 1. Soil pH value was dominantly acid to highly acid in both investigated layers (topsoil and subsoil), according to the classification for soils under orchards and vineyards (Džamić and Stevanović, 2000). The lowest levels of pH values were determined in the topsoil layer (0-30 cm) of ENO (establishment of new orchards) fields for both methods (potential KCl and active H_2O) with a low variation of the complete data set. Significant difference was observed between the treatments, but not between the soil layers (Table 3). High acidity was also confirmed by analyses of hydrolytic acidity (H^+). Investigation of Milić et al. (2019b), based on the response of producers from Šumadija, confirmed that 79% of the examined plots were not calcified. On the contrary, according to our analyses, the majority of investigated parcels/samples (86%) are recommended for the ameliorative measure of calcification. In addition, carbonate content of all the analyzed samples, regardless of the treatment and depth, ranged between 0% and 0.85% without statistical differences. This is also a strong indicator of the overall acidity and the parent material on which the soil was formed. In terms of profile depth, in general, a larger part of carbonates was found in deeper layers (>120 cm).

The soils under plum production in Šumadija region, collected in our study, dominantly belong to the class of low humic soils, with average humus content for two depths of 1.93% and 1.87%, respectively (Tab. 3). The highest organic matter content (humus) was determined in the top layer (0-30) in both investigated variants at 2.23% and 2.27%, respectively (Tab. 1). Soil organic matter content ranged from 0.65% to 3.39%, whereby the statistically highest average values were obtained in the first soil layers. There were no statistical differences between treatments. Besides the specific soil properties in plum orchards, the reduction of humus was possibly the consequence of the intensification of cultivation practices (Morari et al., 2006; Gardi, 2007). In the observed area, soil management was based on the reduced use of organic fertilizers, which were mainly applied when establishing perennial crops. Soil humus content directly determines soil fertility. Humus is the source of nutrients, enhancing physical, chemical, water and biological soil properties (Halajnia et al. 2007). Also, Sharpley et al. (2004) and Whalen et al. (2000) observed that, soils in which manure was continually applied had significantly higher organic matter content and pH values than untreated soils. Besides the specific soil properties in plum orchards, the reduction of humus is possibly the result of the long term intensification of cultivation practices (Gardi and Sconosciuto, 2007; Morari et al., 2006). Findings of the readily available P content indicate very low levels (<4 P_2O_5 mg/100 g) for the majority of the investigated plots/samples, according to the classification of Ubavić et al. (1990). The analysis indicates that the readily available P ranges between 0.55 and 26.46 mg/100 g soil, ranging from 1.10 to 4.81 mg/100 g soil (Tab. 1). Low level of available phosphorus was confirmed in other investigations of the central Serbian regions (Ninkov, 2014; Milinković, 2017).

Table 1. Descriptive statistics of the main soil fertility characteristics

Indicator	depth	pH (KCl)	pH (H_2O)	(H^+) (meq/100 g)	$CaCO_3$ (%)	Humus (%)	P_2O_5 mg/100g	K_2O mg/100g
Plum orchards **(PO)**								
No	0-30cm	39	39	39	39	39	39	39
Min.		3.89	5.39	5.50	0.00	0.75	0.78	10.29
Max.		6.91	7.83	16.25	0.85	3.31	16.46	63.50
Average		**4.97**	**6.22**	**9.17**	**0.16**	**2.23**	**4.81**	**23.90**
Stan. Dev.		0.71	0.55	2.25	0.25	0.55	5.37	10.16
C. Var.		14.35	8.88	24.54	159.7	24.54	111.54	42.50
No	30-60 cm	39	39	39	39	39	39	39
Min.		3.88	5.48	3.17	0.00	0.650	0.55	8.92
Max.		6.96	7.80	12.85	4.64	3.39	14.35	42.30
Average		**4.98**	**6.34**	**3.17**	**0.34**	**1.62**	**2.32**	**19.00**
Stan. Dev.		0.84	0.61	2.02	0.91	0.64	2.52	6.65
C. Var.		16.88	9.58	24.62	262.88	39.39	108.67	35.02
Establishment of new orchards **(ENO)**								
No	0-30cm	12	12	12	12	12	12	12
Min.		3.80	5.13	6.61	0.00	1.14	0.57	14.10
Max.		4.87	6.36	17.73	0.00	2.80	8.19	25.50
Average		**4.50**	**5.92**	**10.77**	**0.00**	**2.27**	**2.36**	**19.15**
Stan. Dev.		0.37	0.37	3.35	0.00	0.51	2.07	3.44
C. Var.		8.28	6.32	31.06	0.00	22.61	87.62	17.98
No	30-60 cm	12	12	12	12	12	12	12
Min.		4.01	5.52	5.60	0.00	0.80	0.53	14.1
Max.		5.02	6.44	12.30	0.25	2.26	2.09	22.13
Average		**4.52**	**6.07**	**8.46**	**0.02**	**1.46**	**1.10**	**17.45**
Stan. Dev.		0.34	0.27	2.01	0.07	0.49	0.53	2.65
C. Var.		7.66	4.38	23.77	346.4	34.07	48.21	15.18

Content of available P statistically differ significantly between both, treatments (PO/ ENO) and investigated depth (0-30 cm/30-60 cm). The level of soil readily available P is affected by an array of factors, most of all by soil mechanical composition, pH, content of $CaCO_3$, and other physical and chemical soil properties. Soil pH and calcium carbonate content play a significant role in nutrient distribution and availability of phosphorus and its compounds in particular (Naeem et al., 2013).

Table 2. Descriptive statistics for microelements, extracted in DTPA (ppm) and boron (B) extracted in hot water.

Indicator	**depth**	**Cu**	**Fe**	**Mn**	**Zn**	**B**
Plum orchards **(PO)**						
No	0-30cm	39	39	39	39	39
Min.		0.67	22.80	11.45	0.60	0.056
Max.		16.25	91.11	75.95	5.00	0.59
Average		**3.81**	**55.33**	**34.16**	**1.54**	**0.29**
Stan. Dev.		3.47	16.49	12.16	0.82	0.14
C. Var.		90.84	29.81	35.60	53.40	46.40
No	30-60 cm	39	39	39	39	39
Min.		0.50	19.67	8.17	0.05	0.06
Max.		10.73	88.82	64.78	4.00	0.60
Average		**2.53**	**48.46**	**25.09**	**1.11**	**0.21**
Stan. Dev.		1.97	15.74	11.58	0.81	0.10
C. Var.		77.93	32.47	46.16	73.07	49.67
Establishment of new orchards **(ENO)**						
No	0-30cm	12	12	12	12	12
Min.		1.52	32.58	15.93	0.01	0.163
Max.		3.54	153.3	52.33	4.34	0.39
Average		**2.64**	**80.76**	**35.73**	**1.54**	**0.29**
Stan. Dev.		0.62	36.32	11.45	1.42	0.07
C. Var.		23.59	44.98	32.06	92.18	24.69
No	30-60 cm	12	12	12	12	12
Min.		0.92	19.73	10.73	0.01	0.11
Max.		3.52	101.3	36.78	2.56	0.36
Average		**2.04**	**60.89**	**24.28**	**0.64**	**0.20**
Stan. Dev.		0.68	23.98	8.81	0.70	0.07
C. Var.		33.36	39.38	36.31	108.5	36.49

Regarding the content of readily available potassium, a statistical difference was observed between the investigated depths 0-30 and 30-60 cm, but not between plum orchards and plots under orchard establishment (Tab. 3). Most of the examined soil samples had an average or optimal content of available potassium (15-30 mg/100 g). Findings reported by Ninkov (2014), Milinković (2017) and SEPA (2020) covering the same region, indicate an optimal to high potassium supply in arable lands, which supports the geochemical origin of potassium characteristics for the tested area.

Table 3. The least significant difference (Fisher's test) of the analysed soil characteristics

Analyses/ treatment A/ Depth (cm) B	(PO)			(ENO)			Average B (depth)	
	0-30 cm	30-60 cm	**Average A (tret.)**	0-30 cm	30-60 cm	**Average A (tret.)**	**0-30 cm**	**30-60 cm**
pH in KCl	4.97 bc	4.98 c	**4.98 a**	4.50a	4.52ab	**4.51 b**	**4.86 a**	**4.87 a**
pH in H_2O	6.22 bc	6.34 bc	**6.28 a**	5.92a	6.07ab	**5.99 b**	**6.15 a**	**6.28 a**
$CaCO_3$%	0.1 ab	0.34 a	**0.25 a**	0.00a	0.02a	**0.08 a**	**0.12 a**	**0.26 a**
Humus%	2.23 a	1.62 b	**1.93 a**	2.27a	1.46b	**1.87 a**	**2.24 a**	**1.59 b**
P_2O_5 (mg/100 g)	4.81 a	2.36 b	**3.57 a**	2.36ab	1.10b	**1.73 b**	**4.23 a**	**2.03 b**
K_2O (mg/100 g)	29.90 a	19.00 b	**21.45 a**	19.51 ab	17.45 b	**18.30 a**	**22.78 a**	**18.63 b**
H+ (meq/100 g)	9.17 b	8.18b	**8.68 a**	10.77 a	8.47b	**9.62 a**	**9.55 a**	**8.25 b**
Cu DTPA mg/kg	3.82 a	2.53 bc	**3.17 a**	2.65 ab	2.05 bc	**2.35 a**	**3.54 a**	**2.42 b**
Fe DTPA mg/kg	55.33 b	48.47 b	**51.90 b**	80.76 a	60.89 b	**70.82 a**	**61.31 a**	**51.39 b**
Mn DTPA mg/kg	34.17 a	25.09 b	**29.62 a**	35.73 a	24.28 b	**30.01 a**	**34.53 a**	**24.90 b**
Zn DTPA mg/kg	1.54 a	1.11 bc	**1.32 a**	1.54 ab	0.64 c	**1.09 a**	**1.54 a**	**1.00 b**
B in H_2O mg/kg	0.30 a	0.21 b	**0.25 a**	0.29 a	0.19 b	**0.24 a**	**0.29 a**	**0.21 b**

*Factor levels marked with the same letter in a row do not differ at the $P < 0.05$ level of significance

Soil extraction with DTPA, as a chelating agent, can simulate the natural process of introduction of biogenic elements (metals) by the plant root system, i.e. it can be used to determine the concentration of microelements readily available to plants (Lindsay and Norvell, 1978). Statistically significant differences were not found between the examined PO and ENO treatments for the studied microelements, except for the significantly higher content of available iron (Fe), observed on the plots intended for plum orchard establishment. The content of all studied microelements was significantly higher in the topsoil layer (0-30 cm) compared to the subsoil layer (30-60 cm). The examined plots had a high content of microelements (Fe, Mn, and Cu). However, low content of readily available zinc of 0.6 ppm, as the lowermost limit of the desired Zn supply (Lanyon et al., 2004; Ubavić et al., 2008), was found in about 30% of the plots. In addition to the sporadic zinc deficiency, low levels of water-soluble boron (B) were also determined. Low content of available boron (B), i.e. the content below which signs of B deficiency are exhibited, was detected in most of the tested samples (70%). Based on the results of the mean value of both observed depths, B was below a favorable supply limit of 0.35 ppm (Table 3).

CONCLUSION

Study results showed a predominant acidic soil reaction in the examined area and low content of $CaCO_3$, confirming the need for calcification. Fertilization, as one of the main cultivation practices, is vital for providing soils with humus and phosphorus. Low humus content (<1 or 1-2%) was found in the topsoil and subsoil layer (30-60 cm), in 32% and over 80% of the plots, respectively. On average, the content of readily available phosphorus was very low or low in most of the examined areas, and it significantly decreased with the depth of the soil profile. The content of readily available potassium was satisfactory in most of the examined soil samples. However, a very high content was also observed as a result of excessive fertilization. Regarding the content of readily available microelements, low level of boron and zinc dominated as a result of the poor geological base.

Optimization of soil physical and chemical properties by means of rational fertilization and tillage is one of the most important factors for the achievement of the full yield potential of plums orchards. The mentioned cultivation practices can only be implemented following a detailed analysis of the soil, thereby ensuring long-term positive effects.

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CLIMATE CHANGE AS THE DRIVING FORCE BEHIND THE INTENSIFICATION OF ACRICULTURAL LAND USE

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Abstract

Climate change in Europe will lead to new precipitation patterns over the next few years and the annual temperature will increase significantly. These changes in climate variables and the resulting effects on agricultural productivity must be differentiated regionally. Plant production depends on sufficient rainfall in summer and, in some regions, on the amount of rainfall in winter. In Central Europe, the amount of precipitation in summer will decrease in the coming decades due to climate change, in some regions the amount of winter precipitation will increase significantly. Agricultural production can suffer severely as a result of rising summer temperatures and low water retention capacities in the soil. The effects of climate change were examined and described 15 years ago. They were examined on the basis of scenarios using plant simulation models. The effects of reduced summer precipitation and increased air temperatures are partially offset by the expected increased CO_2 concentration. Therefore, the effects of changed climatic conditions on crop production are sometimes less drastic on crop yields. The greatest impact of climate change on land use is expected from increasing evapotranspiration and lower amounts of precipitation in the production of leachate. In addition to the expected mean changes, the occurrence of extreme weather conditions is decisive. Here, periods of drought in the growing season and heavy flooding as a result of extreme rainfall are to be expected. However, these events are very difficult or impossible to predict! In addition to the effects of climate change on regional crop production, global changes will have a strong impact on world markets for agricultural products. Another consequence of climate change and population growth is a higher demand for agricultural products on world markets. This will lead to dramatic local land use changes and intensification of agriculture that will transform existing crop production systems. The intensification caused by rising land and lease prices will primarily affect the maximization of the use of fertilizers and pesticides.

Keywords: climate change, crop production, intensification of land use, water balance, global agricultural production, sustainability, population growth

INTRODUCTION

Regional changes in precipitation and air humidity are associated with global climate change. As a result of the rise in temperature, the annual evaporation requirement of the atmosphere will increase. This results in an acceleration of the hydrological cycle of evaporation and precipitation. The temperature-dependent increase in the water vapor storage capacity of the atmosphere leads to an increase in latent energy in the troposphere. This also results in a worldwide increase in the number of extreme climatic events, such as storms, droughts and heavy precipitation with subsequent flooding. The main problem with these extreme events is that they cannot be predicted by any currently available climate models and that their occurrence as a result of climate change is becoming more and more frequent. In addition, the principles developed by humans, rules of conduct in everyday life, but also the production methods of agricultural land use are geared to typical, mean weather situations. Planning and reacting under such uncertain framework conditions is very difficult and in most of our economic and social areas not well or not yet developed. In addition to changes in the economy, population aging and migration, climate change is the central element of "global change". The expected changes in the climate in the coming decades will not be underestimated in terms of productivity (e.g. due to water shortage or excess), but also in the landscape-ecological functionality of land use systems (e.g. habitat function for species, new groundwater formation). It can already be foreseen today that the direct effects of climate change on the productivity of land use systems will in the short and medium term, influence the world markets for agricultural products and thus also energy supply to a considerable extent. For this reason, the investigation and assessment of the production and landscape ecological consequences of climate change on agriculture must be subdivided into the three areas of impact of climate change:

- Impact of climate change on the production function of land use systems
- Impact of climate change on the ecological functionality of land use systems and
- Effect of climate change on the world markets for agricultural products with the expected feedback effects on agriculture.

This is the focus of the present consideration. Only such a complex consideration of the effects of climate change will make it clear in the results of the analyzes that agriculture will be among the winners as well as the losers in terms of socio-economic and landscape-ecological aspects.

MATERIALS, METHODS, RESULTS

Effect of climate change on the production and the land-ecological function of the agricultural landscape

Using the example of two specific study areas with typical land use and similar soils, Eulenstein et al. (2005, 2006) examined how the components of the soil water balance and especially the water availability for agricultural crops could change as a result of the expected climate change. When selecting the study areas, emphasis was placed on the fact that both study areas were dominated by sandy soils with low field capacity. This factor represents the size of the reservoir for water in the soil (corresponds to the area that can be rooted in the depths). In the sandy areas, the agricultural conditions, which are already difficult during the growing season, become even more unfavorable. Between 1961 and 1990 the mean precipitation in Germany determined over many years was 790 mm (1 mm "water column" corresponds to an amount of one liter of water per square meter of soil). For regions in eastern Germany, however, the long-term mean precipitation is only 615 mm, in the Müncheberg area (small town east of Berlin) only 520 mm / year and in the Oderbruch further east it is only 460 mm / year. In addition to the low rainfall, the fact that we are mainly dealing with soils with low water storage capacity in northeast Germany and western Poland is noticeable. The soil value figures determined with the official soil estimate correlate very well with the amount of water that is available for plants and stored in the rooted area of the soil. The soils that dominate the regions are predominantly ground and terminal moraines shaped by the Ice Age, as well as sand areas with relatively low soil values. These sandy soils have a storage capacity of around 100–150 mm down to a depth of one meter. The soils that are considered to be the best in this regard, the black earth soils in Central Germany, on the other hand, can store approx. 240 mm of water at the same depth as available for plants. On warm days in midsummer, approx. 6 mm of water evaporates (corresponds to 6 l / m^2). Under these conditions, a Chernozem would be able to provide the plants with water for 40 days. In purely mathematical terms, a population on sandy soils has reached the end of the water replenishment from the soil after just 17 days. Results from lysimeter and field tests (Roth et al., 1997; Schindler et al., 2001; Müller et al., 2004, Schindler et al., 2007) on with regard to between water consumption, effectiveness of water use and yield formed the basis for deriving the water availability classes. In eastern Germany and western Poland, these problems of poor soil storage capacity and low rainfall accumulate in a way that is unique in Central Europe. It is precisely in these regions that the effects of the expected climate change are likely to be most serious. These location conditions - with water as the most important production factor in shortage - in combination with very little water-storing soils lead to the fact that the production conditions for farms in these regions are to be assessed as problematic, especially during periods of low precipitation within the vegetation periods. In the course of the forecast warming, the decline and the intra-annual redistribution of precipitation from summer to winter half-year (Gerstengabe et al., 2003), this situation may worsen in the future.

Effects on the water balance and the yields of agricultural production systems

The aim of a study by Wiggering et al. (2008) and Eulenstein et al. (2016) was the analysis of the effects of the expected climate change on land use and the landscape water balance of agricultural locations in northeast and central Germany. The first thing to do was to clarify in detail: how the climatic water balance and substance discharges (nitrate and sulphate) under agriculturally used areas as well as the yields of agricultural crops will change under future climatic conditions. An agricultural landscape, located directly at the east of the German capital Berlin was selected for these calculations. It covers 54,000 ha. Exact surveys in the period 1993-2001 on crops, yields and fertilization of a total of 54 farms served as the basis for the calculations. The period from 1993–2001 serves as the reference period for the Gerstengabe et al. (2003) defined climate scenario (Fig. 4.3-3). The scenario calculations are based on a temperature increase of approx. 1.4°K for the period 2001–2055. This trend was determined from the result data of the ECHAM4-OPYC3 model from the Max Planck Institute for Meteorology Hamburg. This model run is based on the IPCC (2001) emissions scenario A1B-CO2, which results in a relatively moderate increase in temperature.

Effects on the water balance of agricultural

It was shown that the plant population already completely deplets the water supply of the soil under today's climatic conditions during the vegetation period. Therefore, the calculated current evapotranspiration during the summer half-year shows no differences between the actual climate and the assumed climate scenario. With the help of the HERMES / SULFONIE models from Kersebaum (1995), a potential evapotranspiration of 510 mm per year was calculated. Taking into account the cultivated crops and the limited water availability in the summer months, the current evapotranspiration is almost 100 mm lower and amounts to 417 mm per year. The leachate donation is around 140 mm per year on average over the years. In the model, the ground water displaced downwards is shown as seepage water, which is displaced deeper than 2 m. The data of the weather patterns of the climate scenario, synthetically generated on the basis of the results of the climate models, show the following picture: the evapotranspiration largely follows the precipitation rates, while the seepage water rate falls to a very low level.

From these calculations (Fig. 1) it can be deduced that under the mean climate changes to be expected in the future, the stress situations for plant populations caused by the water availability could increase. Evaporation, especially in the winter months, due to a rise in temperature, is likely to increase. From the overall extent of the change in evaporation, however, the increase in water shortage for arable crops can be classified as rather moderate.

Therefore, the negative consequences for the generation of income should remain rather manageable under medium conditions. However, the frequency with which extreme weather conditions occur, such as 2018, 2019, 2020 (summer drought) or 2002, 2013, 2021 (precipitation-related floods), is certainly decisive for the economic situation in agriculture. The accumulation of such extreme years could become the real problem for agricultural crop production.

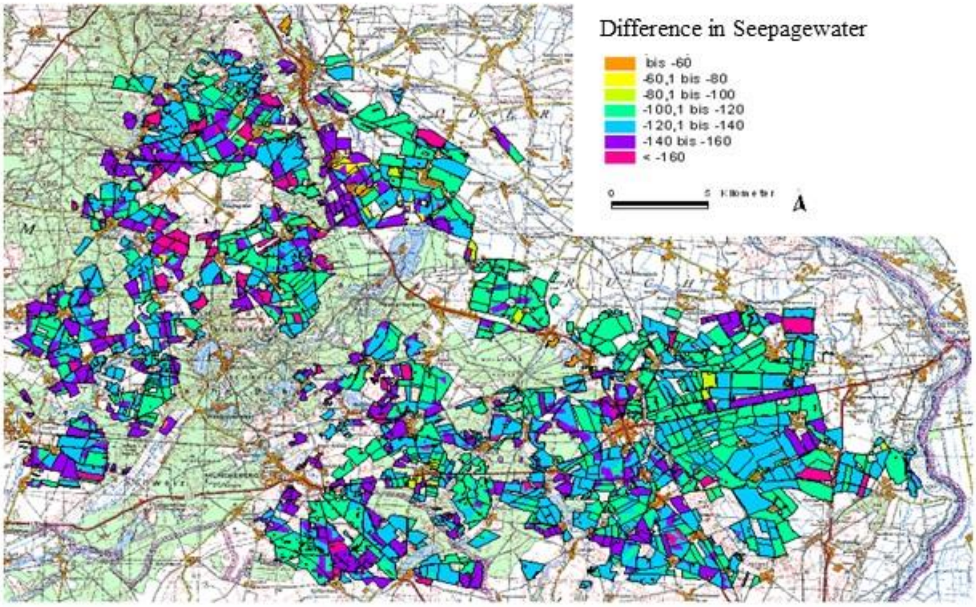

Figure 1. Spatial distribution of percolation water [mm/year] decrease as result of the scenario comparison (Scenario 2050 – Scenario2000)

Effects on the yields of arable crops

The ZALF (Leibniz Center for Agricultural Landscape Research eV, Müncheberg; www.zalf.de) has developed a model approach for regional yield estimation and, through integration into the Spatial Analysis and Modeling Tool (SAMT) (Wieland et al. 2004), has developed a spatial simulation tool expanded. The yield models developed with the help of this tool make it possible to examine the influence of changing weather patterns on the yield. Calculations made with these models for the study area result in a yield depression of between 14% for potatoes and approx. 5% for the main grain types barley, wheat, rye and triticale. Taking into account the effects of increased CO_2 concentrations known from other studies (such as the so-called FACE experiments: free-air concentration enrichment), the estimated yield decreases for all crops are less than 10% and especially marginal for the cereals that are dominant in terms of cultivation. This means that ultimately the emission-related increase in the CO_2 content in the atmosphere promotes plant growth and more efficient utilization of the water supply and can help to compensate for the drop in yield. With regard to the effect of the CO_2 concentration in the atmosphere on many cultivated plants, numerous experiments and valuable data on the relationships between the CO_2 concentration and the temperature-dependent reaction of the cultivated plants have recently been obtained. This was done experimentally in sunlit, controlled chambers, “open top chambers”, free-air CO_2 enrichment (FACE) studies and to a limited extent, phytotron studies. (Boats et al., 2011; Hatfield et al., 2011; Jones et al., 2011). The spatial distribution of the climate-related decline in yields at the climate level 2050 compared to the climate level 2000 shows clear differences on a small scale. In the study area in the areas of influence of the Oderbruch, the lowest yield losses can be expected, which can be explained by the better groundwater supply in this floodplain area. The yield losses there are mostly only in the range of up to 5%. On the other hand, on the fields of sandy soils, the losses are higher and are usually more than 5% and sometimes more than 10–15%.

The effects of the climate to be expected locally for the climate level 2050 (PIK climate scenarios) on the yield of agricultural crops are shown in Table 1 in comparison to the yield of the climatic level 2000 on the considered representative fields for the most important fruit species cultivated in the study area summarized. Taking into account the CO_2 effect, the yield losses caused by changes in temperature and precipitation are compensated for in the cultivated cereals.

Table 1 Simulated impact of climate change (Scenario 2050 vs. Scenario 2000) on crop yields for the study area (two CO_2 levels)

Crop	Cropping rate (%)	Mean crop yield change (%)	
		at 370 ppmv CO_2	at 465 ppmv CO_2 *)
Winter rye	17	- 6	- 0.3
Winter wheat	16	- 5	0.5
Silo corn	9	- 8	- 3
Winter rape	9	- 11	- 6
Winter barley	6	- 5	0.5
Triticale	6	- 4	0.1
Sugar beets	2	- 9	- 4
Alfalfa	3	- 12	- 7
Spring barley	2	- 5	0.3
Spring rape	< 1	- 7	- 2
Spring wheat	< 1	- 4	0.9
Clover gras	1	- 13	- 8
Oat	1	- 5	0.2
Potatoes	1	- 14	- 9

***) Basis: CO_2 fertilization effects obtained in the FACE-experiment of the Federal Research Centre for Agriculture Brunswick, Germany (at 550 ppmv → 10.7 % yield increase in average)**

However, this is not the case with root crops, silage maize, rapeseed, alfalfa and grass clover and yield losses are likely. Effect of climate change on the ecological function of the agricultural landscape The impact of the decline in groundwater recharge on the feeding of the ecologically valuable wetlands is likely to be much more serious than on agricultural yields. Unlike the forestry alternative, agricultural land use currently leads to significant new groundwater formation rates (Eulenstein et al. 2005b). From the seepage and its lateral runoff, it supplies the numerous ecological wetlands occurring in Brandenburg (lakes, brooks, moors and other lowland areas). Should the leachate donation from the agricultural land actually develop as the scenario suggests, then the ecological functionality of these ecosystems will have to be questioned. According to the climate scenarios, a lower nitrogen discharge is initially forecasted. This is mainly explained by the fact that, as a result of lower seepage water rates, nitrogen and sulfur are not shifted into the subsoil as quickly and thus ultimately the supply of these substances initially accumulates in the upper, 2 m deep soil layer. The modeling for the fields recorded and accounted for in the study area was carried out using the HERMES / SULFONIE models by Kersebaum (1995). In Fig. 4.3-5 and -6, in addition to the components of the water balance, the sulphate and nitrate discharges from the rooted zone and their concentrations in the seepage water are shown. With the exception of the peak, nitrogen discharges vary between 25 and 100 kg/ha per year.

DISCUSSION AND CONCLUSION

Effects on the world markets for agricultural products and the expected feedback on agriculture

The previously known and generally applicable influences on agriculture will change considerably over the next few years. In addition to a predicted climate change, the economic framework conditions in particular have a major influence on how farmers make strategic long-term, but also short-term decisions for their farms and production. In addition to technical progress and new markets, this decision-making behavior is primarily shaped by agricultural policy and social requirements. In addition to the significantly increasing importance of market mechanisms, these include:

- Decrease in agricultural trade policy or market and price policy
- Increasing environmental, animal welfare and consumer policies at the same time
- Intensification of production processes as a result of increasing demand and prices worldwide.

If one looks at the global climatic changes that are emerging, it becomes clear that other previously intensively used agricultural regions will be more severely affected by climate change than Europe due to rising temperatures and falling amounts of precipitation. For this reason, it will not be possible to significantly expand the range of agricultural products from the regions affected, such as Australia and the Midwest of the USA. On the other hand, as recent studies show, there are certainly favorable locations such as in southern Brazil. Using yield simulations for maize and soybeans, Lana (2013) was able to show that with the right choice of varieties, no significant yield losses are to be expected under the conditions of future climate change. In contrast to Australia, the same applies to New Zealand. With increasing demand and constant or decreasing supply, prices will rise and with them farmers' incomes. The previous income situation of the farms is often quite inadequate, sometimes ruinous. The prospects for higher prices for the farmers' products are therefore fundamentally positive from the point of view of maintaining the farms. As a result of the supply shortage and increases in energy prices, animal feed, fertilizers and fuels are also becoming more expensive and thus the costs of agricultural production are higher. Rising revenues due to rising market prices for agricultural products are thus partially offset by the increasing cost pressure.

Increasing variability in the climate leads to higher uncertainties in production, which will result in greater risks / failures and therefore higher costs.

Nevertheless, due to the high productivity of the agricultural locations in Central Europe and the often very good, flexible management of the farms, it is to be expected that the vast majority of agricultural areas in Central Europe will continue to be used for agriculture in the future, with the exception of a few border locations. If one then also takes into account that the world population will increase from currently over 6 billion to over 9 billion by the mid-2030s, one can imagine the increase in demand for agricultural products. The FAO anticipates an increase in annual demand of one billion tons of plant products by the mid-2030s (Fig. 2).

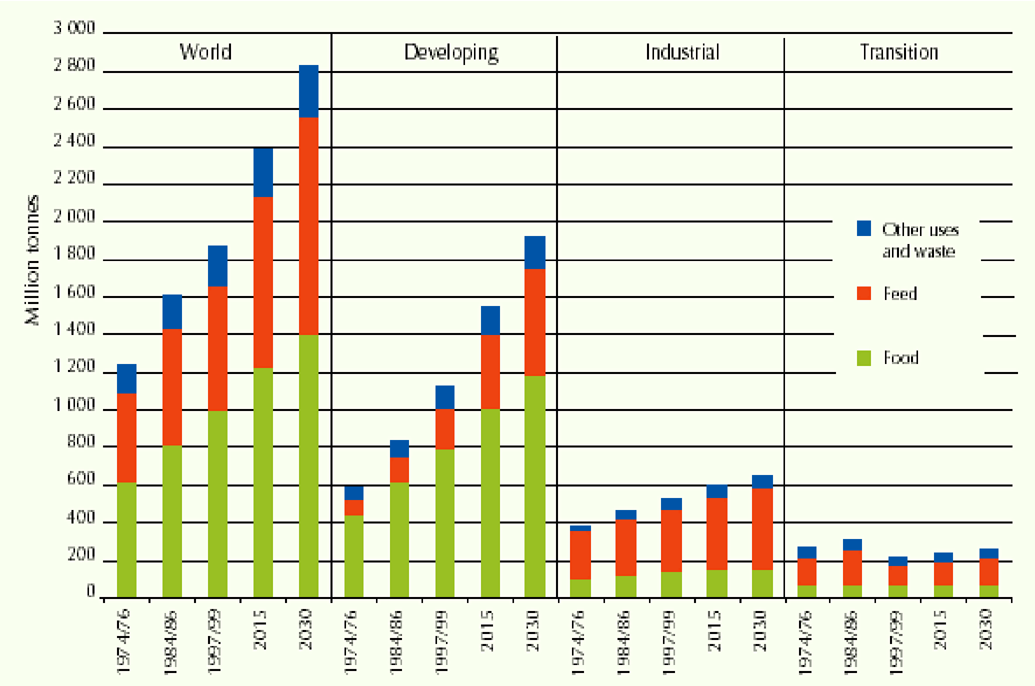

Figure 2. Aggregate consumption of cereals, by category of use. from: World Agriculture: Towards 2015/2030. An FAO perspective.

The 32% increase in world population by 2050 will be a powerful factor in food distribution. In addition, the daily energy intake will increase from the current 2831 kcal (FAOSTAT, 2013) to 3130 kcal in 2050. The competition for land for the agricultural production of biomass for nutritional purposes, as animal feed, for industrial raw materials and as an energy source, as well as for available water resources (with water retention in the landscape for ecological functions, for irrigation, etc.) will therefore increase. The following graphic (Figure 3) already illustrates the trend towards price increases for agricultural land in Germany.
This trend is particularly evident where agricultural land is traded on the market. The intensification caused by rising land and lease prices will primarily affect the maximization of the use of fertilizers and pesticides.

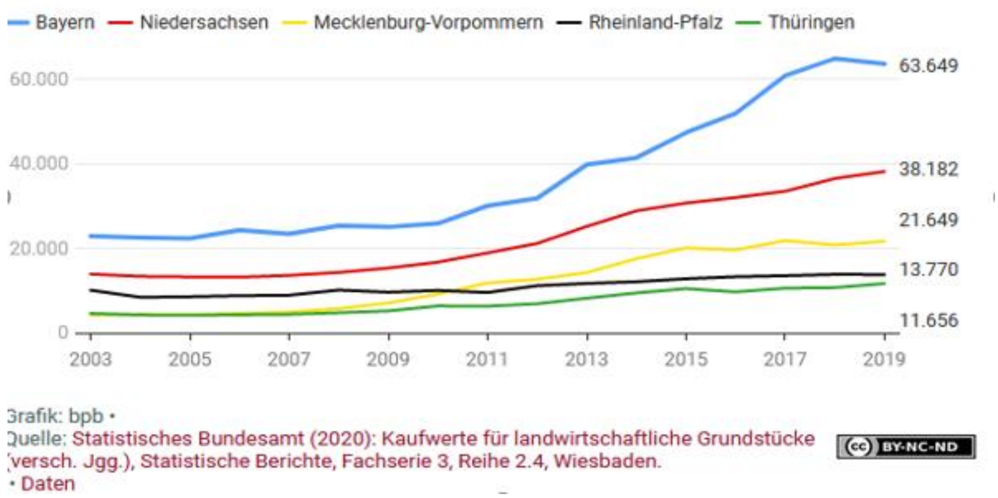

Figure 3. Trend towards price increases for agricultural land in in some regions in Germany

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USE OF TRACERS IN SOIL EROSION RESEARCH - APPROACHES AND CHALLENGES

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Abstract

Soil erosion is a significant environmental problem worldwide. The need to obtain accurate and reliable soil erosion intensity to identify erosion-prone areas and select appropriate soil conservation options is emphasized. Besides the existing monitoring and modelling methods (e.g., (R)USLE-based models, erosion pins, etc.), the potential of nuclear techniques to study erosion has been recognized. The fallout radionuclides (FRNs): artificial ^{137}Cs and $^{239+240}$Pu, natural geogenic ^{210}Pb$_{ex,}$ and natural cosmogenic ^{7}Be are used as soil redistribution tracers. The FRN techniques can provide information on soil redistribution rates at different temporal (from a few days up to a period of ~100 years) and spatial (from plot to large catchment) scales and the soil redistribution patterns. There are different available models for calculating soil redistribution rates based on FRN inventories, i.e., conversion models. This contribution reviews current models for soil erosion assessment, discussing the advantages and limitations of traditional and conversion approaches and highlighting the specific needs for their further improvement. It also summarizes soil erosion assessments obtained by conversion models in studies conducted in Serbia in areas significantly affected by soil erosion.

Keywords: Soil redistribution; Nuclear techniques; Erosion models; Radiotracers.

SOIL EROSION

Although being a naturally occurring process, soil erosion has been greatly accelerated in the past several decades mostly by human activity. Soil erosion involves detachment, transport/movement and deposition of soil particles caused by one or more erosive forces (heavy rain, runoff, wind, gravity, tillage, etc.) (Martín-Fernández and Martínez-Núñez, 2011; Senanayake et al., 2020). Erosion by water (Fig. 1) is the primary and most common soil degradation process worldwide.

Erosion Models

Many empirical, semi-empirical, and physically-based (or process-oriented) soil erosion models (such as *Revised Universal Soil Loss Equation* (RUSLE), *Universal Soil Loss*

Equation (USLE), *Water Erosion Prediction Project* (WEPP), *Soil and Water Assessment Tools* (SWAT), *Water and Tillage Erosion Model and Sediment Delivery Model* (WaTEM/SEDEM), *European Soil Erosion Model* (EUROSEM), *Pan-European Soil Erosion Risk Assessment* (PESERA), etc) have been developed and tested (Borrelli et al., 2021; Pandey et al., 2016; Zi et al., 2019).

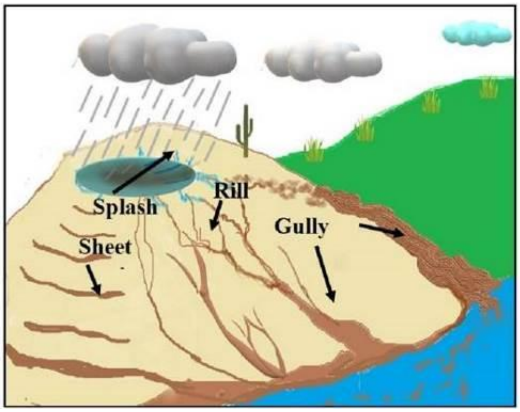

Figure 1. The types of soil water erosion (Senanayake et al., 2020).

According to the GASEMT database, most widely used models for water erosion assessment are (R)USLE[1]-type models, and for wind erosion assessment are (R)WEQ[2], SWEEP[3], and WEPS[4] (Borrelli et al., 2021). Review and limitations of (R)USLE have been described in publications (Alewell et al., 2019; Benavidez et al., 2018). The integrated use of remote sensing, Geographic Information System (GIS), and soil erosion models have been widely used in soil erosion assessment (Mitasova et al., 2013).
By using a modified version of the RUSLE model (RUSLE2015) (Fig. 2), Panagos et al. (2015) reported that the average annual soil loss rate due to water erosion for the reference year 2010 in the European Union's erosion-prone lands were 2.46 t ha^{-1} yr^{-1} (total soil loss of 970 Mt annually). The highest average annual soil loss rate was found in Italy, Slovenia, and Austria - 8.46 t ha^{-1}, 7.43 t ha^{-1}, and 7.19 t ha^{-1}, respectively, and the lowest were found in Finland, Estonia, and the Netherlands - 0.06 t ha^{-1}, 0.21 t ha^{-1}, and 0.27 t ha^{-1}, respectively (Panagos et al., 2015). Employing WaTEM/SEDEM at European scale, USLE-based model, estimated sediment yield totals was 0.164±0.013 Pg yr^{-1} and average soil loss was 4.62±0.37 Mg ha^{-1} yr^{-1} in the erosion area (Borrelli et al., 2018).
Soil erosion is the primary cause of land degradation in the Republic of Serbia and over the years different erosion models were used to study erosion on territory of Serbia. The Gavrilović method (*Erosion Potential Method* - EPM) (Gavrilović, 1972) is an empirical model developed in Serbia and most commonly applied in Serbia and neighbouring countries (Manojlovic et al., 2017). According to the Erosion Map of the Republic of

[1]Universal Soil Loss Equation family
[2] Wind Erosion Equation
[3]Single-event Wind Erosion Evaluation Program
[4]Wind Erosion Prediction System

Serbia (1966-1971), about 86% of the territory of Serbia is affected by different categories of soil erosion (Lazarević, 1983). Over the years impact of demographic and socio-economic changes on the intensity of erosion in Serbia has been recognized (Dragićević et al., 2009; Gocić et al., 2020), also erosion control works performed in Serbia resulted in a reduction of erosion intensity (Kostadinov et al., 2018).

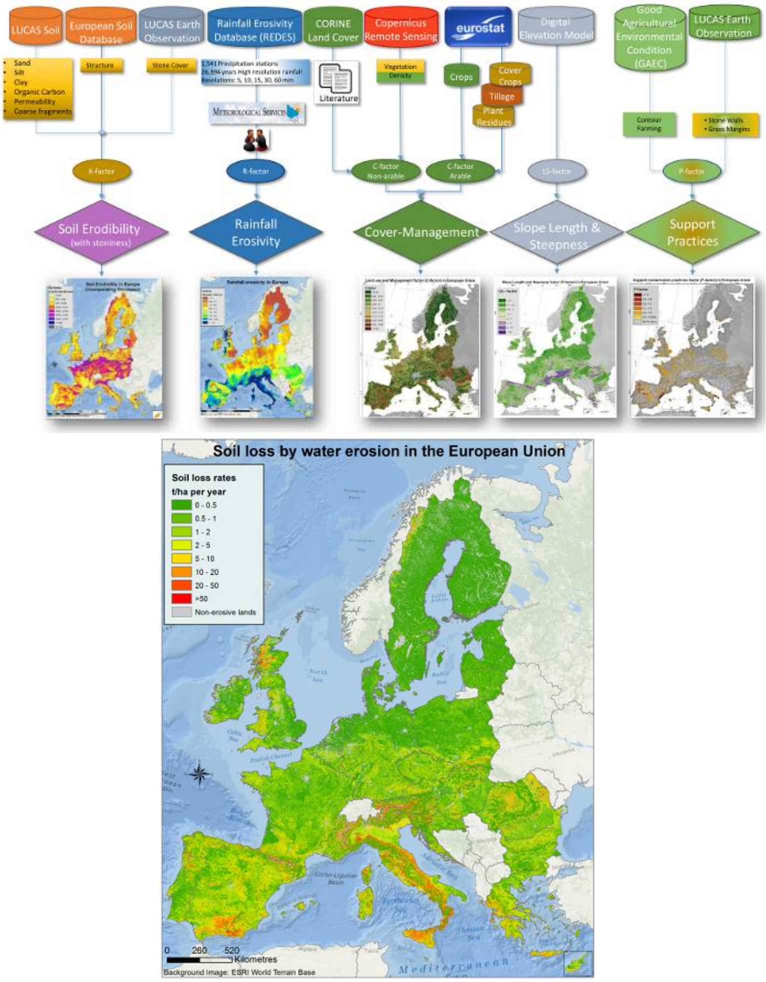

Figure 2. Input layers for the estimation of soil loss factors and Map of soil loss rates in the European Union (Reference year: 2010) based on RUSLE2015 (Panagos et al., 2015).

The Erosion Potential Method (EPM) was used for soil erosion assessment in different parts of Serbia: Nišava River Basin (Manojlovic et al., 2017), Kolubara River Basin (Kostadinov et al., 2017), Jablanica River Basin (Gocić et al., 2020), Vlasina River Basin (Durlević et al., 2019), Grdelica Gorge (South Morava River) (Kostadinov et al., 2018), etc. Manojlovic et al. (2017) reported that annual gross erosion in the Nišava River basin reduced in 2011 (533.3 m^{-3} km^{-2} $year^{-1}$) when compared with 1971 (765.3 m^{-3} km^{-2} $year^{-1}$)

due to anthropogenic influences. Gocić et al. (2020) reported that annual gross erosion reduced in the Jablanica River Basin in 2016 (472.03 m^{-3} km^{-2} $year^{-1}$) when compared with 1971 (654.41 m^{-3} km^{-2} $year^{-1}$). In Grdelica Gorge (South Morava River) as a result of the performed technical and biotechnical erosion control works, the intensity of soil erosion processes decrease between 1953 (annual gross erosion was 1920.34 m^{3} km^{-2} $year^{-1}$) and 2016 (annual gross erosion was 492.42 m^{3} km^{-2} $year^{-1}$) (Kostadinov et al., 2018).

The (R)USLE soil erosion model was applied in different parts of Serbia: Pirot municipality (Perović et al., 2012), Kolubara district (Belanović et al., 2013), Nisava River Basin (Perović et al., 2013; Zivotić et al., 2012), municipality of Nis (Perović et al., 2016), Polomska River Catchment (Miljković and Belanovic Simic, 2020). In the Kolubara district, very low, low, moderate, high, and very high erosion classes covering 53.94%, 15.60%, 14.72%, 9.51%, and 6.23% of the study area, respectively (Belanović et al., 2013). By using the USLE model, Životić et al. (2012) and Perović et al. (2013) reported average annual soil loss of 13.1 t ha^{-1} yr^{-1} and 27.0 t ha^{-1} yr^{-1}, respectively, in the Nišava River Basin; Perovic et al. (2016) reported average erosion intensity of 8.48 t ha^{-1} $year^{-1}$ in the municipality of Nis.

Application of the SHETRAN model in the area of torrential Lukovska River catchment, Serbia, during the rain event in 1986 showed that 69.1 % of the study area was affected by erosion, with the mean soil loss of 2.92 t ha^{-1} (Đukić and Radić, 2014). Perović et al. (2018) applied InVEST SDR[5] model and the MOLUSCE[6] model, integrated with methods of remote sensing to analyze the impact of LULC[7] changes on soil erosion in the Oplenac wine-producing area in Serbia in the past (1985 and 2013) and in the future (2041).

Fallout radionuclides (FRNs) as soil erosion tracers

Fallout radionuclides (FRNs) represent effective and useful tools for the assessment of soil redistribution since the 1960s (Mabit et al., 2018). For a detailed description of the method (advantages and limitations) and application of fallout radionuclides (FRNs) for investigating soil redistribution see IAEA publication "*Guidelines for Using Fallout Radionuclides to Assess Erosion and Effectiveness of Soil Conservation Strategies*" (IAEA, 2014), and some of the most important basis of this approach is briefly described hereinafter. A video illustrating the ^{137}Cs method developed by the Joint FAO/IAEA Division is available online[8].

The three FRNs (Fig. 3) including anthropogenic radionuclide the cesium-137 (^{137}Cs, medium-lived $t_{1/2}$=30.17 years) and natural radionuclides geogenic lead-210 ($^{210}Pb_{ex}$, medium-lived $t_{1/2}$=22.8 years) and cosmogenic beryllium-7 (^{7}Be, short-lived $t_{1/2}$=53.12 days) are commonly used as soil erosion tracers. These FRNs have been successfully employed for estimating erosion rates worldwide (Evans et al., 2017; Hancock et al., 2008; Iurian et al., 2012, 2014; Khodadadi et al., 2021; Porto et al., 2001). Recently, anthropogenic plutonium isotopes ($^{239+240}Pu$) has been proposed as the new soil redistribution tracers (measurements of Pu can be performed by inductively coupled

[5]Integrated Valuation of Ecosystem Services and Trade-offs Sediment Delivery Ratio
[6]Modules for Land Use Change Evaluation
[7]Land Use Land Cover
[8]http://www-naweb.iaea.org/nafa/resources-nafa/Soil-Erosion-web.mp4

plasma mass spectrometry, alpha spectrometry and accelerator mass spectrometry) (Alewell et al., 2017). Among investigated FRNs, ^{137}Cs is the most frequently used in soil erosion studies.

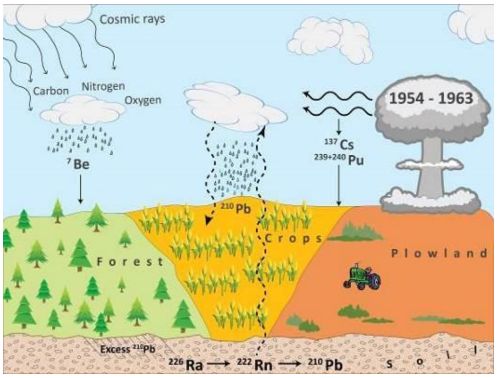

Figure 3. The FRNs used as soil tracers.

After FRNs deposition on the soil surface, the key feature is their rapid and strong bonding to soil particles which allow making the fundamental assumption that FRNs after deposition move across the landscape primarily together with soil particles to which they are bound, through physical processes (Arata et al., 2016; Guzmán et al., 2013; Mabit et al., 2018).

The FRNs method is based on a comparison of the FRNs inventory at selected sampling point - A_u (Bq m^{-2}) with a inventory measured in an adjacent stable reference site A_{ref} (Bq m^{-2}), i.e., a $A_u < A_{ref}$ is indicative of erosion, whereas $A_u > A_{ref}$ is indicative of deposition (Fig. 4) (Arata et al., 2016; Guzmán et al., 2013; Mabit et al., 2018; Walling, 2012). The measurements of ^{137}Cs, $^{210}Pb_{ex}$ and ^{7}Be activity (in Bq kg^{-1}) in soil can be performed by gamma spectroscopy and then to be converted into inventory (Bq m^{-2}).

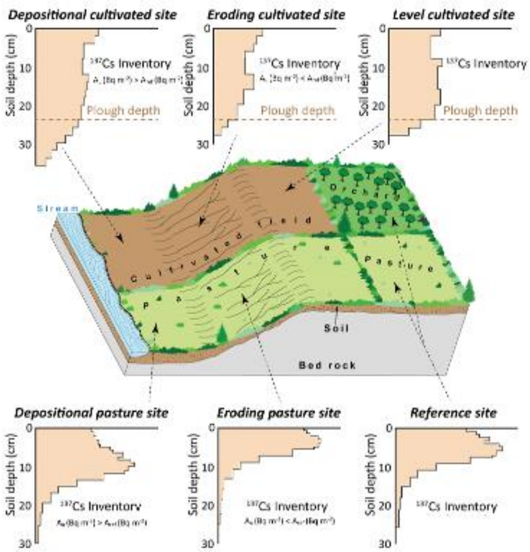

Figure 4. The principles of ^{137}Cs method.

Finding the depth profile of the FRN distribution and local reference inventory (representing the local fallout input) are key parameters of FRN methods. In the study conducted by Petrović et al. (2016), special attention was drawn to the fact that the territory of Serbia was affected by the Chernobyl accident so additional recommendations for the selection of the reference site must be followed (FAO/IAEA, 2017; IAEA, 2014) when applying ^{137}Cs method. Differences in ^{137}Cs reference inventory values obtained in different studies conducted in Serbia (Kalkan et al., 2020; Krmar et al., 2015; Petrović et al., 2016) are consistent with inhomogeneous surface contamination of Serbia after the Chernobyl accident (Dragović et al., 2012; Kalkan et al., 2021; Krmar et al., 2018). The Fig. 5 present the total ^{137}Cs inventories (Bq m^{-2}) documented in a recent study conducted by the authors of this paper from the reference sites at Vlasina, Serbia.

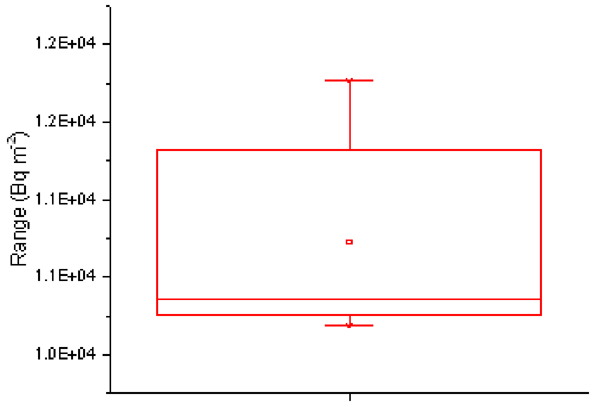

Figure 5. Total ^{137}Cs inventories (Bq m^{-2}) in the selected reference points at Vlasina, Serbia.

Different models for cultivated and uncultivated land were developed for conversion of FRN inventories into soil erosion and deposition rates (Arata et al., 2016; Walling, 2012; Walling et al., 2011): *Proportional Model* (PM); *Simplified mass balance model* (MBM1); *Mass balance model* (MBM2); *Mass balance model with tillage* (MBM3); *Profile distribution model* (PDM); *Diffusion and migration model* (DMM) - Excel™ based software for models implementation is free and public[9]; and *Modelling Deposition and Erosion rates with Radio-Nuclides* (MODERN) - code as MatLab or R package (modeRn) is free and public[10].

The FRNs technique was successfully applied for study soil erosion in different part of Serbia: Titel loess plateau, Vojvodina - applying ^{137}Cs method soil redistribution rates ranged from -6.12 to -1.07 t ha^{-1} yr^{-1} calculated by PDM (1963); from -10.6 to -1.8 t ha^{-1} yr^{-1} calculated by PDM (1986); and from -8.4 to -1.8 t ha^{-1} yr^{-1} calculated by DMM; and applying $^{210}Pb_{ex}$ method soil redistribution rates ranged from 0.62 to -8.6 t ha^{-1} yr^{-1}

[9]http://www-naweb.iaea.org/nafa/swmn/models-tool-kits.html
[10]https://duw.unibas.ch/de/umweltgeowissenschaften/forschung-fg-alewell/modern/

calculated by DMM (Kalkan et al., 2020); Deliblato Sands - applying ^{137}Cs method soil redistribution rates ranged from -54 to -291 t ha^{-1} yr^{-1} calculated by PM; from -0.15 to -8.7 t ha^{-1} yr^{-1} calculated by PDM; and applying $^{210}Pb_{ex}$ method soil redistribution rates ranged from 48 to -316 t ha^{-1} yr^{-1} calculated by PM (Krmar et al., 2015); and Pčinja and South Morava River Basins - applying ^{137}Cs method soil redistribution rates ranged from 41.5 to -44.0 t ha^{-1} yr^{-1} calculated by PDM; and from 21.1 to -13.3 t ha^{-1} yr^{-1} calculated by DMM (Petrović et al., 2016). The selection of the conversion models has a direct impact on the obtained soil redistribution rates, due to different underlying assumptions in their algorithms (IAEA, 2014).

CONCLUSION

The development of reliable erosion models is of great importance for obtaining precise erosion rates and identifying the erosion-prone areas and also selecting appropriate soil conservation options. The use of FRNs methods confirmed the validity and potential of this methodology, indicated their advantages among traditional methods but also pointed out some limitations of the methods.

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INTEGRATED WATER RESOURCES MANAGEMENT: EVOLUTION OF CONCEPT, PRINCIPLES AND APPROACHES

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Abstract

The present document addresses the evolution of concept, basic principles and approaches in integrated water management with a particular attention of its implementation in agricultural sector. Water management plays an important role in society since it intersects different technical, economic, technological, environmental and societal sectors, and policy issues. The difficulties of properly approaching this topic are increasing since management solutions should be seen in the context of continuously altering spatial-temporal scenarios generated by climate variability and change, population growth and migration, land use transformation, uncontrolled pollution of resources and socio-economic concerns. Accordingly, the integrated water management concept embraces, in a comprehensive way, the numerous technical, socio-economic and environmental factors, institutional settings and stakeholders' interests interplaying throughout the scales in the water management process.

The concept of integrated water resources management has been evaluating during the last three decades with the aim to consider new challenges related to climate change, land/water/energy/food insecurity and a common need to achieve the sustainable development goals. The water management in agriculture should be seen in the same perspective of integration and consider different interests of stakeholders across administrative, hydrological and management scales. In this context, it is fundamental the resolution of conflicts between sectors with the aim to balance the "demand vs. availability" equation and the "agronomy-engineering" symbiosis and to optimize the use of resources and performance of irrigation networks. Consequently, the concept of nexus is introduced as a core strategy to deal with the global challenges. The adoption of the eco-efficiency approach as a modern management concept and indicator of sustainable water use represents one of win-win solutions.

Keywords: Water management, irrigation, eco-efficiency, sustainability.

INTRODUCTION

Water cycle has clear and well-defined hydrological boundaries and units interplaying harmoniously according to the hydrological laws when they are not affected by external factors. Nevertheless, water management scales differ among sectors and stakeholders, each having specific and frequently contrasting interest. In the last decades, the conflicts among the sectors and among the states are increasing due increased variability of hydrological parameters, pollution of resources and changed water demand by different sectors. It is particularly relevant in water-scarce regions where water availability and its efficient use are primary drivers of socio-economic development and environmental protection.

The agricultural sector is the principal consumer of freshwater resources especially in the water-scarce regions. On the global scale, around 70% of freshwater withdrawal is used for crop cultivation. This irrigation water is applied over only 20% of agricultural land. Nevertheless, it produces more than 40% of the world food requirements (Grafton et al., 2017). Thus, an efficient use of water in agriculture is of primary interest to all.

The concept of integrated water management has been evaluating continuously since the last decade of 20th Century. Water is recognised as a fundamental component of the development strategies at global and local scale and key-source for many inter—related issues as they are food security, environmental degradation, ecosystem functioning, energy production etc. Henceforth, the integrated water management intersects different technical, economic, technological, environmental and societal sectors, and policy issues. Consequently, the management solutions should be seen in the context of continuously altering spatial-temporal scenarios and needs to face numerous disputes at different scales and with various stakeholders' groups (Todorovic, 2018).

EVOLUTION OF CONCEPT, PRINCIPLES AND APPROACHES

The overall concept and strategies for integrated water management are inherently linked with the sustainable development approach that seeks to meet the needs and aspirations of the present generation without compromising the ability to meet those of the future (WCED, 1987). Then, the integrated water resources management (IWRM) concept had been endorsed as a globally recognized concept for sustainable water management at the "United Nation Conference on Environment and Development" (UNCED) held in 1992, in Rio de Janeiro, Brazil.

The Rio conference affirmed the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization (UNCED, 1992). Hence, IWRM is defined as a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000).

IWRM invokes the adoption of a holistic and multi-stakeholders driven approach built on the common basic principles and objectives (UNCED, 1992):

- To promote a dynamic, interactive, iterative and multi-sectoral approach to water resources management,
- To identify/protect all potential sources of freshwater supply,
- To monitor/evaluate water withdrawal/pollution by potential users,
- To integrate technological, socio-economic, environmental and human health considerations,

- To plan for the sustainable and rational utilization, protection, conservation and management of water resources based on community needs and priorities within the framework of national economic development policy,
- To design, implement and evaluate projects and programmes that are both economically efficient and socially appropriate,
- To promote full public participation, including that of women, youth, indigenous people and local communities in water management policy and decision-making,
- To identify/strengthen/develop the appropriate institutional, legal and financial mechanisms,
- To ensure that water policy and its implementation are a catalyst for sustainable social progress and economic growth.

The concept of IWRM has been reaffirmed and reviewed during the last 25 years on several occasions. The International Conference on Freshwater, held in Bonn, Germany, in 2001, focused on the guiding principles for practical implementation of IWRM and identified the priority actions in the fields of governance, mobilization of economic resources, capacity building and knowledge sharing. The 2002 World Summit on Sustainable Development (WSSD), held in Johannesburg, adopted the Bonn recommendations and extended the concept of IWRM:

- To embrace the impact of climate change on water resources, and to adopt adaptation and mitigation measures and initiatives in water management plans,
- To recognize the priority of the water-food security issue in water development plans especially in the less developed areas/countries,
- To promote the public-private partnership initiatives for funding and implementation of water management plans,
- To consider the link between water and energy sector in water development and management.

The Rio+20 Conference, in 2012, confirmed the need for full and permanent consideration of climate change adaptation and mitigation including the extreme weather events (i.e. floods and droughts), endorsed the relevance of water-energy-food security nexus in sustainable water management and promoted the concept of green economy as an opportunity to implement innovative (“clean”) technological solutions that achieve management objectives while consuming less resources and reducing the negative impact on environment (EC, 2014a).

The implementation and functioning of IWRM requires the creation of a proper three-dimensional mechanism/framework (Fig. 1) at the national level that includes: a) Enabling environment (policies, legislation, financing structures), b) Institutional arrangements (regulatory, implementation, assessment, service provider and capacity building roles) and c) Management tools (water supply/demand monitoring, multi-objective assessment, Decision Support Systems and Shared Vision Planning, communication tools, efficiency evaluation, economic instruments).

The purpose is to build a set of comprehensive and complementary goals/rules/institutions/instruments for all stakeholders in the IWRM process (from the national down to river basin and watershed/community/farm level) to achieve sustainable water management goals while balancing social, economic and environmental needs (GWP, 2017). In this context, water governance tends to be decentralized and the institutional decision-making should be based on the principles of subsidiarity scaling down management actions to the lowest appropriate level.

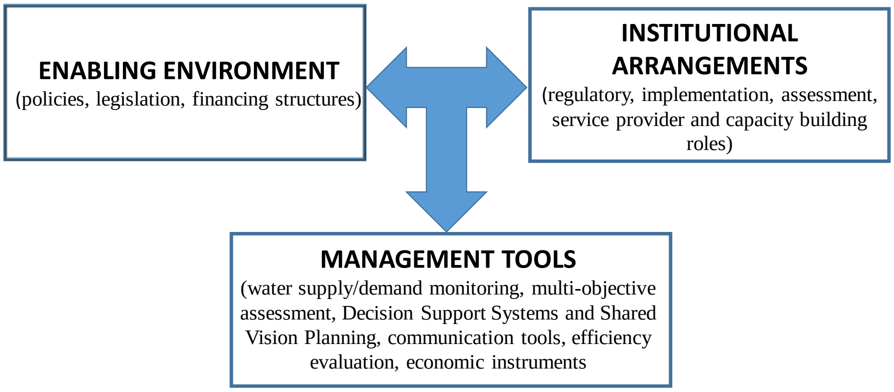

Figure 1. Three-dimensional mechanism/framework for implementation and functioning of IWRM

The IWRM comprises systematic monitoring and coordinated administration of water availability within a hydrological/administrative unit, water storage in physical structures (reservoirs), and water delivery, distribution and use by different sectors (Fig. 2).

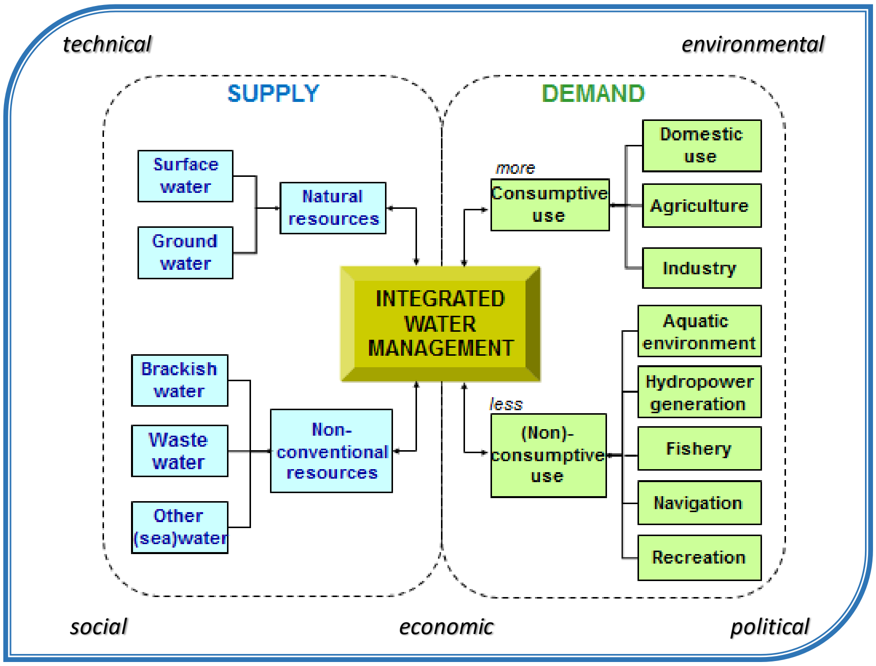

Figure 2. Integrated water management concept: a balance between water demand and supply equations (Todorovic, 2018)

The overall objective of water management is to balance water demand with water supply over time within a specific management unit, and among them whenever the transfer of resources is possible. In many water-scarce regions, this means the consideration of non-conventional water resources (treated wastewater, brackish water, etc.) and other marginal water use sectors like fishery, navigation and recreation. In this context, it is important to address properly the water quality issues and to distinguish between more and less water consumptive sectors.

AGRICULTURAL WATER MANAGEMENT

In the years to come, the demand for water in agriculture will continue to raise to meet the growth in food needs for an ever-increasing world population. Moreover, the impact of climate change and variability on agricultural production will enhance, which will trigger additional water needs in agricultural sector and possible extension of irrigated land. However, freshwater resources are limited especially in irrigated, usually arid and semi-arid regions. Moreover, the water demand of other sectors (domestic, industrial, environment, etc.) is expected to increase. Hence, a more efficient water use in agriculture should be based on the sustainable and integrated water management that includes agronomic and engineering aspects as well as environmental, social and economic factors.
Hence, the water management in agriculture should be seen in the same perspective of integration and consider different interests of stakeholders across administrative, hydrological and management scales (Todorovic, 2018).
Agricultural water management is a dynamic process inside the IWRM and represents a loop of mutually dependent issues (Fig. 3).

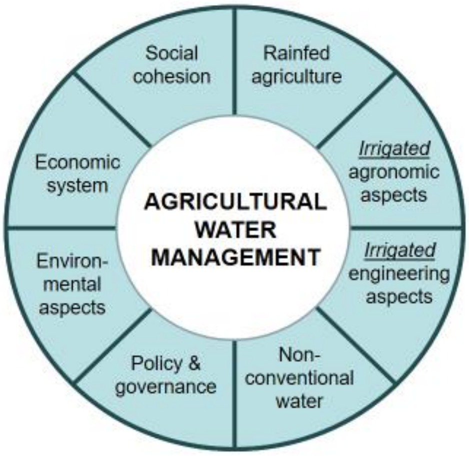

Figure 3. Agricultural water management loop: interdependence of various issues for sustainable development (Todorovic, 2018)

The agricultural water management requires the analysis and enhancement of the rainfed agricultural system (i.e., “green” water use) and its perspectives, the identification and use of additional water sources (i.e., “blue” water), the design and construction of the irrigation network and on-farm/plot irrigation systems, the establishment of a management body (e.g., water users association), planning/optimization of activities, monitoring, operation, maintenance and collection of fees. Thus, it requires strong collaboration between farmers, agro-meteorologists, hydrologists, soil experts, agronomists, engineers, economists, environmentalists, social-science experts and politicians since the beginning of the irrigation project preparation. Moreover, sustainable agricultural water management strategies should consider the use of non-conventional water resources as treated waste effluent, brackish and saline water and construction of adequate drainage system (Pereira, 2002). The interaction between the specific issues across different scales is presented graphically in Fig. 4.

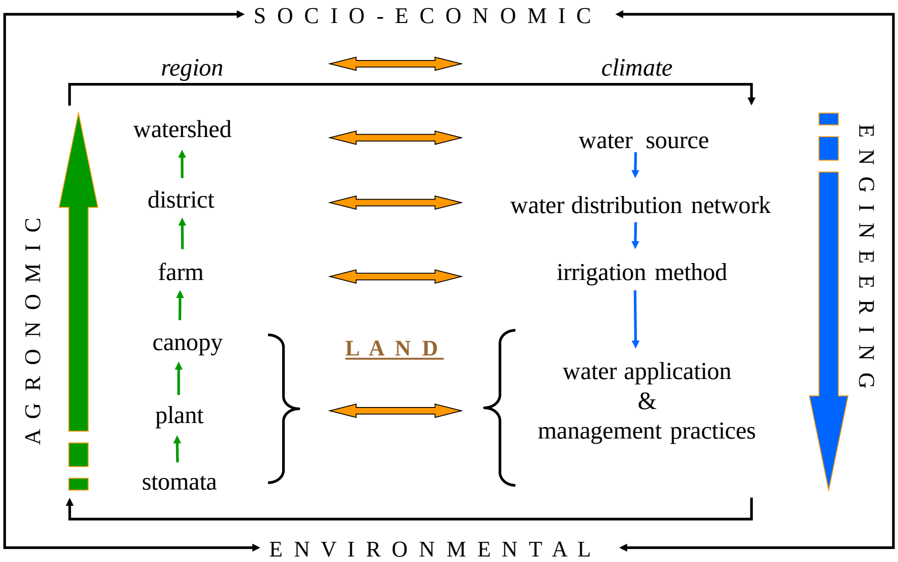

Figure 4. Interaction between specific issues and scales in crop growth modelling

ECO-EFFICIENCY CONCEPT IN AGRICULTURAL WATER MANAGEMENT

The modern regional strategies for sustainable water management in the agricultural sector aim to optimize the use of resources while respecting the interest of numerous stakeholders in a complex context of interactions, overlapping of responsibilities, policies and legislation (EC, 2013; EC, 2014b; OECD, 2010).

The concept of eco-efficiency offers the opportunity to establish a new conceptual framework for the evaluation of the performance of agricultural water management that is based on the overall economic benefits of irrigation and the corresponding environmental impact.

The concept of eco-efficiency provides the opportunity to upgrade the set of common indicators for the assessment of agricultural water management and to introduce a new conceptual frame that evaluates the performance of irrigation schemes and adopted management practices in a more comprehensive way. Eco-efficiency has not a specific spatial and temporal context. Instead, it is a concept of global interest, and it is spreading independently across the hydrological scales and water management units. The eco-efficiency aims to bridge the gap towards the effective implementation of IWRM at different scales since it contemplates, in a consistent and rational way, technical, environmental, social and economic aspects of water management.

The eco-efficiency concept may be used to assess the adoption of technological achievements in agricultural water management to attain economic and environmental progress through more efficient uses of resources and lower pollution. In the context of infrastructure development, the eco-efficiency approach represents an effort to promote design, construction, operation and maintenance and to maximize the value and/or function of sustainable water services. This concept can be applied in different water and other sectors and at different management levels and spatial scales (plot, farm, irrigation district, irrigation consortia and watershed).

A novel approach to the meso-level eco-efficiency indicators for technology assessment and promotion of stakeholder participation in water management was developed by EcoWater project (EcoWater, 2014). The meso-level assessment focuses on the interconnection between micro and macro level to address the dynamic behaviour of a product/service system for support policies towards sustainable water management and agricultural production. It is based on the Life Cycle Assessment (LCA), and the valuation of Life Cycle Costing (LCC). The methodological approach for the eco-efficiency assessment of agricultural water systems was described by Todorovic et al. (2016), Mehmeti et al. (2016), Canaj et al. (2021), and others.

The eco-efficiency concept of agricultural water use is developed on a system-based approach that interweaves among heterogeneous stakeholders across the entire value chain of a production/service process, as is agricultural water management (Fig. 5). Therefore, it includes managers of irrigation infrastructures, farmers, agricultural extension staff, environmental authorities and decision makers.

Eco-efficiency embraces all management activities, on a plot/farm/district level, which contribute to the farming process accomplishment, i.e., including water management as well as the use of energy, application of nutrients and agro-chemicals and adoption of land management and other farming practices necessary for crop cultivation and harvesting. In agricultural water management, eco-efficiency considers the entire water chain from its origin (source), where it is extracted as a natural resource, to the final use in agricultural fields and encompasses actions (processes) related to the creation of the economic value from the commercialization of the final product (yield) and other (any) by-products (Fig. 5). Accordingly, at each stage of the water chain (withdrawal, storage, conveyance, delivery, distribution and irrigation) the relevant stakeholders responsible for management decisions and actions, which affect the overall performance of the system, are identified.

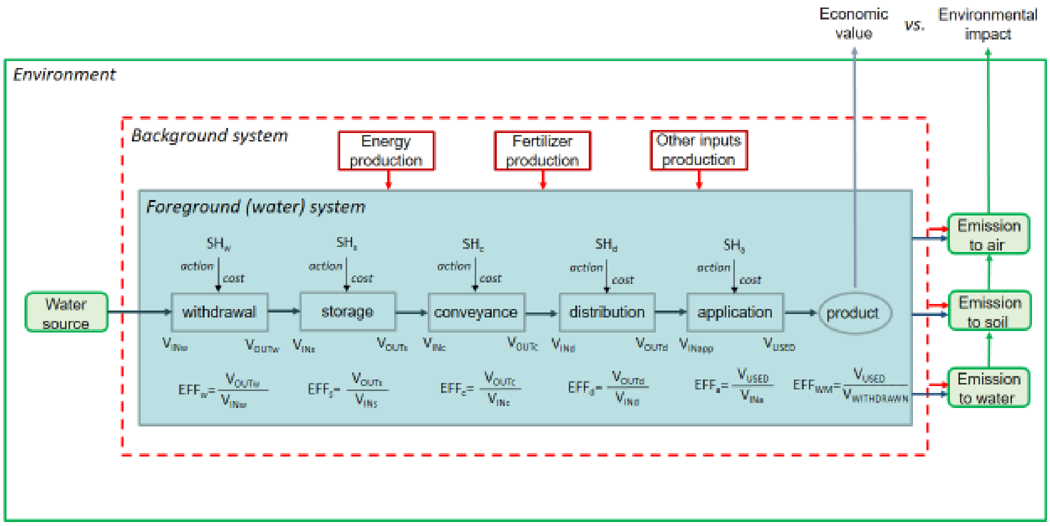

Figure 5. Value chain of water from the source (where it is withdrawn) to the plot (where it is used for irrigation). V indicates water volumes – inflows and outflows for different stages indicated as w (withdrawal), s (storage), c (conveyance), d (distribution), a (application). SH and EFF indicate the corresponding stakeholders and water management efficiencies, respectively.

Eco-efficiency overcomes the specificity of other water performance indicators since it includes the overall economic benefits (of all production outputs) and different environmental burdens. Therefore, it makes possible to shift from a specific ratio (e.g., yield or biomass vs. crop evapotranspiration or irrigation supply) to a more comprehensive approach that integrates the appropriateness and interaction of different management practices and inputs (e.g., water, fertilizer, energy, etc.), overall benefits of stakeholders and various environmental impacts. This is of importance at all hydrological and management scales.

PROSPECTS FOR THE FUTURE

Nowadays, the unceasing challenge is to embrace, in a comprehensive way, the numerous technical, socio-economic and environmental factors, institutional settings and stakeholders' interests interplaying throughout the scales in the water management process. In the agricultural sector, it is particularly important the consideration of new challenges related to climate change and increased frequency of extreme events (heat, drought, floods), land/water/energy/food insecurity and a common need to achieve the sustainable development goals. The primary aim is to implement effective water management platforms and information systems that contain historical, real time and forecasting data about water availability and demand of different sectors (WWAP, 2009) and within specific sectors as it is agriculture. This calls for the application of modern technological

solutions for big data acquisition, transfer and elaboration. The research should focus on the adoption of blockchain approach and development of modern monitoring tools and technologies (Internet of Things, remote sensing), data assessment techniques, integrated and smart modelling software and real-time management solutions (Abi Saab et al., 2019; Abi Saab et al., 2021). The overall aim should be the consolidation of a mutual link between the biophysical and technical factors, on one side, and social, economic, environmental and policy issues on the other. The focus should be on a more efficient use of water in agriculture (Levidow et al., 2014).
Communication, understanding of data and consequences of each specific water management action should be upgraded to enhance awareness and involvement of the whole society and of different stakeholders in the water management process. Transparency and trust are the keys to success. Research should focus on the improvement of weather forecasting tools and identification of the most suitable proactive management options to adapt to both droughts and floods. Hence, a setup of modern early warning systems and new regional/watershed management plans is needed to attenuate the vulnerability of water systems and of the society to climate change and extreme weather events.
The adoption of innovations, based on green technologies, should be guided at all hydrological and administrative management scales in a concerted manner. A matrix for the adoption of water management solutions on the ground should be adaptive and inclusive. The priorities for actions and interventions could vary for different scenarios, locations, and water sectors. However, they should be agreed jointly among all stakeholders considering the risk of not acting, the overall benefits of specific water users and of the society, the costs and attenuation of ecosystem vulnerability.
The eco-efficiency concept might be among the top approaches and indicators for the evaluation of the performance of water systems and especially of agricultural water management. However, further research is needed to develop more complete procedures and detailed databases that support the assessment of eco-efficiency at different scales.

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SECTION 1

SOIL FUNDAMENTALS

ELEMENTAL COMPOSITION OF HUMIC ACIDS ISOLATED FROM CHERNOZEM, VERTISOL, REGOSOL, PLANOSOL AND HISTOSOL

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Abstract

Humic substances, including humic acids (HAs), are the most abundant fractions of soil organic matter. Their composition, structure and properties, determined by soil formation conditions, can be used as indicators of pedogenetic processes. In this study, elemental composition as very important part of HAs characterization was determined for humic acids isolated from the soils of Serbia developed under different pedogenetic conditions (Chernozem (CH), Smonica/Vertisol (VR), Rendzina/Regosol (RG), Pseudoglej/Planosol (PL) and Prelazni treset/Histosol (HI) and related to soil properties and origin. Soil samples were collected at 0 to 15-30 cm depth. Soil texture, organic C (soil organic matter for HI), and pH were determined by common methods. HA samples were isolated using a modified IHSS method. The C, H, and N contents of HA samples were determined using elemental analyzer (CHNS 628, LECO Corporation, USA) after drying the samples over P_2O_5 under vacuum. Their percentages were calculated on the ash-free basis. The oxygen content was obtained as the difference. The ash content was determined by a dry combustion method. The C/N, O/C, H/C and O/H atomic ratios were used as indicators of variations in HA properties as a function of HA origin. Internal oxidation degree (ω) was calculated by the equation: $\omega = (2O+3N-H)/C$, where: O, N, H and C are element contents (atomic %). Elemental compositions of investigated HAs fall within the range of average values reported for soil HAs. According to the humification degree obtained, HAs studied are ranged as follows: CH>VR>RG>HI>PL. Both correlations done (H/C versus O/C and H versus C) separate HAs in three groups: CH and VR - the most dehydrogenated and demethylated, i.e. the most stable; RG - the most oxidated; and HI and PL - the most hydrogenated. HAs elemental composition is related to soil organic C and pH, but not related to soil clay. Internal oxidation degree is used as an indicator of plant residue humification progress. Positive ω values point out well drained soils with prevailing oxidizing conditions and negative values reflect anaerobic soil conditions. Internal oxidation degree values are obviously lower in hydromorphic HI and PL HAs compared to terrestrial RG, CH and VR HAs, but positive values indicate predominance of aerobic under anaerobic conditions in surface layer of hydromorphic soils. Results obtained in this study are in agreement with the literature data, indicating characteristics of HAs as particularly dependant on environmental conditions.

Keywords: Humic acids elemental composition, Atomic ratio, Internal oxidation degree, Environmental conditions

INTRODUCTION

Humic acid (HA) is one of the main components of soil humic substances. HAs reflect characteristics of the environment forming them in an internal state, which affects their composition, structure and properties (Dergacheva et al., 2012; Kononova 1975). Hence, they can be used as indicators of pedogenetic processes (Vishnyakova and Chimitdorzhieva, 2008). Elemental composition, particularly the ratio of main elements, is one of features of HAs specifically related to natural environment (Dergacheva et al., 2012). Nowadays, HAs are considered to be group of high-molecular weight compounds with heterogenous molecular and elemental composition (Lodygin et al., 2017). So, elemental composition of HAs is an important and informative characteristic, which indicates humification level, oxidation and condensation degree. It is also possible to assess the level of soil organic matter stabilization by assessment of atomic ratios and HA oxidation degree (Lodygin et al., 2017; Schnitzer 1982).
In this study, elemental composition was determined for humic acids isolated from five soils of Serbia, developed under different pedogenetic conditions, and related to soil properties and origin. Chernozem (CH), Smonica/Vertisol (VR) and Rendzina/Regosol (RG) were developed under terrestrial conditions, while Pseudoglej/Planosol (PL) and Prelazni treset/Histosol (HI) pedogenesis proceeded under hydrogenic conditions. Furthermore, difference in basic physical and chemical properties of these soils can effect HA elemental composition.

MATERIAL AND METHODS

Chernozem soil originates from Novi Banovci, 44º57′N, 20º16′E; 85 m above sea; mean annual precipitation (MAP) 690.9 mm; mean annual air temperature (MAAT) 12.5°C. Smonica/Vertisol soil originates from Umka, 44º39′N, 20º17′E; 111 m a.s; 690.9 mm; MAAT 12.5 °C. Rendzina/Regosol soil originates from Pirot, 43º07′N, 22º34′E; 370 m a.s.l; 605.8 mm, MAAT 11.4°C. Pseudoglej/Planosol soil originates from Varna, 44º41′N, 19º38′E; 110 m a.s.l; 693.3 mm, MAAT 11.2°C. Prelazni treset/Histosol soil originates from Divčibare (44º06′N, 19º59′E; 975 m a.s.l; 1017.3 mm; MAAT 7.7°C). Prelazni treset/Histosol was under swamp vegetation, while other soils were used as cropland. Soil samples were collected at 0-30 cm depth. Soil texture, organic C (soil organic matter for HI), and pH were determined by common methods (Carter, 2000).
HA samples were isolated using a modified (HA gel was dried at 35 °C, powdered, and sieved using a 0.05 mm sieve) IHSS method (IHSS, 2017). The C, H, and N contents of HA samples were determined using elemental analyzer (CHNS 628, LECO Corporation, USA) after drying the samples over P_2O_5 under vacuum. Their percentages were calculated on the ash-free basis. The oxygen content was obtained as the difference. Ash content was determined by a dry combustion method (50 mg HA at 750 °C for 8 h) (Conte et al., 2003). The C/N, O/C, H/C and O/H atomic ratios were calculated by determining the ratio of C to

N, O to C, H to C, and C to H contents, respectively. Internal oxidation degree (ω) was calculated by the equation: ω=(2O+3N-H)/C, where: O, N, H and C are element contents (atomic %). The correlation analysis were processed using StatSoft, Inc. Statistica software package for Windows, Version 8.

RESULTS AND DISCUSSION

Soil texture of investigated soils (Table 1) was RG - sandy clay loam, CH and PL - clay loam, and VR - clay. CH and RG were calcareous and moderately alkaline, while other soils were acid: VR slightly, PL strongly and HI - very strongly acid. Organic matter content was 64.7% in HI, and 1.98-3.33% in other mineral soils.

Table 1. General soil properties

Soil	Coarse fragm. (%)	Sand (%)	Silt (%)	Clay (%)	$CaCO_3$ (%)	pH in H_2O	Organic C (%)	Organic matter (%)
Chernozem	0	35.4	35.7	28.9	2.51	7.87	1.93	3.33
Vertisol	0	20.7	34.1	45.2	0	6.08	1.91	3.29
Regosol	18.0	53.2	23.4	23.4	14.5	7.98	1.15	1.98
Planosol	0	24.7	39.8	35.6	0	5.20	1.28	2.21
Histosol	0	ND[a]	ND	ND	0	5.09	ND	64.7

[a]ND

Elemental compositions of investigated HAs (Table 2) fall within the range of average values reported for soil HAs (Rice and Maccarthy, 1991).

Table 2. Elemental composition, ash content, atomic ratios and internal oxidation degree (ω) of humic acids

Humic acids	C	H	O	N	Ash
	(wt. %, ash and moisture-free basis)				(%)
Chernozem	52.5	4.33	39.3	3.85	0.230
Vertisol	52.5	4.37	39.2	3.87	1.48
Regosol	50.5	4.78	41.0	3.70	0.648
Planosol	49.5	5.78	39.9	4.74	0.071
Histosol	49.8	5.55	40.8	3.75	0.416
	C/N	H/C	O/C	O/H	ω
	(atomic ratio)				
Chernozem	16.8	0.974	0.550	0.565	0.3049
Vertisol	15.8	0.991	0.560	0.565	0.3191
Regosol	15.8	1.14	0.614	0.541	0.2829
Planosol	12.2	1.39	0.605	0.435	0.0663
Histosol	15.5	1.33	0.615	0.464	0.0970

The C/N, O/C, H/C and O/H atomic ratios were used as indicators of variations in HA properties as a function of HA origin (Liu et al., 2010; Rice and Maccarthy, 1991).

Generally, high C/N and O/H and low O/C and H/C reflect high degree of aromatic condensation, maturity and stability of HAs, i.e., the degree of HA humification. According to the humification degree obtained, HAs studied are ranged as follows: CH>VR>RG>HI>PL.

Chemical processes influencing formation of HAs (Barančíková al., 1997), as well as compositional differences between humic materials as a function of source (Rice and Maccarthy, 1991) can be evaluated by the Van Krevelen diagram (H/C versus O/C). This graphical data presentation illustrates modification of HA elemental composition by oxidation and condensation, meaning that humification of plant residues decreases both H/C and O/C ratios and enlarges share of aromatic structures in HA molecules (Lodygin et al., 2017). The H/C ratio is dependent on landscape and climatic conditions, remaining constant within time (Dergacheva et al., 2012). The H/C ratio decreases with humification (Zaccone et al., 2007) and has been used as molecular complexity index (Ejarque and Abakumov, 2016).

Both correlations done (H/C versus O/C in Fig. 1, and H versus C in Fig 2) separate HAs in three groups: CH and VR - the most dehydrogenated and demethylated, i.e. the most stable; RG - the most oxidated; and HI and PL - the most hydrogenated. Terrestrial CH, VR and RG HAs were more humified compared to hydrogenic HI and PL HAs. Similar results, obtained by Lodygin et al. (2017), have shown that HAs of Albeluvisols were more humified than over-moisted soils with stagnic horizons. It is the consequence of low microbiological activity in over-moisted soils which favouring conservation of carbohydrate and amino acid fragments in HA structure. So, specific HA characteristics of over-moisted soils with stagnic features are increment of aliphatic compounds in molecules.

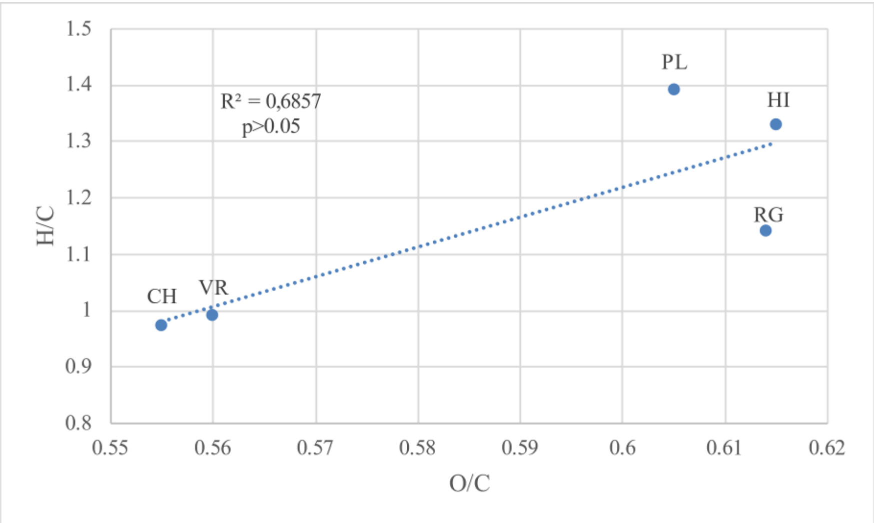

Figure 1. Atomic ratios of elements in humic acids (CH - Chernozem, VR - Smonica/Vertisol, RG - Rendzina/Regosol, PL - Pseudoglej/Planosol and HI - Prelazni treset/Histosol)

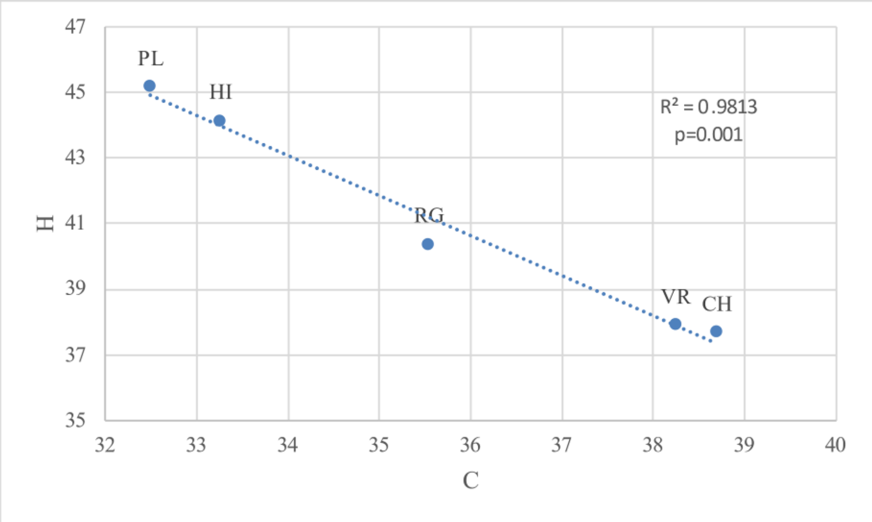

Figure 2. H versus C (atomic %) in humic acids (CH - Chernozem, VR - Smonica/Vertisol, RG - Rendzina/Regosol, PL - Pseudoglej/Planosol and HI - Prelazni treset/Histosol)

Internal oxidation degree is used as an indicator of plant residue humification progress (Dębska et al., 2012). Positive ω values point out to well drained soils with prevailing oxidizing conditions while negative values reflect anaerobic soil conditions (Siong Fong and Mohamed, 2007). Internal oxidation degree values are obviously lower in hydrogenic HI and PL HAs compared to terrestrial RG, CH and VR HAs, but positive values indicate predominance of aerobic under anaerobic conditions in surface layer of hydrogenic soils.
Soil organic C of mineral soils was in negative significant correlation with O/C ratio ($r=-1.00$, $p<0.01$), and non-significant with H/C ($r=-0.77$), and in positive non-significant correlation with C/N and O/H ($r=0.56$ and 0.62, respectively), indicating higher HAs humification degree in more humified soils. Soil pH was non-significant positively correlated with C/N, O/H and negative with O/C and H/C (r=0.71, 0.75, -0.24 and -0,66, respectively). HA humification degree was higher in slightly acid (VR) and alkaline (CH and RG) than in strongly and very strongly acid (PL and HI) soils. HA from the most calcareous RG soil showed lower humification degree compared to those from less calcareous CH soil. Correlations of soil sand, silt and clay with HA elements content and ratios were very weak.
All three terestial soils (CH, VR and RG) were used as cropland. Altitude differences were not very pronounced. Climate conditions of RG soil area are characterized by slightly lower precipitation in comparison to CH and VR soils areas. Besides lower precipitation, coarse gravel presence and higher sandy content in RG soil likely cause lower soil moisture and more pronounced aerobic conditions. Further, high carbonate and low soil organic matter content could cause lower humification degree of RG HAs in comparison to other terrestial HAs (CH and VR).
Experimental results obtained, as well as corelation analysis done, reveal that very pronounced differences in hydrological regime of terrestial (CH, VR and RG) and hydrogenic (Pl and HI) soils likely have been the main reason of differences in their HA

elemental composition. Difference in climate (precipitation) and chemical properties (soil organic matter, pH and carbonate) possibly have resulted in minor differences in elemental composition of investigated HAs.

CONCLUSION

Elemental compositions of investigated CH, VR, RG, HI and PL HAs fall within the range of average values reported for soil HAs. According to the humification degree obtained, HAs studied are ranged as follows: CH>VR>RG>HI>PL. Both correlations done (H/C versus O/C and H versus C) separate HAs in three groups: CH and VR - the most dehydrogenated and demethylated, i.e. the most stable; RG - the most oxidated; and HI and PL - the most hydrogenated. Internal oxidation degree values are obviously lower in hydromorphic HI and PL HAs compared to terrestrial RG, CH and VR HAs, but positive values indicate predominance of aerobic under anaerobic conditions in surface layer of hydromorphic soils.

Results obtained in this study are in agreement with the literature data, indicating HA characteristics as particularly dependant on environmental conditions. More pronounced differences in HA elemental composition were consequences of various hydrological regimes in terrestial (CH, VR and RG) and hydrogenic (Pl and HI) soils, while climate (precipitation) and chemical properties (soil organic matter, pH and carbonate) possibly had minor influence.

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CORRELATION BETWEEN RANKER SOIL TYPE OF NATIONAL CLASSIFICATION SYSTEM AND LEPTOSOLS REFERENCE SOIL GROUP OF WORLD REFERENCE BASE FOR SOIL RESOURCES – THEORETICAL APPROACH

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Abstract

National soil classification system (NSCS) used in Serbia is based on the principles of genetic classification. It is utilizes the concept of genetic soil horizons. The world reference base (WRB) for soil resources is based on soil properties defined in terms of diagnostic horizons, diagnostic properties, and diagnostic materials, which to the greatest extent possible should be measurable and observable in the field. The difference between genetic vs. diagnostic horizons creates an obstacle in correlation of soil types from NSCS with reference soil groups (RSG's) of WRB for soil resources, whereas the advantage in this work is that most of the soil names of national system correlate to the revised legend of the Soil Map of the World which is an forerunner of WRB for soil resources.
This work aims to compare Ranker soil type of NSCS with corresponding RSG from WRB for soil resources, namely with Leptosols, as they have been reported in Serbia and abroad, as an appropriate reference soil group. The comparison was conducted on the base of qualitative and semi–quantitative information collected from the literature and experience of the authors – theretical approach. It was conducted in two ways: a) Leptosols vs. Rankers, meaning which Leptosols of WRB for soil resources are Rankers in NSCS, and b) Rankers vs. Leptosols, meaning which Rankers of NSCS are Leptosols in WRB.
The conclusion of our work is that Leptosols RSG can correspond to Rankers in NSCS, but some WRB Leptosols are also Lithosols, Technosols, soils of Subaquatic soil order, Eugleys, Humogleys, Peat Soils, Rendzinas, Kalkomelanosols, Eutric and Dystric Cambisols, whereas Gypsiric Leptosols can not be classified according to NSCS. Observing in different direction, the results show that Ranker Soils could be also part of some other RSG with Leptic principal qualifier, such as Andosols, Phaeozems, Umbrisols, Cambisols, and Regosols. This work represents a small contribution to soil science in Serbia as WRB is comprehensive classification system that enables accommodation of NSCS's for communication at the international level.

Keywords: National soil classification, WRB, Rankers, Leptosols

INTRODUCTION

Soil classification deals with the systematic categorization of soils based on their characteristics as well as the defined criteria that dictate choices in use. Among others, it serves as a basis for an assessment of a soil production and ecological value. The classification of soils according to the World Reference Base for Soil Resources (WRB) is based on soil properties defined in terms of diagnostic horizons, diagnostic properties, and diagnostic materials, which to the greatest extent possible should be measurable and observable in the field (IUSS, 2015). This is an international soil classification system covering the entire Globe. Soil classification system used in Serbia (Škorić et al., 1985) is not based on the use of diagnostic horizons. It uses genetic horizons and it is based on the principles of genetic classification as it is created under the great influence of Russian school of soil science. The central unit of classification system is soil type. Soil types are grouped into higher categories according to soil profile sequences and the character of wetting and soil water quality. Lower classification levels in NSCS (soil subtypes, soil varieties, and soil forms) are not differentiated based on unique classification criteria, which is a disadvantage of this system. Also, NSCS do not ecover entire Globe but rather the territory of ex–Yugoslavia, and it has only regional extent compared with WRB. This work aims to correlate Ranker soil type of NSCS with corresponding RSG's of WRB. Some of the authors in Serbia and abroad (Knežević et al., 2011; IUSS Working group, 2015; Mrvić et al., 2016; Pavlović et al., 2017; Đorđević and Radmanović, 2018) stated that Rankers correspond to Leptosols in certain situations, and the goal of this work is to elaborate their reports.

MATERIALS AND METHODS

Rankers

Rankers are part of automorphic soil order in NSCS. They belong to humus–accumulative soil class, and are characterize with the following soil horizon sequence: A – R, A – C, or A – C – R. They have well developed humus–accumulative horizon and are formed on non-calcareous parent materials. The genetic soil horizons of ranker soil type are: a) A horizon – humus-accumulative soil horizon, b) R horizon – the consolidated (hard) rock, which is non-calcareous, siliceous material in Rankers, and c) C horizon – the loose part of the parent material, non affected, or partially affected by the pedogenic processes. They could have lithic contact with A – R soil sequence or regolithic contact with an A – C, or A – C – R soil horizon sequence.

Ranker’s name is derived from the word rank which means slope (Kubiena, 1953), since this soil is formed on steep slopes. In Serbia, Rankers are also called Humus–siliceous soils, as they are rich in humus and are formed on siliceous parent materials. In Serbia, rankers are found at altitudes between 150–2000 m a.s.l, but mainly between 800 and 1600 m a.s.l (Živković, 1965). They are distributed on Zlatibor, Kopaonik, Maljen, Suvobor, Tara, Rudnik, Radan, Jelica, Golija, Miroč and Deli-Jovan Mountains. According to different authors they cover from 5.2 (Đorđević and Radmanović, 2018) to 16.4% (Pavlović et al., 2017) of the Serbian territory. Geological substrate are igneous, metamorphic or sedimentary rocks. In Serbia, the most dominated igneous rocks which are parent materials of Rankers are granite and grano-diorite (acid igneous rocks), andesite, diorite-syenite and dacyte (intermediate igneous rocks). The most encountered metamorphic rocks are quartzite, gneiss, schists, phylite, mycaschists, and sepentinite, whereas the most distributed sedimentary rocks are sandstones and cherts. Rankers are mostly overgrown with pastures or forests. In forests, they could also have organic horizon. Rankers in Serbia are soils of high and moderately high hilly-mountainous regions. They are formed on all landscape forms, but they are pre-dominant on sloping and steep terrains. In Serbia, they are formed in mountainous climate conditions, with cold winters, and relatively hot and short summer season, which favors physical weathing more than chemical weathering.

Rankers are known as shallow soils, and the soil thickness varies from few centimetres to 40–50 cm, or even more. They are often rich in gravel and often have a low amount of clay. Rankers are characterized with stable and very stable micro- and macroaggregates, which is related to high content of humus and its properties. They are usually highly water permeable soils, and they have low to moderate water retention capacity. Total water retention depends on soil thickness. Since the soils are found on steep slopes a huge amount of water is lost through surface runoff. Therefore, dry pedo-climatic conditions prevail in these soils. The content of humus very often ranges between 10 and 15%. depending on the stage of evolution. They have mollic, umbric or ochric A – horizons. The soil pH in water ranges from strongly acid to neutral but most frequently between 4 and 6. Accordingly, base saturation varies greatly, from 5 to 95%, depending on the parent material, landscape position and the bioclimatic conditions in which they are formed.

Soil productivity is directly linked to the soil depth and the characteristics of parent material (Đorđević and Radmanović, 2018). This soil is susceptible to wind and water erosion and ease for tillage. In natural conditions, Rankers are populated with forest communities or they are overgrown by grasses and used as meadows or pastures. Rankers are partly used as arable lands for growing of potatoes, oats, barley and berries. They are constrained mainly with soil depth and water retention, and they may contain low amount of available macro and micronutrients.

Lithic rankers are formed directly on the detritus of hard rocks and they have slowed down genesis, whereas the regolithic rankers change faster. The soil genesis is directed either to the formation of cambic horizon – progressive soil genesis, or it can be static and regressive. Rankers formed on basic rocks evolve into Eutric Cambisols, whereas rankers formed on siliceous acid rocks evolve to Dystric Cambisols, and further in genesis to Brown podzolic soils and Podzols. Rankers of slopy terrains formed on consolidated non-permeable rocks are very prone to soil water erosion, and therefore these soils can be degraded to Regosols, or remain with ths same soil horizon sequence.

Ranker Soils have two subtypes: Eutric and Dystric Rankers. Soil varieties for Eutric Rankers are Lithic, Regolithic, Brownized lithic, Brownized regolithic, and Colluvial, whereas Dystric Rankers can have also Podzolic lithic and Podzolic regolithic varieties. Soil forms are divided according to soil texture to sandy, clayey, and loamy, and according to gravel content to forms with low (less then 25%), moderate (25-50%), and high gravel content (more than 50%).

Leptosols

The major connotation of Leptosols is thin soils (Leptos gr. – thin). They are formed on various kinds of continuous rocks or of unconsolidated materials, and have more than 80% (by volume) of coarse fragments. They have continuous rock at or very close to the surface, or are extremely gravelly. If they are formed in weathered calcareous material,

they may have a mollic horizon and belong to Rendzinas in many national systems. They include Lithosols of the Soil Map of the World (FAO–UNESCO, 1971–1981), Lithic subgroups of the Entisol Order (Soil Survey Staff, 2010), and Petrozems and Litozems (Shishov et al., 2001). Leptosols formed on non calcareous rocks are often classified as Rankers in national systems. This is also partially the case in Serbian classification system.
Leptosols are the most extensive soils on our Planet, distributed at over 1655 million ha (IUSS, 2015). They are mostly found on high to medium altitudes and on terrains with strongly dissected topography and high altitudinal gradients in all climatic zones, and in particular in strongly eroding areas. Leptosols can be found on weathering–resistent rocks, or where the soil genesis is regresive since the soil erosion removes the parts of soil profile. The most extensive Leptosols are found in montainous regions and have the thickness up to 10 cm. They are found from the tropics to the Polar Regions, and from the sea shores to the highest mountain peaks. They are widespread also in desert areas, in Polar Regions and regionally elsewhere.
Leptosols are commonly used for grazing during wet seasons, and as a forests. Rendzic Leptosols are planted with teak and mahogany or are under deciduous mixed forests, whereas acid Leptosols are commonly under coniferous forests. The greatest threat to Leptosols in mountainous areas with temperate climate is soil water erosion. Leptosols on hill slopes can be used in agricultural production with proper management practices, such as terracing and removal of stones. Leptosols areas are considered mainly as dry habitats because of the shallow soil depth, low water retention, and excessive drainage and/or surface runoff.
In Table 2 of WRB document (IUSS, 2015) Leptosols are ordered at fifth place, after Histosols, Anthrosols, Technosols, and Cryosols.
1. Leptosols should have one of the following:
a. continuous rock or technic hard material starting ≤25 cm from the soil surface; or
b. <20% (by volume) fine earth, averaged over a depth of 75 cm from the soil surface or to continuous rock or technic hard material, whichever is shallower; and
2. Leptosols should not have calcic, chernic, duric, gypsic, petrocalcic, petroduric, petrogypsic, petroplinthic or spodic horizon.
Principle qualifiers used for Leptosols RSG are listed by rank as: Nudilithic/Lithic, Technoleptic, Hyperskeletic/Skeletic, Subaquatic/Tidalic, Folic/Histic, Rendzic/Mollic/ Umbric, Cambic/Brunic, Gypsiric, Dolomitic/Calcaric, and Dystric/Eutric. Supplementary qualifiers used for Leptosols soil group are listed by alphabetic order: Andic, Arenic/ Clayic/ Loamic/ Siltic, Aric, Protocalcic, Colluvic, Drainic, Fluvic, Gelic, Gleyic, Humic/ Ochric, Isolatic, Lapiadic, Nechic, Novic, Ornithic, Oxyaquic, Placic, Protic, Raptic, Salic, Sodic, Protospodic, Stagnic, Sulfidic, Takyric/ Yermic/ Aridic, Technic, Tephric, Toxic, Transportic, Turbic, Protovertic, and Vitric. The examination of supplementary qualifiers is not a goal of this work due to high complexity of the subject.
A goal of this work is to compare Rankers of NSCS and Leptosols of WRB. The comparison is conducted in two ways:
1. Leptosols vs. Rankers, meaning which Leptosols of WRB for soil resources are Rankers in NSCS,
2. Rankers vs. Leptosols, meaning which Rankers of NSCS are Leptosols in WRB.

RESULTS AND DISCUSSION

The result of the comparison between Leptosols and Rankers is presented in Table 1. The overall results show that Leptosols can correspond to 12 different soil types in NSCS: Lithosols, Rankers, Technosols, Eugleys, Humogleys, Subaquous Soils, Rendzinas, Kalkomelanosols, Peat Soils, Regosols, Eutric and Dystric Cambisols.

Table 1. Leptosols vs. Rankers and RSG's with Leptic qualifier which can be Rankers

Reference Soil Group	Principal qualifier	Soil type - National soil classification system (NSCS)
Leptosols	Nudilithic/ Lithic	Lithosols / Rankers
	Technoleptic	Technosols
	Hyperskeletic/ Skeletic	Lithosols, Rankers, Regosols / Technosols
	Subaquatic/Tidalic	Subqauous Soils/ Eugleys, Humogleys
	Folic/ Histic	Peat Soils
	Rendzic/ Mollic/ Umbric	Rendzinas, Kalkomelanosols/Rankers
	Cambic/Brunic	Rankers, Eutric Cambisols, Dystric Cambisol/Rankers
	Gypsiric	Not exist
	Dolomitic / Calcaric	Rendzinas
	Dystric/ Eutric	Rankers
Andosols**	Leptic*	Rankers
Phaeozems**	Leptic*	Rankers
Umbrisols**	Leptic*	Rankers
Cambisols**	Leptic*	Rankers
Regosols**	Leptic*	Rankers

*Leptic means that contiuous rock or technic hard material starts ≤ 100 cm from the soil surface

** These RSG's can belong also to other soil types than Rankers; Here, the comparison was only into one way direction.

The comparison between Rankers soil subtypes and soil varieties with appropriate qualifiers of Leptosols RSG is presented in Table 2. The overall results show that Rankers soil subtypes and varieties in NSCS could assign eight different principal qualifiers of WRB: Lithic, Hyperskeletic, Skeletic, Mollic, Umbric, Cambic, Dystric, and Eutric. In the table is also added Colluvic supplementary qualifier as it directly arose from the corresponding soil variety in national system.

Table 2. Rankers to Leptosols

Soil subtype in NSCS	Soil variety in NSCS	WRB solution within Leptosols RSG
Eutric Rankers	Lithic	Lithic Leptosols, Hyperskeletic Leptosols, Skeletic Leptosols, Mollic Leptosols, Eutric Leptosols
	Regolithic	Hyperskeletic Leptosols, Skeletic Leptosols, Mollic Leptosols, Eutric Leptosols
	Brownized lithic	Cambic Lithic Leptosols, Cambic Hyperskeletic Leptosols, Cambic Skeletic Leptosols, Cambic Mollic Leptosols, Cambic Leptosols, Eutric Cambic Leptosols
	Brownized regolithic	Cambic Hyperskeletic Leptosols, Cambic Skeletic Leptosols, Cambic Mollic Leptosols, Cambic Leptosols, Eutric Cambic Leptosols
	Colluvial	Hyperskeletic Leptosols (Colluvic), Skeletic Leptosols (Colluvic), Mollic Leptosols (Colluvic), Cambic Leptosols (Colluvic), Eutric Leptosols (Colluvic)
Dystric Rankers	Lithic	Lithic Leptosols, Hyperskeletic Leptosols, Skeletic Leptosols, Umbric Leptosols, Dystric Leptosols
	Regolithic	Hyperskeletic Leptosols, Skeletic Leptosols, Umbric Leptosols, Dystric Leptosols
	Brownized lithic	Cambic Lithic Leptosols, Cambic Hyperskeletic Leptosols, Cambic Skeletic Leptosols, Cambic Umbric Leptosols, Cambic Leptosols, Dystric Cambic Leptosols
	Brownized regolithic	Cambic Hyperskeletic Leptosols, Cambic Skeletic Leptosols, Cambic Umbric Leptosols, Cambic Leptosols, Dystric Cambic Leptosols
	Podzolized lithic	These should be Luvisols or Podzols, if they have E and B horizons in National classification system
	Podzolized regolithic	These should be Luvisols or Podzols, if they have E and B horizons in National classification system
	Colluvial	Hyperskeletic Leptosols (Colluvic), Skeletic Leptosols (Colluvic), Umbric Leptosols (Colluvic), Cambic Leptosols (Colluvic), Dystric Leptosols (Colluvic)

Soil forms in NSCS are given based on soil texture to sandy, clayey and loamy. These terms potentially correspond to following supplementary qualifiers of WRB: Arenic, Clayic and Loamic. Soil forms according to the gravel content for all varieties are: low, moderate, and high gravel content. In the NSCS it is not mentioned wheatear those percentages referred to volume or mass. Nevertheless, WRB corresponding principal qualifiers are Hyperskeletic or Skeletic.

CONCLUSION

The results of our investigations are multiple. Leptosols RSG mainly correspond to Rankers in NSCS, but Nudilithic and Hyperskeletic Leptosols are Lithosols, Technoleptic Leptosols are Technosols, Subaqautic Leptosols are part of Subaquatic soil order, Tidalic Leptosols are Eugleys or Humogleys, Follic and Hystic Leptosols are Peat Soils, Rendzic Leptosols are Rendzinas or Kalkolmelanosols, Cambic Leptosols can be Rankers, but also Eutric or Dystric Cambisols, Gypsiric Leptosols do not exist in NSCS, whereas Dolomitic and Calcaric Leptosols are Rendzinas in national system.
Also, Ranker Soils in NSCS can have continuous rock deeper than 25 cm and they could also have more than 20% vol. of fine earth averaged over a depth of 75 cm from the soil surface. In this case, in the WRB is used Leptic principal qualifier. Leptic means having continuous rock or technic hard material starting ≤100 cm from the soil surface. This means that Rankers could be also part of some other RSG with Leptic principal qualifier: Leptic Andosols, Leptic Phaeozems, Leptic Umbrisols, Leptic Cambisols, Leptic Regosols.
This work represents a small contribution to soil science in Serbia in better understanding of WRB for soil resources since WRB is comprehensive classification system that enables accommodation of NSCS for communication at the international level.

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TOXIC ELEMENTS IN SOILS FROM VLASINA REGION

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Abstract

In this research, the optimized three-step sequential extraction procedure for the fractionation of micro- and macroelements, proposed by Commission of European Communities of reference (BCR) has been applied to the soils from Vlasina region. Element concentrations in the extracts were determined using ICP OES. Magnetic susceptibility (MS) was measured using magnetic susceptibility meter. The index of geoaccumulation (I_{geo}) has been applied to assess trace elements distribution and contamination in studied soils. An assessment of toxic element levels in the studied soils is made by comparing the total contents of the extracted elements with the limit values determined by Serbian Regulation. Metal fractionation showed that easily mobile form is dominant for lead and manganese. Other elements (Zn, Ni, Cr, Co, As, Cu, Cd, and V), found dominantly in the residual fraction indicate that these elements may be an indicator for natural sources input. Obtained results indicated that the soils from Vlasina region were not contaminated with toxic elements and the origin of elements is mostly from natural processes such as soil and rock weathering.

Keywords: contamination; extraction; fractionation; magnetic susceptibility

INTRODUCTION

The widespread contamination of soil with potentially toxic elements (PTE) represents currently one of the most severe environmental problems that can seriously affect environmental quality and human health. Activities in urban areas, including emissions from transport (exhaust gases, tyre wear, particles formed by road erosion), industrial waste (from power plants, fuel combustion, metallurgy, automobile repair plants, chemical industry, etc.), household waste, and erosion of buildings or sidewalks, etc., can be a source of soil pollution (Poznanović Spahić et al. 2018).

Elements in soils may be present in several different physico-chemical forms, i.e. as simple or complex ions, as easily exchangeable ions, as organically bound, as occluded by or coprecipitated with metal oxides or carbonates or phosphates and secondary minerals, or as ions in crystal lattices of primary minerals (Žemberyová et al., 2006). For evaluation of the PTE in the environment, it is not sufficient to measure only the total element content, it is also very important to establish the proportions of elements present in various easily and sparingly soluble soil fractions (Svete et al., 2001). From an environmental standpoint, it is

important to determine under which conditions toxic elements could be released from sediments. Sequential extraction is an important and widely applied tool that has provided considerable insights into the environmental behaviour of potentially toxic elements (Sakan et al., 2016). In these extraction procedures various extractants are applied successively to the sediment and soil for selective leaching of the particular chemical forms of elements from samples analysed (Svete et al., 2001).
However, the PTE contamination cannot just be assessed by analysing element concentration alone. Therefore, complementary approaches that combine soil quality guidelines and the geoaccumuation index are highly recommended in order to predict the ecological risk of particular areas (Haris et al. 2017).
In order to assess the general pollution of soils from Vlasina region, the PTE contamination in this region were evaluated by using: the BCR sequential extraction procedure, the sediment quality guidelines, calculation of Igeo, and determination of magnetic susceptibility.

MATERIALS AND METHODS

Study area

In the presented study, 15 soil samples were collected in Vlasina region (Figure 1).

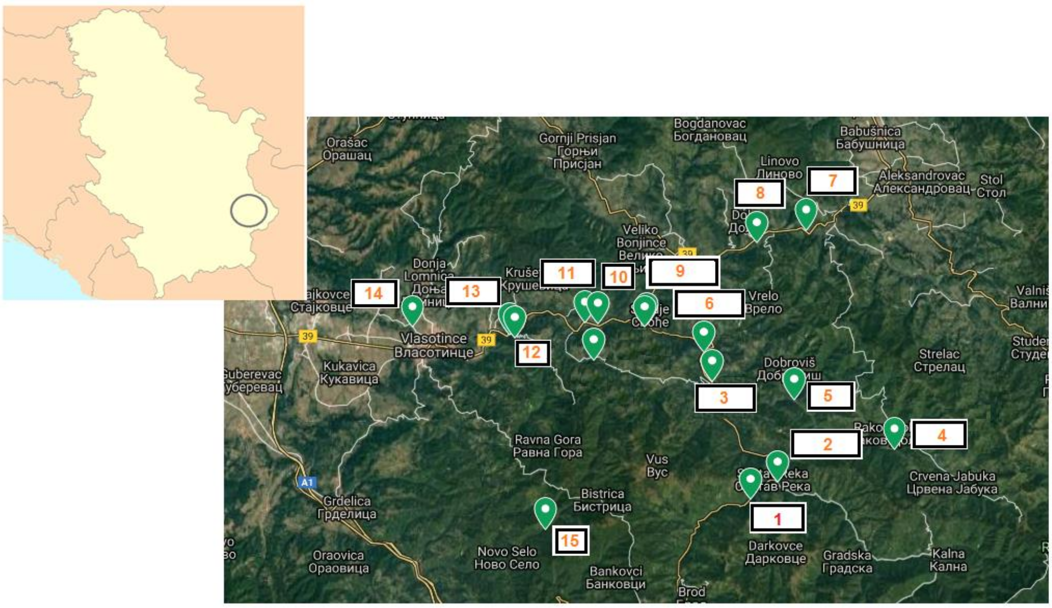

Figure 1. Sampling locations: 1- Vlasina (before all tributaries); 2 - Gradska reka (before casting in Vlasina); 3 - Vlasina (before the mouth of Tegošnica); 4 - Tegošnička reka (stone pit); 5 - Tegošnička reka (Dobroviš); 6 - Vlasina (below Tegosnica, upper walnut); 7 - Ljuberađa (medium flow); 8 - Ljuberađa (measuring profile); 9 - Ljuberađa (the mouth of Ljuberađa in Vlasina); 10 - Pusta reka; 11 - Vlasina (under Pusta river); 12 – Rastavnica; 13 - Vlasina (before the water intake); 14 - Vlasina (under Vlasotince); 15 - Zelenička reka

Soil samples (Figure 1) were collected near the river Vlasina and its tributaries: Vlasina (6 samples), Gradska reka, Tegošnička reka (2), Ljuberađa (3), Pusta reka, Rastavnica and Zelenička reka.

Chemical analysis

Soil samples were analysed by the optimized BCR three step sequential extraction procedure (Sakan et al., 2016). The following fractions were extracted: exchangeable, reducible – bound to iron/manganese oxides, and oxidizable – bound to organic matter and sulfides. Sequential extractions were applied to 1 g of soil samples.
Element concentrations in the extracts obtained at each step of sequential extraction procedure were determined using an atomic emission spectrometer with an inductively coupled plasma iCAP-6500 Duo (Thermo Scientific, United Kingdom). The analytical data quality was controlled by using laboratory quality assurance and quality control methods. The total amounts of elements in this paper are defined as the sum of the element contents in three fractions plus aqua-regia extractable content of the residue.

Determination of magnetic susceptibility (MS)

Magnetic susceptibility (MS) was measured using magnetic susceptibility meter SM30. Each sample was measured in triplicate and the mean value was taken as final result of measurement, to assure as much precise data as possible.

Geo-accumulation index

This determination equation was introduced by Müller (1979) as a quantitative measure of the intensity of contamination in aquatic sediments. The equation used for the calculation of I_{geo} was as follows:

$$I_{geo} = \log_2 C_n/1.5 \cdot B_n \qquad (1)$$

where C_n - the measured concentration of toxic elements and B_n - the geochemical background. Background contents of elements were calculated for each element as the 75th percentiles of the frequency distribution of the data – soil content (Dos Santos et al., 2013). The I_{geo} is typically divided into six grades: I_{geo} = 0: background concentration; I_{geo} = (0–1): unpolluted; I_{geo} = (1–2): moderately polluted to unpolluted; I_{geo} = (2–3): moderately polluted; I_{geo} = (3–4): moderately to highly polluted; and $I_{geo} > 5$: very highly polluted (Haris et al. 2017).

RESULTS AND DISCUSSION

Distribution of elements among fractions

Geochemical fractionation of elements (F1-F4) is shown in Figure 1. The diagrams show that the elements Zn, Ni, Cr, Co, As, Cu, Cd, and V were mostly concentrated in the

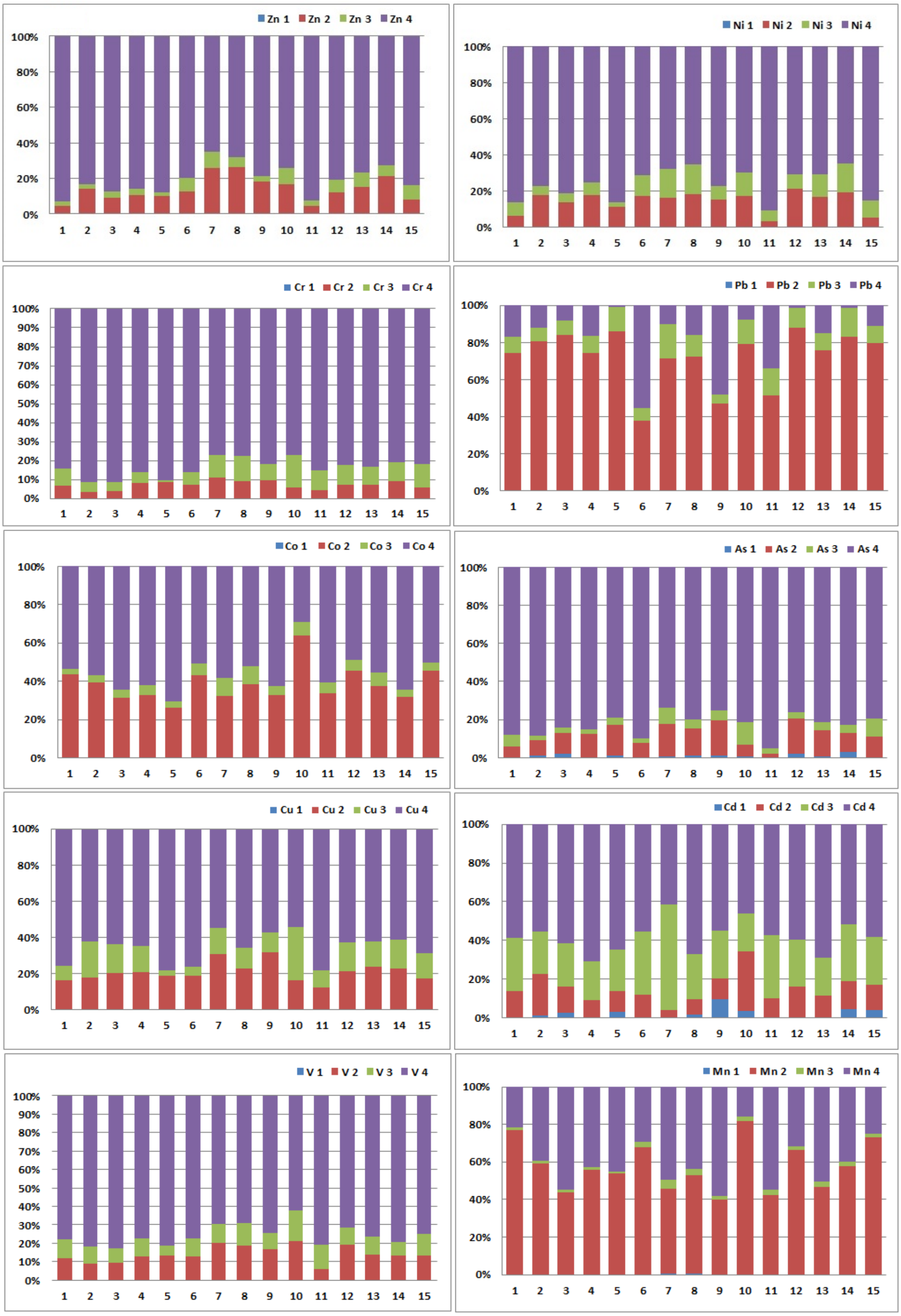

Figure 2. Partitioning of studied elements in soils

"residual fraction" (F4). The exceptions are Pb and Mn with dominant presence in the"reducible fraction" (F2). It can be concluded that the most mobile elements are Pb and Mn, as they make up a significant part of elements detected in the mobile fraction F2. This result indicates that lead was primarily associated with Fe-Mn oxides and this is in accordance with earlier findings (Sakan et al., 2016). Lead may be released from the soil if there is a change in Fe and Mn oxidation state and thus may pose a long-term source of contamination. Fractionation of Zn, Ni, Cr, Co, As, Cu, Cd, and V showed that the major portion of these elements was in the residual fraction. The elements are retained within the crystal lattice of minerals and in well-crystallized oxides, and could be used as an indicator of natural sources input.

Comparison of total element content with soil standard

The total content of the investigated elements (Table 1), extracted from the soil sample was compared with the limit and remediation values defined by the Decree on limit values of polluting, harmful and dangerous substances in the soil ("Official Gazette of RS", No. 30/2018 and 64/2019).

Table 1. Comparison of element content with soil standard [$mg\ kg^{-1}$]

	Content (Studied soils)	MAV*	RV**
Cd	0.34-0.66	0.8	12
Cr	17.6-39.8	100	380
Cu	15.4-**38.8**	36	190
Ni	8.97-24.5	35	210
Pb	6.41-48.2	85	530
Zn	30.5-84.3	140	720
As	5.52-15.5	29	55
Co	5.12-**22.2**	9	240
V	16.1-**45.1**	42	250

* Maximum allowed values; ** remediation value

An increased content of the following elements was observed: Cu in the soil sample near the Tegošnička river (Dobroviš), V in the soil sample near Vlasina (in front of the water intake, below the Pusta river), as well as Co in several locations. The values of copper and vanadium content are slightly higher than the maximum limits defined by the Serbian Regulation. These elements are predominantly bound in the residual, immobile, fourth fraction (about 50% of extracted Cu, 70% V and 50% Co), which indicates that the aforementioned elements do not represent a danger to the environment. Taking into account the rock composition characteristic for this region, the binding site of microelements such as Co, Ni, Cr, and Cu could be shales, as well as ultrabasites-basites and serpentinites. Considering that, due to the influence of complex geological substrate, it is possible to expect increased cobalt contents in the soil and its origin is natural. Given that the highest percentage of Co is bounded to immobile fractions, there is no risk of environmental contamination.

Magnetic susceptibility (MS)

In this research, Boxplot analysis of the studied elements and magnetic susceptibility were performed and the obtained results are shown in Table 2. Most of the studied elements does not show any statistical anomaly: Zn, Ni, Mn, and V. Their distribution is completely regular and it is assumed that their origin is natural, without any anthropogenic influence.

Table 2. Anomalies of studied elements and magnetic susceptibility (MS)

Sample	Outlier
1	Cd, As
2	As
3	-
4	MS
5	MS
6	Cr, Co
7	-
8	-
9	-
10	Cu, Cr
11	-
12	-
13	-
14	Pb, Cd
15	Pb

Also, it is important to mention that all other elements, which show some anomaly, mostly show weaker anomalies (outliers). Majority of these anomalies are most probably of natural origin and anthropogenic influence is obviously not significant in the studied area.

Index of geoaccumulation

The calculated I_{geo} values for Zn, Ni, Cu, Cr, Pb, Cd and As are shown on Figure 3. The majority of investigated soils were in class 0 (background concentration) with the exception of samples 5 and 6 for Cr and 10 and 15 for Pb, which were in class 1 (unpolluted). This indicates that the soils in Vlasina region were practically uncontaminated regarding quoted elements. Negative Igeo values for most soils indicated that there was no contamination and that the origin of elements is mostly from natural processes such as soil and rock weathering.

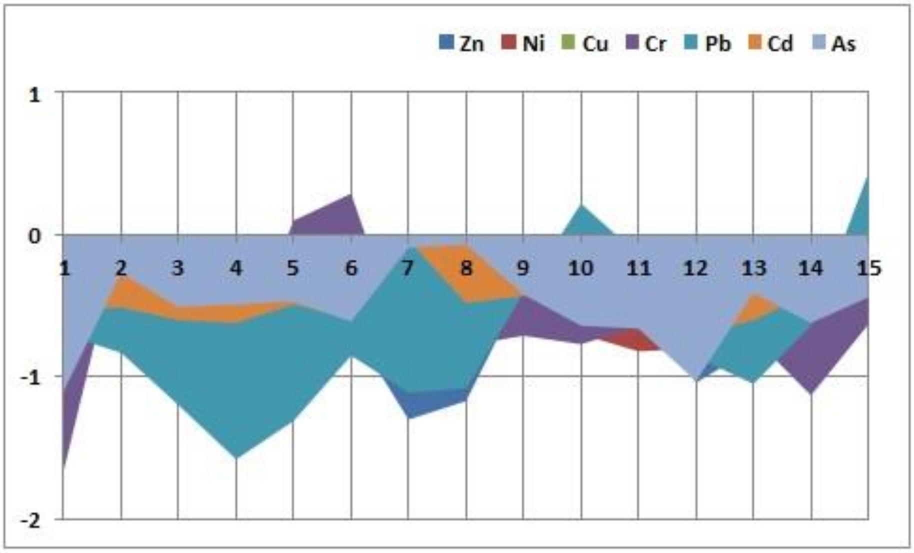

Figure 3. Index of geoaccumulation

CONCLUSION

In this manuscript are studied the contents of micro- and macroelements in the soils from Vlasina region. Fractionation of Zn, Ni, Cr, Co, As, Cu, Cd, and V showed that the major portion of these elements was in the residual fraction, implying that these elements were strongly bound to the soils. Lead showed a different partitioning pattern than other studied metals, with a large percentage in Fe-Mn oxide fraction, indicating that slight redox potential changes may make significant influence on the removability of Pb.
The results of magnetic susceptibility measurements confirm the hypothesis of the dominant natural (geogenic) origin of the elements from the metamorphic rocks that predominate in this area. The calculated Igeo values indicated that the origin of elements are predominantly natural processes such as soil and rock weathering. Results of our research indicated that studied region is not under significant anthropogenic influence and that Vlasina is a clean area.

ACKNOWLEDGMENT

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ANDOSOLS AND PROBLEMS OF THEIR CLASSIFICATION IN CONDITIONS OF SLOVAKIA

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Abstract

Andosols occurring and developed in Slovakian conditions are evaluated in this contribution. Andosols are situated on volcanic rocks, mainly on pyroclastic deposits with vitric components and existence of allophanes. More typical Andosols have been identified under forest, slightly developed Andosols occur also on agricultural land (situated mostly on greenland near the forest land) with often existing of andic cambic B horizon (as a part of cambic B horizon) and could be classified as Andic Cambisols. These soils are represented by very dark brown to black colour (Munsell colour value and chroma 10YR 2/1 – 2/2 when moist), humous (more than 10% of soil organic carbon – SOC), and acid to very acid (pH/KCl values range between 4.0 – 5.0). Soil colour is strongly influenced by high content of organic matter and parent material. Andic properties may be identified using the sodium fluoride field test of Fieldes and Perrott. A pH in NaF of 9.5 and more indicates allophane. According to several previous and latest international and national classification systems andic properties include mostly: Al_{ox} + ½ Fe_{ox} value of 2.0 percent or more; and a bulk density of 0.90 $g.cm^{-3}$ or less; and a phosphate retention of 85 percent or more (FAO 2015); and less than 25 percent (by mass) organic carbon; and increasing amount of allophanes with depth; and thixotropy (field test for soil material change under pressure or by rubbing, from a plastic solid into a liquefied stage and back into the solid condition). However, above described properties are not always sufficient for identification of typical Andosols. According to our additional experimental results as well as Δ pH $\leq$ 0.9 (difference between pH/H_2O and pH/KCl), content of $Fe_d > 2$ % (iron in dithianite extract), resp. Fe_{ox} /$Fe_d < 0.6$, Al_{ox} + ½ $Fe_{ox} > 3$ % (oxalate extractable aluminium and iron), content of Nt > 0.5 %, $C_{HA} : C_{FA} < 1$ and C : N ratio between 12 – 15 (moder humus form), Q^4_6 between 3.5 – 4, bulk density less than 0.9 $g.cm^{-3}$ are characteristic for these soils. Concerning the indicators of ^{13}C NMR spectrum is also very important a percentual distribution of aliphatic (Calif) and aromatic carbon (Car). It was determined that the aliphatic carbon is predominant (Calif/Car ratio is running mostly in the range 1.3 – 1.8) in evaluated soils. In addition, existence of melanic A horizon was not determined according to our obtained results but fulvic A horizon has been found in all described soils in Slovakia where melanic index was higher than 1.7. These additional indicators could help better to classify typical Andosols in heterogenous soil cover.

Keywords: Andosols, soil classification, andic properties, thixotropy, Slovakia

INTRODUCTION

The occurrence of Andosols in neovolcanic part of West Carpathians is only sporadic. These soils are situated on volcanic rocks, mainly pyroclastic deposits with vitric components mostly under forest in humid areas. Slightly developed Andosols are situated also on agricultural land (sporadically on greenland along the forest land). Therefore these soils have been described mostly in forest land (Šály and Mihálik, 1970, 1971, 1977; Šály, 1978, 1982), less in agricultural land (Juráni, 1972). Total area of Andosols is 8.89 % of soil cover in Slovakia (Kobza, 1999). These ones are represented by very dark brown to black soils (10YR 2/2- 2/1 if moist), humous (often more than 10 % of organic carbon), and acid to very acid (pH/KCl mostly between 4.0 – 5.0). There it is possible to distinguish the soils with more or less developed andic properties mostly from Andic (Vitric) Cambisols to Andosols sequence mainly in forest landscape. According to several previous international (WRB 2006, FAO 2015) and national classification systems (Collective, 2014) andic properties include mostly: an Al_{ox} + ½ Fe_{ox} value of 3.0 percent or more; and a bulk density of 0.90 $g.cm^{-3}$ or less; and a phosphate retention of 85 percent or more; and less than 25 percent (by mass) organic carbon; and exchangeable alkality pH ≥ 9.4 in NaF; and increasing amount of allophanes with depth; and thixotropy (field test for soil material change under pressure from solid into a liquefied stage and back into the solid condition). However, these properties could not be always sufficient for identification of typical Andosols. In Slovakia, the baseline for classifying andic soils in forest land was given by Šály and Mihálik, who analysed chemical and physical properties and mineralogy of these soils (Šály et Mihálik, 1970, 1971, 1977, 1979).

MATERIALS AND METHODS

Study area

Selected 4 soil profiles with andic properties in the three neovolcanic geomorphological units: Poľana mountains (Kalamárka) – Fig. 1, Štiavnické vrchy – mountains (Sitno) – Fig. 2 and Kremnické vrchy – mountains (Suchá hora 1, 2) – Figs. 3 and 4 in Central part of Slovakia are compared and evaluated in this contribution.

Soil analysis

Soil samples were analysed for the following parameters: pH/KCl (0.2 M KCl), pH/H_2O available phosphorus and potassium (according to Mehlich III. method) - Kobza et al. 2011, soil organic carbon (SOC) and Nt (total nitrogen) using dry way on CN analyzer, fractional composition of humus (C_{HA}, C_{FA}, $Q^4{}_6$), ^{13}C NMR of humic acids (HA) parameters, content of labile carbon (C_L) – oxidized by 333 M $KMnO_4$, potentially mineralizable nitrogen (N_{pot}) (Sotáková, 1982), iron in dithionite extract – Fe_d (Coffin), oxalate iron Fe_{ox} (Tamm), oxalate aluminium Al_{ox} (Tamm), aluminium in dithionite extract – Al_d (Coffin), allophane (according to Mizota and Van Reeuwijk, 1989), ferrihydride (according to Childs et al., 1990), mechanical fractional composition (according to FAO), bulk density in 100 cm^3 cylinders.

All chemical and physical procedures have been prepared according to Uniform analytical procedures for soil in Slovakia (Kobza et al., 2011).

Fig. 1 Kalamárka: Dystric Skeletic Umbric Leptosol (Andic, Fulvic, Loamic)

Fig. 2 Sitno: Dystric Umbric Episkeletic Andosol (Fulvic, Loamic, Thixotropic)

Fig. 3 Suchá hora 1: Dystric Umbric Andosol (Fulvic, Loamic, Thixotropic)

Fig. 4 Suchá hora 2: Dystric Umbric Endoskeletic Andosol (Fulvic, Loamic, Thixotropic)

RESULTS AND DISCUSSION

Andosols situated and developed in Western Carpathians mostly under forest are represented by very dark brown to black colour (ando = black in Japanese) with Munsell colour value 10YR 2/1-2/2 when moist). Soil colour is strongly influenced by parent material (Richardson and Daniels, 1993) as well as the high content of humus. The parent material of evaluated soils consists mostly of andesites, pyroclastics, aglomerates and aglomerate tuffs often with occurrence of vitric components. There are mostly humous and medium deep to deep soils well rooted (mainly forest soils). Characteristic andic soils were selected (soil monitoring system in Slovakia) and analysed for basic and important soil parameters. The quantitative and qualitative parameters of humus are given in the Table 1.

Table 1 Quantitative and qualitative parameters of humus

Localities	Depth (cm)	SOC	Nt	C/N	C_{HA}/C_{FA}	Q^4_6	C_L ($mgkg^{-1}$)	Npot	C_L/ Npot
		%						($mgkg^{-1}$)	
Kalamárka	0-10 50-60 90-100	6.1 4.6 4.7	0.5 0.3 0.2	13.0 14.8 18.8	0.9 - -	4.5	6775.2 - -	218.2 - -	31.0 - -
Sitno	0-10 50-60 90-100	10.5 7.8 5.6	0.9 0.8 0.5	12.1 9.6 10.2	0.9 - -	4.8 - -	20000.4 - -	299.0	68.4 - -
Suchá hora 1	0-10 50-60 90-100	21.2 7.8 5.9	0.9 0.8 0.6	23.0 7.2 10.3	0.4 0.3 0.3	6.4 6.6 6.4	39897.90 - -	218.75 - -	182.4 - -
Suchá hora 2	0-10 50-60 90-100	20.1 6.3 5.9	1.4 0.5 0.81	14.1 12.3 7.3	0.5 0.2 0.2	4.1 3.6 3.4	15680.9 - -	300.2 - -	52.2 - -

SOC - soil organic carbon, Nt - total nitrogen, HA - humic acids, FA – fulvoacids, Q^4_6 - colour quotient, C_L - labile carbon, Npot – potentially mineralizable nitrogen

The existence of humous soils is confirmed. The content of SOC in surface layer was determined in the range of 5.5 to 12.7 %. It means 9.5 to 21.9 % of humus (calculated from content of SOC x 1.724). The content of humus in deeper part of soil profile slightly decreases, but its amount is also very high. The high content of humus in evaluated soils is caused by the creation of „allophane-organic matter" complexes. In addition, the measured content of allophane in evaluated soil profiles is given in the Table 4.

The total nitrogen content is in correlation to high content of humus. The total nitrogen content in evaluated soil profiles is running between 0.47 - 0.92 % in A horizon. These values are the highest in comparison with the other soils of Slovakia (Bielek, 1984). The C/N ratio is in the range of 12.1 - 23.0 what refers to moder humus form (Šály, 1978). In spite of high content of humus, its quality is relatively low (C_{HA}/C_{FA} < 1, Q^4_6 is running between 4.1 – 6.4). It refers to labile and slightly humificated soil organic matter in evaluated soils (also high content of raw organic matter and mostly non-decomposited organic components in the forest). It is in correlation with labile carbon (C_L) which value is practically the highest from among the soils of Slovakia (Zaujec and Kobza, 2002). Very high content of labile carbon is a result of high to very high content of soil organic carbon and low degree of humification. For assessment of humus substances quality can be also used ratio C_L: N_{pot} , when high values determined low quality of humus substances (Zaujec and Kobza, 2002). It was indicated that more typical Andosols are characteristic with C_L : N_{pot} ratio > 50 (Suchá hora 1 and 2 and Sitno) where C/N ratio is running between 12.1 – 23.0 (Table 1). C_L: N_{pot} ratio seems to be a better indicator for quality of humus unlike C/N ratio. In addition, also very important is a fractional composition of humic acids which is given in the following Table 2.

Table 2 Fractional composition of humic acids (HA) in A horizon (depth of 0-10 cm)

Localities	C	H	H/C	O	N	COOH	$E^{1\%}_6$	Car	Calif	α
	atomic %					meq/1gHA		%	%	%
Suchá hora 1	42.6	34.2	3.5	19.6	0.8	3.9	18.4	28.5	51.7	35.5
Sitno	42.6	33.9	3.5	20.0	0.8	4.1	25.9	35.1	48.2	42.1

COOH – carboxylic groups, $E^{1\%}_6$ – optical parameter, Car – aromatic carbon, Calif – aliphatic carbon, α – degree of aromaticity of humic acids

The basic parameter of HA structure is elementary analysis C- H- N- O which reflects dominant characteristics of soil humification. H/C ratio clarifies stability and degree of HA condensation (Rossell et al., 1989). Values of H/C ratio in evaluated soils were determined 3.50 (Table 2). It refers to more labile structure of HA opposite chernozems, where the H/C ratio is much more lower (0.55-0.65) in conditions of Slovakia (Kobza et al., 2014). The next important parameter concerning the quality of HA is the content of carboxylic groups (COOH). The process of humification is characterized by carboxylation of peripheral portions of HA (Ševcova and Sidorina, 1988). The higher values of COOH refer to higher degree of humification and low values of COOH are characteristic for low humification degree of HA. Measured values of COOH for evaluated soils are in the range of 3.9 - 4.1 meq/1g HA (Table 2) which are lower unlike chernozems (Kobza et al., 2014) where the COOH values are determined often in the range of 4.0 - 5.0 meq/1g HA. In addition, significant parameter concerning evaluation of HA structure is ^{13}C NMR analysis (Novák and Hrabal, 2011). Here is important distribution of aliphatic carbon (Calif) and aromatic carbon (Car) from which is determined degree of aromaticity (α). Based on obtained results (Table 2) aliphatic carbon (Calif) is predominated in Andic soils. Degree of aromaticity (α) was determined between 35.5 - 42.1 % what are lower values unlike fertile humous soils like Chernozems and Phaeozems (Kobza et al., 2014). The higher share of aliphatic carbon (Calif) in Andic soils could be a result of input of raw organic matter (forest) what is characteristic for in corporation of plant residues (Peréz et al., 2004). The next important parameter of HA structure is an optical parameter $E^{1\%}_{6}$ which represents an extinction of HA solution measured at wave length of 600 nm.This parameter is named according to Kumada (1987) the degree of humification. If the optical parameter is higher, the degree of humification is also higher. In evaluated Andic soils the optical parameter $E^{1\%}_{6}$ was determined between 18.4 and 25.9 (Table 2) what are lower values in comparison with Chernozems and Phaeozems (also dark humous soils but with Mollic horizon) where the values of optical parameter $E^{1\%}_{6}$ are often higher than 30 (Kobza et al., 2014). Predominance of fulvoacids and raw organic matter in various degree of decomposition (forest) is in relation to acid pH values of evaluated soils (Table 3).

Table 3 Soil profile distribution of pH values

Localities	Depth (cm)	pH/H_2O	pH/KCl	ΔpH	pH/NaF
Kalamárka	0-10 20-30 35-45	5.5 5.3 5.3	4.8 4.6 4.5	0.7 0.7 0.8	9.8 10.6 10.7
Sitno	0-10 20-30 35-45	5.2 5.2 5.3	4.3 4.3 4.4	0.9 0.9 0.9	10.1 10.5 10.7
Suchá hora 1	0-10 20-30 35-45	4.3 4.5 4.6	4.0 4.3 4.5	0.3 0.2 0.1	9.9 10.9 11.2
Suchá hora 2	0-10 20-30 35-45	3.9 4.2 4.6	3.7 4.1 4.4	0.2 0.1 0.2	9.7 11.1 11.2

ΔpH – difference between pH/H_2O and pH/KCl

Based on obtained results it may be said that these soils are acid to very acid (pH/KCl ≤ 5.5). One of characteristic properties of andic soils is the small difference between pH/H_2O and pH/KCl (ΔpH) (Šály, 1982). This difference is the most significant in the 3-rd and 4-th soil profiles (Suchá hora 1 and 2) with the range 0.2 - 0.3 caused by mineralogical composition (higher occurence of allophanes), which is determined in the following Table 4.

Weathering of volcanic ash commonly includes the formation of poorly crystalline minerals such as allophane and ferrihydrite. Detection of these minerals is rather difficult (Mizota and Reeuwijk, 1989; Childs et al., 1990), because they may govern soil functions and processes, e.g. stabilization of soil organic matter and nutrient availability.

In addition, weathering of volcanic ash, including the formation of allophanic compounds, typically leads to the formation of andic soils (IUSS Working group WRB, 2006). Content of allophane increases with depth of soil profile (Table 4), what was confirmed also by Balkovič et al., (2006). The highest values of allophane were determined in soil profiles of

Suchá hora 1 and 2. Presence of allophanes and existence of andic properties were also identified using the sodium fluoride field test by Fieldes and Perrott (1966). Also the pH in NaF of 9.5 and more indicates allophane occurrence in all soil profiles, what was confirmed in all of evaluated soil profiles (Table 3).

Table 4 Mineral composition

Localities	Depth (cm)	Allophane %	Ferrihydride %
Kalamárka	0-10 20-30 35-45	2.0 3.5 5.4	2.0 2.0 1.9
Sitno	0-10 20-30 35-45	1.8 2.7 4.3	1.9 2.0 2.1
Suchá hora 1	0-10 20-30 35-45	2.5 5.7 7.9	1.7 1.7 1.9
Suchá hora 2	0-10 20-30 35-45	2.4 6.1 8.2	2.2 1.9 0.4

Ferrihydrite is associated with the better crystalline Fe oxides (Stahr, 1972; Campbell and Schwertmann, 1984). Presence of silicates and organics such as humics, promote ferrihydrite formation, because these factors impede the formation of crystalline Fe oxides. The content of ferrihydride in all evaluated soil profiles is even-tempered, but the content of ferrihydride with the depth is slightly decreased (Table 4).
Andosols are characterized by allophane and ferrihydrite (Arnalds, 2006). The content of allophane is running between 1.80 – 2.50 % and content of ferrihydrite varies in the range of 1.7 – 2.2 % in surface layer of evaluated soils. Ferrihydrite is most commonly calculate as oxalate extractable iron (Fe_{ox}) times the factor 1.7 (Parfitt and Childs, 1988). Ferrihydrite is common in young iron oxide accumulations (Bigham et al., 2002). These minerals are characteristic for development and genesis of Andosols.
From soil genesis point of view unsilicated forms of pedogenic oxides - just iron and aluminium are significant. Their distribution in soil profiles of Andic soils is given in the following Table 5.
The content of Fe_{ox} and Fe_d in soil profiles is even-tempered with slight increase to the depth. The Fe_{ox}/Fe_d is often used for the approximate explanation of development status of soil as well as for the effort to differentiate old soil processes (Schlichting and Blume, 1961). This ratio is very similar in all soil profiles and shows the degree of iron migration in soil profiles. One of the main diagnostic criteria is $Al_{ox}+{}^1/_2Fe_{ox}\geq 2$ (FAO, 2015) which is on evaluated soil profile fulfiled (Table 5).
The object of wide discussions is the sequence of quality of humus horizons (melanic-umbric-fulvic). Based on our obtained results the criteria for fulvic horizon were determined (MI > 1.7). It was confirmed also by some previous works (Balkovič et al., 2006; Kobza, 2017) in Andic soils of Slovakia.

Table 5 Distribution of pedogenic oxides of Fe and Al (in %)

Localities	Depth (cm)	Fe_{ox}	Fe_d	Fe_d-Fe_{ox}	Fe_{ox}/Fe_d	Al_{ox}	Al_d	$Al_{ox}+^1/_2 Fe_{ox}$	Melanic Index (MI)
Kalamárka	0-10 20-30 35-45	1.16 1.16 1.12	2.04 2.10 2.20	0.88 0.94 1.08	0.57 0.55 0.51	2.92 2.50 2.62	0.06 0.05 0.05	3.50 3.08 3.18	1.75 - -
Sitno	0-10 20-30 35-45	1.12 1.20 1.26	2.09 2.29 2.40	0.97 1.09 1.14	0.53 0.52 0.52	3.00 2.45 2.23	0.14 0.19 0.16	3.58 3.05 2.86	1.98 - -
Suchá hora 1	0-10 20-30 35-45	1.01 1.01 1.14	1.81 1.69 1.94	0.80 0.68 0.80	0.53 0.63 0.62	3.15 2.02 3.02	2.73 2.07 3.02	3.65 2.52 3.59	2.63 2.24 2.31
Suchá hora 2	0-10 20-30 35-45	1.27 1.13 0.25	- - -	- - -	- - -	2.30 3.34 2.69	- - -	2.94 3.90 2.82	2.26 2.13 2.33

Fe_{ox} – oxalate iron, Fe_d – iron in dithionite extract, Al_{ox} – oxalate aluminium, Al_d – aluminium in dithionite extract

Except chemical properties also physical properties are important (Table 6).

Table 6 Mechanical fraction composition (according to FAO) and bulk density

Localities	Depth (cm)	<0.002 mm %	0.002-0.05 mm %	0.05-2 mm %	ρ_d g.cm^{-3}
Kalamárka	0-10 20-30 35-45	10.45 10.41 11.18	65.73 69.38 69.30	23.82 20.21 19.52	0.88 - -
Sitno	0-10 20-30 35-45	10.02 11.10 12.04	51.42 62.00 68.73	38.56 26.90 19.23	0.85 - -
Suchá hora 1	0-10 20-30 35-45	8.53 4.94 5.77	31.91 29.51 25.27	59.56 65.55 68.96	0.42 - -

ρ_d - bulk density

Based on obtained results fraction 0.002-0.05 mm is mostly predominated, resp. sandy fraction (0.05-2 mm) in the soil profile of Suchá hora 1. One of the most important indicators for Andosols is bulk density ($\rho_d \leq 0.9$ gcm^{-3}). This criterion is fullfilled in all evaluated soil profiles.

In addition, andic layers have more or less different characteristics, depending on the type of the dominant weathering process acting upon the soil material. They may exhibit thixotropy, i.e. the soil material changes, under pressure or by rubbing. In perhumid climates (in conditions of Slovakia evaluated soil profiles are situated over 1000 m over sea), humus-rich andic layers may contain more than twice the water content of samples that have been oven-dried and rewetted (hydric characteristics).

CONCLUSIONS

Total area of andic soils is max. 0.14 % of soil cover in Slovakia (Kobza, 1999) which are situated on weathered products of neovolcanites (from neogene volcanic period in Tertiary) and their pyroclastics with vitric components mostly under forest. Based on obtained results it may be said that Andosols in conditions of Slovakia are humous soils (SOC is often higher than 10%) with low value of bulk density ($\leq$ 0.9 g.cm^{-3}) with existence of fulvic A horizon (melanic index value >1.7). Except high content of humus its quality is low with predominance of fulvoacids ($C_{HA}/C_{FA} < 1$) and colour quotient ($Q^4{}_6 > 4$). From among the fractional composition of humic acids it was determined the predominance of aliphatic carbon (Calif) - about 50 % what is in relation to content of labile carbon which is the highest from among the soils of Slovakia (Kobza et al., 2014).
More labile structure of humic acids determines also H/C ratio (0.5). For assessment of humus substances quality in more typical andic soils can be also used $C_L : N_{pot}$ ratio (> 50) - the highest values from among the soils of Slovakia, what reflects the low quality of humus substances (Zaujec and Kobza, 2002) in contrast with high to very high content of humus (SOC content varies mostly in the range 10 – 20 % and more) in evaluated soils. The degree of humification in Andosols was indicated lower opposite Chernozems and Phaeozems where optical parameter $E^{1\%}{}_6$ in Andosols is lower (18.4 - 25.9) in comparison with Chernozems and Phaeozems ($E^{1\%}{}_6$ is often higher than 30) (Kobza et al., 2014).
Evaluated soils are very acid (pH/KCl < 4.8). One of the main diagnostic criteria is also fulfilled (Al_{ox} +1/2 $Fe_{ox} \geq 2$). The evaluated soils represent relatively old soil cover (Fe_d is mostly higher than 2 %) - in recent soils the content of Fe_d is often less than 2 %). From among the other diagnostic criteria the phosphate retention more than 85 % in conditions of andic soils in Slovakia was also identified (Balkovič et al., 2006).
According to our additional experimental results as well as Δ pH $\leq$ 0.9 (difference between pH/H_2O and pH/KCl), content of Fe_d > 2 %, resp. $Fe_d – Fe_o$ > 0.8 %, content of Nt > 0.5 % and C:N ratio is in the range 12.1 – 23.0 and C_L: N_{pot} ratio in typical Andosols is more than 50 unlike the other soils in Slovakia where this ratio is lower (Zaujec and Kobza, 2002). Therefore the C_L:N_{pot} ratio seems to be a more significant indicator for evaluation of quality of humus unlike C:N ratio.
In addition, existence of allophanes and ferrihydrites could help better to classify more typical Andosols in the landscape. Considering melanic horizon as often mandatory for Andosols, resp. andic soils appeared as incorrect as melanic index (MI) was not identified under 1.7 in any of Slovakian Andosols (Balkovič, 2005), what was confirmed also in our work. In addition, fulvic horizon is characteristic for Slovakian Andosols, resp. Andic soils what was confirmed by measured of higher values of melanic index (MI > 1.7).
Finally, for the better characterization of Andosols it would be more useful except recommended diagnostic criteria according to FAO 2015 to know also the other analytical characteristics in more details especially concerning the fractional composition of humus and humic acids, as well.

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PEDOLOGICAL CHARACTERISTICS OF GREEK MAPLE (*ACER HELDREICHII* ORPH.) SITES IN SERBIA

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Abstract

Greek maple (*Acer heldreichii* Orph. subsp. *heldreichii*) is an endemic taxon of the Balkan Peninsula and a Tertiary relict. It is distributed in the following countries: Serbia, Bosnia and Herzegovina, Montenegro, Northern Macedonia, Bulgaria, Greece and Albania. The species occurs only in mountain areas and in Serbia it has been recorded in the following mountain massifs: Rudnik, Goč, Željin, Jastrebac, Kopaonik, Golija, Javor, Javorje, Stara planina, Prokletije, Žljeb and Šar-planina. The northernmost site of this species is located in Serbia on the Rudnik mountain. In addition to the typical subspecies, *Acer heldreichii* subsp. *heldreichii*, in the Caucasus grows a subspecies *Acer heldreichii* Orph. subsp. t*rautvetteri*, which is autochthonous in the following countries: Turkey, Georgia, Armenia, Azerbaijan and Russia. Given that the Greek maple is rare and strictly protected species in Serbia, and represents a subendemic taxon of the Balkans and a Tertiary relict, the study of ecological conditions in which this species grows is of great practical importance in order to preserve its gene pool and in situ conservation. Regarding this, pedological studies were performed on the most important sites of this species in Serbia. The studied edaphic characteristics at the investigated sites include determining the types of parent material and soil, as well as determination of physical and chemical soil properties. The results of the research are based on 14 soil profiles, four on Jastrebac and two soil profiles on the following mountains: Goč, Javorje, Stara planina, Rudnik, and Golija, respectively. Based on the determination of geological material collected during the opening of soil profiles in the field, performed in the laboratory of the University of Belgrade Faculty of Forestry, it was determined that Greek maple is found on eight different types of geological parent material in studied areas. On Rudnik locality, sandstone and clay occur, on Goč granite and granodiorite,on Jastrebac schist, phyllite and gneiss, on Stara Planina sandstone, on Golija schist and phyllite and on Javorje schist. Based on the pedological analysis, it was determined that there are two types of soil on the investigated localities, Dystric cambisol and Leptosol (Ranker). It was almost always Dystric cambisol, while Ranker was recorded only in Jastrebac, on one soil profile. The analysed soils are mostly moderately deep to deep, with depths ranging from 35 to 73 cm, on average (49.8 cm). According to the classification of Tommerup, the samples of the studied Dystric cambisol are: loamy, coarse to fine sandy loamy or clayey loamy mechanical composition. The humus content is relatively high and ranges from 3.0 to 26.2%, and decreases with profile depth. The reaction of the soil in water ranges from extremely acidic to very strongly acidic, with pH values ranging from 3.9 to 5.2. The content of total nitrogen is in accordance with the content of humus with values ranging from 0.1% to 1.3%. In terms of the content of easily accessible phosphorus and potassium, the studied soils in Greek maple communities are

poorly to moderately supplied with phosphorus (1.2 mg – 18.0 mg per 100 g of soil), i.e, from poorly to well supplied with potassium (4.4 mg – 22,0 mg per 100 g of soil).

Keywords: Greek maple, *Acer heldreichii* Orph. subsp. *heldreichii*, Serbia, soil properties

INTRODUCTION

Greek maple (*Acer heldreichii* Orph. subsp. *heldreichii*) is an endemic taxon of Balkan Peninsula and a tertiary relict. It occurs in the following countries: Serbia, Bosnia and Herzegovina Srbiji, Montenegro, Northern Macedonia, Bulgaria, Greece and Albania. This species grows in mountain areas only and it is recorded on following mountain massifs in Serbia: Rudnik, Goč, Željin, Jastrebac, Kopaonik, Golija, Javor, Javorje, Stara planina, Prokletije, Žljeb and Šar-planina (Cvjetićanin and Perović, 2016). The northernmost site of this species is Rudnik mountain in Serbia. Apart from typical subspecies, *Acer heldreichii* subsp. *heldreichii*, subspecies *Acer heldreichii* Orph. subsp. *trautvetteri* (Medvedev) Murray ocdcurs in Caucasus area and it is native in the countries: Turkey, Georgia, Armenia, Azerbaijan and Russia (van Gelderen et al., 2010).
Given that the Greek maple, which is rare in Serbia and is a strictly protected species (Official Gazette, 2011), represents a subendemic of the Balkans and a Tertiary relict, the study of ecological conditions in which this species grows is of great practical importance in order to preserve its gene pool and in situ conservation. Regarding this, pedological studies were performed on the most important sites of this species in Serbia.

MATERIAL AND METHODS

Research was done on the following localities: Rudnik, Goč, Jastrebac, Golija, Javorje and Stara Planina. Researched orographic characteristics comprise elevation, aspect and terrain inclination. These parameters were calculated using GPS device GARMIN Vista HCX. Researched edaphic characteristics consist of determination of geological parent rock material and soil types. Research results are based on 14 analysed soil profiles - 4 on Jastrebac and 2 from other five localities, respectivelly (Perović, 2014). Samples of geological substrate were macroscopically determined in Laboratories of University of Belgrade-Faculty of Forestry. Analyses of soil characteristics comprised field and laboratory research method accepted from Serbian soil research society (Bogdanović et al., 1966, Filipovski et al., 1967, Bošnjak et al., 1997). During field research ecological conditions were investigated, and morphogenetical soil research were done on open soil profiles. Also, soil samples were collected for determination of granulometric composition and standard chemical soil properties. Laboratory research was done in Laboratories for physical and mechanical soil properties of University of Belgrade-Faculty of Forestry. This research included determination of following characteristics:
1. Granulometric composition (by treating soil samples with sodium-pyrophosphate, and soil fractioning was done combining of pipette method and elutration method using sieve by Atterberg with determination of percentage composition fractions: 2-0.2 mm, 0.2-0.06

mm, 0.06-0.02 mm, 0.02-0.006 mm, 0.006-0.002 mm and smaller than 0.002 mm. Soil classification according to mechanical composition was made by Tommerup (1934);
2. Active acidity - pH in H_2O (electrometrically using pH-meter device);
3. Substitutional acidity - pH in 0.01M $CaCl_2$ (electrometrically using pH-meter device);
4. Hydrolytical acidity (by Kappen method);
5. Sum of adsorbed alkali cations - S in cmol*kg $^{-1}$ (by Kappen method);
6. Total cation adsorption capacity - T in cmol*kg $^{-1}$;
7. Sum of acidic cations - T-S in cmol*kg $^{-1}$ (calculated through hydrolytical acidity);
8. Alkali saturation level of soil – V% (calculated by Hissink);
9. Total nitrogen content in soil (by Kjeldahl method, in %);
10. Carbon to nitrogen ratio - C:N;
11. Content of easily accessible P_2O_5 and K_2O mg/100 g soil (by Al method);
Determination of classificational adherence of researched soils was done according to the principles of valid „Soil classification of Yugoslavia“ (Škorić et al., 1985).

RESULTS

Table 1 and Figure 1 show researched localities and display geographical coordinates and their elevations (Perović, 2014).

Table 1. Geographycal coordinates and elevations of researched localities

Locality	Geographical coordinates	Elevation (m a.s.l.)
Rudnik	44° 08' N.lat; 20° 32' E.lon.	1000 - 1100
Golija	43°21' N.lat; 20°16' E.lon.	1400 - 1700
Goč	43°32' N.lat; 20°47' E.lon.	1400 - 1550
Jastrebac	43°24' N.lat; 21°26' E.lon.	1350 - 1450
Javorje	43°33' N.lat; 19°19' E.lon.	1300 - 1400
Stara planina	43°20' N.lat; 22°47' E.lon.	1500 - 1600

Most researhed localities are located in subalpine vegetation zone, at elevations 1400 - 1700 m a.s.l, with the exception of Rudnik site, where Greek maple was recorded in montane area at elevations between 1000 and 1100 m a.s.l. Rudnik mountain is, at the same time, the northernmost site of this species in the world (Figure 1). Greek maple populations mostly occur on cold and sheltered aspects, mostly on northern, than nortwestern, northeastern, more rarely on western, southwestern or eastern, while it never occur on southern aspect. Inclinations are different, but they are mostly mild and vary from completely flat grounds (inclination 0°), to moderately steep slopes (15-25°). Only on Stara Planina Greek maple was recorded on very steep slopes (inclination up to 40°).
According to Perović (2014), observed for the period 1981 – 2010. years, it is determined that mean yearly temperature is from 4.1°C (Stara Planina) to 7.0°C (Rudnik), average 5.2°C, while in vegetation period it circulates between 9.4°C (Stara Planina) to 12.7°C (Rudnik), average 10.7°C. Mean yearly precipitation sum is between 1026.0 mm (Golija) to 1407.2 (Goč), average 1203.9 mm, while in vegetation period it is from 562.4 mm

(Golija) to 812.0 mm (Goč), average 675.3 mm. June is the month with highest precipitation, while the dryest period is during winter (January and February). Value of Lang's rain factor (KF) indicate that most Greek maple sites occur in conditions of altimontane perhumid climate (mean KF=260.7), except Rudnik site, which distinguishes itself by humid climate (KF=155.1), which is also in accordance to the values of Thornthwaite's climate index. According to Köppen's climate classification, D climate type dominates in all localities, which excels by moist temperate climate with harsh winters.
Based on the determination of petrological material collected during producing of soil profiles in the field, it is ascertained that Greek maple occurs on seven types of geological parent material in the researched area. On Rudnik locality, sandstone and clay occur, on Goč granite and granodiorite,on Jastrebac schist, phyllite and gneiss, on Stara Planina sandstone, on Golija schist and phyllite and on Javorje schist. It can be concluded that Greek maple communities grow on igneous (granite and granodiorite), metamorphic (schist, phyllite and gneiss) and sedimentary rocks (sandstone and clay).
In sandstones sand particles are tied by binding material: clayi, silicate, carbonate, irony, bituminose etc. (Kukin et al., 2007). Sandstones rich in quartz or with sand particles tied by silicate binding material produce soils of bad properties, while sandstones where soil particles are bonded by calcium carbonate or clay produce better quality soils. Soils formed on sandstones are mostly of light mechanical composition (sandy), poorly skeletal, well aerated but poorly retain water. As a consequence of lightly sandy mechanical composition, watter easily runs through soil profile and causes alkali leaching, hence soils produced on sandstone are always acidic and prone to podzolisation.
Clays belong to pelilothic rocks, where soil particles are smaller than 0.005 mm and represen dryed and solidified clay minerals where partial destruction of mineral structure occured. Properties of clays are narrowly connected with their mineral composition, so they can be built of one or several clay minerals, and frequently as a secondary minerals occur: quartz, iron oxides, manganese oxides, apatite, garnet etc. On clays form soils with heavier texture mechanical composition, with higher or lower swelling (in moist conditions), and lacing and breaking capabilities (in dry conditions). Also, they have increased adsorption capability and pronounced affinity towards K^+ and NH_4^+ ions, which makes soils produced on clays well suplied with nutrients.
Granites and granodiorites are rocks very rich in quartz (>66%), increased alkanli content (K_2O and Na_2O), and low content of magnesium, iron and calcium, so that weahering of these igneous rocks produces acidic and sandy soils.
Phyllites, schists and gneisses belong to regional metamorphic rocks, where phyllites possess low, schists medium and gneisses high cristallinity. Soils formed on gneiss are similar to soils formed on granite or granodiorite. Phyllites occur by metamorphism of clay rocks, and during weathering produce crumbling mass. Schists have foliate texture, they are medium to large grained rocks which contain philosilicates and quartz. Soils formed on mentioned rocks are usually acidic, skeletal and have low to medium fertility.
Results of integrated field and laboratory research confirmed that two soil types occur on researched localities: dystrophic brown soil (Dystric cambisol) and Leptosol (Ranker). Dystric cambisol is a dominant soil type and it was recorded on all localities, making 13 of 14 studied soil profiles, while Ranker occurs only on one soil profile on Jastrebac locality.

Dystric cambisol was studied in detail on five localities: Rudnik (2 soil profiles), Goč (2 profiles), Jastrebac (3 profiles), Stara Planina (2 profiles), Golija (2 profiles) and Javorje (2 profiles). On this soil type, Greek maple populations occur in elevation amplitude from 1000 to 1700 m a.s.l, aspects are usually cold (mostly northern and nortwestern), but other can occur also (western, southwestern, eastwern). Inclinations are mostly mild to moderately steep (only on Stara Planina very steep to 40°). Geological parent material is various and consists of sandstone, clay, granite, granodiorite, schist, phyllite and gneiss.

Accumulated layer of forest litter occurs on the top of profile. Transformation of organic matter is more or less slowed down. Researched soils are moderatelly deep to deep, with depths from 35 cm to 73 cm, average 49.8 cm. Thickness of A-horizon is between 10 and 30 cm, average 13.7 cm, its color is brown to black (on Stara Planina locality it is reddish-brown), structure is crumby, with higher or lower content of small to large skeleton, interwowen by plant roots. Cambic (B)-horizon is characterized by various nuances of brown color, which depends on bedrock type. Thickness of (B)-horizon varies from 27 cm to 63 cm, average 36 cm. Color is brown (on Stara Planina reddish-brown), and structure finely crumby. This horizon is more or less skeletal (mostly with over 70% skeleton), and excells by high presence of plant roots throughout.

According to Tommerup classification (1934), samples of researched dystric cambisol have silty, coarse to fine sandy-silty or clayi mechanical composition (Table 2). Granulometric soil structure is mostly determined by geological substrate, so that soils formed on granite, granodiorite, gneiss and sandstone posses higher contend of sandy fraction, compared to soils formed on clay and phyllite, which contain more clay fraction. Soils formed on schists show variation in regard of texture characteristics considering that it deals with schist group of various mineral composition. Within A horizon coarse sand fraction is dominant, sharing from 51.3% to 82.9% (average 63.1%), while total silt and clay content is between 17.1% to 48.1% (average 37.0 %). Content of clay and coloid particles (particles finer than 0.002 mm) is lower and varies from 5.8% to 21.1%, average 13.5%. Silt content is somewhat higher and varies between 11.3% to 31.6% (average 23.4%). Among granulometric fractions of (B) horizon, fraction of total sand has globaly the highest content of 42.9% to 77.4% (average 59.6%), while total silt and clay content is somewhat lower, 22.6% to 57.1% (average 40.9%).

Humus content in soil samples is very high and fluctuates between 3.0% to 26.2%. In A horizon this content varies in wide range from 4.1 to 26.2% (average 13.9%), while in subsoil it is from 3.0% to 12.0% (average 5.6%). C/N ratio, which indicates mineralisation process intensity varies between 9.7 and 16.4 (average 12.2%) in A horizon, and from 8.4 to 13.8 (average 10.5) in (B) horizon. Soil reaction in water, in A horizon, is from extremely acidic to very strongly acidic, with pH values from 3.9 to 5.0 (average 4.4 pH unites). Somewhat milder values of active acidity were recorded in (B) horizon. In that horizon pH-values are slightly increased compared to A horizon, but remain very low and amount 4.5 to 5.2 pH units (average 4.9), so they belong to very strongly to strongly acidic. Substitutional acidity values (Table 3), are in accordance with values of active acidity and point out pronounced acidity of researched soils. Values of hydrolytic acidity are variable and stay in function of different constitution conditions. Within A horizon values are from 22.5 to 120.8 cm^3, (average 70.9 cm^3), while within cambic horizon from 26.5 to 64.0 cm^3 (average 36.7 cm^3). Values of total adsorption capacity are conditioned by fraction of clay and colloids content from one side and humus content from other side, and on average, higher values are found in A horizon (58.1 cmol/ kg) compared to cambic horizon (29.4 cmol/ kg). Values of base saturation (V%) are from 0% to 37.6%, average 20.3 % in A horizon, and from 0% to 34.2%, average 15.8% in (B) horizon.

Figure 1: Dystric cambisol on phyllite (Jastrebac – soil profile 1)

Figure 2: Dystric cambison on schist (Golija – soil profile 1)

Figure 3. Dystric cambisol on schist (Javorje – soil profile 1)

Figure 4. Dystric cambisol on sandstone (Stara planina- soil profile 2)

All values indicate that soils are not saturated by bases, with exception of one profile on Jastrebac, where V% surmounts to around 52.0% (Table 3).

Table 2. Granulometric composition of Dystric Cambisols

Locality, profile number, parent material	Hor.	Depth (cm)	Granulometric composition (%)						Soil texture
			Clay	Silt	Total	Total	Fine sand	Coarse sand	
			<0.002 mm	0.02 - 0.002 mm	clay+silt	sand	0.2 - 0.02 mm	2.0 - 0.2 mm	
Jastrebac Profile 1, phyllite	A	0 - 10	15.0	30.5	45.5	54.5	31.0	23.5	CL
	(B)	10 - 45	20.0	28.4	48.4	51.6	25.9	25.7	CL
Jastrebac Profile 2, schist	A	0 -15	12.1	31.6	43.7	56.3	24.4	31.9	L
	(B)	15 - 50	16.1	35.6	51.7	48.3	25.2	23.1	CL
Jastrebac Profile 3, gneiss	A	0 -13	6.4	23.1	29.5	70.5	50.0	20.5	FiSaL
	(B)	13 - 40	6.1	18.1	24.2	75.8	53.7	22.1	FiSaL
Goč Profile 1, granodiori te	A	0 - 15	17.2	18.6	35.8	64.2	44.1	20.1	SaCL
	(B)	15 - 55	19.0	17.1	36.1	63.9	45.1	18.8	SaCL
Goč Profile 2, granite	A	0 - 8/10	14.9	19.3	34.2	65.8	50.6	15.2	FiSaL
	(B)	8/10 - 73	20.6	16.4	37.0	63.0	37.7	25.3	SaCL
Rudnik Profile 1, sanstone	A	0 -12	14.2	27.6	41.8	58.2	47.1	11.1	loam
	(B)	12 - 52	18.4	32.0	50.4	49.6	42.5	7.1	CL
Rudnik Profile 2, clay	A	0 - 15/20	21.1	27.6	48.7	51.3	40.2	11.1	CL
	(B)	15/20 - 47	22.6	34.5	57.1	42.9	32.3	10.6	CL
St. Planina Profile 1, sandstone	A	0 - 18	5.8	11.3	17.1	82.9	17.9	65.0	CoSaL
	(B)	18 - 50	10.0	12.6	22.6	77.4	45.3	32.1	FiSaL
St. Planina Profile 2, sandstone	A	0 - 14	7.1	12.2	19.3	80.7	22.7	58.0	CoSaL
	(B)	14 - 48	8.9	15.4	24.3	75.7	31.7	44.0	CoSaL
Golija Profile 1, schist	A	0 - 10	13.2	28.2	41.4	58.6	39.7	18.9	L
	(B)	10 - 35	18.0	25.8	43.8	56.2	38.6	17.6	CL
	(B)	35 - 50	14.4	21.8	36.2	63.8	45.2	18.6	L
Golija Profile 2, phyllite	A	0 - 10	14.9	22.3	37.2	62.8	43.2	19.6	L
	(B)	10 - 50	19.1	28.6	47.7	52.3	37.7	14.6	CL
Javorje Profile 1, schist	A	0 - 23	11.1	25.8	36.9	63.1	35.0	28.1	L
	(B)	2 3- 52	15.7	29.4	45.1	54.9	20.0	34.9	CL
Javorje Profile 2, schist	A	0 - 11	10.4	33.1	49.9	50.1	24.9	25.2	L
	(B)	11 - 51	22.5	26.1	48.6	51.4	25.9	25.5	CL

CL – Clay loam; L – Loam; FiSaL – Finely sandy soam; CoSaL - coarsely sandy loam; SaCL – Sandy clay loam.

Levels of nitrogen, potassium and phosphorus in soil, belonging to macroelements, were also analysed in research. These elements are neccesary to plants in high amounts (Cheswort et al., 2008). Content of basic macroelements (nitrogen, phosphorus and potassium) is very variable, which depends on geological substrate type, humus content and biological activity of soil. Content of easily accessible phosphorus is in the range from poorly to medium supplied, with values from 1.2 to 18.0 mg on 100 g of soil, while content of easily accessible K_2O is from 4.4 to 22.0 mg on 100 g of soil. Researched soils are poorly supplied with phosporus, and somewhat better by potassium. Soils formed on clays, phyllite, sandstone and schists possess lower content of easily accessible phosphorus, while soils formed on granite, granodiorite and gneiss are better supplied. The lower contents are found in Dystric Cambisols formed on schist on Golija, where supply is poor within whole soil profile. The highest content of easily accessible phosporus is found in soils formed on schists and gneiss on Jastrebac, where it is moderately well provided. Content of easily accesible potassium is the highest in upper A horizon in all profiles and it belongs to medium to well supplied category, while in (B) horizon decreases and belongs to poorly provided group, except in soils formed on clay or sandstone, where it is medium supplied.

Nitrogen content in samples of Dystric Cambisol varies from 0.1% to 1.3% so the soils are well provided, rich to very rich in this macroelement. Having in mind direct corelative connection between humus and nitrogen contents, ground A horizons are better suplied than (B) horizons. Ranker is researched only morphologically on Jastrebac locality, on one soil profile. It is located on a ridge, at elevation 1350 m a.s.l. Geological substrate is phyllite. Ranker belongs to dystric subtype and brownised lytic variety. A horizon is 30 cm thick, skeletal, with finely crumby structure aggregates, of light mechanical composition, rich in sand fraction, loose, with poor water properties. (B) horizon is 20 cm thick, of brown color, loose, sandy, with presence of large substrate particles.

Table 3. Chemical properties of Dystric Cambisols

Locality	Hor.	Depth (cm)	pH		Y1 (cm^3) NaOH	(T - S)	S	T	V	Humus	C	N	C/N	Accessible	
			H_2O	KCl		cmol/kg			(%)					P_2O_5	K_2O
														mg/100g	
Jastrebac Profile 1, phyllite	A	0 - 10	4.44	3.80	66.7	43.4	18.6	62.0	30.0	14.02	8.13	0.68	11.90	3.8	18.1
	(B)	10 - 45	4.77	4.12	37.0	24.1	8.6	32.6	26.2	4.84	2.80	0.29	9.60	0.3	5.3
Jastrebac Profile 2, schist	A	0 - 15	4.42	3.75	56.7	36.9	17.3	54.2	32.0	11.97	6.94	0.62	11.20	14.5	20.8
	(B)	15 - 50	4.86	4.04	36.6	23.8	10.0	33.8	29.6	5.26	3.05	0.33	9.20	18.0	9.0
Jastrebac Profile 3, gneiss	A	0 - 13	4.82	4.12	43.9	28.5	30.9	59.4	52.0	9.64	5.59	0.48	11.60	10.3	14.7
	(B)	13 - 40	5.15	4.35	26.5	17.2	19.0	36.2	52.4	3.08	1.79	0.18	9.90	11.4	6.5
Goč Profile 1, granodiorite	A	0 - 15	4.08	3.40	98.5	64.0	11.9	75.9	15.6	20.24	11.74	0.85	13.80	13.0	17.4
	(B)	15 - 55	4.90	4.20	41.6	27.1	5.1	32.1	15.8	7.70	4.46	0.39	11.40	4.5	4.7
Goč Profile 2, granite	A	0 - 8/10	3.96	3.37	101.0	65.6	14.6	80.2	18.2	21.76	12.62	0.77	16.40	9.8	18.5
	(B)	8/10 - 73	4.80	4.30	35.2	22.9	6.0	28.9	20.8	6.60	3.83	0.35	10.90	1.2	4.4
Rudnik Profile 1, sandstone	A	0 - 12	4.83	4.14	61.3	39.8	19.2	59.0	32.5	13.81	8.01	0.71	11.30	3.5	24.5
	(B)	12 - 52	4.98	4.18	38.9	25.3	13.1	38.4	34.2	5.05	2.93	0.35	8.40	0.3	12.7
Rudnik Profile 2, clay	A	0 - 15/20	4.21	3.56	121.4	78.9	15.5	94.4	16.4	26.25	15.23	1.33	11.50	6.0	17.0
	(B)	15/20 - 47	4.70	4.02	64.0	41.6	11.3	52.9	21.4	12.02	6.97	0.78	8.90	7.3	10.4

Table 3 (continued). Chemical properties of Dystric Cambisols

Locality	Hor.	Depth (cm)	pH		Y1 (cm^3) NaOH	(T - S)	S	T	V	Humus	C	N	C/N	Accessible	
														P_2O_5	K_2O
			H_2O	KCl		cmol/kg			(%)					mg/100g	
Stara Planina Profile 1, sandstone	A	0 - 18	4.27	3.64	31.8	20.6	0.0	20.6	0.0	4.19	2.43	0.19	12.79	2.6	9.1
	(B)	18 - 50	4.51	3.88	33.0	21.5	0.0	21.5	0.0	3.00	1.74	0.14	12.43	0.8	6.8
Stara Planina Profile 2, sandstone	A	0 - 14	4.63	3.96	22.5	14.6	2.2	16.8	13.1	4.07	2.36	0.23	10.26	2.0	10.2
	(B)	14 - 48	4.67	3.96	26.5	17.2	0.0	17.2	0.0	3.51	2.04	0.21	9.69	1.0	6.4
Golija Profile 1, schist	A	0 - 10	4.21	3.53	71.9	46.7	5.0	51.7	9.7	14.87	8.62	0.67	12.87	5.1	21.9
	(B)	10 - 35	4.62	4.09	48.1	31.3	0.0	31.3	0.0	4.91	2.85	0.22	12.94	0.3	8.2
	(B)	35 - 50	4.74	4.30	34.8	22.6	0.0	22.6	0.0	3.56	2.06	0.15	13.77	2.7	4.9
Golija Profile 2, phyllite	A	0 - 10	3.90	3.35	120.8	78.5	0.0	78.5	0.0	16.04	9.30	0.63	14.77	6.2	22.0
	(B)	10 - 50	4.46	3.87	29.0	18.9	1.0	19.9	5.0	4.37	2.53	0.20	12.67	0.0	6.8
Javorje Profile 1, schist	A	0 - 23	5.02	4.43	43.3	28.2	17.0	45.2	37.6	12.72	7.38	0.73	10.11	7.6	18.0
	(B)	23 - 52	5.23	4.42	28.5	18.5	3.5	22.0	15.9	4.75	2.76	0.32	8.61	4.9	4.9
Javorje Profile 2, schist	A	0 - 11	4.18	3.54	81.9	53.2	3.8	57.0	6.7	11.41	6.62	0.68	9.73	11.3	14.2
	(B)	11 - 51	4.68	4.09	34.5	22.4	0.0	22.4	0.0	3.57	2.07	0.25	8.28	1.2	4.9

DISCUSSION

Lakušić (1989) mentions that Greek maple grows on all rock types, carbonate and silicate massifs, but on silikates it attains higher frequency and coverage. The same author mentions that this maple growns on various soil types, from Organomineral Rendzinas to Dystric Cambisols and Podzols, where pH value ranges between 4.0 and 7.5 and percentage share of humus can be higher than 25%. Tomić (1992) states that plant community of beech and Greek maple (*Aceri heldreichii - Fagetum*) occurs in conditions of humid climate and on soil of sufficient fertility – mostly humus subtype of Dystric Cambisol. Černjavski (1936) describes one *Acer heldreichii* Orph. stand on Crvena Stena (Bjelasica Mt.), on very steep slope, with inclination 45°, at elevation 1500 m do 1600 m a.s.l., on almost bare "loamy soil". According to Fukarek (1943), Greek maple has very limited occurence in forest ecosystems, grows only on high mountains, and: "..it is content with shallow and leached soil…". According to Antić et al. (2007), Greek maple populations always grow on very strongly acidic to strongly acidic soils where pH values in water in (B) horizon vary from 4.5 to 5.2. It requires moderately moist to fresh soils (Cvjetićanin et al., 2016).

On the basis or research results, it is determined that most Greek maple populations occur in subalpine zone of forest vegetation, as mentioned by Fukarek (1943), but occurence on Rudnik at elevations from 1000 m to 1100 m a.s.l. indicates that this species can occur at lower elevations, in montane belt. Dominant aspects are cold, and inclinations mild to moderately steep, which is not in accordance to Černjavski (1936), who describes Greek maple community on very steep slope of 45°. On researched localities Greek maple grows mostly on Dystric Cambisol, and only on one locality it grows on Ranker. More precisely, Greek maple grows on lesser numbar of soil types than quoted by Lakušić (1989), but stays in accordance to Tomić (1992) that Greek maple mostly grows on Dystric Cambisol.

Parent geological materials on researched localities are primarily poorly supplied with nutrients and also produce relatively small quantity of clay fraction, high quantity of sand fraction and higher or lower volume of skeleton. Such granulometric composition, together with low inclinations, cause distiling of water through soil profile and to alkali leaching and acidification. During acidification process, high yearly precipitation level play important role, which is significantly above 1000 mm on all localities. Soil reaction in water, in A horizon, is extremely acidic to very strongly acidic, with pH values from 3.9 to 5.0 (average 4.4 pH units), and in (B) horizon it is very strongly to strongly acidic, with values between 4.5 to 5.2 pH units (average 4.8), which is in accordance with results of Antić et al. (2007). Similar situation is with substitutional and hydrolytic acidity. Namely, values of hydrolytic acidity are high throughout soil profile depth (A horizon - average 70.9 cm^3, occasionaly up to 120.8 cm^3; (B) horizon - average 36.7 cm^3, occasionaly up to 64.0 cm^3.

Low mean yearly temperatures, which are significantly below 7°C on most localities (average 5.2°C), as well as high precipitation level and relative air humidity, affect weaker transformation of organic matters. Conditions for organic matter decomposition on soil surface are frequently not so favourable as within soil profile, because plant litter is under strong influence of external factors, above all climate (Ćirić, 1991). Very strong influence for organic matter transformation velocity possesses C:N ratio in leaves. According to research of C:N ratio in various species of forest trees, among others beech and sycamore maple, is >50 (Wittich, 1952; in Ćirić, 1991). Having in mind low alkali content in parent substrates, i.e. low alkali saturation level of soil, and considering previously mentioned climate characteristics, it ensues that chemical composition of plant litter in beech and Greek maple plant communities also influences delayed transformation of organic residues.

On all reserched localities, there is no equal possibility for production of organic-mineral complex, so commences higher or lower accumulation of free humus matters. Humus level in topsoil of researched soils is very variable, but it can outpass 25% (26.2%), which is in accordance with quotation of Lakušić (1989). High humus content is found in cambic horizon also (average 5.6). Formed humus belongs to mull or moder type, and main humificators are arthropodes, fungi and bacteria.

According to Antić et al. (2007), natural conditons for distribution of Dystric Cambisols are moderately humid climate, with average yearly precipitation 700 - 1000 mm, average yearly temperature 5 - 8°C and elevation 500 – 1100 m a.s.l. It can be concluded that researched Dystric Cambisols in communities of beech an Greek maple, especially on higher elevations (above 1100 m a.s.l.) and geological substrates which produce high level of sandy fraction during weathering, very easily and rapidly become very acidic with tendency of humus accumulation. Considering research of Košanin (2004) and all facts presented in this research, it can be concluded that processes of Dystric cambisol genesis on particular Greek maple sites, has tendency to form podzolized and humus rich Dystric Cambisol, which is in accordance to claims of Antić et al. (1972) and Tomić (1992).

Soil is very importnant ecological factor, because the productivity of forest ecosystems on sites defined by heterogenic soil units, depends on type and structure of soil combination, i.e. on productivity of members of combinations and their percentage share (Knežević and Košanin, 2004). On the basis of production classification of forest soils, made in Bosnia and Herzegovina (Ćirić, 1991), Dystric Cambisols score 56 points of maximal 100, so they are considered moderately productive forest soils. Ranker possess much lower productivity (21 point), but *Acer heldreichii* only rarely occurs on that soil type. Jović et al. (2009) state that forests of beech and Greek maple (*Aceri heldreichii-Fagetum* B. Jov. 57) on Dystric cambisol, where this species usually grows, have high production capacity. Researched soils are moderately deep to deep, with depths span from 35 cm to 73 cm, average 49.8 cm. Favourable depth and high annual precipitation level on one side, and high share of fraction of total sand with higher or lower presence of skeleton fraction on the other side, contrive that these soils dispose of sufficient quantities of accesible water, which confirms claims of Cvjetićanin et al. (2016) that Greek maple requires moderately wet to fresh soils.

It is determined that *Acer heldreichii* possesses wide ecological valence considering geological parent material and soil, because it was found on seven different parent rock types. However, on the basis of results of this research, it can be concluded that all researched localities contain only silicate rocks. In Serbia, Greek maple was not found on carbonates, but it grows on such rocks in Montenegro and Republic of Srpska (Bosnia and Herzegovina). However, its populations are much smaller on such sites.

CONCLUSION

Greek maple (*Acer heldreichii* Orph. subsp. *heldreichii*) on researched area occurs primarily in subalpine vegetation zone, at elevations 1300-1700 m a.s.l. Only on Rudnik, it is found in montane zone at elevation 1000-1100 m a.s.l. It grow on various aspects, but mostly on cold and humid (northern, northwestern, eastern, northeastern), rarely on warmer aspects (western and southwestern).

Greek maple in Serbia mostly grows on sites with milder inclination, from completelly flat terrains (inclination 0°), to moderately steep slopes (15-25°). Only on Stara Planina it is recorded on very steep slopes (up to 40°). *Acer heldreichii* has great ecolocical valency considering geological parent material, it grows on various rock types, but always on silicate rocks (schist, phyllite, gneiss, granite, granodiorite, sandstone and clay).

Greek maple on researched localities grows on two types of soil – Dystric cambisol and Leptosol (Ranker). It was almost always recorded on Dystric cambisol, in 13 out of 14 researched soil profiles, and only in one case in Jastreba grows on Ranker. Analysed soils are mostly moderatelly deep to deep, relatively well provided with nutrients, and its chemical reaction is between extremely acidic to strongly acidic.

Considering that Greek maple (*Acer heldreichii* Orph. subsp. *heldreichii*) is subendemic of Balkan peninsula and that it is a strictly protected species in Serbia, this research will bring valuable contribution to better knowledge of ecological conditions in which this species grows in Serbia.

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RESEARCH ON THE FAUNA OF EARTHWORMS (ANNELIDA: OLIGOCHAETA) OF SOKOBANJA

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Abstract

Soil is a complex and dynamic entity, made up of abiotic and biotic components. Earthworms are one of the most important organisms of terrestrial ecosystems. They are often presented as bioindicators of soil quality. That is why it is extremely important to know their diversity, ecology and distribution. The aim of this paper is to present new data on the earthworm fauna of Sokobanja and to summarize the published data. The list underlines earthworm diversity and provides a general overview of their distributions, zoogeographical positions, and ecological categories. The earthworms were obtained by the diluted formaldehyde method complemented with digging and hand sorting as well as turning over rocks, debris, and logs.The total number of earthworm species in Sokobanja comprises 7 taxa belonging to 7 genera. Our analysis showed that almost all species are peregrines (six out of seven). The only species of *D. byblica byblica* is Circum-Mediterranean. According to the ecological category classification, four species were epigeic, two species were endogeic, and one species was anecic. In our research, we found three new species for this area (*A. rosea*, *D. byblica byblica*, *E. fetida*). The Lumbricidae fauna of Sokobanja, with several cosmopolitan species, is fairly uniform. However, the investigations are still insufficient and the earthworm inventory of Sokobanja is far from complete. Also, in order to protect the biodiversity, we need to increase our knowledge of biological diversity, especially considering its link to the soil functioning. Hence, this study indicates the importance of such studies.

Keywords: earthworms, soil, Sokobanja, Serbia

INTRODUCTION

Soil is a complex and dynamic entity, made up of abiotic and biotic components. Both of these components are interdependent and interconnected. It is known that physical and chemical parameters are no longer sufficient to assess the state of the environment. The primary role is taken over by living organisms. The most important biological component in the soil is microorganisms that make up 0.1 to 5% of the total organic matter of the soil. They participate in the total transformations of organic matter in the soil with 60-80% and are the main factors in the processes of energy flow and matter circulation. The activity of macrofauna in the soil, primarily earthworms, has a significant influence on their number and activity. Earthworms make up 12% of living organisms in the soil and, are one of the most important organisms of terrestrial ecosystems. They are often presented as bioindicators of soil quality (Klemens et al., 2003). In addition, they are considered ecosystem engineers because they directly or indirectly modify the availability of resources for other species, such as plants and microorganisms (Jouquet et al., 2006). Earthworms grind organic matter, and prepare it for further transformation under the influence of the microbial population. The synergistic action of microbes and earthworms creates a permanent clay-humus complex that affects the level of soil fertility, both in forests and on pastures, as well as in agroecosystems. The role of earthworms is very important in the process of decomposition of the matter of dead plants and animals, and in the continuous excavation, soil composition maintenance, aeration and drainage (Römbke, 2008). It is important to note that different types of earthworms have different effects in the soil. They include several functional groups and each is clearly distinguished by location in soil profile, their body size and pigmentation and their primary food resource. The basic division includes three ecological forms: epigeic, endogeic, and anecic species (Bouché, 1977). That is why it is extremely important to know their diversity, ecology and distribution.

Sokobanja is located in east part of Serbia. Although Eastern Serbia is generally considered to be well studied, there are parts that are not. There is very little data on the earthworms from this area. The first data were provided by Šapkarev (1980) recording four taxa. Unfortunately, during the 90s, sporadic research has not led to the discovery of new species.

Therefore, the aim of this paper is to present new data on the earthworm fauna of Sokobanja and to summarize the published data. The list underlines earthworm diversity and provides a general overview of their distributions, zoogeographical positions, and ecological categories.

MATERIALS AND METHODS

Study area

The study was carried out in Sokobanja (between 43°38'N, 21°52'E), in the middle of the Balkan Peninsula. It is located at an average altitude of 400 meters. Sokobanja is located between the Carpathian-Balkan Mountains, Rtanj and Ozren. The Carpathian system is composed of old metamorphic rocks with deposits of Mesozoic limestone, which conditioned the formation of karst relief which is characteristic of all the mountains of northeastern Serbia with numerous gorges, sinkholes and caves. These mountains naturally continue on the Balkan Mountain system, which belong the Ozren Mt. Through Sokobanja flows the river Sokobanjska Moravica. Also, it is located thermal and geothermal groundwater resources. The climate is moderate continental.

Methods

The earthworms were obtained by the diluted formaldehyde method complemented with digging and hand sorting as well as turning over rocks, debris, and logs. The earthworms were killed in 70% ethanol, fixed and stored in 90% ethanol. Identification of species was made in accordance with: Mršić (1991), Csuzdi and Zicsi (2003) and Blakemore (2004).

We collected all available literature data on earthworms in order to establish the definitive list of biogeographic type. It was used categorization of Lumbricidae species on the basis of their geographical distribution proposed by Csuzdi and Zicsi (2003), Pop et al. (2010), Csuzdi et al. (2011).

RESULTS AND DISCUSSION

We analyzed the total 39 individuals, of which 28.21% were adults and 71.79% were juveniles. Starting from the total number of earthworms listed by Šapkarev (1980) and Stojanović (1996) and taking into account our research, the total number of earthworm species in Sokobanja comprises 7 taxa belonging to 7 genera (Table 1). Classification of ecological categories and zoogeographic distribution type are shown in Table 1.

Our analysis showed that almost all species are peregrines (six out of seven). The only species of *Dendrobaena byblica byblica* (Rosa, 1893) is Circum-Mediterranean. According to the ecological category classification, four species were epigeic, two species were endogeic, and one species was anecic (Table 1). In our research, we found three new species for this area (*Aporrectodea rosea* (Savigny, 1826), *D. byblica byblica*, *Eisenia fetida* (Savigny, 1826)).

Table 1. List of the earthworm taxa with habitat, ecological category and zoogeographic type

Species	Habitat	Ecological category	Zoogeographic type
Aporrectodea rosea (Savigny, 1826)	forest (authors' data, 4 exp., 30.04.2016.)	endogeic	Peregrine
Bimastos rubidus (Savigny, 1826)	under the rock (Šapkarev 1980)	epigeic	Peregrine
Dendrobaena byblica byblica (Rosa, 1893)	forest (authors' data, 1 exp., 30.04.2016.)	epigeic	Circum-Mediterranean
Eisenia fetida (Savigny, 1826)	forest (authors' data, 1 exp., 30.04.2016.)	epigeic	Peregrine
Eiseniella tetraedra (Savigny, 1826)	under the rock (authors' data, 1 exp., 30.04.2016.); forest (Šapkarev 1980); meadow (Stojanović 1996)	epigeic	Peregrine
Lumbricus terrestris Linnaeus, 1758	forest (authors' data, 1 exp., 30.04.2016.); meadow (Šapkarev 1980)	anecic	Peregrine
Octolasion lacteum (Örley, 1881)	forest (Šapkarev 1980); meadow (Stojanović 1996)	endogeic	Peregrine

Extensive research on the flora and fauna of the Balkan Peninsula has indicated that this area is exceptional biodiversity (Griffiths et al., 2004). The geomorphology of the Balkans peninsula, slightly warmer climate and the position in relation to most of Europe, enabled the Balkan Peninsula, including the territory of Serbia, becomes one of the most important refugium centers of European fauna, which is also the reason for the current high degree of biodiversity (Mršić, 1991, Džukić et al., 2016). If we take into account that 54 species of earthworms were found in eastern Serbia (Stojanović et al., 2017), then the number species in Sokobanja is very low. However, the earthworm fauna of Sokobanja has been sparsely researched. Nevertheless, it is worrying that endemic species have not been found, and almost all are peregrines.

East Serbia is a highly complex area, primarily due to the presence of the Carpathian-Balkan mountain system, which is composed of complex geological bases. According to Jakšić et al. (2011). Distribution of carbonate rocks has a significant impact on the biodiversity of the Balkans. Also, the complex geological history of this area together with hydrological and climatic conditions they have contributed to the development of an extremely complex and heterogeneous terrestrial fauna (Stojanović et al., 2017). On the other hand, living organisms provide the best reflection of the true state ecosystems and changes in them. The ecological form of each species provides reliable information about ecological and climatic conditions in the biotope in which the species lives. Species of the *Eisenia* and *Eiseniella* genus are often found in areas that are rich in organic matter (Stojanović-Petrović et al., 2020). Species from these genera were found in forest litter layer. *Octolasion lacteum* (Örley, 1881) is classified as an oligohumic endogeic earthworm species, which has ability to use the resources of a poorer quality due to an efficient digestion process. With progressive warming, the process of stepification of lowlands begins biotopes in Serbia, and thus leads to the expansion of some xerothermic species (*A. rosea*), which have been in numerous studies characterized as indicators of dry habitats. Steppe expansion biotopes have been greatly accelerated by man's activity (Stojanović et al., 2020). An interesting fact is that this species has not been found in previous research.

CONCLUSION

The Lumbricidae fauna of Sokobanja, with several cosmopolitan species, is fairly uniform. However, the investigations are still insufficient and the earthworm inventory of Sokobanja is far from complete. In addition, the analysis for assessing of species of a particular fauna is per se a never-ending dynamic process. Also, in order to protect the biodiversity, we need to increase our knowledge of biological diversity, especially considering its link to the soil functioning (Gardi et al., 2009). Hence, this study indicates the importance of such studies.

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MEASUREMENT OF HYDRAULIC PROPERTIES OF GROWING MEDIA WITH THE HYPROP SYSTEM

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Abstract

Knowledge of hydro-physical properties is an essential prerequisite for assessing the suitability and quality of growing media. The method used for sample preparation is important for the measurement results. Three different sample preparation methods were compared. The methods differed in terms of the way the cylinder was filled and the height of preloading. Measurements on loosely filled cylinders were included. The comparison was carried out on 15 growing media using the HYPROP device. HYPROP enables a complex analysis of the hydro-physical properties with high accuracy and reproducibility. The water retention curve, the unsaturated hydraulic conductivity function, the dry bulk density, the shrinkage and the rewetting properties can be measured simultaneously. The air capacity and the amount of plant-available water in pots depend on the height of the pot. In the field, it is related to the field capacity. The quality assessment was carried out both for flowerpots of different height and for field conditions with free drainage. Loosely filled samples consolidated hydraulically shortly after the start of the measurement. These geometric changes can be taken into account with the HYPROP. The sample preparation method – preloading or loose filling – yielded significantly different results for the pore volume, dry bulk density, plant-available water and air capacity. The total pore volume of the loosely filled cylinders varied between 86.8 and 95.2°% by vol. (preloaded 81.3 and 87.7°% by vol.). The most critical factor was the air capacity. Loosely filled substrate samples achieved the highest air capacities, but also did not reach the critical value of 10°% by volume in shallow flowerpots, e.g. in 10 cm pots with 5.8°% by volume. The sample preparation method, measurement and quality assessment of the hydro-physical properties of growing media should be adapted to the conditions of use – whether they are used in a field with free drainage or in pots or containers in greenhouses.

Keywords: sample preparation, air capacity, plant-available water, water retention curve, unsaturated hydraulic conductivity function, re-wetting, water drop penetration, time, shrinkage, Extended Evaporation Method (EEM), HYPROP.

INTRODUCTION

Knowledge of hydro-physical properties is an essential prerequisite for assessing the suitability of soils in agriculture and of growing media in horticulture (Raviv and Lieth, 2008, Schindler et al., 2015, Schmilewski, 2017). Beside the capillarity, the tendency to shrinkage and swelling and the rewetting properties, the most important hydro-physical variables are the air capacity and the plant-available water.

According to the Garden Industry Association (IVG, Schmilewski, 2017), the average total pore volume of growing media is 94°% by volume. Such high values could not be confirmed by Schindler and Müller (2017a). Previous studies (Schindler and Müller 2017a) showed that the air capacity can assume especially critical values in shallow flowerpots. The air capacities recommended by different authors in Schmilewski (2017), however, varied between 10 and 40°% by vol. This range of air capacities is in strong contradiction to the results gained by Schindler and Müller (2017a). In that study, the air capacity of 36 different growing media was a crucial variable. The limit of 10°% by vol. was exceeded in only very few cases. The study included growing media consisting of pure peat, pure coir, peat-free substrates and very different mixtures of peat with compost, bark, perlite and other materials. The average air capacity in line with DIN EN 13041 (2012) was 5°% by vol. (max. 17.5°% by vol., min. 1.6°% by vol., standard deviation 3.3°% by vol.).The question is, how can these extreme differences be explained and what is the cause – the measurement method, the evaluation procedure, the sample preparation, the growing medium itself or other factors?

The standard means of measuring hydro-physical properties is the sandbox method (Raviv and Lieth, 2008, DIN EN 13041, 2012). The measurement is time-consuming, and the results are limited to a tension range between saturation and 100 hPa. Only the water retention properties can be measured as the basis for calculating the air capacity and the plant-available water. The HYPROP (HYdraulc PROPerty analyzer), however, simultaneously enables an accurate, effective and reproducible measurement of all the hydro-physical properties required of growing media, including capillarity, shrinkage and re-wettability (Schindler et al., 2017a).

The sample preparation method for measuring and evaluating the physical properties of growing media is an important issue. Methods are used with mechanical preloading (PPO in Wever, 1999; Schindler et al., 2017a) or loosely filled cylinders with pre-wetted material (DIN EN 13041, 2012). These individual procedures can lead to different results.

The assessment of growing media quality must be directly related to horticultural practice. In practice, flowerpots are loosely filled with the growing medium by hand or with a potting machine (Fig. 1), planted and watered so that water emerges at the base (Fig. 2). The preparation and measurement of hydro-physical properties must correspond to these conditions to be sufficient. The conditions in the field are different. There, the substrate is under free drainage and can be driven over with machines. Here, we studied the effect of different sample preparation procedures. The measurements were carried out with the HYPROP system, focusing on the air capacity and the plant-available water. The following results are presented and discussed.

MATERIALS AND METHODS

Hydro-physical basics

DIN EN 13041 (2012) defines the air capacity as a fixed value. It is calculated as a difference in water content ranging between saturation and a tension of 10°hPa. This value is suitable to compare growing media, but of limited significance for practical issues such as evaluating the air and water capacity in flowerpots or in the field.

Figure 1. Potting machine

Figure°2. Samples on a water-saturated fleece after filling and planting in the market

The air and water capacity in flowerpots are not fixed values, but depend on the height of the pot. In horticultural practice, flowerpots are watered after filling and planting so that water drains at the base (Fig. 2). Then, the flowerpots are placed on a water-saturated fleece. In this case, there is a tension of 0 at the base of the flowerpot. The water and air content in the flowerpots is calculated from the water retention curve (Eq. 1, Fig. 3, left). The air capacity of 10°hPa as defined in DIN EN 13041 (2012) is assumed to be available throughout the pot (Fig. 3, right). The air capacity in the field (Fig. 3, right) is a “fixed” value in the profile with free drainage and corresponds to the water content at field capacity (FC) at 60°hPa (AG Boden, 2005).

$$\int_0^{\Psi} \Theta(\Psi)\, dz \qquad (1)$$

With □ being tension and □ being water content.

Sample preparation procedures

Method A

The cylinder (250 cm^3, 5 cm high) was loosely filled with the substrate directly from the package (Schindler et al., 2017). The water content of the sample was not changed. The sample surface was loaded for one minute with a 10 kg weight (0.2 kg cm^{-2}). A second cylinder was placed on top of the first, half-filled with substrate, and the compression procedure was repeated. The surface was smoothed. The sample was saturated and prepared for the HYPROP measurement.

Method B

The substrates were loosely poured into plastic tubes (diameter 15 cm, height 60 cm). The pipes were placed in a bowl with water and saturated by capillary action for about 48 hours (Fig. 4).

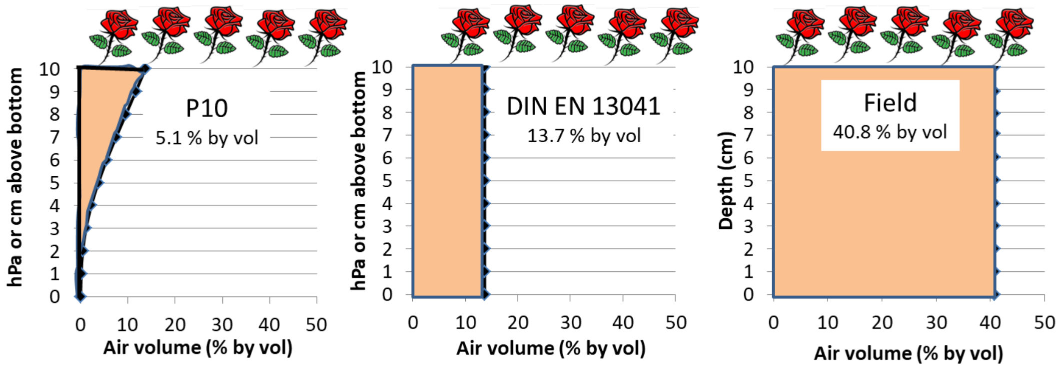

Figure 3. Air capacities in 10-cm-high pots: left, Air_{DIN} at 10 hPa: middle and right: in the field. Substrate 25W1.

After capillary saturation, the tension at the surface varied between 50 to 55 hPa. In the following, the upper 5 cm of the substrate were removed and mixed and the 250 cm^3 cylinders were filled loosely. The filling took place in 2 stages. First the cylinder was completely filled and rammed onto the table 5 times by hand. The sample material compressed hydraulically. A second cylinder was then placed on top, half-filled with substrate and the two were rammed onto the table another five times. The second cylinder was removed and the sample surface was smoothed. The samples were saturated and the measurement with the HYRPOP could start.

Figure 4. Capillary saturation to 50 hPa.

Method C

Comparable to practice, the substrate was loosely poured into the cylinder directly from the package. The sample was saturated, the surface smoothed and prepared for the

HYPROP measurement. Immediately after the start of the measurement, the sample material consolidated hydraulically. The consolidation process was finished shortly after the start of the measurement at a tension between 1 and 3 hPa. The geometric changes were taken into account with the HYPROP. This procedure is comparable to DIN EN 13041 (2012), the difference being that the DIN-defined hydraulic consolidation already took place before the measurement (capillary pre-saturation to 50 hPa).

Growing media

Table 1 gives an overview of the composition of the tested growing media.

Table 1. Composition of the substrates for the comparison of sample preparation

No.	Ingredients
9W	75°% H3-H5, H6-H7, Co, Cl, Ca
9W1	80°% H3-H5, H6-H7, Ko, Cl
16W	H2-H5, G, R, Ca
25W	60°% H3-H5, H6-H7, R, G, Co, Ca
25W1	60°% H3-H5, H6-H7, Co, Cl, P
27W	50°% H3-H5, G, R, Cl
K1	80°% Hh,(H3-H4), 20°% Hh (H7-H9), Cl, gramoMicro
K2	45°% Hh /H3-H4), 30°% Hh (H7-H9), 25°% F, Cl, gramoMicro
HTC_150C	K1 plus 10°% HTC, 150°C
HTC_150D	K1 plus 20°% HTC, 150°C
HTC_170D	K1 plus 20°% HTC, 170°C
HTC_190C	K1 plus 10°% HTC, 190°C
HTC_190D	K1 plus 20°% HTC, 190°C
HTC_190E	K1 plus 30°% HTC, 190°C
DK	50°% Hh (H2-H4), 50°% Hh (H7-H9), Cl, Ca

Hh – bog peat, H3 – degree of decomposition 3, HTC – hydrothermally carbonized plant material at different temperatures, F – compost from forest residues, Ca – lime, G – compost from garden residues, Cl – clay, Co – coir, P – perlite, R – bark mulch.

Hydro-physical measurement with HYPROP

The HYdraulic PROPerty system (HYPROP, UMS 2012) was used to simultaneously measure the water retention function (pF curve), the hydraulic conductivity function (K-function) and dry bulk density in the range between saturation and the permanent wilting point (Fig. 5; Schindler et al., 2010; Schindler et al., 2017a). With minimal additional effort, the shrinkage and rewetting properties can be quantified simultaneously (Schindler et al., 2015). The function is covered with a large number of data. The measurement accuracy and reproducibility are high (Schindler et al., 2012). The measured values are recorded online. It is possible to measure multiple samples in parallel.

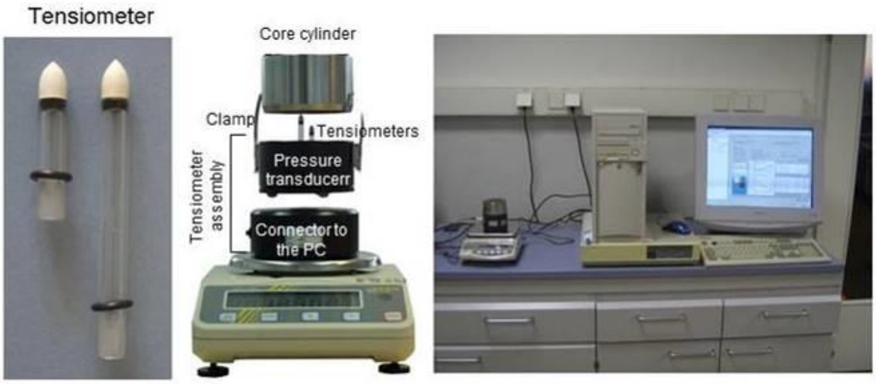

Figure 5. HYPROP system

Brief description

Hydro-physical properties of soils or growing media can be measured with the HYPROP at undisturbed or disturbed cylinder samples (100 or 250 cm^{-3}). The sample is saturated, connected to the HYPROP and placed on a scale. The scale and the HYPROP are connected to the PC. The sample surface is exposed to free evaporation and the measurement data (tensions, sample mass) are recorded at time intervals. When the evaporation measurement is finished, the sample is dried at 105°C in the oven to measure the amount of residual water and the dry bulk density. The evaluation (calculation, fitting, data export) takes place with the HYPROP-Fit software (UMS 2015). The measurement takes about 3 to 10 days and depends from the water content of the sample. The measurement can be stopped at any tension between saturation and the permanent wilting point (pWP, AG Boden, 2005).

RESULTS AND DISCUSSION

The high reproducibility of the HYPROP measurements is shown as an example in Fig. 6 for 3 replicates of substrate K1. Statistical results for the replicates are given by the HYPROP software. The results of sample preparation are summarized in Table 2 and Table 3. Methods A and B were carried out with mechanical preloading. Method B corresponds to the PPO standard (Wever, 1999). Method C was without any mechanical preloading. This method was close to horticultural practice and comparable to DIN EN 13041 (2012).

Fig. 7, left shows the example of minor differences in the water retention functions of the sample preparations A and B with preloading for substrate 25W1 as an average function of three replicates. Table 2 presents average values of three replicates as the basis for statistical evaluation (average of the tested substrates, standard deviation and t-test (Excel, Windows 10). The air capacity in 10-cm-high pots (A: 3.2°% by vol. and C: 5.4°% by vol.) did not reach the 10°% by vol. threshold value (Raviv and Lieth, 2007; Fischer, 2010). The air capacities as defined in DIN EN 13041 (2012) were, as expected, more than twice as high. With the exception of air and water, no other variables were significantly different. The dry bulk density (A: 0.23 g cm^{-3}, B: 0.22 g cm^{-3}) and the pore volume differed only slightly (A: 81.7°% by vol., B: 81.5°% by vol.) but did not come close to the values in Schmilewsky (2017) of 90°% by vol. and more. Under field conditions, the air capacity was very high (A: 36.9°% by vol., B: 38.3°% by vol.); however, due to this, the plant-available water was reduced by 10°% by vol. and more (A: 24.2°% by vol., B: 22.7°% by vol.).

Table 2. Hydro-physical results of growing media after applying sample preparation methods A and B.

M[1)]	No	DBD	PV	FC	Air_DIN	Air				Water			
					10 hPa	P10	P20	P30	Field	P10	P20	P30	Field
		g cm^{-3}	% by vol										
A	9W	0.24	81.8	43.4	4.5	2.0	8.8	15.5	38.4	43.2	36.4	29.7	18.4
A	9-1W	0.22	87.1	46.8	7.0	3.0	10.0	18.9	40.3	41.8	34.7	25.8	25.5
A	16W	0.26	75.9	37.0	14.9	6.7	14.4	19.8	38.9	37.2	29.6	24.2	17.5
A	19W	0.20	82.9	51.2	2.2	1.1	4.9	15.2	31.7	35.6	31.8	21.5	25.0
A	25W	0.22	81.3	44.0	6.6	2.7	9.9	17.5	37.3	40.0	32.9	25.3	35.1
A	25-1W	0.24	82.2	44.2	8.9	5.3	11.0	17.8	38.0	40.0	34.3	27.5	25.7
A	27W	0.25	80.8	46.8	3.4	1.4	6.4	15.5	34.0	36.7	31.7	22.6	22.4
B	9W	0.22	80.7	38.8	14.0	7.3	14.8	21.4	41.9	40.1	32.6	26.0	23.9
B	9-1W	0.18	84.4	44.1	13.6	6.9	14.5	20.9	40.4	38.1	30.5	24.1	24.3
B	16W	0.28	78.8	43.2	10.8	4.8	12.4	17.0	35.6	36.1	28.5	23.8	21.4
B	19W	0.19	83.4	49.0	4.3	2.5	8.7	16.2	34.4	36.0	29.8	22.3	24.4
B	25W	0.19	81.1	39.8	14.6	7.1	15.6	21.6	41.3	39.1	30.6	24.6	21.3
B	25-1W	0.23	80.8	40.8	13.6	6.4	14.7	20.4	40.0	39.5	31.2	25.5	19.9
B	27W	0.26	81.5	47.1	6.6	2.5	7.8	15.6	34.4	36.4	31.1	23.3	23.7
A	Av	0.23	81.7	44.8	6.8	3.2	9.3	17.2	36.9	39.2	33.1	25.2	24.2
B	Av	0.22	81.5	43.3	11.1	5.4	12.6	19.0	38.3	37.9	30.6	24.2	22.7
A	stabw	0.02	3.3	4.3	4.2	2.1	3.1	1.8	3.0	2.8	2.3	2.8	5.8
B	stabw	0.04	1.9	3.8	4.1	2.1	3.2	2.6	3.3	1.7	1.3	1.3	1.8
t-test		0.20	0.79	0.33	0.05	0.06	0.02	0.13	0.21	0.06	0.003	0.15	0.56

1) Preparation method, DBD - dry bulk density, PV - total pore volume, FC - field capacity at pF 1.8 (AG Boden 2005), stabw - standard deviation, P10 - pot, 10°cm high, Av - average.

The results of comparing methods B and C are presented in Table 3 and Fig. 7, right. The substrate in the loosely filled cylinders (C) compacted hydraulically shortly after the start of the measurement. The sample height and the volume decreased from 5 cm to a minimum of 4.5 cm, or from 250 cm^3 to 225 cm^3. These geometrical changes were taken into account by the HYPROP Fit software. This process is comparable to the hydraulic compaction during pre-saturation as defined in DIN EN 13041 (2012), but more effective because no pre-saturation step to 50°hPa is required. As expected, the differences between Method B with preloading and the loosely filled cylinders from Method C were highly significantly different for all variables. The pore volume exceeded 90°% by vol. with Method C. These values were comparable to the results gained by Schmilewski (2017). With Method B, the average pore volume was 83°% by vol. The air capacities in shallow, loosely filled pots (Method C) were considerably higher than with the preloaded samples of Method B (C: 5.8°% by vol., B: 2.8°% by vol.). However, even when the cylinder was loosely filled (C), the air capacity was far from the threshold value of 10°% by vol. The air capacities Air_{DIN} were also twice as high as Air P10. In higher pots, and especially under field conditions, the air capacity was sufficient. For growing media with sufficient air capacity in the upper part of the pot, intelligent knowledge-based water management can reduce the air problem. Under field conditions, however, the plant-available water was reduced by more than 10°% by vol. compared to cultivation in pots.

According to information from the Garden Industry Association (IVG), the average pore volume of gardening substrates is between 90 and 94°% by vol. The results from these studies confirmed these high pore volumes only for the samples of Method C. In those, the pore volume varied between 86.8 and 95.2°% by volume. The recommended air capacities published in Bohne (2006), Raviv and Lieth (2007), Huntenberg (2016), Fischer (2016) and Schmilewski (2017) varied between 10 and 40°% by vol. This range is in strong contrast to the results of this paper and Schindler et al., 2017a, b, c). The main reason for the differences is seen in the methodology.

As defined in DIN EN 13041 (2012), the air capacity corresponds to the difference in the water content, comparing the total pore volume and the water content at a tension of 10 hPa. However, this value cannot be determined exactly with the standard method (sandbox), since the tension applied is related to the centre of the sample. The tension at the lower and upper edges of the sample is -7.5 and -12.5°hPa, respectively. Linear averaging is not permitted and can lead to uncertainties. Another uncertainty arises from the determination of the total pore volume, since only fixed particle density values (also known as the true density or particle density) are used of the mineral and organic substance. This could result in very high values for the total pore volume and also for the air capacity, whose relevance for horticultural practice has to be questioned. The air capacity and the plant-available water are different under field conditions compared to pots.

The measurement and evaluation methods for assessing the quality of the hydro-physical properties of growing media must be adapted to the conditions of use. Under field conditions, the air capacity and the amount of plant-available water are calculated from the field capacity (AG Boden, 2005). In the greenhouse, the height of pots and containers must be taken into account. In addition, the sample preparation should also be adapted. Under field conditions, the substrate may be walked on by people and driven over by machines, so sample preparation methods with preloading are required and used (PPO in Wever, 2012 and Schindler et al., 2017a). Pots in the greenhouse are filled loosely. The samples for hydro-physical measurements should also be prepared accordingly. It has been shown that there are significant differences in air capacity and the plant-available water between the sample preparation with and without preloading. Method C is comparable to DIN EN 13041 (2012). The difference lies in the way hydraulic consolidation occurs. According to

DIN EN 13041 (2012), this happens in the 50°hPa cylinder. With the HYPROP, the sample consolidated directly in the cylinder during the measurement. Under these conditions, it would not be possible to measure the retention properties in the sandbox. However, HYPROP can take the geometric changes into account. This can save equipment, labour, time and money.

Intelligent growing media water management requires knowledge of hydro-physical properties. The air capacity in shallow pots can assume critical values.

Table 3. Hydro-physical results of growing media after applying sample preparation methods B and C

M[1)]	No	DBD	PV	FC	Air_DIN	Air				Water			
					10 hPa	P10	P20	P30	Field	P10	P20	P30	Field
		g cm^{-3}	% by vol.										
B	K1	0.22	83.5	47.6	6.2	2.7	7.3	15.4	35.8	39.2	34.6	26.5	29.5
B	K2	0.25	82.9	49.5	5.5	2.8	7.4	12.0	33.4	36.3	31.7	27.1	28.0
B	HTC_150C	0.23	81.3	49.9	6.3	3.6	7.8	11.6	31.3	34.4	30.3	26.4	31.2
B	HTC_150D	0.22	80.5	45.6	7.6	2.1	7.8	12.9	34.9	38.5	32.8	27.7	27.9
B	HTC_170D	0.23	82.6	49.5	9.5	3.8	9.3	13.6	33.1	34.9	29.4	25.1	28.2
B	HTC_190C	0.24	84.9	54.5	2.9	0.9	4.2	22.5	30.3	43.7	32.1	22.1	29.2
B	HTC_190D	0.23	83.3	55.0	3.0	1.0	3.6	7.3	28.4	33.4	30.8	27.1	30.2
B	HTC_190E	0.22	80.6	50.8	7.9	4.9	9.2	12.7	29.9	30.2	25.9	22.5	26.9
B	DK B170	0.17	87.7	47.4	8.7	3.3	10.0	24.5	40.3	42.5	35.9	21.3	27.6
C	K1	0.19	95.2	46.7	11.6	7.6	14.4	28.6	48.6	47.9	41.1	26.9	27.7
C	K2	0.20	89.8	41.6	16.3	8.2	16.7	22.9	48.2	44.6	36.1	29.8	19.1
C	HTC_150C	0.21	93.5	43.3	17.7	6.4	14.9	21.7	51.8	55.2	46.6	39.8	20.7
C	HTC_150D	0.19	88.2	40.7	13.3	4.0	13.0	20.1	47.5	48.3	39.4	32.3	21.6
C	HTC_170D	0.22	90.6	42.5	12.9	5.8	13.6	20.5	48.0	46.8	39.0	32.1	19.8
C	HTC_190C	0.22	92.8	50.1	9.6	5.4	11.4	27.5	42.7	43.6	37.6	21.5	26.4
C	HTC_190D	0.20	91.0	42.5	16.7	7.7	17.0	23.8	48.6	45.5	36.1	29.4	20.5
C	HTC_190E	0.22	86.8	44.5	10.3	4.1	11.2	17.4	42.3	42.4	35.2	29.1	22.1
C	DK B170	0.17	88.8	47.0	7.4	2.9	8.6	25.0	41.9	44.7	39.0	22.6	27.9
B	Av	0.22	83.0	50.0	6.4	2.8	7.4	14.7	33.0	37.0	31.5	25.1	28.7
C	Av	0.20	90.7	44.3	12.9	5.8	13.4	23.1	46.6	46.6	38.9	29.3	22.9
B	stabw	0.022	2.3	3.1	2.3	1.3	2.2	5.4	3.6	4.4	2.9	2.5	1.4
C	stabw	0.017	2.7	3.1	3.5	1.9	2.7	3.6	3.5	3.8	3.5	5.5	3.5
t-test		0	0	0	0	0	0	0	0	0	0	0.02	0

1) Preparation method, DBD- Dry bulk density, PV- Total pore volume, FC- Field capacity at pF 1.8 (AG Boden 2005), stabw- standard deviation, P10- Pot 10cm high, Av- average.

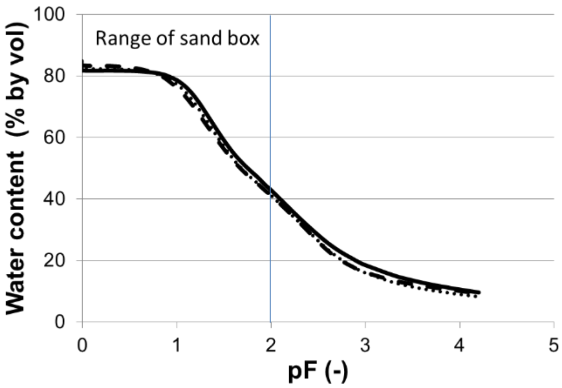

Figure 6. Reproducibility of water retention curves, K1 sample, preparation Method B, three replicates

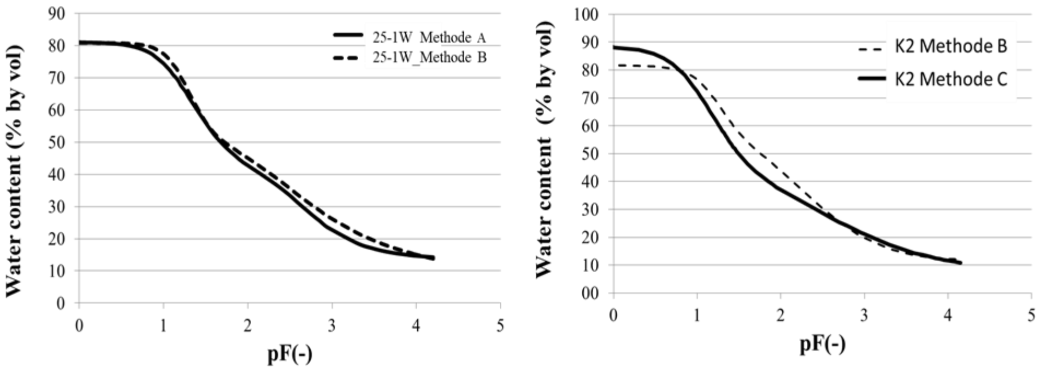

Figure 7. Example of the water retention functions, preparation methods A and B (left), B and C (right).

CONCLUSIONS

- HYPROP is an effective system for the complex measurement of hydro-physical properties of growing media with high quality and reproducibility. It is the basis for intelligent, knowledge-based air and water management in horticulture. Beside the water retention curve and the unsaturated hydraulic conductivity function, the dry bulk density, capillarity, shrinkage and rewetting properties can be simultaneously measured and enable a complex hydro-physical evaluation of soils and growing media.
- The sample preparation method – preloading or loose filling – yielded significantly different results in terms of the pore volume, dry bulk density, plant-available water and (especially and most critically) air capacity.

- The sample preparation method, the measurement and the assessment of the quality of hydro-physical properties of growing media must be adapted to the conditions of use: a field with free drainage or a greenhouse with pots or containers. The air capacity and the amount of plant-available water in pots depend on the height of the pot. In the field, they are related to the field capacity.
- The air capacity as defined in DIN 13041 (2012) can be used to compare different growing media. However, this value is of limited significance for air and water management and quality assessment in horticulture.
- For growing media with sufficient air capacity in the upper part of the pot, intelligent knowledge-based water management can reduce the air problem.
- Further investigations are required to study how the sample preparation method affects the hydro-physical properties of a wide variety of growing media.

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BACTERIAL COMMUNITIES IN ACIDIC SOIL

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Abstract

Acidification is one of the main types of soil degradation in Serbia, as a result of excessive use of mineral fertilization, pollution, as well as reduction of soil organic matter. Increased soil acidity directly affects plant nutrition and food productivity, at the same time leading to biodiversity changes. Bacterial diversity in soil is recognized as the main pillar of soil quality, ecosystem stability, climate change resilience, and represents an important element of sustainable agriculture. The diversity and abundance of bacteria in soil are strongly related to various abiotic factors, particularly to soil pH as one of the major determinants shaping their community structure.

The main objective of the research was to access the bacterial community in agricultural acid soils using metagenomic approach. Soil samples were taken at three locations: cornfield near Zaječar (Eastern Serbia), apple and raspberry orchards near Čačak (Central Serbia). The representative samples were subjected to sequencing of V3 and V4 regions of 16S rRNA gene using Illumina® MiSeq™. Besides microbiome, physico-chemical analyses were performed, including mechanical composition, adsorptive complex properties, and basic parameters of soil fertility.

Soil samples from Čačak have strongly acidic reaction, belonging to class of clay loam with a significant share of powder fraction. Soil from Zaječar is heavy clay with 48.80% of the clay fraction, and middle acidic reaction. Cation exchange capacity (CEC) is the middle level, and saturation of the adsorptive complex with base cations is weak in raspberry orchard soil, while soil under apple and corn showed high levels of CEC and middle saturation of adsorptive complex with base cations. Soil from apple orchard is characterized by low humus content and low content of available phosphorous (P), and middle P content in the raspberry orchard and cornfield. Available K content was similar for three analyzed fields (35.60-37.90 mg $100g^{-1}$).

In all of the studied soils, the most abundant phyla were *Firmicutes*, *Proteobacteria*, and *Actinobacteria* (each above 20%), which are the usual predominant phyla in the fertile soil. *Proteobacteria* composition showed differences between the soil samples, with higher share of *Enterobacteriales* in cornfield soil. Acid soil from Zaječar had 4.89% abundance of *Chloroflexi*, while the soils from Čačak included six additional phyla besides *Chloroflexi* (with more than 1% abundance), indicating significantly higher biodiversity. After the three most common phyla, *Acidobacteria* were predominantly abundant, and the presence of these oligotrophic taxa is characteristic of less fertile soil. *Actinobacteria* are mainly related to neutral or alkaline soil, but in recent decade acidotolerant *Actinobacteria* are being highlighted in terms of maintaining ecosystem balance, and raise of pH.

The composition of bacterial community showed some similarities between tested soils, with differences within their microbiome that can be attributed to mechanical composition and agronomic practice.

Keywords: acidic soil, bacterial community, metagenomic analysis, 16S DNA

INTRODUCTION

The need to provide food for the growing population leads to the intensification of agricultural production, and makes the soil quality and biodiversity decrease a global issue. Soil acidification is one of the main types of soil degradation in Serbia, where acidic soils make more than 60% (Ličina et al., 2011). Among the main reasons for soil acidification is excessive use of mineral fertilization, pollution, as well as reduction of soil organic matter content. Most of the cultivated plants require a weak acid, neutral or weak alkaline reaction. Increased soil acidity directly affects plant nutrition through nutrient solubility (Rousk et al., 2020), which seriously limits productivity, and directly leads to food production decrease. Besides the effects on plant nutrition, soil acidity leads to changes in biodiversity. Also, the mechanical composition has a great influence on the water-air, thermal, biological, and nutritional regime of the soil (Gajić, 2006).

Bacterial diversity in soil is recognized as the main pillar of soil quality, ecosystem stability, climate change resilience, nutrient cycling, and important element of sustainable crop production. The diversity and abundance of bacteria in soil are strongly related to various abiotic factors, particularly to soil pH as one of the major determinants and predictors of their community structure. Over time, environmental factors like pH, inevitably shape bacterial diversity and promote microbial groups that are well adapted to the changing surrounding. Bacterial diversity is particularly related to soil acidity and decreases with pH drop (Wu et al., 2017). Wan et al. (2020) confirmed that soil pH predicts and directly influences bacterial diversity and community function of rhizosphere bacteria.

Traditionally, cultivation-based techniques have been used to access microbial diversity in the environment, but those methodologies are restricted to only 0.1 to 1% of bacterial communities, so that the result obtained by cultivation techniques do not represent overall bacterial community (Torsvik et al., 1990). Cultivation-based techniques are irreplaceable in obtaining valuable microbial strains, but in diversity research, they do not provide a complete picture of community composition (Smit et al., 2001).

The main objective of the presented research is to access bacterial community in agricultural acid soil using a metagenomic approach and to relate those results with physic-chemical soil properties. Soil samples were taken at three locations: cornfield (near Zaječar, Eastern Serbia), and apple and raspberry orchard (near Čačak, Central Serbia). In addition to 16S ribosomal RNA gene targeted sequencing, those soils with acidic reactions are analyzed through their bacterial community as well as physico-chemical characteristics, such as pH, the concentration of ions, cation exchange capacity (CEC), and heavy metal concentration, were measured concurrently.

MATERIALS AND METHODS

Soil sampling

The surface layer of soil (0-30 cm) was sampled at three locations: corn field Halovo (near Zaječar, Eastern Serbia), apple orchard in Trnava, and raspberry orchard in Grab (both near Čačak, Central Serbia).

Soil samples were used for physico-chemical analysis, and one portion of the soil was prepared for microbiome analysis by mixing with DNA/RNA Shield (Zymo Research, Irvine, CA) in ratio 1:10 in order to preserve soil DNA prior to analysis.

Physico-chemical analysis

Examination of the mechanical composition, physical-chemical parameters, and basic soil fertility was performed in the laboratory of the Institute of Fruit Growing, Čačak. The aggregate composition of the soils was determined by sieving procedures (Bošnjak et al., 1997), and physico-chemical analyzes included the determination of the sum of exchangeable adsorbed alkaline cations (S meq 100 g^{-1}) (Kappen method), determination of hydrolytic soil acidity (H meq 100 g^{-1}), cation exchange capacity (CEC (T) meq 100g^{-1}), saturation with adsorbed bases (V%) (Gajić and Dugalić, 2005). Basic soil fertility included testing the pH value in H_2O and 1N KCl (potentiometrically); humus (the method by Kotzman); total nitrogen (the method by Kjeldahl); easily accessible phosphorous and potassium (AL method, P_2O_5 colorimetrically, K_2O flame photometrically).

Microbiome analysis

Soil samples are analyzed by the ZymoBIOMICS® Targeted Sequencing Service for Microbiome Analysis (Zymo Research, Irvine, CA). DNA was extracted, and 16S ribosomal RNA gene sequencing was performed by ZymoBIOMICS®-96 MagBead DNA Kit (Zymo Research, Irvine, CA). PCR inhibitors were removed from DNA using OneStep™ PCR Inhibitor Removal Kit (Zymo Research, Irvine, CA). DNA samples were prepared for targeted sequencing with the *Quick*-16S™ NGS Library Prep Kit (Zymo Research, Irvine, CA). Primer set used for amplification was: *Quick*-16S™ Primer Set V3-V4 and (Zymo Research, Irvine, CA). The final library was sequenced on Illumina® MiSeq™ with a v3 reagent kit (600 cycles). The sequencing was performed with 10% PhiX spike-in. Afterward, unique amplicon sequences were inferred from raw reads using the Dada2 pipeline (Callahan et al., 2016). Chimeric sequences were also removed with the Dada2 pipeline. Uclust from Qiime v.1.9.1 (Caporaso et al., 2010) and internally designed Zymo Research 16S Database were used for taxonomy assignment. Where applicable, a taxonomy that has significant abundance among different groups was identified by LEfSe (Segata et al., 2011).

RESULTS AND DISCUSSION

Soils of the shallow profile, low content of clay with low capacity of absorption of cations and acid reaction, have limited possibilities for the cultivation of certain crop types. The clay fraction content of 20-30% enables optimum potential soil fertility, given that other suitable agro-ecological conditions of fruit cultivation must be met. Plots in apple and raspberries plantations are in the class of clay loam with 59.30 to 67.30% of the physical clay and a high proportion of the powder (41.20 to 43.80%). The soil under corn contains 48.80% of colloidal clay and 79.50% of physical clay, which classifies it in the class of heavy clays (Table 1).

Table 1. Mechanical composition of soil (%)

Samples	2-0.2 mm	0.2-0.02 mm	0.02-0.002 mm	<0.002 mm	>0.02 mm	<0.02 mm	Soil texture
Apple orchard	8.35	24.35	43.80	23.50	32.70	67.30	Clay loam
Raspberry orchard	15.36	25.34	41.20	18.10	40.70	59.30	Clay loam
Cornfield	2.36	18.14	30.70	48.80	20.50	79.50	Heavy clay

Physico-chemical characteristics of the soil (Table 2) show that the values of hydrolytic acidity are very high (> 8 meq 100 g^{-1}) in all of the three plantations. The highest values are in the raspberry orchard, followed by cornfield and apple orchard. The sum of exchangeable adsorbed base cations is lowest in raspberries (7.22 meq 100 g^{-1}), higher in apples (12.76 meq 100 g^{-1}), and highest in maize (28.98 meq 100 g^{-1}). The previously mentioned results are in accordance with the degree of saturation with adsorbed bases, so that the soil in the raspberry orchard is poorly saturated, and in the apple orchard and cornfield it is moderately saturated (Baize, 1993). Based on the classification of Culman et al. (2019) soil in the apple orchard is in the class of silt loams with values of CEC 22.48 meq 100g $^{-1}$, and in the soil under raspberries and corn in the class of clay and clay loam with values of 27.53 meq 100 g $^{-1}$ and 40.03 meq 100 g^{-1}.

Table 2. Hydrolytics and adsorptive complex

Samples	H	S	CEC-S	CEC	V
	meq 100 g^{-1}				%
Apple orchard	14.95	12.76	9.72	22.48	56.76
Raspberry orchard	31.25	7.22	20.31	27.53	26.23
Cornfield	17.00	28.98	11.05	40.03	72.40

Soil acidity is one of the most important chemical properties and affects nutrient uptake and microbiological activity (Liu and Hanlon, 2012). Most fruit species are grown in soil pH ranging from 5.5 to 7.0. Large deviations from the stated soil pH values are not suitable for nutrient uptake and achieving optimal yields (Liu et al., 2014). In production practice, the pH value of the soil is often not in the optimal range, so one of the following alternatives should be considered: using only suitable soils with appropriate pH values; selection of fruit species and/or varieties that are tolerant to existing soil pH values; application of lime fertilizer for bringing the soil into the range of optimal acidity

(Milinković et al., 2017). The basic fertility of the soil in an apple orchard showed a strongly acidic reaction with a low content of humus, a medium content of total N, low content of easily accessible phosphorus and high content of easily accessible potassium. Similar fertility results of the soil of the Čačak region were determined by Milinković et al. (2016). The uptake of phosphorus is related to the reaction of the soil solution. When soil pH is lower than 5.5 or higher than 7.5, iron and aluminium or calcium and magnesium can bind phosphorus ion and phosphorus becomes unavailable for adoption by fruit trees (Lui et al., 2014). In the raspberry plantation, in addition to the strongly acidic reaction, there is medium humus content, a high content of total N and an optimal content of easily accessible phosphorus and potassium. The examined soil in the Zaječar area is in the class of degraded vertisol, with acid reaction, medium humus content, high total N content, medium content of easily accessible phosphorus and high content of easily accessible potassium (Table 3).

Table 3. Basic soil fertility

Samples	pH H_2O	pH KCl	$CaCO_3$ (%)	humus (%)	total N (%)	P_2O_5 mg 100 g^{-1}	K_2O mg 100 g^{-1}
Apple orchard	5.29	4.21	0.56	2.86	0.14	6.41	37.50
Raspberry orchard	4.61	3.84	0.28	4.63	0.23	15.98	35.60
Cornfield	5.86	4.90	0.56	4.21	0.21	11.21	37.90

Lauber et al. (2009) analyzed bacterial communities in a wide variety of locations in America, and they concluded that community composition depends on soil pH, while geographical location is not crucial for its composition. Later, Cho et al. (2016) obtained results indicating that pH is not so crucial for shaping bacterial community, since its effect is combined with other environmental factors. Anyhow, the effects of various environmental and anthropogenic factors on soil microbiome are not well understood, and their synergistic effect makes them challenging to understand.

The obtained microbiome results showed that soil from cornfield (Zaječar) have significantly lower bacterial diversity compared to two soils collected in the Čačak region, which are similar to each other to some level (Figure 1, Table 4). In all of the studied soils, the most abundant phyla were *Firmicutes*, *Proteobacteria*, and *Actinobacteria* (each above 20%, Fig. 1), which are the usual predominant phyla in the agricultural soil (Qi et al., 2018). Acid soil from Zaječar had 4.89% abundance of *Chloroflexi*, while the soils from Čačak included six additional phyla besides *Chloroflexi* (with more than 1% abundance), indicating significantly higher biodiversity.

After the three most common phyla, *Acidobacteria* were predominantly abundant in soil from Čačak region, and the presence of these oligotrophic taxa is characteristic of less fertile soil (Qi et al., 2018). Although metagenomic analysis showed a significant abundance of those microbes in soil, their reluctance to cultivation led to unfamiliarity with their functions (Kalam et al., 2020). They have an important role in the transformation of organic matter in soil (de Chaves et al., 2019). Their presence in soil is strongly connected to nutrient inputs, as well as organic matter content, and *Acidobacteria* could have a role in soil recovering after drastic ecosystem disturbances (Kielak et al., 2016). *Actinobacteria* are mainly related to neutral or alkaline soil, but in the recent decade acidotolerant *Actinobacteria* are being highlighted in terms of maintaining ecosystem balance, and raise of pH (Tamreihao et al., 2018a; Tamreihao et al., 2018b). The abundance of *Actinobacteria* in soil is usually lower compared to some other phyla such as *Firmicutes*, but their carbohydrate-active enzymes make a significantly higher portion in soil indicating their important role in plant residue decomposition (Bao et al., 2021). Besides their plant growth promoting and biocontrol activities provide multiple benefits for sustainable agriculture (Tamreihao et al., 2018b).

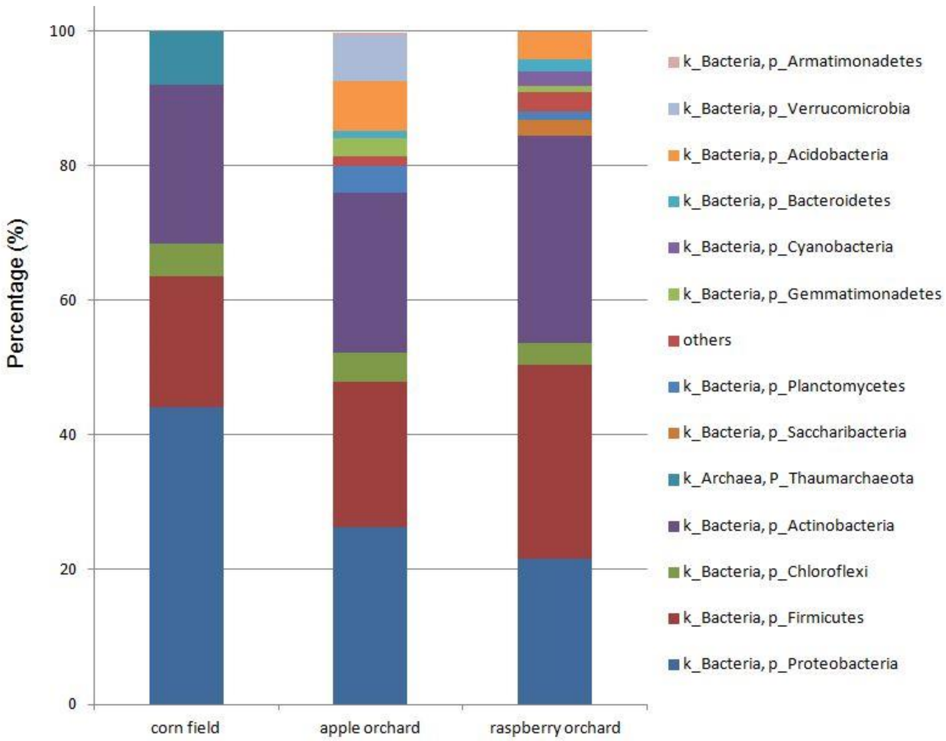

Figure 1. Microbial community composition at phylum level, based on 16S RNA sequences (relative abundance)

Proteobacteria are commonly abundant soil microbes, but their composition showed differences between the soil samples, with a significantly higher share of *Enterobacteriales* in cornfield soil (Table 5). *Enterobacteriales* are ubiquitous order in nature, capable to survive in soil, and including numerous foodborne pathogens (Iwu et al., 2020). Although they could have a beneficial effect on organic matter transformation in anoxic zones (Degelmann et al., 2009), and some of them even exhibit plant growth promoting characteristics (de Souza, et al., 2015; Khalifa et al., 2016), their presence in soil represents a risk for food production safety. One of the possible sources of *Enterobacteriales* in cornfield could be soil fertilization with inappropriately prepared manure.

Soil from cornfield generally showed significantly lower bacterial diversity that is evident at all of the taxonomy levels. Only five orders belonging to *Proteobacteria* are detected in that soil, which is almost twice lower diversity compared to the acidic soil from apple orchard (Table 5). The most abundant representatives in the soil from apple orchard were *Rhizobiales* (6.72%), and *Rhodospirillales* were the most abundant for the soil from raspberry orchard (Table 5). The abundance of those orders in soil, and rhizosphere particularly is of importance because of the nitrogen availability, especially in N-deficient conditions (Wasaki et al., 2018).

Table 4. Classes-level relative abundance of the three most abundant phyla: *Firmicutes*, *Proteobacteria*, and *Actinobacteria*

Taxonomy	Relative abundance (%)		
	Soil from corn field	Soil from apple orchard	Soil from raspberry orchard
p_Proteobacteria, c_Gammaproteobacteria	24.23	2.52	9.72
p_Proteobacteria, c_Deltaproteobacteria	9.79	4.61	0.2
p_Proteobacteria, c_Betaproteobacteria	7.92	4.69	0.9
p_Proteobacteria, c_Alphaproteobacteria	2.28	14.54	10.72
p_Firmicutes, c_Bacilli	19.42	11.38	9.21
p_Actinobacteria, c_ Thermoleophilia	17.69	6.23	5.2
p_Actinobacteria, c_ Actinobacteria	5.78	15.96	21.59
p_Firmicutes, c_NA	/	1.01	1.08
p_Firmicutes, c_Erysipelotrichia	/	0.32	2.42
p_Firmicutes, c_Clostridia	/	8.83	16.13
p_Actinobacteria, c_Acidimicrobia	/	0.42	2.89
p_Actinobacteria, c_NA	/	1.26	/
Classes belonging to other phyla	12.89	28.23	19.94

According to Xue et al. (2018), the basic soil fertility properties are connected to the absolute abundance of microbial groups, however, other factors such as pH and texture had higher impact on their relative proportion. In our study, it seems that soil mechanical composition significantly affects bacterial diversity, making it scarcer in heavy clay compared to clay loam. The other factor contributing to bacterial community differences could be applied agricultural practices, which demand their upgrade through application of bioferilizers and corresponding base cations directed to the improved microbial diversity and ecosystem stability.

Tab. 5. Proteobacteria community composition

Taxonomy	Relative abundance (%)		
	Soil from corn field	Soil from apple orchard	Soil from raspberry orchard
c_Alphaproteobacteria, o_Rhizobiales	2.23	6.72	3.25
c_Alphaproteobacteria,o_Sphingomonadales	/	3.64	2.14
c_Alphaproteobacteria, o_Rhodospirillales	/	3.92	4.74
c_Alphaproteobacteria, o_Caulobacteriales	/	/	0.59
c_Betaproteobacteria, o_Burholderiales	7.92	1.47	0.86
c_Betaproteobacteria, o_Nitrosomonadales	/	1.2	/
other Betaproteobacteria	/	1.79	/
c_Gammaproteobacteria,o_Xantomonadales	4.19	1.57	9.72
c_Gammaproteobacteria, o_Enterobacteriales	20.04	/	/
other Gammaproteobacteria	/	0.96	/
c_Deltaproteobacteria, o_Myxococcales	9.79	4.13	/

CONCLUSION

Analyzed soils with acidic reaction showed significant differences in the composition of their bacterial communities. Based on physico-chemical analysis, soil from cornfield showed high potential fertility, but significantly high content of the colloid clay affects chemical and microbiological properties, including bacterial community composition. The results indicate that other environmental factors besides pH acting on different geographical locations have additional effects on bacterial diversity in soil. Future extensive research is needed to evaluate the particular contribution of soil acidity to microbial communities, since our findings indicate that other factors such as mechanical composition are more important determinant.

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TEMPERATURE AND MOISTURE REGIMES OF RENDZINA SOILS IN SERBIA ACCORDING TO THE USDA SOIL TAXONOMY SYSTEM

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Abstract

Soil moisture and temperature regimes are diagnostic characteristics used for higher categories of the USDA Soil Taxonomy System. The first step of Rendzina soil classification in Serbia according to this international system is to determine the soil temperature and moisture regime classes. As measured soil moisture and temperature data of the investigated Rendzina profiles were missing, the Rendzina soil temperature and moisture regimes were estimated based on climate data (30 years) – monthly and annual air temperature and precipitation, and potential evapotranspiration. Six weather stations were selected: at Novi Sad for the northern, Valjevo for the western, Belgrade for the central, Negotin for the eastern, Sjenica for the southwestern and Niš for the southeastern regions of Serbia. The estimated mean annual soil temperature in the study areas ranged from 8.7 to 14.5°C, and the mean summer and winter soil temperatures differed by 18.6-21.4°C. The Rendzina soils in all the study areas match the criteria for the mesic soil temperature regime. Precipitation becomes greater than potential evapotranspiration and water recharge begins in September in Sjenica and October in the other areas. Potential evapotranspiration exceeds precipitation and utilization starts in March (Novi Sad, Belgrade and Niš) or April (Valjevo, Sjenica and Niš). The amount of moisture stored in the soil during this period, plus precipitation, is believed to be sufficient to support potential evapotranspiration and avoid significant water deficits in western and southwestern Serbia (Valjevo and Sjenica). Utilization is expected to exceed recharge plus precipitation in all other areas, causing soil water deficit to begin in April in Belgrade and May in Novi Sad, Negotin and Niš. Therefore, the soils in the western and southwestern areas match the criteria for the udic soil moisture regime, whereas soils in the other areas (central, east and southeast) correspond to the ustic soil moisture regime. Possibly lower water infiltration and available water capacity, caused by geomorphological and physical properties of Rendzina soils, can increase water deficits further, but precipitation in the summer months is hopefully sufficient to avoid long periods of dry days. Separation of Rendzina soils in Serbia into two soil moisture regimes, udic and ustic, could affect their classification at higher taxonomic levels according to the Soil Taxonomy System.

Keywords: Mesic soil temperature regime, Udic soil moisture regime, Ustic soil moisture regime

INTRODUCTION

Soil Taxonomy (Soil Survey Staff, 1999) is a basic soil classification system for making and interpreting soil surveys, developed by the United States Department of Agriculture (USDA). According to Krasilnikov and Arnold (2009), Soil Taxonomy is used as an official classification system not only in the US, but also in dozens of other countries. It has an international status. Many national and international classifications created later (in Canada and China, the World Soil Map legend of FAO-UNESCO and WRB, and many others), borrowed basic ideas from that system. Soil Taxonomy comprises the following levels: order, suborder, great group, subgroups, family and series (Soil Survey Staff, 1999). All the levels need to be separated based on quantitative soil properties specified through diagnostic horizons and characteristics.

Soil moisture and temperature regimes are diagnostic characteristics used for higher categories of soil classification. According to Soil Survey Staff (1999), the term "soil moisture regime" (SMR) refers to the presence or absence of either groundwater or water held at a tension of less than 1500 kPa in the soil or in specific horizons during certain periods of the year. Each pedon has a characteristic soil temperature regime (STR) that can be measured or described by the mean annual soil temperature, average seasonal fluctuations from that mean, and mean warm or cold seasonal soil temperature gradient within the main root zone, which is the zone from a depth of 5 to 100 cm. SMR and STR classes as soil classification criteria are required by USDA Soil Taxonomy because they affect the genesis, use and management of soils (Emadi et al., 2016; Soil Survey Staff, 1999). Within limits, temperature and moisture control the possibility of plant growth, soil fauna survival and soil formation. Therefore, soil temperature and moisture have a major effect on the biological, chemical and physical processes in the soil and on the adaptation of introduced plant species. Because it uses atmospheric climatic data to estimate internal temperature and moisture parameters in soils, Krasilnikov and Arnold (2009) note that Soil Taxonomy appears to be more "climatic" than any other soil classification. Bonfante et al. (2011) highlight that Soil Taxonomy differs from other international soil classification systems because it includes the estimation of SMR and is primarily based on the estimation of dry days in a soil moisture control section.

Rendzina is a soil type (Škorić et al., 1985) developed on parent rock containing more than 20% of calcareous material (except soils with an A-R profile developed on hard pure limestone or dolomite, which are classified as a distinct soil type: Limestone-Dolomite Black Soil - Kalkomelanosol). Rendzina is widespread in many regions of Serbia. Numerous characteristics have been determined in order to describe Serbia's Rendzina soils as comprehensively as possible and 29 Rendzina soil profiles have been classified according to the domestic (Škorić et al., 1985) and international WRB soil classification (IUSS Working Group WRB, 2015) systems (Radmanović et al., 2017). Superficial and generalized correlations of Rendzina soils in Serbia identify with the WRB reference soil group of Leptosols (Đorđević and Radmanović, 2016; Dugalić and Gajić, 2012). Classification of individual soil profiles by Radmanović et al. (2017), based on analyses of quantitative soil data as required by WRB, correlates Rendzina soils with three reference soil groups – Leptosols, Regosols and Phaeozems. As of this writing, correlation of Rendzina soils and Serbia's soils in general with the USDA Soil Taxonomy System appears to be missing. In order to update and harmonize national with international soil classification systems, correlation of various soil classification units with both international systems, WRB and USDA Soil Taxonomy, has been common practice worldwide over the past couple of decades (Florea and Munteanu, 2012; Krasilnikov et al., 2013; Němeček et al., 2001). As such, detailed classification of Rendzina soil profiles in Serbia according to USDA Soil Taxonomy, the other widely used international soil classification system, is desirable. According to literature sources (Allaby, 2013; Fisher, 1983; Florea and Munteanu, 2012; Krasilnikov et al., 2013; Němeček et al., 2001; Shishkov and Kolev, 2014), Rendzina soils in the world are in correlation with several Soil Taxonomy great groups and suborders, belonging to three orders: Mollisols, Entisols and Inceptisols. As many of the orders, suborders and some great groups are defined by their temperature and moisture parameters, determination of Rendzinas' SMR and STR classes is the first step toward their classification according to the USDA Soil Taxonomy System. Based on current knowledge, there is no STR and SMR data on Rendzina soils in Serbia, and STR and SMR of soils in general, as defined by USDA Soil Taxonomy.

MATERIAL AND METHODS

The parameters needed for SMR and STR determination can be either measured or estimated (Soil Survey Staff, 1999, 2014, 2015). Given that measured soil moisture and temperature data on the investigated Rendzina profiles were missing, Rendzinas' SMR and STR were estimated based on climate data (30 years) downloaded from the Nation Hydrometeorological Service of Serbia website (NHSS, 2021), including mean monthly and annual air temperatures and precipitation (1981-2010) and potential evapotranspiration (PE) (1971-2000). The mean annual soil temperature (MAST) was estimated by adding 2°C to the mean annual air temperature (MAAT). The difference between the mean summer (June, July, and August) and mean winter (December, January and February) soil temperatures (Diff(MSST-MWST)) was also calculated.
The STR classes are gelic, cryic, frigid, mesic, thermic and hyperthermic. STRs are defined by MAST at a depth of 50 cm from the land surface (or at the densic, lithic, or paralithic contact if shallower than 50 cm) and Diff(MAAT-MAST). The SMR classes are aquic, arridic (torric), udic, perudic, ustic and xeric. Generally, SMR classification is based on MAST, Diff(MSST-MWST)) and the period of dry soil days, cumulative or consecutive (Soil Survey Staff, 1999; 2015). To obtain SMR, six graphs (one per weather station) containing precipitation, PE, actual evapotranspiration (AE) and soil temperature curves, were constructed according to Soil Survey Staff (1999, 2015). In these graphs (Soil Survey Staff, 1999), the area between the line that joins all of the precipitation normals and the line that joins all of the PE normals indicates the status of soil moisture. Beginning at the point where precipitation becomes greater than PE, the area to the right shows recharge (the amount of moisture stored in the soil). The point where PE exceeds precipitation is utilization. Utilization is the amount of PE necessary to remove the water held at a tension of less than 1500 kPa. Excess PE, if any, before the time that recharge begins, is called deficit.

Twenty-nine Rendzina soil profiles on marl, marly limestone and soft limestone were investigated. Given that Rendzina is widespread in many regions of Serbia, six weather stations were selected: at Novi Sad for the northern, Valjevo for the western, Belgrade for the central, Negotin for the eastern, Sjenica for the southwestern and Niš for the southeastern region.

The geomorphological and soil characteristics that can affect STR and SMR were presented as follows. Rendzina soils are found at altitudes starting from 150 m near Lajkovac to 1200 m on the Sjenica-Pešter plateau. The elevations of most sites, i.e. those in northen Serbia (Vojvodina), eastern Serbia, central Serbia (Šumadija region) and southeastern Serbia (Pirot and Bela Palanka), are up to 400 m. Altitudes exceeding 400 m were in western Serbia (Valjevo environs), whereas sites around Niš in southeastern Serbia exceeded 700 m. Eight soil profiles were flat, eight slightly sloping and thirteen sloping, with gradients in the range from 20 to 80° (49.2±30.8). All aspects were represented and those facing the west and southwest were dominant. Flattened areas and hilltops are generally used as arable land, while steep slopes are covered with forest and grassy vegetation. The largest soil profile depths were in the 15-30 cm range, with only a few 40-60 cm deep. Coarse fragment content ranged from 0.6 to 43.3% (16.4±13.5) in the A and 1.6-68.4% (32.0±24.7) in the AC horizon. Soil texture was sandy loam in two, sandy clay loam in three, loam in three and clay loam in twenty profiles. Soil organic carbon ranged from 0.5 to 5.3% (2.7±1.4) in the A and 0.2-2.8% (1.3±1) in the AC horizon (Radmanović et al., 2017).

RESULTS AND DISCUSSION

Table 1 presents estimated soil temperatures of Rendzina soils in Serbia and Figs. 1 and 2 show the plots used to estimate Rendzina SMR.

Table 1. Estimated mean soil temperature of Rendzina soils in Serbia (°C)

Weather station	Annual +1 degree[a]	Annual +2 degrees	Annual +3 degrees	Diff(MAAT-MAST)[b]
Novi Sad	12.4	**13.4**	14.4	**20.1**
Valjevo	12.4	**13.4**	14.4	**19.6**
Belgrade	13.5	**14.5**	15.5	**19.8**
Negotin	12.8	**13.8**	14.8	**21.4**
Sjenica	7.7	**8.7**	9.7	**18.6**
Niš	12.9	**13.9**	14.9	**20.0**

[a]Mean soil temperature approximated by adding 1, 2 and 3 °C to the mean air temperature.
[b]Difference between mean summer (June, July and August) and mean winter (December, January and February) soil temperatures.

According to Soil Survey Staff (2015), soil temperature data can be obtained by measuring in the field, estimating from available records of air temperatures, and inferring from the geographical location, if well documented in previous soil survey reports. Estimation from air temperature data is a widely used method. MAST should be estimated by adding 1, 2 or 3°C to the mean annual air temperature (MAAT) (Soil Survey Staff, 1999, 2015). Soil

Survey Staff (1999) recommends adding 2 or even 3°C (rather than 1°C) for some regions of the United States. To test and improve the soil temperature estimation method, the difference between MAAT and MAST was determined for different climate/soil regions where both data have been recorded. Thus, at a depth of 50 cm, MAST is greater than MAAT for 1.8°C in Guizhou Province of China, 1.9°C in Japan, 2-5°C in Finland, etc. (Lu et al., 2016; Takata et al., 2011; Yli-Halla and Mokma, 1998). The difference between MAAT and MAST has been determined for Croatia (Husnjak et al., 2014), a neighboring country to Serbia with similar climate conditions and soils. Temperature has been recorded in eight soil types, where Rendzina was represented by 7.5%. In the Pannonian region of Croatia, the largest difference was 1.6°C at a depth of 10 cm, and 2.0°C at 50 cm. In the mountainous region, the largest difference was 2.9°C at 10 cm and 2.7°C at 50 cm.

In accordance with the above instructions (Soil Survey Staff, 1999, 2015), MAST was estimated in the present study by adding 1, 2 and 3 degrees to MAAT. For four weather stations, except Sjenica and Belgrade, all three estimated MAST had the same impact on SMR and STR. The MAST obtained by adding 1 and 2 degrees to MAAT was 7.7 and 8.7°C, respectively, in the mountainous Sjenica region. The MAST obtained by adding 2 and 3 degrees to MAAT was 14.5 and 15.5°C, respectively, in the area around Belgrade. Both Sjenica and Belgrade estimations significantly affected their STR classification, since a MAST of 8°C is the boundary between frigid and mesic, and 15°C between mesic and thermic STR classes. Soil temperature is affected by inherent soil properties that determine the capacity of the soil to absorb and transmit heat, such as moisture content, porosity and mineralogy. It is also greatly influenced by site characteristics, such as drainage, vegetation, seasonal snow cover, slope steepness and aspect, elevation, and latitude (Soil Survey Staff, 1999; 2015). The Rendzina soil from Sjenica was shallow, west facing, at a gradient of 40°, under grass. Nonetheless, Sjenica is located at about 1200 m above sea level and characterized by an average of 103 days (1981-2010) of snow cover (NHSS, 2021). Yli-Halla and Mokma (1998) report that MAST was 2 to 5°C higher than MAAT, depending on the duration of snow cover ($R^2 = 0.91$) in Finland. Based on literature data (Husnjak et al., 2014; Yli-Halla and Mokma, 1998) and soil characteristics, it was concluded that MAST could be estimated by adding 2 degrees to MAAT for all locations in the present study, including the mountainous region of Sjenica and the area around Belgrade. Thus, the estimated MAST in all the studied locations ranged from 8.7 to 14.5°C, which matches the criteria for mesic STR according to Soil Survey Staff (1999) (mean annual soil temperature 8°C or higher but lower than 15°C, and the difference between mean summer and mean winter soil temperatures more than 6°C either at a depth of 50 cm from the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower).

In all the study areas, MAST ranged from 8.7 to 14.5°C and the mean summer and winter soil temperatures differed by 18.6-21.4°C. As seen in Figs. 1 and 2, precipitation becomes greater than PE and water recharge begins in September in Sjenica and October in the other areas. PE exceeds precipitation and utilization starts in March (Novi Sad, Belgrade and Niš) or April (Valjevo, Sjenica and Niš). The duration of water recharge was four to six months. The amount of moisture stored in the soil during that period, plus precipitation, is believed to be sufficient to support PE and avoid a significant water deficit in western and southwestern Serbia (Valjevo and Sjenica). Utilization is expected to exceed recharge plus precipitation in all the other areas, causing soil water deficit to begin in April in Belgrade and May in Novi Sad, Negotin and Niš. According to available meteorological data, soils in the western and southwestern regions (Valjevo and Sjenica) meet the criteria for udic SMR, whereas other areas (central, east and southeast) correspond to ustic SMR. According to Soil Survey Staff (1999), the udic moisture regime is one in which the soil moisture control section is not dry anywhere for as long as 90 cumulative days in normal years. If MAST is lower than 22°C and if MWST and MSST at a depth of 50 cm from the soil surface differ by 6°C or more, the soil moisture control section, in normal years, is dry in all parts for less than 45 consecutive days in the four months following the summer solstice. In addition, except for short periods, the udic moisture regime requires a three-phase system, solid-liquid-gas, in a part or all of the soil moisture control section when the soil temperature is above 5°C. The udic moisture regime is common to soils in humid climates that have well distributed rainfall (i.e. enough rain in summer so that the amount of stored moisture plus rainfall is approximately equal to or exceeds the amount of evapotranspiration).

Valjevo

Sjenica

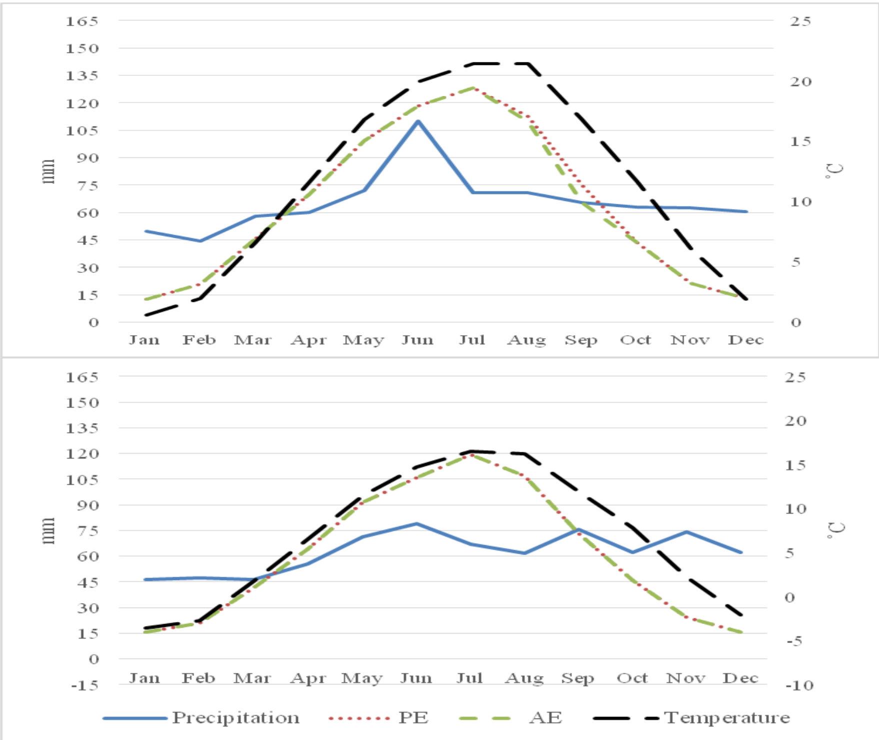

Figure 1. Mean monthly precipitation, potential (PE) and actual (AE) evapotranspiration (in mm), and soil temperature (in °C) in areas with udic moisture regimes of Rendzina soils in Serbia

According to Soil Survey Staff (1999), if MAST is lower than 22°C and if MSST and MWST differ by 6°C or more at a depth of 50 cm from the soil surface, the soil moisture control section in areas of the ustic moisture regime is dry in some or all parts for 90 or more cumulative days in normal years, but it is not dry in all parts for more than half of the cumulative days when the soil temperature at a depth of 50 cm is higher than 5°C.

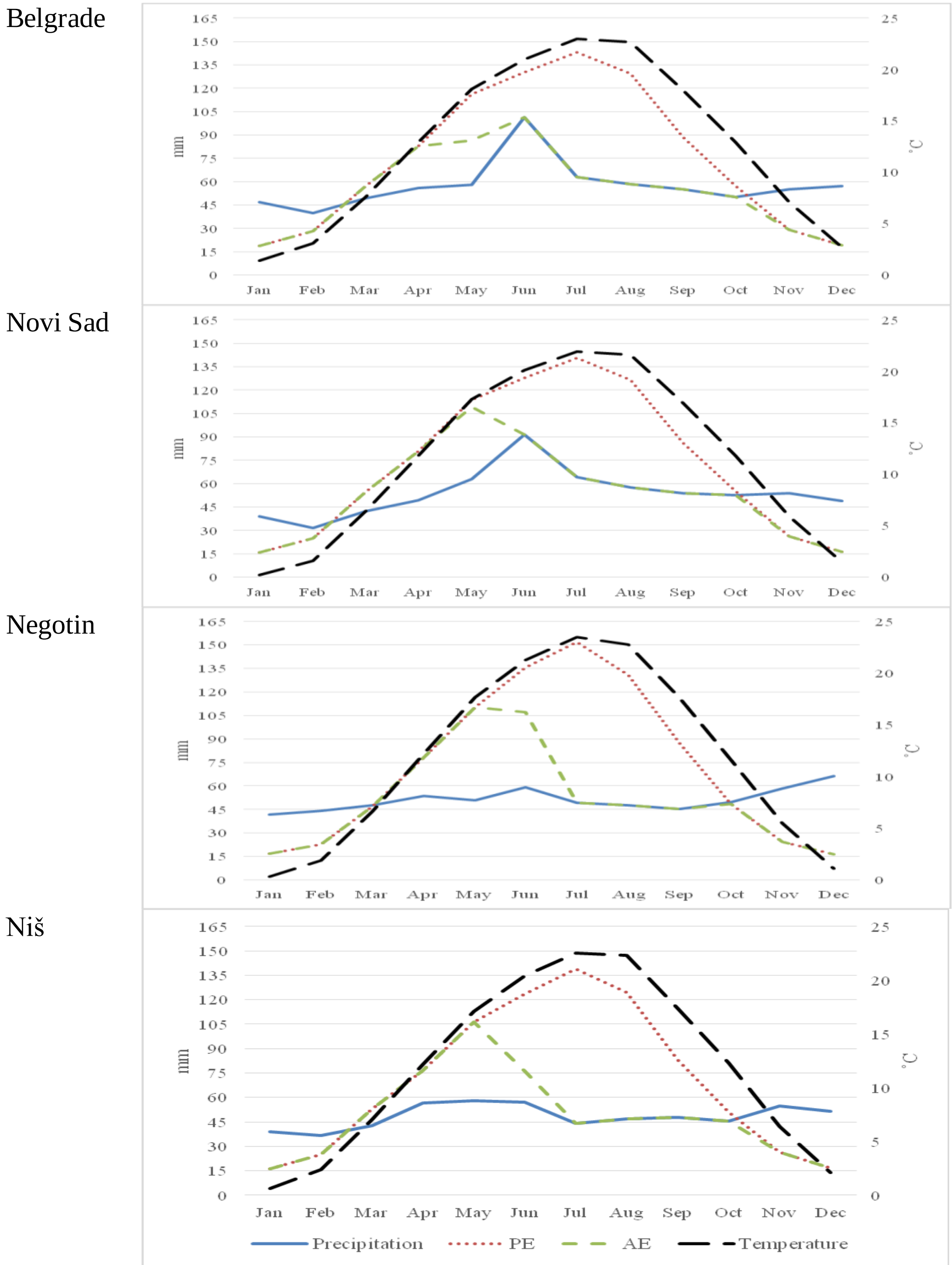

Figure 2. Mean monthly precipitation, potential (PE) and actual (AE) evapotranspiration (mm), and soil temperature (in °C) in areas with ustic moisture regimes of Rendzina soils in Serbia

If in normal years the moisture control section is moist in all parts for 45 or more consecutive days in the four months following the winter solstice, the moisture control section is dry in all parts for less than 45 consecutive days in the four months following the summer solstice. Ustic is the temporarily dry regime for soils in intermediate climates, between dry (aridic) and moist (udic) (Soil Survey Staff, 2015). Further, Soil Survey Staff (1999) adds that in temperate regions of sub-humid or semi-arid climates with ustic SMR, the rainy seasons are usually spring and summer (as is exactly the case in Serbia) or spring and fall, but never winter.

According to Soil Survey Staff (1999), the amount of water recharge is limited by either the available water capacity (AWC) of the soil or the fact that PE again exceeds precipitation before AWC has been filled. In most of the investigated Rendzina soil profiles, AWC was limited due to shallow depths and the presence of coarse fragments. Furthermore, 45% of the soils were on slopes and that can cause surface runoff, limit water infiltration and increase water deficit of the Rendzina soils. Nevertheless, due to lower temperatures (Sjenica STR was borderline mesic-frigid) causing lower evapotranspiration, and higher precipitation in the spring-summer period, any water deficit likely lasts for a very short period (late summer) in western and southwestern Serbia, with udic SMR. Other areas, with ustic SRM, have exhibited water deficits (based on meteorological data) in the periods from April to September (Belgrade) or May to September (other regions). Possibly lower water infiltration and AWC, caused by topographic features and physical properties of Rendzina soils, can increase water deficit in the future, but precipitation in the summer months might be sufficient to avoid long periods of dry days (typical of soil with xeric or aridic SMR). Soil is certainly dry for less than 45 consecutive days in the four months following the summer solstice, which is proposed for the ustic SRM. Ustic soil is intermittently moist and dry; moisture is limited but usually available during portions of the growing season. In most years, the soil is moist for more than 180 cumulative days or more than 90 consecutive days (Soil Survey Staff, 2015). Soil Survey Staff (1999) indicates that native plants are mostly annuals or plants that have a dormant period while the soil is dry in ustic SMR areas. Consequently, native vegetation is lush forests with dense canopies in western udic areas, unlike degraded forests and coppice in ustic eastern and southern Serbia. Unfortunately, water deficit and dryness of Rendzina soils is expected to increase in the future. According to climate projections (Ćirić et al., 2017; Mihailović et al., 2016), soil temperature increase and soil moisture decrease are predicted for Serbia in general, by the end of this century.

The results in this study suggest that Rendzina soils in Serbia correspond to the same STR (mesic), but they were separated into two SMRs, udic and ustic, which could affect their classification according to the USDA Soil Taxonomy System. SMR strongly influences soil classification because it is used at the first taxonomic level in Soil Taxonomy (Badía et al., 2013). Many models have been developed for assessing soil temperature and moisture regimes because of missing measured soil temperature and moisture data (Lu et al., 2016). Murtha and Williams (1986) indicate that errors produced by methods for estimating soil temperature can be sufficient to cause important changes to soil classification when using Soil Taxonomy, which is why Badía et al. (2013) ascertained that Soil Taxonomy classification was tentative, given uncertainties concerning the exact soil climate regime.

Despite determination problems, others (Zdruli et al., 2001) highlight that STR and SMR, defined for soil classification, can be useful for other purposes such as the identification of areas where agricultural drought is likely to be an issue.

CONCLUSIONS

Estimated MAST in the study areas of Rendzina soils in Serbia ranged from 8.7 to 14.5°C, and mean summer and winter soil temperatures differed by 18.6-21.4°C.
Rendzina soils in all the areas matched criteria for mesic STR. Precipitation becomes greater than PE and water recharge starts in September in Sjenica and October in the other areas. PE exceeds precipitation and utilization starts in March (Novi Sad, Belgrade and Niš) or April (Valjevo, Sjenica and Niš). The amount of moisture stored in the soil during this period, plus precipitation, is expected to be sufficient to support PE and avoid significant soil water deficits in western and southwestern Serbia (Valjevo and Sjenica). Utilization is expected to exceed recharge plus precipitation in all the other areas, causing soil water deficit to begin in April in Belgrade and May in Novi Sad, Negotin and Niš. Therefore, the soils in the western and southwestern areas meet the criteria for udic SMR, while other areas (central, east and southeast) correspond to ustic SMR. Possibly lower water infiltration and AWC, caused by geomorphologic and physical properties of Rendzina soils, can increase water deficits in the future, but precipitation in the summer months will likely be sufficient to avoid long periods of dry days. Separation of Rendzina soils in Serbia into two SMRs, udic and ustic, might influence their classification at higher taxonomic levels according to the Soil Taxonomy System.

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SOIL STRUCTURE OF CALCOMELANOSOLS FROM THE RTANJ MOUNTAIN, SERBIA

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Abstract

Soil structure pertains to the natural organization of soil particles into various forms as a result of pedogenic processes. On one hand, it is formed in interaction of physical, chemical, mineralogical, and biological factors, whereas on the other hand it affects them. Soil structure can differ in grade of development, size and type of aggregates, and their stability to mechanical pressure and water, which is often soil-horizon or soil-type dependent. This paper aims to analyze the structure of Calcomelanosols of mountain Rtanj, Serbia, as that is the most widespread soil type in this area. Calcomelanosols are soils from the national classification system that often correspond to Rendzic Leptosols in the World Reference Base (WRB) for soil resources. Soil structure is analyzed in terms of soil dry aggregate size distribution (ASD) and soil aggregate stability to water (WAS), and related soil structure indices, as they are essential parameters in understanding the structural state of the soil. Eight soil profiles have been excavated, described and sampled in the field. Soil horizon sequence of all profiles was A – R, with humus-accumulative horizon overlying calcareous bedrock. Six profiles of Calcomelanosols correspond to Rendzic Leptosols of WRB, whereas other two profiles correspond to Leptic Rendzic Phaeozems and Leptic Chernic Rendzic Phaeozems. Basic physical and chemical soil properties were determined. Both ASD and WAS were determined by Savinov's method. The following soil structure indices were calculated: dry mean weight diameter (dMWD), wet mean weight diameter (wMWD), dry geometric mean diameter (dGMD), wet geometric mean diameter (wGMD) and structural stability index (SI). The results indicate favorable structure of the examined Calcomelanosols. The content of agronomically most valuable aggregates (0.25–10 mm) in all soil profiles exceeds 80% (90.5±3.6% on average). Among these aggregates, very fine, fine and medium size aggregates dominate. Dry MWD showed values ranging from 3.0–5.5 mm, whereas wMWD ranges from 1.9–3.3 mm. The wMWD and dMWD ratio is an indicator of the stability of structural aggregates. A small change in the aggregate size after wet sieving was found, 0.7±0.1 mm on average. In all examined soil profiles SI is higher than 19% (32.9±7.1% on average), which indicates an extremely stable structure, without risk of the structural degradation of soil. Correlation analysis showed a significant positive relationship between the content of agronomically valuable fractions (0.25–10 mm) and the following soil parameters: soil organic matter (SOM), pH, and base saturation (%V). Also, there is a strong positive correlation between SI and pH, and SI with %V. Other calculated structural indices show a strong negative correlation with SOM, pH and %V. All analyzed soil profiles have favorable soil structure and water stable soil aggregates with low risk of soil structure degradation. This is of extreme importance because Calcomelanosols cover the steep and sloping land which is naturally more prone to soil water erosion and soil degradation.

Keywords: MWD, GMD, structural stability index, Rendzic Leptosols, Leptic Rendzic Phaeozems, Leptic Chernic Rendzic Phaeozems

INTRODUCTION

Soil structure refers to the size, shape and arrangement of solids and voids, continuity of pores and voids, their capacity to retain and transmit fluids and organic and inorganic substances, and ability to support vigorous root growth and development (Lal, 1991). Structural development and aggregation of soil occur as a part of natural pedogenetic processes and/or anthropogenic activities. Bronick and Lal (2005) defined soil aggregates as the basic unit of soil structure. Aggregates are secondary particles formed through the combination of mineral particles with organic and inorganic substances. The complex dynamics of aggregation are the result of the interaction of many factors including the environment, soil management factors, plant influences and soil properties such as mineral composition, texture, SOC concentration, pedogenic processes, microbial activities, exchangeable ions, nutrient reserves, and moisture availability (Kay, 1998).

Soil structure is an important to be evaluated as it mediates many biological, physical and chemical processes in soil. For example, soil structure determines porosity and infiltration, plant water availability and soil erosion susceptibility. Since soil structure also influences losses of agrochemicals, sequestration of C, and N gas losses, it is important to maintain soil structure in order to reduce the environmental impact of agricultural practices (Six et al., 2000).

Aggregate distribution and stability are often used as a measure of soil structure (Six et al., 2000). Arshad and Coen (1992) proposed aggregate stability as one of the physical soil properties that can serve as an indicator of soil quality. Aggregate stability has been shown to be a good indicator for erodibility (Chan and Mead, 1988; Coote et al., 1988). Soil aggregate stability to water (WAS), mean weight diameter (MWD), structural stability index (SI) are all indicators of soil aggregate stability. Favorable soil structure and high aggregate stability are important to improving soil fertility, increasing agronomic productivity, enhancing porosity and decreasing erodibility (Bronick and Lal, 2005).

There are numerous methods used to determine soil structure with varying degrees of success and accuracy, which shows that this property is difficult to quantify and interpret. Common method used to analyze soil structure in Serbia is Savvinov's method (Savvinov, 1931).

Over 160.000 ha of Calcomelanosols were mapped in Serbia (Đorđević and Radmanović, 2018). They are widespread in hilly and mountainous regions, on inclined terrains covered with different grass types and forests. In our country, the structure of Calcomelanosols has so far been studied by Djordjevic (1993) on Rajac Mountain and Zivotić et al. (2019a) on the toeslopes of Vukan Mountain. A few authors (Živković and Pantović, 1953; Antonović et al., 1974.) analyzed the texture and chemical properties of Calcomelanosols from Rtanj mountain, but did not examine soil structure. Soil structure of different soil types in Serbia

has been studied by many authors (Cupać et al., 2006; Gajić et al., 2006; Dugonjić et al., 2008; Gajić et al., 2010.; Cirić et al., 2012; Nešić et al., 2014; Gajić et al., 2014).
The aim of this study is to: 1) to perform quantitative assessment of soil structure after dry and wet sieving, 2) to compute different indices of soil aggregation in order to assess stability of soil structure, 3) to find relationship of agronomically valuable fractions (0.25–10 mm) with the following soil properties: soil organic matter (SOM), pH, and base saturation (%V) and 3) to find relationship between structural indices and above mentioned properties.

MATERIALS AND METHODS

Study area

The study was carried out on mountain Rtanj, which is located in the eastern Serbia, north of the Sokobanja town. The area belongs to Carpathian-Balkan mountain system, and the most encountered bedrock are limestones.
The cone shaped peak Šiljak (1565 m a.s.l.), with mountain slopes inclined at different angles, dominates over the entire area. Karst relief structures, with numerous sinkholes and various forms of the exhumed subcutaneous karst, are particularly interesting. The broader region around Rtanj, including the surrounding basins and valleys, is characterized by modified temperate-continental climate, with a pluviometric regime affected by Mediterranean climatic influence. Hence, the mountain itself is characterized by much lower temperatures and higher amount of precipitation compared to Sokobanja. Vertical gradient in temperatures and precipitation is present.
The vegetation of this area is specific. The north facing slopes are mainly overgrown with forests. The mixed community of the silver fir (*Abies alba*) and Balkan beech (*Fagus moesiaca*), which spreads out as far as to the peak Šiljak, is especially beautiful and very old. The south facing slopes are overgrown with communities of rocky terrains, pastures and shrubs. These communities are floristicaly very rich and diverse. The relic dwarf Russian almond (*Prunus tenella*) as well as many species of orchids protected in Serbia as natural rarities are particularly important. However, the symbol of the Rtanj are the well-known Rtanj savoury (*Satureja kitaibelii*) and Rtanj catmint (*Nepeta rtanjensis*). These species are strict local endemites of the mountain Rtanj and, due to their limited distribution, are included in the national, European and global Red Lists of the flora (Dajić Stevanović et al., 2015). Of the animal species the European copper skink (*Ablepharus kitaibelii*) is especially interesting, which has the status of a strictly protected species in Serbia. Rtanj is protected as a Special Nature Reserve.

Soil sampling

Field researches were conducted in 2020. Eight profiles were opened and described. Disturbed soil samples were collected from topsoil horizons. A total number of 10 soil samples were analyzed in the laboratory.

Basic soil analysis

The main physical and chemical characteristics of the examined soil were determined by following methods: particle-size distribution of the soil was determined by combining sieving and the pipette methods, with 0.1 M sodium pyrophosphate as a dispersing agent (Rowell, 1997); soil texture was classified using the USDA triangle (Natural Resource Conservation Service, 2004); soil reaction (pH) was measured potentiometrically method in a suspension (soil: water and soil:1 M KCl ratio 1:2.5) (Reewijk, 2002); soil organic carbon concentration (SOC) was determined using the dichromate method (Rowell, 1997), the humus content was calculated = SOC x 1.72; hydrolytic acidity (H) was determined by Kappen's method using the 1 M Na-acetate solution (Mineev et al., 2001); sum of exchangeable basis (S) was determined by 0.1 M HCl according to Kappen (Mineev et al., 2001); cation exchange (T) was calculated as sum of exchangeable basis and hydrolytic acidity (Mineev et al., 2009); base saturation (%V) was calculated as the ratio of exchangeable basis and T (Mineev et al., 2001).

Aggregate-size distribution and aggregate stability

Dry ASD and WAS were determined by Savinov's method (Savinov, 1936). This method uses dry and wet sieving procedures. Soil aggregates were separated on sieves of 10, 5, 3, 2, 1, 0.5 and 0.25 mm into eight dry aggregate size classes. Wet sieving is carried out on 3, 2, 1, 0,5, and 0.25 mm sieves and aggregates are separated into six size classes.

Structure indices

The following soil structure indices were calculated: dMWD, wMWD, dGMD, wGMD and SI. The weights of different aggregate size classes (ASCs) obtained after dry and wet sieving were used to calculate dMWD, wMWD, dGMD, wGMD. Both dMWD and wMWD were calculated by the following equation (Hilel, 2004):

$$MWD = \sum_{i=1}^{n} x_i \cdot w_i \qquad (1)$$

Where: x_i is the mean diameter of each ASC (mm) and w_i is the weight of each ASC (g) with respect to the total sample.

Geometric mean diameter was calculated as index of Mazurak (1950) after dry and wet sieving using following equation:

$$GMD = \exp\left|\frac{\sum w_i \cdot \log x_i}{\sum w_i}\right| \qquad (2)$$

Where: w_i is the weight of the aggregates of each size class (g) and x_i is the mean diameter of its size class (mm).

SI proposed by Pieri (1992) was calculated as a way of assessing the risk of structural degradation as per the following equation:

$$SI = \frac{1.274 \cdot SOC}{silt + clay} * 100 \quad (3)$$

Where: SOC (%) is soil organic carbon content and (silt + clay) (%) is the combined silt and clay content of the soil. SI higher than 9% indicates stable structure, 7% < SI ≤ 9% means low risk of structural degradation, 5% < SI ≤ 7% indicates high risk of degradation, and SI ≤ 5% structurally degraded soil (Pieri, 1992).

Statistics

Descriptive statistic was used to present the results of soil structure. Correlation analysis was performed to investigate the relationships between some soil properties and structure indices. The correlations were expressed as Pearson's linear coefficients with the indication of statistical significance (* for P<0.05, ** for P<0.01). Data analyses were carried out using STATISTICA 8.0 for Windows software.

RESULTS AND DISCUSSION

Basic soil properties

The studied Calcomelanosols are located on sideslopes and foot slopes at an elevation from around 880 – 1030 m a.s.l. Teh main soil properties are presented in Table 1. Soil has a silty clay loam texture, with a high percentage (71.2–83.6%) of particles smaller than 0.02 mm. Soils are moderately acid to neutral, pH in H_2O ranges between 5.76 and 6.85, with an average value of 6.46±0.39. pH in KCl ranges from 4.99 to 6.19, 5.71±0.44 on average. Average soil organic carbon (SOC) content amounts 6.23±0.93%. The values of hydrolytic acidity (H) in all tested samples did not exceed 6.8 cmol/kg (3.9 ±1.8 cmol/kg on average). Sum of exchangeable base cations (S) varies in analyzed soil samples from Rtanj from 36.2–60.5 cmol/kg (51.0±8.8 cmol/kg on average). The examined Calcomelanosols had high values of cations exchange capacity (T), between 43.0 and 63.0 cmol/kg. Soils are highly saturated with bases, %V ranges between 84.3% and 97.0% (92.4±4.6 on average).

Dry aggregate size distribution (ASD)

The results obtained from dry sieving analysis are shown in Table 2. The distribution of aggregate size classes (ASCs) is as follows: >10 mm on average 7.3±3.9%; 10-5 mm on average 19.6±5.4%; 5-3 mm on average 18.1±3.4%; 3-2 mm on average 18.8±3.3%; 2-1 mm on average 24.1±6.9%; 1-0.5 mm on average 4.0±1.2%; 0.5-0.25 mm on average 6.0±1.5%; <0.25 mm on average 2.2±1.1%. The obtained results after dry sieving indicate very favorable structure of the examined Calcomelanosols. Favorable soil aggregate distribution is best illustrated by the fact that the average content of agronomically valuable fractions (0.25–10 mm) is 90.5±3.6%, in all analyzed soil profiles it exceeds 80%. Among these aggregates, very fine, fine and medium size aggregates dominate. In the study of Životić et al. (2019b) the amount of agronomically valuable fractions amounts to 75.6±10.6% which is a lower value. The difference can be explained by the fact that Colluvial Calcomelanosols of mountain Vukan are located on lower elevations and contain lower amounts of soil organic matter. Soil aggregates with large diameters (greater than 10 mm) are not conductive to water conservation and crop emergence, while aggregates with diameters that are too small (less than 0.25 mm, known as microaggregates) can clog pores and damage soil permeability (Wu and Hong 1999).

Soil aggregate stability to water (WAS)

The stability of structural aggregates is a performance of soil quality (Mapa and Ariyapala, 1998). The distribution of the aggregate size classes obtained after wet sieving for each of the eight profiles is presented in Table 3. Content of individual aggregate size classes after wet sieving is as follows: > 3 mm in average 32.3±10.2%; 3-2 mm in average 9.3±2.2%; 2-1 mm in average 23.6±5.5%; 1-0.5 mm in average 12.1±2.7%; 0.5-0.25 mm in average 2.0±0.7%; <0.25 mm in average 13.2±3.8%. Megaggregates and macroaggregates of size 10-5 mm are generally not resistant to water, however, in all our examined soil profiles, aggregates of size 10-5 mm were present, whereas in profiles 3,4,5,7, megaaggregates (>10 mm) were also present. The content of water-stable macroaggregates (10-5 mm) ranges from 3.2–11.6% (6.6±2.7% on average). Percentage of megaggregates (>10 mm) are ranging from 4.1 in profile 7 to 0.8% in profile 5 (2.5±1.4% on average). The presence of these aggregates after wet sieving indicates high aggregate stability to water. Also, high soil aggregate stability is evident from the fact that water stable aggregates >1 mm account for 64.4–82.0%, 72.7±5.4% on average. The content of water stable aggregate is one of the indicators for gauging soil resistance to water erosion. They have a significant role in maintaining the stability of the soil structure (Tang et al., 2012). The average content of soil water stable aggregates higher than 0.25 mm is 86.8±3.8%, which is a similar value to the results of Životić et al. (2019b), 83.4±5.7% on average.

Table 1. Basic soil physical and chemical properties

Soil profile	Depth (cm)	Horizon	Particle size distribution (%, mm)			Soil texture	pH in H_2O	pH in KCl	SOC (%)	SOM (%)	H (cmol/kg)	S (cmol/kg)	T (cmol/kg)	V (%)
			total sand, 2-0.05	silt, 0.05-0.002	clay, <0.002									
1	0-18	A	4.7	63.2	32.0	SiCL	6.32	5.58	6.57	11.33	4.1	51.5	55.5	92.7
2	0-24	A	2.8	65.8	31.3	SiCL	6.22	5.39	6.18	10.66	5.0	47.6	52.6	90.4
3	0-20	A	2.7	70.0	27.3	SiCL	6.68	5.88	5.83	10.06	2.8	51.1	53.8	94.8
4	0-22	A	3.2	69.0	27.8	SiCL	6.78	6.12	6.83	11.78	4.2	58.8	63.0	93.4
	22-40	A	1.5	70.0	28.4	SiCL	6.69	6.19	6.60	11.38	1.8	59.5	61.3	97.0
5	0-22	A	1.7	64.7	33.6	SiCL	6.83	6.01	5.94	10.23	2.4	52.6	54.9	95.7
6	0-18	A	1.3	68.6	30.1	SiCL	6.85	6.05	7.78	13.41	2.2	60.5	62.8	96.4
7	0-29	A	1.3	66.5	32.2	SiCL	5.76	4.99	5.25	9.04	6.6	36.4	43.1	84.6
	29-50	A	2.5	60.8	36.6	SiCL	5.90	5.03	4.32	7.45	6.8	36.2	43.0	84.3
8	0-20	A	1.8	69.8	28.4	SiCL	6.60	5.84	7.00	12.07	3.1	56.0	59.1	94.7

SiCL – silty clay loam

Table 2. Dry aggregate size distribution

Soil profile	Depth (cm)	Horizon	Dry aggregate size distribution (%)							
			>10 (mm)	10-5 (mm)	5-3 (mm)	3-2 (mm)	2-1 (mm)	1-0.5 (mm)	0.5-0.25 (mm)	<0.25 (mm)
1	0-18	A	7.5	17.3	17.4	19.0	24.3	6.0	6.2	2.4
2	0-24	A	10.9	17.7	14.4	17.5	26.3	4.8	6.5	1.9
3	0-20	A	9.0	21.8	16.2	16.7	26.0	3.8	5.1	1.4
4	0-22	A	6.9	23.7	15.9	17.0	22.3	5.1	6.4	2.7
	22-40	A	4.2	19.1	18.7	18.9	21.4	3.5	9.0	5.2
5	0-22	A	2.9	15.9	21.5	24.7	24.3	4.0	5.2	1.5
6	0-18	A	3.7	14.3	21.2	22.3	26.0	3.7	6.7	2.1
7	0-29	A	10.3	23.7	18.1	15.8	21.1	4.4	5.3	1.9
	29-50	A	14.5	30.6	24.1	13.9	10.3	1.5	3.1	2.0
8	0-20	A	3.1	12.3	13.4	22.2	38.5	3.0	5.9	1.7

Table 3. Soil aggregate stability to water

Soil profile	Depth (cm)	Horizon	Soil aggregate stability to water (%)							
			>10 (mm)	10-5 (mm)	5-3 (mm)	3-2 (mm)	2-1 (mm)	1-0.5 (mm)	0.5-0.25 (mm)	<0.25 (mm)
1	0-18	A	-	6.3	37.4	7.0	24.2	14.0	2.3	8.8
2	0-24	A	-	9.5	26.1	9.5	27.7	14.9	2.4	9.9
3	0-20	A	2.9	5.8	24.5	10.9	26.6	12.0	1.7	15.7
4	0-22	A	-	4.4	23.5	10.3	26.2	11.1	3.5	21.1
	22-40	A	2.3	9.0	33.7	8.5	17.8	12.5	1.8	14.5
5	0-22	A	0.8	7.2	35.2	9.1	24.4	9.6	1.6	12.0
6	0-18	A	-	4.6	34.6	14.2	21.6	10.9	1.5	12.7
7	0-29	A	4.1	11.6	36.6	6.1	16.6	12.2	2.1	10.6
	29-50	A	-	3.2	53.8	8.1	16.9	7.0	1.0	9.9
8	0-20	A	-	4.8	17.0	9.0	33.7	16.6	2.2	16.7

Soil structure indices

Structure indices together with ASD and WAS present essential parameters in understanding the structural state of the soil (Table 4). The following soil structure indices were calculated: dry mean weight diameter (dMWD), wet mean weight diameter (wMWD), dry geometric mean diameter (dGMD), wet geometric mean diameter (wGMD) and structural stability index (SI).

Table 4. Structure indices of Calcomelanosols of mountain Rtanj

Soil profile	Depth (cm)	Horizon	dMWD (mm)	wMWD (mm)	wMWD/ dMWD	dGMD (mm)	wGMD (mm)	SI (%)
1	0-18	A	3.81	2.63	0.69	1.49	1.27	30.8
2	0-24	A	4.11	2.54	0.62	1.53	1.22	31.2
3	0-20	A	4.21	2.54	0.60	1.58	1.34	33.5
4	0-22	A	4.06	2.04	0.50	1.53	1.03	38.0
	22-40	A	3.54	2.89	0.82	1.41	1.23	38.0
5	0-22	A	3.43	2.73	0.80	1.53	1.25	29.0
6	0-18	A	3.37	2.51	0.74	1.45	1.22	42.7
7	0-29	A	4.50	3.34	0.74	1.93	1.62	27.0
	29-50	A	5.53	2.92	0.53	2.00	1.35	19.0
8	0-20	A	3.02	1.92	0.64	1.40	1.04	40.0

Mean weight diameters were calculated for dry (dMWD) and wet (wMWD) sieving. Dry MWD showed values ranging from 3.0 to 5.5 mm (4.0±0.7 mm), Calcomelanosols studied by Životić et al. (2019a) had a higher average value for dMWD 5.7±1.0 mm, which can be contributed to higher gravel content and lower soil organic matter. wMWD values had ranges from 1.9 to 3.3 mm. Previous studies showed that soils with a higher wMWD are likely to have a greater resistance to soil degradation (Chan and Mead, 1988; Teixeira and Misra, 1997). The wMWD and dMWD ratio is an indicator of the stability of structural aggregates. A small change in the aggregate size after wet sieving was found, 0.7±0.1 mm on average. Also, in the study of Životić et al. (2019a) there was a small change after wet sieving. In the soils that we had analyzed the least significant change between dMWD and wMWD was in profile 6, this profile has the highest content of soil organic matter (SOM) which indicates a positive impact of SOM on the stability of structural aggregates. Soil aggregate stability may also be expressed by dry and wet geometric mean diameter (GMD). dGMD values ranged from 2.0 mm in profile 7 to 1.4 mm in profile 8. wGMD was between 1.6 mm and 1.0 mm. In all examined soil profiles SI is higher than 19% (32.9±7.1% on average), which indicates an extremely stable structure, without the risk of the structural degradation of soil.

SOM content, pH and %V vs. structure indices

The quantity of agronomically most valuable aggregates (0.25–10 mm) is highly correlated with SOM content (R^2 = 0.5269*), pH (R^2 = 0.5762*), %V (R^2 = 0.6087*). The results indicated that the dMWD had significant negative correlation with SOM content (R^2 = 0.7166**), pH (R^2 = 0.5324**) and %V (R^2 = 0.7050**). Also, correlation analysis showed a significant negative relationship between dGMD and SOM content (R^2 = 0.7640*), pH (R^2 = 0.6701*), %V (R^2 = 0.7640**). Additionally, there is a positive correlation between SI and pH (R^2 = 0.5730*), and SI with %V (R^2 = 0.6394*).

CONCLUSION

All analyzed soil profiles have favorable soil structure and water stable soil aggregates with low risk of soil structure degradation. The average content of agronomically most valuable aggregates (0.25–10 mm) amounts to 90.5±3.6%. High aggregate stability is indicated by the fact that water stable aggregates >1 mm account for 64.4-82.0%, or 72.8% on average. Also, high wMWD and dMWD ratio is an indicator of the stability of structural aggregates. In all examined soil profiles SI is higher than 19% (32.9±7.1% on average), which indicates an extremely stable structure. Correlation analysis showed a significant positive relationship between the content of agronomically valuable fractions (0.25–10 mm) and the following soil parameters: soil organic matter (SOM), pH, and base saturation (%V). Also, there is a strong positive correlation between SI and pH, and SI with %V. Other calculated structural indices show a strong negative correlation with SOM, pH and %V. Calcomelanosols soil structure stability is of the major concern considering the fact that these soils are often distributed on terrains with higher inclinations and in topographic positions which are naturally more prone to soil water erosion.

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CONTENT OF AVAILABLE CALCIUM AND MAGNESIUM IN THE VERTISOLS OF THE PČINJA DISTRICT

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Abstract

This paper represents the results of the content of available Ca and Mg, in the vertisol type soils found in the Pčinja District area, using the method of ion chromatography. Ten different pedologic profiles of vertisols were created, seven profiles of carbonate vertisol subtype and three profiles of noncarbonate vertisol subtype. Fieldwork research was carried out in the Pčinja District - GPS space positioning of all profiles, along with coordinates, altitude and terrain exposition.

The results obtained by analysis indicate that the carbonate vertisols are the richest in calcium, the average content being 20.57 g/kg, varying between 17.3 and 24.2 g/kg.

The average content of calcium in noncarbonate vertisols is 12.45 g/kg, varying between 6.1 and 22.9 g/kg. The correlation analysis has shown that there is a complete correlation between the pH value and the content of Ca (r=0.80) and Mg (r=0.96).

The research results show that noncarbonate vertisols of the Pčinja District contain more magnesium than carbonate vertisols from the same area. The results also indicate that the humus-accumulating horizon of noncarbonate vertisols contains the average of 1.41 g/kg of Mg, varying between 0.67 and 2.9 g/kg. The average content of Mg in the humus-accumulating horizon of carbonate vertisols is 1.27 g/kg, varying between 0.83 and 2.20 g/kg.

The magnesium content in the majority of tested profiles of both carbonate and noncarbonate vertisols tends to rise with the depth of the profile.

Keywords: Vertisol, Pčinja District, carbonate, noncarbonate, calcium, magnesium

INTRODUCTION

Vertisol is one of the most widespread soil type in Serbia and covers an area of 780,000 ha. The main areas of its distribution are: Sumadija with about 260,000 ha, eastern Serbia - Negotinska Krajina (120,000 ha), southern Serbia - Aleksinac, Nis and Vranje valleys (120,000 ha), Kosovo and Metohija (110,000 ha). In Vojvodina, around Vršac and Bela Crkva, this soil type covers an area of about 36,000 ha, while significantly smaller areas (20,000 ha to 30,000 ha) are located in the area of Raška and Stari Vlah. (Škorić et al., 1985).

The standard vertisol properties are described in many works of our researchers (Stebut, 1923; Filipovski and Ćirić, 1963; Živković et al., 1964; Živković, 1968; Filipovski, 1999) who point out that these are soils formed on clay sediments (mainly carbonate) with a content of more than 30% of clay from the group of smectites or on basic and ultrabasic rocks which decomposition gave the specified type of clay. It has A-C profile structure, where A horizon has vertic characteristics (Avt), and the character of its humus is specific: it is formed in conditions of terrestrial pedogenesis, but due to poor internal drainage it shows certain characteristics of hydromorphic humus, which is especially visible by color. The depth of the A horizon is greater than 30 cm, and almost always there is a transitional AC horizon with a capacity of 20-30 cm, which are heavy mechanical composition, high porosity and soil water capacity, low air capacity, large amounts of dead water, low volume masses values and high values of solid phase density. It is a soil which pH value in water ranges from slightly acidic to slightly alkaline. The carbonate may be to the top, but there is a regularity that the carbonates increase with depth. The adsorption complex degree of saturation with bases is very high and the adsorption capacity is higher than 30 mmol eq. H +. The soils in our country contain 2-6% humus and gradually decrease in the depth of the humus-accumulative horizon.

Jakovljević et al. (2001) examined the total and accessible content of alkaline elements: Ca, Mg, K and Na in representative samples of various soils of Serbia. According to the obtained results, the total mean contents of alkaline elements in our soils have the highest Ca (2.25%), then K (1.77%), then Na (0.85%) and the least Mg (0.61%). According to the average available contents, it has the most Ca (947mg/100g), and the mean contents for other alkalies (Mg, K and Na) are very similar and range around 40mg/100g. Soils with an acid reaction have fewer total and accessible alkali, while those with an alkaline and neutral reaction have higher contents. The following mean total alkaline contents were found in the tested vertisols: Mg - 0.35%, Ca - 0.68%, K - 1.94% and Na - 0.75%, and the mean available alkaline contents were: Mg - 27mg/100g, Ca - 340mg/100g, K - 31mg/100g and Na - 33mg/100g.

The most researchers (Stebut, 1923; Negebauer et al., 1965; Živković, 1968; Antonović et al., 1973; Babović, 1977; Škorić et al., 1985; Jakovljević et al., 1985) examined the vertisol of Central and Eastern Serbia, as well as vertisol in Kosovo and Metohija. The degree of vertisol study in the area of Pčinja district is insufficiently researched and refers only to noncarbonate vertisol in the Vranje valley. The research shown in this paper aimed to determine the vertisols subtypes of Pčinja District, with a detailed description of the identified soils chemical properties.

MATERIALS AND METHODS

Field researches of vertisol were performed on the territory of Pčinja District. Ten pedological profiles of vertisol soil type were opened (seven profiles of noncarbonate vertisol subtype and three profiles of carbonate vertisol subtype). Spatial positioning of all profiles was performed by GPS, and the altitude and terrain exposure were determined along with the coordinates.

The basic chemical properties of the soil were determined by standard methods: humus content, bichromatic method, Kocman method, total nitrogen according to Kjeldahl, content of available potassium and phosphorus by Al-method according to Egner-Riehm, content of accessible Ca and Mg, by ion chromatography method. The obtained results were statistically processed by the methods of correlation analysis in the StatSoft program.

RESULTS AND DISCUSSION

The obtained results of the analyzes are presented in Tables 1 and 2, and show that the highest content of calcium is in carbonate vertisols.

Table 1. Content of humus, accessible P_2O_5, K_2O, Ca and Mg in noncarbonate vertisols of Pčinja District

Profile place	Depth (cm)	Humus (%)	Total N (%)	Accessible			
				P_2O_5 mg/100g	K_2O mg/100g	Ca g/kg	Mg g/kg
Noncarbonated vertisol							
PROFILE 1 (Coordinates N 42°42.035', E 022°02.789', altitude 483 m)							
V. Han Repince	0-20	2.60	0.130	2.76	16.57	6.1	2.0
	20-40	1.83	0.092	2.64	14.97	8.4	2.8
	40-60	1.18	0.059	1.14	10.17	21.3	2.3
	60-80	1.02	0.051	2.11	7.07	31.2	2.8
PROFILE 2 (Coordinates N 42°42.320', E 022°04.230', altitude 405 m)							
V. Han Rid	0-20	2.41	0.121	4.81	18.31	22.9	2.9
	20-40	1.73	0.087	3.01	14.17	28.5	3.2
	40-60	1.41	0.071	1.63	9.28	32.1	4.5
	60-80	1.15	0.058	1.43	7.77	31.4	2.8
PROFILE 3 (Coordinates N 42°28.888', E 021°49.971', altitude 417 m)							
Vranje Davidovac	0-25	2.77	0.139	5.68	28.17	9.8	1.2
	25-50	1.44	0.072	3.18	14.28	8.6	1.6
	50-80	1.18	0.059	1.42	14.13	23.5	2.6
PROFILE 4 (Coordinates N 42°26.934', E 021°53.058', altitude 445 m)							
Vranje Milanovo	0-20	3.04	0.152	18.56	34.68	5.9	0.67
	20-40	2.15	0.108	11.73	27.58	6.1	0.42
	40-60	1.52	0.076	7.81	24.68	6.7	0.41
	60-86	1.01	0.051	5.56	20.04	7.4	0.76
	86-106	0.78	0.039	3.32	19.44	7.6	0.93
PROFILE 5 (Coordinates N 42°42.164', E 022°00.392', altitude 610 m)							
V. Han Kunovo	0-25	3.56	0.178	15.62	19.02	20.8	1.1
	25-45	2.02	0.101	8.32	11.75	25.4	1.0
	45-85	1.04	0.052	3.14	8.48	13.8	1.3

Table 1 (continued). Content of humus, accessible P_2O_5, K_2O, Ca and Mg in noncarbonate vertisols of Pčinja District

Profile place	Depth (cm)	Humus (%)	Total N (%)	Accessible			
				P_2O_5 mg/100 g	K_2O mg/100 g	Ca g/kg	Mg g/kg
PROFILE 6 (Coordinates N 42°42.410', E 022°01.101', altitude 564 m)							
V. Han Repince	0-35	2.12	0.106	3.42	17.71	13.4	1.3
	35-65	1.41	0.071	3.18	12.57	15.2	1.5
	65-100	0.91	0.046	2.03	7.67	8.9	1.9
PROFILE 7 (Coordinates N 42°27.968', E 021°53.058', altitude 450 m)							
Vranje Žabsko	0-20	3.70	0.185	8.44	28.76	8.3	0.71
	20-45	1.64	0.082	5.78	22.84	7.8	0.56
	45-63	1.01	0.051	3.41	11.39	32.0	0.92

Table 2. Content of humus, accessible P_2O_5, K_2O, Ca and Mg in carbonate vertisols of Pčinja District

Profile place	Depth (cm)	Humus (%)	Total N (%)	Accessible			
				P_2O_5 mg/100 g	K_2O mg/100 g	Ca g/kg	Mg g/kg
Carbonated vertisol							
PROFILE 8 (Coordinates N 42°31.259', E 021°53.207', altitude 409 m)							
Vranje Neradovac	0-20	2.68	0.134	6.82	28.32	20.2	2.20
	20-40	1.89	0.095	4.63	25.16	18.2	3.30
	40-65	1.24	0.062	2.32	34.84	21.9	3.80
	65-100	0.75	0.038	1.88	19.13	32.0	4.80
PROFILE 9 (Coordinates N 42°26.104', E 021°54.232', altitude 489 m)							
Vranje Buštranje	0-25	2.94	0.147	17.42	37.15	24.2	0.96
	25-50	1.88	0.094	10.38	37.04	22.2	0.93
	50-75	1.58	0.076	7.42	36.66	17.9	0.62
	75-100	0.82	0.041	2.32	30.15	15.5	0.98
	100-120	0.51	0.026	1.41	28.17	15.0	0.37
PROFILE 10 (Coordinates N 42°31.620', E 021°56.410', altitude 345 m)							
Vranje Ćukovac	0-20	2.50	0.125	7.53	19.68	17.3	0.83
	20-40	2.23	0.112	582	17.31	25.0	1.20
	40-60	1.12	0.056	5.02	10.21	13.7	0.93
	60-80	1.05	0.053	2.48	7.02	19.0	1.00
	80-106	0.95	0.048	1.75	7.15	17.8	1.10

Carbonate vertisols have higher content of calcium, where the average content is 20.57g/kg and varies from 17.3 to 24.2 g/kg. The average calcium content in noncarbonate vertisol is 12.45 g/kg and varies from 6.1 to 22.9 g/kg (Figure 1.).

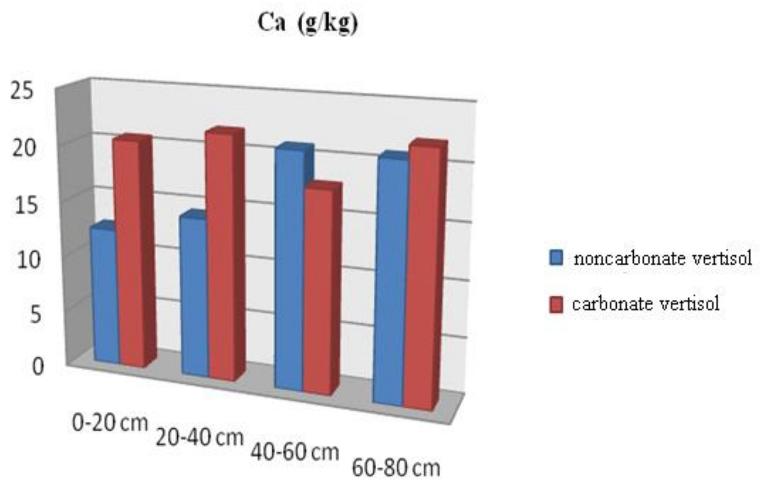

Figure 1. Average values of Ca (g/kg) content in noncarbonate and carbonate vertisol

The calcium content in the soil is directly dependent on the calcium content in the parent substrate. Another source of calcium in the soil is organic matter, which is subject to the process of mineralization. During that process Ca^{2+} ion is released, and it is used directly by plants, or synthesized the salts of different solubility.

Calcium plays a very important role in maintaining and increasing soil fertility. Soil which adsorption complex is saturated with Ca^{2+} ions has good physical properties, high adsorption capacity and favorable conditions for biological and biochemical processes, which affect the mobilization of nutrients from soil reserves.

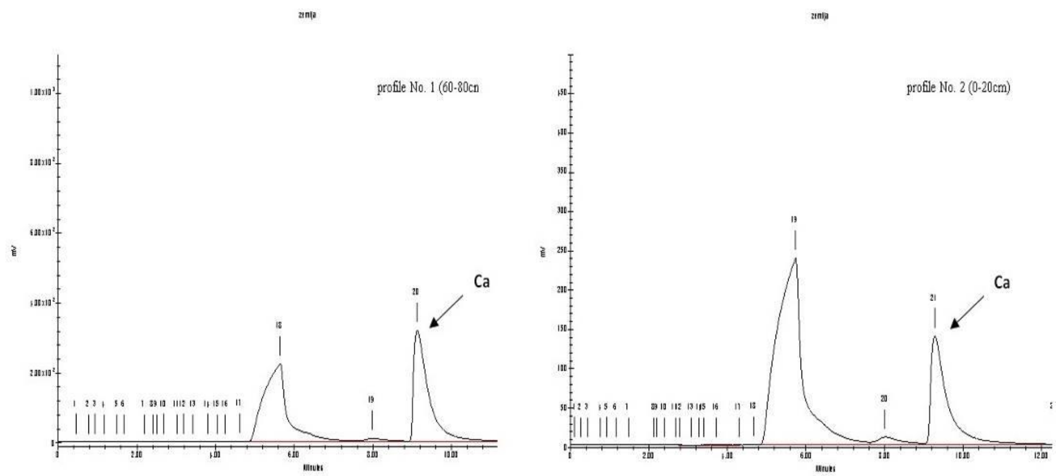

Figure 2. Ca chromatograph in noncarbonate profiles

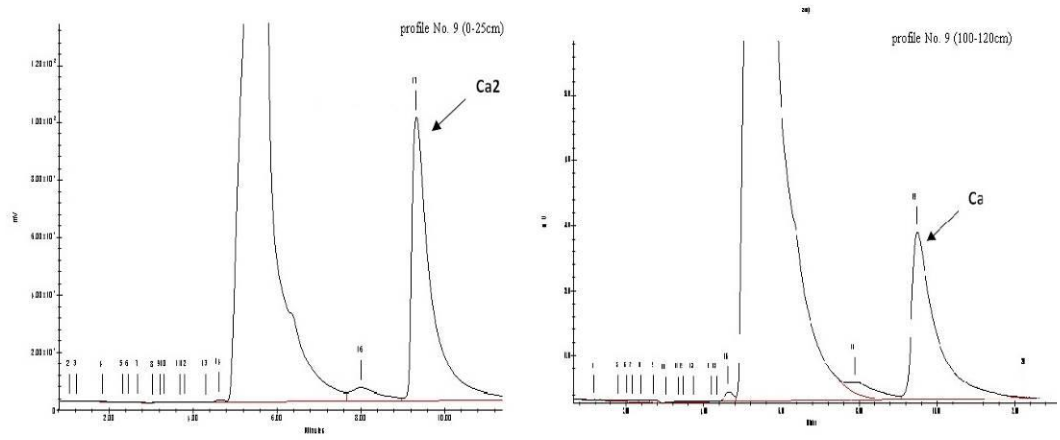

Figure 3. Ca chromatograph in carbonate profiles

Sources of magnesium in the soil are primary and secondary minerals whose decomposition produces Mg-ions that can bind to the adsorption complex or pass into the soil solution. Magnesium is released from organic matter, passing into the soil solution in the process of mineralization.

According to research by Popović (1989), the content of Mg in the soil ranges from 0.1 to 1.5%, and in the vertisol it is on average 1.41%.

The results of our research, shown in Tables 1 and 2, show a higher content of magnesium in noncarbonate vertisol in relation to the examined carbonate vertisol of Pčinja District. Namely, the obtained analysis results (Figure 4.) show that magnesium in the humus-accumulative horizon of noncarbonate vertisol has an average of 1.41 g/kg and varies from 0.67 to 2.9 g/kg.

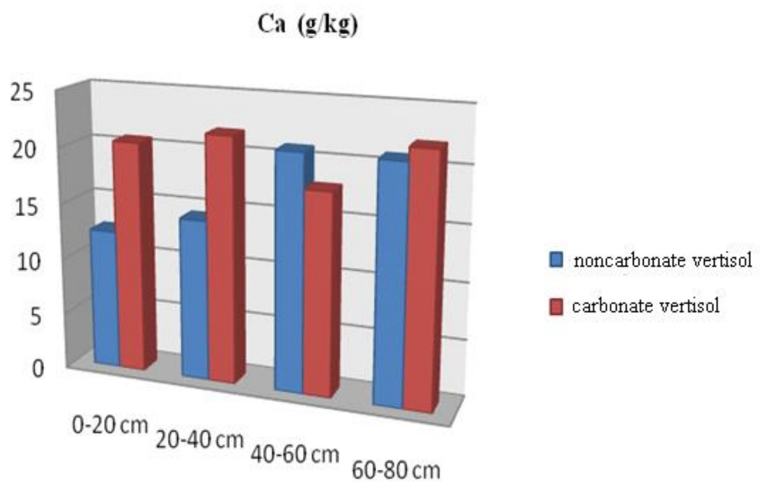

Figure 4. Average values of Mg (g/kg) content in noncarbonate and carbonate vertisol

The average magnesium content in the humus-accumulative horizon of carbonate vertisol is 1.27 g/kg and varies in the range from 0.83 to 2.20 g/kg. The content of magnesium in the largest number of tested profiles, both in noncarbonate and carbonate vertisol, increases with profile depth.

Clay minerals adsorb magnesium almost five times less than calcium. Due to the competition of Ca-ions in carbonate soils and H-ions in acid soils, adsorbed magnesium accounts for 2 to 20% of the total adsorption capacity, (Aubert et al., 1997).

Based on the examination of the vertisol in the Aleksinac valley, Živković et al. (1964) came to the conclusion that adsorbed Mg-ions play an important role in the genesis of the smonica and that they are one of the causes of their unfavorable physical properties.

We found, based on the correlation analysis (Figure 5. and 6.), that there is a complete correlation between the pH value and the content of Ca (r = 0.80) and Mg (r = 0.96).

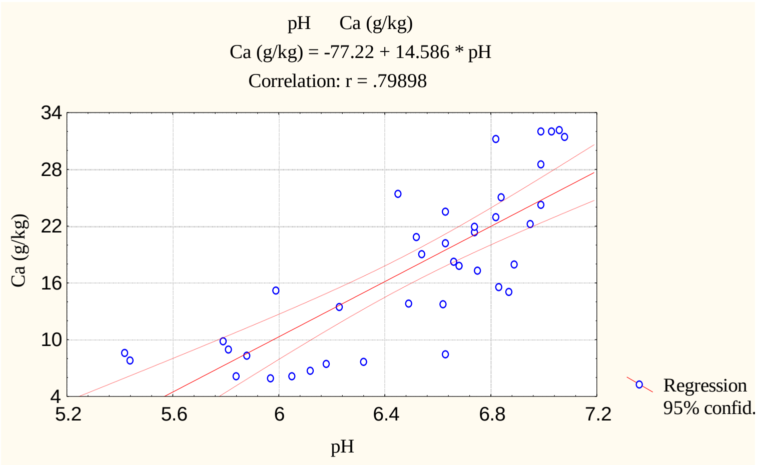

Figure 5. Regression model of pH values and Ca contents

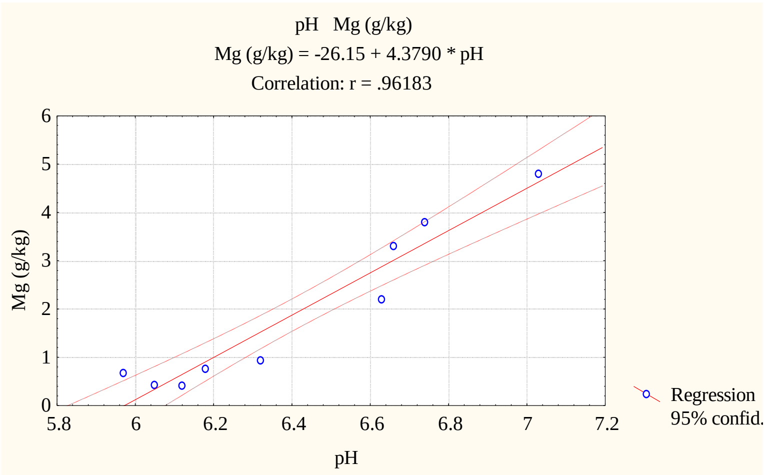

Figure 6. Regression model of pH values and Mg contents

CONCLUSION

Based on the obtained results of the Pčinja District vertisol research, the largest number of researched profiles belongs to noncarbonate vertisol, and a smaller number of profiles belong to the subtype of carbonate vertisol. The formation of carbonate vertisol is related to carbonate clay substrates, and noncarbonate ones follow the carbonate subtype and have been formed under conditions of increased wetting and leaching of $CaCO_3$.
The content of Ca in the examined soils is directly dependent on the Ca content in the parent substrate. The obtained results of the analysis show that the calcium content in the examined vertisols of Pčinja District is conditioned by the process of a certain microrelief humidity in the examined area and that its presence affects the potential fertility of the examined soil.
The results of the research show a higher content of magnesium in the nocarbonate vertisol in relation to the examined carbonate vertisol of the Pčinja District. The content of magnesium in the largest number of tested profiles, both in noncarbonate and carbonate vertisol, increases with profile depth.
According to the correlation analysis, it was determined that there is a complete correlation between the pH value and the content of Ca ($r = 0.80$) and Mg ($r = 0.96$).

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SECTION 2

SOIL-WATER-PLANT-ATMOSPHERE CONTINUUM

ASSESMENT OF A SMARTPHONE APP FOR POTATO IRRIGATION SCHEDULING

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Abstract

Information and communication technologies (ICT) are the base to develop tools to help farmers with irrigation scheduling. In Lebanon, in order to provide a step towards improved agricultural water use, technological advances and fundamental irrigation principles should be more investigated particularly through testing mobile app that are currently being developed worldwide. Therefore, an irrigation scheduling tool, called Bluleaf, was tested in the Bekaa valley. Bluleaf is a multiplatform application consisting of a PC and a mobile module. It takes into account agro-climatic, soil data and information related to the hydraulic system and offers farmers information about the required irrigation intervals and amounts. The main objective was to assess the performance of Bluleaf smart irrigation scheduling application for potato production in the Bekaa valley during the growing season 2017. Therefore, a field trial was implemented, it was organized in 16 plots within a randomized complete block design consisting of four irrigation scheduling treatments and four block replicates: I - 100: 100% replenishment of soil water depleted when 35% of available soil moisture was consumed in the 0.6 m soil profile depth; I - 80: 80% replenishment of soil water depleted; I - 60: 60% replenishment of soil water depleted; I - 40: 40% replenishment of soil water depleted. Bluleaf was used to track when and how much water to supply. The soil moisture content was tracked. In addition, the yield and water productivity were estimated. The validation of the soil water balance in Bluleaf was assessed through the analysis of some statistical indicators such as the Nash-Sutcliffe coefficient (NSE), that were applied to evaluate model predicted and observed data of soil water content. The midday leaf water potential was measured in addition to the canopy infrared temperature for the estimation of the crop water stress index. Obtained results revealed that Bluleaf simulated the soil water dynamics with a good agreement with measured values considering the amount of spatial variability and soil heterogeneity. In fact, the goodness of fit indicators, such as the NSE showed that the model was classified as good, with values ranging from 0.80 to 0.88. The obtained results showed that Bluleaf could constitute a good tool for simulating not only irrigation schedules under optimal water stress but also under limited water conditions. Bluleaf was able to support real-time scheduling with respect to the specific crop response to stress and with respect to the need to save water.

Keywords: Irrigation scheduling, potato, smartphone application

INTRODUCTION

Studies conducted in various parts of the world have shown that improved irrigation scheduling practices providing information about 'when' and 'how much' water to apply have an important role in achieving higher water savings and water productivity. Irrigation management requires reliable and easy-to-use methods to support real-time scheduling with respect to the specific crop response to stress (Steduto et al., 2012), and with respect to the need to save water and increase its productivity (Fereres and Soriano, 2007).
Jones (2004) provided detailed information about irrigation scheduling methods based on soil water balance approach (SWB). The SWB methods either directly measure or estimate the change in soil water contents within the crop root zone over a period of time given the water inputs during the period, i.e., irrigation and rain, and the water losses, including crop evapotranspiration, deep percolation, and runoff (Evett et al., 2012). A soil water balance method that estimates crop evapotranspiration (ETc) by the reference crop evapotranspiration multiplied by crop-specific coefficients has been in practice for decades and continues to be an acceptable method for irrigation scheduling within the scientific community, and by providers and managers of irrigation water (Jensen et al., 1990; Allen et al., 2005).
The application of new technologies to the control and automation of irrigation is becoming a very relevant issue in the last decade, and especially the automatic irrigation scheduling is receiving growing attention. Information and communication technologies (ICT) are the base to develop tools to help farmers with their managerial tasks. In the last decade a huge amount of works about ICT applications in agriculture and in particular in irrigation have been developed at farmer or irrigation district scales (Bartlett et al., 2015). They include most of the available technology from local monitoring, remote sensing, crop modelling or remote control of the irrigation process.
In Lebanon, in order to provide a step toward improved agricultural water use, technological advances and fundamental irrigation principles should be more investigated particularly through testing mobile app that are currently being developed worldwide. Particularly, the Bekaa valley is considered as the food basket of Lebanon where winter cereals are being produced under supplemental irrigation and spring/summer vegetables are being cultivated under full irrigation. The increasing water scarcity in the valley constitutes the main driver threatening farmers that are, nowadays, more exposed to use less water for food production. In addition, the use of irrigation scheduling tools is minimal. In this valley, still traditional irrigation scheduling based on farmer knowhow to add water is the norm. The most common traditional method of irrigation scheduling is according to a time set calendar schedule, the number of days elapsed since the last irrigation, visual detection of a change in crop color or wilting leaves, and/or according to how dry the soil feels. However, none of these traditional methods can provide information on 'how much' water to apply.
Therefore, an irrigation scheduling tool, called Bluleaf, currently developed and tested by an Italian consortium of private ICT companies and Research institutions, mainly the Mediterranean Agronomic Institute of Bari (IAMB), was tested in the Bekaa valley. Bluleaf is a multiplatform application consisting of a PC and a mobile module. It takes into

account agro-climatic, soil data and information related to the hydraulic system and offers farmers information about the required irrigation times and amounts. The current version was developed to guide growers during the crop season to apply the required amount of water at and during the right time. Thus, the main output variable is the updated daily irrigation time during the crop season. The main objective was to assess the performance of Bluleaf smart irrigation scheduling application for potato production under full and limited water conditions during the growing season 2017. This work is very important at national level because local studies are required to improve farmer's irrigation practices and to disseminate new water efficient technologies to reduce the pressure on freshwater withdrawal.

MATERIALS AND METHODS

Brief description of Bluleaf

Bluleaf is based on the integration of the following series of software and hardware components: a) a crop-soil water balance model, to compute the daily balance for each single irrigated plot; b) a specific software 'module' elaborating the weather data collected from a meteo station close to the area of interest and the short-time (3-7 days) weather forecast to compute a sort of 'predicted' crop water balance for incoming days, in order to support the decision process; c) a specific 'multi-plot and multi-crop management module' for the optimal water allocation considering all farm's irrigated plots, water availability and economic parameters of cultivation; d)capacitance sensors, for the real-time monitoring of soil water content; e) modern information and communication technologies for data-cloud computing; f) specific software applications for both 'desk' computers and 'mobile' devices (tablet, smartphone); g) field data-loggers, connected with weather and/or soil moisture sensors; h) remote monitoring in the water supply network (volumes, discharges, pressures, etc.) and control of actuators (at the level of pumping station, hydrants, electro-valves, etc.) to support farm operational management.
The 'core' algorithm of Bluleaf is designed to run simulations at the scale of a single 'irrigated plot', defined as 'the field-unit cultivated with the same crop (also in terms of variety type, planting date, density, etc.), with relatively homogeneous soil characteristics (average depth, texture, soil water holding capacity, etc.) and receiving the same irrigation applications (in terms of timing and amount)'.Crop-soil water balance and irrigation scheduling are computed by means of a specific model, originally written in the MS Excel® programming language and previously tested and applied for similar applications (Todorovic, 2006). The model estimates crop evapotranspiration, irrigation water requirements and relative yield through the standard procedure proposed by the FAO 56 Paper (Allen et al., 1998).
Additionally, the following three databases are provided: 1) the 'climate database', created with the aim to store historical climate data (for a specific year or as multi-year averages) coming from the public meteorological services and/or as recorded from a specific station; 2) the 'soil database', containing the basic hydrological properties as required for the model for several typical soil types, and connected to a specific pedo-transfer function

(PTF) allowing to create and store new types according to site-specific soil analysis; 3) the ‘crop database’, containing the ‘default’ standard parameters for a wide number of crop types, as suggested by literature (Allen et al., 1998; Allen and Pereira, 2009).

Field testing at farm level

Bluleaf tool was tested for potato (variety Spunta). The experiment was carried out in Tal Amara in the Bekaa valley (Lebanon) at the experimental field of the Lebanese Agricultural Research Institute (LARI) during the growing season 2017. The main weather parameters, including solar radiation, air temperature, relative humidity and precipitation, were taken from a standard agro-meteorological station located at 400 m far from the experimental field. Weather data, from November 2016 until November 2017 are provided in Table 1.

Table 1. Monthly climate data from February until May 2017 as recorded for Tal Amara region.

Month	ETo (mm)	P [mm]	Tmax [°C]	Tmin [°C]	RHmean [%]
Feb-17	48.00	29.80	14.13	-1.39	62.20
Mar-17	70.40	36.80	16.24	3.90	71.65
Apr-17	136.90	10.80	23.22	6.11	52.71
May-17	190.30	2.00	28.75	9.32	44.56

Soil samples have been taken in order to evaluate the basic physical soil characteristics as required by the model for the soil water balance simulation. The soil texture has been determined and the corresponding texture class has been referred to the USDA classification. The basic soil hydrological properties have been estimated from basic soil data (texture, organic matter, gravel content, etc.) by means of the pedo-transfer function suggested by Saxton and Rawls (2006). The field grown with potato was sandy clay loam in texture characterized with 30% clay, 65% sand and 5% silt and the hydrological properties were 28.2 $cm^3.cm^{-3}$ for field capacity, 18.8 $cm^3.cm^{-3}$ for wilting point and 42.4 $cm^3.cm^{-3}$ for saturation point. The total available water was 93 mm/m.

Specific crop parameters have been selected to run the model. The planting date, the value of depletion fraction (p), initial and maximum rooting depth, crop coefficient (Kc) and length of development stages (L), have been done by considering FAO reference values (Allen et al., 1998). The basic crop parameters for the model were initially set according to Allen et al. (1998). However, both biometric measurements (percentage of effective ground cover) and phenological survey have been done on a weekly basis, together with the acquisition of the basic agronomic information. This work was necessary to correct and adjust the Bluleaf specific crop parameters according to what was observed in real conditions in the field. The crop parameters initially set to Bluleaf as well as the modified values according to field observations are reported in Table 2.

Table 2. Crop parameters initially set in the model according to standard values suggested by Allen et al.(1998)

Crop type: potato				
Stage length - L (days)				
Ini	Dev	Mid	Late	Total
25	30	45	30	130
Crop coefficient - Kc				
Ini	Dev	Mid	Late	
0.5	1.15	1.15	0.75	
Rooting depth - Rd (m)				
Min		Max		
0.2		0.6		
Depletion coefficient - p				
0.35				

The trial

The irrigation scheduling experiment consisted of 16 plots (each 5 x 12 m long). The 16 plots were randomized in a complete block design consisting of four irrigation scheduling treatments and four block replicates: I - 100: 100% replenishment of soil water depleted when 35% of available soil moisture was consumed in the 0.6 m soil profile depth; I - 80: 80% replenishment of soil water depleted when 35% of available soil moisture was consumed in the 0.6 m soil profile depth of fully irrigated treatment; I - 60: 60% replenishment of soil water depleted when 35% of available soil moisture was consumed in the 0.6 m soil profile depth of fully irrigated treatment; I - 40: 40% replenishment of soil water depleted when 35% of available soil moisture was consumed in the 0.6 m soil profile depth of fully irrigated treatment.

Bluleaf was used to track when and how much water to supply. All the plots were equipped with low polyethylene surface laterals with 16 mm external diameters. All the laterals were supplied by in-line drippers (theoretical discharge rate of 4 L h^{-1} at a pressure of 100 kPa) with emitters spaced at 0.25 m. The spacing between laterals was 0.7 m. Each treatment had its own valve and flow meter. The seasonal net irrigation amounts are provided in Figure 1. The experimental details and dates of the main phenological stages during the growing season 2017 are reported in Table 3.

Soil moisture content and ecophysiology measurements

Soil moisture readings are useful to support the site-specific calibration of model parameters. This can help to test the validity of Bluleaf by checking the differences between simulated (model) and measured (sensor) data. Therefore, an FDR (or ‘capacitance’) sensor, the PR2 profile probe (DeltaT Devices Ltd, UK), have been used for periodic monitoring of the soil water content along the profile in several access tubes placed at 1m depth in the different treatments of both trials.

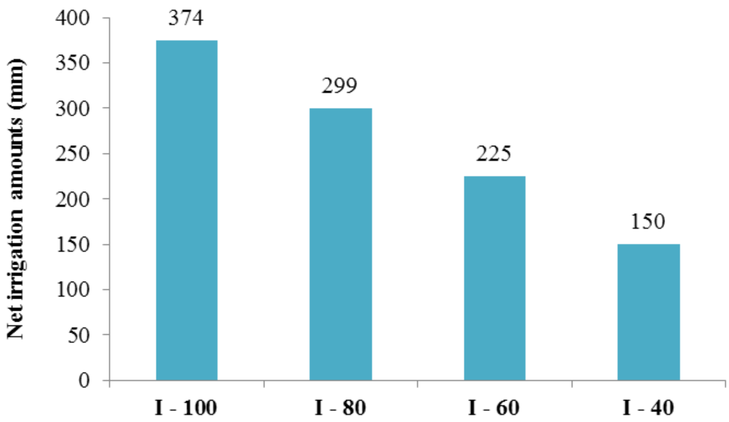

Figure 1. The net irrigation amounts for the four treatments in potato trial

Table 3. Experimental details and dates of the main phenological stages for potato during the growing season 2017. In brackets the days after sowing (DAS) are reported

Potato	
Season	2017
Sowing time	2/27/2017
Germination	4/3/2017 (36)
Vegetative development	4/15/2017 (48)
row closure/beginning stolinization	4/23/2017 (56)
Inter-row closing/tuber formation	5/3/2017 (66)
Flowering/growth of the tubers	5/13/2017 (76)
Yellowing lower leaves, tubers during maturation	6/7/2017 (101)
Full ripening, harvest	7/5/2017 (129)
Length of crop cycle (days)	129

Midday leaf water potential was measured weekly using a Scholander pressure chamber (P3000, Soil Moisture Corp., Santa Barbara, USA). In addition, canopy temperature was monitored by using an infrared thermometer; values were used to estimate the crop water stress index (CWSI) according to Idso's procedure (Idso et al. 1981) by means of three components (canopy temperature (Tc), air temperature (Ta) and vapor pressure deficit (VPD)).

Crop yield, quality attributes and yield water productivity

The analyses measured the marketable tuber fresh yield. Yield water productivity (Y-WP) was calculated as the ratio of yield over the sum of effective rain and irrigation water applied.

Validation of the soil water balance in Bluleaf and statistical analysis

The robustness of the soil water balance in simulating irrigation scheduling should be validated. Therefore, the validation of Bluleaf was done by comparing the simulated and measured values of soil water content over the whole growing cycle. Goodness-of-fit parameters, mainly the root mean square (RMSE), the coefficient of variation of the RMSE (CV(RMSE)), the Mean Bias Error (MBE), the Maximum Absolute Error (MAE), the index of agreement (d_{IA}), and the Nash-Sutcliffe coefficient (NSE), were applied to evaluate model predicted and observed data of soil water content.

The average difference between simulation outputs and experimental data was described by the root mean squared error (RMSE) as:

$$RMSE = \left[N \sum_{i=1}^{N} (P_i - O_i)^2 \right]^{0.5} \quad (1)$$

where N is the number of pairs of observed/measured (Oi) and predicted/simulated (Pi) data.

Then, the coefficient of variation of the RMSE (CV(RMSE)) was applied to normalize the RMSE to the mean of the observed/measured values ($\bar{O}$) as:

$$CV(RMSE) = \frac{RMSE}{\bar{O}} \quad (2)$$

The Mean Bias Error (MBE) was used to indicate the under/over estimations by the model as:

$$MBE = N^{-1} \sum_{i=1}^{N} (P_i - O_i) \quad (3)$$

The Maximum Absolute Error (MAE) was estimated as:

$$MAE = Max \left| P_i - O_i \right|_{i=1}^{N} \quad (4)$$

The index of agreement (dIA), representing the ratio between the mean square error and the "potential error", was calculated according to Wilmot (1982) as:

$$d_{IA} = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} 2\left(\left|P_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right)^2} \quad (5)$$

The dIA is a descriptive parameter that varies between 0 and 1, with the value of 1.0 indicating excellent agreement.

In addition, the Modelling Efficiency (NSE), representing a normalized statistic that determines the relative magnitude of the residual variance compared to the measured data variance (Nash and Sutcliff, 1970; Moriasi et al., 2007), was defined as:

$$NSE = 1.0 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} \left(O_i - \overline{O}\right)^2} \quad (6)$$

According to Mbabazi et al. (2017) that worked on validating a smartphone application for avocado, the validity of the model was considered very good when the probability of fit showed an NSE = 0.9-1; good for NSE = 0.8-0.899; acceptable for NSE = 0.65-0.799; unsatisfactory for NSE < 0.65.

Statistical analyses were carried out by using SAS v9.

RESULTS AND DISCUSSION

The soil water balance

The simulated soil water depletion was plotted against the measured values through the PR2 probes. The trends of the soil water balance simulations in the root zone are presented in Figure 2 for the four treatments in potato trial.

In general, the total net irrigation requirements of the fully irrigated treatment I - 100 were 374 mm while precipitation amounts registered during the season were 68 mm. The plants were kept under optimal water conditions the whole season and the soil water depletion was never below the threshold of the readily available water in the 60 cm root zone. Therefore, the plants were not exposed to water stress during irrigation period (Allen et al., 1998). When irrigation was stopped, few week prior to harvest, the soil water content dropped below the readily available water threshold. The total net irrigation amounts of I – 80, I – 60 and I- 40 were 299 mm, 225 mm and 150 mm. Accordingly, soil water depletion dropped below the threshold of readily available water for the whole irrigation period.

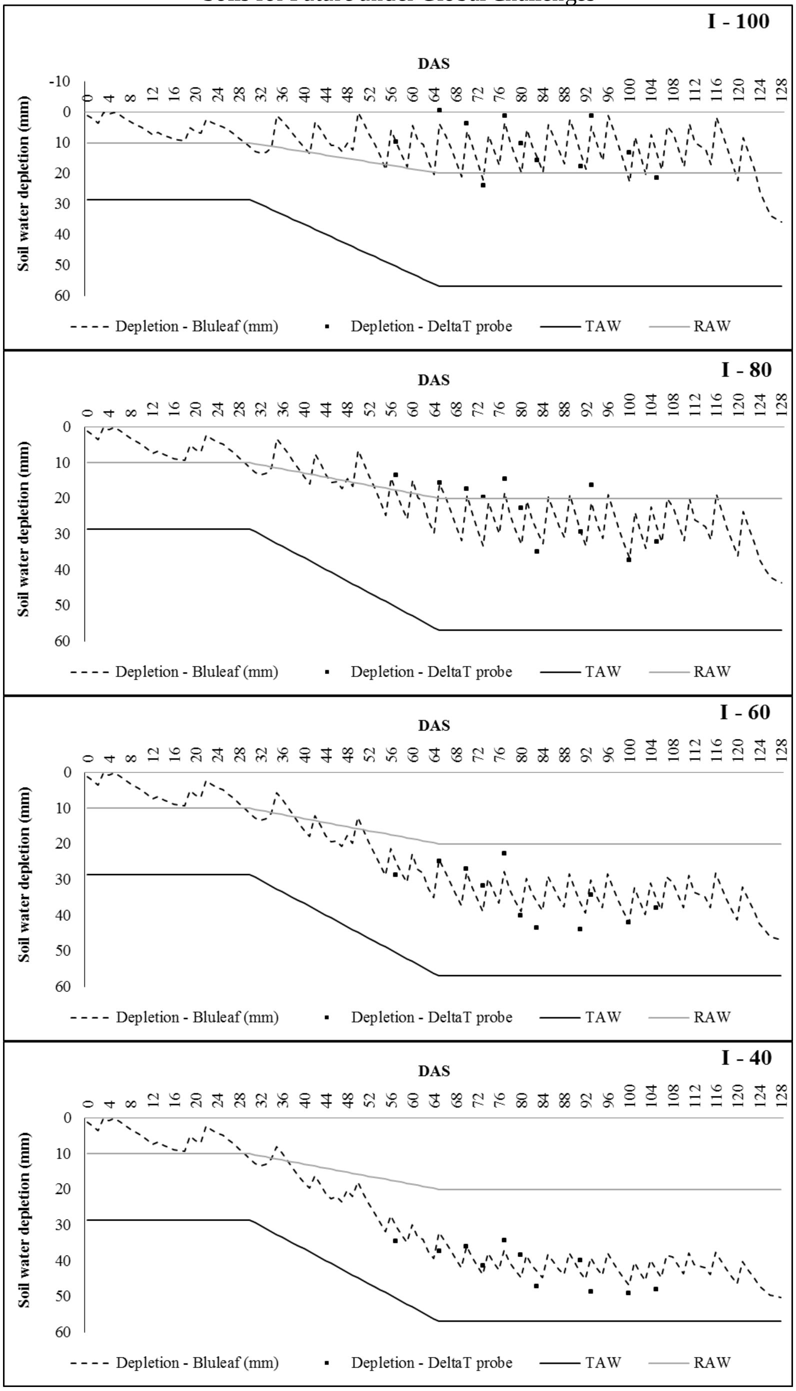

Figure 2. Simulated soil water depletion (Bluleaf) versus measured soil water depletion (PR2 probes) for the four different treatments in potato trial. (TAW: total available water; RAW: readily available water).

Considering the validity of Bluleaf to predict the soil water balance, the model simulated the soil water dynamics with a good agreement with measured values. In fact, the goodness of fit indicators are presented in Table 4. The RMSE ranged from 4.57 mm to 6.10 mm with a CV(RMSE) between 0.12 and 0.50 mm. The d_{IA} ranged from 0.86 to 0.96 while the NSE showed that the model can be classified as good (Mbabazi et al., 2017), with values ranging from 0.80 to 0.88. Variations in soil water simulations are mainly due to the soil properties heterogeneity (Beven and Germann, 2013; Nimmo, 2010; Nimmo and Mitchell, 2013). In conclusion, obtained results showed that Bluleaf could constitute a good tool for simulating not only irrigation schedules under optimal water stress but also under limited water conditions.

Table 4. Goodness of fit indicators for soil water balance simulation in potato trial

Statistical Indicator	I-100	I-80	I-60	I-40
RMSE (mm)	5.39	6.10	4.57	4.86
CV (RMSE)	0.50	0.27	0.13	0.12
MBE (mm)	1.48	2.63	-1.28	-1.49
MAE (mm)	4.27	4.58	3.66	4.19
dia	0.86	0.96	0.94	0.94
NSE	0.84	0.80	0.88	0.84

Yield and Y-WP

The fresh tuber yield and the yield water productivity, expressed as the ratio of fresh yield over irrigation amounts, are reported in Table 5 for all treatments. In general, the fresh yield was significantly influenced by the water regime, particularly the treatment I - 40. In fact, I - 40 produced 45.25%, 40.61%, and 37.04% lower yield than I – 100, I – 80, and I - 60, respectively. In addition, the yield did not vary significantly in relation to water practice for I – 100, I – 80 and I -60. Concerning the yield water productivity (Y-WP), the results revealed that there was no significant difference among treatments. The reported values are in agreement with the findings of Cantore et al. (2014).

Table 5. Fresh tuber yield and the tiled water productivity for the different treatments in potato trial

	Tuber Yield (t/ha)	Y-WP (kg/m^3)
I-100	37.90 a	10.127 a
I-80	34.94 a	11.668 a
I-60	32.96 a	14.675 a
I-40	20.75 b	13.856 a
LSD	11.52	6.50
Significance	*	NS
CV	23.80	3.10

Stress indicators: Leaf water potential and crop water stress index

The leaf water potential values were in accordance with the trend demonstrated in the volumetric soil water content (Figure 3). In fact, the average values for the fully irrigated treatment I -100 remained constant all over the growing season at approximately -6 bars which could be considered as a no stress status. I -80 treatment showed average leaf water potential of approximately -8 bars indicating a moderate water stress. I -60 and I -40 showed lower values for the leaf water potential and a more severe water stress progressing with the increase in climatic demand. The most pronounced water stress for I -40 was reached at day 100 with a value of -15 bars. The reported leaf water potential values were very low in comparison with the values obtained by Cantore et al. (2014). Such low values could explain the close values of tuber yield in the I-100, I-80 and I-60 treatments.

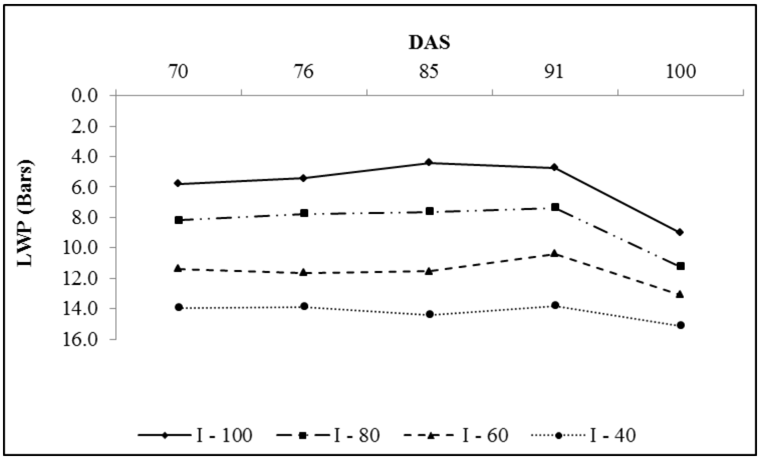

Figure 3. Midday leaf water potential (LWP) for the different treatments in potato trial

In Figure 4 (a), the values of canopy temperature minus air temperature ($T_C - T_A$) are plotted against the corresponding values of air vapor pressure deficit (VPD), and delimited by the estimated upper and lower baselines. The CWSI values are then calculated as the relative distance of the measured point between the upper and lower limits. A selection of the I- 40 data under high water stress conditions was used to draw the upper baseline parallel to VPD axis. Meanwhile, the lower baseline was derived from a selection of I -100, I -80 and I -60 data.

The variation of the empirical CWSI under the four water regimes is shown in Figure 4 (b). In general, the obtained trends showed clearly that Bluleaf was able to generate an irrigation schedule under optimal water supply with no signs of stress occurring on the plants; this was revealed through the low values of CWSI in I – 100, ranging between 0 (no stress) and 0.29 at the end of the season when irrigation was stopped. In addition, Bluleaf was also able to provide irrigations schedules under different levels of water supply. The trends of CWSI in I-80, I-60 and I-40 explained those findings. Obtained results of CWSI are in agreement with those reported in the study of Hammaoui et al.

(2013) who evaluated the CWSI for potato under different water regimes in Southern Italy. In addition, Bluleaf was able to support real-time scheduling with respect to the specific crop response to stress (Steduto et al., 2012), and with respect to the need to save water and increase its productivity (Fereres and Soriano, 2007).

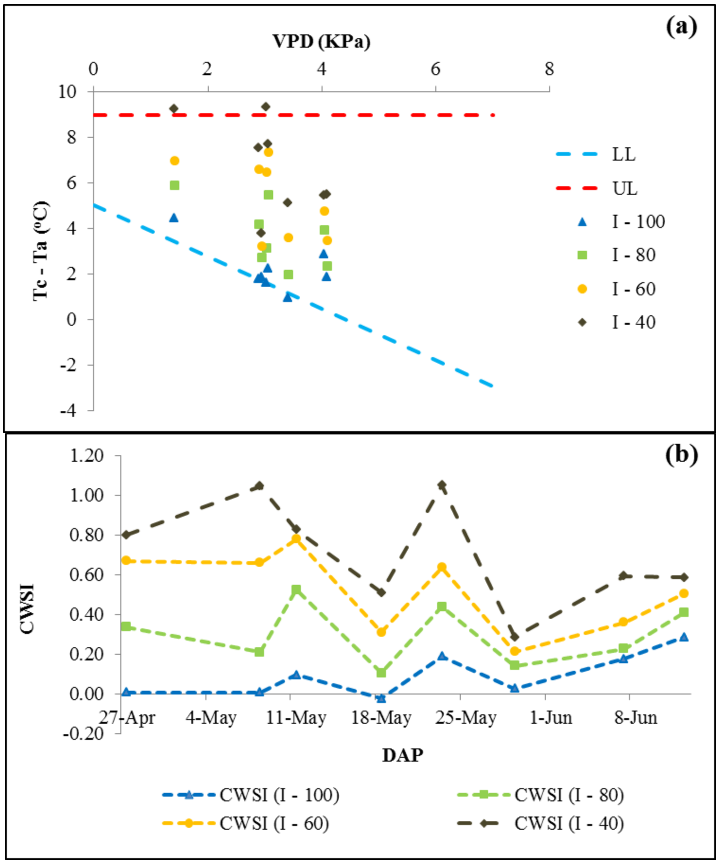

Figure 4. (a): Plot of the difference canopy–air temperature versus air vapour pressure deficit with the corresponding upper and lower limits. (b): Crop Water Stress Index variation for the four treatments during the potato growing season.

CONCLUSION

Potato is a water consuming field crop that is important for stabilizing food security at national level. Although the water authorities are trying to develop several regulations to limit water abstraction from groundwater, their effective application requires support to help farmers in the implementation of new water efficient technologies. For this reason, a user-friendly application for irrigation scheduling is of great importance in rationalizing water quantities. Bluleaf can provide daily customized irrigation scheduling for each farm at irrigation sector scale using local meteorological data on real time basis, the hydraulic performance of the irrigation network, and the type of soil. It was tested in season 2017 on potato grown in the Bekaa valley of Lebanon, and the results revealed that the model could constitute a promising tool for irrigation scheduling with a "good" simulation of the soil water balance. There is an increasing demand for friendly-use platforms in the agricultural sector, like Bluleaf, that should be able to provide relevant information for farmers by means of various types of sensors. Additionally, these applications could be used as reliable traceability records of farm activities, what is increasingly demanded by the market. Finally, Bluleaf structure allows being easily adapted to other crops or production conditions. Further research is needed to test and adapt the tool to local conditions.

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EFFECT OF *CHLORELLA VULGARIS* ON SWISS CHARD (*BETA VULGARIS L.* VAR. *CICLA*) GROWTH PARAMETERS AND YIELD

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Abstract

Swiss chard (*Beta vulgaris L.* var. *cicla*) is a leafy vegetable which is grown in Serbia mainly in home gardens on smaller areas. It is highly valued for its nutrient composition, resistance to low temperatures, pests and for its high yield. Microalgal application in plant production could improve quantity and quality properties of the crop but also its aroma and flavor. In this research, foliar application of three *Chlorella vulgaris* strains on Swiss chard growth parameters (average leaf number, leaf length, weight per leaf, total weight per plant and average yield per treatment) were investigated. The highest yield (60.91 t ha^{-1}) was achieved by application *C.vulgaris* strain 63. This strain proved to be the most effective for the majority of morphological parameters such as average leaf number, weight per leaf and total weight per plant (15.7, 29.9 g $leaf^{-1}$ and 454.6 g $plant^{-1}$, respectively). *C. vulgaris* strains 71 also proved as a potentially good plant growth promoter. According to the obtained results, *C. vulgaris* based fertilizers could substitute conventional fertilizer in terms of achieving high Swiss chard yield.

Keywords: leafy vegetables, Swiss chard, *Chlorella sp.*, yield.

INTRODUCTION

Swiss chard (*Beta vulgaris L.* var. *cicla*) belongs to the *Chenopodiaceae* family. Although little is known of the origin and geographic distribution of Swiss chard, in some countries (mostly Africans) it is one of the most commonly grown leafy vegetable (Grubben and Denton, 2004). Producers favor Swiss chard over spinach for its robust habitus and fast growth during the summer months while consumers prefer Swiss chard for its lower price and considerably higher value for most of minerals, except for Ca, K, Fe, Mn, Zn and proteins (USDA National Nutrient Database, 2014). Swiss chard (*Beta vulgaris L.* var. *cicla* or *flavescens*) is considered a good source of fiber, betalains, flavonoids, b-carotene, vitamin K, and minerals like potassium and magnesium (Gamba et al., 2020). Swiss chard is a species with short vegetation period often recommended for growing as forecrop or aftercrop in crop rotation in order to extend the period of market supply from early summer to autumn months (Kolota et al., 2010).
Organic and sustainable agriculture give priority to the application of non-synthetic chemicals and bioproducts to control pathogens and to increase soil fertility (Bileva, 2016). As an alternative to commercial fertilizers, a considerable number of new products and fertilization techniques had been developed. Application of compost, different organic and

microbial fertilizers aim to promote sustainable agricultural practices which are favorable to the environment and also improve the nutritional quality of the final products (Helmy, 2018; Ortiz-Moreno et al., 2020). Microbial fertilizers are products containing living microorganisms or substances of microbial origin that can improve soil chemical and biological properties, stimulate plant growth, and restore soil fertility (Rongachner, 2012). Microalgae and their positive effects on plants properties are getting more attention in recent years. Algalization is a novel method that was investigated for their effect on improving growth and productivity of different crops and on managing soil health. Various algal species can be used, but *Chlorella spp.* based products are the most frequent. Application of these products can improve soil physical properties, increase the nutrients available for plants, and produce substances that promote plant development (Helmy, 2018; Ortiz-Moreno et al., 2020).

Elhafiz et al. (2015) found that living cells of *Chlorella vulgaris,* distributed with irrigation water on lettuce, cucumber, rice and eggplant may be a promising sustainable biofertilizer, in terms of both plant dry weight and chlorophyll content. According to La Bella et al. (2021) all the morphological traits (fresh and dry weight, height and number of leaves) of lettuce seedlings were strongly affected by *C. vulgaris* extract applied foliarly. Moreover, the enzyme activity, protein and pigment content were increased as well. Other authors reported increase in soil enzymatic activity treated with living microalgae or their extract (Ronga et al., 2019). Soil treated by *C. vulgaris* and *Scenedesmus quadricauda* positively affected the soil biological activity and the growth of tomato plants. *C. vulgaris* living cells proved to be the best treatment and showed an increase of 4.3 fold higher dehydrogenase activity than the untreated soils. Results of Vig et al. (2012) found that corn treated by fertilizers containing *Chlorella sp.* extract, living cells, and powdered cells, respectively achieved higher average yield than the control treatment.

Therefore, the aim of this study was to evaluate and compare three strains of *C. vulgaris.* on Swiss chard growth by monitoring various morphological traits in field conditions.

MATERIALS AND METHODS

Study site and soil properties

The experimental field is located at 45°24' N latitude, 19°59' E longitude and at an altitude of 86m above sea level. A 30 m^2 of experimental plot was used (4m^2 per treatment). Agrochemical analysis of soil samples showed adequate conditions for plant growth. Soil had neutral to slightly alkaline pH reaction (7.09 to 7.88), with medium content of total carbonates (5.07% $CaCO_3$), rich in humus (3.77%). Total nitrogen (N) content was high (0.19%), phosphorus (P_2O_5) content was 188.05% and potassium (K_2O) 166.62%.

Meteorological properties

Meteorological parameters (RHMSS, 2019) during the growing season are shown in Table 1 and Graph 1. Environmental conditions for Swiss chard production were favorable.

Table 1. Average monthly values of meteorological parameters (RHMSS, 2019)

Meteorological parameters	April	May	June	July	August	September
T average (°C)	13.4	14.7	23.2	23.3	24.4	18.2
T max (°C)	30.5	25.4	33.9	35	37	33.9
T min (°C)	2.6	3.8	13.5	11	11.6	3.6
Rainfall (mm)	54.1	147.5	63.7	21	79.1	53.1
Rainfall days	7	17	9	4	6	8

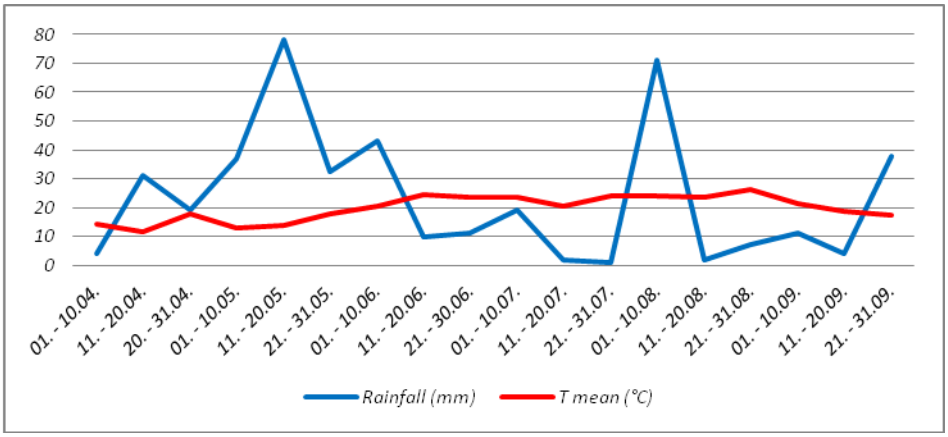

Figure 1. Mean daily temperature (°C) and rainfall (mm)

Microalgae isolate and culture conditions

Three soil microalgae (*Chlorella vulgaris* strains 45, 63, 71) from Algae Collection, Faculty of Agriculture, University of Novi Sad, Serbia were used in field experiment. Algal strains were multiplied in BG11 medium (Waterbury and Stanier 1981). Growth was carried out as batch cultures (Fig. 1) with a volume of 500 ml in 800 ml glass flasks at room temperature (24±2°C), controlled light:dark photoperiod 12:12 and a light intensity 100µmol photons m^2s^{-1}.

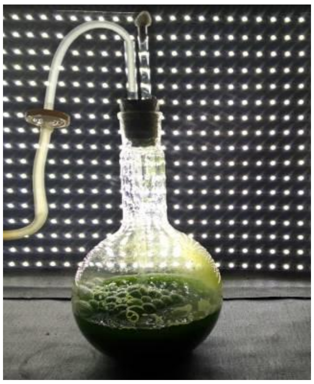
Figure 1. Algal batch culture in front of LED panel

Aeration was enabled using air pump and cellulose syringe filters with pore size 0.22μm to prevent contamination. Two weeks later, the obtained algal biomass was used to prepare 5% algal cell suspension mixture with sterile distilled water (dH_2O) for each strain, respectively. The treatments were: 1. Control (H_2O), 2. *C. vulgaris* strain 45 (C45), 3. *C. vulgaris* strain 63 (C63), 4. *C. vulgaris* strain 71 (C71).

Sowing and planting

Swiss chard (NS seme, cultivar Silver green) seeds were sown in April. The seeds were sowed in rows spaced 30 cm apart (Echer et al., 2012). The depth of sowing was up to 2 cm. Two weeks later, plants were thinned within the rows to a spacing of 25 cm. Thinned plants were then used for transplanting in order to fill any gaps where necessary. Plant density was 20 plants m^{-2} (200.000 plants ha^{-1}). Ten weeks after sowing, the outer leaves were large enough to be harvested. To eliminate non uniformity before the algal treatments, plants were adjusted to the same leaf number and leaf length. The young leaves were treated with 5% microalgal suspension (strain 46, 63 and 71), respectively by foliar spraying. Plants in the control treatment were watered. Seven days later, yield component were measured. Total number of algal treatments during growing season was three (July, August and September). Average leaf number, leaf length, weight per leaf, total weight per plant were measured using scales and ruler during vegetation (7 days after spraying, respectively).

Average yield (equation 1) per treatment was calculated using following formula:

$$Y = N * y \tag{1}$$

Where: Y – yield (t ha^{-1}); n - average number of plants ha^{-1}; y - average yield per plant in tons (10 plants per plot).

Statistics

Experimental design was developed according to the Fisher (1990). Randomized block design was used to minimize the effect of experimental error. Each block had 4 repetitions on the study site. Average values and standard deviations were calculated for each replicate. Data processing (Fisher LSD test) was performed to compare the results between treatments at $P > 0.05$ using R program (version 4.0.2).

RESULTS AND DISCUSSION

The foliar treatments of Swiss chard plants by *C. vulgaris* suspensions affected the plant yield traits as shown in Tables 2 and 3.

Growth parameters of Swiss chard plants subjected to foliar algal treatments were presented in Table 2. Data of the experiment indicated high differences in growth parameters of Swiss chard between treatments and the untreated control. However, strain C63 proved to be the most effective for the majority of morphological parameters (average leaf number, weight per leaf and total weight per plant). In September, average leaf number, leaf length and weight per leaf compared with control were increased up to 57, 105.32, and 260.24%, respectively. Meanwhile, C71 significantly increased leaf length by 91.78% related to the control treatment.

Table 2. Swiss chard growth parameters

	Average leaf number (No plant^{-1})		
Treatments:	july	august	september
H_2O	6.3 ± 0.80 bc*	8.1 ± 1.43 c	10.0 ± 0.88 c
C45	7.2 ± 0.26 b	8.6 ± 1.02 c	10.2 ± 0.51 c
C63	9.7 ± 1.47 a	10.2 ± 1.55 b	15.7 ± 0.80 a
C71	9.8 ± 0.86 a	12.0 ± 1.13 a	11.8 ± 0.51 b
LSD test	1.19	2.69	0.82
	Average leaf length (cm plant^{-1})		
Treatments:	july	august	septermber
H_2O	18.901 ± 1.33 c	18.773 ± 0.88 c	18.819 ± 0.45 d
C45	29.502 ± 0.98 b	29.577 ± 0.82 b	29.62 ± 0.70 c
C63	31.224 ± 1.79 ab	29.937 ± 0.25 b	38.586 ± 3.14 a
C71	32.739 ± 2.17 a	33.966 ± 0.80 a	36.092 ± 2.11 b
LSD test	1.5	0.86	2.27
	Average leaf weight (g leaf^{-1})		
Treatments:	july	august	september
H_2O	16.5 ± 1.51 c	13.0 ± 0.69 c	8.3 ± 1.02 d
C45	21.2 ± 1.84 b	19.2 ± 1.55 b	19.9 ± 0.42 c
C63	26.6 ± 3.92 a	24.8 ± 2.62 a	29.9 ± 2.01 a
C71	27.3 ± 2.87 a	26.0 ± 0.87 a	23.2 ± 1.28 b
LSD test	3.35	1.92	1.53
	Total leaf weight (g plant^{-1})		
Treatments:	july	august	september
H_2O	103.4 ± 9.11 c	104.2 ± 9.85 c	83.2 ± 7.32 d
C45	151.4 ± 11.86 b	163.3 ± 5.95 b	203.6 ± 14.28 c
C63	248.5 ± 15.40 a	243.5 ± 14.21 a	454.6 ± 32.36 a
C71	246.9 ± 10.37 a	247.7 ± 3.69 a	264.2 ± 25.14 b
LSD test	20.0	15.58	25.67

**Different letters in subscripts indicate statistically significant difference according to Fisher LSD test ($p<0.05$)*

These findings are in accordance with La Bella et al. (2021), who also found that a *C. vulgaris* extract applied foliarly stimulated lettuce leaf number by 22.7%, shoot height by 21.48% and shoot fresh weight by 23.35%. *C. vulgaris* living cells increased weight of banana plants (corm) and number of banana leaves in comparison to control by 17.72 and 4.17%, respectively. Besides productivity, *C. vulgaris* had a positive effect on banana crops quality (Hamouda and El-Ansary, 2017). Results of Vig et al. (2012) also suggested positive effect of *Chlorella spp.* living cells based fertilizers on corn yield. This fertilizer (commercial product Natur plasma) improved corn yield and grain number per plant by 26.43 and 56.38%, respectively. Bileiva, (2016) found positive impact of *Chlorella vulgaris* on grape seedlings (cv. *Cabernet Saugvinon*). A 1g of *C. vulgaris* dry extract improved plant height and fresh weight by 63.11 and 55%, respectively.

The highest average yield (60.91 t ha^{-1}) was achieved by foliar application of strain C63 (Table 3). Achieved results were in accordance to the findings of Kolota et al. (2010). They obtained Swiss chard total yield of about 65 t ha^{-1}, while Topalović et al. (2018), using only chemical N fertilization achieved approximately 32 t ha^{-1} with four harvests. These results suggest that all tested algae strains applied as living cells increased agricultural productivity of Swiss chard.

Table 3. Average yield of Swiss chard per treatment (t ha^{-1})

Treatments	July	August	September
H_2O	20.72 ± 1.82 c*	20.85 ± 1.97 c	16.63 ± 1.46 d
C45	30.47 ± 2.37 b	32.70 ± 1.19 b	40.75 ± 2.86 c
C63	49.98 ± 3.08 a	48.69 ± 2.84 a	60.91± 6.47 a
C71	49.30 ± 2.07 a	49.50 ± 0.74 a	52.65± 5.03 b
LSD test	2.8	2.18	5.13

**Different letters in subscripts indicate statistically significant difference according to Fisher LSD test (p<0.05)*

Chlorella sp. based fertilizers are especially focused on foliar nutrition, since they have high levels of vitamins, amino acids, and hydrolyzed form enzymes, that can be incorporated through stomas. These formulations are mainly oriented to crops with high added-value such as flowers or medicinal plants (Ortiz-Moreno et al., 2020) but also in vegetable production. Based on the results, it could be assumed that *Chlorella sp.* based fertilizers are able to substitute conventional fertilizers in terms of achieving high yields of Swiss chard. Because of this feature, *Chlorella sp.* suspension can be considered as a promising growth promoter (Alvarez et al., 2021).

CONCLUSION

The highest yield (60.91 t ha^{-1}) was achieved by application of *C. vulgaris* strain 63. This strain proved to be the most effective regarding morphological properties as well. The average leaf number, weight per leaf and total weight per plant were 15.7, 29.9 g $leaf^{-1}$ and 454.6 g $plant^{-1}$, respectively. Positive effects of *C. vulgaris* strains on morphological properties of Swiss chard indicated that all of investigated strains (C45, C63 and C71) could be good potential growth promoters.

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FUNGAL MICROBIOME OF FOREST SOIL: A HIDDEN MICROCOSMOS UNDER BLUEBERRY ROOTS

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Abstract

Soil fungi are crucial component of ecosystem biodiversity, stability and health. They play an irreplaceable role in energy streaming, nutrient cycling, organic matter mineralization and degradation, and the establishment of symbiotic and pathogenic interactions with plants. Together with bacteria residing in soil, they build a micro basis for plant growth, development, functioning, and productivity of the whole ecosystem. Natural forest ecosystems provide a unique perspective for the study of the soil microbiota. Those ecosystems are less exposed to anthropogenic impact compared to planted forests or agricultural soils. A great microbial diversity observed in them is a key to improve soil health and biogeochemical cycles. Realizing the importance of this, the aim of this study was to examine fungal diversity of natural forest soil. Soil samples used for microbiome analyses were taken from area settled in Nature Park Golija (Ivanjica, Serbia) covered with mixed beech-fir-spruce forests (*Piceo-Fago-abietetum*) and blueberry shrubs (*Vaccinium myrtillus* L.). Soil samples were mixed with DNA/RNA Shield (Zymo Research, Irvine, CA), which is a preservative of the genetic integrity of the sample. Soil samples are subjected to analysis by the ZymoBIOMICS® Targeted Sequencing Service for Microbiome Analysis (Zymo Research, Irvine, CA). The results showed that *Ascomycota* are the most present (53.80%), followed with *Basidiomycota* (27.60%), and *Mucoromycota* (6.50%). The share of unassigned category is 10.30%. Within the *Ascomycota* group *Leotiomycetes* are dominant (29.90%). This class is consisted of ecologically diverse representatives who form mycorrhiza, colonize inner tissues of roots and leaves, and act as a plant and mammals pathogens. Among *Leotiomycetes* 12.80% are *Helotiales*. Order *Helotiales* is related to *Vaccinium* sp. and mainly consisted of fungi which form ericoid mycorrhiza, crucial for *Ericoidaceae* accommodation to low pH value and low organic matter transformation. Within the *Basidiomycota* group *Agaricomycetes* are dominant (24.80%) with *Agaricales* and fam. *Clavariaceae* as the most present. *Mucoromycota* share is 6.50% and those fungi are very important in ecosystem functioning since the majority is involved in mineralization of very complex organic matter (pectin, hemicelulose, lipids, proteins). Those fungi are pioneers in ecological succession processes of different substrates. *Mucoromycota* establish a wide range of interactions, from useful to pathogenic, with their green hosts. Among them class *Mortierellomycetes* are mainly present in rhizosphere while *Glomeromycetes* are well-known as the widespread arbuscular mycorrhizal fungi. Obtained results show that better microbiome understanding may open new possibilities and rise usage of useful plant-microbe interactions in forestry and agriculture.

Keywords: natural forests, blueberry, soil microbiome, *Ascomycota*, *Basidiomycota*, *Mucoromycota*

INTRODUCTION

The growing world population emphasise the imperative of higher yields while global pollution demands crucial changes in conventional agriculture. One of the carriers of those changes are „solutions from nature" and soil microorganisms emerged as eco-friendly alternative to mineral fertilizers and chemical plant protection. The seek is intensified resulting in numerous data on new, multitraits microbes with the ability to promote plant growth (Morvan et al., 2020). In that context, analyses of the microbiome gained special importance. Microbiome analyses provide insight into the zone close to a plant, considered as a potential reservoir of microorganisms for better crop management (Bhatt et al., 2020). A better acquaintance with the rhizosphere microbiome is considered the basis for managing the rhizosphere to benefit the plants (Mohanram and Kumar, 2019).

Due to every present anthropogenic influence, the composition of microbial communities is more or less modified. On the other side, natural forest ecosystems provide a unique perspective for the study of the soil microbiota since those ecosystems are less exposed to anthropogenic impact compared to planted forests or agricultural soils. Forest microbiome and total microbial activity are highly dependent on plant species (Augusto et al., 2015; Baldrian, 2017), and the influence on communities of fungi is particularly significant, while the effect on bacteria seems to be looser (Baldrian, 2017).

The European blueberry (*Vaccinium myrtillus* L.) belongs to the *Ericaceae* family and is well-known as a functional, healthy food with high potential in the pharmaceutical industry (Pires et al., 2020). The members of this family grow in moist forests on acidic soils, with slow litter decomposition and low N and P availability (Morvan et al., 2020). The association with ericoid mycorrhizae (EM) fungi is crucial for *Vaccinium* sp. accommodation to such conditions (Li et al., 2020). These fungi form a network around the root, penetrate and form coils in the cells (Morvan et al., 2020). On the other side, *V. myrtillus* reduced environmental adaptability make cultivation extremely difficult and those berries are mainly obtained from wild plants (Pires et al., 2020).

The objective of this study was to characterize the fungal communities in the rhizosphere of *V. myrtillus* by identifying the most abundant taxa. A better insight into microbial communities may help to overcome the cultivation issues. Also, the presented work is the starting point of broad research aiming to map micro-communities of non-disturbed or soils exposed to a low level of anthropogenic influence.

MATERIALS AND METHODS

Soil sampling

Soil sample used for microbiome analyses was collected from area settled in Nature Park Golija (Ivanjica, Serbia) covered with mixed beech-fir-spruce forests (*Piceo-Fago-abietetum*) and the European blueberry shrubs (*Vaccinium myrtillus* L.). The separation of the rhizosphere soil from the blueberry roots was done according to Schlaeppi et al. (2014) with modification. The roots were cut in 3-cm long segments and placed in 100 ml of sterile PBS solution (NaCl 8.1 g/L, KCL 0.2 g/L, Na_2HPO_4 g/L), homogenized on a shaker (Biosan, Latvia) at 180 rpm/min for 20 min. After removing root segments, the remaining suspension was centrifuged for 20 min at 4000 rpm/min (5804R, Eppendorf, Germany). The obtained rhizosphere sample that formed pellet after centrifugation was resuspended in DNA/RNA Shield (Zymo Research, Irvine, CA) in ratio 1:10 to preserve soil DNA prior to microbiome analysis.

Microbiome analysis

The ZymoBIOMICS® Targeted Sequencing Service was used for Microbiome Analysis (Zymo Research, Irvine, CA). DNA extraction was performed by ZymoBIOMICS®-96 MagBead DNA Kit (Zymo Research, Irvine, CA). OneStep™ PCR Inhibitor Removal Kit (Zymo Research, Irvine, CA) was used to remove PCR inhibitors. *Quick*-16S™ NGS Library Prep Kit (Zymo Research, Irvine, CA) was used for DNA samples preparation. Primer set used for amplification was: ZymoBIOMICS® Services ITS2 Primer Set (Zymo Research, Irvine, CA). The final library was sequenced on Illumina® MiSeq™ with a v3 reagent kit (600 cycles). The sequencing was performed with 10% PhiX spike-in. Unique amplicon sequences were inferred from raw reads using the Dada2 pipeline (Callahan et al., 2016). Chimeric sequences were also removed with the Dada2 pipeline. Uclust from Qiime v.1.9.1 (Caporaso et al., 2010) and internally designed Zymo Research 16S Database were used for taxonomy assignment. A taxonomy that has significant abundance among different groups was identified by LEfSe (Segata et al., 2011).

RESULTS AND DISCUSSION

Obtained microbiome results showed that the most abundant phyla in *V. myrtillus* rhizosphere are *Ascomycota*, *Basidiomycota*, *Mucoromycota*, and *Rozellomycota* while a large portion (10.30%) goes on unassigned category (Figure 1).

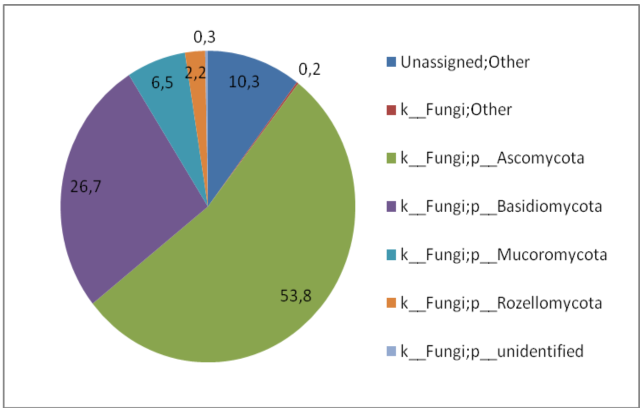

Figure 1. Fungal community composition at phylum level, based on ITS sequences (relative abundance in %)

Li et al (2020) reported a similar phyla composition of *V. virgatum*, *V. corymbosum*, and *V. darrowii* rhizosphere. The differences are visible in relative abundances of the same phyla. The presence of *Ascomycota* detected in our study was much lower (53.80%) in comparison to 72.40% reported in the rhizosphere communities of those blueberry species (Li et al., 2020). On the other side, soil tested in our study contained two-fold times higher number of *Basidiomycota*. Yurgel et al. (2017) reported the same composition of fungal phyla in the blueberry fields, *Ascomycota*, *Mucoromycota* and *Basidiomycota* but relative abundance was much lower compared to results of our study, 21, 2, and 1%, respectively.
Representatives of *Ascomycota* are well-known for the formation of ericoid mycorrhizae which have an important role in blueberries adjustment to soils with low fertility, promote N and P uptake and alleviate drought stress (Yurgel et al., 2017). The *Basidiomycota* improve plant growth by mineralization of lignin-rich residues (Vohnik et al., 2012), while the majority of *Mucoromycota* are involved in mineralization of very complex organic matter (pectin, hemicellulose, lipids, proteins). *Mucoromycota* establishes a wide range of interactions, from useful to pathogenic with their green hosts and represent pioneers in ecological succession processes of different substrates (Spatafora et al., 2016).
At the class level the communities of *Leotiomycetes*, *Agaricomycetes*, *Eurotiomycetes*, *Mortierellomycetes*, and *Sordariomycetes* dominated (Table 1).

Table 1. Classes-level of fungi in blueberry soil with relative abundance > 0.5%

Phylum	Class	Relative abundance (%)
Ascomycota	Dothideomycetes	3.10
	Eurotiomycetes	13.50
	Geoglossomycetes	0.60
	Leotiomycetes	29.90
	Sordariomycetes	4.70
	Xylonomycetes	0.70
	Unidentified	0.80
Basidiomycota	Agaricomycetes	24.80
	Tremellomycetes	1.30
	Mortierellomycetes	5.20
	Umbelopsidomycetes	0.80
Rozellomycota	Rozellomycotina	2.20
Other	Other	10.50

A similar class level composition was reported by Li et al. (2020) at *V. virgatum*, *V. corymbosum*, and *V. darrowii* rhizosphere. The differences are reflected in the presence of *Rozellomycotina* in soil from Golija while *Archaeorhizomycetes* and *Saccharomycetes* detected by Li et al. (2020) were not present in our study. Two classes, *Leotiomycetes* and *Agaricomycetes* make up more than one half of the fungi community. *Leotiomycetes* and *Sordariomycetes* have ecologically diverse representatives who play a diverse role in the ecosystem, from plant pathogens to mycorrhizal fungi (Bizabani and Dames, 2015; Yurgel et al., 2018). Also, *Sordariomycetes* are marked as plant-influenced species in the wild blueberry rhizosphere (Yurgel et al., 2018). Yurgel et al. (2018) noted *Leotiomycetes*, as one of the leading hub taxa, suggesting an important role of these microorganisms in soil fertility and mediation between soil and plant. The same authors also characterized *Geoglossomycetes* as hub taxa and their share in the studied rhizosphere was 0.60% (Table 1).

Glomeromycetes the widespread arbuscular mycorrhizal fungi are characterized as potassium solubilizing fungi (Devi et al., 2020) and their relative abundance in *V. myrtillus* rhizosphere is 0.10%.

The order level report emphasizes the presence of *Chaetothyriales*, *Helotiales*, and *Agaricales* with relative abundance higher than 10% (Table 2).

Among them, *Agaricales* were the most present (23.90%). Among *Leotiomycetes* 12.80% are *Helotiales*. Order *Helotiales* mainly consists of fungi that form ericoid mycorrhiza (Morvan et al., 2020). Beside already mentioned orders, a significant portion of the fungal community goes on *Mortierellales*, *Hypocreales*, *Pleosporales*, and *Eurotiales*. Rhizosphere microbiome of *V. angustifolium* and *V. myrtilloides* showed similar composition at this level, *Helotiales* (16.90%), and *Chaetothyriales* (13.50%) and *Agaricales* (11.50%) with the exception of *Valsariales* (15.00%) which presence was not recorded in the presented study (Morvan et al., 2020). *Helotiales* and *Chaetothyriales* are already recognized as the most abundant orders in *Ericaceae* microbiomes (Lukešová et al., 2015).

Table 2. Orders in blueberry soil with relative abundance > 0.5%

Class	Order	Relative abundance (%)
Dothideomycetes	Capnodiales	1.00
	Pleosporales	2.00
Eurotiomycetes	Chaetothyriales	11.50
	Eurotiales	2.00
Geoglossomycetes	Geoglossales	0.60
Leotiomycetes	Helotiales	12.80
	unidentified	16.80
Sordariomycetes	Hypocreales	2.80
	Sordariales	0.80
	unidentified	0.90
Xylonomycetes	GS34	0.70
Agaricomycetes	Agaricales	23.90
	Sebacinales	0.50
Tremellomycetes	other	0.60
	Filobasidiales	0.70
Mortierellomycetes	Mortierellales	5.20
Umbelopsidomycete	Umbelopsidales	0.80
Rozellomycotina	GS11	2.20

The highest relative abundance goes on fam. *Clavariaceae* (22.60%) within the *Basidiomycota* group (Table 3).

Interestingly, this family had an increased abundance (60%) in the lowbush blueberries' microbiome treated with prothioconazole (Loyd et al., 2021). *Clavariaceae* is followed by *Herpotrichiellaceae*, *Mortierellaceae*, and *Hyaloscyphaceae*. Particularly representatives of the *Clavariaceae* family together with *Geoglossaceae* are marked as endangered due to habitat loss (Griffith et al., 2013).

Table 3. Families of fungi in blueberry soil with relative abundance > 0.5%

Order	Familly	Relative abundance (%)
Capnodiales	Cladosporiaceae	1.00
Pleosporales	other	0.50
	Melanommataceae	1.10
Chaetothyriales	other	1.90
	Herpotrichiellaceae	5.20
	unidentified	4.30
Eurotiales	Aspergillaceae	2.00
Geoglossales	Geoglossaceae	0.60
Helotiales	other	0.60
	Hyaloscyphaceae	3.70
	Leotiaceae	0.50
	unidentified	7.70
unindentified	other	0.80
	Myxotrichaceae	1.20
	Pseudeurotiaceae	3.30
	unidentified	11.50
Hypocreales	Clavicipitaceae	0.60
	Hypocreaceae	1.10
Sordariales	other	0.50
Agaricales	Clavariaceae	22.60
	Tricholomataceae	0.80
Filobasidiales	Piskurozymaceae	0.70
Mortierellales	Mortierellaceae	5.20
Umbelopsidales	Umbelopsidaceae	0.80
GS11	unindentified	2.20

In consistence to family composition, the most abundant gender in the microbiome of *V. myrtillus* is *Clavaria* sp. (18.40%) followed with *Mortierella* sp., *Leohumicola* sp., *Camarophyllopsis* sp., *Penicillium* sp., *Hyaloscypha* sp., *Oidiodendron* sp., and *Chalara* sp. (Table 4).

Table 4. Genders of fungi in blueberry soil with relative abundance > 0.5%

Familly	Gender	Relative abundance (%)
Cladosporiaceae	Cladosporium	0.90
Melanommataceae	other	1.10
Herpotrichiellaceae	unidentified	5.10
Aspergillaceae	Penicillium	2.00
Geoglossaceae	Trichoglossum	0.50
Hyaloscyphaceae	other	1.40
	Hyaloscypha	1.50
	Lachnum	0.60
Leotiaceae	Pezoloma	0.50
Myxotrichaceae	Oidiodendron	1.20
Pseudeurotiaceae	other	3.30
Hypocreaceae	Trichoderma	0.90
Clavariaceae	Camarophyllopsis	3.50
	Clavaria	18.40
Tricholomataceae	Pseudotricholoma	0.80
Mortierellaceae	Mortierella	5.20
Umbelopsidaceae	Umbelopsis	0.80
Unindentified	Chalara	1.10
Unindentified	Leohumicola	4.50

The targeted sequencing of obtained DNA sample revealed the presence of several genera of ericoid mycorrhizal fungi, *Clavaria* sp., *Hyaloscypha* sp., *Oidiodendron* sp., *Lachnum* sp. and *Pezoloma* sp. in the rhizosphere of *V. myrtillus*. Those fungi are in charge of nutrients supply and the utilisation of organic complexes as a source of mineral nutrients (Kariman et al., 2018). The presence of above-mentioned genders in the analyzed microbiome is not a surprise, just a justification of universal pattern related to *Vaccinium* sp. or *Ericaceae* microbial communities.

Eleven species belonging to the *Ascomycota* were identified (Table 5). It is already mentioned that *Helotiales* harbors numerous EM fungal species and one of them; *P. ericae* is identified as a member of the screened microbiome. Talking about EM fungi, particularly this organism was the first species that has been isolated and identified (Morvan et al., 2020). Associations of *Ericaceae* with the *P. ericae* enable successful establishment on soils with slow rates of decomposition and extremely limited N and P (Kowal et al., 2016). *Oidiodendron* sp. represented in *V. myrtillus* rhizosphere with *O. maius* and *O. griseum*, form the typical EM structure in the root cells (Morvan et al., 2020). *O. maius* is one of the most researched EM fungi in charge of exchange of nutrients in the roots of ericaceous plants (Wei et al., 2016). Inoculation of *Rhododendron fortunei* with *O. maius* OM 19 resulted in significantly higher content of total N and dry weights in comparison to the control seedlings, implying its potential for growth promoting of *Rhododendron* and possibly *Vaccinium* sp. or other ericaceous plants (Wei et al., 2016).

Recently it was confirmed that *O. maius* protect host plants from high concentrations of heavy metals toxicity (Daghino et al., 2016).

Table 5. Species of fungi in blueberry soil

Gender	Species	Relative abundance (%)
Penicillium	Penicillium daleae	0.20
	Penicillium javanicum	0.30
	Penicillium simplicissimum	0.10
	Penicillium swiecickii	0.10
Trichoglossum	Trichoglossum walteri	0.40
Pezoloma	Pezoloma ericae	0.50
Coccomyces	Coccomyces australis	0.10
Oidiodendron	Oidiodendron griseum	0.10
	Oidiodendron maius	0.70
Acremonium	Acremonium persicinum	0.10
	Acremonium spinosum	0.10
Hygrocybe	Hygrocybe cantharellus	0.10
Neohygrocybe	Neohygrocybe ingrata	0.30
Mortierella	Mortierella elongata	0.20
	Mortierella exigua	0.50
	Mortierella globulifera	0.20
	Mortierella minutissima	3.10
	Mortierella pseudozygospora	0.20

Targeted sequencing of *V. myrtillus* rhizosphere revealed the presence of *T. walteri* which is on The IUCN Red List of Threatened Species (Jordal, 2019). This fungus is characterized as rare in Europe with a major habitat decrease (90%) over the last 8 decades

(Griffith et al., 2013). Its presence is reported all over Europe but, according to Jordal (2019) there is no data on its distribution in Serbia or Balkan.

Penicillium gender is characterized as essential for plant growth promotion and protection, and it is within K solubilizing fungi group (Devi et al., 2020). Also, *P. simplicissimum* is marked as Zn solubilizing microorganism (Devi et al., 2020) while *P. daleae* EF4 expressed antimicrobial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa* (Iswarya and Ramesh, 2019). *P. javanicum* caused growth suppression of significant crop pathogens, *Macrophomina phaseolina*, *Rhizoctonia solani*, *Fusarium solani* and *F. oxysporum* simultaneously promoting the growth of sunflower (Urooj et al., 2018).

Two species belonging to the *Basidiomycota* phylum, *Hygrocybe cantharellus* and *Neohygrocybe ingrate* were identified as members of the studied rhizosphere (Table 5). Both species belong to a vulnerable category at The IUCN Red List of Threatened Species (Kautmanova et al., 2015; Kadarev, 2021) and, to our knowledge, this is the first-time record that *N. ingrate* is distributed in Serbia.

Fungi residing in rhizosphere represent a crucial component of ecosystem biodiversity, functioning, stability and health. They are included in energy streaming, nutrient cycling, organic matter mineralization and degradation, and the establishment of symbiotic and pathogenic interactions with plants. The fact that approximately 75% of all N and P acquired by plants are provided by nitrogen-fixing bacteria and mycorrhizal fungi illustrates the significance of microbial communities (Baldrian, 2017). Still, a lot is unknown related to microbiome composition and a better understanding may represent a basis for a new way of exploitation of beneficial microorganisms and plant-microbe interactions in agricultural production.

CONCLUSION

Our results revealed the presence of various EM fungi in the analyzed rhizosphere. Like other *Ericaceae*, *V. myrtillus* rely on microorganisms which facilitates the growth in nutrient-poor conditions and some of the detected organisms are already known as N, P, K, Zn suppliers. Targeted sequencing of soil DNA sample revealed the presence of several species at The IUCN Red List such as *T. walteri*, *H. cantharellus* and *N. ingrate*. The fact that a lot of DNA was unassigned/unidentified confirms how much is still unknown related to micro-world and how big potential is hidden under blueberry roots.

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IMPACT OF NATURE BASED SOLUTIONS FOR FLOOD RISK MANAGEMENT ON SOIL AND AGRICULTURAL DEVELOPMENT - EU CONSIDERATION AND SERBIAN PROSPECTIVE

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Abstract

Throughout history, floods have played one of the most important roles in soil formation, maintenance and modification of soil fertility. Flooding of rivers left mud full of organic matter in the fields, salts were washed out of the soil, and a large amount of water was retained in the soil profile. Urbanization on the banks of rivers, regulation of water flow, and construction of dams for flood control narrowed river beds and increased hydraulic flow, resulting in greater concentration of flood waves during floods and shortened flood control times. Since the beginning of the 21st century, numerous large floods have occurred across Europe. Various climate models suggest an increase in the frequency and intensity of future flood events. Dams were built to accommodate flood waves with a return period of 50 years on smaller watercourses and 100 years on large rivers. Floods with higher return periods may or may not occur at all. In this respect, dams are no guarantee that towns and agricultural land can be successfully protected from flooding, so their enhancement is questionable. In recent decades, there has been extensive debate about the use of agricultural land for flood protection of cities and industrial areas, about the cost of land and agriculture. Since private property is involved in both cases, a compromise solution should be found that satisfies all parties. The main theme of the COST project LAND4FLOOD is to consider all aspects of flood risk management and land management, such as.: geographical, hydrological and hydraulic, ecological (soil pollution, compaction, water retention, ecological services, habitat restoration), agricultural (agricultural development in the area reserved for temporary water retention), economic (how to compensate damages or provide incentives for flood retention, public subsidies), public participation (how to ensure the participation of landowners), property rights issues (how to allow temporary flood retention and what does it mean for agricultural use) and sociological. The aim of this paper is to present some reflections on flood risk management and its implications for land and agricultural development in the EU, as well as some considerations on the implementation of the NBS in Serbia from the perspective of flood protection, land protection and agricultural development..

Keywords: Soil, Flood, Nature-based solutions, agriculture, LAND4FLOOD

INTRODUCTION

In recent decades, climate-related extreme events have increased in Europe, with hydrological events, in particular, outweighing flood risks, causing damage and placing an increasing burden on national economies (Kron et al., 2019; EASAC, 2018). Various climate models suggest an increase in the frequency and intensity of future flood events across Europe (IPCC, 2018). Dams have been built to accommodate flood waves with a return period of 50 years on smaller watercourses and 100 years on large rivers. Floods with higher return periods may or may not occur. Many European countries have already experienced severe floods on large rivers (Kundzewicz et al., 2017), as shown by this summer flood in Germany and Belgium. Therefore, dams are no guarantee that cities and agricultural land can be successfully protected from floods, which makes their valorisation questionable. In recent decades, there has been extensive debate on the use of nature- based solutions (NBS) for flood risk management, including the use of agricultural land for flood protection of cities and industrial areas at the expense of land and agriculture (Hartman et al., 2019; Bridges et al., 2021). Since private property is involved in both cases, a compromise solution should be found that satisfies all stakeholders (Thaler and Hartman, 2016; Alvarez et al., 2019). The main theme of the COST LAND4FLOOD project is to consider all aspects of flood risk management and land management, such as: economic issues (e.g., how to compensate for or incentivize flood retention services); property rights issues (e.g., how to allow temporary flood storage on private land); issues of public participation (e.g. how to ensure the involvement of private landowners) as well as issues of public subsidies (e.g., how to integrate/mainstream flood retention in agricultural subsidies). (https://www.land4flood.eu/land4flood-project/; Löschner et al., 2021; Kaufman et al., 2021; Slavíková et al., 2020). The aim of this paper is to present some considerations on flood risk management and its impact on land and agricultural development in the EU and surrounding countries, as well as some considerations on the implementation of NBS in Serbia from the perspective of flood protection, land protection and agricultural development.

NATURE BASED SOLUTIONS: IMPLICATION ON SOIL AND AGRICULTURE

Floods are natural phenomena that affect settlements, human activities and ecosystems. In order to prevent adverse effects on nature, economy and society, appropriate measures must be found and applied. Flood risk management aims to reduce the impact of floods (EEA, 2017). Ensuring risk management measures such as prevention (spatial planning so that the space reserved for flooding by the river/sea is not consumed), protection (dams and other structures, flood management) and preparedness (forecasting and communication, awareness raising, education and information, early warning) are often cited as the most effective approach in the EU and surrounding countries (Geaves and Penning-Rowsell, 2016). Although technical and engineering methods and measures still prevail in many countries, a new approach to flood management based on natural solutions (NBS) has been introduced in recent decades. These solutions for risk reduction and adaptation in river basins include Natural Water Retention Measures (NWRM), which include: Interception (retention of water in and on plants), increased transpiration of plants, enhanced soil infiltration, ponds and wetlands, and reconnection of floodplains. These measures have the potential to reduce extreme runoff, helping to offset extremes (Hartman et al., 2019). In addition, floodplain restoration is considered NBS, i.e., creating more space for the river, restoring degraded terrestrial ecosystems (grasslands, croplands, and forests), and retaining water in the upper part of the watershed.

If we look at NBS from the perspective of applicability, this means that all measures involve the use of private land for temporary water retention to mitigate the flood e for the benefit of others (mostly cities). However, some measures include improving infiltration rates by ploughing under, cross-cutting, applying farm manure to increase organic matter to improve soil structure, installing a water borehole or drainage system, and the like. Various stakeholders are involved in the implementation of these measures, such as policy makers, planners and Non-Governmental organisations, who may have different views on problems and desired outcomes (Posthumus et al., 2008). The European Commission and many academics advocate NBS, often framed positively in terms of 'solutions', 'win-win' or 'no-regret' options. However, recent articles have also criticised the NBS for promoting a utilitarian approach with neoliberal values (such as a focus on quantifiable benefits, profit, quick economic returns and growth), but ignoring inherent social and environmental inequalities and injustices, and the associated negative societal consequences (Kaufman et al, 2020), e.g., changing property values, displacing residents who can no longer afford these costs to areas with lower quality housing, ultimately increasings community segregation, etc.

A study conducted in United Kingdom on the perceptions of local stakeholders and farmers found that they can only contribute to flood risk management if landowners go beyond good agricultural practice and take measures to reduce runoff from agricultural land for the public good by implementing runoff retention measures such as water storage ponds, and they should be compensated for the additional costs involved (Posthumus et al., 2008). However, stakeholders should be informed and advised by experts on appropriate measures and establish demonstration sites that clearly show how the measures can make a difference.

In Austria, there are significant ongoing processes to shift certain flood risk management tasks and responsibilities from the national to the local level. The new policy direction underlines the importance of linking actors at the same and different levels, especially between the local and the national level. The main work of local actors relates to negotiations with private landowners for compensation agreements or purchase of farmland. Private landowners have the power to block the implementation process. However, their interest strongly depends on whether they are directly affected by flood protection measures (Thaler et al., 2017). The study site in the Aist River basin demonstrates an approach to flood risk management based on upstream-downstream relationships. Downstream communities, which are at higher risk of flooding, contribute significantly more than upstream communities, as compensation for taking land and sharing risks in a regional setting. Even when solidarity-based risk-sharing is agreed upon, there is evidence in practice that both sides benefit due to commuting relationships and economic linkages (Seher and Löschner, 2018).

Collentine and Futter (2018) highlight that many scholars suggest short-term flooding of farmland as a tool for downstream flood management because it is less costly to pay farmers for temporarily flooding of upstream land than for urban flood damage. However, it is important to determine whether changes in the management of rural land, such as blocking drains or agricultural practices such as retaining stubble that increases surface roughness and thereby slows water flow, or compacting the soil due to water pressure to increase runoff, siltation, and the like, should qualify for additional compensation or be considered part of the basic requirement to maintain the land in "good agricultural or environmental condition" required to receive the single farm payment. In addition, the authors note that the implementation of NWRM in Sweden (measures based on drainage management and short rotation coppice) may contribute to water retention but may also lead to loss of agricultural income and therefore trade-offs in the inclusion of agricultural land are necessary.

In the countries of Central-Eastern Europe such as Slovenia, social acceptance of purely green measures is limited and often meets resistance in the planning stage due to institutional path dependency related to the implementation of grey measures in the past, as well as related land use restrictions on land under nature-based solutions (Glavan et al., 2020). Due to the specific topographical and geographical characteristics in Slovenia and the high degree of urbanisation of floodplains, site-specific conditions and the impact of different measures on hydrological conditions in the catchment and consequently on flood risk need to be assessed before measures are implemented (Johnen et al., 2020).

In the Republic of Croatia, green measures have been included in recent legislation, e.g. River Basin Management Plans or National Climate Adaptation Strategy, where they are recognised as flood risk management and climate adaptation measures. Although current flood risk management measures still rely heavily on traditional 'grey' elements, there are also large-scale flood protection programmes that have integrated semi-natural retention systems and natural floodplains in the lowland areas of the country, in the Sava and Drava River basins (Potočki et al., 2021, Schwartz, 2018). NBS are also supported by payment mechanisms, e.g. in the Forest Act and Rural Development Programme, where funds are allocated for some forest management measures and for "restoration of habitats important for biodiversity conservation (e.g. meadows, pastures and ponds for livestock watering)". But this approach is not yet widely used or recognised as a useful mechanism (The Biodiversity information system for Europe, 2021, Vuletić et al., 2020).

When the Republic of Serbia became an official candidate for membership in the European Union, it had to transpose EU legislation into national law, including the principles of the EU- Water Framework Directive (WFD) and the EU Floods Directive. The EU legislation forced Serbia to prepare flood risk maps and expand its flood risk management measures by now considering, among others, nature-based solutions (NBS) (Kaufman et al., 2021). Such a method of flood management has not yet been formally adopted. Ongoing activities in the context of the implementation of the EU Flood Directive are i) the evaluation of the existing River Basin Management Plan (RBMP) development process, ii) the improvement of the knowledge and practices of Rural Water Directorate and technical bodies in relation to stress and impact analyzes, cost recovery and cost-effectiveness analyzes, and iii) the

increased involvement of the public and stakeholders in the development of elements of RBMPs.
In this context, the Water Protection Improvement Study (Study, 2020) was prepared for the case study of the Kolubara River. This river was selected due to the 2014 flood, as the existing infrastructure was not able to protect the area from the negative impacts of the flood. The aim of this study was to develop a concept for integrated flood protection, including both structural and non-structural measures: Erosion control in the catchment area, retention of water in the upper parts of the catchment area, creation of water retention areas, modernization and reconstruction of flood protection facilities and nature-based solutions. Many other activities related to the implementation of the Water Framework Directive are underway (www.srbijavode.rs; www.vodevojvodine.com).

DISCUSSION

Like the global policy framework, EU policy also supports to varying degrees the adoption and implementation of NBS (EEA Report, 2021) by enabling permanent innovation based on research and experimentation through the EU funding programme Horizon 2020 and continuing in the upcoming Biodiversity Partnership at Horizon Europe, the next EU Framework Programme (2021-2027) (European Commission, 2021). Therefore, each country applies NBS measures according to its needs and natural conditions. The work of Thaler et al. (2020) discussed the different legal frameworks for compensation in Austria and the Netherlands, and thus the different nature of compensation for land use. In many countries, compensation is paid for actual damages (yield losses) in case of floods, neglecting the fact that actual negative impacts can occur in different ways (e.g. restrictions on agricultural land in flood polders, obligation to tolerate measures related to the construction or maintenance of water protection structures). No special consideration is given to restricted agricultural development on land designated for temporary flooding. Farmers are discouraged from investing in highly profitable enterprises (greenhouses, orchards). Needless to say, land in the plains designated for flood retention of major rivers such as the Danube, Rihne, and Maine is prone to compaction and pollution from various pollutants that could prove harmful to humans in the food of animals (grazing livestock) and consequently in meat or milk. This concern about pollution was triggered by the negative impact of the 2014 floods in Serbia, which certainly degraded the quality of surface waters and all water-related ecosystems (Ristić et al., 2021; Solomun et al., 2021). Pollution risk assessments have been carried out in all affected agricultural areas and the resources required for remediation and restoration of soils have been identified for government needs (SEPA; 2014). However, the possibility that affected people could achieve environmental justice and claim a compensation fee for land rehabilitation, e.g. in small farms, is difficult to demonstrate, as scientists are cautious and dispute in certain segments that the changed condition is solely due to the floods or that different guidelines and quantitative indices have different degrees of risk (Čakmak et al., 2018; Antić Mladenović et al., 2019).
As the application of the NBS approach is long process, the use of land and compensation for loss should be based on a broader consideration, through public participation, because

we need to leave the land in the same or better condition for the new generation and currently live and work from agriculture, which means that compensation should be based on economic, environmental and social justice when land is used to mitigate the negative impacts of flooding downstream.

CONCLUSION

NBS as a complementary measure to flood defence infrastructure, with the approach *keep water where drops*, to mitigate the rapid concentration of flood waves and thus the downstream adverse effects. Each country, whether in the EU or surrounding countries such as Serbia, has specific topographical and hydrological conditions, so the implementation measure should be site-specific, as per EU policy. Serbia, as a candidate country for EU accession, is expanding its flood risk management measures taking into account the implementation of the NBS. The implementation has not been done yet, only a case study has been prepared for the Kolubara River. The main challenge in implementing the NBS is compensation for land use to achieve social, procedural and environmental justice in the interest of farmers and people and structures protected upstream. As in EU countries, the development of NBS measures in Serbia should be constantly improved, tested and researched. Land use and compensation for loss should be based on a broader consideration, through the public participation, in order to leave the land in the same or better condition for the new generation that currently lives and works from agriculture.

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MICROBIOLOGICAL-SANITARY QUALITY OF SOIL AND SAFE VEGETABLE PRODUCTION

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Abstract

The soil represents dynamic, alive resource and it is very important for food production and the functioning of ecosystems. The soil microorganisms provide its fertility and productivity but the soil also could be a reservoir of human pathogens. The most important sources of pathogens in the agroecosystem are inadequately treated manure, waste sludge, contaminated irrigation water. Vegetables, grown in contaminated soil, are a good environment for human pathogens.

The Republic of Serbia is the largest regional producer of vegetables but with increasing fresh vegetable consumption there are possibilities for contamination by soil human pathogens that can cause serious diseases. Health risks from pathogens in soil, water and food are highly dependent on their transport and survival in agroecosystems. It is known that human pathogens are able to colonize plant tissues and could be transported to edible parts of plants, so the sanitary quality of the soil is extremely important for the safe production of vegetables.

Considering that such research has not been carried out to the narrow area of the Republic of Serbia so far, the aim of this study was investigation of microbiological and sanitary quality of soils and vegetable which are produced on those soils.

The sampling of soils and vegetables was done from fields and green-houses at 6 locations of the municipality of Leskovac. The vegetable samples were: tomato, pepper and cabbage. Microbiological analyzes of soils and vegetables included the detection of total bacteria count; total and fecal coliforms; enterococci; *Pseudomonas aeruginosa*.; *Salmonella* sp.; *Escherichia coli*; *Listeria monocytogenes*; Microbiological analyzes of vegetables were done according to standard methods prescribed by the Rulebook of food hygiene of production of the Republic of Serbia.

The results of the analysis showed that 7 out of 13 vegetable samples were positive on *Salmonella* sp., which was isolated from pepper (5 samples) growing in green-house condition. *Salmonella sp*. was also found on pepper and cabbage (1 sample each) growing in the field.

The presence of *Escherichia coli* and enterococci was detected at all investigated vegetable samples, but the highest number was noticed at pepper. *Pseudomonas aeruginosa* was only detected at cabbage. The *Listeria monocytogenes* was not found out in any vegetable sample. The number of coliform bacteria in the soil ranged from 302.7 (average in greenhouses) to 372 (average in fields) MPN/gDM.

This study points out to necessity for new agricultural models which would enable high productivity with less risk for human health.

Keywords: human pathogens, vegetable, soil, coliforms, *Escherichia coli*, *Salmonella* sp.

INTRODUCTION

The basis of safe agricultural production is healthy soil which is defined as "the ability of soil to function as a living system within ecosystem boundaries, maintain or improve water and air quality, and promote plant and animal health." (Doran and Zeiss, 2000) The basic functions of healthy soil are: maintenance of biological productivity, nutritional and water cycle, decomposition of organic matter, degradation of toxic compounds, pathogen control water quality protection. The soil is a dynamic, living system whose properties are vital for food production and the functioning of the whole ecosystem. The physical and chemical components of the soil are important but living organisms ensure fertility and productivity of soil.

Soil is the main reservoir of microorganisms in nature with huge spectrum of different habitats for them. There are more than 10^9 bacterial cells which belong to different species, as well as kilometers of fungal hyphae in just one gram of soil. The soil is inhabited by a wide range of microorganisms such as bacteria, fungi, algae, viruses and protozoa. The natural characteristics of the soil have an effect of spreading indigenous and non-indigenous microbial populations to other ecosystems such as aquatic ecosystems and aerosols. These microorganisms are in various and complex mutual interactions as well as in interaction with other soil living organisms and they contribute to great biodiversity. The microbial biodiversity in the soil allows circulation of biogenic elements, pedogenesis, soil fertility, plant nutrition and soil microorganisms are included in nitrogen fixation, organic matter and waste decomposition, pesticide degradation, plant protection from pathogens, bioactive compounds production (vitamins, hormones, enzymes) which stimulate plant growth.

According to estimates of United Nations, the global human population is going to reach 8.9 billion till 2050 (Wood, 2001) and a number of environmental problems related to the nutritional needs of a growing population will increase in the future (Singh, et al., 2011). The sustainable agriculture is vital and it has the potential to supply our needs for food. It uses special techniques in order to supply food needs with environmental resources protection. The soil microbial populations are very important because they enable the fundamental processes of stability and productivity of agroecosystems (Singh, et al., 2011). Sustainable agricultural practices include the use of biofertilizers and biopesticides which contain effective microorganisms that produce bioactive substances to stimulate plant growth and protection against pathogens (Harish et al., 2009) and thus contribute to improving agriculture and environment protection. The environmental pollution from soil erosion, inadequate application of mineral fertilizers and pesticides, as well as inefficient treatment of human and animal waste is serious problem worldwide. It is concluded that these problems could be solved by application of technologies based on microorganisms. The soil microorganisms could be divided into "beneficial" or "harmful" depending on how they affect soil quality, crop growth and yield. The soil surface particles, pores, plant root surface and niches are excellent habitats for various microbial populations, whether they are free-living forms or as biofilms. Except beneficial soil microorganisms, human pathogen microorganisms may be present in these habitats. Humans are in contact with the soil through food, water and air so that contaminated soil could be a vector and source for transmission human pathogens which cause various diseases.

Although many soil-related diseases are well known, the intestinal diseases and their relationship to soil have been insufficiently studied and underestimated. Some of the outbreaks in recent years have been associated with soil such as the Campylobacter-outbreak, associated with “swallowing mud” during a mountain bicycle race in British Columbia (Stuart et al., 2010). The outbreak caused by *E. coli* O157:H7 was related to soil (probably through dirty hands with mud), in a Scottish camp that was previously used for grazing sheep (Ogden et al., 2002). The several strains of *E. coli* O157:H7 were isolated from infected child and playground where child had previous played (Mukherjee et al., 2006). The soil is a reservoir of *E. coli* O157:H7 due to its ability to replicate and survival a long time in it (Barker et al., 1999).

Fruits and vegetables are vital to human health and provide essential vitamins, minerals and plant fibers and World Health Organization (WHO) recommend eating at least 400 g of fresh vegetables and fruits a day. Fresh vegetables usually have natural, non-pathogenic, epiphytic microorganisms on the surface but during the production chain (harvesting, transport, handling) contamination with human pathogens can occur. The most of these products are consumed in raw and microbial contamination could be a risk for human health. The foodborne illnesses have changed in recent decades and more and more outbreaks are associated with contamination of fresh fruits and vegetables but leafy green vegetables stand out significantly. The World Health Organization (WHO) has identified this vegetable as the highest priority in terms of microbiological hazards. In the United States, the proportion of outbreaks associated with fresh vegetables increased from 0.7% in 1970 to 6% in the 1990s (Sivapalasingam et al., 2004). The number of outbreaks caused by pathogens on fresh products has been increasing in developing as well as developed countries (Heaton and Jones, 2008). Thus, in Croatia, out of 229 vegetable samples, the presence of enterococci was detected in 48% of samples, while *E. coli* in 37% of leafy vegetable samples, 25% of fruit vegetable samples and 31% of root vegetables (Pavić et al., 2005). In the European Union, during the 2007. *Salmonella* sp. was found out in about 0.3% of tested vegetable samples (Westrell et al., 2009). Some studies about prevention of human pathogen in fruits and vegetables were conducted in the United Kingdom, Ireland, Germany and Netherlands (Westrell et al., 2009).

Diseases related to products, water and soil are caused by different pathogens, like viruses, bacteria, protozoa (Yoder et al., 2008). The most common pathogens on fresh vegetables are *Shigella* spp., *Salmonella* spp., *E. coli*, *Campylobacter* spp., *Listeria monocytogenes*, *Yersinia enterocolitica*, *Bacillus cereus* and *Clostridium botulinum* (Beuchat, 2002).

The Strategy of agriculture and rural development of the Republic of Serbia for the period 2014-2024. ("Official Gazette of RS", No. 85/2014) were identified soil degradation, disorder of water channels, inadequate waste management system and low quality of fertilizers as the main weaknesses of agriculture which are risk for the microbiological safety of the products.

The determination of human pathogen microorganisms is relatively expensive so detection of indicator microorganisms is a good alternative. The indicator organisms survive longer than pathogens (Mubiru et al., 2000).

MATERIALS AND METHODS

Sampling of soil and vegetables was done on the territory of the municipality of Leskovac on 6 locations: Badince, Stajkovce, Batulovce, Krajince, Donje Krajince, Nomanica which are presented in Table 1. Also, it is shown type of vegetables that were sampled and its location in the table. Taking samples was done in open field and greenhouses. The vegetable samples were: tomato, pepper, cabbage.

The microbiological analyses included: total bacterial count (TBC), number of total coliforms (TC), number of fecal coliforms (FC), *E. coli* number, enterococci number, presence of *Salmonella* sp., *P. aeruginosa* and *Listeria monocytogenes*. Detection of microorganisms in soil and vegetable samples was done using appropriate nutrient media which were inoculated by direct and diluted samples.

Table 1. Locations where soil and vegetables were sampled

Location	Plant	Crop type	Coordinates
Badince	tomato	field	N 42°58'18.7" E 22°1'8.68"
	pepper		
Stajkovce	tomato	greenhouse	N 42°58'46.86" E 22°3'31.16"
	cauliflower	field	N 42°58'45.48" E 22°3'30.38"
	pepper	greenhouse	N 42°58'46.44" E 22°3'36.14"
	pepper	greenhouse	N 42°58'24.82" E 22°2'36.29"
	tomato	greenhouse	N 42°58'26.02" E 22°2'36"
	pepper	greenhouse	N 42°58'25.83" E 22°2'37.01"
Batulovce	pepper	greenhouse	N 42°58'3.15" E 22°4'5"
	cabbage	field	N 42°58'1.05" E 22°4'5.67"
Krajince	pepper	greenhouse	N 43°00'3.45" E 22°1'23.10"
	tomato	greenhouse	N 43°00'3.45" E 22°1'23.10"
	pepper	field	N 43°00'3.45" E 22°1'23.10"
	hot pepper	greenhouse	N 42°59'59" E 22°1'24.33"
	tomato	greenhouse	N 42°59'58.96" E 22°1'22.74"
Donje Krajince	pepper	greenhouse	N 42°59'34.67" E 22°1'31.44"
Nomanica	tomato	greenhouse	N 42°58'41.61" E 22°1'38.72"

Total bacterial count was determined on the soil-10x-diluted Tryptone Soy Agar (Torlak, Serbia). Dilution of samples was done in Peptone Water (Torlak, Serbia), media was inoculated and incubation was performed at 30°C, during 24 h. After incubation bacterial colonies were counted and its number was represented as CFU/gDM

Total, fecal coliforms and *E. coli* were detected using MPN method and test tubes with MacConkey Broth (Torlak, Serbia) and Durham tubes were inoculated with diluted samples. It was done in triplicate for each sample. Inoculated tubes were incubated at 37°C for detection total coliforms and 44°C for fecal coliforms during 24 h. The change of medium color and bubbles presence in Durhams indicated on bacterial present. The most probable number was calculated based on positive tubes, using the MPN table and represented as MPN/g DM (DM-Dry Matter).

Microbiological analyzes of vegetables were done according to the standard methods prescribed by the Rulebook of food hygiene of production of the Republic of Serbia. All taken vegetable samples were washed and sliced in order to obtain characteristic of ready to eat. In the protocol of preparation samples for analysis the special attention was paid to the hygienic conditions which included prevention, washing and disinfection of work surfaces and hand equipment. In this way, it prevented cross-contamination in order to get real condition of vegetables ready to eat. Each vegetable sample for microbiological analyses was divided into five units according to Rulebook of food hygiene of production of the Republic of Serbia. The 20 g of each vegetable sample was homogenized in Peptone Water and shaked at 250 rpm for 30 min. It was taken 1 ml of dilution and inoculated selective media for target bacteria. Total bacterial count was detected on Tryptone Soy Agar with incubation at 30°C for 24 h, total and fecal coliforms were determined by MPN method with incubation at 37°C and 44°C during 24 h (described above). The confirmation of *E. coli* was done using EMB agar (Biomerieux, France). Enterococci was detected using of Azide Dextrose Broth (Torlak, Serbia) for enrichment and Bile Exulin Agar (Torlak, Serbia) and incubation was done at 37°C for 24 h. It was used Citrimide Agar (Torlak, Serbia) for isolation and detection *Pseudomonas aeruginosa* with incubation at 37°C for 24h, after that it was checked appearance of typical pigmented colonies.
The presence of *L. monocytogenes* in vegetable samples was determined by the standard method EN ISO 11290-2 and for *Salmonella* sp., standard method EN ISO 6579 was applied. It was used Selenite Broth (Biomerieux, France) and SS Agar (Biomerieux, France) for *Salmonella* sp. followed by incubation at incubated at 37°C for 24 h and typical black colonies were confirmed as *Salmonella sp*. Isolation and detection of *Listeria monocytogenes* was done using Fraser Broth (Biomerieux, France) for enrichment with incubation at 37^0C for 48 h. After that, it was inoculated Palcam Agar and Tryptone Soy Yeast Extract Agar (TSYEA) (Biomerieux, France) and incubated at 37^0C in micro-aerobic condition for 24 – 48h. Presence of typical gray colonies with central depression and black zone considered as *Listeria* spp. In addition, PCR method was used for confirmation *Listeria monocytogenes* (as described Kljujev et al., 2018). After preliminary tests on selective media, all strains which belonged to genus Listeria were checked by PCR and *L. monocytogenes* ATCC 19111 was used as a positive control. The number of bacteria in soil is represented as CFU/g and MPN/100 g DM (DM- Dry Matter), and MPN/100 gFM (FM- Fresh Matter) for vegetable samples.

RESULTS AND DISCUSSION

Our results showed that total bacterial count (TBC) had different values in soil and it depends on location and kind of crop on the soil. The highest number of total bacterial count was noticed in the soil with pepper which was grown in greenhouse condition on the location Stajkovce (3.70 x 10^7 CFU/g DM). Also, the high number of these bacteria was found out in soil under the tomato which was grown in same condition and location. The smallest number of total bacterial count was detected in the soil under the cabbage grown in the open field on location Batulovce (1.28 x 10^7 CFU/g DM). Generally, it was noticed much smaller number of total bacterial count in soil of open field than in soil in greenhouse (Table 2). It is desirable that soil bacterial populations are represented in a larger number because it stimulates fundamental soil processes for stability and productivity of agricultural production (Singh, et al., 2011). Within soil bacterial populations, there is effective bacteria species that produce bioactive substances to stimulate plant growth and thus contribute to improving crop production (Harish et al., 2009).

The high number of total coliforms in soil was found under the crops grown in open field as well as soil in greenhouses. The highest number of these bacteria was detected in open field soil where pepper was grown on location Badince (1358 MPN/g DM). Also, high number bacteria were in open field soil under the tomato (112 MPN/g DM), cauliflower (289 MPN/g DM), cabbage (523 MPN/g DM), pepper (324 MPN/g DM) which were grown in different locations. The high number of total coliforms was noticed in greenhouse soil on two locations, Donje Krajince and Nomanica, where pepper and tomato were grown (333 MPN/g DM and 613 MPN/g DM). The number of total coliform bacteria in the soil ranged from 302.7 (average in greenhouses) to 372 (average in fields) MPN/g DM. The fecal coliforms was detected in all soil samples, but the smallest number was found in soil under hot pepper grown in greenhouse on location Krajince (<4 MPN/g DM). The high number of these bacteria was noticed in open field soils under tomato and pepper in Badince (112 MPN/g DM and 115 MPN/g DM), cauliflower in Stajkovce (112 MPN/g DM) and pepper in Krajince (304 MPN/gDM). The fecal coliforms were much more represented in greenhouse soils and the highest number of these bacteria was found in soils located in Batulovce 296 MPN/g DM (pepper), Donje Krajince 333 MPN/gDM (pepper) and Nomanica 613 MPN/g DM (tomato) (Table 2). The number of total and fecal coliforms is same at these three mentioned locations which indicate on fecal contamination of soil. There is a possibility that this is a consequence of the using improperly prepared manure for fertilizing.

Table 2. Total bacterial count and coliforms in soil samples

Location	Plant	TBC (x 10^7 CFU)	TC (MPN/g DM)	FC (MPN/g DM)
Badince	tomato	2.20	112	112
	pepper	1.74	1358	115
Stajkovce	tomato	1.44	111	27
	cauliflower	1.60	289	112
	pepper	2.00	118	<4
	pepper	3.34	58	58
	tomato	3.54	52	52
	pepper	3.70	29	29
Batulovce	pepper	2.61	296	296
	cabbage	1.28	523	23
Krajince	pepper	1.74	54	19
	tomato	1.42	183	11
	pepper	1.71	304	304
	hot pepper	1.86	115	<4
	tomato	2.14	57	5
Donje Krajince	pepper	1.68	333	333
Nomanica	tomato	1.40	613	613

Our results showed representation all investigated bacterial groups in vegetable samples. The highest number of total bacterial count was detected on cabbage (38.40 x 10^4 CFU/gFM) grown in the opened field and pepper (33.80 x 10^4 CFU/g FM) grown in greenhouse condition on locations Batulovce and Krajince. Also, high number of these bacteria was detected on pepper in greenhouse in Batulovce.

The total coliforms were present in the extremely large number at pepper grown in locations Batulovce and Krajince. The number of bacteria was 110000 MPN/100 g FM on pepper grown in greenhouse (Batulovce) and 46000 MPN/100 g FM on pepper grown in open field (Krajince). Also, high number of total coliforms was detected on cabbage and tomato on the mentioned locations (Table 3).

The high number of fecal coliforms was noticed in the same vegetables on the same locations where the largest number of total coliforms was also detected. The highest number of these bacteria was determined at pepper on two locations, Batulovce (110000 MPN/100 g FM) and Krajince (46000 MPN/100 g FM). The same situation was with presence and number of *E. coli* whose largest number was found at pepper in Batulovce and Krajince (110000 MPN/100 g FM and 46000 MPN/100 g FM). The origin of *E. coli* on vegetable may be from the soil because it is a reservoir of *E. coli* species due to its ability to survive a long time in it (Barker et al., 1999). The Enterococci was present in large numbers only on peppers grown in the open field in location Badince while other vegetable samples were also positive on Enterococci but in small amount (Table 3). The presence of human pathogen on vegetables, especially vegetables that are consumed in raw, may be the cause of outbreaks which has been increasing in developing countries (Heaton and Jones, 2008). Thus, Pavic et al., (2005) showed that 48% out of 229 vegetable samples were positive on enterococci while 37% of leafy vegetable samples, 25% of fruit vegetable samples and 31% of root vegetables were positive on *E. coli*. Our research showed that all tested vegetable samples were positive for enterococci and *E. coli* but the highest number of these bacteria was noticed only in three pepper samples.

Table 3. Total bacterial count, coliforms, *E. coli* and Enterococci in vegetable samples

Location	Plant	TBC (10^4cfu/ G FM)	TC (MPN/ 100g FM)	FC (MPN/ 100g FM)	*E. coli* (MPN/ 100g FM)	Enterococci (MPN/ 100g FM)
Badince	tomato	0.08	<300	<300	<300	300
	pepper	16.50	<300	<300	<300	21000
Stajkovce	tomato	11.90	360	360	<300	<300
	pepper	0.23	360	360	<300	<300
	pepper	11.60	<300	<300	<300	<300
	tomato	16.30	9300	9300	<300	<300
Batulovce	pepper	25.10	110000	110000	110000	<300
	cabbage	38.40	1500	730	730	<300
Krajince	pepper	33.80	<300	<300	<300	<300
	tomato	0.05	910	<300	<300	<300
	pepper	12.00	46000	46000	46000	<300

The *Salmonella* sp. was detected in 7 samples out of 13 total vegetable samples which were tested. The 5 positive samples were pepper which was grown in greenhouses and two samples were cabbage and pepper grown in the open field. The locations where *Salmonella* sp. was detected were Stajkovce, Batulovce and Krajince. Our results are in correlation with other researchers which determined that *Salmonella* sp. was found out in about 0.3% of tested vegetable samples in EU countries (Westrell et al., 2009).
Regarding the presence of *Listeria monocytogenes,* all vegetable samples were negative. The *P. aeruginosa* was detected only in cabbage which was grown in open field on location Batulovce. Diseases related to contaminated vegetables and soil are caused by bacteria (Yoder et al., 2008). The most common human pathogen bacteria on fresh vegetables are *Salmonella* spp., *E. coli*, *Listeria monocytogenes*, *Pseudomonas aeruginosa* (Beuchat, 2002) and we detected most of these bacteria on vegetables in our research.

CONCLUSION

Personal hygiene practices are very important because human pathogens are present in human and animal faeces and could be easily transmitted to vegetables. This help to prevent transmission of these microorganisms and reduce the risk of food-borne diseases (washing hands, protection injuries and wounds, using toilet).
Protecting the field from faecal contamination is the main problem because wild and domestic animals are able to contaminate vegetables and soil in the field with their feces. It is necessary to prevent moving animals from through the field where vegetables are produced, to place cattle in the fenced area, to remove waste that attracts animals from the field for production and around it.
Quality control and management of organic fertilizers is mandatory because human pathogens are able to survive a long time in manure and compost, reach the soil and contaminate crops. These organic fertilizers must be properly treated to destroy pathogens as well as to extend time distance between the application of fertilizers and harvesting fruits.
Estimation and management of irrigation water is required because human pathogens could contaminate water and be transported to soil and vegetables through irrigation. It is necessary to identify all water sources and prevent contamination applying permanent microbiological monitoring and appropriate treatment if contamination occurs.
Keeping harvesting equipment clean and applying hygiene practices during the harvesting is important because direct contact with contaminated harvesting equipment could lead to contamination of vegetables. The restricting access to harvesting areas is recommended for animals, children and the unemployed because improper hygiene during the harvest increases the risk of contamination vegetables by human pathogens.

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MICROGRANULES AND BIOSTIMULANTS AS ALTERNATIVES TO DIAMMONIUM PHOSPHATE FERTILIZER IN MAIZE PRODUCTION ON MARSHLAND SOILS IN NORTHWEST GERMANY

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Abstract

The eutrophication of groundwater through the widespread Diammonium Phosphate (DAP) fertilization and excess of farm fertilizer is a major problem in the European agriculture. Organo-mineral fertilizer reduced in phosphorus (P) content, alone or in conducted a field experiment with maize (*Zea mays*) on a marshland soil site in order to compare the yield increase and the Phosphorus leachate of DAP and microgranule fertilizer variants. Treatments were realized as combination of two (organo-) mineral fertilizer, viz. DAP or a P-reduced microgranular depot-fertilizer (Startec) and the biostimulants mycorrhiza, humic substances and soil bacteria single or in parallel application with two of the mentioned biostimulants. Also (organo-) mineral fertilizer variants have been single tested without additional biostimulants. Every fourth parcel has been used as control, only treated with biogas slurry, to identify site-specific spatial variability and to implement correction factors to process raw data using standardized methods. Startec performed as good as DAP in both, yield and corn cob ratio, while P-balance is significantly better in parcels with Startec (av = 4,5 kg P2O5 / ha) compared to DAP (av = 43,7kg P2O5 / ha) resulting in small P-values of high statistical significance. Single and multiple combination of biostimulants rarely resulted in significant higher yields, with the exception of some combinations with humic substances and mycorrhiza in single years. The influence of the climatic conditions of the different years was higher compared to the influence of biostimulants. However, average increases in yield over three years would be economically beneficial for farmer in case of the applied humic substances product and mycorrhiza. An adequate alternative to DAP has been found in the P-reduced microgranulate fertilizer Startec.

Keywords: microgranule, diammonium phosphate, eutrophication, phosphorus balance, biostimulants

INTRODUCTION

Even if the extent of existing phosphate rock reserves is controversially discussed in literature, it is undisputed that these resources for conventional fertilizer production are finite (Edixhoven et al., 2014; Kisinyo and Opala, 2020). Further ecological problems as the eutrophication of ground and surface water systems by agricultural phosphorus inputs

(Torrent et al., 2007; Ulén et al., 2007) led politics in European Union to strict regulation of nutrient management and fertilizing systems (91/676/EWG, 2000/60/EC). Thus a more responsible usage of phosphorus fertilizer is necessary. Recently new fertilizing systems, as the application of microgranules, also known as pop-up fertilizer, and biostimulants, as alternative to wide spread Diammonium Phosphate (DAP) fertilization have been successfully tested (Lahde, 2016; Marilena and Aurel, 2021). In contrast to DAP and other fertilizer applied as fertilizer band with a certain distance of around 10 cm to the seed, ideally microgranules getting put together with the seed into soil or few centimeter distant to the seed. The direct contact of the fertilizer to the seed requires both a less amount of fertilizer and nutrients, especially phosphorus (P), used per plant and a lower salt index of the used components of the fertilizer itself (Alley et al., 2010). Further, the dispersal of the granules smaller than 2 mm in diameter prevents long term osmotic gradients. While microgranules as depot fertilizer become to be more frequently used in german agricultural practice, and thus develop into a promising tool to encounter the above mentioned ecological challenges, the application of biostimulants is not to the same extend spread. This stands in contrast to the numerous studies in laboratory scale (germination essays), greenhouses and successful field trials for different plant taxa (Mackowiak et al., 2001; Nardi et al., 2002; Cavaglieri et al., 2005; Jakobsen et al., 2005; Anjum et al., 2011; El-Hassanin et al., 2016; Eulenstein et al., 2016; Fan et al., 2018). However, the world market for biostimulants is growing fast since the last decade (Calvo et al., 2014).
Field trials are suitable to proof the concept of alternative fertilizing systems including the usage of biostimulants. In the present study field trials were carried out over three years to compare the effect of a standard fertilizer (DAP), rich in P, and a microgranular depot fertilizer with less P-content (Startec) in single or multiple combination with biostimulants, viz. liquid humic substances extract, soil bacteria and mycorrhiza in maize.

MATERIALS AND METHODS

Study area

Experiments were carried out as field trial with 22 parcels (50 x 6 m) each repeated 5 times during past three years (2018-2020) near Wanna in northwest Germany (53.729995, 8.810990). The region is classified as European atlantic climate (Cfb) according to Köppen and Geiger (1930) characterized by mild winter and moderate summer temperatures. The average precipitation per year for Wanna is 735 mm, average annual temperature is 9.9°C. 45% of annual precipitation is during maize crop season from April to September.
Hydromorphic loamy marshland soil, rich in humus, is present on the whole study site. Ground water levels are 40-60 cm below the surface with insignificant changes over the year due to the presence of drainage channels communicating directly with the regulated system of the small stream Emmelke.
The site has been used for maize cultivation over years and treated with following plant protectants Laudis, Spectrum Gold, Milagro Forte, Nagano (in 1, 2, 1, 0.5, and 0.3 litres per hectar). Regular tillage operations were ploughing and grubbing.

Experimental setup

The maize cultivar Amaroc S230 has been sown with a density of 8.5 seeds per square meter using AMAZONE single corn seeder system (EDX 6000-2C precision air seeder). DAP fertilizer has been applied as band 12 cm below the soil surface and Startec (De Ceuster Meststoffen NV (DCM) Bannerlaan 79, 2280 Grobbendonk, Belgium) microgranules few centimetres underneath the corn respectively. 100 kg/ha of DAP has been applied. The latter contains 18% total N, all in form of NH_4-N, and 46% P_2O_5. Startec can be classified as organomineral fertilizer consisting by 80% (of the original substance) of the organic industrial by-products oil cake and bone meal and mineral components Ammonium phosphate, Ammonium sulphate, EDTA-chelated Fe, Mn, Zn, Zinc sulphate and Zinc oxide. Nutrient composition of Startec is 7.5% N, 22% P_2O_5, 4% K_2O, 10% S, 0.5% Fe and Mn respectively and 1.5% Zn. The application rate of Startec in the present study was 25 kg/ha. Mycorrhiza, grown on expanded clay, and soil bacteria, sprayed on natural zeolite (clinoptilolite) as carrier material were powdered and filled into separate chambers of AMAZONE precision seeder for exact, parcel-specific application in the same go as fertilizer treatment. The study site has been treated with biogas slurry (30 m^3/ha) containing 4.3 kg total N, 1.3 kg P_2O_5, 5.2 kg K_2O per m^3. Humic substances were sprayed directly on the soil after treatment with biogas slurry. This form of application has been used due to organizational reasons and differs from manufacturer's prescription. Manufacturer of the humic product (GeoFert Germany GmbH) prescribed to mix the humic substances directly into the slurry to reduce technical effort in agricultural practice. Treatments were realized as combination of two mineral fertilizer, viz. DAP or the P-reduced microgranular depot-fertilizer Startec and the biostimulants mycorrhiza (abbreviated as M), humic substances (GeoOrganic®, GeoFert Germany GmbH) (abbreviated as HS) and soil bacteria (BactoFert®, GeoFert Germany GmbH) (abbreviated as Bac) single or in parallel application with up to two of the mentioned biostimulants. Also mineral fertilizer variants have been single tested without additional biostimulant. Every fourth parcel has been used as control, only treated with biogas slurry, to identify site-specific spatial variability and to implement correction factors in data analysis. Hand-harvest was performed by removing 20 plants involuntarily per parcel. Cob and the remaining plant were weighed and shredded separately using a garden shredder (AL-KO Master 32-40). Shredded material of cob and corn respectively for each of the five repetitions of a variant was used to prepare samples for measurement of dry matter and afterwards pulverized for NIRS-analyses using a FOSS NIRS-spectrometer 5000-M (FOSSNIRSystems). The latter data were used to calculate the year-specific removal of N, P_2O_5 and K_2O by harvest.

Statistical analysis

Control parcels without additional fertilization have been used to detect soil spatial variability on the study site. Differences in control parcels have been used to implement correction factors as described in Thomas (2006) and Dospechov (1979). To ensure normal distribution, yield was transformed via an exponential function. Differences between fertilizer variants were tested using students t-test. All statistical analyses were performed in R (R Core Team 2014). For data selection the package dplyr (Wickham et al., 2018) was used. Visualization in R was conducted by using the package ggplot2 (Wickham, 2009).

RESULTS AND DISCUSSION

P is an essential and often yield limiting nutrient for plants in general and in crop production in particular (Sharpley, 1997). The low solubility of P in water forces the usage of mineral fertilizer (as DAP) containing P-compounds, which solves in watered soil matrix into highly plant available form. Thus the major source of P in commercial crop fertilization is usually not applied by using farm fertilizer like slurry. However, P is also in organic form in Startec. Organic P in Startec is predominantly in bone meal as Hydroxyapatite ($Ca_5(PO_4)_3(OH)$), typically present in bone structures (Kattimani et al., 2016). Within the framework of experimental setup design it was supposed that the organic bounded P and other organically bound nutrients in Startec will be transformed in plant available form better, if biostimulants are used. Contrary to the hypothesis of a higher benefit of the mutual application of biostimulants and Startec the effect on DAP-fertilized plants has been higher. After data sampling of the three years study, average dry matter yield of all DAP combinations with biostimulants has been 14.8 % higher than DAP without any biostimulant (Figure 1). In comparison the effect of biostimulants on Startec has been smaller and overall insignificant resulting in 4% higher yield compared to Startec without biostimulants. A possible explanation may be the positive effect of Startec's organic compounds as oil cake and bone meal on microbial activity. Oil cakes are used to rise microbial activity in bioremediation of soils (Govarthanan et al., 2015) and further ranges of biotechnological application (Ramachandran et al., 2007). Also bone meal is known to rise mineralization dynamics and thus extractable macronutrients in soils (Mondini et al., 2008) and act as biostimulant for bacteria (Liu et al., 2019). In other words, the supposed positive effect of biostimulants on microbial activity may already be contributed by the organic compounds in Startec acting in direct periphery of the roots of young maize plants. The concept of Startec's mode of action on root growth is promotion through fine microgranule dispersal of organic nutrients, which are in that form mineralizable within the vegetation period, and direct attraction of root growth into the soil-microgranule matrix by mineral NH_4-N. On the other hand the DAP fertilizer band, which is more distant to the seed within the soil, also attracts root growth by ammonia but may not be able to support microbial activity to the same extend as Startec's organic, mineralizable pool for macro- and micronutrients. However, adding humic substances or/and mycorrhiza can support beneficial plant-microorganism interactions. Another hypothesis for the lower effect of the used biostimulants on yields gained with Startec is that the soil P was sufficient and not the limiting factor. Thus lower mineral P-inputs will not result in lower yields. It is noteworthy that in case of Bac effects have been neutral on dry matter yield of DAP and negative, albeit non-significant, on Startec (-10.3%) (data not shown). Further no effect has been found in combination between mycorrhiza plus HS and Bac plus mycorrhiza on yield with Startec alone (data not shown) while these combinations resulted in higher average yields over three years in DAP (HS plus mycorrhiza: +11.7%; Bac plus mycorrhiza +32.1%). Greatest positive differences in average yield over the three years were found in Bac plus mycorrhiza (+32.1%) and application of HS (+15.2%) for DAP and HS (+13.75) and mycorrhiza (+14.9%) on Startec. Statistically significant differences were only present in case of the effect of HS plus mycorrhiza on DAP in 2018 (P = 0.0127), the effect of Bac plus mycorrhiza on DAP in 2019 (P = 0.0041) and HS on Startec's yield in 2018 (P = 0.0087).

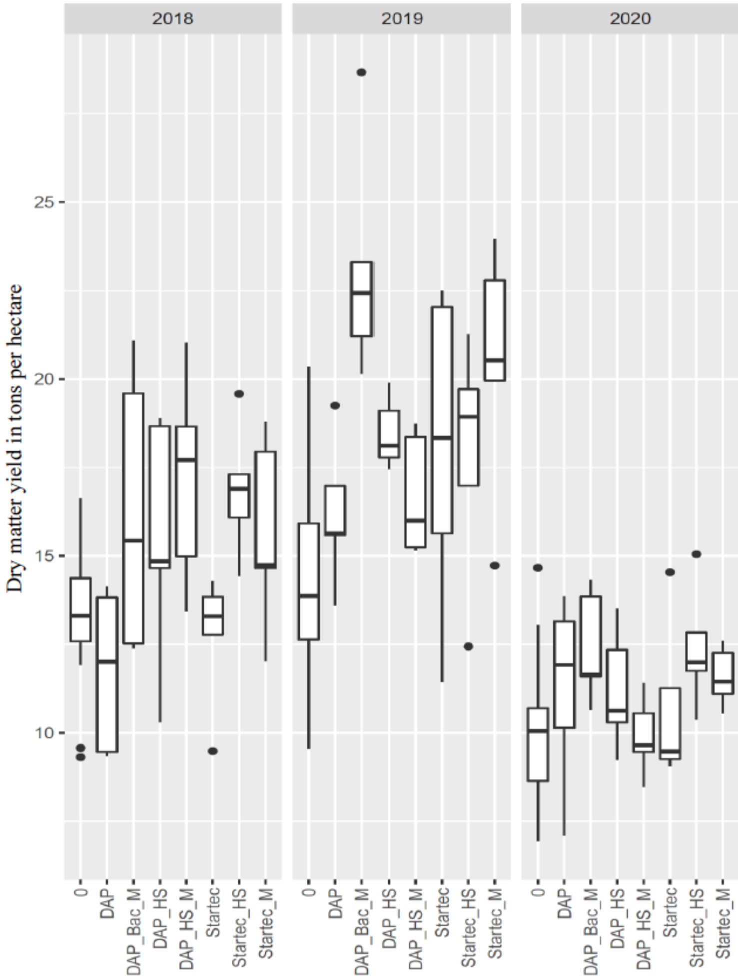

Figure 1. Dry matter yield per hectare gained with fertilizer variants DAP and Startec single or in combination with biostimulants soil bacteria (BAC), mycorrhiza (M) and humic substances (HS) in 2018, 2019 and 2020, 0 shows yield of control parcels. Variants not shown: Startec_Bac, DAP_Bac, Startec_HS_M, Startec_Bac_M

Discontinuous impacts of biostimulants over the years were caused by higher influence of climatic conditions. In other words, the influence of the year was higher than the influence of the biostimulant, which was verified via modelling in R-software. The study site has been chosen to minimize fluctuation in soil water and temperatures over the three cropping periods. However, compared to the other years 2018 has been dry in spring, which may provoke osmotic stress in DAP-fertilized plants without biostimulants and accordingly a lower yield. Mycorrhiza and humic substances alleviation of osmotic stress (Ruiz-Lozano, 2003; Anjum et al., 2011; Aydin et al., 2012; Santander et al., 2017) may play a role in better performance of DAP-biostimulant combination compared to DAP control application in 2018. The locations of the parcels were not precisely the same each year. An occurring shift may prevent control parcels from gradual decreasing P-contents in soil over the years. To avoid shifts of the parcels on the study site and for higher statistic validity future studies should be realized in fully randomized experimental setup. While the average dry matter yield gained with Startec applied without biostimulants is slightly, viz. 4.8%, higher than DAP (without biostimulants), the phosphorus balance of all Startec variants over the three years study is close to be neutral (4.5 kg excess per hectare and year) compared to DAP phosphorus excess of 43.7 kg/ha over all DAP-variants (Figure 2).

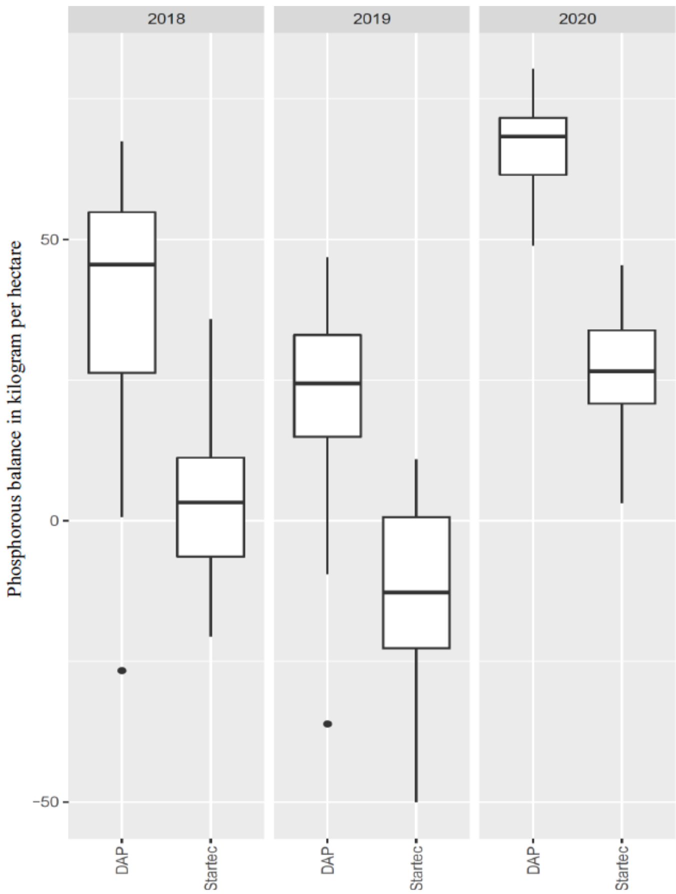

Figure 2. Phosphorus balance of all variants with and without biostimulants gained with DAP and Startec in 2018, 2019 and 2020.

The difference in phosphorus balance between all Startec variants compared to all DAP variants were of highest statistical signifincance ($P < 0.0001$). Thus microgranular P-depot fertilizer Startec turned out to be an adequate alternative to DAP-fertilization in maize on fertile, well-watered marshland soils. No differences were present in corn cob ratio over all variants. For regions with high densities of livestock units and biogas plants the export of slurry and manure is resource consuming and puts farmer under financial pressure. By using alternative fertilizer with lower P-content more organic P from regional farm fertilizer can be used and inefficient export in regions with lower densities of livestock units can be avoided. Potential modes of action on P availability for plants of each used biostimulant in the study were hypothetical to present state of knowledge. However, in literature it is often stated that solubilization of soil P into plant available form is driven by both plant-soil interaction and microorganism-soil interaction. The latter types of interaction are not independent but rather characterized by interrelated processes within the rhizosphere. Microorganisms solubilize soil P for example by releasing small, two to six C-atom, organic anions (Khan et al., 2007) and incorporate it in labile structures as membranes and metabolism related molecules (Achat et al., 2010). Due to the short lifespan of dominant soil bacteria the microbial P has habitat-specific turnover rates, which are shorter than a vegetation period (Oberson et al., 2001; Bonkowski, 2004). In other words, organic and inorganic bound soil P can be transferred in plant available form trough incorporation into soil microorganisms and mineralization of the latter. The use of soil bacteria, as performed in the experiment by using BactoFert® (*Bacillus subtilis*), (GeoFert Germany GmbH) or the application of leonardite derived humic substances (GeoOrganic®, GeoFert Germany GmbH), and thus the increase of microbial activity (Lovley et al., 1996; Field et al. 2000), has the potential to support the above described process of soil-P turnover by microorganisms. Further the growth of roots can be increased by humic substances (Adani et al., 1998; Nardi et al., 2000), soil bacteria (Araújo et al., 2005) and mycorrhiza (Vessey and Heisinger, 2001) by raising the effective root surface for P-acquisition. In case of mycorrhizal effect on plant P uptake Vessey and Heisinger (2001) point out that the effect can be traced back to the increase of effective root surface and is thus indirect. However, effects of microorganisms may be also negative because of direct competition between plants and microorganisms for orthophosphate (Oehl et al., 2001; Bühnemann et al., 2007; Ehlers et al., 2010). Especially for mycorrhizal fungi it is known that positive effects on plants are limited in soils with high biological activity before the treatment (Eulenstein, 2016) or even negative on well-watered sites (Lahde, 2016). Also in terms of microbial P turnover the potential competition between plants and mycorrhiza may be higher due to a longer lifespan of fungi compared to bacteria, which lacks robust chitin structures of fungi and higher symbiosis related resistance to environmental fluctuation (Kassim et al., 1981; Simpson et al., 2004). In general positive effects of biostimulants predominate in literature and in the present study as well.

CONCLUSION

The used microgranular fertilizer Startec performs as good as DAP in yield and can be considered to be an adequate alternative to DAP-fertilization in maize cultivation on fertile marshland soils. Phosphorus balance of Startec variants were around nine times lower than all DAP-variants ((P < 0.0001). The impact of biostimulants has been discontinuous in general, comprising years with a significant positive and without remarkable impact. The influence of the climatic conditions of the years has been higher than the influence of the biostimulants. In average the effects of humic substances and mycorrhiza where economically beneficial if established into agricultural practice. Influence of biostimulants on less fertile or less watered soils is supposed to be higher. Thus, further studies has to be realized comprising parallel trials on different soil types, including soils with low soil-P content, during the same year and additional microbiome monitoring to prove the above mentioned hypothesis of the biostimulants mode of action.

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WATER REQUIREMENTS OF FRUIT AND VINE PLANTATIONS IN THE AREA OF THE KOLUBARA DISTRICT IN PRESENT AND FUTURE CONDITIONS

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Abstract

Fruit and vine production in the territory of the Kolubara District encompasses 15,685 ha, which accounts for around 15.3% of the total plant production. When it comes to fruit plantations, plums are the most represented (70%), while peaches and strawberries account for only 0.3%. The aim of this research was to determine the seasonal water requirements of fruit trees in climate change condition, to find out wheter will be changes in irrigation requirement. In addition, the paper includes the analysis of water requirements for the future periods in order to enable producers to adapt their agronomy practices and growing systems to the forthcoming conditions. FAO methodology (FAO Irrigation and Drainage Paper No. 56), was used to estimate the evapotranspiration, effective precipitation, crop evapotranspiration and water deficit, for 8 groups of fruit plantations: (I) apples, pears, plums, quinces, walnuts and hazels – the orchard without grass cover; (II) apples, pears, plums, quinces, walnuts and hazels – grassy orchard; (III) apricots and peaches – the orchard without grass cover; (IV) apricots and peaches – grassy orchard; (V) sweet cherries and sour cherries - the orchard without grass cover; (VI) sweet cherries and sour cherries - grassy orchard; (VII) strawberries, raspberries, blackberries and blueberries and (VIII) grapevine. The fruit plantations were categorised into the above-mentioned eight groups according to the length of the vegetation period and the crop coefficient values. The observed period from 2000–2019 and two future periods (2021–2040 and 2041–2060) were analysed. The climate data for the reference 2000–2019 period were obtained from the meteorological station in Valjevo. Data for the future climate were obtained using 8 climate models for the RCP 8.5 climate scenario. The paper provides the results obtained as the median of the calculations for eight climate models. The evapotranspiration value varies from 438.6, 429.0 and 440.5 mm for fruit trees from group V, respectively, to 892.2, 857.5 and 884.6 mm for fruit trees belonging to group II, with the average values of 596, 577.9 and 595.4 mm for the reference period, the future 2021–2040 and 2041–2060 periods, respectively. The seasonal water deficit varies from 88.0, 41.3, and 90.6 mm for grapevine (group VIII) to 405.6, 352.3, and 405.3 mm for fruit trees from group II, with the average values of 224.4, 198.7 and 245.3 mm for the reference period, and future 2021–2040 and 2041–2060 periods, respectively. The results of this research indicate that no significant differences in the water requirements between the future periods and the reference period.

Keywords: evapotranspiration, water deficit, fruit plantations

INTRODUCTION

Climate changes have resulted in frequent periods of droughts during summer months, as well as in the decrease and inadequate distribution of precipitation during the vegetation period. Therefore, irrigation is becoming a necessary measure in plant production required for reaching a high and stable yield. In order to satisfy food requirements of the global population and water requirements of other users, irrigation strategies have to be improved while maintaining the focus on water savings (Fereres and Evans, 2006). Fruit production without the application of irrigation is extremely uncertain and risky, particularly in arid and semi-arid regions of the world. Regardless of the available water resources, the common problem of all fruit producers is establishing the optimal irrigation regime (irrigation time and amount) which would provide a high-quality yield and protect the environment. Due to the differences in the anatomical and morphological structure of orchards and their adaptation to the water excess or deficit in the soil, estimating the irrigation water requirements is easier to conduct for herbaceous plants. Estimating the water requirements of fruit trees is not sufficiently reliable (Yahyai, 2012). Planning and application of irrigation is a demanding task which has to include a multidisciplinary approach to the problem. In addition to the economic aspect, irrigation planning has to rely on the knowledge about the vicinity of water sources and available water quantities, soil suitability for irrigation and interests of water users (Vega et al., 1998; Petersen et al., 2001). Different scenarios of future emissions are used to estimate the impact of climate change on water resources and consequently to evaluate the risks of fruit production. In order to offer recommendations for alleviating negative effects of climate change, preserving sources of water and ensuring high yield, Stričević et al. (2017) used a modern approach which quantified the direct and indirect water use – WF (Water Footprint). They analyzed two options for cultivating apples (the orchard with grass cover and the orchard without grass cover). The results of their research showed that there would be an increase in total water requirements, as well as blue water requirements. They also highlighted that water consumption increased in grassy orchards. However, they recommended covering the erosion-prone sloped terrains with grass. Ruml et al. (2012) examined the impact of climate predictions on vine growing in the Republic of Serbia. They predicted that requirements for vineyard irrigation would rise and that the formerly cold and unsuitable areas would become adequate for vine growing by the mid-21st century. Frost protection of fruit plantations is the most efficiently conducted by means of irrigation. This leads to increased water requirements and to an additional risk of production in the conditions of limited water resources. Parker et al. (2021) analyzed the climate change impact on the occurrence of frost in California. Their results showed that by the mid-21st century there would be a significant decrease of exposure to frost (approximately 63%), which would lead to a significant reduction of water consumption. This is one of the positive effects of climate change, in addition to its numerous negative effects.

This study included the analysis of water deficit of fruit plantations in the area of the Kolubara District for the observed period and two future periods. The aim of the research was to analyse risks occurring during the vegetation period regarding the water requirements of fruit trees in order to help producers make decisions and apply suitable agronomic practices for reaching a high (stable) yield of good quality.

MATERIALS AND METHODS

Meteorological data from Valjevo (44° 17’ N; 19° 55’ E; 174 m a.s.l) were used to determine the seasonal water requirements of fruit and vine plantations in the Kolubara District.

Due to optimization, number of active climatological stations are reduced in the observation network of the Republic Hydrometeorological Service of Serbia (which fell from the total number of 99 synoptic and meteorological stations in 2010 to the total number of 66 stations in 2019) and the public unavailability of the observed daily data for most stations, this study used an alternative source of meteorological observations – spatially interpolated fields of daily minimum and maximum temperatures and daily precipitation at an approximately 10-km resolution from the E-OBS dataset. The reference period was the period including the last 20 years for which data were available, i.e. the period from 2000 to 2019.

The analysis of future climate changes has to include current and relevant results of climate projections, which implies the appropriate selection of one or more scenarios related to greenhouse gases and appropriate integrations of climate models with the greatest spatial resolution possible. The scenario RCP8.5 (Relative Concentration Pathway) from *the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) was selected for the analysis. This scenario does not envisage the application of mitigation measures and therefore it can be regarded as “the worst option“. However, Serbia has already reached the values of temperature change envisaged for the following 20 years, so the selection of more moderate scenarios would be inappropriate in this case.*

The selected integrations of climate models were taken from the project “Development of the internet application and platform for assessing vulnerability to climate change and adaptation” realized within the UNDP project “Advancing medium and long-term adaptation planning in the Republic of Serbia (Djurdjevic et al., 2021) and they include a set of 8 regional climate models with a 0.1° (about 12 km) spatial resolution from the EURO-CORDEX project dataset (Table 1). In accordance with the mentioned project, this study included the analysis of two selected twenty-year-long future periods, 2021–2040 and 2041–2060.

Data on daily values of air temperatures and precipitation obtained in the above-mentioned manner were used for calculating effective precipitation, reference evapotranspiration and crop evapotranspiration of fruit trees in the Kolubara District using the FAO IDP (Irrigation and Drainage Paper) No. 56 methodology (Allen et al., 1998).

Table 1. Selected combinations of global and regional climate models

Regional climate model	Global climate model
CCLM4-8-17	ICHEC-EC-EARTH
CCLM4-8-17	MOHC-HadGEM2-ES.rcp85
CCLM4-8-17	MPI-M-MPI-ESM-LR
HIRHAM5	ICHEC-EC-EARTH
RACMO22E	ICHEC-EC-EARTH
RACMO22E	MOHC-HadGEM2-ES
REMO2009	MPI-M-MPI-ESM-LR
REMO2009	MPI-M-MPI-ESM-LR

The fruit trees included in the analysis and the area under it are shown in Table 2.

Table 2. Fruit trees included in the analysis and percentage of area

Culture	Group	Area (%)
apple, pear, plum, quince, walnut and hazel (frost, orchard without grass cover)	I	40
apple, pear, plum, quince, walnut and hazel (frost, grassy orchard)	II	40
peach and apricot (frost, orchard without grass cover)	III	0.4
peach and apricot (frost, grassy orchard)	IV	0.4
cherries (frost, orchard without grass cover)	V	1.1
cherries (frost, grassy orchard)	VI	1.1
strawberry, raspberry, blackberry and blueberry	VII	16.3
grapevine	VIII	0.7

Crop evapotranspiration is determined by multiplying the reference evapotranspiration by the crop coefficient. The difference between the crop evapotranspiration and effective precipitation provides the net water deficit for the given plant species (crop) (In).
This research includes the calculation of water requirements of eight fruit plantation groups in the area of the Kolubara District for the reference 2000–2019 period and two future periods – 2021–2040 and 2041–2060. The fruit plantations were categorised into eight groups according to the length of the vegetation period and the crop coefficient value using the FAO IDP No. 56 methodology.

RESULTS AND DISCUSSION

The evapotranspiration value varies from 438.6, 429.0, and 440.5 mm for fruit trees from group V, to 892.2, 857.5, and 884.6 mm for fruit trees belonging to group II, with the

average values of 596, 577.9, and 595.4 mm for the reference and 2021–2040, and 2041–2060 periods, respectively. The seasonal water deficit varies from 88.0, 41.3, and 90.6 mm for grapevine (group VIII) to 405.6, 352.3, and 405.3 mm for fruit trees from group II, with the average values of 224.4, 198.7, and and 245.3 mm for the reference and 2021–2040, and 2041–2060 periods, respectively (Tab. 3, Fig. 1). It can be noticed that water consumption is higher for all fruit trees in grassy orchards by approximately 24% on average than for those in orchards without a grass cover. Although evapotranspiration and water deficit are higher in grassy orchards, grassing over the orchards in the regions with sufficient precipitation creates favourable microclimatic conditions in orchards, which has a positive impact on the quality of fruits and protects soil from water erosion. Similarly, Stričević et al. (2017) also concluded that covering orchards with grass led to increased water requirements. Nevertheless, they underlined the advantage of covering sloped terrains with grass in order to protect them from erosion.
The comparison of water consumption of fruit plantations in different periods shows that there are no significant differences. In the period 2021–2040, 3% less water is used on average than in the observed 2000–2019 period. There are no differences between water consumption for the evapotranspiration process in the observed period and in the 2041–2060 periods. There is a slight increase (by 2%) in effective precipitation in the 2021–2040 in comparison to the reference period. In the 2041-2060 period, effective precipitation decreases by approximately 7%. The differences in the net water deficit (In) decrease by 14% in the 2021–2040 period compared with the reference period, while in the 2041–2060 period the net water requirements increase by 11% in relation to the reference period. In the month of July are the highest water requirements in all the analysed periods (Tab. 3).

Table 3. Crop evapotranspiration (ETc), effective precipitation (Pe), water deficit (In) during the vegetation season per fruit group for the observed 2000-2019 period and two future periods of 2021-2040 and 2041-2060

Group of fruit trees	I	II	III	IV	V	VI	VII	VIII	Average
Period	2000-2019								
ΣETc (mm)	717.3	**892.2**	478.7	588.3	**438.6**	549.5	552.4	551.3	596.0
ΣPe (mm)	486.7	486.7	332.2	332.2	299.6	299.6	346.1	462.6	380.7
ΣIn (mm)	303.6	**405.6**	146.5	256.1	139.0	249.9	206.3	**88.6**	224.4
Period	2021-2040								
ΣETc (mm)	689.5	**857.5**	468.8	574.8	**429.0**	537.4	536.4	530.1	577.9
ΣPe (mm)	513.5	513.5	328.8	328.8	298.8	298.8	348.2	494.0	390.6
ΣIn (mm)	264.8	**352.3**	138.4	245.1	126.4	234.4	187.0	**41.3**	198.7
Period	2041-2060								
ΣETc (mm)	711.2	**884.6**	482.0	592.5	**440.5**	552.1	554.1	546.7	595.4
ΣPe (mm)	478.4	478.4	302.3	302.3	273.7	273.7	319.7	452.3	360.1
ΣIn (mm)	321.7	**405.3**	175.8	283.2	172.8	283.6	229.2	**90.6**	245.3

Studying the impact of climate predictions on vine growing in the Republic of Serbia, Ruml et al. (2012) came to a similar result stating that there would be no significant changes in the next few decades. In the second half of the 21st century, water requirements would rise, as well as the need for changing the vine variety due to the changed growing conditions and locations. Stričević et al. (2019) highlighted that climate change would not have a significant impact on water requirements of fruit at the beginning of the century. However, their results indicated that water requirements of both fruit and vine would significantly increase throughout the century and particularly by its end.
The average net irrigation requirements are 2783.9, 2434.0, and 2924.8 m3·ha-1 for the reference and two future periods, respectively (Tab. 4).

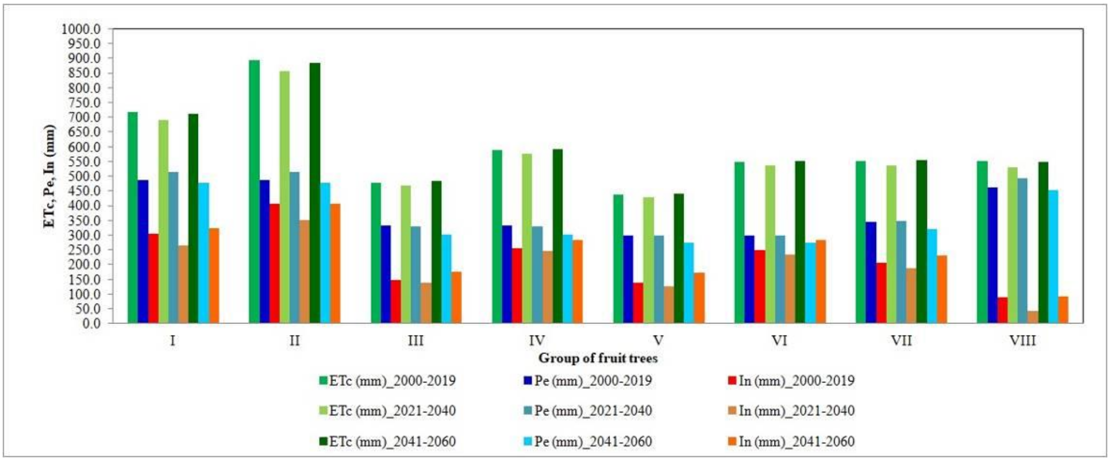

Figure 1. Crop evapotranspiration (ETc), effective precipitation (Pe), and water deficit (In) during the vegetation season per fruit group, for the reference period (2000–2019) and two future periods (2021–2040 and 2041–2060)

Table 4. Net (nNi) irrigation requirements for the reference period (2000-2019) and two future periods (2021–2040 and 2041–2060)

Period	2000-2019	2021-2400	2041-2060
nNi (mm)	278.4	243.4	292.5
nNi ($m^3 \cdot ha^{-1}$)	2783.9	2434.0	2924.8

CONCLUSION

The results of this research indicate the water requirements of fruit trees in the Kolubara District for the reference period (2000–2019) and two future periods (2021-2040 and 2041-2060). It can be noticed that there are no significant differences in the water requirements between the future periods and the reference period. The obtained results can help producers analyse water deficit risks during the vegetation period of fruit trees and consequently apply appropriate agronomic practices in order to obtain a high-quality and stable yield.

As mentioned above, intensive fruit production is impossible to be conducted without the application of irrigation. In addition to the deficit of available water resources, there is a serious problem related to the establishment the adequate irrigation regime of fruit plantations (irrigation amoount and time). The application of the deficit irrigation strategy can represent a favourable option in the areas with insufficient water resources. Nevertheless, good water management has to include the knowledge of the seasonal sensitivity of crops to water stress.

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PROJECTION OF THE WATER REGIME PARAMETERS OF ZEMUN CHERNOZEM FOR WINTER WHEAT PRODUCTION BY THE END OF THE 21ST CENTURY

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Abstract

This paper presents the projection of the water regime parameters of the Chernozem soil under winter wheat crops in the region of Zemun (Serbia) from 2021/2022 to 2099/2100. The average values of the simulated parameters in the near (2021/2022-2050/2051) and distant future (2070/2071-2099/2100) were compared with the values of the simulated parameters from the reference period (1970/1971-1999/2000). The projection of climate parameters was made under the assumption that no mitigation measures for greenhouse gas emissions would be implemented in the future (RCP8.5). Air temperature (Tmin, Tmax and Tmean) and effective rainfall were simulated using a climate model. The projection of the water regime parameters of Chernozem was obtained using the FAO CROPWAT 8.0 crop model. A simulation of the following soil water regime parameters was performed: potential winter wheat evapotranspiration (ETc), actual winter wheat evapotranspiration (ETa), winter wheat irrigation water requirement and yield reduction in relation to the genetic yield potential. The results of the climate model indicate that by the end of 2100 air temperature will have increased in the region of Zemun in the winter wheat growing season (October 16th – June 22nd). The projections indicate a Tmean increase of 2.6 ^{o}C in the near future, and 5.2^{o}C in the distant future, relative to the reference period. The projected precipitation amounts (October-June) indicate that precipitation is expected to increase by 5% in the near future and 3% in the distant future, in relation to the reference period. The crop model simulations indicate that, compared to the reference period, Chernozem water regime conditions for the winter wheat production are expected to be more favourable in the near future. It is expected that ETc and ETa would increase (by 4% and 3% respectively), that the irrigation water requirements would decrease (-7%) and that yield reduction would decline compared to the reference period. Contrary to the projections for the near future, in the last three decades of this century (distant future), Chernozem water regime conditions for the production of winter wheat are expected to be less favourable than the conditions so far. ETc is expected to increase (by 3%), ETa to remain unchanged, the irrigation water requirements to increase (by 12%) and yield reduction to get higher compared to the reference period.

Keywords: climate change, winter wheat, water requirements, irrigation water requirements, yield reduction, CROPWAT

INTRODUCTION

The assessment of climate change impacts on the future agricultural production is of great importance, especially in the areas where agriculture is a dominant economic sector. It is particularly important to assess climate change impacts on the most common agricultural plants, which play a primary role in the nutrition of the population and are mostly cultivated in rainfed conditions. After maize, winter wheat represents the most widespread crop in Serbia. It is mostly cultivated without the application of irrigation, and water represents the main and limiting factor for its growth (Lalic, 2013).

An increasing trend in air temperatures has been registered in the territory of Serbia over the recent decades (Ruml et al., 2017), and future projections indicate a continuation of air temperature increase, followed by a decrease in precipitation in the summer months (Lalic et al., 2011; Vukovic et al., 2018; Jancic Tovjanin et al., 2019). Such conditions will cause an increase in crop water requirements, a decrease of water available to crops, an increase of irrigation requirements (Gregoric et al., 2020), and finally, a reduction of yields (Stricevic, 2014), especially in terms of spring crops (Lalic et al., 2011).

Researches by Pocuca et al. (2021) have shown that the water regime of the Chernozem soil under winter wheat crops in the region of Zemun has slightly deteriorated in the last 54 years (1966/67-2019/20). There has been an increase in potential evapotranspiration, an increase in irrigation water requirements, and a major decrease in winter wheat yield relative to the reference period. The aim of this paper is to establish, using the climate and crop models, whether this deteriorating trend of the Chernozem water regime would persist by the end of the 21st century, under the assumption that the most aggressive scenario in assumed fossil fuel use would play out in the future (RCP8.5) (Schwalm et al., 2020), that is, that no mitigation measures for greenhouse gas emissions would be implemented. This paper should answer the following question: Under the mentioned conditions related to greenhouse gas emissions and concentrations, are we to expect better or worse conditions for the cultivation of winter wheat on the Chernozem soil in the region of Zemun by the end of the 21st century?

MATERIALS AND METHODS

The CROPWAT 8.0 crop model was used for the projections of the water regime of Chernozem soil under winter wheat crops in the region of Zemun. The projections were made for the period from 2021/2022 to 2099/2100. The following parameters were analysed: minimum, maximum and mean air temperature (Tmin, Tmax, Tmean), effective rainfall, potential winter wheat evapotranspiration (ETc), actual winter wheat evapotranspiration (ETa), winter wheat irrigation water requirements and yield reduction (in relation to the genetic potential). The near (2021/2022-2050/2051) and distant future (2070/2071-2099/2100) simulations were compared with the reference period (1970/1971-1999/2000) simulations. The simulations were created based on the model inputs consisting of climate, crop and soil parameters. In terms of climate data, the input comprised monthly values of reference evapotranspiration (ETo), calculated using the modified Hargreaves method (Trajkovic, 2007), based on the projections of the daily values of minimum (Tmin) and maximum (Tmax) air temperature. The Tmin and Tmax projections, as well as the precipitation projections for the period from 2021/2022 to 2099/2100, were obtained using the results from the Nonhydrostatic Multi-Scale Model on the B grid (NMMB), which is a regional climate model with 8 km horizontal resolution (Djurdjevic and Krzic, 2014). The climate parameter simulations were based on the RCP8.5 scenario, which implies the continuation of greenhouse gas (GHG) emissions, with a constant increase scenario (Vukovic et al., 2018). In order to remove a systematic error (bias), the daily values of Tmin, Tmax and Tmean, as well as the daily values of precipitation were corrected using the quantile mapping statistical method (Piani et al., 2010; Dettinger et al., 2004). The correction was performed using the meteorological data (1970/1971-1999/2000) measured at the Surcin meteorological station of the Republic Hydrometeorological Service of Serbia.

Crop parameters were obtained from the FAO56 (Allen et al., 1998). It was assumed that winter wheat was sown on October 16th, that the growing period lasted 260 days, and that harvest was performed on June 22nd. The crop coefficients (Kc) were as follows: 0.4 (initial phase), 1.15 (mid season stage) and 0.25 (maturity). The soil was Chernozem on the Zemun loess terrace, with the total available water capacity of 170 mm per meter of depth. It was assumed that the initial soil moisture (on the sowing day) was at the level of field capacity.

The values of the simulated parameters in the near (2021/2022-2050/2051) and distant (2070/2071-2099/2100) future were compared with the values in the simulated reference period (1970/1971-1999/2000), and not with the measured values (Shen et al., 2018), in order to avoid the effect of the biases caused by the climate model.

RESULTS AND DISCUSSION

The growing period of winter wheat (October 16th - June 22nd) in the region of Zemun is characterized by an average mean air temperature (Tmean) (1970/1971-1999/2000) of 8.5 ^{o}C, an average Tmin of 4 ^{o}C and an average Tmax of 13.3 ^{o}C. Climate model simulations have indicated an increase of air temperature in the future (Figure 1). In the near future (2021/2022-2050/2051) Tmean will be higher by 2.6 ^{o}C, and in the distant future (2070/2071-2099/2100) it will be higher by 5.2 ^{o}C compared to the reference period (1970/1971-1999/2000). Differences relative to the reference period are expected to be larger for Tmin than for Tmax. It is expected that in the near future Tmin would be higher by 2.8 ^{o}C, and in the distant future by even 5.6 ^{o}C, relative to the reference period. An upward trend of Tmin and Tmax during the entire simulated period (2021/2022-2099/2100) is shown in Figure 1 – right.

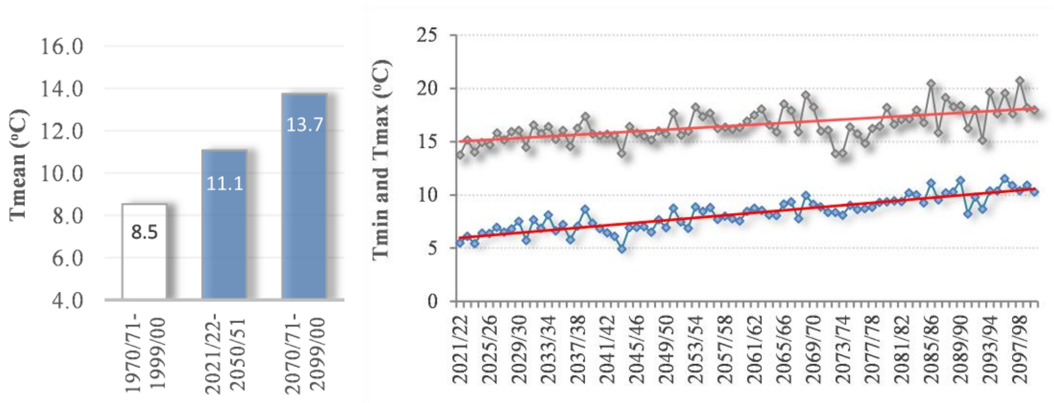

Figure 1. Left: Average mean air temperature (Tmean) in the reference period (1970/1971-1999/2000), in the near future (2021/2022-2050/2051) and in the distant future (2070/2071-2099/2100). Right: Simulation of the minimum and maximum air temperatures (Tmin and Tmax) during the entire observed period (2021/2022-2099/2100) and their upward trend.

During the growing season (1970/1971-1999/2000), an average amount of 342 mm of precipitation water is available to winter wheat. Simulations from the climate model have shown that in the future no major changes are to be expected (in the October-June period) in terms of precipitation quantity compared to the reference period. In the next thirty years, precipitation amounts are expected to increase by 5%, and in the final thirty years of the 21st century by 3% (Figure 2 – left).

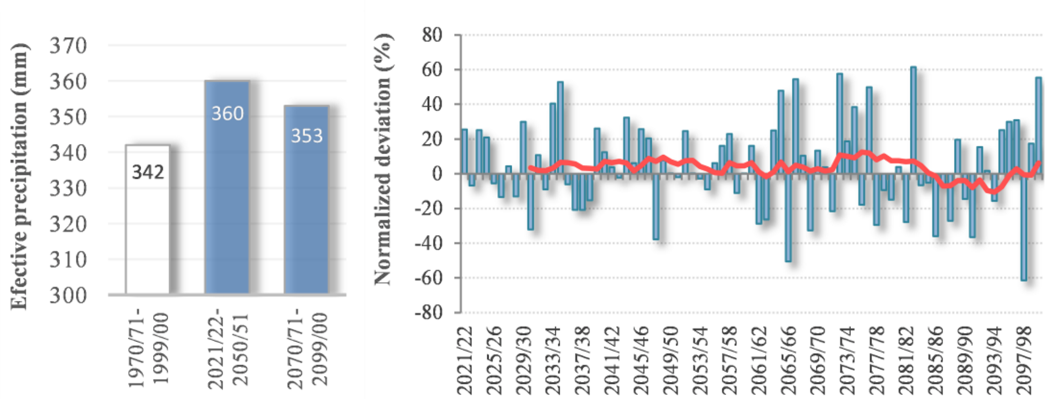

Figure 2. Left: Average value of effective precipitation in the reference period (1970/1971-1999/2000), in the near future (2021/2022-2050/2051) and in the distant future (2070/2071-2099/2100). Right: Time series of the normalised anomalies of projected effective precipitation (P_{eff}) during the winter wheat growing season 2021/2022-2099/2100 relative to the 1970/71–1999/2000 mean. The curve shows the moving average values for a 10-year period assigned to the last year of the period.

A time series of the normalised anomalies of effective rainfall relative to the 1970/1971–1999/2000 period indicates larger amplitudes of anomalies (both positive and negative) in the distant future than in the near future (Figure 2 – right). A ten-year moving averages curve shows a slightly increasing trend in precipitation in the near future, while in the distant future there will be an alternating trend between mild positive and negative anomalies (Figure 2 – right). It is interesting to mention that simulations from the same climate model have shown a decreasing trend in spring and summer precipitation (April-September), which in the distant future (2075-2100) even goes down to -34%, relative to the 1975-2000 period (Gregoric et al., 2020).

The winter wheat water requirements (1970/1971-1999/2000) equalled 341 mm on average. This is in line with the studies of Pocuca et al. (2021), who ascertained that in the region of Zemun in the 1966/67-2019/20 period an average winter wheat ETc was 348 mm. Simulations from the crop model have indicated an ETc increase of 4% in the near future and 3% in the distant future, relative to the reference period (Figure 3 – left). The differences in the projected water requirements between winter and spring crops should be pointed out. Namely, by applying the same climate and crop model, Gregoric et al. (2020) simulated a slight increase (1%) of maize ETc (April-September) in the near future (2023-2048), and a significantly higher increase of ETc (18.6%) in the distant future (2075-2100), relative to the reference period (1975-2000).

A time series of the normalised anomalies of ETc (Figure 3 – right) shows higher values of positive anomalies and a more frequent occurrence of negative anomalies in the distant future than in the near future.

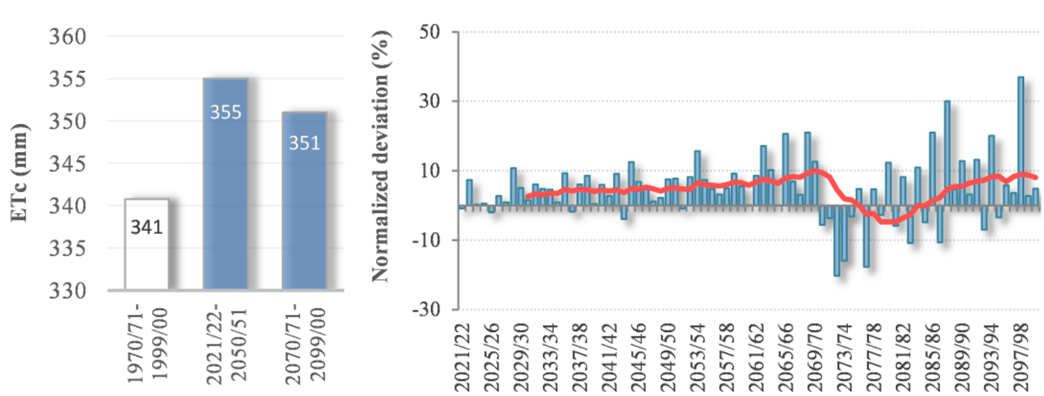

Figure 3. Left: Winter wheat potential evapotranspiration in the reference period (1970/1971-1999/2000), in the near future (2021/2022-2050/2051) and in the distant future (2070/2071-2099/2100). Right: Time series of the normalised anomalies of projected potential winter wheat evapotranspiration in the area of Zemun during 2021/2022-2099/2100, relative to the 1970/71–1999/2000 mean. The curve shows the moving average values for a 10-year period assigned to the last year of the period.

The winter wheat crops have been spending an average (1970/1971-1999/2000) water amount of 305 mm for actual evapotranspiration (ETa). The simulations have shown that the winter wheat ETa will increase by 10% in the near future, and that it will be equalized to the reference period in the distant future (Figure 4 – left). A time series of the normalised anomalies of ETa (Figure 4 – right) shows a more frequent occurrence of negative anomalies in the distant future than in the near future (Figure 4 – right). A ten-year moving averages curve shows a steady trend with positive ETa anomalies of around 10% in the near future, while in the distant future there is a decrease in positive anomalies and fluctuation of anomalies around zero (Figure 4 – right).

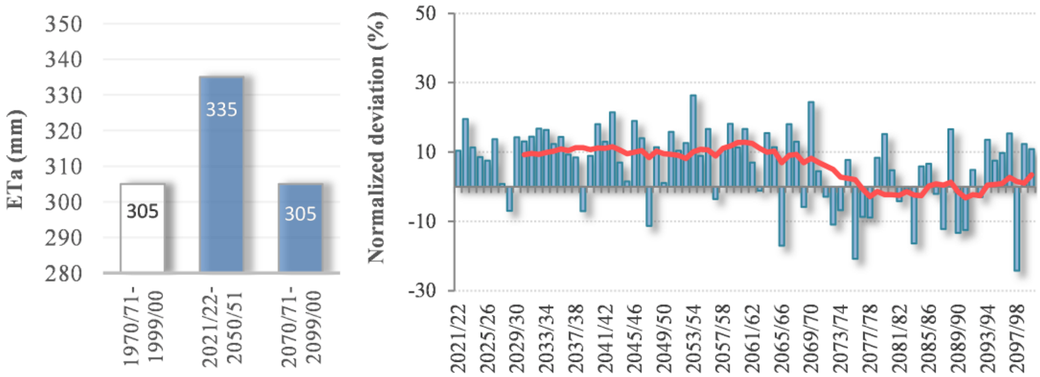

Figure 4. Left: Average winter wheat actual evapotranspiration (ETa) in the reference period (1970/1971-1999/2000), in the near future (2021/2022-2050/2051) and in the distant future (2070/2071-2099/2100). Right: Time series of the normalised anomalies of the projected winter wheat ETa in the area of Zemun during 2021/2022-2099/2100, relative to the 1970/71–1999/2000 mean. The curve shows the moving average values for a 10-year period assigned to the last year of the period.

The irrigation water requirements (IR) of winter wheat are 175 mm on average (1970/1971-1999/2000). The simulations have shown that irrigation water requirements will decrease (-7%) in the near future, and increase by 12% in the distant future, compared to the reference period (Figure 5 – left). The differences in the IR predictions for the near and distant future are the result of the simulations of ETc and precipitation amounts (Figure 2 and Figure 3) in the two observed future periods. The IR projections for the Zemun Chernozem, produced using the same models (Gregoric et al., 2020), only not for a winter, but for a spring crop – maize (April-September), have also indicated a decrease of irrigation water requirements (-9%) in the near future (2023-2048), and an increase as high as 73% in the distant future (2075-2100), compared to the reference period (1975-2000). The differences in the simulated IR between spring and winter crops lead to the conclusion that in the distant future water regime conditions are expected to be significantly less favourable for the production of spring crops than for the production of winter crops.
The normalised anomalies of IR relative to the 1970/1971–1999/2000 period are more characterized by negative (63%) than positive (37%) anomalies in the near future, while in the distant future negative anomalies (43%) are fewer than positive anomalies (57%) (Figure 5 – right). It can also be observed that the values of positive anomalies are significantly higher in the distant future (maximum of 121%) than in the near future (maximum of 32%). A ten-year moving averages curve shows an increasing trend of IR in the near future, starting from small negative anomalies and ending at zero. In the first

decade of the distant future, the ten-year moving averages curve indicates a decreasing IR trend, and in the following two decades, an increasing positive trend (Figure 5 – right).

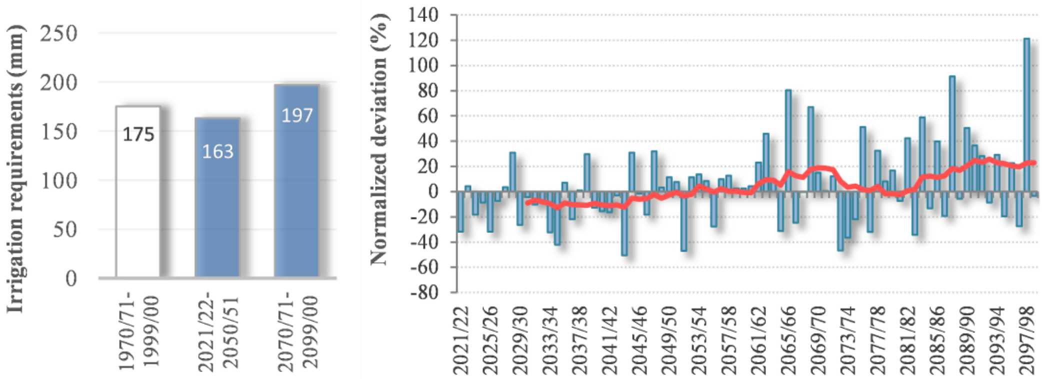

Figure 5. Left: Average irrigation water requirements in the reference period (1970/1971-1999/2000), in the near future (2021/2022-2050/2051) and in the distant future (2070/2071-2099/2100). Right: Normalised deviation of the projected winter wheat irrigation water requirements in the area of Zemun during 2021/2022-2099/2100, relative to the 1970/71–1999/2000 mean. The curve shows moving average values for a 10 year-period assigned to the last year of the period.

The Chernozem water regime under the natural rainfall regime has so far (2070/2071-2099/2100) caused an average reduction of winter wheat yield of 9.8% relative to the genetic yield potential. Simulations from the crop model have indicated that the soil water regime conditions will be more favourable in the near future, leading to a smaller yield reduction (5%), compared to the reference period (Figure 6 – left).

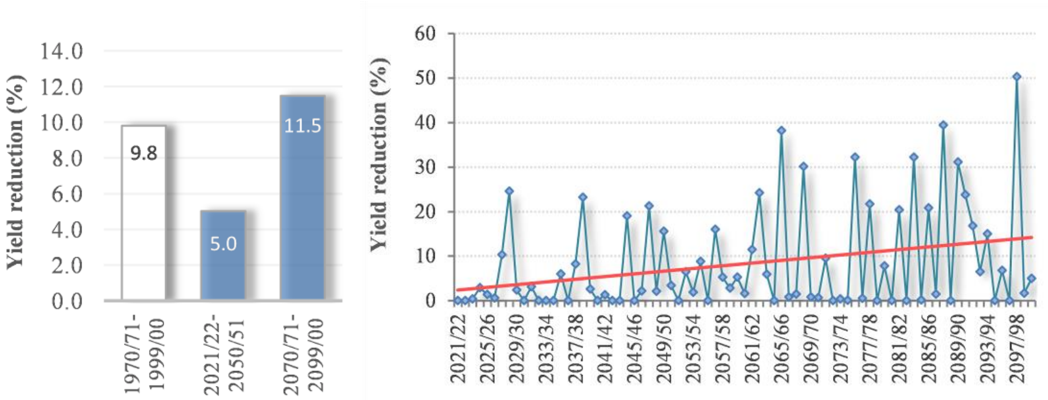

Figure 6. Left: Average winter wheat yield reduction in the reference period (1970/1971-1999/2000), in the near future (2021/2022-2050/2051) and in the distant future (2070/2071-2099/2100). Right: Simulation of the winter wheat yield reduction over the entire studied period (2021/2022 - 2099/2100) and its increasing trend.

In the distant future, due to the prediction of a higher water deficit, yield reduction is expected to be larger (11.5%). A graph of the yield reduction distribution over the entire studied period 2021/2022-2099/2100 (Figure 6 – right) shows a frequent occurrence of very high yield reduction values in the distant future. In the near future, over the course of 12 years (more than a third of the near future period), the simulations have indicated maximum yields (reduction equals zero). The highest simulated yield reduction value in the near future is 24.6%. In the distant future, over the course of 10 years, maximum yields are expected (reduction equals zero), and the maximum simulated yield reduction value is as high as 50.3%.

The predicted worsening of the Chernozem water regime conditions for the production of winter wheat in the distant future could be prevented by implementing adaptation measures to changing climate conditions. One of such measures is shifting of the winter wheat sowing date (Stricevic et al., 2021), which could prevent an increase in the water deficit in the future.

CONCLUSION

The projected climate parameters (2021/22-2099/2100) based on the RCP8.5 greenhouse gas emission scenario, have shown that by the end of the 21st century in the region of Zemun air temperatures are expected to increase, while precipitation amounts are not expected to change significantly during the winter wheat growing season (October-June).

The CROPWAT model simulations have shown that the Chernozem water regime conditions for the production of winter wheat are expected to be more favourable in the near future (2021/2022-2050/2051) and less favourable in the distant future (2070/2071-2099/2100), relative to the reference period (1971/1972-1999/2000).

In the near future it is expected that there will be an increase in the potential (ETc) and actual (ETa) evapotranspiration, and a decrease in irrigation water requirements and yield reduction, compared to the reference period.

In the distant future, ETc is expected to increase, ETa to remain unchanged and irrigation water requirements and yield reduction to increase, relative to the reference period.

ACKNOWLEDGMENT

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GROWTH CONTROL AND FRUIT QUALITY OF APPLE CULTIVAR 'GALA SCHNIGA' USING ROOT PRUNING TECHNIQUE

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Abstract

The aim of this study was to evaluate influence of different level intensity of root pruning on vigour and fruit quality of apple cultivars 'Gala Shniga'. Root pruning was done two weeks before buds burst, on one (RP1) and both side of rows (RP2), at a distance of 30 cm from the trunk and depth of 40 cm. The study included the following vegetative properties: stem diameter, trunk cross-sectional area, number and length of young shoots, number and length of internodes, while generative traits were included following a number of flowers buds per tree, a number of fruits per tree, return blooming, yield, the mass of fruit, a diameter of fruit, percentage of colored of fruits. A non pruning rootstock tree was as control. The highest values of total length and number of shoots were found in control trees. The value of TCSA was between 46.9 cm^2 to 57.0 cm^2, and the highest annual increase of TCSA had control trees (22.3%). Light root pruning (RP1) did not reduce the mass and diameter of fruits compared to control trees. The techniques of root pruning had significant effects on yield of the cultivar 'Gala Schniga'. The highest yield had trees in the RP1 treatment (29.2 kg), while control trees had the smallest (22.5 kg). The percentage of marketable fruits was higher in control trees compared to treated trees. The highest content of total soluble solids was found in fruits from treatment 2, while control trees had the lowest. Root pruning had strong influence to decreasing vigour of trees. So, moderate root pruning techniques at the end of the winter period could be recommended for successful control of vegetative growth and improved generative properties.

Keywords: apple, root pruning, vigour, yield, fruits quality.

INTRODUCTION

The growth control of apple trees is of great importance in orchard management for sustainable production. According to Carra et al. (2017) control of vegetative growth of trees is necessary to avoid excessive shading within the canopy, improve fruit quality and yield, and also better control pests and diseases and decreased pruning cost. The main techniques for controlling vegetative growth in fruit trees are branch bending, pruning, use plant bioregulators and the use of dwarfing rootstocks. However, traditional manual shoot pruning is time-consuming and expensive, therefore alternative methods for controlling canopy growth have been used in orchards. Also, chemical growth retardants have been widely used to control excessive shoot growth of fruit trees, but this has resulted in increased chemical residues on the fruit and a negative impact on the environment (Wang

et al., 2014a). Control of vegetative growth by summer and winter pruning, therefore, is essential to ensure the productivity of orchards and to improve fruit quality but may increase production costs.
A successful alternative to controlling fruit growth, reducing vigour, increasing yield, improving yield quality, along increasing productivity of production can be pruning of the root system (Sharma et al., 2008). Root pruning reduces its area, reducing the flow of nutrients, water and hormones to the branches, which altogether results in weaker tree growth (Maas, 2008). This technique is an effective tool for controlling vegetative growth, reduction in shoots number and shoot length, as well as a higher number of flower buds and a more regular production (Asin et al., 2007). Also, pruning the roots prevents the fall of fruits before harvest and improves their stored properties. Root pruning has a special significance in dense planting systems, as a successful measure in controlling the growth and yield of fruit trees. The pruning of root impeded the canopy growth, altered the plant water status leading to flower promotion. In addition, it is also a promising practice to overcome the alternate bearing on fruit tree (Budiarto et al., 2019). Root pruning shows the best effects if it is done during the winter dormancy of fruit trees, and one should be careful with the intensity of pruning. Root pruning on both sides of the trunk, before the beginning of vegetation, reduced the average length of young shoots by 72% and the total number of young shoots by 43%, with increasing differentiation of flower buds, but with reducing fruit size (Wang et al., 2014b). Nevertheless, it increased tree productivity and enhanced fruit colouring (Kviklys et al., 2020).
By applying pruning on one side of the root, in the direction of providing rows, a more moderate effect is achieved, while pruning the root on both sides can be too sharp, followed by a bad influence on the development of the tree (Khan et al., 1998). Pruning of the root system in two terms, in the autumn after the fall of the leaves and in the spring before flowering, had a significant positive effect on the yield and quality of fruits in apple varieties (Miter et al., 2012). Pruning of the apple root system applied to control growth, immediately after June fruit decline, had a negative impact on fruit yield and quality, causing intense fruit decline before harvest (McArtney and Belton, 1992).
The aim of this study was to examine the influence of different intensity of root pruning technique on growth control and productivity and fruit quality of apple cultivar 'Gala Schniga'.

MATERIALS AND METHODS

The study was carried out at a commercial orchard located at the village Nakovo, near Kikinda city, district of North Banat. The area has a continental climate with an average annual rainfall of 550 mm. The trees were trained as slender spindle under irrigated standard cultural practices. The plantation was built on sandy soil type, average pH in H_2O amounts to 6.3. The root trees were pruned at the end of the winter period in season 2020 (March 14th). The treatments of root pruning (RP) were applied one side of the tree (RP1) and on two sides of the tree (RP2), at a distance of 30 cm from the trunk and depth of 40 cm. Non-pruning rootstock trees were used as control.

The experiment comprised research of the influence of different levels of root pruning to vegetative and generative properties and fruits quality of apple cultivar 'Gala Schniga'. The study included the following vegetative properties: stem diameter (SD), trunk cross-sectional area (TCSA), number and length of young shoots, number and length of internodes. Within generative traits were included following a number of flowers buds per tree, a number of fruits per tree, return blooming, yield, the mass of fruit, a diameter of fruit, percentage of radish of fruits. Also, evaluated chemical properties of fruits: soluble solid contents (SSC), total sugars (TS), total acids (TA). For the determination of the ripening stage, the Streif index (SI) considering starch, sugar and firmness was implemented to reduce subjectivity (Streif, 1996).

The experiment was conducted by a random field with five repetitions (four trees were taken from a repeat). Physical properties of fruits were determined with four repetitions, and each repetition included 20 fruits. Chemical properties were determined with three repetitions. The physical properties were determined by using standard morphometrics methods. SSC was determined by refractometer (Atago, pocket PAL-1. Kyoto, Japan). Titratable acidity (TA) was determined by titrating 25 g of fruits with 0.1N NaOH up to pH 7.0 in %. Total sugars (TS) were determined by the Luff-Schoorl method, expressed in %. Analysis of variance has been done with STATISTICA 9 software package. The significant differences between means determined at $P<0.05$, measured with LSD test.

RESULTS AND DISCUSSION

Root pruning had a significant influence on vegetative properties and control the growth to apple trees (table 1). The control trees had significantly lowest values of stem diameter compared to treatments trees at start of seasons. Meanwhile, at the end of season differences between stem diameters did not sign. The content of TCSA valued from 46.9 cm^2 to 57.0 cm^2. The highest annual increase of TCSA had control trees (22.3%), while treatments trees had similar values.A root pruning did not influence the number of young shoots and the number of internodes per shoots.

Table 1. Vegetative properties of apple trees cultivar 'Gala Schniga'

	SD 1 (mm)	SD 2 (mm)	TCSA 1 (cm^2)	TCSA 2 (cm^2)	% increase of TCSA	Number of young shoot	Length of young shoots (cm)	Number of internodes	Length of internode (cm)
RP1	55.9	58.2	55.9	58.2	4.15	52.2	28.1	12.2	2.7
RP2	57.0	59.7	57.0	59.7	4.70	50.8	25.4	12.1	2.5
Control	46.9	57.4	46.9	57.4	22.30	53.2	32.4	12.7	3.1
lsd 0.05	4.1	6.0	4.1	6.0	10.3	10.8	3.7	3.7	0.5

SD 1 – the start of the season; SD 2 – end of the season; TCSA 1 – the start of the season; TCSA 2 –end of the season. Data are means of four replications; different letters in columns indicate a significant difference between cultivars according to LSD test at 5% level ($p < 0.05$)

However, root pruning had strong effects on the length of young shoots and the length of internodes. Control trees had a significantly higher values of those parameters compared to treatments trees. The results of ours study were confirmed with results of others authors (Khan et al., 1998; Yang et al., 2010). Also, authors report that root restriction decrease vegetative growth, and alter the metabolism of vegetative organs, due to affects leaf photosynthesis and nutrient content (Zhu et al., 2006; Zhao et al., 2013). The root pruning treatment significantly improves the photosynthesis of plants, decrease the root system redundancy, and plays an important role in inhibiting vegetative growth (Zhou et al., 2015).

The root pruning had strong effects to generative properties and fruits quality of cultivar ‘Gala Schniga’ (table 2). Control trees had the lowest parameters of generative properties compared to treatments trees especially to the number of flower buds. Our results have a confirmed to Raja et al. (2018), which observed that a maximum number of flowers was recorded in root pruning (193.20) while the minimum number of flowers was recorded in control plants (48.50). The control trees had a higher mass of fruits (165.0 g), while the severe root pruning (RP 2) influenced the smallest fruits mass (153.3 g). Also, fruits from control trees had higher values of diameter. Light root pruning (RP1) did not reduce the mass and diameter of fruits compared to control trees. To the moderate root pruning leaf gas exchange rate recovered within 11 days after root pruning thus ascribing the effects on plant growth to a transfer on metabolites allocation pattern rather than to a reduction of plant activity (Lodolini et al., 2017).

Table 2. Generative properties and fruit quality of ‘Gala Schniga’

	No. of flower buds	No. of fruits	Return bloom	Mass of fruits (g)	Diameter of fruits (mm)	% rudish of fruits	Firmness (kg/cm^2)	SSC (%)	Iodine scale (1-10)	SI
RP1	135.5	137.4	112.1	160.2	70.5	65.3	7.4	13.4	6.5	0.08
RP2	145.0	123.9a	142.9	153.3	68.9	68.2	7.9	14.2	7.3	0.08
Control	73.8	102.2	89.0	165.0	73.7	56.3	6.8	13.0	5.9	0.09
lsd 0.05	33.4	20.8	18.3	7.9	3.6	6.1	1.0	0.7		

Data are means of four replications; different letters in columns indicate a significant difference between cultivars according to LSD test at 5% level ($p < 0.05$)

The higher vigour of the canopy in control trees was produced the lowest values of coloured fruits. According to Blanke (2015) root pruning is the first steps to improve fruit colouration by improving light penetration into the tree canopy and to the fruits.

The techniques of root pruning had significant effects on yield of the cultivar ‘Gala Schniga’ (Table 3). The highest yield had trees in the RP1 treatment (29.2 kg), while control tees had the smallest (22.5 kg). Control trees had a significantly higher percentage of mature fruits at the first time of harvest (64.4%), while fruits in both treatments had uniformly and evenly matured at the first and second time of harvest. Also, control trees had higher values of marketable fruits (> 65 mm), especially fruits higher than 70 mm, while fruits in treatments RP2 had the smallest values of marketable fruits. Khan et al. (1998) recorded that severe root pruning increased the number of flowering spurs, but at the same time induced a decrease in total yield and average fruits size. A compared fruits in both treatments authors recorded significantly higher values of fruits at 65-70 mm class in care of RP1.

Table 3. Productivity and percentage of a different class of fruits cultivar 'Gala Schniga'

	Yield (kg)	Harvest I (%)	Harvest II (%)	% of fruits (<65 mm)	% of fruits (65-70 mm)	% of fruits (> 70 mm)
RP1	29.2	49.7	50.3	10.6	32.1	57.4
RP2	27.2	47.8	52.2	15.8	25.5	58.8
Control	22.5	64.4	35.6	7.7	28.6	63.8
lsd 0,05	5.3	13.4	12.6	5.4	4.9	5.0

Harvest I – harvest at first time, Harvest II – harvest at a second time; Data are means of four replications; different letters in columns indicate a significant difference between cultivars according to LSD test at 5% level ($p < 0.05$)

CONCLUSION

The techniques of root pruning had significant effects to the control of vegetative growth and productivity and fruits quality. Root pruning affected to decrease of TSCA and length of young shoots. Compared to the control trees a root pruning treatments had higher values of flower buds and a positive effect on the return blooming. Only RP2 treatment had effects to decrease of mass and diameter of fruits, and decrease of the percentage of marketable fruits. The moderate root pruning techniques at the end of the winter period could be recommended for successful control of vegetative growth and improved generative properties.

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APPLICATION OF MULTISENSOR CAPACITANCE PROBES (MCAP) FOR SPATIAL AND TEMPORAL MONITORING SOIL MOISTURE, SALINITY, AND TEMPERATURE DYNAMICS IN IRRIGATED ORCHARDS

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Abstract

Irrigation using treated wastewater is a promising alternative for Southern Italy as this area currently faces chronic water scarcity and high irrigation requirements. An issue associated with agricultural irrigation using reclaimed wastewater is the impact on soil characteristics. A field experiment was established on an apricot orchard growing in a Mediterranean environment to investigate the effects of freshwater groundwater (GW) and treated wastewater (TWW) on irrigated soils including soil temperature, soil salinity, and soil water content at different depths in the soil profile (5, 15, 25, 35, 45, 55 cm depth). To monitor these parameters, advanced network-based multi-depth soil moisture sensors were installed and in-field real-time data via a web-based platform were obtained during the cropping season. The results provide numerical references into the soil moisture-salinity-temperature dynamics for areas considering the use of treated wastewater. The results obtained show that in comparison with GW, the use of TWW can lead to a decrease in soil infiltration rate, an increase in soil water content but slightly higher salinity. There was no significant difference in soil temperature. This study also demonstrates the benefits of soil moisture monitoring as a reliable tool for water-efficient crop management practices.

Keywords: crop monitoring; intelligent irrigation system; soil measurement probes; soil water content; soil temperature; soil salinity; irrigation management

INTRODUCTION

As a consequence of increasing water scarcity, irrigation with non-conventional water resources is a growing phenomenon in many arid and semi-arid countries. Consequently, the sustainability of irrigated agriculture in these regions depends, mainly on the level of soil salinity and the quality of irrigation water (Aldakheel, 2011). Therefore, exploring the spatial distribution pattern and its driving factors of soil salinity and moisture can provide a basic reference for improving soil salinization, increasing agricultural production, and maintaining regional stability. Several advanced technologies are available to assist with achieving and implementing optimized irrigation management. They include weather stations, air- and space-borne remote sensing platforms, computer models, plant feedback sensors, and soil moisture sensors (Datta et al., 2018). The use of soil moisture monitoring probes has continued to increase in popularity in the design, monitoring, and control of irrigation systems. They assist irrigation management to improve yields, quality, conserve water and energy, and reduce nutrient leaching. Some example of capacitance-based sensors includes EnviroScan, Decagon 5TE, Decagon 10HS, Delta-T PR1/PR2 probes, Sentek TriScan, or other types (Sharma et al., 2018). One of the goals of the IR2MA project (www.interregir2ma.eu) was the implementation of Sentek Drill & Drop sensors to monitor soil-water relation parameters of crop growth under conventional groundwater and treated wastewater. The objective of this study is therefore to present results of soil moisture, salinity and temperature dynamics in freshwater and wastewater irrigated orchards using multi-sensor capacitance probes (MCAP).

MATERIALS AND METHODS

Experimental details

A set of Sentek Drill & Drop sensors equipped with data loggers were installed at an apricot tree field (Figure 1) in Acquaviva delle Fonti (40°56'11.8"N 16°49'20.4"E), in Southern Italy. The probes were situated 5-12 m apart in different orchard rows and were installed at three freshwater plots and three at the TWW plots. The site is characterized by a Mediterranean climate with mild winters and warm to hot, dry summers.

Figure 1. Drill&Drop automated sensors installed in an Apricot farm, Southern Italy.

The apricot trees were managed according to the usual cultural practices on the farm. Irrigation was performed using a drip irrigation system. Rainfall during the irrigation season of the nectarine orchard amounted to 250 mm. The total volume of irrigation water was 3160 $m^3 ha^{-1}$. The electrical conductivity of irrigation water tested was 0.5 dS m^{-1} for GW and 1.5 dS m^{-1} for TWW. The soil of the experimental grove is a sandy loam. The monitoring period of the in-situ observational system was from 01 April 2020 to 15 September 2020, and data were recorded over 10-minute intervals on a data logger. The readings were made at several depths in the soil profile (5, 15, 25, 35, 45, 55 cm). The data was assessed in real-time and processed using the IrriMAX software provided by the Sentek Multi system. Additional data analysis and mapping were performed by using Excel 2016. The values were calculated using the default calibration curve parameters from the supplier, so no site-specific soil calibration procedures were performed.

RESULTS AND DISCUSSION

Soil Water Content (SWC)

Table 1 presents the minimum, maximum, and average cumulative SWC measured in the soil profile (0-55 cm). The results revealed that SWC in the TWW plots (154.5 mm) was higher than in FW plots (113.2 mm). Similar findings have been observed in orchards by other authors (Assouline et al., 2016; Bardhan et al., 2016; Rahav et al., 2017; Albalasmeh et al., 2020). Generally, the higher water content in the TWW-irrigated soil profile could be attributed to reduced root water uptake, reduced evaporation through the soil surface, or both (Rahav et al., 2017). TWW irrigation is likely to decrease the soil infiltration rate and diminish its saturated hydraulic conductivity (Assouline et al. 2016; Albalasmeh et al. 2020) leading to reduced water-uptake rate, despite the assumption that high water content increases water availability for root uptake (Rahav et al. 2017).

Table 1. Soil water content (SWC) for freshwater (FW) and treated wastewater (TWW) irrigated apricot orchard (0-55 cm).

Water source	Parameter	Cumulative SWC (mm)
FW	Average Season	113.2
	Maximum Season	213
	Minimum Season	88.6
TWW	Average Season	154.5
	Maximum Season	228.1
	Minimum Season	127.1

Figure 2 shows the average moisture content in the soil at different depths. Ranges of SWC increase in T1, T2, and T3 (0-35 cm) and decrease in soil depth above 35 cm. The upper layers are mainly controlled by precipitation and evapotranspiration, which are variable in time.

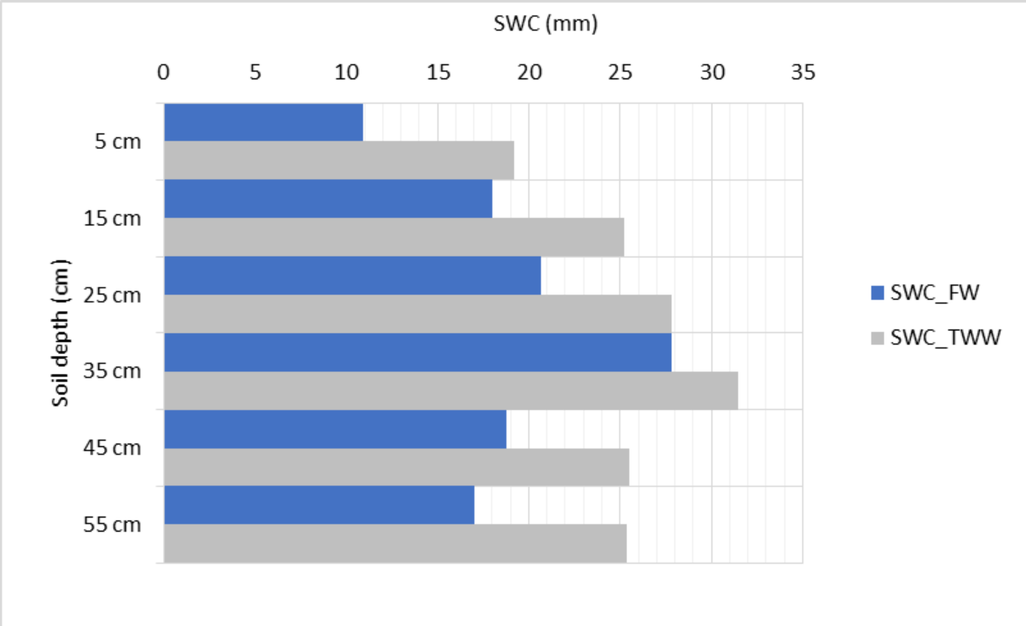

Figure 2. Average soil water content (SWC) at different soil depths using Drill&Drop sensors for freshwater (FW) and treated wastewater (TWW) irrigated apricot orchard.

Volumetric Ion content (VIC)

The sensor produces an output of salinity in VIC a surrogate measure for soil EC. Measured VIC will increase with increasing irrigation water electrical conductivity (EC). Acceptable VIC data range from 1000 to 17,000. Values above 5000 VIC are generally considered to be causing significant plant stress and loss of yield, but this degree of risk is dependent upon soil type (Dalton et al., 2018). The results revealed that the high salt concentrations in the TWW induce high average salinity (Table 2).

Table 2. Volumetric ion content (VIC) for freshwater (FW) and treated wastewater (TWW) irrigated apricot orchard.

Water source	Parameter	Cumulative VIC
FW	Average Season	1526.6
	Maximum Season	2002.6
	Minimum Season	1104.7
TWW	Average Season	1585.1
	Maximum Season	2191.1
	Minimum Season	1371.1

Similar results were reported by other authors (Kaboosi, 2017; Lyu and Chen, 2016; Rahav et al., 2017). The VIC of TWW irrigation was valued between 1371.1 and 2191.1 with an average of 1585 VIC. The VIC of FW irrigation was valued between 1104.7 and 2002.1 with an average of 1526.6 VIC. These numerical results show that the soil salinity in the wastewater-irrigated area is a little more (<10%) than freshwater irrigated land.

Figure 3 shows a dynamic change of salinity level at multiple depths. The general patterns indicate that VIC increased with a decrease in soil water content. Salt accumulation mainly occurred in the middle layers. In the upper soil layers of T1 (0-5 cm) and T2 (5-15 cm), the VIC was lower than those of T3, T4, and T5.

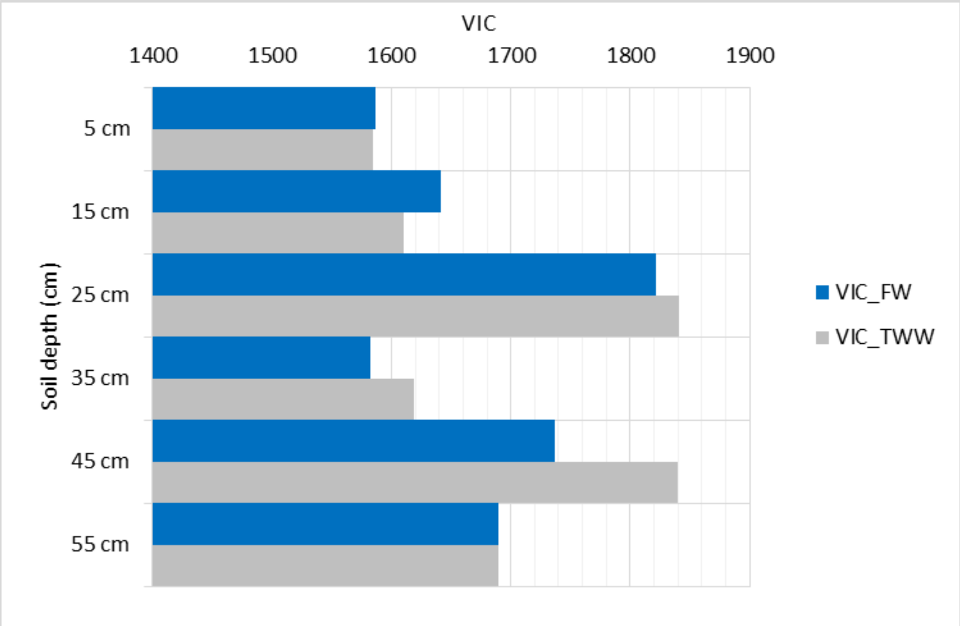

Figure 3. Volumetric Ion content (VIC) at different soil depths using Drill&Drop sensors for freshwater (FW) and treated wastewater (TWW) irrigated apricot orchard.

Soil Temperature (ST)

The measurement of soil temperature (ST) is often needed in understanding its impact on these various processes and in turn the plant growth and crop yields. Soil temperature affects soil water retention, transmission, and availability to plants (Onwuka, 2018).

Table 3. Soil Temperature (ST) for freshwater (FW) and treated wastewater (TWW) irrigated apricot orchard (0-55 cm).

Water source	Parameter	Soil Temperature (°C)
FW	Average Season	22.7
	Maximum Season	36
	Minimum Season	7.8
TWW	Average Season	22.7
	Maximum Season	35.5
	Minimum Season	8.6

Higher ST enhances physiological activity, thus promoting ion uptake, including salt ion(s) uptake resulting in more serious salt damage to crops (Bai et al., 2017). The ideal ST for planting most plants is 18-24 °C. Soil temperature was quite similar at both monitoring irrigated plots (Table 3). The estimated annual average ST (0-55 cm) ranged from 7.8 to 36 °C for GW and 8.6 to 35.5 °C for TWW.

The results from soil temperature sensor readings indicated that both the highest and lowest observed soil temperatures occur at the surface and the largest depth. As illustrated in Figure 4 the increase in soil temperature followed a T1 < T2 < T3 < T4 < T5 pattern (decreases with an increase in depth). The fluctuations of soil temperature are more regular in the topsoil than in the lower soil layers, because soil temperature variations are primarily driven by the fluctuating temperature of the soil surface (Zou, 2012). After a depth of 35 cm, the soil temperature tends to become constant. Changes in temperature around deep roots can change moisture uptake.

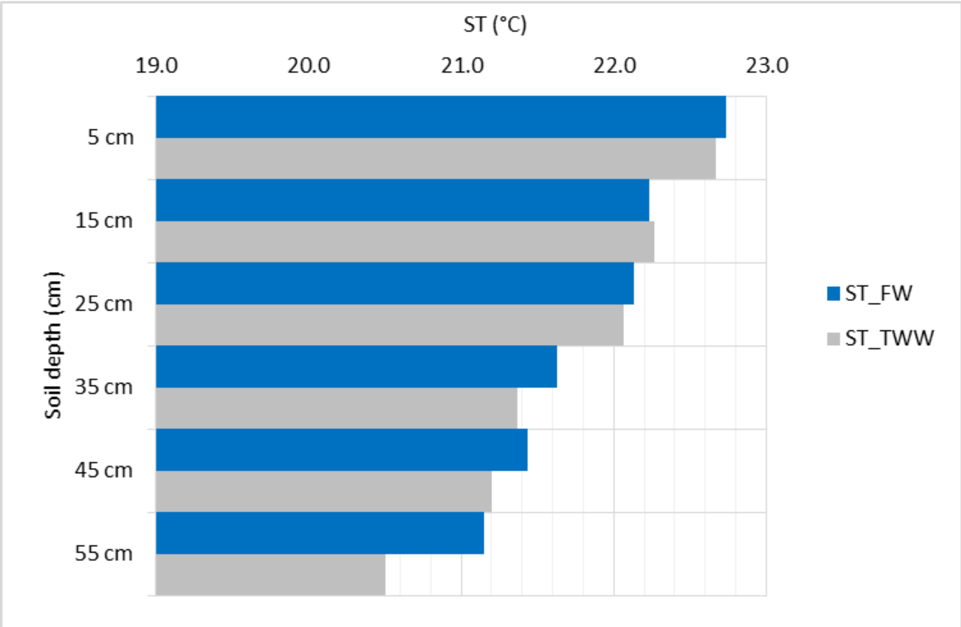

Figure 4. Average soil temperature (ST) at different soil depths using Drill&Drop sensors for freshwater (FW) and treated wastewater (TWW) irrigated apricot orchard.

2D Moisture, Salinity and Temperature information

A new feature in IrriMAX™ software, called 2D Imager, allowed for the 2-dimensional spatial and temporal visualization (Figure 5) of monitored parameters throughout the whole root zone. The 2D analysis was found a very useful and easy tool for visualizing the dynamic changes at any depth. The analysis can generate a time series of images, forming a video sequence that can be viewed at a convenient speed. The imagery analysis confirmed that SWC was mainly concentrated at a depth of 0–35 cm. As the depth of soil increases, the amplitude of temperature decreases, and soil temperature variability is low. On the seasonal scale, SWC shows a decreasing trend, while salinity and soil temperature have an increasing trend from spring to summer.

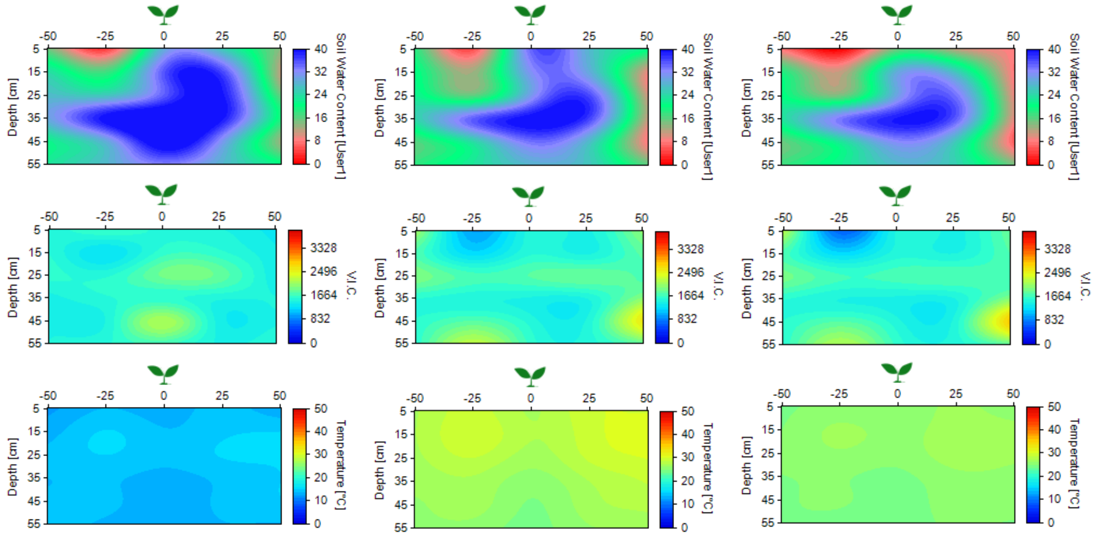

Figure 5. SWC, VIC, and ST at different depths in the soil profile on different days (15 April left, 15 August center, and 15 September right) of the growing season.

CONCLUSION

In this study, automated measurement of soil moisture, salinity, and soil temperature was carried out using state-of-the-art soil moisture sensing devices. The overall results of this experiment indicated the use of TWW can lead to a decrease in soil infiltration rate, an increase in soil water content but slightly higher salinity. The higher levels of salinity in the irrigation water are not dangerous, however, water delivery and distribution systems must be operated efficiently to facilitate the timely supply of water in the right quantities and to avoid waterlogging and salinity build-up in irrigated lands, especially when saline waters are involved. The use of saline water needs to utilize in combination with other water of low salinity or adopting a "dual-rotation" strategy. The results of this trial demonstrate the feasibility of automated sensor-based orchard monitoring to provide useful information to monitor crop growth and refine irrigation management.

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THE EFFECT OF THE INTER-ROWS GRASS COVER CROPS ON QUALITY OF GRAPES

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Abstract

The experiment was set up in vineyard of "Radovanović" winery, Serbia with grass cover sown in inter row spaces. Row spacing is 2.4 m and 0.9 m between vines in row. Guyot training system was used and clones examined were Cabernet sauvignon VCR: 169, 191, 412 and ENTAV 15. Two layers of soil (surface 0-30 cm depth and subsurface 30-60 cm depth) were examined on soil fertility parameters: pH value, total N, organic C, quantity of available K_2O and P_2O_5. The inter-row space was sown with a grass-legume mixture composed of 60% red fescue, 30% perennial ryegrass and 10% white clover. The experiment with the grass-legume mixture was set up in 2020 and the mixture was fertilized by nitrogen fertilizer (ammonium nitrate) during the budbreak growth stage with doses of 0, 50 and 100 kg ha^{-1}. The dry biomass yield, nitrogen content in biomass, and visual assessment of lawn quality under the influence of nitrogen application were monitored. The aim of the research was to determine the influence of grass cover and N fertilization on grape quality in the vineyard inter-rows maintained according to the criteria of optimal lawn management. Grape quality is shown through content of sugar and total acids expressed as tartaric acid content in grape juice-must, pH and glycoacidometric index. The grass cover temperature was measured with a thermal imaging camera (FLIR, T335) twice during the vegetation period. The average grass cover temperature for all treatments during the first measurement date varied from 22.0ºC to 30.7ºC, averaging 25.9ºC. During the second measurement, it varied from 27.9ºC to 33.8ºC, averaging 30.4ºC. In both measurements, the highest temperatures were obtained for clones 169 and ENTAV 15 which were similar; while for clones 191 and 412 the lowest temperatures were obtained. The results show that the clone influences the temperature of the plant cover, which can influence the quality of grass and grapes. A high degree of variation was found for sugar content, from 17.3% (clone ENTAV 15, AN 100) to 25.2% (clone 169, AN 50). The content of total acids expressed as tartaric acid had the lowest values for clone ENTAV 15 treatment AN 100 (5.4 g/l), and the highest for clone 191 treatment AN 100 (9.9 g/l). Glycoacidometric index varied from 1.78-4.49.

Keywords: Cabernet Sauvignon, grass cover, ammonium nitrate, quality, grape, thermal imaging

INTRODUCTION

Viticulture is one of the most soil eroded land use and frequently its soils are poor in organic matter, intensively tilled and with no protective plant cover (Barrena-Gonzalez et al., 2020). Cover crops are important ecological vineyard management tools, which improve the soil structure and soil erosion control, enrich nitrogen and organic matter content, and regulate excessive grapevine vigour (Pardini et al., 2002). Many experiments have been carried out to identify the influence of different floor covers in grapevine vegetative growth, yield, berry and wine quality better (Monteiro and Lopes, 2007; Guerra and Steenwerth, 2012; Mercenaro et al., 2014). Today, cover crops are widely used in vineyard inter-rows combined with herbicide strips under the vines.

Since the early 1900s, cover crops have been used in Californian vineyards (Sulas et al., 2017) to reduce erosion, add or reduce N and grapevine vigour, when leguminous plants or grasses are used, increase soil organic matter, improve soil structure, and water penetration. Cover crops proved to be a useful tool to limit the excessive vine vigour, resulting in changes in the quality of the grapes and wines (Nieddu et al., 2000). The use of permanent grass cover in vineyards is spreading because it is supported by specific subsidies for environmental measures of the EU Common Agricultural Policy (Napoli et al., 2017).

The introduction of cover crops in vineyards is being tested as it mitigates some undesirable environmental impacts of these cropping systems, such as surface runoff and soil erosion. In some cases, it could even reduce an excessive vegetative vigour of grapevine. However, in most cases, wine growers are worried that severe competition for soil resources between the intercrop and grapevines could impair grape yield and quality (Celette et al., 2010).

Soil temperature is one of the most important environmental regulators of numerous physical and chemical processes in soil, plant roots and tops growth and nutrient availability (Abu-Hamdeh, 2000; Abu-Hamdeh and Reeder, 2000). Heat flow and associated soil temperature are strongly periodic because of variations in daily and seasonal solar radiation (Mihalakkou, 2002). These are greatly modified by grass cover or plant-residue and soil management practices. Grass cover and plant residue affect soil temperature mostly by altering the reflection coefficient, thereby changing the net radiation at the soil surface. The controlled grass cover and reduced tillage technique were proposed to prevent soil structural degradation (Ferrero et al., 2004). On various hilly lands, in central Italy, the grass cover management of orchards has proved, to mitigate soil erosion, by reducing runoff (Bazzoffi and Chisci, 1999). In the study of Ferrero et al. (2004) the average daily soil temperatures in most of autumn and winter months were higher under grass cover than traditional tillage. The differences between minimum and maximum daily temperatures were pronounced the most strongly during the February - March period and in August. The mean standard deviations of monthly soil temperature were lower in grass cover than in tillage in most months, mainly due to the damping effect of grass cover.

One of the most important indicators of crop water stress is the canopy temperature, which helps determine the time of irrigation. Evaluation of the canopy temperature is of the utmost importance for monitoring the water regime of plants (Wang et al., 2010) and scheduling irrigation (Jones and Ilkka, 2003).

Muscas et al. (2017) findings highlight that complete vineyard floor cover cropping significantly influences grapevine growth, yield and must composition and, when optimized, represents a sustainable tool to improve the quality of wines. Making generalizations about the most suitable floor management system in vineyards is difficult, as response to cover crop is site-specific and variety-dependent due to differences in terms of soil, plant vigour, level of production and oenological objectives. Therefore, the choice of cover crops strongly depends on the wine grape cultivar and cultivation site. In this context, complete grass cover is recommended in order to limit excessive vegetative growth and improve must quality, especially the phenolic content.

To ascertain the efficiency of this practice to improve the physical properties of the soil, a farm scale experiment was established in 2020. The aim of this study was to determine the effects of controlled grass cover and fertilisation in the inter-rows on annual course of grass cover temperature and grape quality of Cabernet Sauvignon clones.

MATERIAL AND METHODS

The influence of cover cropping quality (inter-row) on grapevine growth and must quality was evaluated in a field trial in a commercial vineyard in central Serbia. The experiment was set up in 2020 at Krnjevo, Velika Plana municipality, Central Serbia (alt. 220 m a.s.l., lat. 44º 25' 47" N and long. 21º 02' 14" E), in a vineyard that had been under cultivation since establishment. The soil was Eutric Cambisol.

Data were collected in a commercial 12-year-old Cabernet Sauvignon CV vineyard. The vineyard had a planting density of 4630 vines per hectare, spaced 0.9 m within and 2.4 m between east-west oriented rows. Guyot training system was used and clones examined were Cabernet sauvignon VCR: 169, 191, 412 and ENTAV 15.

For the analysis of basic soil fertility, samples were collected with a drill from depths important basically for grass development (0-30 cm) and in the main, important for vineyard (30-60 cm). Using standard agrochemical methods it was determined: pH, (actual pH_{H2O} and exchangeable pH_{KCl}), total organic carbon, total nitrogen content, available phosphorus (P_2O_5) and potassium (K_2O).

The experimental design was a randomized complete block design with fertilizer treatments of different rates (N1 - 0 kg N/ha; N2 - 50 kg N/ha; N3- 100 kg) and three replications per treatment, plot size 10 m^2 (700 x 143 cm in each plot, in inter-row spacing). The nitrogen fertilizer ammonium nitrate, 34% N (AN) was applied on sown grass-legume mixture: 60%, *Festuca rubra* 30% *Lolium perenne* and 10% *Trifolium repens,* sown in autumn 2017 (under clones 412 and 191), and sown in autumn 2019 (under clones 169 and ENTAV 15). Vegetation above-ground biomass was periodically assessed, swards were mowed when their height reached 10–15 cm in order to control the cover crop vegetative growth and ensure a proper establishment. The grass cover in clones 169 and ENTAV 15 was cut once, while cover in clones 412 and 191 was cut two times, and dry biomass, N content in biomass and visual assessment of grass quality under influence of nitrogen fertilization were monitored. Plant samples were oven-dried at 60 °C to constant weight and then weighed to determine the above-ground dry matter yield. The total nitrogen content in soil and plant biomass was determined by Kjeldahl digestion

(Bremner, 1996). The sward covering rate per cut was measured as a turf-grass stand density scale, based on a 1 to 9 rating scale (Morris, 2001). One is the poorest or lowest (invasive species/bare ground percents increased, 1=76–100%) and 9 is the best or highest rating (9=complete stand).
The grapes quality was expressed through sugar content in grape which was determined by Oeshle mostwage and Dujardin-Salleron tables. Total acid content expresed as tartaric was determined by titration method with n/4 NaOH.
The grass cover temperature was measured with a thermal imaging camera (FLIR, T335) twice during the vegetation period. The obtained images were analyzed on a sample of 30 temperature spots per treatment.
Data were analysed through analysis of variance and LSD test, in order to recognize significant effects of fertilization treatments.

Soil analysis
The surface (0-30 cm) and subsurface layer of the soil (30-60 cm deep) is acidic (Table 1). In relation to soils under other cultivated crops and natural stands, the difference between the measured values of pH (so-called ΔpH) in the surface layer is very large. According to the content of total organic carbon, the surface layer of the soil is weakly in humus, the subsurface is very weakly to slightly. The nitrogen content in the soil under the vineyard is generally low, while in the available P_2O_5 this soil is poor. In available K_2O, the land under the vineyard is generally well supplied.

Table 1. Agrochemical properties of soils

Treatment (kg N/ha)	Depth (cm)	pH in H_2O	pH in 1M KCl	Total organic C (%)	Total N (%)	Available (mg/100 g)	
						P_2O_5	K_2O
0	0-30	6.98	4.87	0.589	0.054	1.82	19.76
	30-60	6.48	4.78	0.954	0.069	2.19	24.62
50	0-30	6.71	5.34	0.938	0.107	3.95	22.78
	30-60	6.85	4.95	0.866	0.103	1.37	22.06
100	0-30	7.19	5.12	0.618	0.088	1.87	19.93
	30-60	6.58	4.78	0.966	0.117	2.57	21.32

RESULTS AND DISCUSSION

The ground cover of standing plants and herbage debris varied along the plots. On the middle surface of the inter-row the debris of chopped herbs in the second (summer) cut has formed a 1.5-2 cm thick layer, almost continuous. The observations showed that the grass covers were different in examined vineyards. The grass covers in clones 169 and ENTAV 15 were poor, as a consequence of later sowing. It is resulted in one cutting (beginning of May), while other grass covers (under clones 191 and 412) were more productive, compact, generally in better condition (Table 2). There are no significant differences among N treatments in individual clones, dry matter yield and N content in biomass were without effect of applied amount of fertilizer. The grass cover quality

Table 2. Grass cover temperature, dry biomass, N content in biomass, visual assessment of grass cover, must quality of Cabernet Sauvignon CV

Clone	**169**			**412**			**191**			**ENTAV 15**		
Doses	**0**	**50**	**100**	**0**	**50**	**100**	**0**	**50**	**100**	**0**	**50**	**100**
Average grass cover temperature first measurement (17.4.2020)	29.2	29.1	30.7^{+}	22.0^{-}	22.3	22.9	23.2	22.5	23.6	28.3	29.0	27.9
Average grass cover temperature second measurement (11.5.2020)	31.6	32.1	33.8^{+}	29.4	27.9^{-}	29.1	29.9	28.8	29.0	31.0	31.1	31.8
Dry biomass of grass cover (t/ha)	0.71	0.63^{-}	0.78	2.69^{+}	2.42	2.46	1.92	2.19	2.53	0.72	0.83	1.29
N content in biomass	1.57	1.56	1.62	1.85	2.11	2.20^{+}	1.85	1.84	1.95	1.31	1.68	1.20^{-}
Visual assessment of grass quality	*2.70^{-c}	3.33^{b}	4.00^{a}	7.33^{C}	8.33^{B}	9.00^{+A}	7.33	7.00	8.33	5.92	6.00	6.33
Sugar content (%)	24.9	25.2	23.7	19.9	21.1	19.7	20.8	19.9	17.6	19.7	22.3	17.3
Acid content (g/l)	8.0	7.2	8.1	8.4	7.8	7.1	9.0	8.7	9.9	5.7	6.9	5.4
Glycoacidometric index	3.11	3.50	2.93	2.37	2.71	2.77	2.31	2.29	1.78	3.46	3.23	3.20

*Values followed by the same letter are not significantly different according to Fisher's protected LSD values (P = 0.05); $^{+}$highest temperature, $^{-}$lowest temperature followed date of establishment, much better average quality was noticed under clones 191 and 412, while significant differences among N treatments were assessed under clones 169 and 412. The both clones had best quality of cover under highest application of N treatment (100 kg N ha^{-1}).

A high degree of variation was found (Table 2) for sugar content, from 17.3% (clone ENTAV 15, AN 100) to 25.2% (clone 169, AN 50). The content of total acids expressed as tartaric acid had the lowest values for clone ENTAV 15 treatment AN 100 (5.4 g/l), and the highest for clone 191 treatment AN 100 (9,9 g/l). Glycoacidometric index varied from 1.78-4.49. By sugar and acid content expressed as tartaric in must clone 169 (all treatments), 412 (treatment AN 50) and ENTAV 15 (treatment AN 50) can recommended as superior for high quality wine production.

Practices that increase nutritional and water competition, such as cover crops, are effective in avoiding excessive crop yield and are more economically sustainable compared to some other measure. In addition, cover crops have a number of beneficial effects on the vineyard agro-ecosystem, including all-year-round accessibility for time-sensitive cultural practices (e.g. harvest, fungicide applications) (Pardini et al., 2002). The overall results showed no influence on crop yield, while changes in the must composition were observed after 2-3 years (Lopes et al., 2008; Mercenaro et al., 2014).

Most of research results showed that the grass cover in vineyard could reduce the vine vigour, decrease the work amount of summer trimming and winter pruning. Under grass cover conditions the vine roots could be stimulated to penetrate deep into the subsoil. At the same time, grass cover in vineyard could reduce the leaf nutrimental element content and production; but on the other hand it improves the microclimate conditions and the berry quality. The berry has lower titratable acidity and higher sugar contents than those grown in clean tillage conditions; the pH value, anthocyanin and polyphenol contents in wine are increased, made significant difference in wine colour and configuration. It can be concluded that grass cover improves the quality of grape berry and wine evidently (Li et al., 2005). According to Muscas et al. (2017), effects of cover crop treatments appear to be mediated through nutrient availability and content in grape plants. Consequently, utilizing competitive cover crops, while reducing yields, would improve must quality and reduce pest development.

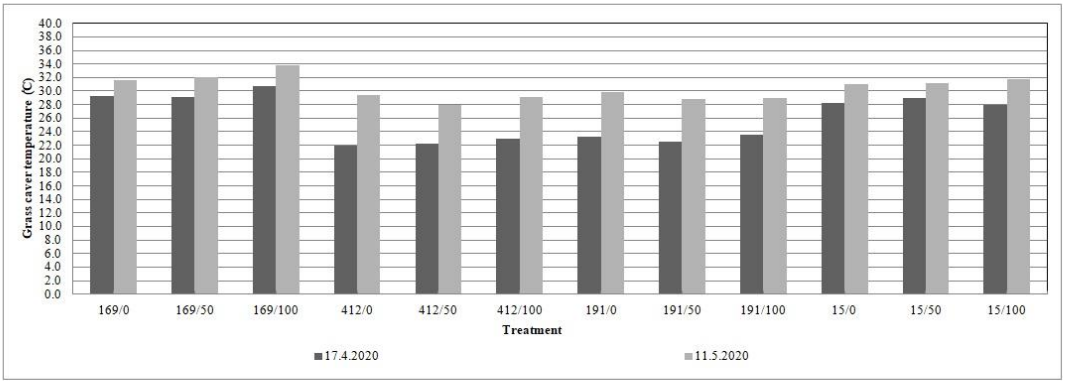

Figure 1. Grass cover temperature

Using the obtained values of grass cover temperature, the average temperatures of each treatment were calculated. The average grass cover temperature for all treatments during the first measurement date is 25.9ºC, and the variable is from 22.0ºC to 30.7ºC. During the second measurement, it varied from 27.9ºC to 33.8ºC, averaging 30.4ºC (Tab. 2, Fig. 1). The influence of fertilization levels on the measured temperature of the grass cover was not observed, while the influence of the clone was clearly noticeable. In both measurements, the highest temperatures are for clones 169 and ENTAV 15 and are very similar, while for clones 191 and 412 the lowest temperatures are observed. The obtained results showed that the clone influences the temperature of the plant cover, which can influence the quality of grass and grapes.
At the end of the experiment with interrow sward in vineyard, observations showed that the permanent grass cover was affected by the clone, fertilizer doses, temperature of the plant cover, which can influence the quality of grass and grapes.

CONCLUSIONS

Our findings highlight that complete vineyard floor cover cropping significantly influences must quality and, when optimized, represents a sustainable tool to improve the quality of wines. Making generalizations about the most suitable floor management system in vineyards is difficult, as response to cover crop is site-specific and variety-dependent due to differences in terms of soil, plant vigour, yield and oenological potential. Clearer results would be obtained if there was a treatment without grass cover (which is risky for the exposure of the examined vineyard), which will be the focus of further research. Therefore, the choice of cover crops strongly depends on the wine grape cultivar, clone and cultivation site. The viticultural terroir investigated in this study was characterized by a typical Serbian climate, fertile soil and a productive and vigorous Cabernet sauvignon CV. In this context, complete grass cover with fertilisation treatment AN 50 is recommended in order to improve must quality (sugar and acid content expressed as tartaric acid).

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INFLUENCE OF MYCORRHIZAL FUNGI ON SATUREJA MONTANA L. GROWN IN LEACHED CHERNOZEM AND ARENOSOL

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Abstract

Satureja montana L. is a valuable perennial medicinal and aromatic plant belonging to Lamiaceae family. In this paper, the effects of mycorrhizal fungi (mix of spores of *Glomus mosseae* and *G. intraradices*) were studied on growth of the aboveground part of *S. montana* potted plants. Winter savory plants were grown in low carbonate Chernozem with high clay content and typical Arenosol with low plant-available phosphorus in both soil types. It is known that mycorrhizal fungi can improve the phosphorus nutrition of plants under phosphorus limiting conditions, enhance plant growth, and increases the yield of crop plants. Prior to the pot experiment made in a field, the winter savory was vegetatively propagated by softwood cuttings. Rooted cuttings were transplanted into 1.5 L plastic pots (one plant per pot) filled with Chernozem and Arenosol taken from the plow layer of the soils in a disturbed condition. The experiment was set in a split-plot design with 4 replications. The main plots were soil types, while sub-plots were 2 treatments (inoculated and non-inoculated plants) with 6 pots in a random arrangement in each repetition. Plants were watered regularly with an installed drip irrigation system and weeds were regularly removed. At 60 days after inoculation with mycorrhizal fungi, non-inoculated and inoculated plants were harvested and the absolute stems and leaves dry masses of plants were recorded. Inoculated plants, in both soil types, had higher absolute stems and leave dry masses compared to absolute stems and leaves dry masses in non-inoculated plants. The absolute stems and leave dry masses in Chernozem and Arenosol of inoculated plants ranged from 0.37 to 1.16 g and from 0.35 to 0.73 g, respectively; while in non-inoculated plants in ranged from 0.069 to 0.27 g and from 0.17 to 0.53 g, respectively. The mean values for absolute stems and leaves dry masses in Chernozem and Arenosol in treatments of inoculated plants were 0.75±0.21 and 0.58±0.10 g/plant; while in treatments of non-inoculated plants were 0.18±0.06 and 0.36±0.09 g/ plant, respectively. These preliminary results indicate that the mycorrhizal fungi have a positive effect on plant growth and development. Further research should focus on studying how mycorrhizal fungi affects the content of essential oil, as well as the supply of phosphorus to plants in the soils examined by this study.

Keywords: Arenosol, Chernozem, winter savory, mycorrhizal fungi

INTRODUCTION

Winter savory (*Satureja montana* L.) is perennial medicinal and aromatic plant belonging to Lamiaceae family. It grows in arid, sunny and rocky habitats of the sub-Mediterranean area. Winter savory is semi-evergreen subshrub growing to about 50 cm tall with the lanceolate leaves and white flowers that attract bees (Rzepa et al., 2012; Stepanović and Radanović, 2011). Genus *Satureja* counts about 30 species out of which 9 species have been registered in the area of central and western Balkans (Čopra-Janićijević et al., 2020). It is valuable plant, recognized for its therapeutic values. The leaves, flowers, and stems are used for herbal tea and, in traditional medicine, to treat various ailments (with carminative, digestive, expectorant, antidiuretic, etc. activities). Also, it is known as culinary herb due to flavor of its leaves (Ćetković et al., 2007; Rzepa et al., 2012).

Winter savory is highly variable plants specie with evident polymorphism within a single population and in populations coming from distant habitats (Slavkovska et al., 2001; Milos, et al. 2001). Variability is caused by cross-pollination leading to a large number of subspecies, varieties, and forms with different botanical characteristics and a broad chemical heterogeneity (Čopra-Janićijević et al., 2020). In family *Lamiaceae*, cross-pollination results heterozygous seeds from which heterogeneous plants arise with phenotypical variability and substantial phytochemical inconsistency (Kwon et al. 2006). Strategies within breeding programs to obtain phenotypical and phytochemical uniform individuals involve selection work, and also implementation of vegetative propagation techniques (Shetty, 1997), mostly by stem cuttings (Venkateshappa and Sreenath, 2013).

Biofetrilizers containing arbuscular mycorrhizal fungi (AM) are applied in agriculture in order to obtain benefits in yield, relying on mutual symbiotic association between a fungus and the root of cultivated plant. AM fungi of the phylum Glomeromycota are commercially most commonly used in agriculture, especially the species *Rhizophagus* (*Glomus*) *intraradices* and *Funneliformis* (*Glomus*) *mosseae* (Krüger et al., 2012). By applying these fungi, the plant more efficiently absorbs soil nutrients like phosphorus, zinc and copper (Burni and Hussain, 2011), increases resistance to drought and pathogenic diseases (Gupta et al., 2000; Koltai and Kapulnik, 2010). Also, these fungi improve the quality of the soil; when passing through the soil aggregates it positively affects the water-air regime of the soil (Hajnal-Jafari et al., 2012). Although AM is a naturally occurring phenomenon, colonization of plant roots is conditioned by a number of factors: the plant species and the type of fungus and environmental factors, among which low nutrient levels in the soil and poor plant nutrient supply are important (Chen et al., 2018).

In this research, the effects of mycorrhizal fungi (combination of *Glomus mosseae* and *G. intraradices*) were studied on growth and development of winter savory grown as a pot culture in a low carbonate Chernozem (“leached chernozems”) with high clay content and typical Arenosol with low plant-available phosphorus content in both soil types.

MATERIALS AND METHODS

Production of rooted cuttings in laboratory conditions

Plant material used for the preparation of stem cuttings was one year-old shoots taken at the end of June 2020 from the 3-year-old mother stock plants, grown outdoors in a private collection in Stara Pazova, Serbia (44° 59′ 3.6″ N, 20° 9′ 23.4″ E). Softwood terminal stem cuttings, 13cm in length, were made. The leaves on the lower portion of the cuttings were removed, leaving 4 nodes. All cuttings were sterilized in 0.5% sodium hypochlorite for 10 min and then twice quickly rinsed with distilled water as recommended by Arango et al. (2012). The basal portion of cuttings (3cm) was treated with IBA (indole-3-butyric acid) based rooting powder (“Rhizopon AA powder 1%”, Rhizopon®, Netherlands (IBA 1%). Following the application of rooting powder, the cuttings were put into the trays for propagation, filled with a cutting-specific medium (Steckmedium, Klasmann-Deilmann GmbH) of following characteristics provided by the manufacturer: a mix of peat moss and perlite, structure 0 - 6 mm, fertilizer NPK 12:14:24 -0.5 kg/m3, pH value 5.5 - 6.5, the EC value 15 mS/m (+/- 25 %). The trays with cuttings were kept inside a polythene tent (Grow Box) in the laboratory of the Institute for Medicinal Plants Research "Dr Josif Pančič", located in Belgrade, Serbia during the period June 25th to July 25th, 2020, under the following growing conditions: the artificial lighting produced by cool fluorescent tubes (fluorescent Biolux 36W and Flora 36W), with a 16-hour photoperiod, providing up to 4,000 lux ≈ 54 µmol m^{-2} s^{-1} of photosynthetic photon flow density (PPFD); the relative humidity of 70 to 90% provided by intermittent automatic mist-propagation system, which was set to operate in following time-dependent modes: from 1st to 10th day - 5s/15 min, from 11th to 20th day – 5s/30 min, and from 21st to 30th day – 5s/90min; the air temperature was from 20°C to 23°C, while the substrate temperature was kept almost constant (23±2°C) (Svenson and Davies, 1995; Wilson et al.,2017; Mrđan et al., 2020). Monitoring of the relative humidity and the air temperature and in the Grow Box was provided by the use of HAXO-8 Data logger, while monitoring of the substrate temperature was provided by the use of Testo 110 NTC Thermometer.

Hardening-off process, inoculation and experimental design

After 30 days period of rooting was concluded, the trays were taken outside the Grow box and left inside the laboratory, and were occasionally taken outdoor in order to ensure adaptation of cuttings to natural light irradiance, lower air temperatures and reduced relative air humidity of the outdoor environment. This acclimatization process (hardening-off process) of rooted cuttings started in Grow box by gradually decreasing the misting period during rooting of cuttings and lasted 10 days after trays have been taken outside the Grow box as recommended by Wilson et al. (2017). During the adaptation period the plants were watered with tap water. Rooted cuttings were transplanted into 1.5 L plastic pots (one plant per pot) filled with low carbonate Chernozem with high clay content and typical Arenosol taken from the plow layer of the soils in a disturbed condition. Soils used for filling pots were classified as Chernozem and Arenosol soil type according to The Classification of Yugoslav Soils (Škorić et al., 1985). Its main chemical and physical properties of soils are given in Table 1. Chernozem soil type originated from arable land in

Pančevo (N 44° 52' 40"; E 20° 42' 05"), while Arenosol originated from the The Deliblato Sands (N 44° 53' 05"; E 21° 04' 47").

Table 1. Main chemical and some physical properties of the plow layer (0 - 30 cm) for soil type 1(Chernozem) and type 2 (Arenosol)

Soil type	pH		$CaCO_3$ %	Humus %	N %	P_2O_5 mg/100g	K_2O mg/100 g	Coarse sand %	Fine sand %	Silt %	Clay %
	KCl	H_2O						2-0.2 mm	0.2-0.02 mm	0.02-0.002 mm	< 0.002 mm
1	5.61	6.73	0.08	2.03	0.15	2.26	34.64	0.33	38.11	24.36	37.2
2	8.02	8.56	15.63	0.28	0.03	1.22	5.22	29.86	66.86	1.00	2.28

Experiment was established in Pančevo (44°52’20.0” N, 20°42’04.7” E), South Banat, Serbia. The potted plants were taken outdoors and placed on 1 mm thick water permeable black “agrotextil” film and arranged according to applied treatment. Treatments were potted plants with or without added inoculum (inoculated plants or non-inoculated plants/control) in different soil types (Chernozem and Arenosol): MCh-mycorrhiza in Chernozem; CCh- control in Chernozem; MAr-mycorrhiza in Arenosol; and CAr- control in Arenosol. In treatment with inoculated plants, the rooted cuttings were planted into a hole where the inoculum was previously added (15g of inoculum per plant) according to Arango et al. (2012). The used inoculum (Aegis Clay, Italpollina) is a mix of spores (25 spores/g of *G. mosseae* and 25 spores/g *G. intraradices*) and 60% of organic matter in powder formulation; structure < 1 mm, pH value 7. The experiment was set up in a split-plot design with 4 replications. The main plots were soil types, while sub-plots were 2 treatments (inoculated and non-inoculated plants) with 6 pots in a random arrangement in each repetition. Plants were watered regularly with an installed drip irrigation system with a flow rate 1L/h for each pot and weeds were regularly removed.

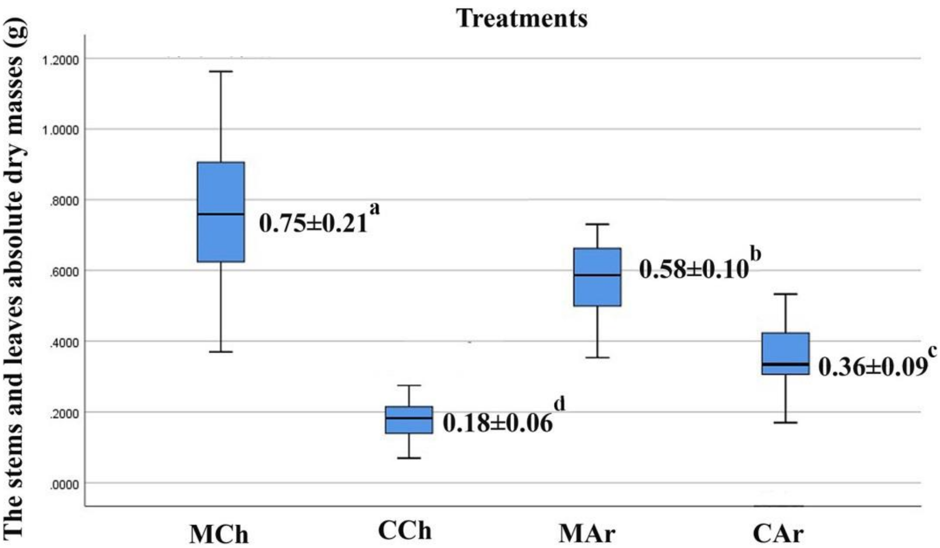
Growth parameter

Plants from each treatment were harvested at 60 days after inoculation with *G. mosseae* and *G. intraradices*. The absolute stems and leaves dry masses of plants from each treatment were recorded after have been dried at 105 °C during 48 hours to a constant mass.

RESULTS AND DISCUSSION

Inoculated plants, in both soil types, had higher absolute stems and leave dry masses compared to the absolute stems and leaves dry masses in non-inoculated plants. The absolute stems and leave dry masses per plant in MCh and MAr ranged from 0.37 to 1.16 g and from 0.35 to 0.73 g, respectively; while in CCh and CAr ranged from 0.069 to 0.27 g and from 0.17 to 0.53 g, respectively. The mean values for absolute stems and leaves dry masses per plant in MCh and MAr were 0.75±0.21 and 0.58±0.10 g/plant, while of CCh and CAr were 0.18±0.06 and 0.36±0.09 g/plant, respectively (Figure 1).

Soil analysis show that in both soil types, Chernozem and Arenosol, low plant-available phosphorus and humus content were determined, while Arenosol lacks also in plant-available potassium (Table 1). Chernozem soil used in study is low in $CaCO_3$ and has high clay content. According to classification of soils shown by Pavlović, at al. (2017) in accordance with WRB classification (World Reference Base for Soil Resources), it is a variety of Chernozem (leached gleyed) characterized by less favourable mechanical composition, the absence of $CaCO_3$ in the humus-accumulative horizon and with the adsorption complex that exhibits slight acidification, accompanied by a decrease in pH. Although it is important to emphasize that soil with these properties, in large majority, refer to Chernozems in WRB; however, may also belong to Phaeozems due to lack of $CaCO_3$ in humus-accumulative horizon (Kabała et al, 2019). Due low water-retention capacity and low adsorption capacity, Arenosol soils have low productive value (Pavlović, at al., 2017).



Treatments-MCh(mycorrhiza in Chernozem); CCh(Control in Chernozem); MAr(mycorrhiza in Arenosol); CAr(Control in Arenosol).

Figure 1. Comparative presentation of average ± standard deviation for absolute stems and leaves dry masses of *S. montana* [g/plant] with regard to fertilization models; Error bars denote standard deviation; means followed by the same letter are not significantly different at $p<0.05$

Hence, in this in this particular study, Chernozem has a better nutrient adsorption capacity, although less favorable mechanical composition, due to the high clay content, creates potential problems in land cultivation and in faster percolation of water into deeper layers. On the other hand, Arenosol with a sandy texture, has good physical properties in terms of air capacity and water percolation to depth, but has a very small capacity of adsorption of nutrients and water, and thus has limited fertility potential compared to Chernozem.
In order to achieve high yields in the production of cultivated crops on degraded soils, AM fungi are used as a tool wherein production of medicinal plants there are studies that

confirm the benefits of their use. AM fungi promotes the growth of medicinal plants and improves the production and accumulation of active ingredients of medicinal plants such as terpenes, phenols, and alkaloids (Zeng et al., 2013; Pandey et al., 2018; Piszczek et al., 2019). It also improves nutrition of plants, particularly in phosphorus (Lermen et al., 2019; Lazarević, et al., 2020) and helps plant to survive abiotic stressful conditions like water stress (Pirzad and Mohammadzadeh, 2018; Javan Gholiloo et al., 2019). In study of Khalediyan et al. (2021) on *Satureja hortensis* in a 2-year field trial conducted in Iran, showed that *G. mosseae* and *G. intraradices* fungi had an impact on dry mass of shoots, increasing it for 35,73 and 47.5 % in the first year and for 23.55 % and 62.84% in second year, respectively, in comparison to control. Carreón-Abud et al. (2015) investigated the effect of *Rhizophagus irregularis* inoculation on the growth of *Satureja macrostema* plants grown in soil: sand mix sterilized substrate (1.5 kg, v/v, 3:1, pH 5.5) in greenhouse, where after 60 days shoot dry mass was 18.4 g/plant in mycorrhizal plants and 8.8 g/plant in non-mycorrhizal plants. Arango et al. (2012) in study done on *Mentha piperita* L. showed that 40 days after inoculation, used *Glomus intraradices A4 and G. intraradices B1* had increased shoot dry mass and was 0.61g and 0.54g, respectively, compared to control (0.41g), which was similar to our results for *S. montana* grown in Arenosol (Figure 1). It is noted that plants in Chernozem control treatment had the lowest absolute stems and leaves dry mass. It is assumed that the plant species, taking into account its natural habitat, prefers porous soil types. Thus the growth of pot winter savory plants in Arenosol control is proven to be better concerning non-inoculated plants in Chernozem (Figure 1). It can be assumed that increment of the aboveground plant parts in inoculated plants in Chernozem is result of AM fungi being able to enhance plant nutrition by external hyphal network of AM fungi providing better contact with soil particles and increasing effective root surface, in combination with the existing adsorption capacity of Chernozem soil (Bagyaraj, et al., 2015) although it has less favourable mechanical composition due to high clay content (Table 1).

CONCLUSION

This study was conducted in order to determine how suitable is *S. montana* for cultivation on degraded soils and to which extent will mycorrhizal fungi contribute to better and more efficient land use and expansion of the cultivation area of the studied species to areas with reduced soil fertility. The preliminary results indicate that the mycorrhizal fungi have a positive effect on plant growth and development. Further research should focus on studying how mycorrhizal fungi affects the content of essential oil, as well as the supply of phosphorus to plants in the soils examined by this study.

ACKNOWLEDGMENT

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SECTION 3

SOIL DEGRADATION AND SOIL AND WATER CONSERVATION

THE CONTENT OF CD AND PB IN UNDEVELOPED SOILS AND PLANT MATERIAL IN THE AREA OF NP (NATIONAL PARK) TARA

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Abstract

Ultramafic (serpenites) are a group of igneous or metamorphic rocks, which are characterized by high concentrations of Mg, Fe, Ni, Cr, and Co, along with low concentrations of Ca, P, and K, contain less than 45% silicon (SiO_2). Tara Mountain is natural good of western Serbia where areas under serpentinites occupy 28%. Researchers agree that the flora of serpentine areas is unique and botanically very important. The specificity of the flora and the development of vegetation on serpentinites are characterized by special mechanisms of plant species adaptation to increase concentrations of some heavy metals in the soil with low content of essential elements (nutrients). This paper examines the influence of serpentinite geological substrate on the occurrence of certain plant species in the initial stages of plant community development. The soil was mainly sampled in rock crevices in the early phases of soil development (*Lithosols)* where the influence and origin of the metals from the rock can be considered the most obvious. Content of cadmium (Cd) and lead (Pb) in geological substratum, soil and plants biomass are analysed in order to differentiate levels and extents of natural and anthropogenic pollution and also deposition data from the EMEP program (European Monitoring and Evaluation Programme). Results shows that the content of lead and cadmium in the soil and plant samples are higher than the content in the corresponding rock sample, this suggest that the origin of the increased Pb and Cd content might be from anthropogenic sources. Deposition (data from EMEP program) of Cd and Pb, which were analysed for the period from 1990-2018, indicate significant cumulative effect. The values of cumulative deposition in research area have a value of 91,51 kg/km^2 lead, while the value of cadmium is 1665 g/km^2, which classifies NP Tara in above-average polluted area in R. Serbia.

Keywords: serpentinite, heavy metals, parent material, soil, EMEP, deposition

INTRODUCTION

Ultramafic (serpenites) are a group of igneous or metamorphic rocks, which are characterized by high concentrations of Mg, Fe, Ni, Cr, and Co, along with low concentrations of Ca, P, and K, contain less than 45% silicon (SiO_2). Soils on serpentinites are rich in chromium, nickel, manganese, zinc, cobalt, lead, etc. Determining the content of metals in the geological substratum, eg. potential natural soil pollution, as well as anthropogenic pollution of soil by heavy metals is important regarding plant species usage growing on such area. Due to intensive use of medicinal plants in modern pharmacology, but also in the traditional lifestyle, there is a need to monitor the levels of elements in the herb of these plants, especially potentially toxic to health, such as mercury, lead and cadmium (Obratov-Petkovic et al., 2008).

Serpentine soils have properties that are highly unfavourable for most plants. They are often characterized by gravely texture, low clay content, shallowness, susceptible to erosion and with a low content of organic matter (Farag, 2013). Strongly serpentinized rocks are more susceptible to mechanical breakdown and disintegration, as well as to chemical decomposition involving considerable changes in chemical and mineralogical composition (Knežević et al., 2009). High concentrations of heavy metals (nickel, chromium, lead, cobalt, cadmium...) in serpentine soils were responsible for their infertility. Vegetative cover at serpentine sites is usually scarcer than the surrounding areas and is characterized by obligate and facultative serpentinophytes. Due to high levels of metal concentrations, plants accumulate them, which require different adaptation mechanisms to reduce their harmful effect (Farag, 2013).

The main goal of this paper is to determine the degree of influence of the parent substrate and potential anthropogenic pollution on the content of non-essential toxic metals in poorly developed soils on serpentinites. In order to determine the potential transfer of these metals in the environment, the contents in the soil, aboveground and belowground biomass were analysed. In order to define “natural pollution” rates through weathering, content of microelements in the geological substratum were analysed. Atmospheric deposition data from EMEP program were analysed.

MATERIAL AND METHODS

Research area and sampling method

Geological substratum, soil, and plant biomass samples were collected in the NP Tara at 3 localities. Konjska reka (43°53'53.5"N, 19°25'01.0"E), Zmajevacki potok-Trenice (43°53'1.5"N, 19°25'4.6" E) and Popovici (43°51'18.7"N, 19°24'49.8"E) (Figure 1). The total number of samples is: 3 of geological substratum, 17 samples of soil, 15 samples of below ground biomass and 17 samples of above ground biomass. Plant samples were collected under favourable weather conditions using appropriate equipment, according to plant abundance and cover. The research was perfomed for 9 plant species: *Dorycnium pentaphyllum* subsp. *germanicum* (Gremli) Gams, *Asperula purpurea* (L.) Ehrend., *Odontarrhena muralis* (Waldst. & Kit.) Endl., *Thymus* sp., *Vaccinium myrtillus* L., *Euphorbia glabrifora* Vis., *Cytisus procumbens* (Waldst. & Kit. ex Willd.) Soil analysis were performed according to standard JDPZ methods (eng. Yugoslav Society of Soil Science); (Bošnjak et al., 1997). The content of cadmium and lead in geological substratum, soil and biomass were determined according to the standard ISO (ISO 11466:1095 Soil quality, 1995) procedure and measured by the AAS method.

Lead (Pb) and cadmium (Cd) have no established biological functions and are considered as non-essential, toxic elements (Grozdic, 2015; Tchounwou et al., 2012). In accordance with the Regulation on limit values of pollution, harmful and dangerous substances in soil (Official Gazette of the Republic of Serbia 30/2018 and 64/2019) obtained results were compared with the limit and remediation values of dangerous and harmful substances and values that can indicate significant soil contamination.

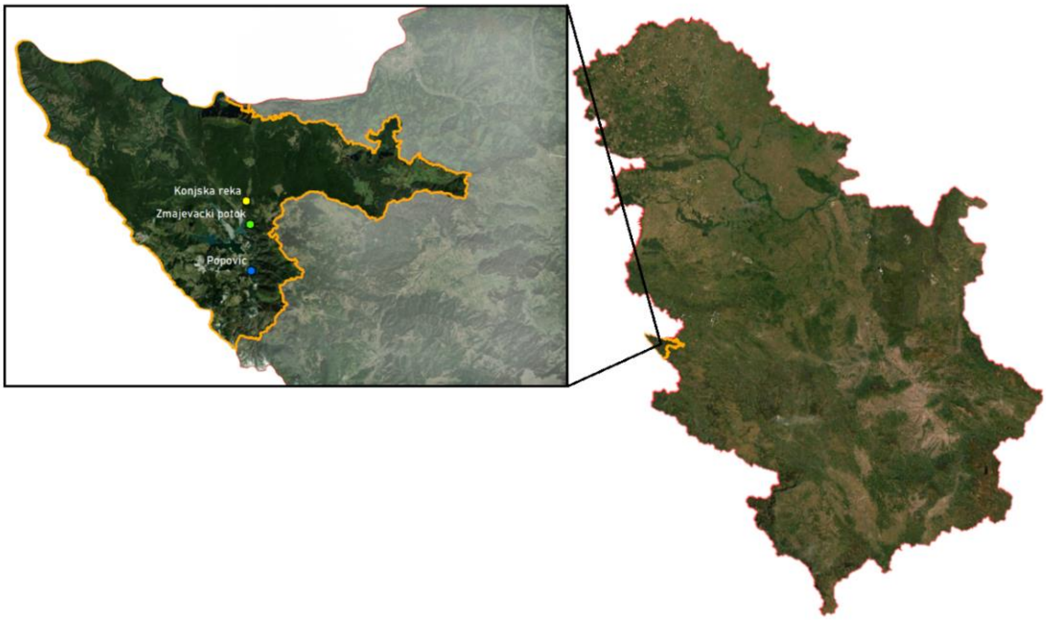

Figure 1. Research area and sampling locations

Deposition data - EMEP

The European monitoring and evaluation programme for transboundary long-range transported air pollutants (EMEP) started in 1977. EMEP programme is focused on assessing the transboundary air pollution: (1) collection of emission data, (2) measurements of air and precipitation quality and (3) modelling of atmospheric transport and deposition of air pollutants. The Meteorological Synthesizing Centre-East (MSC-E) of the EMEP program is focused on heavy metals, whose data were used in this paper (https://www.emep.int/). Lead and cadmium deposition data were downloaded and processed, in order to determine the connection whether the metals are anthropogenic or of natural origin, for the period 1990 to 2018, for the entire Republic of Serbia, therefore, and three sampling locations in the NP Tara.

RESULTS AND DISCUSSION

Physical and chemical properties of soil

At the Konjska reka site, all samples show a weakly alkaline reaction, with a mean value of 7.46. At the Zmajevacki potok site, the soil is moderately acidic to neutral with a mean value of 6.52 (Knezevic et al., 2016). At the third sampling location (Popovici) soil is included in the class of weakly to moderately alkaline, with a maximum measured value of 8.27. The soil is carbonate-free, so it can be concluded that the alkaline reaction of the soil is caused by a high level of magnesium. The soil at Konjska reka and Popovici site has moderate to high content of humus, and the soil in Zmajevacki potok is considered semi-peat soil with an average humus content 19.42% (Knezevic et al., 2016).

Cadmium (Cd)

Cadmium shows a constant concentration in geological substratum, and its value is around 0.02 mg/kg.

The maximum measured concentration of cadmium in the soil is 0.18 mg/kg, the minimum – 0.003, while the limit value according to the Regulation is – 0.80. The concentration of 0.003 mg/kg was measured in all samples of lithosol, and slightly higher in the samples of cambisol – 0.093 and 0.186.

In biomass below ground the lowest concentration (0.003 mg/kg) was measured in *Thymus* sp. and *Euphorbia glabriflora*, and the highest (0.083) in the species *Odontarrhena muralis* and *Dorycnium pentaphyllum* subsp. In biomass above ground the lowest contents (0.003 mg/kg) are found in the species *Thymus* sp. and *Asperula purpurea*, and the maximum measured concentration (0.12 mg/kg) was in the sample of blueberry *(Vaccinium myrtillus)* (Figure 2).

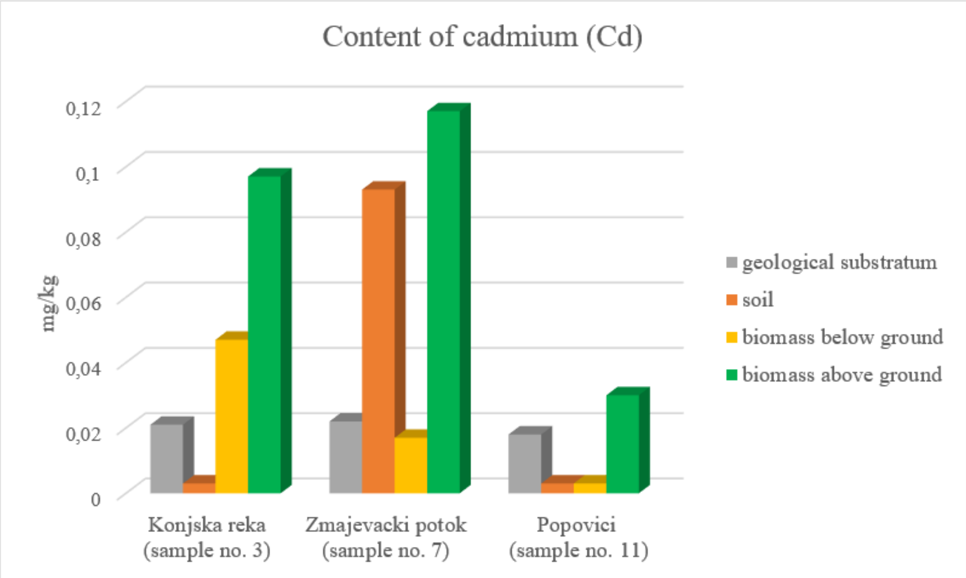

Figure 2. Cadmium contents in the tested samples distributed by localities

According to Kastori (1993) the average cadmium content in plants is 0.05-0.2 mg/kg, while the toxic value of Cd is estimated at 3-30 mg/kg. None of the tested plant species has a concentration close to toxic. In the soil as well, the concentration is lower than the prescribed limit and from the concentrations measured in other serpentine areas found in the literature sources.

Jovanovic (2019) have recently shown that cadmium concentrations in the soil layer of 0–15 cm, are much higher, about 6.5 times, than in layer of 15–35 cm, which indicates that the reason for the high concentration of deposition.

Lead (Pb)

Lead concentration of 0.02 mg/kg was measured in geological substratum from Konjska reka and Popovici, while concentration of 54.72 mg/kg was measured in Zmajevacki potok.

The maximum measured concentration of lead in the soil is 86.74 mg/kg, while the limit value according to the Regulation is 85. This is the only sample where the value exceeded the limit, and it is a sample of soil under the blueberry (*Vaccinium myrtillus*). However, even the minimum measured concentration in soil (0.94 mg/kg), as in all other samples, is significantly higher than that measured in the corresponding rock sample, which suggests that the presence of lead is not the result of weathering but anthropogenic origin.

This assumption is supported by the constant contents of this metal in both below ground (average 1.81 mg/kg) and above ground (average 2.56 mg/kg) plant biomass which may further indicate that this accumulation process is not naturally. None of the species, which occur naturally in this area, did not show increased accumulation as a mechanism of adaptation, when the presence of lead would be the result of natural, pedogenetic processes (Figure 3).

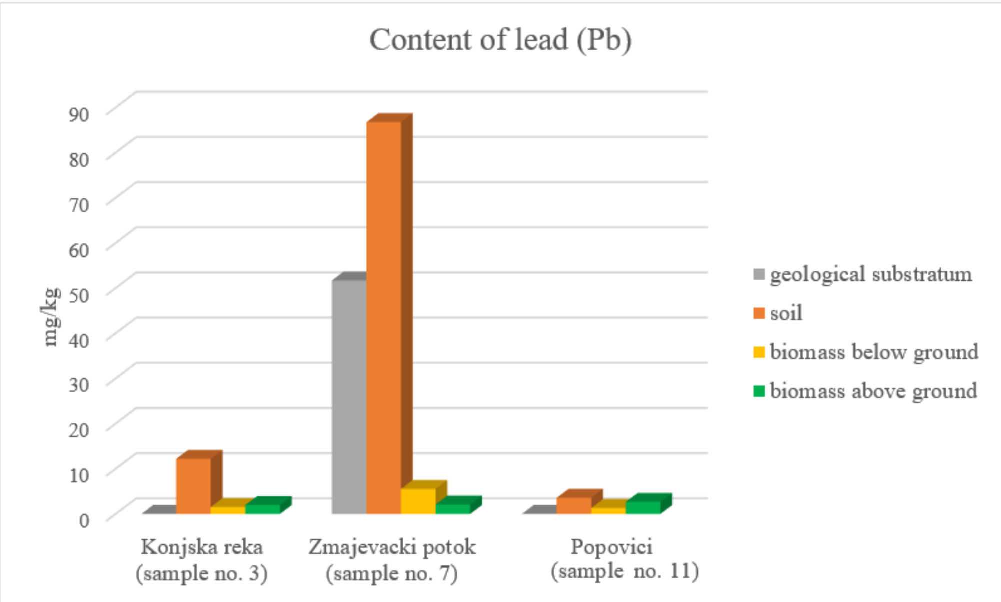

Figure 3. Lead contents in the tested samples distributed by localities

The measured concentration of lead in geological substratum, as well as in the soil where lithosol is present, is significantly lower than some previous measurements (Oze et al., 2020; Brankovic et al., 2016; Obratov-Petkovic et al., 2008; Vasic, 2017), while in the samples of rocks and soil from Zmajevacki potok it is almost double higher. According to the research of Jovanovic (2019) the values of lead at the same location (Zmajevacki potok) on the same geological substratum reach much higher values (228.75 mg/kg).

The content of Pb in the plant biomass is constant and it is in accordance with the other published data (Arsenijevic et al., 2011; Kucukbay et al., 2010). According to Kabata-

Pendias (2011), the Pb content in plants is in the range of 0.05-3.0 mg/kg, therefore, the tested samples do not deviate much from the average.

Deposition data trends-EMEP

According to the European Program for Monitoring and Evaluation of Deposition Values (EMEP), the cumulative values of Cd and Pb deposition for the period 1990-2018 were obtained, presented for the whole R. Serbia (Figure 4).

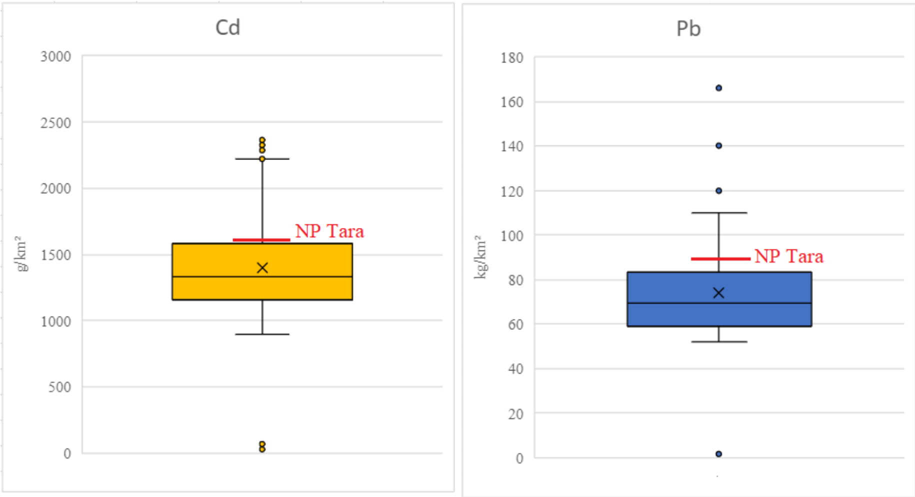

Figure 4. Cumulative values of Cd and Pb deposition for the period 1990-2018 in R. Serbia and mountain Tara

The values of cumulative deposition in the research area have value above the 75th percentile, ie, the value of lead is 91.51 kg/km², while the value of cadmium is 1665 g/km². Figure 5 shows the values by years for both heavy metals, for those pixels that correspond to the sampling location. Although the values have a declining trend, over the years, with slight oscillations, in both cases (Cd and Pb), there is a significant cumulative effect achieved by deposition, where the aboveground parts of vegetation imply the first level of deposition of dry and wet atmospheric deposition (Kadovic et al., 2002).

CONCLUSION

Serpentinite participates in the geological substratum of the Republic of Serbia, mainly in the western and central part of the country, forming the base of many mountain massifs. The specificity of this substrate and the vegetation that grows on it is the motive for their better understanding. As previously said, one of the characteristics of the soils formed on serpentinite is high content of metals, so the plants that grow on such terrains accumulate them.

Unlike other metals, cadmium and lead are non-essential, exclusively toxic elements. They occur naturally in very small quantities, so their toxic effect results from anthropogenic influence.

The summarized result of this paper is reflected in a couple of key points. The content of lead and cadmium in the soil and plant biomass, compared to samples of geological substratum indicate that the pollution is anthropogenic origin. Values of lead concentrations regarding pollution are clear, since it exceeds the limit values according to the Regulation (Official Gazette of the Republic of Serbia 30/2018 and 64/2019), regarding cadmium it could be notified the same origin of pollution.

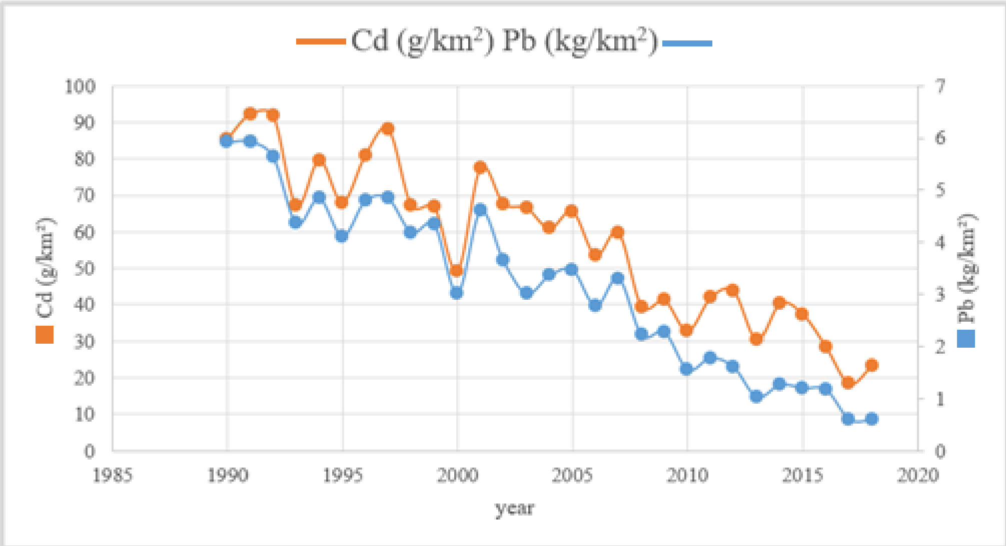

Figure 5. Pb and Cd values for the period 1990-2018 in the research area

Although cadmium concentrations in soil and plants are below the limit values (Official Gazette of the Republic of Serbia 30/2018 and 64/2019; Kastori, 1993), the presence of light anthropogenic pollution should not be neglected and have to be monitored in future. Also, the confirmation of these results are the cumulative values obtained by the EMEP program which only confirm the measured results, where the values for research area are above-average polluted region in R. Serbia, which should not be because it is a protected area.

Monitoring of heavy metals in contaminated soils and plant is one of the most significant nature conservation challenges. Such studies should provide guidelines for further control of pollutant emissions and ratification of existing protocols on air pollution by heavy metals especially in protected areas.

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THE DYNAMICS OF CHEMICAL PROPERTIES IN THE MINE TECHNOSOLS AFTER SIX YEARS OF RECLAMATION

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Abstract

The open pit mining results in disturbance of a very large area landscape. The research of agro-technical and biological phases of soil reclamation by seeding and growing different agricultural crops was conducted on technogenic soil in Stanari coal basin. The aim of this survey refers to implementation of reclamation of technogenic soil in Deposol–plant–Rekultisol system on plateau at internal disposal area for overburden from Raskovac open pit in "EFT – Rudnik and Termoelektrana Stanari" (Republic of Srpska, Bosnia and Herzegovina). Several forms of reclamation and techniques were applied (agrotechnical and biological reclamation, fertilization, seeding, mowing in a mulch system), as well as the studied changes and development of technogenic soil. The survey task refers to examination of the dynamics of main chemical properties in the technogenic soil through six-years period reclamation (2011–2016). The analyzed chemical properties in technogenic soil are as follows: organic matter content, humus content, N, P_2O_5, K_2O. Biological reclamation is carried out by establishing the vegetation in two directions: seeding perennial grassland, and growing of annual arable crops. The research was conducted in a direct type of reclamation of the sandy-loamy Deposol adverse physical and chemical properties. Potential toxic elements in the Deposol are below the allowable limits. Application of agromeliorative measures and techno-pedogenesis process in six-years has resulted in forming Rekultisol with improved chemical properties. The initial process of humification and mineralization are started in Rekultisol formed. The content of organic matter in surface layer of Rekultisol (at 20 cm) has the average increase by 2.85 times. The average value of organic matter content at the begining of the research was 2.3% and at the end 6.55%. From the initial zero value of humus content, in the end of the survey amounted to 0.8%, content of N to 0.075%, and content of P_2O_5 to 1.9%. The content of K_2O has the average increase by 7.6 times. Technological fertility of Rekultisol represents the result of implemented measures of reclamation and agrotechnic that, depending of time distance, with the leading climatic impact, affect the technogenic parent substrate.

Keywords: Deposol, Rekultisol, seeding grasland, arable crops

INTRODUCTION

The fertility of the Deposol (the surface of the disposal area for overburden), and most other types of Technosols (and mine soils), is usually low (Resulović et al. 2008; Malić, 2015;). The density of the Deposol with the basic biogenic elements (N, P and K) is within or below the minimum concentrations (Dvurechensiy and Seredina, 2015; Pivic et al., 2011; Sheoran et al., 2010; Markovic, 1996; Veselinovic, 1995; Coppin and Bradshaw, 1982; Antonović et al., 1978). In addition to the deficit of nutrients, technogenic soils are poor at all with pedobios, organic matter, and poorly developed adsorptive complex (Rasulić et al., 2005). Shukla et al. (2004) states the following disorders in technogenic soil: loss of aggregate and soil structure, decrease in soil C concentration, increase in volume, and decrease in porosity.

All new Deposol, as well as older ones, require significant application of fertilizers as well as elements for the establishment and maintenance of vegetation (Sheoran *et al.*, 2008; Copiin and Bradshaw, 1982; Malić and Matko, 2019). Chatterjee (2009) and Malić et al., (2017) have recently shown that the soil in the process of reclamation (by seeding grassland, as well as by afforestation) can potentially restore fertility, and that C, total N, increases over time, and that pH value changes from acidic to alkaline environment.

Organic matter in low-fertility soils serves as the main source of nutrients (Maiti and Ghose, 2005), which coincides with proving the needs of the conducted research. Long-term productivity for plants and the new soil system also depends on the accumulation of organic matter, together with the presence of total N in the Deposol, as stated by Daniels (1999) and Ghose (2005). The importance of the organic medium is also in the retention of applied nutrients with less leaching loss, especially in the initial stages of reclamation of technogenic soils (Mercury et al., 2006).

Improving the incorporation of organic matter in the type of direct reclamation of technogenic soils may be an alternative to replacing or applying more fertile soil material (topsoil) to the surface layer of the disposal area for overburden (Olsen and Jones, 1989). Coyne et al. (1998) and Malić (2015) have shown that the accumulation of organic matter in Deposol and Rekultisol leads to increase fertility and stimulates microbiological activity, supports the transformation and circulation of N and accelerates the restoration of ecosystems.

Malić and Matko (2018) states that for technogenic soils, one of the most important active factors is anthropogenic activity. This activity with reclamation measures can significantly direct and accelerate the processes of pedogenesis (Sobocka et al., 2017).

The results of the past physical and chemical analyzes of Deposol at disposal area for overburden at the Stanari mine found that they have favorable physical - mechanical but unfavorable chemical properties (Malić, 2015; Malić i Marković, 2012; Malić i Marković, 2020). The same authors state that, based on the content of organic matter, the researcehed Deposol belong to the class of low and medium content, while there is no pure humus and nitrogen. According to the content of P_2O_5 and K_2O in the Deposol, they are classified as very poorly secured by these elements. The Deposol is characterized by a non-carbonate substrate, a strong unsaturation with base cations, a medium and highly acidic chemical reaction.

Geological series of roof coverings of coal layer on the surface mine Raškovac at the Stanari mine are mostly mixed sandy-pebbles, and clay zones and layers. These materials represent poorly bound and unbound sediments. The roof cover thickness varies from 10 to 60 m. The sandy material is a quartz mineralogical composition and low fertility. Bentonite clay is the second building material of the roof of the coal layer. The basic components of bentonite clay are: montmorillonite, kaolinite, ilite.

MATERIALS AND METHODS

Study area

The coal basin Stanari is located between 44°40' and 44 ° 50' north latitude and 17°45' and 18°00' east longitude, in the northern part of the Republic of Srpska and Bosnia and Herzegovina. Research on biological reclamation of a direct type was carried out in an experimental field (y: 6.486.822.33, x: 4.957.645.63, z: 220 m) at the internal disposal area for overburden of the excavation from the surface mine Raskovac in the lignite coal basin Stanari: "EFT - Mine and Thermal Power Plant Stanari". The survey was conducted in a six-years period (2011–2016). Part of the disposal area for overburden site where the experimental field is located was formed during 2010.

The experiment plots area is 10 m^2 (5 x 2 m). The distance between the plots is 50 and 80 cm, and between the blocks is 1 m. Plots are without inclination. The first factor of research is year (factor A), with six treatments: a_1 - 2011, a_2 - 2012, a_3 - 2013, a_4 - 2014, a_5 - 2015 and 2016 year.

The second factor of research is system based vegetation, or different plant species within the framework of agro-technical and biological reclamation (factor B), with two treatments. Treatment b_1 is a seeding grassland based on the sowing of complex grass-leguminous mixtures, with the following species: *Festuca arundinacea* Schreb. 25%, *Festuca rubra* L. 20%, *Dactylis glomerata* L. 10%, *Phleum pratense* L. 10%, *Poa pratensis* L. 5%, *Trifolium repens* L. 10%, *Trifolium pratense* L. 10%, and *Medicago sativa* L. 10%. The grassland is seeded in the spring season in 2011. The standard for seeding is 45 kg ha^{-1}. Fertilization with mineral fertilizers NPK 15:15:15 in dose 90 kg ha^{-1} of pure nutrients (N, P, K) was performed in pre-seeding phase. The N fertilizer KAN (27% N), with 54 kg ha^{-1} N of pure nutrient was applied in two nutrition treatments in 2012, 2013, 2014, 2015 and 2016 year of research. First dose was applied at the initial vegetation stage. The second dose was applied on the tenth day after mowing the first cutting. The grassland was mowed by mulching machine twice a year leaving the plants at the Deposol surface in the process of reclamation.

Treatment b_2 encompassed the crop rotation of the following annual arable crops: *Sorghum bicolor* (L.) Moench., *Sorghum sudanense* Pers., *Secale cereale* L., *xTriticosecale Wittmack* and *Triticum aestivum* L.

Sorghum bicolor (L.) Moench. and *Sorghum sudanense* Pers. are seeded in the spring season in 2011 and 2012. The standard for seeding are 35 and 40 kg ha^{-1}, respectively. Fertilization with mineral fertilizers NPK 15:15:15 in dose 60 kg ha^{-1} of pure nutrients (N, P, K) was performed in pre-seeding phase. The N fertilizer KAN (27% N) in a dose 54 kg ha^{-1} N of pure nutrient was used used at the beginning of jointing phenophase. Biomass in the phenophase of forming and soaking grains was incorporated with ploughing to the depth of 25–30 cm.

Secale cereale L., *xTriticosecale Wittmack* and *Triticum aestivum* L. are seeded in the fall season in 2012, 2013 and 2014. Standard agrotechnique used in growing cereale crops.

After the cereals harvest the plant residues are plowed at the Deposol in the process of reclamation.

The obtained results were examined by analysis of variance (ANOVA). The significance of the differences between the basic factors and their interactions was tested with the F-test, while the differences between mean values determined by the Lsd test.

Soil analysis

For the purposes of laboratory pedological research, the average samples of the Deposol were taken before the study at the beginning of 2011, and the samples of Rekultisol at the end of the vegetation in 2016. The samples were taken from a depth of 0-20 cm. The analysis of the technogenic soil included the examination of the following parameters: content of organic matter, humus, total N, P_2O_5 and K_2O.

1. content of organic matter in %, dry burning method at 550 ^oC;
2. humus content in %, colorimetric method, in a wet-burned sample with 1N $K_2Cr_2O_7$ and concentrated H_2SO_4;
3. total N in %, semimycro Kjeldahl method;
4. plant available P_2O_5 and K_2O, in mg per 100 g of soil, AL-method.

The determination of the studied types of technogenic soil was carried out according to Resulović and Čustović (2007), and the WRB classification (2014). According to the soil classification in Bosnia and Herzegovina, the newly discovered soils mine belong to the class of technogenic soils (types Deposol and Rekultisol). Deposol represents the type of surface layer of disposal area for overburden prior to biological phase of the reclamation. Rekultisol is a layer of soil where reclamation measures have been carried out and the initial processes of humification and mineralization begin. The researched Deposol and formed geogenic Rekultisol are of a silicate subtype. According to the WRB classification (World Reference Base for Soil Resources, 2014), these soils are determined as Technosols (Epiarenic and silicit material).

The basic climate indicators (precipitation and air temperature) in the researched six-year period are shown in the following tables (Tables 1–2).

Table 1. Monthly quantities of precipitation (mm) for the period 2011–2016

Year	Months												∑
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2011	63	37	32	21	76	42	71	26	13	44	14	111	550
2012	86	71	4	129	154	44	45	18	81	130	77	142	980
2013	78	115	130	43	181	100	54	33	123	38	160	2	1057
2014	48	73	74	227	378	135	155	244	197	112	50	99	1792
2015	106	98	127	49	166	65	13	46	106	141	78	8	1003
2016	120	123	137	64	103	73	186	64	69	93	99	7	1138
$\bar{x}$	83	86	84	89	176	76	87	72	98	93	79	61	1086

Table 2. Average monthly and average annual air temperature (°C) for the period 2011–2016

Year	Months												$\bar{x}$
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2011	0.8	0.7	5.3	11.3	15.32	20.1	22.4	22.5	19.0	11.5	4.9	5.7	11.6
2012	3.4	-1	9.3	12.6	16.4	22	24.4	22.9	17.7	12.7	10.7	2.7	12.8
2013	4.5	4.2	7.1	14.7	13.7	23.3	22.3	22.4	15.4	13.2	8.9	3.7	12.8
2014	6.6	7.7	9.5	13.2	16.3	19.8	21.7	20.5	16.6	13.6	9.8	5.5	13.4
2015	4.8	4.2	7.8	12.0	17.6	19.3	23.4	22.9	17.0	11.9	6.9	4.6	12.7
2016	2.6	8	9.1	13.6	16.9	20.5	21.8	19.6	17.1	10.3	6.4	0.9	12.2
$\bar{x}$	3.8	4	8	12.9	16	20.8	22.6	21.8	17.1	12.2	7.9	3.8	12.5

RESULTS AND DISCUSSION

The average results of the analysis of the chemical properties of the Deposol and Rekultisol are given on the following tables (Tables 3–7). According to the results of the chemical properties of Rekultisol after the reclamation process, a slight improvement of the examined parameters was shown in comparison with Deposol before the beginning of biological reclamation.

Table 3. Average content of organic matter (%)

Treatments basic factors		Factor A (year)					
		a_1: 2011	a_2: 2012	a_3: 2013	a_4: 2014	a_5: 2015	a_6: 2016
Factor B	b_1: seeding grassland	2.3	3.07	4.23	3.78	4.4	5.7
	b_2: arable crops	2.3	2.9	4.1	4.64	4.33	7.4

ANOVA $F_{calc.}$		A	B	A x B
		320.05**	29.61**	21.87
Lsd	0.05	0.218	0.126	0.308
	0.01	0.289	0.166	0.408

An increase in the content of organic matter by individual treatments by 2.30% was the result of the accumulation of decomposed plant residues in the surface layer. Factor A and factor B are statistically highly significant. During the applied reclamation period of six years, the increase in organic matter content was 5.7% and 7.4%, for arable crops and grassland, respectively. The increase was from 2.5 to 3.2 times.

The presence of pure humus was observed in both vegetation systems from the second year of study. Basic factors are statistically highly significant. Applied agrotechnical and reclamation measures, with ecological conditions during the research (years) had a significant impact on the changes at the average content of humus. At the end of reclamation, it was shown that the content of pure humus increased by 1.1% and 0.5%, for arable crops and grassland, respectively.

Table 4. Average content of humus (%)

Treatments basic factors		Factor A (year)					
		a_1: 2011	a_2: 2012	a_3: 2013	a_4: 2014	a_5: 2015	a_6: 2016
Factor B	b_1: seeding grassland	0.0	0.1	0.2	0.25	0.31	0.5
	b_2: arable crops	0.0	0.19	0.5	0.55	0.41	1.1

ANOVA $F_{calc.}$		A	B	A x B
		31.04**	33.95**	5.01
Lsd	0.05	0.13	0.075	0.185
	0.01	0.173	0.1	0.244

After six years of biological reclamation, the examined Rekultisol samples showed an increase in the content of organic matter, as well as the appearance and increase in the content of humic matter (Tables 3 and 4). The appearance of humus is a sign of the current process of humification, and the importance of improving and including organic matter in the reclamation of technogenic soil has already shown by other authors (Olsen and Jones, 1989). The application of a set of agrotechnical and agro-ameliorative measures in the reclamation process influences the maximum increase of the content of organic matter. Accumulation of organic matter in technogenic soil leads to increased fertility and stimulates microbiological activity, as previously shown by many authors (Coine et al., 1989; Malić et al., 2015). In the research of Tordoff et al. (2000) it was shown that reclamation with organic substances (sawdust, compost, green manure, etc.) increases soil pH, improves soil structure, water capacity, cation exchange capacity, provides slower release of nutrients from fertilizers and serves as an inoculum for microorganisms.

The advantage of this process was also observed in the previous research of Technosol during the reclamation process, at the disposal area for overburden in the Stanari mine, where Malić and Marković (2012) found that humus content increased from 0.1% to 0.8%, as a result of three-year soil reclamation with field crops. In addition, in other research (Mujačić, 2013) it was shown that a higher humus content can be measured at marl disposal area for overburden, where it was observed that after a thirty-two-year reclamation period (growing legume and fruit reclamation), the average humus content increased by 6.91%.

At the end of the third year of reclamation, the content of total nitrogen was 0.01%. Factor A is statistically highly significant. The total value of nitrogen increased to 0.05% and 0.1%, respectively, in the Rekultisol under grassland and arable crops (Table 5). These lower values confirmed higher humification processes than organic nitrogen mineralization, which was proven in previous studies at the same location (Golić et al., 2014).

Table 5. Average content of total N (%)

Treatments basic factors		Factor A (year)					
		a_1: 2011	a_2: 2012	a_3: 2013	a_4: 2014	a_5: 2015	a_6: 2016
Factor B	b_1: seeding grassland	0.0	0.0	0.01	0.015	0.02	0.05
	b_2: arable crops	0.0	0.0	0.01	0.02	0.025	0.1

ANOVA		A	B	A x B
$F_{calc.}$		11.48**	2.38	1.53
Lsd	0.05	0.022	0.012	0.031
	0.01	0.029	0.017	0.042

Sheoran et al. (2010) reported the appearance of mineral N in trace, initially Rekultisol, as a consequence of an insufficient population of essential nitrogen fixers. Chatterjee et al. (2009) stated that reclamation by seeding grassland, among other things, provided a significant increase in the content of total N in a reclamated soils at a depth of 0–10 cm. Đikić (2010) in his research direct type of autoreclamation presented the results of N content in 0.01% and 0.09%, for a yellow and grey marly clays Technosols, respectively.

Table 6. Average content of P_2O_5 (mg 100 g^{-1})

Treatments basic factors		Factor A (year)					
		a_1: 2011	a_2: 2012	a_3: 2013	a_4: 2014	a_5: 2015	a_6: 2016
Factor B	b_1: seeding grassland	0.0	0.45	1.9	1.2	1.5	1.4
	b_2: arable crops	0.0	0.3	0.8	1.0	2.85	2.4

ANOVA		A	B	A x B
$F_{calc.}$		69.87**	3.29	19.33
Lsd	0.05	0.271	0.157	0.384
	0.01	0.36	0.207	0.509

Factor A (year) is statistically highly significant. An increase of P_2O_5 content during the reclamation process has noticed up to 1.5 and 2.85 mg 100 g^{-1} of Rekultisol, under seeding grassland and arable crops, respectively.

Table 7. Average content of K_2O (mg 100 g^{-1})

Treatments basic factors		Factor A (year)					
		a_1: 2011	a_2: 2012	a_3: 2013	a_4: 2014	a_5: 2015	a_6: 2016
Factor B	b_1: seeding grassland	1.0	2.05	5.25	6.43	5.8	7.8
	b_2: arable crops	1.0	2.8	5.5	7.2	8.5	7.4

ANOVA		A	B	A x B
$F_{calc.}$		532.49**	48.97**	21.01
Lsd	0.05	0.318	0.183	0.45
	0.01	0.421	0.243	0.596

An increase of K_2O under grassland was from 1 to 7.8 mg 100 g^{-1} Rekultisol, whereas under arable crops, this increase was from 1 to 7.4 mg 100 g^{-1}. Similar findings were observed in a three-year soil reclamation (dyrect type of reclamation with growing arable crops) study on ameliorated Deposol (Malić and Marković, 2012).
In other study, (Mujačić, 2013) found P_2O_5 values from 0.83 to 1.04 mg 100 g^{-1} of soil in the Deposol of marly disposal area for overburden, where, after 32 years of a reclamation period, these values have increased due to fertilization process from 3.71 to 11.45 mg 100 g^{-1} of soil (depending on the depth of the profile) and were a significantly higher compared to the measured values before the reclamation. According to the same author, the K_2O content was 5.05 mg 100 g^{-1} at the beginning of the study and has increased up to 14.79 mg 100 g^{-1} of Technosols at the end of the study.
Low concentrations of P_2O_5 in Technosols are also reported by Đikić (2013), whose values ranged from 0 (deeper layers) to 3.2 mg 100 g^{-1} (surface layers), measured in yellow marly clay Deposol. In the case of gray marly clays Deposol, these values range up to 5.7 mg 100 g^{-1}. In contrast, K_2O values have over 40 mg 100 g^{-1} at depths up to 20 cm.

CONCLUSION

Based on the results of the research carried out on the biological reclamation of the technogenic soil at the disposal area for overburden at the Stanari coal basin, the following conclusions are drawn:

- The chemical properties of the researched Deposol before the beginning of the reclamation are very unfavorable. It is characterized by a no humus substrate, a medium and highly acidic chemical reaction, low content of organic matter and basic biogenic elements.
- The ecological conditions during the research, together with the anthropogenic factor (through the applied agro-technical and reclamation measures), had a significant impact on the changes in the surface layer of the researched technogenic soil.
- Under the influence of intensive implemented measures of biological reclamation on the Deposol, forming of the reclamated soil was conditioned, the type of Rekultisol, which on the basis of the analysis indicates improvement of the researched chemical properties.
- The accumulation of unplanned plant residues in the surface of Rekultisol, as an important feature of biological reclamation, resulted in an increase in organic matter content by 2.5 to 3.2 times for seding grassland and arable crops, respectively.
- The appearance of humus in both vegetation system in the second year of research is evidence of the established humification of organic matter, and as a direct consequence of the efficiency of the applied biological reclamation measures of the Deposol.
- Total nitrogen was determined in samples at the end of the third year of research, whose value at the end of the study increased to 0.05% (treatment with seeding grassland), and 0.1% (treatment with arable crops).

- The value of plant available phosphorus at the end of the study is 1.4 mg of P_2O_5 100 g^{-1} of soil, on plots under seeding grassland, and 2.4 mg on plots under arable crops.
- The value of plant available potassium at the end of the study is 7.8 mg of K_2O 100 g^{-1} of soil, on plots under seeding grassland, and 7.4 mg on plots under arable crops.
- The impact of reclamation measures and agro-technology, which, with the time of reclamation, and the ruling climate impact, act on the technogenic parent substrate, is of crucial importance for the period of formation and formed technological fertility of the Rekultisol.

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LAND USE EFFECTS ON SOIL PORE-SIZE DISTRIBUTION AND SOIL WATER RETENTION

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Abstract

Soil pore characteristics can have great impact on plant growt and environment. A study was conducted to evaluate the efects of different land use on porosity, pore size distribution (PSD) and soil water retention (SWR) of Fluvic Phaeozem in the Kolubara River valley, Serbia. The land use treatments included: natural forest, native meadow, and arable land managed in the same way for more than 100 years. Disturbed and intact soil samples were collected from three soil profiles at each of the three different land use types from depths of 0–15, 15–30 and 30–45 cm. The capillary rise equation was used to estimate effective pore sizes from water retention measurements. Pressure cells are used to mesure water retention in the water potential range from –33 to –1500 kPa. The bulk density (BD) was significantly ($P < 0.05$) larger for meadow (1.48–1.49 g cm^{-3}) and arable land (1.28–1.42 g cm^{-3}) than forest (0.99–1.29 g cm^{-3}) at the top 30 cm of soil. There was no significant difference in BD between meadow and arable land in the subsurface soil layer (15–30 cm). Depending upon the increases in BD and disruption of pores by mowing and tillage management, total porosity decreased accordingly in meadow and arable land. Land use had significant effect on PSD. Volume of macropores (> 30 μm) were significantly higher for forest (10.93–16.19%) than meadow (4.77–5.74%) and arable (4.83–7.81%) land for 0–30 cm soil layer. Among the diferent land use types, forest and arable land had significantly higher mesopores (30–3 μm) volume compared with meadow. Mowing and tillage management significantly decreased volume of micropores < 3 μm diameter size at the 0–30 cm soil depth. The results showed that in the 0–0.15 m and 0.15–0.30 m depth soil layers, forest soils showed a significantly higher the available water capacity compared to meadow and arable lands. The S-index also detected clear differences among land uses. In this study, the soil water retention data are well described by the van Genuchten model. In conclusion, our results showed that total porosity, PSD, and moisture retention significantly changed because of the different management systems in the top 30 cm of soil, which can potentially influence crop yields and ecosystem function.

Keywords: land use change, Fluvic Phaeozem, bulk density, soil porosity, water retention curve, S-index

INTRODUCTION

Land use change has been recognised as one of the major drivers for global environmental change (Dale et al., 1993). Conversion of forest or natural grassland into agricultural soils is of considerable concern worldwide due to environmental degradation and global climate change (Smith et al., 2016; Sanderman et al., 2017). Ecologically consequences of incompatible human land-use and management practices implemented locally such as deforestation and soil fertility depletion have led cumulatively to an alteration in the global biogeochemical cycles (Celik, 2005) and in soil hydraulic and soil hydrological properties (Fuentes et al., 2004; Bormann and Klaassen, 2008). Porosity, pore size distribution, water retention and hydraulic conductivity and connectivity together with bulk density, and are important soil physical property that can be to a great extent influenced by the land degradation due to the land use change and cultivation. Quantitative information about the amount and distribution of the pore space is more important in characterizing the soil as a medium for plant growth than particle size distribution (Danielson and Sutherland, 1986). Soil porosity refers to the amount of pores or voids between solid (soil) particles (elementary particles) and structural units of a soil (soil aggregates). The size and distribution of pore spaces, particularly of those between particles or soil aggregates, are important to plant growth because they affect the storage, availability and movement of air and water, and provide space for root growth (Eynard et al., 2004; Wairiu and Lal, 2006). Porosity and pore size distribution may be greatly reduced in soils subjected to tillage or cultivation or heavy loads in wet conditions (Celik, 2005).

Soil pore characteristics and their relation to water retention are subject of many discussions and studies in order to improve the understanding of soil physical behavior. Soil water infiltration, retention and flow rate depend on the quality, interconnectivity, and size of pores. Conversion of forest to perennial grasses and/or arable land will also, over time, effect changes in soil water retention (Mapa, 1995; Schwartz et al., 2003; Borman and Klaassen, 2008). On a local scale, deforestation, and increase in the agricultural activity causes problems of soil degradation and increases the risk of floods and droughts (Jarvis, 1991). Mapa (1995) reported that deforestation affected the hydrologic balance, creating unregulated stream flows and increasing flood intensities while destabilising steep land and enhancing soil erosion. The major reasons for these problems are increased run-off due to low infiltration rates and a decrease in soil water retention. Land use change can also alter soil bulk density. Bulk density can increase considerably in the top soil due the effect of long-term tillage operation (Bewket et al., 2003; Bormann and Klaassen, 2008; Gajić, 2013; Hebb et al., 2017). In summary, they reported that forest soils have a reduced bulk density compared to non-forest soils.

Soil-specific information on porosity, pore size distribution and soil water retention is needed for assessing sustainability of land use and soil management practices. However, comparative effect of land use conversion on porosity, pore size distribution and soil water retention have been less documented, especially with silty clay soils in continental climate. Thus, the objective of this study were to evaluate the effects of land use change on soil physical properties including bulk density, total porosity, pore size distribution and water retention of noncarbonated, silty clay Fluvic Phaeozem in the lowland ecosystems of Western Serbia.

MATERIALS AND METHODS

Study area

Three study locations were selected in the Kolubara Valley located about 10 km south of Obrenovac town (≈90 m above mean sea level with mean annual rainfall of 730 mm and mean air temperature around 10 °C) in western Serbia. The experimental area, which was originally under natural decidous forest was cleared for cultivation (agricultural production) over 100 years ago. The soil is a noncarbonated, silty clay Fluvisol according to national soil taxonomy (Dugalić and Gajić, 2012) or a Fluvic Phaeozem (IUSS Working Group WRB, 2014), developed on a poorly carbonated alluvium of the Kolubara River. The area is geomorphologically plain and nearly flat. At each location, adjacent land, natural decidous forest, natural meadow, and long-term conventionally tilled land for 100 years, were selected. The natural vegetation of the forest sites is characterized by a community of common oak and common ash (*As. Querceto- raxinetumserbicum*, Rud.). Meadow is dominated by annual meadow-grass (*Poa annua*), black medick (*Medicago lupulina*) and sweet peas (*Lathyrus sp*.). Meadow was cut only once in summer (july) and, later on, grazed sporadically by sheep and cows. On crop land winter wheat (*Triticum aestivum* L.) and corn (*Zea mays* L.) were planted. Plant residues removed each year and used as animal bedding or animal feed. Normal tillage for the plots is fall plowing. History show that the three types of land use (natural forest, natural meadow, and crop rotation) have not changed for the respective study sites for more than 100 years (farmers' statements). Pore size distribution and soil water retention characteristics were compared in these adjacent natural forest, natural meadow and cultivated lands (all in one soil types) over a period of 100 years or so. Ancillary soil properties for the selected field sites are shown in Table 1.

Soil sampling design and soil analysis

Within each land use area, three sampling sites with similar soil profiles and landscape positions were selected at each location. Soil bulk density, total porosity and soil water retention was evaluated using soil core samples from topsoil (0–15 cm) and subsoil (15–30 cm and 30–45 cm) depths. Soil core samples of 5.4 cm diameter and 4.4 cm height were obtained from the topsoil and subsoil horizons with minimum disturbance. The topsoil (0–5 cm) was carefully removed above this sampling depth prior to core insertion. In forest and meadow lands, the upper 5 cm soil layer would consist of primarily litter, roots, undecomposed organic matter and crust rather than mineral soil, therefore, land use effects would be less apparent at this depth. Five replicates per treatment were obtained from the middle of each depth from all three treatments. These were transported to the laboratory with minimum disturbance and soil water retention was measured using a pressure plate apparatus (Soil Moisture Equip. Co., Santa Barbara, CA) for suction levels of 0–1500 kPa as described by Klute (1986). The core samples were saturated and were weighed after equilibration at each suction increment. They were then oven dried at 105 °C to obtain the dry soil mass. Gravimetric soil moisture was calculated at each suction level and was converted to volume basis using the bulk density of each core. The water retention relationship was used to obtain the soil water parameters at field capacity (FC), permanent wilting point (PWP) and plant available water (PAW). The field capacity and PWP were estimated as the volumetric water content at – 33 kPa and 1500 – kPa respectively. The difference between FC and PWP was obtained as the PAW. The field air capacity was obtained as the difference between saturated water content (0 kPa) and FC (Hillel, 1980). Retention curve data were determined by calculating the mean volumetric water content at tensions of approximately 0, 10, 33, 100, 680, and 1500 kPa. Soil water characteristics were analyzed using the van Genuchten model (van Genuchten, 1980):

$$\theta = \theta r + (\theta s - \theta r)[1 + (\alpha \cdot h)^n]^{-m} \tag{1}$$

where θ is the volumetric water content ($cm^3\ cm^{-3}$), θr is the residual water content ($cm^3\ cm^{-3}$), θs is the saturated water content ($cm^3\ cm^{-3}$), α (hPa^{-1}), n and m ($m = 1 - 1/n$) are empirical shape parameters, h is the tension potential (–hPa).
We estimated pore-size distribution from the soil water retention data. The equivalent pore diameter (d, μm) of the smallest drained pore neck was estimated using the foloving relation:

$$d \approx 3000/-h \tag{2}$$

where h is the soil matric potential (hPa).

We used pore-size classes to categorize pore size macropores, >30 µm diameter; mesopores, 30–3 µm diameter; and micropores; < 3 µm diameter.
To evaluate the simulations' performance of the van Genuchten model, the root mean square error (RMSE) was calculated as follows:

$$RMSE = \sqrt[2]{\frac{\sum_{i=1}^{N}(\theta_p - \theta_m)^2}{N}} \tag{3}$$

where θm and θp represent the measured and predicted soil water content, respectively, and N is the number of data points.

The same soil cores used to determine soil water retention were employed to measure dry bulk density (Blake and Hartge, 1986). Soil total porosity was estimated using measured bulk density values, assuming a soil particle density of 2.65 g cm^{-3} and expressed on a fractional basis ($cm^3\ cm^{-3}$). In addition, soil organic carbon (SOC) and particle size distribution were determined using disturbed soil samples from all three depths, air dried and sieved through a 2 mm. The SOC was determined by the wet combustion procedure as described by van Reeuwijk (1995). Multiplying the SOC by 1.72 resulted in the soil organic matter (SOM), i.e. humus. Particle size distribution in three fractions i.e. clay (0–0.002 mm), silt (0.002–0.05 mm) and sand (0.05–2.00 mm) was determined using a wet sieving and the pipette method without SOM destruction (van Reeuwijk, 1995). For all the plots, soil texture was silty-clayey with less than 8% of sand on average (Table 1).

Statistical analyses

The one-way analysis of variance (ANOVA) was used to compare the effects of the three land-use types on the following soil properties for the three soil depths of 0–0.15, 0.15–0.30, and 0.30–0.45 m separately: SOM, bulk density, field air capacity, soil porosity, and soil water holding characteristics. The LSD procedure was conducted to compare means of the soil properties at $P \leq 0.05$. The parameters of the soil water retention curves were performed using SWRC Fit software (Seki, 2007). Data analyses were carried out using STATISTICA 8.0 for Windows software.

RESULTS AND DISCUSSION

Soil organic matter

In the 0–0.15 m depth soil layer, the conversion of natural forest soil into soils under meadow and crop rotation resulted in significantly decreased in the concentration of SOM in bulk soils (Table 1). In the present study, SOM content showed a decreasing trend for these three treatments from the surface to the 0.30–0.45 m layer. Relative to the SOM of forest soil, the SOM of meadow and tilled soils decreased by 65.7% and 69.6% for the 0–0.15 m layer after >100 years agricultural land use, respectively. Our results were consistent with Mapa (1995); he found that SOM content in the 0–0.30 m and 0.30–0.60 m layer of soils under forest was significantly higher compared to that of grassland and cultivated soils. Similar findings were reported by Celik (2005) that deforestation and subsequent tillage practices resulted in nearly a 44% and 48% decrease in SOM for a soil depths of 0–0.10 m and 0.10–0.20 m, respectively over 12 years in the southern Mediterranean highland of Turkey. The higher SOM content in the 0.15–0.30 m depth in meadow and arable soils than forest is attributed to the absence of disturbance, which promotes root development and increases crop residue accumulation in ploughed layer (Bronick and Lal, 2005; Paustian et al., 2000). The higher SOM observed in meadow and arable at depth of 0.15–0.30 m is likely due to a greater root biomass decomposition compared to forest soils (Hook and Burke, 2000). There was no statistically significant difference between land use systems at the 0.30–0.45 m depth. However, at this depth forest and arable land showed a higher SOM content than meadow.

The loss of SOM by the conversion of the nature forest to agricultural soils probably caused a higher bulk density in the meadow and arable soils (Table 1). In addition, following conversion from the forest and cultivation, a decline in soil aggregation resulted in the increased bulk density (Gajić et al., 2010). This process could get worse by the continuous use of agricultural machinery for cultivation (Lal, 1987). According Minasny and McBratney (2018), gradual loss of organic matter from soil would have a small effect on soil water holding capacity. Furthermore, they highlighted that a 1% mass increase in SOC (10 g C kg^{-1} soil mineral), on average, increase water content at saturation, field capacity, wilting point and available water capacity by: 2.95, 16.61, 0.17 and 0.16 mm H_2O 100 mm $soil^{-1}$, respectively. The increase is larger in sandy soils, followed by loam and is least in clays. The largest effect of SOC was in large pores, possibly from the formation of macroaggregates, and its effect decreases with a decrease in size of pores.

Table 1. Soil organic matter (SOM), bulk density (BD), and particle size distribution in the 0–0.15 m, 0.15–0.30 m and 0.30–0.45 m depth layer under forest, meadow and arable treatments

Layer (m)	Land use	SOM (g kg^{-1})	BD (g cm^{-3})	Particle size distribution (g kg^{-1})		
				Sand	Silt	Clay
0–0.15	Forest	114.7[a] ± 0.78	0.99[c] ± 0.08	54.4 ± 0.24	448.6 ± 0.59	497.0 ± 0.42
	Meadow	35.9[b] ± 0.29	1.49[a] ± 0.04	77.1 ± 0.29	498.3 ± 0.90	424.6 ± 0.43
	Arable	31.8[b] ± 0.21	1.28[b] ± 0.02	58.2 ± 0.22	474.2 ± 0.62	467.6 ± 0.52
0.15–0.30	Forest	27.6[b] ± 0.51	1.29[b] ± 0.06	57.4 ± 0.31	460.6 ± 0.29	482.0 ± 0.32
	Meadow	32.8[a] ± 0.30	1.49[a] ± 0.02	75.9 ± 0.18	495.7 ± 0.18	428.4 ± 0.25
	Arable	32.5[a] ± 0.20	1.42[a] ± 0.03	58.5 ± 0.36	478.1 ± 0.33	463.4 ± 0.18
0.30–0.45	Forest	17.7 ± 0.42	1.48[b] ± 0.04	57.7 ± 0.34	459.0 ± 0.62	483.3 ± 0.51
	Meadow	15.7 ± 0.31	1.55[a] ± 0.02	77.3 ± 0.17	504.8 ± 0.58	417.9 ±0.37
	Arable	17.6 ± 0.15	1.47[b] ± 0.01	55.4 ± 0.29	482.0 ± 0.79	462.6 ± 0.22

The data represent means ± SD. Mean values marked with different letters are significantly different at the 5% probability level according to ANOVA. Values without letters are not different among treatments.

Bulk density and porosity

Land use had a statistically significant effect on soil bulk density at 0–0.15 m and 0.15–0.30 m depth, but was not significant at 0.30–0.45 m depth. Native forest had lower soil bulk density than the adjacent natural meadow and arable soils ($P < 0.05$; Table 1), which is in line with the findings from the literature (e.g., Murty et al., 2002; Bormann and Klaassen, 2008). Mean bulk density differences for an arable and a meadow in the topsoil (0–0.15 m) were as great as 0.29 to 0.50 g cm^{-3} than for the forest soils, respectively, and 0.13 to 0.20 g cm^{-3} in the 0.15–0.30 m subsurface layer. The loss of SOM by the conversion of the forest into meadow and cultivated fields probably caused a higher bulk density in the agricultural soils (Table 1). In addition, following conversion from the forest and cultivation, a decline in soil aggregation resulted in the increased bulk density. This process could get worse by the continuous use of agricultural machinery either for mowing or tillage. For the 0–0.30 m depth increment, arable bulk densities were lower of the meadow land use treatments, reflecting the loosening effect of tillage. At greater depths (0.30–0.45 m), significant differences in bulk density were not detected among land use treatments. Our results are not consistent with Hebb et al. (2017) who found lower bulk density of native grassland (1.21 g cm^{-3}) soils in relation to cropland (1.40 g cm^{-3}) at the 5 to 10 cm soil depth.

As expected from the bulk density measurements, the total porosity is highest for the forest soil (Table 2). The effect of 100 years mowing and tillage management resulted in an average decrease of 30.0% and 17.7% in total porosity for the 0–0.15 m layer and 14.4%

and 9.2% for the 0.15–0.30 m layer, respectively for the meadow and arable soils. Land use had no significant effect on total porosity at 0.30–0.45 m soil depth. Total porosity for meadow soils are significantly smaller than for arable soils, which can be assumed as to be due to long-term (> 100 years) non-disturbance of the soil matrix of the natural meadows. Our findings are not in agreement with the results of Hebb et al. (2017) who reported significantly higher total porosity in native grassland soils than in cropland at the 0.05–0.10 m soil depth ($P < 0.001$).

The field air capacity, which is an indication of the macro-porosity (Mapa, 1995), was significantly higher for forest lands (0.056–0.182 cm^3 cm^{-3}) compared with meadow (0.030–0.044 cm^3 cm^{-3}) and arable (0.025–0.088 cm^3 cm^{-3}) soils for any soil layer (Table 2). Generally, field air capacity was higher in the topsoil (0–0.15 m) compared with the subsoil (0.15–0.30 m and 0.30–0.45 m depth) for all land use types. According to Lal and Shukla (2004), a soil is considered healthy if the air field pore spaces are about 50% of the total porosity. In this study, field air porosity is significantly lower than 50% of the total porosity in all land use types and all investigated soil layers. In our study, the air capacity in all land use types was below threshold value of 10% vol., which limits soil aeration, except in the forest topsoil.

Pore size distribution

Table 2 shows the relative proportions of pores divided into macropores (> 30 μm), mesopores (30–0.2 μm) and micropores (< 0.2 μm), as influenced by land use. Pore size distribution in the upper 0.30 m of soil was greatly altered by land use change. Mesopores occupied the majority (about 0.64–0.75 cm^3 cm^{-3}) of pore volume under all three land systems, whereas macropores occupied < 10% (about 1–10%) of pore volume, except in the upper 0.15 m of forest soils (0.174 cm^3 cm^{-3}). Over the entire soil profile (0–0.45 m) macroporosity (volume of > 30 μm pores) was much higher in forest (0.0448–0.174 cm^3 cm^{-3}) than meadow (0.016–0.031 cm^3 cm^{-3}) and arable land (0.010–0.069 cm^3 cm^{-3}), while both mesoporosity (volume of 30–0.2 μm pores) and microporosity (volume of < 0.2 μm pores) were much lower in forest compared to the other land uses at 0–0.15 m soil depth.

There was no significant difference in meso- and micro- porosity between the meadow and arable soils at either depth. These results are in accordance with the behaviour of soil bulk density (Table 1). Changes in soil pore size distribution with deforestation and subsequent tillage practices can be attributed, at least partly, to a decrease in SOM and less soil biological activity, including earthworms. The primary shortcoming of the decrease in macropores and the increase in meso- and micro- pores is a potential deterioration in soil aeration, resulting in a worsening of root growth and proliferation. Thus, mowing and tillage can deteriorate the soil pore-size distribution by decreasing the percentage/volume of larger pores compared to forest soil.

Contradictory results have been described in a review by Hebb et al. (2017). They revealed that different uses of sandy clay loam soils do not have a statistically significant effect on macroporosity in Northern prairie regions, Canada. According to them, the absence of differences in macropore volume of sandy clay loam soils are likely indicative of ongoing disturbance regimes within all three land use systems. In contrast to our results, Wairiu and Lal (2006) reported that land use had no effect on the volume of different pore categories of clay loam soil in the 0–0.30 m depth.

Table 2. Soil porosity in the 0–0.15 m, 0.15–0.30 m and 0.30–0.45 m depth layer under forest, meadow and arable treatments

Layer (m)	Land use	Total porosity ($cm^3 cm^{-3}$)	Field air capacity ($cm^3 cm^{-3}$)	Macro porosity ($cm^3 cm^{-3}$)	Meso porosity ($cm^3 cm^{-3}$)	Micro porosity ($cm^3 cm^{-3}$)
0–0.15	Forest	0.628^{a} ± 0.050	0.182^{a} ± 0.021	0.174^{a} ± 0.048	0.639^{b} ± 0.017	0.187^{b} ± 0.034
	Meadow	0.439^{c} ± 0.023	0.030^{c} ± 0.017	0.016^{c} ± 0.011	0.748^{a} ± 0.018	0.236^{a} ± 0.026
	Arable	0.517^{b} ± 0.038	0.088^{b} ± 0.019	0.069^{b} ± 0.021	0.706^{a} ± 0.015	0.225^{a} ± 0.021
0.15–0.30	Forest	0.512^{a} ± 0.029	0.103^{a} ± 0.017	0.096^{a} ± 0.021	0.683^{b} ± 0.012	0.221 ± 0.024
	Meadow	0.438^{b} ± 0.019	0.044^{b} ± 0.010	0.031^{b} ± 0.018	0.739^{a} ± 0.014	0.230 ± 0.019
	Arable	0.465^{b} ± 0.025	0.041^{b} ± 0.009	0.024^{c} ± 0.023	0.728^{a} ± 0.013	0.248 ± 0.018
0.30–0.45	Forest	0.440 ± 0.016	0.056^{a} ± 0.099	0.045^{a} ± 0.025	0.695^{b} ± 0.015	0.260 ± 0.017
	Meadow	0.415 ± 0.016	0.037^{b} ± 0.082	0.023^{b} ± 0.021	0.735^{a} ± 0.017	0.242 ± 0.013
	Arable	0.446 ± 0.018	0.025^{c} ± 0.005	0.010^{c} ± 0.025	0.731^{a} ± 0.017	0.259 ± 0.012

The data represent means ± SD. Mean values marked with different letters are significantly different at the 5% probability level according to ANOVA. Values without letters are not different among treatments.

In the present research, the numerical values of surface layer (0–0.15 m) macroporosity of meadow and arable land, and the subsurface (0.15–0.30 and 0.30–0.45 m) macroporosity in all three land systems were indicative of inadequate aeration and water flow, except in the surface layer of forest soils in the 0–0.15 m dept.

In general, 10% is the threshold value of the volume of > 50 μm pores believed to hinder root development (Wesseling and Wijk, 1957 in Gregorich and Carter, 1997). Namely, the proportion of > 30 μm pores in the surface layer (0–0.15 m) of meadow and arable land, as well as the subsurface layers (0.15–0.30 and 0.30–0.45 m) of all three types of land use, were below the threshold (10% of soil volume) at limited soil aeration (Greenland, 1981). The sum of meso- and micro-porosity was much greater than macroporosity over the entire soil profile (0–0.45 m) in all three land use systems (Table 2). Macropores are responsible for water flow in saturated soils and infiltration into the soil profile, which reduces surface runoff. In addition, a larger macropore volume enables holding of a larger amount of water during heavy rainfall. This water can later infiltrate deeper parts of the soil profile. Owing to gravity, macropores are easily drained and provide sufficient soil aeration for a useful population of soil flora and fauna (Mapa, 1995). These benefits would be greater in the forest than meadow or arable land soils in the study area due to the higher macroporosity.

Soil water retention characteristics

Table 3 and Figure 1 shows water retention curves influenced by land use management for all three depths. The adjacent three land use types significantly differed in saturated water content for the 0–0.15 m and 0.15–0.30 m soil depths. At 0 kPa retention of water was 36.3% and 17.1% greater in forest than in meadow and arable land in the upper 0.15 m of soil, and 14,0% and 7.6% for the depth of 0.15–0.30 m layer, respectively. We attributed this to the considerably lower bulk densities and the higher total porosity, especially macropores > 30 µm which empty around water tensions of –10 kPa, that were present in the forest soils.

At field capacity (–33 kPa), average volumetric soil water content did not significantly differ between all investigated land use systems over the entire soil profile (0–0.45 m). In this study FC of –33 kPa was used as our soils were typically fine textured (e.g., silty clay), and gravity drainage effectively ceases at water potential of –33 kPa in fine-textured soils (Brady and Weil, 2002). Our results are in the contrast with the observations of Bormann and Klaassen (2008), who reported higher water content at field capacity (pF 1.5) for Podzol and Stagnosol in forest soils than in grass and cropland topsoil (0.15–0.30 m). However, in their study, no differences in the water content at pF 1.5 were found among land uses for the Podzol, in the subsoil, while in subsoil of Stagnosol land use had no statistically significant effect on the volumetric water content at pF 1.5. According to them, the water content at pF 1.5 is used as a proxy for the field capacity. Such differences in results may be related to soil texture, the distribution of natural aggregates in soils, and soil management.

Scott and Wood (1989) observed that 12–30 years of tillage of Crowley silt loam (Typic Albaqualf) lowered water retention at –10 kPa soil water pressure when compared with a virgin prairie and 1 yr of tillage. Messing et al. (1997) indicated no differences in soil water retention between grass pasture and 30-yr-old trees for a high clay content soil, while soil under tree management had higher soil water retention than soil under pasture for sandy-textured soils.

The water contents at –1500 kPa (permanent wilting point) in the upper 0.30 m of forest were significantly lower from those of the meadow and arable lands. The PWP of forest and arable soils were significantly higher compared to meadow land at a soil depth of 0.30–0.45 m. Relative to PWP of the forest soils, PWP of meadow and arable soils increased by 26.20% and 20.32% for the 0–0.15 m layer, and 4.07% and 12.22% for the 0.15–0.30 m layer, respectively. These results are in agreement with Hill et al. (1985). There was an increase in the water content from the topsoil through the third soil depth for PWP. This was probably beacuse of the increase in microporosity through these subsoil horizons (Table 2).

Average plant available water capacity under the forest was significantly greater than under meadow and arable soils in the topsoil (0–0.15 m) (Table 3). Deforestation caused 32.8% and 16.0% decreases in plant AWC for the 0–0.15 m layer and 6.91% and 0.5% for the 0.15–0.30 m layer, respectively for the meadow and arable soils. The variability of the water content is highest for forest soils and decreases for meadow and arable soils. Forest soil had statistical significantly lower plant AWC than the adjacent soils under meadows and arable lands at the 0.30–0.45 m soil depth. In our study the arable land had higher average values of plant AWC than natural meadow bouth in the upper 0.15 m soil and subsoil layers (0.15–0.30 cm and 0.30–0.45 m). Our results contrast with the observation of Hebb et al. (2017), who reported greater plant AWC in native grassland than cropland ($P < 0.05$) by a magnitude difference of more than 4% actual water content. Bormann and

Klaassen (2008) reported similar results for the Podzol and Stagnosol of Northern Germany. They found that more intense the soil is used (agriculture > grassland > forest), the less water is stored in the soil at a distinct pressure head.

Table 3. Soil saturated water content (SWC), soil field capacity (FC), permanent wilting point (PWP) and available water content (AWC) in the 0–0.15, 0.15–0.30 and 0.30–0.45 m depth layer under forest, meadow and arable treatments

Layer (m)	Land use	SWC ($cm^3 cm^{-3}$)	FC ($cm^3 cm^{-3}$)	PWP ($cm^3 cm^{-3}$)	AWC ($cm^3 cm^{-3}$)
0–0.15	Forest	0.616^a ± 0.029	0.434 ± 0.016	0.187^c ± 0.006	0.247^a ± 0.010
	Meadow	0.452^c ± 0.024	0.422 ± 0.005	0.236^b ± 0.002	0.186^b ± 0.002
	Arable	0.526^b ± 0.026	0.438 ± 0.012	0.225^a ± 0.011	0.213^c ± 0.009
0.15–0.30	Forest	0.512^a ± 0.026	0.409 ±0.009	0.221^c ± 0.008	0.188^a ± 0.003
	Meadow	0.449^b ± 0.011	0.405 ± 0.002	0.230^b ± 0.005	0.175^b ± 0.003
	Arable	0.476^b ± 0.018	0.435 ± 0.001	0.248^a ± 0.009	0.187^a ± 0.007
0.30–0.45	Forest	0.454 ± 0.011	0.398 ± 0.005	0.260^a ± 0.013	0.138^c ± 0.007
	Meadow	0.430 ± 0.010	0.393 ± 0.006	0.242^b ± 0.004	0.151^b ± 0.010
	Arable	0.460 ±0.012	0.435 ± 0.006	0.259^a ± 0.012	0.176^a ± 0.007

The data represent means ± SD. Mean values marked with different letters are significantly different at the 5% probability level according to ANOVA. Values without letters are not different among treatments.

In contrast to our results, Mapa (1995) reported that the AWC of investigated sandy clay loam and sandy loam soils, did not become significantly different due to different land use, as the PWP increased in parallel with field capacity, resulting in no net difference. Mapa (1995) reported that the increase in water retention at high suctions (near PWP) can be attributed to more adsorption of water owing to high specific surface (total surface area per a unit mass of soil) resulting from the hydrophilic nature of SOM. Landon (1984) documented that at PWP, water generally remains in the micropores and adsorbed to surface soil particles, and is less dependent on structural configurations.

MacRae and Mehuys (1985) indicated that SOM increased the AWC only under exceptional conditions. Bauer and Black (1992) illustrated how the increase in SOM concentration did not change the plant AWC in sandy soils as the increase in moisture content at field capacity essentially paralleled the change in PWP. Even though the forest soils did not show a great diffrerences in available water, the greater amount of water retained is beneficial for moisture conservation and reducing overland flow.

The soil water retention curves for each land use system at all three sampled soil layers are shown in Fig. 1. The general shapes of water retention curves were different among land use systems. As expected, the soil layers that showed largest changes in BD also showed the most marked differences in water retention. In the 0.30–0.45 m layer where changes in BD were smallest, the water retention curves were the most similar. The potentials at which retained water contents of forest exceeded those of meadow and arable lands were mainly confined within the region from saturation (0 kPa) to –10 kPa for the 0–0.15 m and 0.15–0.30 m layers, which is according to Schwartz et al. (2003). Others have stated that changes in the retention curve due to tillage occurred only in the largest pore-size range (Ahuja et al., 1998). The general shapes of water/moisture retention curves were no different among land use systems at the 0.30–0.45 m soil depth (Fig. 1C).

Overall means of the van Genuchten parameters for the water retention curves strongly differed among native forest, native meadow and arable lands (Table 4). All the root mean square error (RMSE) values of the modelled moisture curves were substantially low for each land use system (i.e., 0.02619 for forest, 0.018497 for meadow and 0.01851 for arable), indicating an excellent fit of the van Genuchten model to the actual measured data. A low RMSE implies close agreement between the observed and predicted values. In this study, the soil water retention data are well described by the van Genuchten model.

After fitting the van Genuchten model to the water retention data (Table 4), we observed significant effects of the land use treatments on the empirical model parameters (α and n). In our case the fitted value of α was significantly greater for forest as compared to meadow and arable lands across the upper 0.30 m of soil (Table 4). The meadow had the highest α value at the 0.30–0.45 m soil depth, whereas, the arable land had the lowest α values at this depth. Contrarily to this study, Hebb et al. (2017) found no statistically significant differences in parameter α between native grassland, introduced pasture and annual cropland at a soil depth of 5–10 cm, although overall porosity was greater in native grassland than the other land uses. The α parameter derived from van Genuchten model is related to the inverse of the air-entry potential and can reflect differences in macropore volume.

In this study no differences were found in the empirical n parameter derived from van Genuchten model for the soil depth of 0–0.15 m and 0.15–0.30 m. In contrast to this study, Hebb et al (2017) found a significantly higher value of n in both native grassland (n = 1.76) and introduced pasture (n = 1.75) than annual cropland (n = 1.43) at a soil depth of 5–10 cm. The fitted values of n differed significantly between forest soil and arable, and between meadow and arable, but not differ between the forest and meadow lands for the subsoil of 0.30–0.45 m depth (Table 4).

Our study also indicated that the land use affected the S-index (i.e., slope of moisture curves at their inflection point), with a sharp increase in S-index within forest compared to meadow and arable lands for the topsoil of 0–0.15 m (Table 4). The S-index did not differ between the meadow and arable soils for the topsoil of 0–0.15 m, but differed significantly for the soil depth of 0.15–0.30 and 0.30–0.45 m. S-index of the forest and meadow soils were not statistically different although that of the arable was significantly different from those of the forest and meadow soils at the depth of 0.15–0.30 m (Table 4). The forest soils had much lower S-index than meadow and arable soils in the 0.30–0.45 m layer. Similar to our study, Hebb et al. (2017) reported significantly higher S-index (2.4-fold) within native grassland vs. annual cropland.

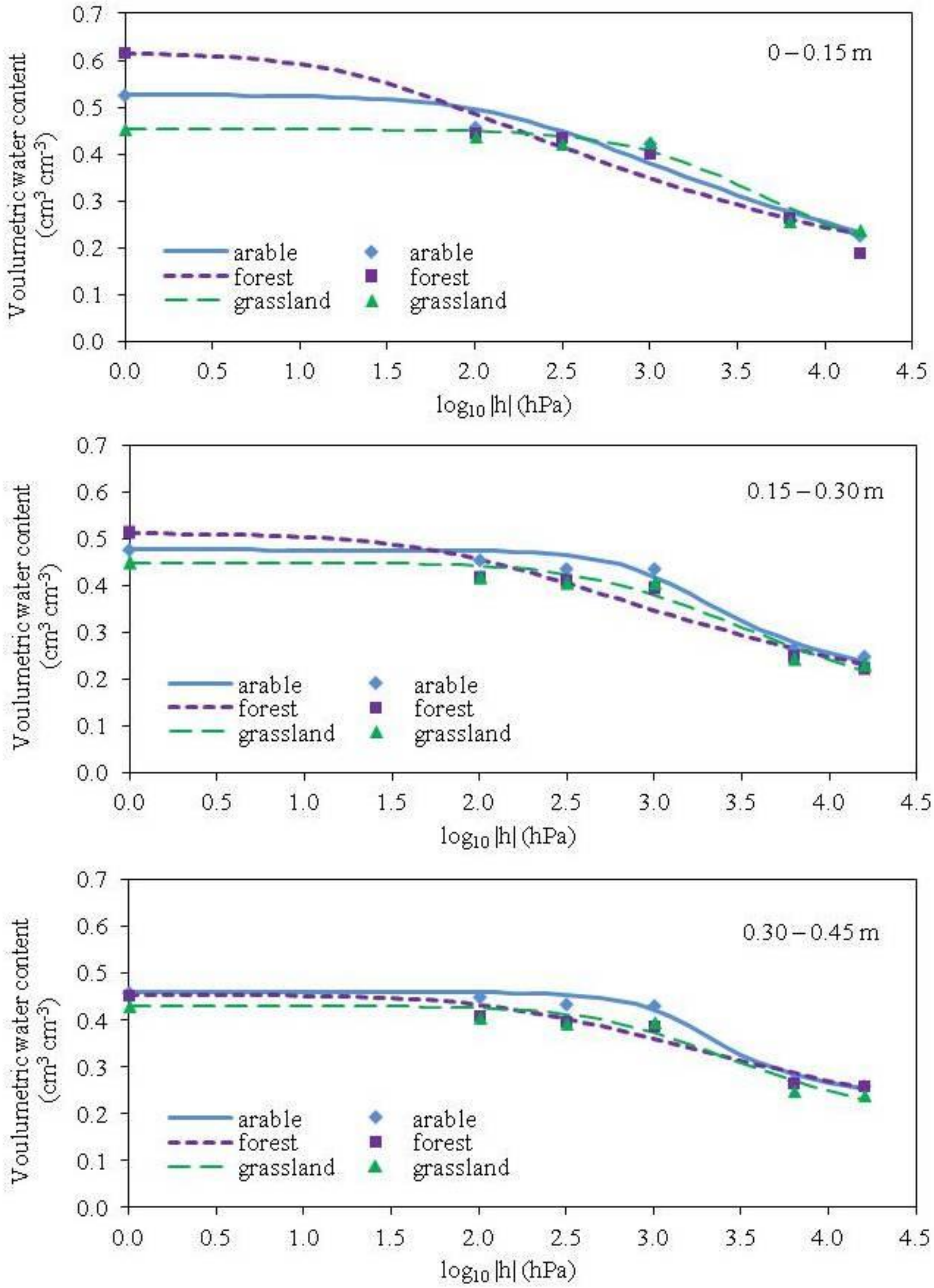

Figure 1. Soil water retention curves in the 0–0.15 m, 0.15–0.30 m and 0.30–0.45 m depth layers under forest, meadow and arable treatments as obtained by fitting van Genuchten model. The symbols represent the measured mean values (for volumetric water content), the lines are the fitted retention curves.

Table 4. Parameters of the fitted water retention curves in the 0–0.15 m, 0.15–0.30 m and 0.30–0.45 m depth layers under forest, meadow and arable treatments from van Genuchten model

Layer (m)	Land use	α (hPa^{-1})	n (–)	RMSE ($cm^3\ cm^{-3}$)	S-index (–)
0–0.15	Forest	0.042^{a} ± 0.051	1.170^{a} ± 0.121	0.035	0.044^{a} ± 0.010
	Meadow	0.001^{b} ± 0.033	1.271^{a} ± 0.978	0.019	0.036^{b} ± 0.008
	Arable	0.006^{b} ± 0.056	1.218^{a} ± 0.115	0.024	0.035^{b} ± 0.003
0.15–0.30	Forest	0.017^{a} ± 0.039	1.321^{a} ± 0.054	0.026	0.029^{b} ± 0.002
	Meadow	0.001^{b} ± 0.024	1.243^{a} ± 0.050	0.019	0.031^{b} ± 0.001
	Arable	0.001^{c} ± 0.020	1.373^{a} ± 0.038	0.018	0.071^{a} ± 0.000
0.30–0.45	Forest	0.006^{b} ± 0.009	1.265^{b} ± 0.017	0.018	0.018^{c} ± 0.001
	Meadow	0.013^{a} ± 0.002	1.344^{b} ± 0.014	0.017	0.040^{b} ± 0.000
	Arable	0.001^{c} ± 0.003	1.530^{a} ± 0.013	0.014	0.085^{a} ± 0.001

The data represent means ± SD. Mean values marked with different letters are significantly different at the 5% probability level. Values without letters are not different among treatments.

The S-index has been proposed as a measure to assess soil structural quality (e.g., pore size distribution, compaction, plant AWC) (Dexter, 2004; Shahab et al., 2013). According Dexter (2004), an S-index of 0.035 is the postulated threshold separating soils of favorable structure from those with poor structure, and soils with much lower S-index (<0.02) are considered to have very poor structure. Accordingly our S-index results indicate that native forest in this study had good soil structure, while native meadow and arable soils had marginal structure in the upper 0.15 m layer (Table 4).

CONCLUSION

The effect of three contrasting land use systems (natural forest, natural meadow and arable) on the physical properties of a silty clay Fuvisol, after >100 years deforestation was evaluated. Conversion of natural forest to meadow and arable soils increased bulk density and decreased soil organic matter and reduced porosity, pore size distribution and soil water retention especially in the uper 0.30 m of soil. The results showed that deforestation caused a decrease in α parametar and S-index. No clear influence of deforestation on *n* water retention curve parameter was observed. Our study also suggests that the soil water properties can well described by the van Genuchten model. In closing, land use can significantly alter the soil pore-size distribution and water retention of silty clay soils, especially of the surface layer. This information can be used to identify and foster land use systems that contribute to sustainable agroecosystems and land stewardship.

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FTIR SPECTROSCOPIC STUDY OF S-METOLACHLOR SORPTION ON INORGANIC AND ORGANICALLY MODIFIED MONTMORILLONITE FROM BOGOVINA

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Abstract

Environmental problems related to the application of herbicides are causing a concern due to their increasing presence in soil, groundwater and surface water. Numerous methods have been developed in order to reduce herbicide mobility and protect natural water resources. The results presented in this paper show the interaction of herbicide S-metolachlor with inorganic and organically modified montmorillonite from Bogovina (Boljevac municipality, Serbia). Clay sample from Bogovina represents Ca-Na montmorillonite with a small amount of quartz, cristobalite and carbonate minerals. Organic montmorillonites were obtained after modification with different concentrations of organic complex (HDTMA and PTMA), whereas inorganic modification was performed with 1M NaCl solution. The interaction between minerals and herbicide was monitored using infrared spectroscopy. IR bands observed in the inorganic modified montmorillonite (Na-montmorillonite) are typical for smectites with a high Al content in the octahedron position.

The intercalation of $HDTMA^+$ cations into the interlayer space produces redshift of the IR bands that originate from the vibrations of the adsorbed water, as a consequence of the hydrogen bond strength reduction in HDTMA-montmorillonite. Also, the intensity of these bands decreases significantly with the increasing concentration of $HDTMA^+$ cation. All these changes are related to the decreasing of the water content in the interlayer space by increasing the content of HDTMA. The occurrence of the stretching CH_2 vibrations is generally the main difference in the spectrum of HDTMA modified montmorillonite in comparison with the spectrum of inorganically modified montmorillonite. The wavenumber, intensity and width of these bands are sensitive to conformation in hydrocarbon chains. After the organic modification of the montmorillonite with the PTMA complex, stretching vibrations of the phenyl ring occurred.

Analysis of FTIR spectroscopy data showed that the hydrogen bond is one of the most important mechanisms that occur between Na-montmorillonite and S-metolachlor. Comparing the FTIR spectra of herbicides before and after the sorption, it can be concluded that the carbonyl group participate in the binding process. Sorption of S-metolachlor on HDTMA-montmorillonites causes the redshift of the C=O absorption band. Shifting to lower wavenumbers and joining with the deformation vibration band of water indicates that the C=O group participated in the formation of a bond with the montmorillonite. Sorption of S-metolachlor molecules on PTMA-montmorillonite takes place through the interaction between the aromatic benzene ring of S-metolachlor and the aromatic benzene ring of the organic complex (π-π bonds). Also, the formation of a hydrogen bond occurs between the molecules of S-metolachlor and the molecules of water

that are in the interlayer space and/or oxygen on the surface of the tetrahedral sheet of the montmorillonite.

Keywords: adsorption, S-metolachlor, HDTMA, PTMA, infrared spectroscopy

INTRODUCTION

The high solubility of some herbicides negatively affects their efficiency and therefore causes serious environmental problems due to the migration into groundwater (Cohen et al., 1986). The reduced inhibitory activity requires repetition of treatment, which leads to increased costs and a negative impact on the environment.
Therefore, attempts were made to create a formulation that would lead to an improvement in the inhibitory activity of herbicides, which will also reduce their migration to groundwater. Certain experiments involved creating a stronger interaction between the mineral surface and the herbicide by making organo-mineral complexes. Montmorillonites previously modified with aromatic or aliphatic organic cations showed better sorption of certain nonionic herbicides than those without any modifications (El-Nahhal et al., 1999).
S-metolachlor, herbicide belongs to the chloroacetanilide group, and is often used to control annual grass and broadleaf weeds in crops of corn, soybeans, sugar beets, sunflowers, etc. The groundwater concentrations vary from 0.08 to 680 μg/mL (Chesters et al., 1989). Neutral degradation products of S-metolachlor may possess a certain dose of toxicity similar to parent herbicides (Hladik et al., 2006).
Montmorillonite is a clay mineral widely used in various industries due to its specific physical and chemical properties, such as cation exchange capacity (CEC), large surface area, high pore volume, high swelling ability, etc. Intercalation of organic complexes into montmorillonite layers changes surface properties from hydrophilic to hydrophobic.
The results presented in this paper show that FTIR spectroscopy can be a valuable technique to examine the organic modification of montmorillonite as well as the interaction of herbicide S-metolachlor with inorganic and organically modified montmorillonite from Bogovina (Boljevac municipality, Serbia).

MATERIALS AND METHODS

Materials

HDTMA-bromide was obtained from Alfa-Aesar Chemical Company (Karlsruhe, Germany), with a purity of 98%. Phenyltrimethylammonium chloride (PTMA) was supplied by the Tokyo Chemical Industry Company (Toshima, Kita-Ku, Tokyo, Japan), with a purity of 98%.
A raw natural sample of bentonite was collected from the Bogovina locality (Serbia). Clay fraction, with montmorillonite as the dominant mineral, was separated using the decantation method. Clay fraction (< 2 mm) was then treated with 30% hydrogen peroxide in order to remove organic matter from the sample.

After air drying, montmorillonite was saturated with 1 M NaCl, and left on a mechanical shaker for 24 h, centrifuged and rinsed with distilled water until the negative reaction on Cl^-. The sample was then air-dried and named Na-montmorillonite (NaM). The cation exchange capacity (CEC) of Na-montmorillonite was 69 mmol/100g, determined using Cu-trien (triethylenetetramine) complex (Meier and Kahr, 1999), which was recommended by the Clay Mineral Society.

Na-montmorillonite was then organically modified using two organic complexes: hexadecyltrimethylammonium bromide and phenyltrimethylammonium chloride. The organoclay complexes were prepared by dropwise addition of 100 mL of HDTMA or PTMA aqueous solution, with appropriate concentration of organic complex, into the aqueous suspension of the NaM clay. Four different concentrations of organic cations were selected for the monitoring of the herbicide adsorption: 17.25 mmol/100 g of Na-montmorillonite (25% of CEC), 34.5 mmol/100 g of Na-montmorillonite (50% of CEC), 51.75 mmol/100 g of Na-montmorillonite (75% of CEC), and 69 mmol/100 g of Na-montmorillonite (100% of CEC). The reaction mixture was continuously stirred on the magnetic stirrer, at the temperature of 50°C. After the modification, the suspension was further agitated for 24 h and centrifuged at 7,000 rpm. All the samples were rinsed five times with distilled water and accordingly labelled as 1H- 0.25 CEC saturated with HDTMA complex, 2H- 0.5 CEC saturated with HDTMA complex, 3H- 0.75 CEC saturated with HDTMA complex, 4H- 1 CEC saturated with HDTMA complex, 1P- 0.25 CEC saturated with PTMA complex, 2P- 0.5 CEC saturated with PTMA complex, 3P- 0.75 CEC saturated with PTMA complex, and 4P- 1 CEC saturated with PTMA complex.

All samples are then treated with 1000 mg/L working solution of S-metolachlor and marked as NaM-SM, 1H-SM, 2H-SM, 3H-SM, 4H-SM, 1P-SM, 2P-SM, 3P-SM, and 4P-SM.

FTIR spectroscopy

All samples were investigated using FTIR method (Fourier-transform infrared spectroscopy). All results were obtained in Laboratory for infrared spectroscopy at the Faculty of Science, University of Kragujevac on a infrared spectrometer (Equinox 55, Bruker Optics) equipped with a single reflection diamond ATR accessory (Dura Sample IR II, SensIR). The samples were prepared in a form of KBr disk, and the spectra (averaged on 32 scans) were collected in the range of 4000-450 cm^{-1}, at a resolution of 4 cm^{-1} with corrections for the effect of the radiation wavelength on the penetration depth. For a better interpretation of the absorption bands, second derivatives were obtained for all samples.

RESULTS AND DISCUSSION

FTIR spectroscopy of samples without S-metolachlor

Detailed information on the interactions between S-metolachlor and the inorganic and organic montmorillonite was obtained by using infrared spectroscopy. In the spectrum of NaM (Fig. 1a), the absorption band at 3626 cm^{-1} was assigned to stretching vibrations of structural OH groups, while the absorption bands at 3447 cm^{-1} and 1643 cm^{-1} were assigned to stretching and bending vibrations of water molecules in interlayer space

(Tomić et al., 2015). The most intensive band in the spectrum at 1034 cm^{-1} was assigned to stretching Si-O vibrations of the tetrahedral sheet. Absorption bands, which originate from Al-Al-OH and Al-Fe-OH bending vibrations, are located around 916 and 871 cm^{-1}, and they are typical for mineral montmorillonite (Madejova, 2003; Tomić et al, 2012).

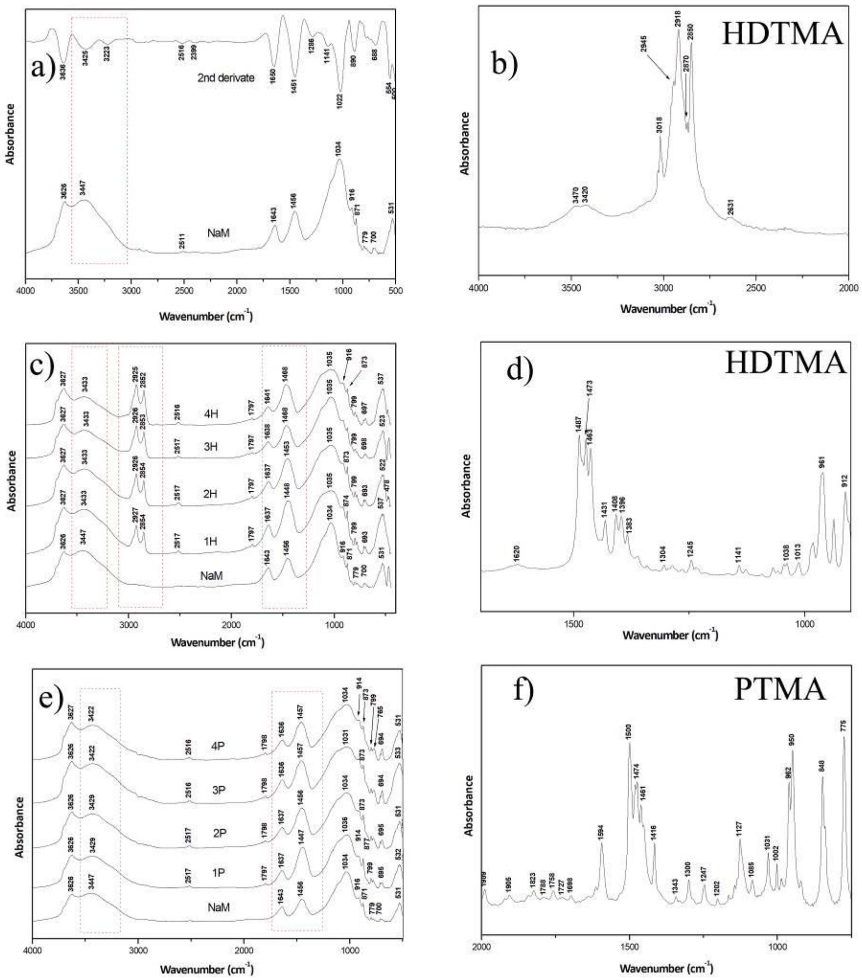

Figure 1. FTIR spectra of a) Na-montmorillonite; b) and d) HDTMA bromide; c) montmorillonites modified with different concentrations of HDTMA cation; e) montmorillonites modified with different concentrations of PTMA cation; f) PTMA chloride.

Absorption bands at 799 and 779 cm^{-1} indicate the presence of cristobalite (Madejova and Komadel, 2001).

The band at 1456 cm^{-1} indicates presence of carbonate minerals in the sample (Jović-Jovičić et al., 2008). Much better band position accuracy, as well as a sharper spectrum image can be obtained in the ATR 2nd derivative spectrum. A broad band at 3447 cm^{-1} in the spectrum of the Na-montmorillonite obtained using KBr technique, in ATR spectrum show two bands (Fig. 1a). Band at 3425 cm^{-1} was attributed to the symmetric $\nu_1(H_2O)$ and asymmetric $\nu_3(H_2O)$ stretching vibrations, while band at 3223 cm^{-1} represent overtone of bending vibrations ($2\nu_2(H_2O)$) (He et al., 2007).

At the spectrum of the HDTMA bromide, in the region from 3050-2800 cm^{-1}, several bands occur (Fig. 1b). Shoulder at 3030 cm^{-1} and band at 3018 cm^{-1} represent $\nu_{as}(N\text{-}CH_3)$ vibrations (Madejova et al., 2009), although some authors state that this band at 3018 cm^{-1} originate from $\nu_s(N\text{-}CH_3)$ vibrations (Li et al., 2008). Shoulder at 2945 cm^{-1} originates from overlapping $\nu_s(N\text{-}CH_3)$ with $\nu_{as}(CH_3)$ vibrations (Madejova et al., 2009). A small band at 2870 cm^{-1} represent symmetric stretching vibrations $\nu_s(CH_3)$ of methyl group which is not bonded to the N atom (Li et al., 2008; Madejova et al., 2009).

Most intensive absorption bands at 2918 cm^{-1} and 2850 cm^{-1} originate from asymmetric and symmetric stretching vibrations of CH_2 group respectively (Tomić et al., 2015).

The interaction of NaM with HDTMA$^+$ cations caused the formation of new bands (Fig. 1c). Strong bands at 2925-2927 cm^{-1} and 2852-2854 cm^{-1} were assigned to asymmetric and symmetric stretching vibrations of CH_2 group respectively (Tomić et al., 2015). Also, the band at 3447 cm^{-1} in the spectrum of NaM, was shifted on lower wavenumbers (3433 cm^{-1}) in the spectrum of HDTMA-montmorillonite, while the intensity of the band became significantly lower with the increment of HDTMA$^+$ loading (Fig. 1c). Interaction of HDTMA$^+$ with NaM caused the decrease of the water content due to the replacement of hydrated Na$^+$ with HDTMA$^+$. Absorption bands around 1473 cm^{-1} in the spectrum of the HDTMA bromide are attributed to CH_2 scissoring vibrational mode (Fig. 1d). The nature of the montmorillonite surface was changed from hydrophilic to hydrophobic.

Stretching vibration bands of phenyl ring appear between 1400 and 1600 cm^{-1} in the spectrum of PTMA, namely, at 1594, 1500, 1474, 1461, and 1416 cm^{-1} (Fig. 1f). The band at 1300 cm^{-1} was assigned to the vibrations of the ammonium group. Heights of these bands decreased after the interaction between PTMA$^+$ cations and montmorillonite (Fig. 1e). The band at 1594 cm^{-1} disappeared, probably as a result of the interaction between π electrons of the phenyl ring and π electrons of the oxygen in the tetrahedral layer of the montmorillonite (Majdan et al., 2009). Also, the band at 1300 cm^{-1} disappeared, which is due to a strong interaction between positively charged nitrogen and negatively charged montmorillonite sites. These interactions result in a bond between the ammonium group and the montmorillonite surface.

FTIR spectroscopy of samples with S-metolachlor

Three bands at 1674, 1462, and 1363 cm^{-1} in the spectrum of pure S-metolachlor were assigned to stretching vibrations of the carbonyl group (C=O), phenyl group and anilidic group respectively (Fig. 2a) (El-Nahhal et al., 2001).

After the adsorption, the band assigned to C=O vibrations red-shifted from 1674 cm^{-1} in the spectrum of S-metolachlor to 1638 cm^{-1} in the NaM-SM spectrum, overlapping with the bending vibrations of water molecules in clay (1643 cm^{-1}). The carbonyl double bond was weakened, almost despaired, after the sorption, indicating its involvement in the bonding process. Possible bonding interactions between montmorillonite and chloroacetanilide herbicide could include coordination bonds between C=O and the exchangeable cation, and/or H bonds between C=O and the hydration water because C=O and C-N in this compound are in a conjugation mode due to the distribution of double bonds and lone electron pairs (Liu et al., 2002).

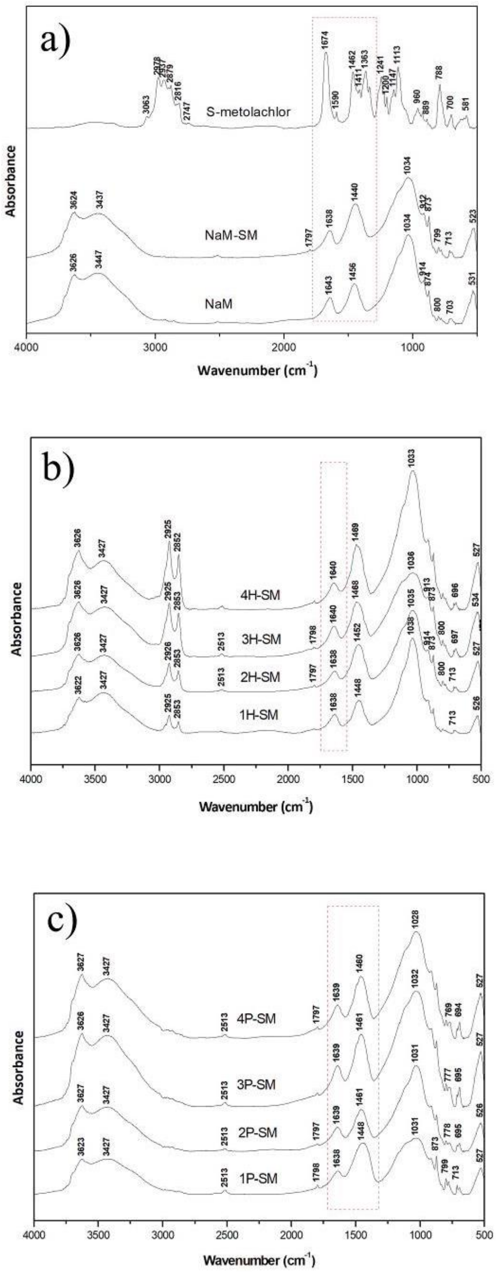

Figure 2. FTIR spectra of: a) S-metolachlor, Na-montmorillonite and Na-montmorillonite with adsorbed S-metolachlor; b) HDTMA-montmorillonite with adsorbed S-metolachlor; c) PTMA-montmorillonite with adsorbed S-metolachlor

Both lone electron pairs on the oxygen of methoxy and ethoxy group are in resonance with the lone pair on nitrogen and the double C=O bond, which delocalizes the charge distribution and reduces the charge density on the carbonyl oxygen (Liu et al., 2000). The second significant change after the S-metolachlor sorption was detected on 1456 cm^{-1} band. This band shifted to 1440 cm^{-1} and increased in its intensity. This is the contribution of phenyl ring vibrations from the adsorbed herbicide.

Interaction of HDTMA-montmorillonite with S-metolachlor caused negligible changes in FTIR spectra. The absorption band of carbonyl group C=O in the spectrum of S-metolachlor (1674 cm^{-1}) (Fig. 2a) shifted to lower wavenumbers (1638-1640 cm^{-1}) (Fig. 2b). Band assigned to the ring vibrations in S-metolachlor (1462 cm^{-1}) (Fig. 2a) was unclear for observation due to the HDTMA absorption bands that attributed to CH_2 scissoring vibrational mode and vibrations which were influenced by the presence of carbonates.

Interaction of PTMA-montmorillonite with S-metolachlor caused also negligible changes in FTIR spectra. The main differences between the spectrum of the pure S-metolachlor and S-metolachlor sorbed on PTMA-montmorillonite are: (1) shifting of the band at 1674 cm^{-1} (C=O vibrations) to lower wavenumbers (1639 cm^{-1}) after the sorption of the herbicide, (2) slightly movement of phenyl ring bands from 1462 cm^{-1} to lower wavenumbers and (3) disappearance of 1363 cm^{-1} band (C=C-N vibrations) after adsorption. According to the literature, one of the most important mechanisms of the herbicide adsorption on PTMA-montmorillonite is π-π bonding between benzene the ring of the herbicide and aromatic ring of the PTMA+ cation (Majdan et al., 2009).

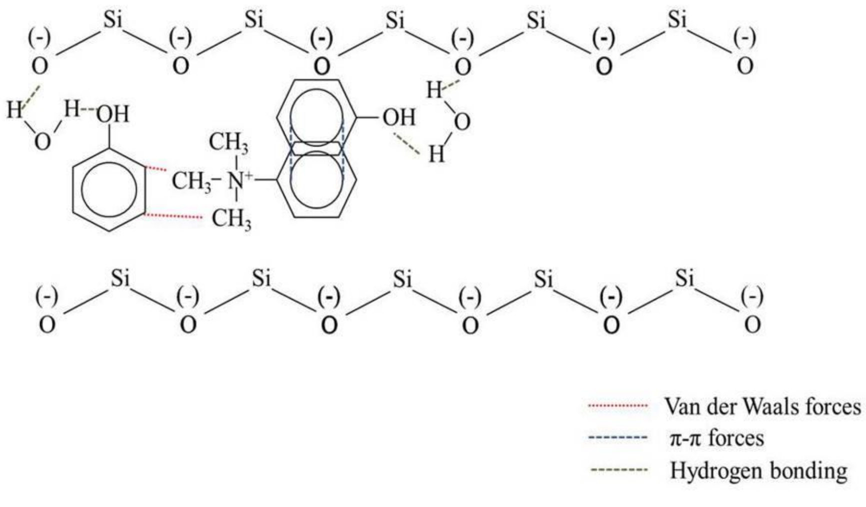

Figure 3. Suggested interactions between $PTMA^+$ cations and phenol in interlayer space of montmorillonite (Majdan et al., 2009)

CONCLUSION

FTIR method was very useful in the process of examination of interactions between Na-montmorillonite and organic complexes such as HDTMA bromide and PTMA chloride.

Adsorption of HDTMA+ cations was easily detected by the occurrence of the stretching CH_2 vibrations. On the other hand, after the organic modification of the montmorillonite with the PTMA complex, stretching vibrations of phenyl ring occurred. The band associated with ammonium vibrations disappeared due to the interaction between the positive charge on nitrogen and the negative charge at the montmorillonite surface. Sorption of S-metolachlor on HDTMA-montmorillonites causes the redshift of the C=O absorption band which indicates that the C=O group participated in the formation of a bond with the HDTMA-montmorillonite. Adsorption of an aromatic compound such as S-metolachlor on PTMA-montmorillonite takes place, beside C=O group, through the interaction between the aromatic benzene ring of S-metolachlor and the aromatic benzene ring of the organic complex (π-π bonds).

ACKNOWLEDGMENT

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SOIL TYPES AND THEIR SENSITIVITY TO THE ACIDIFICATION PROCESS IN THE MUNICIPALITIES OF KOSJERIĆ, POŽEGA AND UŽICE

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Abstract

The acidification process can be considered as main cause of reduced productivity of agricultural soil, which in the previous period was significantly accelerated by anthropogenic factors, primarily increased emissions and deposits of acidic pollutants and inadequate use of mineral fertilizers (Sparks, 2002). The degree of sensitivity of the soil to the acidification process is defined by the buffer capacity of the soil, that is, its physical and chemical properties. Accordingly, 20 soil profiles were opened at the study area and 60 soil samples were taken for laboratory analyses (7 profiles in the municipality of Kosjerić, 9 profiles in the municipality of Požega and 4 profiles in the municipality of Užice). According to the criteria of the national classification (Škorić et al., 1985), 9 types of soils are defined as: Haplic Fluvisol, Haplic Vertisol, Leptic Calcisol, Mollic Umbrisol, Haplic Cambisol (Eutric), Haplic Cambisol (Dystric), Leptic Cambisol, Luvisol and Haplic Planosol. An analysis of the trend of sulfur (S) and nitrogen (N) deposition for the period 1980-2015 was performed, as well as analyzes of soil sensitivity to the acidification process by the following methods: Holowaychuk & Fessenden (1987) (CEC and pH in H2O combined with soil sensitivity to base loss, acidification process and aluminum solubility result in overall sensitivity) and Kuylenstierna (2001) (BS and CEC are included as a criterion of soil sensitivity). For geospatial distribution preview of different sensitivity classes Cinderby (1998) method was applied. Sensitivity classes are defined regarding different soil buffer ranges and buffering mechanisms, weathering of different minerals, base saturation and cation exchange. Soil types characterised with BS=80-100% are in the carbonate buffer range and BS=0-20% are likely to exist in the aluminium buffer range. Sensitivity classes were determined for each soil type according to measured CEC and BS and ISRIC soil database defined sensitivity classes (FAO, 1974). Results are showing the percentage of dominant soil types of the study area, respecting buffer abilities and the sensitivity to acidification. Leptic Calcisol, Haplic Fluvisol and Haplic Cambisol (Eutric) and Leptic Cambisol belonging to the classes of low sensitivity and very low sensitivity to the acidification process (class IV and V) are distributed along the perimeter of the study area. More than 65% of the area belongs to the class of very low sensitivity to the acidification process (class V), and 16.10% to the class of low sensitivity (class IV). In some places, in the northwest, southeast and central part of the studied area, there is Haplic Leptosol, which is classified in the II class of sensitivity to the acidification process. More than 16% of the areas in the municipalities of Kosjerić, Požega and Užice belongs to this category of sensitivity. In the upper part of the course of the river Đetinja, soil types with sensitivity category I are represented and occupy 2.32% of the area.

Keywords: acidification process, degree of sensitivity, cation exchange capacity, soil types, Kosjerić, Požega, Užice

INTRODUCTION

According to the Law on Land Protection „*land degradation is a process of impairing the quality and function of land that occurs naturally or through human activity or is a consequence of failure to take measures to prevent harmful consequences*“ (Zakon o zaštiti zemljišta, „Sl. glasnik RS“, br. 112/2015). Degraded land is land that has lost its actual or potential productivity due to natural and anthropogenic factors (Lal, 1997). One of the indicators for assessing the risk of soil degradation is the degree of vulnerability of the soil to acidification.

Acidification is a process in which the pH value of the soil solution decreases, occurs in surface and subsurface layers and is present in soils with increased sulfur content, soils formed on acidic parent substrate and areas with pronounced humid conditions (Белановић-Симић, 2017). Mrvic et al. (2012) consider that acidification is the main cause of reduced productivity of agricultural land, which according to Sparks (2002) is significantly accelerated by anthropogenic factors (increased emissions and deposition of acidic pollutants, as well as inadequate use of mineral fertilizers) in the previous period.

According to Cakmak et al. (2014) the degree of soil sensitivity to the acidification process defines the buffer capacity of the soil, ie its physical and chemical properties, and is conditioned primarily by the type and rate of decomposition of the parent substrate (Bergholm et al., 2003), soil solution reaction, base saturation, capacity cationic changes, soil texture, organic matter content, and utilization (Misson et al., 2001).

The aim of this paper is to determine the types of soil in the municipalities of Kosjerić, Požega and Užice as well as their degree of sensitivity to the acidification process, using different methods, and then give certain recommendations.

MATERIALS AND METHODS

Study area

The study was conducted in the area of three municipalities: Kosjerić, Požega and Užice. The municipality of Kosjerić covers an area of about 359 km^2, and agricultural areas occupy 56,9%. The municipality of Požega covers 426 km^2 and agricultural areas occupy 9.358 ha. The municipality of Uzice covers an area of 667 km^2, while agricultural land covers about 55% of the area. The research mainly covers lands on areas that are cultivated and used in agriculture.

Soil analysis

During 2018, 20 soil profiles were opened in the study area (7 in the municipality of Kosjerić, 9 in the municipality of Požega and 4 in the municipality of Užice) (Figure 1).

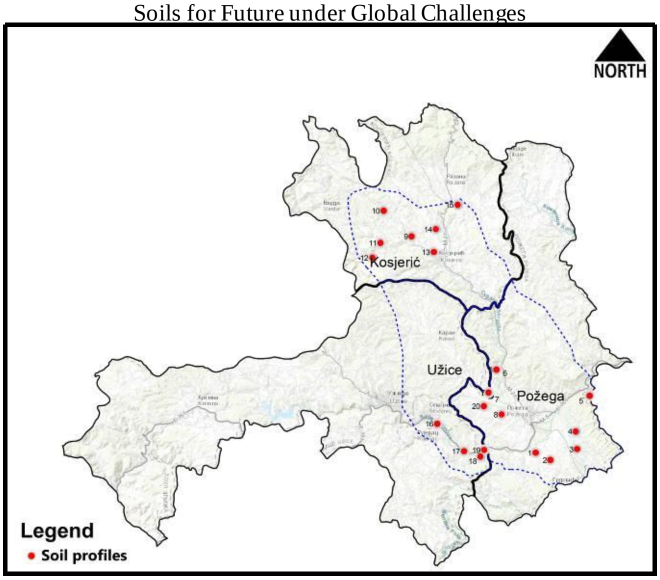

Figure 1. Location of soil profiles

Trend of acidic pollutants - atmospheric deposition

Acid deposition data (SO_2, NO_x, NH_3) were used from the EMEP (European Monitoring and Evaluation Programme for Transboundary Long-Range Transported Air Pollutants) database, which describes transboundary acidification, eutrophication and surface ozone concentration as well as pollution control in Europe (Figure 2).

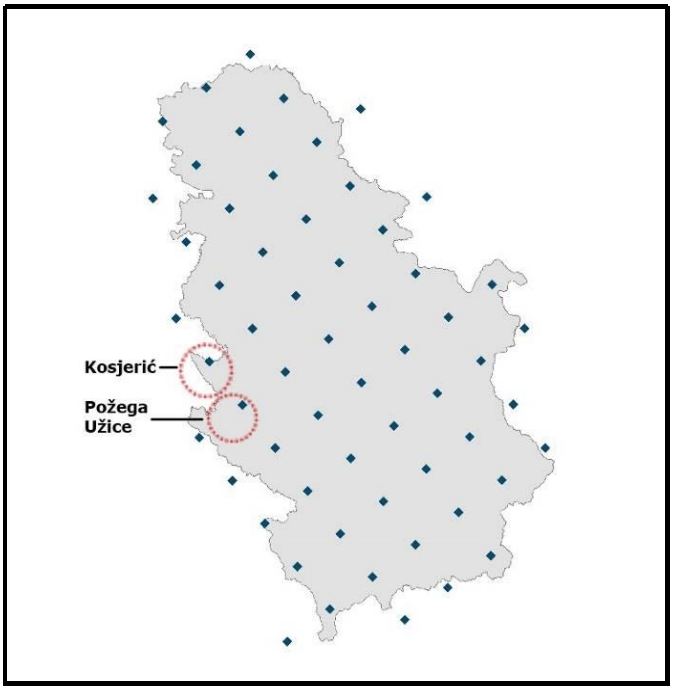

Figure 2. EMEP grid (50x50km)

Soil sensitivity to acidification (Holowaychuk & Fessenden method, 1987)

This method for assessing soil sensitivity to acidification includes cation exchange capacity (CEC) values and pH values in H_2O (Holowaychuk and Fessenden, 1987, Белоица, 2020). By combining them, we get 16 combinations for three categories of soil sensitivity: to the loss of bases, to the acidification process and to the solubility of aluminum. These three categories of sensitivity serve as the basis for determining the overall sensitivity of the soil to the acidification process (Table 1.).

Table 1. Criteria for determining the sensitivity of soil to acidification (Holowaychuk & Fessenden, 1987)

CEC (meq/100g)	pH (H_2O)	Susceptibility to:			Overall susceptibility
		Loss of bases	Acidification	Al solubility	
< 6	< 4.6	H	L	H	H
	4.6-5.0	H	L	H	H
	5.1-5.5	H	M	H	H
	5.6-6.0	H	H	M	H
	6.1-6.5	H	H	L	H
	> 6.5	L	L	L	L
6 - 15	< 4.6	H	L	H	H
	4.6-5.0	M	L	H	M
	5.1-5.5	M	L-M	M	M
	5.6-6.0	M	L-M	L-M	M
	> 6.0	L	L	L	L
> 15	< 4.6	H	L	H	H
	4.6-5.0	M	L	H	M
	5.1-5.5	M	L	M	M
	5.6-6.0	L	L-M	L-M	L
	> 6.0	L	L	L	L

Legend: L- low; M- medium; H- high

Soil sensitivity to acidification (Cinderby method, 1998)

This method is used for global assessment of soil acidification status and susceptibility to increased sulfur and nitrogen deposits (Cinderby et al., 1998, Белоица, 2020). The buffer capacity (acid neutralization capacity) is represented by the base content and the cation exchange capacity. Based on representative values of base saturation and cation exchange capacity for each soil type, sensitivity classes according to soil type are defined (Table 2.).

Table 2. Criteria for determining the categories of sensitivity of certain soil types to acidification based on the mean values of BS and CEC for a certain depth according to Cinderby et al. (1998)

CEC (meq/100g)	Base saturation (%)				
	0 - 20	20 - 40	40 - 60	60 - 80	80 - 100
< 10	1	1	2	3	5
10 - 25	1	2	3	4	5
> 25	2	3	4	5	5

Legend: 1- most sensitive; 5- nonsensitive

The definition of the sensitivity category by soil type was performed on the basis of a large number of analyzed profiles/samples for each soil type that are in the large ISRIC soil database (Cinderby et al., 1998). Estimates of soil buffering capabilities within this methodology were performed for soil depths up to 50 and up to 100 cm. For the needs of this research, the sensitivity assessment for the surface layer of the soil up to 10 cm was performed.

Soil sensitivity to acidification (Kuylenstierna, 2001)

This method includes cation exchange capacity (CEC) and base saturation (BS) as criteria for soil sensitivity to acidification (Kuylenstirna et al., 2001, Белоица, 2020). Based on 3 categories of CEC and 5 categories of BS, 5 classes of soil sensitivity to the acidification process are defined, from I (very sensitive) to V (poorly sensitive) (Table 3.).

Table 3. Criteria for determining the sensitivity of soil to acidification (Kuylenstierna, 2001)

		CEC (cmol/kg)		
		< 10	10 - 25	> 25
BS (%)	0 - 20	I	I	II
	20 - 40	I	II	III
	40 - 60	II	III	IV
	60 - 80	III	IV	V
	80 - 100	V	V	V

Legend: I- very sensitive; III- moderately sensitive; V- poorly sensitive

Geostatistical analyzes

Cartographic data processing was performed using geoinformation programs.

RESULTS AND DISCUSSION

Soils at the study area

In the area of Kosjerić, 7 soil profiles were opened, and in accordance with the criteria of the Soil Classification (Škorić et al., 1985) the following soil types have been determined: Haplic Fluvisol; Leptic Calcisol; Molic Umbrisol; Haplic Cambisol (Dystric) and Haplic Cambisol (Eutric). In the area of Požega, 9 soil profiles were opened and the following soil types were determined: Haplic Fluvisol; Haplic Vertisol; Haplic Cambisol (Eutric); Luvisol and Haplic Planosol. In the area of Užice, 4 soil profiles were opened and 2 soil types were determined: Haplic Fluvisol and Leptic Cambisol.

Analysis of the trend of acidic pollutants - deposition of sulfur (S) and nitrogen (N) for the period 1980-2015

Sulfur and nitrogen deposits for the period 1980-2015 is characterized by a decreasing trend, while deposits of reduced nitrogen form have an increasing trend in the period 2007-2015. In the area of the municipality of Kosjerić, the maximum sulfur deposits were recorded in 1980 and amounted to 30.80 kg/ha, and until 2015 they have a decreasing trend and amount to 9.6 kg/ha. Maximum amounts of nitrogen deposition in the municipality of Kosjerić were measured in 1990 when they amounted to 13.8 kg/ha, until 2007 they had a decreasing trend when they amounted to 7.8 kg/ha, and from 2007 to 2014 they grow again to 11.1 kg/ha (Figure 3.).

In the area of the municipalities of Požega and Užice, the maximum sulfur deposits were also recorded in 1980 and amounted to 25.99 kg/ha, and until 2015 they have a decreasing trend and amount to 9.01 kg/ha. The maximum amounts of nitrogen deposition in the area of these two municipalities were measured in 1990 when they amounted to 11.88 kg/ha, until 2007 they had a decreasing trend when they amounted to 7.2 kg/ha, and from 2007 to 2014 grow again to 10.42 kg/ha (Figure 3.).

Examined parameters

The assessment of soil sensitivity to the acidification process was performed for the surface layer of soil 10 cm deep, and general indicators of the examined parameters are given in Table 4.

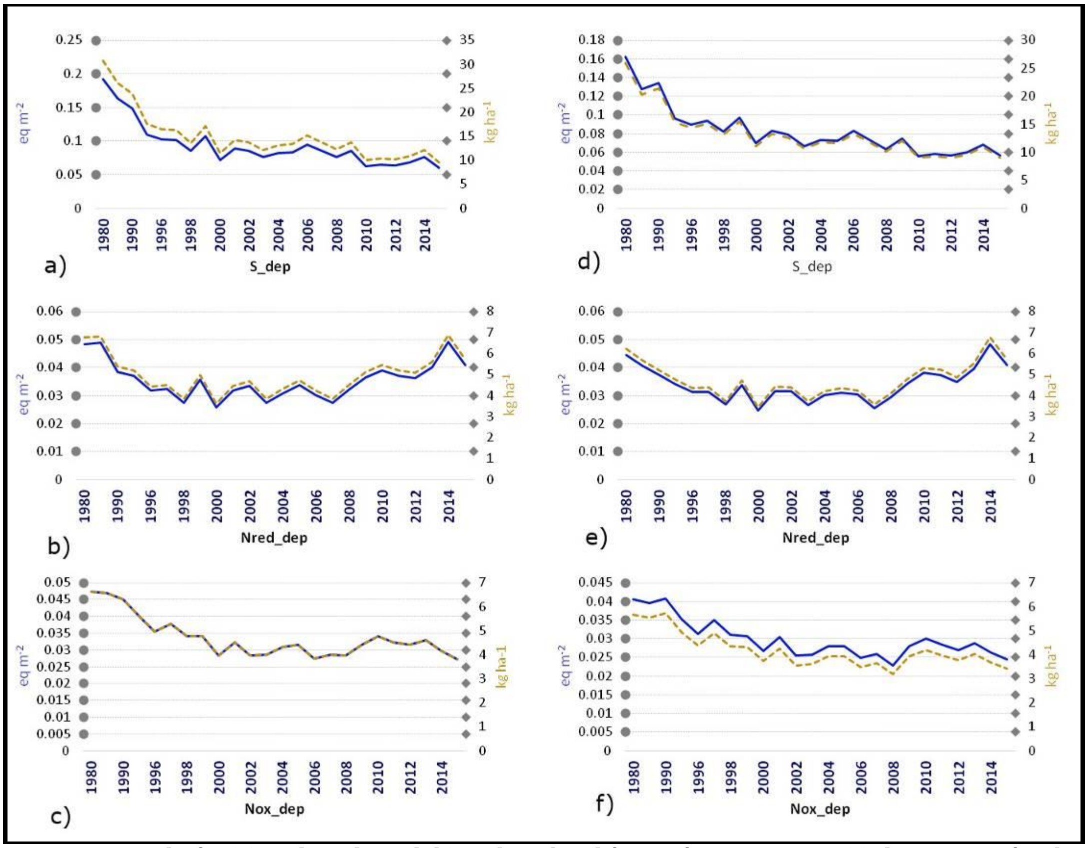

Figure 3. Trend of S (a), reduced Nred (b) and oxidized form of nitrogen Nox (c) depositions for the area of Kosjerić, and (d), (e) and (f) for the area of Požega and Užice

Table 4. General indicators of the studied soil parameters for a depth of 0-10 cm

Locality	**Profile**	**WRB type**	**pH (H_2O)**	**Acidity class (Antić, 1987)**	**Acidity class (Sparks, 2002)**	**$CaCO_3$ (%)**	**CEC (meq/100g)**	**V (%)**
Kosjerić	10/2018	Haplic Cambisol (Dystric)	5.81	4	4	-	21.09	42.21
Kosjerić	13/2018	Haplic Cambisol (Eutric)	6.93	6	5	-	26.05	82.53
Kosjerić	14/2018	Haplic Cambisol (Eutric)	6.49	5	5	-	32.56	73.55
Kosjerić	9/2018	Leptic Calcisol	6.46	5	5	-	29.20	73.29
Kosjerić	15/2018	Molic Umbrisol	6.86	6	5	-	28.13	80.36
Kosjerić	11/2018	Haplic Fluvisol	6.30	5	5	-	14.98	80.47
Kosjerić	12/2018	Haplic Cambisol (Eutric)	7.62	7	6	1.02	47.03	96.54
Požega	1/2018	Haplic Cambisol (Eutric)	5.92	4	4	-	19.86	46.82
Požega	20/2018	Haplic Planosol	5.57	4	4	-	18.78	46.34
Požega	3/2018	Haplic Fluvisol	7.44	7	6	-	43.76	96.66
Požega	4/2018	Luvisol	6.16	5	5	-	21.89	59.17
Požega	5/2018	Haplic Fluvisol	8.11	8	6	-	44.45	98.54
Požega	6/2018	Haplic Vertisol	8.02	8	6	-	41.10	98.42
Požega	7/2018	Haplic Planosol	5.80	4	4	-	18.49	43.25
Požega	8/2018	Haplic Planosol	6.42	5	5	-	16.38	54.35
Užice	16/2018	Haplic Fluvisol	7.83	8	6	2.58	-	-
Užice	17/2018	Haplic Fluvisol	7.98	8	6	3.54	-	-
Užice	18/2018	Haplic Cambisol (Eutric)	7.32	7	6	-	22.85	80.09
Užice	19/2018	Haplic Fluvisol	8.12	8	6	7.13	-	-

Analysis of soil sensitivity to acidification (Holowaychuk & Fessenden, 1987)

Sensitivity to base loss implies sensitivity to leaching of base cations, primarily Ca^{2+}, Mg^{2+} and K^+ with H^+ ions. Increasing the acidity of the soil affects the reduction of the concentration of base cations (Ca, Mg, K) and microelements (Zn, Mo). Table 5 shows the sensitivity to soil base loss at the studied localities where the category of weakly sensitive soil to base loss dominates. Only two categories have been identified for sensitivity to acidification: weak and weak-moderate acidification, among which weak sensitivity dominates. Soils with low to moderate sensitivity are Haplic Cambisol (Eutric), Leptic Calcisol, Haplic Fluvisol and partly Haplic Cambisol (Dystric). Sensitivity to the solubility of aluminum is a very important parameter for determining the overall sensitivity to acidification. Weak and weak-moderate sensitivity of the soil to the appearance of soluble aluminum was expressed in the studied area. The overall sensitivity of the soil to acidification according to the method of Holowaychuk & Fessenden (1987) is weak for all localities and soil types.

Table 5. Soil sensitivity to acidification process (Holowaychuk & Fessenden method, 1987)

Locality	Profile	WRB type	FAO_90	Susceptibility to:			Overall susceptib.
				Loss of bases	Acidifi -cation	Al Solubility	
Kosjerić	10/2018	Haplic Cambisol (Dystric)	CMd	L	L-M	L-M	L
Kosjerić	13/2018	Haplic Cambisol (Eutric)	Cme	L	L	L	L
Kosjerić	14/2018	Haplic Cambisol (Eutric)	CMe	L	L	L	L
Kosjerić	9/2018	Leptic Calcisol	LPk	L	L	L	L
Kosjerić	15/2018	Molic Umbrisol	Ud	L	L	L	L
Kosjerić	11/2018	Haplic Fluvisol	FL	L	L	L	L
Kosjerić	12/2018	Haplic Cambisol (Eutric)	CMe	L	L	L	L
Požega	1/2018	Haplic Cambisol (Eutric)	CMe	L	L-M	L-M	L
Požega	2/2018	Luvisol	LV	L	L-M	L-M	L
Požega	20/2018	Haplic Planosol	W	L	L-M	L-M	L
Požega	3/2018	Haplic Fluvisol	FL	L	L	L	L
Požega	4/2018	Luvisol	LV	L	L	L	L
Požega	5/2018	Haplic Fluvisol	FL	L	L	L	L
Požega	6/2018	Haplic Vertisol	VR	L	L	L	L
Požega	7/2018	Haplic Planosol	W	L	L-M	L-M	L
Požega	8/2018	Haplic Planosol	W	L	L	L	L
Užice	16/2018	Haplic Fluvisol	FL	L	L	L	L
Užice	17/2018	Haplic Fluvisol	FL	L	L	L	L
Užice	18/2018	Haplic Cambisol (Eutric)	CMe	L	L	L	L
Užice	19/2018	Haplic Fluvisol	FL	L	L	L	L

Legend: L- low; M- medium; H- high

Analysis of soil sensitivity to acidification (Cinderby, 1998)

Using the Cinderby (1998) method, 3 sensitivity categories (very sensitive- category 1, moderately weakly sensitive- category 4 and very weakly sensitive- category 5) were separated from a total of 5 categories (Table 6.). In the category of highly sensitive soils, the following types of soils have been singled out: Haplic Cambisol (Dystric), Leptic Calcisol and Molic Umbrisol and are located in the municipality of Kosjerić. The category of moderately weakly sensitive soils includes Haplic Fluvisol and Luvisol, and the category of very weakly sensitive soils includes Haplic Cambisol (Eutric), Haplic Planosol and Haplic Vertisol, which are present in all three municipalities.

Table 6. Soil sensitivity to acidification process (Cinderby, 1998)

Locality	Profile	WRB type	FAO_74	Cinderby, 1998
Kosjerić	10/2018	Haplic Cambisol (Dystric)	Bd	1
Kosjerić	13/2018	Haplic Cambisol (Eutric)	Be	5
Kosjerić	14/2018	Haplic Cambisol (Eutric)	Be	5
Kosjerić	9/2018	Leptic Calcisol	E	1
Kosjerić	15/2018	Molic Umbrisol	U	1
Kosjerić	11/2018	Haplic Fluvisol	J	4
Kosjerić	12/2018	Haplic Cambisol (Eutric)	Be	5
Požega	1/2018	Haplic Cambisol (Eutric)	Be	5
Požega	2/2018	Luvisol	L	4
Požega	20/2018	Haplic Planosol	W	5
Požega	3/2018	Haplic Fluvisol	J	4
Požega	4/2018	Luvisol	L	4
Požega	5/2018	Haplic Fluvisol	J	4
Požega	6/2018	Haplic Vertisol	V	5
Požega	7/2018	Haplic Planosol	W	5
Požega	8/2018	Haplic Planosol	W	5
Užice	16/2018	Haplic Fluvisol	J	4
Užice	17/2018	Haplic Fluvisol	J	4
Užice	18/2018	Haplic Cambisol (Eutric)	Be	5
Užice	19/2018	Haplic Fluvisol	J	4

For the purpose of assessing the geospatial distribution of different categories of soil susceptibility to acidification, a pedological map of Serbia and recommended mean values of CEC and BS for individual soil types defined on the basis of the ISRIC database, presented within the Cinderby method (1998) were used.

Along the perimeter of the studied area, Leptic Calcisol, Haplic Fluvisol and eutric and carbonate soils belonging to the IV (weakly sensitive) and V (very weakly sensitive) classes of sensitivity to the acidification process are distributed (Figure 4). To the sensitivity class V belongs 65.06% and to the sensitivity class IV 16.10% of the soil in the studied area. In some places, in the northwest, southeast and central part of the studied area, Molic Umbrisols are distributed, which are classified in the class II of sensitivity to acidification (16.52%). In the upper part of the course of the river Ćetinje, soil types with sensitivity category I are represented and occupy 2.32% of the area.

Analysis of soil sensitivity to acidification (Kuylenstierna, 2001)

According to the Kuylenstierna method (2001), the most common are soils with weak and moderate total sensitivity to acidification, while there are significantly fewer soils with moderately weak sensitivity to acidification (Table 7).

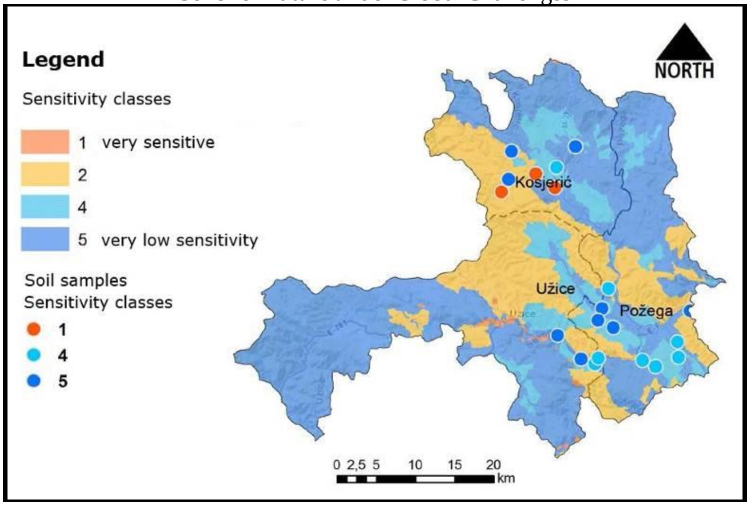

Figure 4. Soil sensitivity classes (Cinderby, 1998)

Table 7. Soil sensitivity to acidification process (Kuylenstierna, 2001)

Locality	Profile	WRB type	FAO_90	Soil buff. capacity (Kuylenstierna et al., 1995)			Overall susceptibility (Kuylenstierna, 2001)
				pH	CEC	BS	
Kosjerić	10/2018	Haplic Cambisol (Dystric)	CMd	3	3	2	III
Kosjerić	13/2018	Haplic Cambisol (Eutric)	Cme	3	3	4	V
Kosjerić	14/2018	Haplic Cambisol (Eutric)	CMe	3	3	3	IV
Kosjerić	9/2018	Leptic Calcisol	LPk	3	3	3	V
Kosjerić	15/2018	Molic Umbrisol	Ud	3	3	4	V
Kosjerić	11/2018	Haplic Fluvisol	FL	3	2	4	V
Kosjerić	12/2018	Haplic Cambisol (Eutric)	CMe	4	3	4	V
Požega	1/2018	Haplic Cambisol (Eutric)	CMe	3	2	2	III
Požega	2/2018	Luvisol	LV	3	3	3	III
Požega	20/2018	Haplic Planosol	W	3	2	2	III
Požega	3/2018	Haplic Fluvisol	FL	4	3	4	V
Požega	4/2018	Luvisol	LV	3	3	3	III
Požega	5/2018	Haplic Fluvisol	FL	4	3	4	V
Požega	6/2018	Haplic Vertisol	VR	4	3	4	V
Požega	7/2018	Haplic Planosol	W	3	2	2	III
Požega	8/2018	Haplic Planosol	W	3	2	3	III
Užice	16/2018	Haplic Fluvisol	FL	4	4	4	V
Užice	17/2018	Haplic Fluvisol	FL	4	4	4	V
Užice	18/2018	Haplic Cambisol (Eutric)	CMe	4	3	4	V
Užice	19/2018	Haplic Fluvisol	FL	4	4	4	V

Legend: III- moderately sensitive; IV- moderately weakly sensitive; V- weakly sensitive

CONCLUSION

Within the study area according to the criteria of national classification (Škorić et al., 1985), 9 types of land were defined: Haplic Fluvisol, Haplic Vertisol, Leptic Calcisol, Mollic Umbrisol, Haplic Cambisol (Eutric), Haplic Cambisol (Dystric), Leptic Cambisol, Luvisol and Haplic Planosol.

The spatial distribution of soil sensitivity classes to the acidification process is shown in Figure 4. Leptic Calcisol, Haplic Fluvisol and eutric and carbonate brown soils belonging to low sensitivity classes and very low sensitivity to acidification process (class IV and V) are distributed around the perimeter of the study area . In the area of Kosjerić, Požega and Užice, 65.06% belongs to the class of very low sensitivity to the acidification process (class V), and 16.10% to the class of low sensitivity (class IV). In some places, in the northwest, southeast and central part of the studied area, Molic Umbrisols are distributed, which is classified in the class II of sensitivity to the acidification process. 16.52% belong to this category of sensitivity in the territories of the municipalities of Kosjerić, Požega and Užice. In the upper part of the course of the river Đetinje, soil types with sensitivity category I are represented and occupy 2.32% of the area. Čakmak et al. (2014) state that the identification of areas sensitive to acidification provides opportunities for land management by selecting the optimal method of land use in order to achieve sustainable productivity in the foreseeable period.

Based on the results of the research of soil sensitivity to the acidification process in the municipalities of Kosjerić, Požega and Užice, the following recommendations can be given:

1. Generally, due to the relatively low humus content in all soils, organic fertilizers should be applied to the areas used for growing agricultural crops. By applying organic fertilizers (manure, compost, green manure) we can maintain or increase the humus content in the soil. Organic matter - humus is characterized by high values of cation adsorption capacity. Adsorbed base cations are major anti-acidification buffers in non-carbonate soils;
2. Grow field crops in crop rotation. Include fodder and leguminous plants in the crop rotation structure. The content of humus or organic matter in the soil can be increased by applying organic fertilizers and plowing crop residues. Some crops impoverish lands (corn, sugar beet) while others enrich them (grasses, legumes);
3. Application of calcification in strongly acidic soils of the Haplic Planosol type and
4. Unforested and unused areas should be afforested with appropriate types of forest trees.

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LAND COVER/LAND USE IN SERVICE OF AGRICULTURAL LAND PROTECTION, USE AND RESTRUCTURING

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Abstract

Prevention of degradation should be the most important part of the land protection policy of every country and local community. In order for this policy to be implemented properly, relevant indicators of the state of land resources are necessary. According to the Law on Agricultural Land of the Republic of Srpska, municipalities and cities are obliged to prepare a planning document “Groundwork for Agricultural Land Protection, Use and Restructuring (The groundwork)”. The Groundwork of municipalities is made by GIS reading and processing of existing relevant data on land resources and climate (digital terrain model, pedology, land cover and method of use, climate data…). With GIS modeling of existing data, new relevant data were created (bonity, agro-ecological zoning, suitability of cultivation…) which are used in the decision-making process. All GIS bases are made in ArcGIS software, *Gauss Krueger* projection in the scale of 1: 100000, 50000 and 25000. The only GIS base that is made in the scale of 1: 5000 is the land cover and land use (LC/LU). The paper presents a semi-automatic and manual method of digitization (vectorization) of the LC/LU classes on the example of making the Basis of Laktaši municipalities. Orthophoto images from 2012 were used to delineate the LC/LU areas, and satellite images from Google Earth for 2017 and 2018 were used to determine the changes in the LC/LU from 2012 compared to 2018. The obtained LC/LU result is presented in the form of a polygon (shape file). For the delimitation of the polygon, 8 main classes were used, which contain 22 out of a total of 36 classes of LC/LU that are represented on the territory of the entire Republic of Srpska. The obtained data are compared with cadastral data that have not been updated for many years, and are used as official data. According to LC/LU data, agricultural areas occupy 49.5% of the municipality, which is a decrease of 15.8% or 6137 ha compared to the data from the cadaster. Of this area, 418.4 ha was converted into unproductive land (built up areas), and most of the changes were identified with the increase of areas under woody vegetation, i.e. in overgrowing of uncultivated areas (17.7% or 5719 ha). From the degraded areas, exploitation fields of gravel (217 ha or 0.6% of the total area of the Municipality) have been identified, which are also open on agricultural areas. The expansion of exploitation came due to the construction of a network of highways. By overlapping the bonity map with the built-up areas, it can be concluded that 264 ha of land of the first bonity class, 61 ha of the second and 397 ha of agricultural land of the third bonity class were permanently lost, which totals in 722 ha of the best land. A comprehensive analysis found that there was a significant increase of non-agricultural land area, and significant reduction of cultivated land in relation to arable land.

Key words: Land cover/Land use, GIS modeling, degradation

INTRODUCTION

Bosnia and Herzegovina (BIH) is a country consisting of two entities (Federation of Bosnia and Herzegovina; Republic of Srpska (RS)) and the Brcko District (Fig. 2). The Entities have jurisdiction over agricultural production. As in other regions of the world, the area of agricultural land for food production, which is available to the Republic of Srpska, is limited and is continuously, decreasing. Anthropogenic influence alone in the Republic of Srpska loses 1600 ha of land (NEAP BIH, 2003) annually. Since all land users are constantly and arguably claiming to use the land, the basic question is how to protect agricultural land from permanent loss, i.e. how to produce sufficient quantities of food in conditions when agricultural areas are constantly decreasing, and at the same time the number of people is increasing in the conditions of evident climate changes. In these circumstances, prevention of degradation and sustainable controlled land use should be the most important parts of the policy of every country, including the Republic of Srpska (Predić et al., 2009, 2011, 2019). In order for this policy to be implemented properly, relevant indicators of the state of land resources are necessary. For these reasons, for the needs of the Ministry of Agriculture, Forestry and Water Management of the Republic of Srpska, in 2009 the “Groundwork for Agricultural Land Protection, Use and Restructuring of the Republic of Srpska” (hereinafter the Groundwork of the RS) was developed, which is a basic component in the land use planning process (Predić et al., 2009). This document was prepared according to the methodology adopted by the FAO (Food and Agricultural Organization of the United Nations) project “Inventory of post war situation of land resources in BIH” (FAO, 2002). The RS Groundwork contains all existing relevant data on the soil and climate of the RS made as GIS bases in the scale of 1: 100000. It is intended for decision-makers at the entity level for planning and implementation of agricultural projects and stopping the trend of permanent loss of agricultural land (Predić et al., 2019), which according to the UN should be reduced to zero by 2030 (UNCCD, 2012).
Republic of Srpska is an entity in BIH that is administratively divided into 64 administrative units, nine cities and 55 municipalities, respectively. According to the Law on Agricultural Land of the Republic of Srpska (Official Gazette of the Republic of Srpska No. 93/06, 86/07, 14/10, 5/12,58/19 and 62/2020), municipalities and cities are obliged to prepare a planning document “Groundwork for Agricultural Land Protection, Use and Restructuring (The groundwork)". This document should provide decision makers at the municipal level with relevant information in the process of planning the use of agricultural land in order to prevent the permanent loss of the highest quality and most productive land and their preservation for the production of sufficient quantities of food. For this reason, the GIS bases of the existing data of land resources, such as pedology map (soil map, land cover and land use) are created in larger scale. The basic pedology map exists in 1:50000 scale, and land cover is created in the 1:25000 scale. These GIS bases can exist as separate units, and their GIS modeling (combining) with the application of modern methodologies for assessing and planning of land use, new relevant data that are used in the decision-making process can be provided (Biancalani et al., 2004). The Groundwork of the Municipalities are harmonized with the Groundwork of the Republic, and are made according to the FAO model (Fig. 2) which consists of: inventory of land and climate

resources, agro-ecological zoning (FAO, 1996; Van Velthuizen H.T., 2001) and economic-ecological zoning (Biancalani et al., 2004)

Most of the created (designed) GIS bases in the inventory process (soil, slope, aspect, administrative units, climate station and temperature growing period) are data that change slowly over a long period of time. However, data on land cover and land use are subject to relatively rapid changes (within one year) as a result of the overall social and economic development in the transition period that this area is currently experiencing. For this reason, data on land cover and land use (hereinafter LC/LU) is one of the most important GIS data, so that in practice it was proved to be necessary to make it in a larger scale than proposed 1:25000. In order to obtain relevant data on agricultural land and the manner of their use, the GIS base of LC/LU needs to be made in a large scale of 1:5000. This data is crucial for decision makers at the municipal level because in the Republic of Srpska and throughout Bosnia and Herzegovina cadastral data are used, which are updated at a slow pace, and therefore the same data on agricultural land exist for decades, although it is stated that up to 1600 ha of land are lost annually (NEAP, 2003). The paper presents a precise (manual) way of digitization (vectorization) of classes LC/LU on one example of creating the Groundwork of Laktaši municipality and the role of this GIS base in the process of land use planning at the municipal level.

MATERIALS AND METHODS

Study area

The Study area covers the area of the Municipality of Laktasi with an area of 38817 ha, which is located in the center of the western part of the Republic of Srpska (Fig. 1).

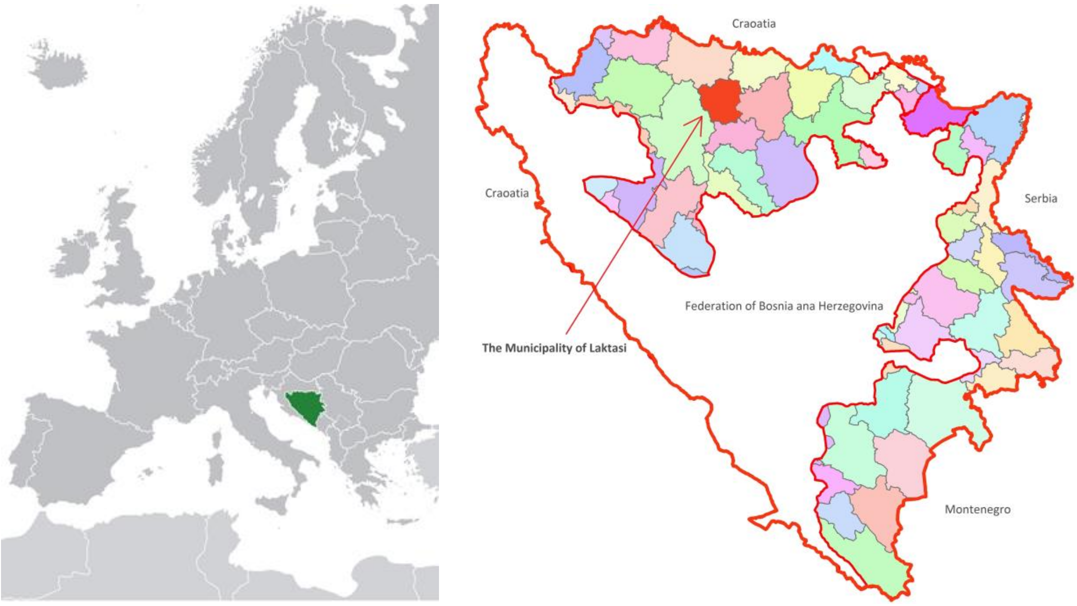

Figure 1. The location of Republic of Srpska entity in the Bosnia and Herzegovina and location of the municipality of Laktasi in the administrative division of the Republic of Srpska

According to the Law on Agricultural Land of the Republic of Srpska (Official Gazette of the Republic of Srpska No. 93/06, 86/07, 14/10, 5/12, 58/19 and 16/2020), the following are considered agricultural land: fields, gardens, orchards, vineyards, meadows and pastures, as well as other land that, according to its natural and economic characteristics, can be most rationally used for agricultural production. In the sense of this law, also considered as agricultural land is the land for which other purposes have been determined by the planning acts of the Republic of Srpska, municipalities and cities, until compensation for change of purpose, in accordance with this law, is paid for those lands in the process of transferring to the planned purpose. Table 1 shows the structure of land use in the municipality of Laktasi according to official data available at the municipality (cadastral data).

Table 1. Land use structure of the Municipality of Laktasi (Cadastral data - data source Administrative Service of the Municipality of Laktasi, 2018)

No	Land use structure	ha	%
1	Total area	38817.4	100.0
1.1	Nonproductive	2850.6	7.4
1.2	Forest	10603.9	27.3
1.3	Agricultural land	25362.8	65.3
1.3.1.	Arable land and gardens	19802	51.0
1.3.2.	Orchards	1843.8	4.8
1.3.3.	Meadows	949.9	2.4
1.3.4.	Pastures	2767.1	7.1

Methods

All GIS bases for the Groundwork are made in *ArcGIS* software, *Gauss Krueger* projection, which is official in BIH.

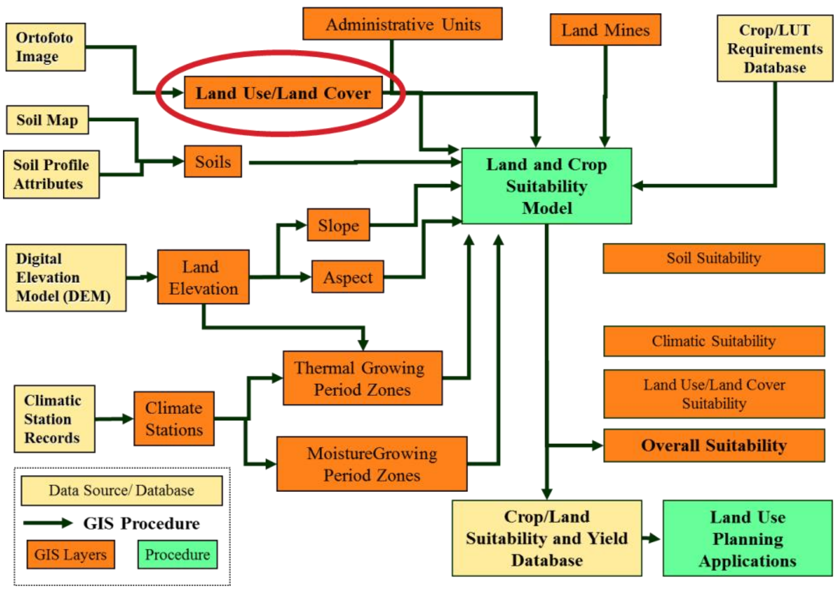

Figure 2. Simplified presentation of the Groundwork of Municipalities scheme (FAO, 2002)

GIS layer LC/LU for 2018 was made in a scale of 1: 5000 (some parts were mapped in a scale of 1: 2500). The delimitation of LC/LU classes was performed on the basis of orthophotos and satellite images. The best option is to differentiate the LC/LU classes on orthophotos from the same year for which the LC/LU layer is created. However, this is usually not the case in practice, because orthophotos for one country are made periodically, depending on the general needs of society. For the municipality of Laktasi, the only available orthophotos were from 2012 which were done for the needs of the 2013 census of BIH. For this reason, the LC/LU was done in two phases. The first phase is the initial detailed delimitation of areas (class) LC/LU based on orthophotos from 2012 (Fig.3.b). The municipality of Laktasi is covered by 58 orthophotos (Fig. 3.a.)

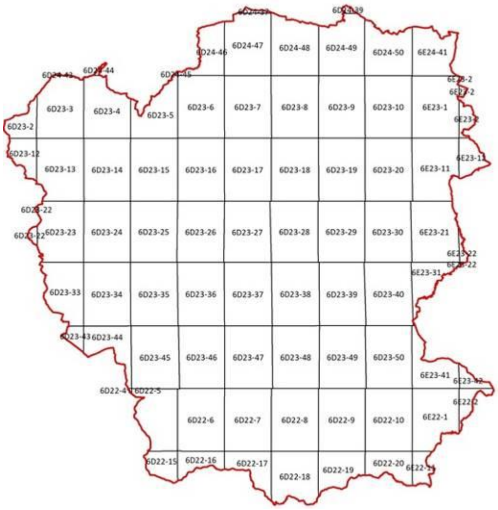

Figure 3.a. Laktaši Municipality – overview map of orthophoto in 1:5000 scale

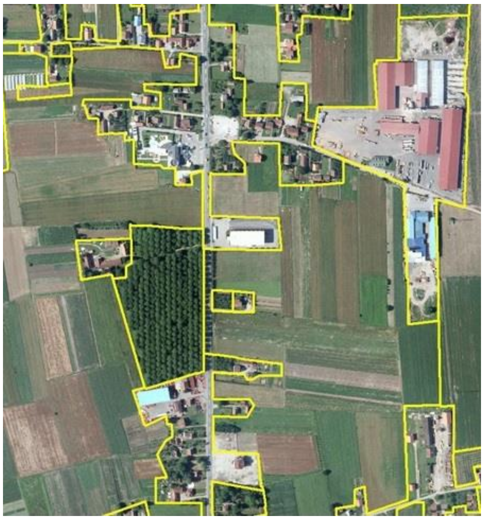

Figure 3.b Initial detailed delineated areas according to LC/LU classes (orthophoto from 2012)

The second phase - creating the final LC/LU for 2018, based on satellite images of Google Earth for 2018. In this phase, corrections (delimitations) were made on those areas where changes occurred compared to the status in 2012 (which is graphically shown in the results and discussion). The obtained LC/LU result is presented in the form of polygons in *shp* format.

The Land Cover Classification System, (FAO LCCS, 2000) was used to demarcate the polygon, which was modified for the conditions of BIH within the implementation of the project "Inventory of post war situation of land resources in BIH" (FAO, 2002). The modified FAO classification does not consider land cover and land use classes separately, but both classes are combined into one LC/LU class. The reason for this approach is that the key to drafting the Municipal Groundwork is the allocation (identification) of agricultural land. Therefore, the LC/LU nomenclature is dominated by classes which both, in terms of land cover and land use, represent agricultural land. In the area of the municipality of Laktasi, 9 main LC/LU classes have been recorded, containing 24 (Tab.2) out of a total of 36 LC/LU classes that are represented in the entire Republic of Srpska. of

the total 24 LC/LU classes, in the area of Laktaši Municipality 13 (54%) are classes that represent agricultural land.
When delimiting agricultural areas, the smallest mapped area for the class "cultivated" is 0.5 ha, for the class "permanent plantation" 0.1 ha, and for the class “plastic greenhouses” 0,01 ha. Due to the large scale, allocated (mapped) are areas with a clear LC/LU class (cultivated, orchard, meadow, pasture, greenhouse, forest, built-up areas). If there are several classes of agricultural land in an area which is less than 0.5 ha, then polygons whose classes are called "dominate" are mapped. Therefore, polygons of larger area which contain two LC/LU classes, one of which dominates, are mapped. For these cases, the following columns are provided in the attribute table: primary LC/LU; percentage (%) of primary LC/LU; secondary LC/LU; percentage (%) of secondary LC/LU. Example: class "cultivated dominates". The primary LC/LU is the class "Cultivated dominates" with a percentage of representation greater than 50%, e.g. 60%. The secondary class LC/LU can be: meadow or abandoned or orchard. If it is, for example, "Meadow", then in the secondary LC/LU column the meadow is written, and in the column percentage of secondary LC/LU: 40%. The sum of the primary and secondary LC/LU class’s percentages must be 100%. The same method is applied for all LC/LU classes with the "dominate" sign. The goal of delimitation of LC/LU classes on a large scale is to keep such polygons (with the sign "dominates") as small as possible, but it is impossible to avoid them due to the fragmentation land in the Republic of Srpska. The characteristic of the rural and semi-urban area is the existence of facilities (houses) between which there are gardens and smaller orchards, i.e., agricultural areas that are less than 0.5 ha. In that case, one polygon was mapped, which unites the built with agricultural areas. The polygon is coded with the LC/LU class " built dominates ", for example the primary LC/LU is built with 60%, and the secondary LC/LU is cultivated with 40%.
In this way, later data processing (polygon area) enables to calculate the actual areas of agricultural land by LC/LU classes that can be compared with "cadastral classes".
The “abandoned " class represents only agricultural land that has not been cultivated for many years, so that the occurrence of shrubs in these areas is visible in a smaller or larger percentage (%), which depends primarily on period of non-use. This LC/LU class is identified by using the Historical imagery option on Google Earth sat images, that is, by comparing the areas that are currently identified as abandoned with the method that land was used 8-10 years ago (history option) (Figure 4a. and 4b.).


Figure 4a. Cultivated land and meadows (2006)


Figure 4b. Shrubs, succession – forest (2018)

Areas identified as "abandoned" can be resumed to the original condition of use (cultivated, orchard etc.) with minor investments. Due to a prolonged period of non-use (about 15 years), a part of agricultural land has already been changed into the class of "Shrubs", i.e. already by succession it altered into the "Forests" class. A significant part of these areas are listed in the cadastre as arable land, gardens or orchards, but in reality they are shrubs or forest (Fig. 4b). These areas can also be returned to their original purpose, but this requires significant investments.

Table 2. LC/LU classes used in the municipality of Laktaši

No.	LC/LU Categories	Main LC/LU classes	LC/LU classes
1.	Agricultural	Cultivated	Cultivated
2.			Cultivated with irrigation
3.			Cultivated dominates
4.			Plastic greenhouses
5.		Abandoned	Abandoned
6.			Abandoned dominates
7.		Permanent plantations	Orchards
8.			Vineyards
9.			Orchards dominate
10.			Nurseries
11.		Meadows	Meadows and uncultivated land
12.			Meadows and uncultivated land dominate
13.		Pastures	Pastures
14.	Non-Agricultural	Forests	Forests
15.			Forests dominate
16.			Shrubs
17.		Bare areas	Open quarries, gravel extraction
18.		Built up	Built up (Settlement, factories, infrastructure, etc)
19.			Built up dominates
20.			Separate estates (farms)
21.			Sports and recreation
22.		Water bodies	Natural water bodies (rivers and lakes)
23.			Ponds and Swamps
24.			Artificial water surfaces

RESULTS AND DISCUSSION

Figure 5 shows the LC/LU map for 2018 with 24 LC/LU classes, and Figure 6 show the percentage share of the 9 main LC LU classes in the total area of the Municipality.

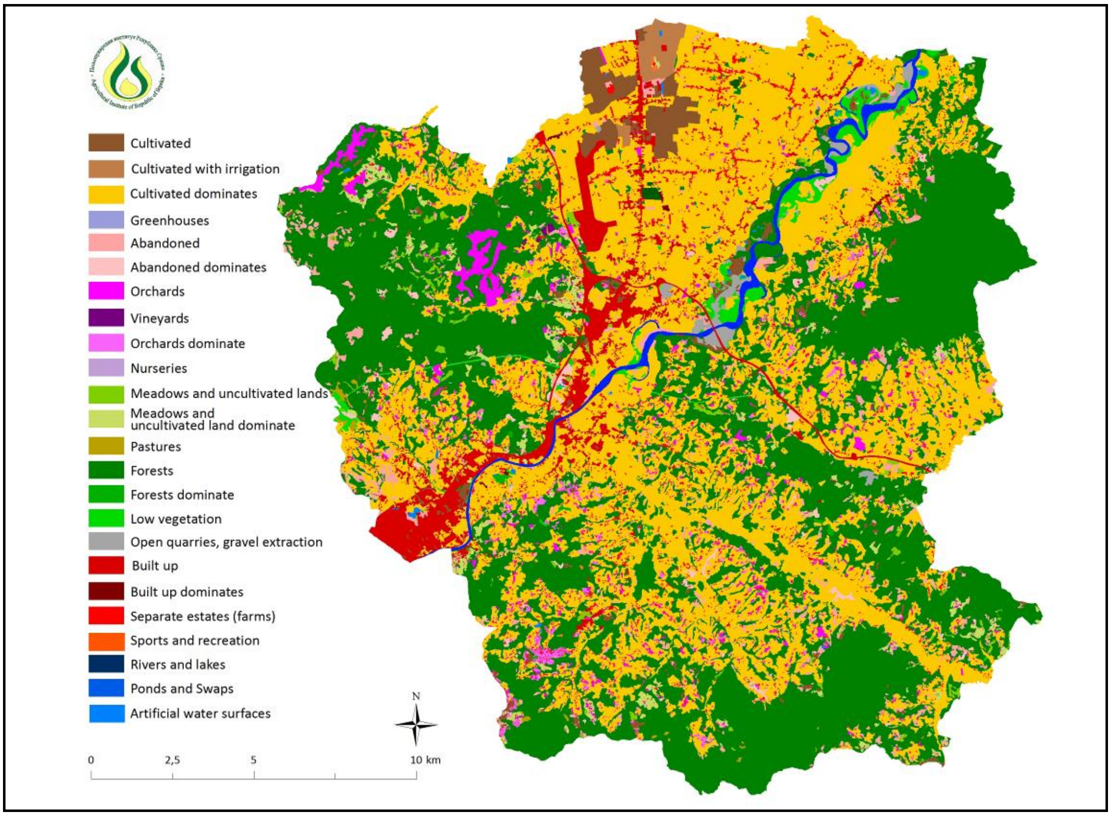

Figure 5. Land cover and land use of the Laktasi municipality (2019)

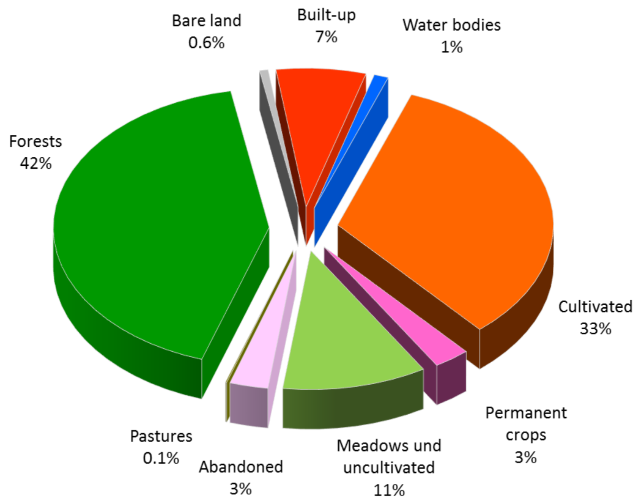

Figure.6. Main LC/LU classes in the total area of the municipality

Data on the land use and land cover, processed and updated in this way, enable a large number of various GIS analyzes and visual representations. Table 3 shows the type of using agricultural land by LC/LU classes that could be identified: cultivated, permanent plantations, meadows, abandoned and pastures. It should be noted that, while interpreting orthophotos, the areas used as meadows could not be reliably separated from arable land that is currently uncultivated (fallow), so the class of meadows contains a part of uncultivated areas.

Table 3. Comparison of LC/LU classes of agricultural land in 2018 based on the digital map LC/LU 1: 5000 and cadastral data

No.	LC/LU data			Cadastral data		
	LC/LU classes of agricultural land	ha	%	Cadastral classes of agricultural land	ha	%
1.	Cultivated	12829	33,1	Arable land and gardens	19802	51,0
2.	Abandoned	1116	2,9			
3.	Meadows and uncultivated	4197	10,8	Meadosws	950	2,4
4.	Permanent plantations (crops)	1046	2,6	Orchards	1844	4,8
5	Pastures	38	0,1	Pastures	2767	7,1
	Agricultural land	19226	49,5	Agricultural land	25363	65,3
	Non-agricultural land	19619	50,5	Non-agricultural land	13454	34,7
	TOTAL:	38845[1]	100,0	TOTAL:	38817	100,0
	Agricultural land per capita	0,56[2]	-	Agricultural land per capita	0,69[2]	-

[1]*The Laktaši municipality polygon area (shp.file)*
[2]*Population: 34210, Census of Population, Households and Dwellings in RS 2013.*

The change in land cover and land use was obtained by comparing the results of LC/LU for 2018 and valid cadastral data on the structure of land use (Fig.7 and 8).

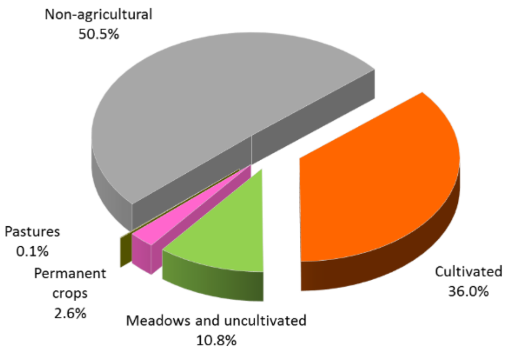

Figure 7. Type of using agricultural land on the basis of LC/LU for 2018

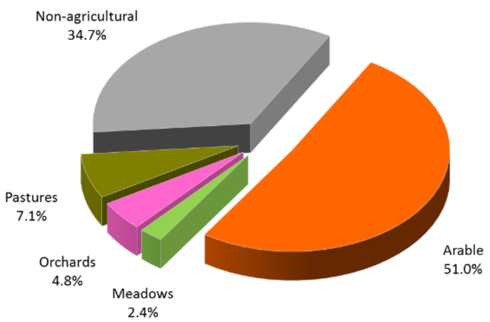

Figure 8. Agricultural land (municipal cadastral data)

It should be noted that cadastral classes and LC/LU classes do not coincide completely. For instance, areas that are classified as arable land according to the cadastral class, according to LC/LU can be: cultivated meadows (if they are not currently cultivated), pastures (if they are currently used for grazing) or abandoned (if they are not cultivated for many years). Also, the forest cadastral class is not the same as the LC/LU forest class. This LC/LU class includes all areas overgrown with trees and shrubs. There are other differences between cadastral classes and LC/LU classes, but the end result, the division into agricultural and non-agricultural land is comparable. Figure 9 show a comparison of cadastral and LC/LU data.

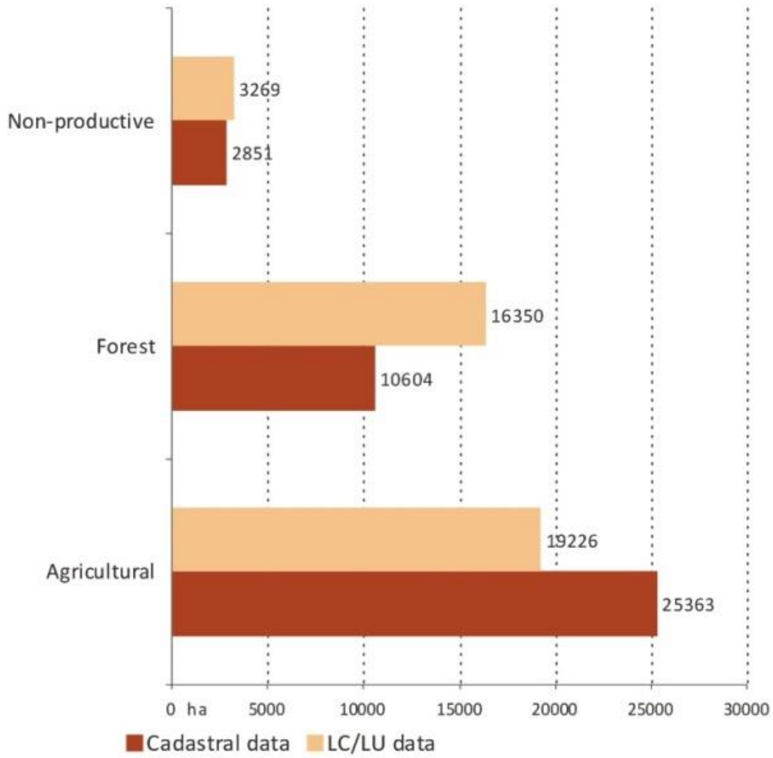

Figure 9. Comparison of land use structure according to cadastral and LC/LU data

Based on the presented data and graphs, it can be concluded that there have been significant changes in land use. According to cadastral data that have not been updated in detail for many years, agricultural areas occupy 65.3%, and according to LC/LU data, agricultural areas occupy 49.5% of the municipal area, which is a reduction of agricultural areas by 6137 ha. From this area, 5746 ha (93.6%) was transferred to the LC/LU class "forests". Part of these areas was created by succession, that is, due to non-use for many years, agricultural areas were gradually overgrown and turned into forests. All areas overgrown with shrubs and trees are included in the LC/LU class "forests" and these areas are now marked as non-agricultural areas. However, during the creation of the LC/LU map (comparison of the situation from 2012 and 2018), several cases were identified where deforestation was carried out and these areas were changed back to agricultural purposes (Figs. 10a and 10b). From the above example, it can be concluded that a certain part of the area that in 2018 belongs to the LC/LU class "forests", were only temporarily lost for agricultural production.

Figure 10a. Forest and shrubs (2012)

Figure 10b. Cultivated (plough land) (2018)

Part of the agricultural land was permanently lost during construction. The built-up areas were increased by only 418 ha, which indicates that the cadaster was partially updated because they built a highway in the Municipality of Laktasi, which was mostly built on agricultural land (Fig. 11a. and 11b.) and these changes were made in the cadaster.

Figure 11a. Cultivated dominant (2012)

Figure 11b. Highway build up (2018)

Due to the construction of the highway, new exploitation fields of sand, gravel and stone from the bed of watercourses and banks of the river Vrbas have been identified, as well as several smaller quarries in the interior of the Municipality. In addition to the exploitation of gravel from the Vrbas basin, areas where exploitation is also carried out on agricultural areas near the Vrbas River (12b) have been identified. All these areas have been mapped and their total area is 217 ha, which is 0.6% of the total area of the municipality. These changes in the use of agricultural land are most likely not all recorded in the cadaster. Also, a significant part of agricultural land was lost in the great floods of 2014. (Fig.12b.)

The analysis of LC/LU map data recorded a significant number of constructed facilities for various purposes located in the inundation area, that is, between the embankment and the river Vrbas, which significantly reduces the protective purpose of this area and increases the risk of floods. This problem is also recorded in the document Flood Risk Management Plan for the Vrbas River Basin (UNDPBIH/MPŠV RS, 2019).

Figure 12a. Agricultural land and shrubs along the Vrbas River (2012)

Figure 12b. Agricultural lands were removed due to floods and degradation caused by gravel extraction (2018)

One of the limiting factors of agricultural production in the Republic of Srpska and Bosnia and Herzegovina is the fragmentation of properties (RS Agricultural Startegy, 2021). An additional problem is that this process does not stop. In the studied area, only 2.2% of agricultural land has plots larger than 20 ha. These plots are the remnants of the state agricultural combine from the socialist era and represent landscaped areas with access roads, a runway for agricultural aviation, irrigation system (Fig. 13a). These are lands of I, II, and III bonity class that are protected by the law on agricultural land, but in practice these areas are also converted into industrial zones (Fig. 13b).

Figure 13a. Agricultural complexes (2012)

Figure 13b. Industrial zones (2018)

The analysis of the presented situation can be performed in several ways, but it is clear that the existing cadastral data are not valid and that it is necessary to update them, which is a slow process and decision makers at the municipal level cannot rely on this data. The digital map LC/LU in the scale of 1: 5000 is a relevant data on the basis of which in the future we can quickly and quite reliably monitor changes in the purpose and changes in land use.

Furthermore, LC/LU GIS layers, i.e. agricultural areas can overlap (combine) with other GIS layers: pedology, erosion, bonity, DEM and thus further analyze the properties of agricultural land in order to better and more rationally use it and protect the land of the best bonity classes from permanent loss.

If the layer LC/LU overlaps with the layer of land bonity the obtained data is that 8018 ha of agricultural land (42% of the total agricultural land) is located on areas of I, II and III bonity class, which should be protected from permanent loss. However, out of a total of 2840 ha of built-up areas (tab. 4. built + bare areas), 25.4% or 722 ha were built on lands of I, II and III bonity class, which means that 264 ha of land of the first, 61 ha of the second and 397 ha of agricultural land of the third bonity class were permanently lost (tab. 4, fig. 14).

Table 4. Bonity classes of land which areas are built

Bonity classes	Area	
	ha	%
I	264	9,3
II	61	2,1
III	397	14,0
IV	445	15,7
V-VII	54	1,9
VIII	1619	57,0
Total:	2840	100,0

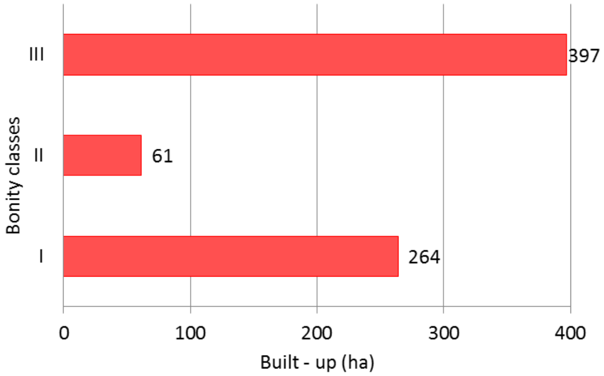

Figure 14. Permanently lost lands of I, II, III bonity classes in the process of urbanization (722 ha)

The responsible departments in the Municipality must find the reasons for such negative trends, and special attention must be paid to the problem of permanent loss or change of use of agricultural land, which causes irreparable permanent economic damage. It is necessary that in all land protection measures, the "fight" against the permanent loss of agricultural land must be elaborated. This commitment of the Municipality and all other competent institutions dealing with land policy must be accompanied by adequate measures, including very rigorous land protection measures.

By drafting the Municipal Groundwork, the municipal administration obtained a reliable tool which can be used to provide relevant data on the use of agricultural land, which is a basic precondition for all other planning and measures.

CONCLUSION

1. Prevention of degradation and sustainable controlled land use should be the most important parts of every state's policy. In order for this policy to be implemented in a

quality manner at all levels of government, relevant indicators of the state of land resources are necessary.

2. Data on land cover and land use (LC/LU) are subject to relatively rapid changes that occur both by human influence and natural processes so that LC/LU is the most important GIS basis in the process of inventory of land resources and the process of planning the use of agricultural land.
3. GIS layer of LC/LU for the municipal level should be made in a large scale of 1:5000.
4. Creating a detailed status of LC/LU in the scale of 1:5000 represents the most relevant basis for determining the actual status of agricultural areas and monitoring changes over time (change of purpose, degradation, etc.). LC/LU is the main basis for GIS modeling (bonity, fertility, suitability, pollution, agroecological zoning etc.)
5. Orthophotos or satellite images with a spatial resolution of 10 m or better should be used when making a GIS layer.
6. To delineate the polygon, one of the valid classifications of land cover and classification of the land use that needs to be modified in accordance with the specific spatial characteristics of the municipality, should be used. The classification should be created in such a way as to identify (mapping) the agricultural area as precisely as possible in accordance with the valid legal regulations on agricultural land.
7. Delineation of areas (LC/LU class) is best done manually, and if it is done automatically, operator correction is mandatory.
8. The smallest mapped area of LC/LU agricultural classes depends on the importance of LC/LU Class and the characteristics of agricultural production.
9. Agriculture of the Republika Srpska is characterized by fragmented land (dominated by plots less than 1 ha in field production and 0.5 ha in fruit production). Therefore, the smallest mapped unit is 0.5 ha for the "cultivated" class, for the class "permanent plantation" 0.1 ha, and 0.01 ha for the class “plastic greenhouses”.
10. It is very important that for "dominant" classes of LC/LU - in which one class dominates, the percentage of the dominant LC/LU class and percentage of the secondary class of LC/LU must be stated in the attribute table.
11. Analysis of LC/LU data and comparison with official cadastral data in the municipality of Laktaši showed a significant increase of the non-agricultural land area (+6137 ha) and significant increase uncultivated areas ("meadows and uncultivated" class)
12. The biggest change was found in the increase of forest vegetation due to non-use of agricultural land. This change is favorable for biodiversity and soil conservation
13. The greatest degradation was determined by the opening of gravel pits on agricultural land and the removal of agricultural land by river erosion (floods)
14. Constructions on the highest quality land have been recorded. Thus, 25.4% of the built-up areas are located on lands of I, II and III bonity class, i.e. 722 ha of the highest quality land was permanently lost.
15. The elaboration of a detailed state of the LC/LU in the scale of 1:5000 is intended for decision makers at the municipal level in the process of planning and implementation of agricultural projects and stopping the trend of permanent loss of agricultural land. Due

to the simple way of monitoring changes, LC/LU is a basic "tool" for "alerting" when noticing negative trends in land use or negative changes in land cover.

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NATURALLY OCCURRING RADIONUCLIDES AND BASIC CHARACTERISTICS OF SOIL AND ASH SAMPLES NEARBY COAL–FIRED POWER PLANTS

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Abstract

Deposition of (fly and bottom) ash generated after coal combustion in the coal fired power plants (CFPP) in Serbia is carried out in active and passive lagoons. Ash waste mixed with water is directly transported to the lagoon currently active and the other one is passive in the stage of temporary inactivity for technical consolidation of ash and drainage and subjected to revegetation process using grass–legume mixtures with the purpose of creating plant cover. In order to obtain similarity, samples studied in this work were all taken from the area covered with grass which included: (1) soil close to CFPP (<2 km), (2) soil further from CFPP (>2 km) and (3) ash from the flat area of associated passive lagoon. Investigated sites were four power plants: TE "Kolubara" (TEK), TE "Morava" (TEM), TE "Nikola Tesla" A (Tent A) and B (Tent B). In order to analyse environmental implications of ash deposition in the surrounding area, basic characteristics such as texture, particle size distribution, pH value, organic matter and carbonate content were determined in the soil and ash samples. Simultaneously, ^{238}U, ^{226}Ra, ^{210}Pb and ^{232}Th activity concentrations were measured as it is known that after elimination of the organic component of the coal in the process of combustion naturally occurring radionuclides activity concentrations in the coal ash could be enhanced up to 10 times. Analyses of differences between soil and ash samples collected in this study showed that for one group of soils some changes of physical and chemical characteristics occurred compared to the rest of the soils. These changes were found to be related to the soil texture, percentages of clay size particles and $^{232}Th/^{226}Ra$ activity concentration ratios.

Keywords: soil; coal ash; CFPP; naturally occurring radionuclides

INTRODUCTION

Coal as naturally found material contains traces of naturally occurring primordial radionuclides that include radioactive decay series precursors (^{238}U, ^{235}U and ^{232}Th) and their decay products (such as ^{226}Ra, ^{210}Pb, ^{228}Ra) as well as potassium isotope ^{40}K, in different quantities depending on geological origin of the coal. After burning of coal in the

coal fired power plants, naturally occurring radionuclides are released from the original coal matrix and distributed between the gaseous phase and solid combustion by-products. Gaseous phase contains volatile nuclides (such as Rn, Pb, Po) while less or non-volatile nuclides (U, Ra, Th, K) are trapped and concentrated in the bottom-ash and slag or in the smallest and lightest particles of fly-ash which are expelled together with the hot gases (Papastefanou, 2008; Karangelos et al., 2004). As a result, after elimination of organic component of the original coal, natural radionuclides activity concentration could be up to 10 times higher in solid combustion wastes (Papastefanou, 2008). For example, if lignite is used as feed coal it could be expected that secular radioactive equilibrium would be maintained in the ^{238}U radioactive series in coal and disturbed in the ashes due to variations in radionuclide enrichment processes in different fractions of ash. Then, fly-ash would be more enriched in ^{238}U and ^{226}Ra than bottom-ash while the smallest fly-ash particles would be highly enriched in ^{210}Pb and depleted in it within bottom-ash (Karangelos et al., 2004).
Subsequently, as a result of CFPPs activities, radionuclides are being dispersed into the environment through the leaching of solid combustion by-products during disposal of ash waste to the disposal sites and after deposition on the nearby soil or through atmospheric emissions in the gaseous or particulate form. Over 80% of the disposed ash waste consists of fly-ash particles ranging in size between 0.5 μm to 300 μm. Nevertheless, coal fly-ash detection in the soil environment is found to be challenging given its small particle size and in the study of Wang et al. (2021) low percentage of fly-ash in the soil (<10%) did not yielded to appreciable differences relative to the reference soil and only the increased fractions of fly-ash leaded to a more distinguishable soil-ash mixtures. The study also explored if trace elements and radioactive isotopes of radium could be used as a detection tool for fly-ash presence in the surface soils and discussed distinctions in radium abundance and ^{228}Ra/^{226}Ra ratios (reflecting the Th/U activity ratios) between coal, fly-ash and common soil.
Deposition of fly-ash and bottom-ash generated after coal combustion in the CFPPs in Serbia is carried out in active and passive lagoons. Ash waste mixed with water is directly transported to the lagoon currently active and the other one is passive in the stage of temporary inactivity for technical consolidation of ash and drainage. At the site Tent A, results of revegetation process were investigated 3 and 11 after the sowing of a grass–legume mixture directly onto the ash (without the application of topsoil), using agronomic measures (Kostić et al., 2018) and concluded that passive lagoons should be subjected to the revegetation creating plant cover in order to improve physical and chemical characteristics and ensure stabilisation of ash waste deposits.
In order to analyse environmental implications of ash redistribution in the surrounding area of four CFPPs from Serbia, basic characteristics such as texture, particle size distribution, pH value, organic matter and carbonate content were determined in the soil and ash samples and simultaneously activity concentrations of ^{238}U, ^{226}Ra, ^{210}Pb and ^{232}Th were measured. The aim of the present study was to analyse whether there were: i) any differences between ash and soil according to the measured physical and chemical parameters and radionuclides activity concentrations and ii) any relations between investigated radionuclides activity concentrations and basic characteristics regardless of sample type.

MATERIALS AND METHODS

Study area

Area in the vicinity of four coal fired power plants from Serbia was under study in this work: "Nikola Tesla A" and "Nikola Tesla B" situated on the Sava River bank, TE "Kolubara" on the Kolubara River and TE "Morava" on the right bank of the Velika Morava River. In the area near Tent A different soil types such as calcaric fluvisols, vertisols, gleyosols, phaeozems, stanic gleyosols, cutanic cambisols, humic gleyosols are found to be developed, but as a consequence of CFPP activities, technosols and spolic regosols could be present (Tanić et al., 2016). In summary, fluvisols may be recognized as the most common soil type distributed along the river valleys where CFPPs are situated.

Soil and ash sampling

The sampling points were chosen to be located within the radius of 6 km around each CFPP. Studied samples were all taken from the area covered with grass. It was assumed that ash and soil samples would be more appropriate to compare according to their properties if conditions for vegetation development are met since revegetation of ash deposits improves physical and chemical characteristics of ash waste. Sampling locations included: (1) soil close to the CFPP (<2 km), (2) soil further from the CFPP (>2 km) and (3) ash from the flat area of associated passive lagoon. In the period from 2012 to 2014, a total of 20 soil and 8 ash samples were collected from the surface horizon of 0-10 cm depth. At each location grass was cut off and removed from the surface layer prior to sampling and about 1–1.5 kg of soil or ash was collected.

Soil and ash analysis

In the laboratory, debris and grass residues were removed from the collected material. Samples left to be air-dried at room temperature and afterwards to be oven dried at 105°C to a constant mass. Prepared like that, soil and ash samples were sieved through 2 mm mesh sieve. The pH-reaction, content of carbonates and organic matter content were analysed using standard procedures. Particle size distribution analysis was conducted by combined pipette and sieve techniques. Determined fractions were sand (particle sizes of 2000–200 μm and 200–50 μm), silt (50–10 μm and 10–2 μm) and clay (<2 μm).

For the determination of radionuclides activity concentration, all prepared samples of soil and ash were packed in 500 ml Marinelli beakers, sealed, covered with a film of beeswax and left for 4 weeks in order to ^{226}Ra and ^{232}Th attain secular equilibrium with their decay products. Applying the gamma spectrometry method, measurements were performed with the HPGe detectors (Canberra Industries, Inc., Meriden, CT, USA) with 18%, 20% and 50% relative efficiency and energy resolution of all the detectors of 1.8 keV at the 1332 keV gamma ray energy of ^{60}Co. The detectors were calibrated using secondary reference material with soil matrix which was produced using certified radioactive mixture solution (9031–OL–427/12 type ERX by Czech Metrology Institute, Inspectorate for Ionizing Radiation, Praha) that contained radionuclides: ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{203}Hg, ^{113}Sn, ^{85}Sr, ^{88}Y and ^{210}Pb with total activity 7.4 kBq at reference date 31.08.2012.

Calibration was performed in the same geometry of V=500 ml Marinelli beaker as the geometry of measured samples.
The activity of ^{238}U was determined through its daughter products in equilibrium in soil ^{234}Th (63 keV) or ^{234m}Pa (1001 keV). The activities of ^{226}Ra were determined by its decay products: ^{214}Bi (609.3; 1120.3 and 1764.5 keV) and ^{214}Pb (295.2 and 351.9 keV) and ^{232}Th activities by its decay product ^{228}Ac (338 and 911 keV). Using 46.5 keV γ-energy photons, ^{210}Pb activity concentrations were determined. The spectra were recorded and analysed using Canberra's Genie 2000 software. Counting time was about 60000 s. Activity concentrations are expressed along with their combine measurement uncertainty at the 95% confidence level.

Statistical analysis
Normality of the data was assessed by the Shapiro-Wilk's test. For data groups with a tendency toward normal distribution summarized results are presented by the arithmetic mean and for one with a tendency towards log-normal distribution by the geometric mean. Statistical analysis was conducted by one-way analysis of variance (ANOVA) to specify the main differences in measured physical and chemical properties and radionuclides activity concentrations between investigated soil and ash samples. To find relationships between radionuclides activity concentration ratios and the measured basic properties, simple linear regression analysis was performed. Significant differences and regression analysis results were considered at the 95% confidence level and the results which were not significant are not presented.

RESULTS AND DISCUSSION

Measurement results from 2012., 2013. and 2014. of basic properties of soil close to each CFPP, soil further from the CFPP and ash from the flat area of associated passive lagoon including their ^{238}U, ^{226}Ra, ^{210}Pb and ^{232}Th activity concentrations are presented in Appendix 1 as supplementary material. Texture of investigated samples was also determined and denoted as: LS–Loamy Sand, SL–Sandy Loam, L–Loam, SiL–Silt Loam, SiCL–Silty Clay Loam and CL–Clay Loam.

Differences between samples of ash and soil
The tests of normality showed that data groups consisting of measured pH values, humus content, fractions of silt (coarse, fine and total), clay and physical clay followed normal distribution. The values of $CaCO_3$ content and sand fractions (coarse, fine and total) followed normal distribution after logarithmic transformation of the data. One-way analysis of variance was applied to identify differences between the properties of ash and soil and the results are shown in Table 1. The mean value of $CaCO_3$ content was not significantly different between ash (1.5%) and soil (1.9%), nor did the humus content, which was about 3% on both substrates. The accumulated humus in the ash samples from the passive lagoon could come from vegetation residues, but also from unburned parts of the coal. Ash was weakly alkaline with pH (in H_2O) in the range of 7.3 to 8.4 and the mean

pH of ash (7.9) differed significantly ($p<0.01$) from that in soil (7.3) which was in the range 6.1 to 7.9.

Table 1. The one-way analysis of variance of investigated basic properties and natural radionuclides activity concentrations of ash and soil samples. The geometric mean (bold letters) is presented for log–normal distribution and the arithmetic mean for normal distribution of data groups.

	Soil	Ash	*F* –ratio	*p* –value
2000–50 µm (%)	**12.0** (1.6–42.3)	**56.0** (13.3–79.6)	28.22	<0.0001
2000–200 µm (%)	**6.7** (0.1–24.8)	**20.3** (2.7–43.6)	10.73	<0.01
200–50 µm (%)	**10.4** (0.1–33.5)	**35.7** (10.6–57.1)	29.63	<0.0001
50–2 µm (%)	54.7 (30.6–77.4)	36.8 (16.9–75.8)	7.7	<0.05
50–10 µm (%)	28.2 (14.1–62.6)	19.0 (8.8–39.7)		
10–2 µm (%)	26.4 (5.0–41.9)	17.8 (6.6–36.1)		
<2µm (%)	28.3 (12.3–39.8)	3.6 (2.3–5.4)	87.39	<0.0001
<10µm (%)	54.7 (27.1–74.6)	25.0 (10.4–63.7)	21.45	<0.001
OM (%)	3.3 (1.2–5.3)	3.5 (0.6–7.3)		
$CaCO_3$ (%)	**1.9** (0–15.0)	**1.5** (0–4.4)		
pH (H_2O)	7.3 (6.1–7.9)	7.9 (7.3–8.4)	9.66	<0.01
pH (KCl)	6.5 (5.4–7.2)	7.5 (6.2–8.2)	15.95	<0.001
^{238}U ($Bqkg^{-1}$)	**38.2** (24–56)	**106.3** (46–190)	66.10	<0.0001
^{226}Ra ($Bqkg^{-1}$)	**38.7** (25–56)	**102.9** (42–167)	66.62	<0.0001
^{210}Pb ($Bqkg^{-1}$)	**46.5** (30–92)	**83.5** (32–258)	9.43	<0.01
^{232}Th ($Bqkg^{-1}$)	**45.9** (24–71)	**73.7** (52–130)	20.3	<0.001

Sand particles of sizes of 2000–50 µm were most abounded in the samples of ash, with the mean content in ash (56%) significantly higher ($p<0.0001$) than in soil (12%). The mean content of silt particles of sizes of 50–2 µm was significantly higher ($p<0.05$) in soil (54.7%) than in ash (36.8%), however individual fractions of silt, coarse (50–10 µm) and fine (10–2 µm), were not statistically different between the two substrates (Table 1). The main difference ($F=87.39$; $p<0.0001$) was observed for the mechanical fraction of clay of particle sizes of <2 μm whose mean content was significantly higher in soil (28.3%) than in ash (3.6%). The study of the particle size distribution of the ash waste generated at the Tent A also showed a quite small representation of particles of the smallest sizes (≤2 μm) (Kostić et al., 2018). Although, distribution like that of mechanical fractions of samples of ash collected from the surface could also be influenced by the leaching of finer particles towards the deeper layers of passive lagoon during the period of rest. For comparison, mean values of all physicochemical features presented in Table 1. were very close to the one reported earlier for the surface soils (Tanić et al, 2016) and ash deposits (Kostić et al., 2018) in the vicinity of Tent A.

The values of activity concentrations of ^{238}U, ^{226}Ra, ^{210}Pb, ^{232}Th determined in the samples of ash and soil followed log-normal distribution. The natural radionuclides activity concentrations in soil were at the natural background gamma radiation levels and similar to the values reported earlier for the Tent A (Tanić et al., 2016). Ranges of activity concentrations in ash from the passive lagoons were comparable with the ranges determined in slag sampled below the boiler and in fly-ash samples collected at the electrostatic precipitators in TEK and Tent A (Kandić et al., 2014). The results of the ANOVA test (Table 1) showed that values of activity concentrations were always significantly higher ($p<0.01$) in ash than in soil. This was also concluded by similar study in which soil and disposed ash situated in Kaštela Bay, Croatia was compared (Skoko et al., 2017). However, mean values of activity concentrations (Bqkg^{-1}) found in the ash were about 10 times higher there (1099 for ^{238}U, 1074 for ^{226}Ra, 1165 for ^{210}Pb, 58 for ^{232}Th) than in this study (106 for ^{238}U, 103 for ^{226}Ra, 84 for ^{210}Pb, 74 for ^{232}Th), except for ^{232}Th.

It was noticed that activity concentration (Bqkg^{-1}) in the samples of soil in this study (38 for ^{238}U, 39 for ^{226}Ra, 47 for ^{210}Pb, 46 for ^{232}Th) was comparable to the one in coal used in CFPPs in Serbia (36 for ^{238}U, 37 for ^{226}Ra, 35 for ^{210}Pb, 49 for ^{232}Th) (Kandić et al., 2014). Furthermore, natural radionuclides activity concentration increase of 1.6 to 2.8 times from soil to the samples of ash in this study was similar to the increase of ~2 to ~4 times from coal to the fly-ash and slag after combustion. This indicated that differences of natural radionuclides activity concentrations between used coal and generated ash might to some extent be reflected in the environment as the differences of that between nearby soil and ash from passive lagoon.

To test this, activity concentration ratios within the same (^{238}U/^{226}Ra and ^{210}Pb/^{226}R) and between different decay chains (^{232}Th/^{226}Ra) were examined in this study and compared to the values of that for coal, slag and fly-ash used in Serbia (Kandić et al., 2014). No significant differences at the 95% confidence level were found in this study between soil and ash for ratios of ^{238}U/^{226}Ra approximately equal to ~1 and analogue to that, ^{238}U/^{226}Ra ratio values were only slightly changed from ~1 in coal to ~0.91 in fly-ash and slag. However, values of ^{210}Pb/^{226}Ra and ^{232}Th/^{226}Ra which were ~1 and ~1.3 in coal, respectively, both decreased significantly to the value of approximately 0.65 after combustion. In this study, ^{210}Pb/^{226}Ra was significantly higher ($p<0.05$) in nearby soil (1.25) then in ash from passive lagoon (0.88), but radioactive disequilibrium and its differences could occur in the environment due to additional dry or wet atmospheric deposition of ^{210}Pb of natural origin resulting from ^{222}Rn decay in the atmosphere. Finally, ^{232}Th/^{226}Ra ratio showed significant difference ($p<0.0001$) between nearby soil (1.20) and ash from passive lagoon (0.74), indicating that this ratio could be used to differentiate unmodified from modified soil due to presence of ash.

^{232}Th/^{226}Ra activity concentration ratio

^{232}Th/^{226}Ra activity concentration ratios (Bqkg^{-1}/Bqkg^{-1}) were calculated in order to observe differences between nuclides activity concentrations of uranium and thorium decay chains in each sample. Range of calculated values was 0.49 to 1.52. It was noticed that those values were increasing with percentages of clay size particles which is why simple linear regression analysis was used to assess this effect. Linear relation between those two variables was found ($p<0.001$), however our analysis showed that two statistically significant linear models could be distinguished, as it is shown at Figure 1.

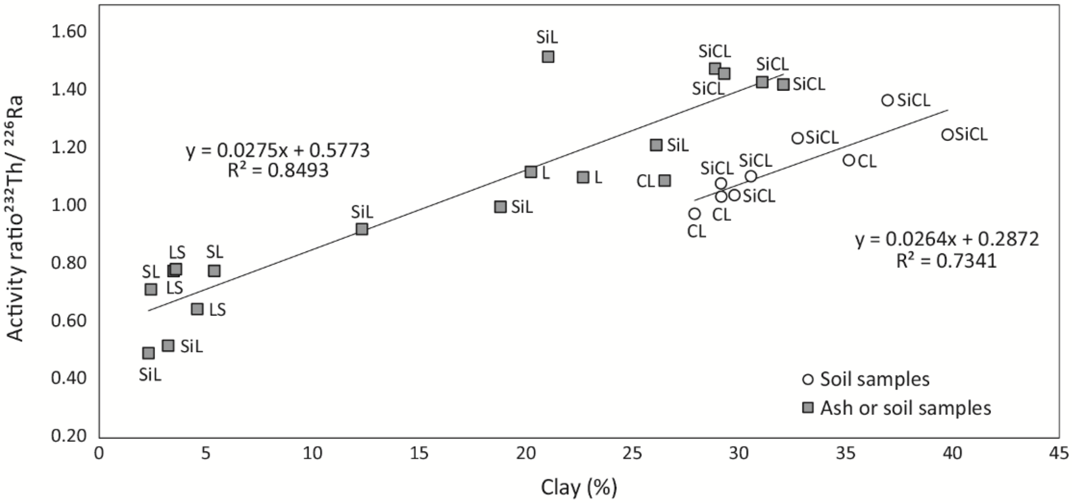

Figure 1. Changes of ^{232}Th/^{226}Ra activity ratios (Bqkg^{-1}/ Bqkg^{-1}) of investigated samples of soil and ash with percentages of clay (%)

Lower line at Figure 1 is fitted through the points which are represented by the soil samples whose mean ^{232}Th/^{226}Ra activity ratio value of 1.14 was close to the natural value of 1.1 observed in the environment (Wang et al., 2021). Based on the balanced ^{232}Th and ^{226}Ra activity concentrations, those samples could be characterised as unmodified i.e., representative soils that surround four coal fired power plants investigated. Their characteristic texture is found to be SiCL (mainly) or CL while clay fraction percentages were in the interval 27.9% to 39.8%.

From Figure 1. can be noticed that upper line is fitted through the points represented by the samples of ash and soil whose ^{232}Th/^{226}Ra ratio values mainly differed from natural being in the broad range from 0.49 to 1.52. First, a group of samples of ash taken from passive lagoon can be noticed with characteristic texture SL or LS while 0.67 was the mean value of their ^{232}Th/^{226}Ra ratio. Ash samples, rich in coarse particles (2000–50 μm), had small amount of clay (2.3% to 5.4%) as expected and there ^{226}Ra was more abounded than ^{232}Th as a consequence of coal combustion process and also reduced mobility of cations (such as Ra^{2+}) due to decreased soluble salt levels of ash (Skoko et al., 2017).

For the second group, which consisted of soil samples of L or SiL texture (Figure 1) with clay percentages from 12.3% to 26.5%, could be assumed that ash particles were incorporated into the soil and consequently changed its texture which became coarser compared to unmodified soil, but it was not the case according to their mean $^{232}Th/^{226}Ra$ ratio value of 1.14 which was the same as for unmodified samples. The rest of the samples were soils with SiCL texture as typical samples from lower regression line, but compared to them higher mean $^{232}Th/^{226}Ra$ value of 1.42 and a bit lower average clay content of ~30% suggested enhanced ^{226}Ra reduction from studied samples relative to ^{232}Th considering its known low mobility in the environment.
It could be noticed that both regression line slopes are approximately the same (α_1=0.0275 vs. α_2=0.0264) and that difference comes from the intercept which is about two times higher for „upper“ line (β_1=0.5773 vs. β_2=0.2872) indicating that $^{232}Th/^{226}Ra$ activity ratios are regularly increasing with clay content while ^{226}Ra removal from surface layers varies between samples. Comparing only samples of soil with SiCL texture, it appears that soils from „upper“ regression line are modified due to proximity of CFPPs and their ash disposal sites based on their higher radium's mobility and hence availability to plants which is different from soils from "lower" line where radium is part of more resistant fractions of soil. In accordance to that, a significant increase in the activity concentration in the samples of vegetation collected from the disposal sites of coal ash and slag was found only for ^{226}Ra and no significant difference was observed for ^{232}Th in comparison with control soil (Skoko et al., 2017). Additionally, unlike redistribution of naturally occurring radionuclides which was most likely took place in this study, no texture changes due to potential incorporation of ashes into the soils couldn't be observed.

CONCLUSION

Differences between samples of soil and ash collected in the proximity of coal fired power plants and coal ash disposal sites according to their physical and chemical properties are analysed in this study. No differences were found between soil and ash regarding $CaCO_3$ and humus content. Ash was weakly alkaline and the mean pH (in H2O) value of ash (7.9) differed significantly from that in soil (7.3). Mean percentage of sand (2000–50 μm) was significantly higher in ash (56%) than in soil (12%), but coarse silt (50–10 μm) and fine silt (10–2 μm) were not statistically different. Clay (<2 μm) mean content was significantly higher in soil (28.3%) than in ash (3.6%). Activity concentrations (Bq kg^{-1}) of naturally occurring radionuclides were also determined and means of ^{238}U, ^{226}Ra, ^{210}Pb and ^{232}Th were always significantly higher in ash (106.3, 102.9, 73.7 and 83.5, respectively) than in soil (38.2, 38.7, 45.9 and 46.5, respectively), as it was expected. Even though texture of investigated samples was predominantly silty clay loam, soils could be distinguished, according to our analyses, based on their different $^{232}Th/^{226}Ra$ activity concentration ratio: unmodified soil with the mean value of 1.14 almost equal to the natural value (~1.1) and modified soil with higher mean value of 1.42 suggesting enhanced ^{226}Ra reduction form surface layers due to proximity of CFPPs and ash disposal sites.

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SECTION 4

SOIL AND WATER FUTURE SOCIO-ECONOMIC PATHWAYS

NEW APPROACH TO IMPROVE WATER QUALITY IN THE DANUBE REGION BASED ON THE ECOSYSTEM SERVICES IN FLOODPLAINS: IDES PROJECT

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Abstract

From its source to its mouth in the Black Sea, the Danube River covers a distance of more than 2,800 kilometers. Flowing through ten countries its water comes from 20 different countries. More than 80 million people live in the catchment area of the river, and - just like flora and fauna - all are dependent on a good water quality. The nutrients flow the Danube water does not stop at national borders and there is a challenge to establish strategies for comprehensive water quality management at the international level. Additionally, the floodplains along the Danube play a key role in quality management, as they are able to retain nutrients. Two aspects in this regard are of interest. The first is: how floodplain areas along the Danube contribute to improving water quality, and the second: how can diverse interests be taken into account in water quality management across national borders? Answering these questions is the main concern of a multinational project IDES under the leadership of the Catholic University of Eichstaett-Ingolstadt, Germany. The project consortium involves over 20 institutions from ten countries along the Danube (Germany, Austria, Romania, Hungary, Slovenia, Slovakia, Bulgaria, Serbia, Croatia and Moldavia). The project title 'Improving water quality in the Danube River and its tributaries by integrative floodplain management based on Ecosystem Services (IDES)' implies that the project should enable partners to jointly develop and implement a transnational integrative ecosystem service approach, improve water quality management, and generate win-win-situations for multifunctional floodplains instead of trade-offs in a multi-actor, multi-sector framework. Paper presents overview of the IDES project. The problems related to water quality degradation in the Koviljsko-petrovaradinski rit, Serbian pilot area, and the first results of ecosystem services analysis are also presented in this paper.

Keywords: water quality management, ecosystem services, floodplain, IDES project

INTRODUCTION

Rivers and their floodplains have many roles and tasks: they serve as shipping routes and recreational areas, as protection against floods and drinking water reservoirs, and as habitats for plants and animals. All these different types of use are, called ecosystem services, influence or are influenced by the water quality of rivers and floodplains. Additionally, all these types of use are planned and regulated individually by different

technical authorities at different administrative levels - this makes it difficult to maintain an overview or coordinate management measures.
How do floodplain areas along the Danube contribute to improving water quality and how can diverse interests be taken into account in their management across national borders? These questions are being researched by a consortium funded by the European Union under the leadership of the Catholic University of Eichstaett-Ingolstadt, Germany.
The project Improving water quality in the Danube River and its tributaries by integrative floodplain management based on Ecosystem Services (IDES) involves over 20 institutions from ten countries along the Danube, Figure 1, that join forces in an EU-funded project to improve water quality in the Danube River and its tributaries by integrative floodplain management based on ecosystem services. Among them are two important international bodies – International commission for the protection of the Danube River (ICPDR) and Sava commission.

Figure 1. IDES Partners

The IDES project was officially launched on September 8th 2020 during a virtual event bringing together key stakeholders and international project partners to focus on the project's main topic.
It is co-funded by the European Union (ERDF, IPA). For more information about it, visit the project website: www.interreg-danube.eu/ides.

AIMS OF THE IDES PROJECT

The IDES project aims to develop and implement a transnational integrative ecosystem service approach to improve water quality management and thus, generating win-win situations for multifunctional floodplains instead of trade-offs. The IDES tool should enable the national key actors in water quality management to identify the most sustainable measures without neglecting the needs of other sectors. The innovative IDES tool will provide both in pilot areas and on the transnational level an ecosystem service assessment for floodplains that support sustainable decision making in floodplain management.

During the two-and-a-half-year implementation timeline, the innovative actions will focus on the following:

1. Analysis of the actual situation of water quality and its pressures and of ecosystem services in the whole Danube region by geographical explicit models, GIS analysis and literature review. Harmonization of different approaches and joint development of the framework of an ecosystem service evaluation tool (IDES tool) on basis of these enquiries.
2. Stakeholder workshops in five pilot areas in Austria, Slovenia, Hungary, Serbia and Romania where innovative water quality management concepts will be elaborated and assessed by the newly developed IDES tool. The results and the experience on the implementation of the IDES tool will be summarized in the IDES manual and transferred to key actors of the participating countries during national training courses.
3. Joint developing of a transnational strategy providing the operational pathway to integrate the ecosystem service approach in future water quality planning processes. Feedback from a transnational stakeholder workshop will help to fine-tune the IDES tool and strategy in the final phase and to foster its implementation.

STUDY AREA IN SERBIA

The Special Nature Reserve 'Koviljsko-Petrovaradinski Rit' (KPR) in Serbia is one of the pilot areas for the IDES project. It is located in the autonomous province of Vojvodina, northern Serbia, near the city of Novi Sad, Figure 2. The KPR is located on the left and right banks of the Danube River, between 1250 and 1225 river kilometer. The smaller part of the KPR wetlands (on the right side of the Danube river) is known as the Petrovaradin marsh while the significantly larger side of the KPR (located on the left side of the Danube river) is known as the Kovilj marsh.

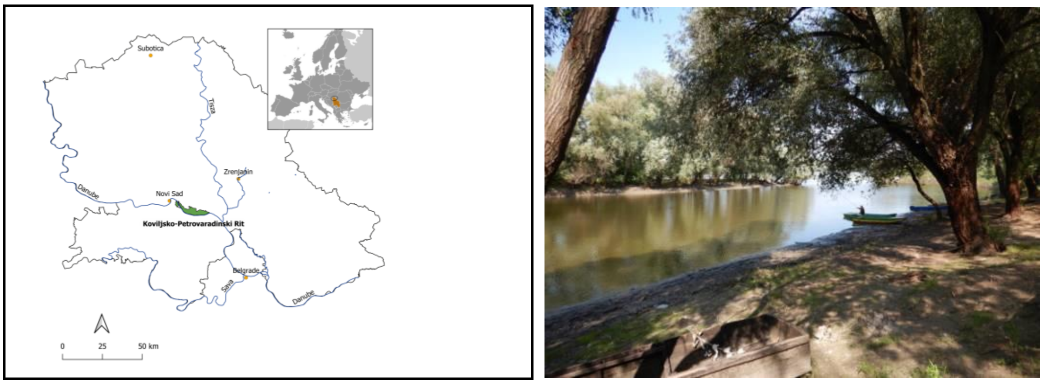

Figure 2. Location of the Koviljsko-petrovaradinski rit, Serbian Pilot area

The KPR is located on the territory of 4 municipalities, Novi Sad (49%), Inđija (27%), Sremski Karlovci (17%) and Titel (7%), that have around 447000 inhabitants. Within these four municipalities, nine settlements lie next to the borders of KPR, meaning that 56,312 inhabitants are directly or indirectly connected to KPR.
The territory of KPR is mainly state-owned land (69%); 17% is owned by religious organizations (orthodox church and monasteries), around 3% is a form of public ownership, and 5% is private property. A small percentage (6%) of the KPR has other specific forms of ownership.
Forests cover the majority of the area of KPR (69% of the total area), while wet meadows and pastures occupy 15% of KPR. Wetlands and aquatic habitats (e.g. marshes, oxbows, channels, riverine habitats) cover around 12%. KPR is a protected area of national importance. Due to its exceptional natural values (rare and protected flora and fauna, as well as preserved habitats) and specific characteristics of wetlands, it has been declared as a Special Nature Reserve (First Category protected area), according to the Serbian Law on Nature Protection. The importance of KPR for biodiversity preservation has been recognized internationally, and has international protection: IBA (Important Bird areas) – important area for birds; ICPDR - Special nature reserve 'Koviljsko-Petrovaradinski Rit' was in 2004 enlisted within the list of protected areas dependent on water and significant for the Danube basin; IPA (Important plant areas) – significant botanical region; DANUBE NETWORK PROTECTED AREAS (Danube Network Protected Areas), in 2007 has been enlisted within the network of protected areas of the river Danube, as one out of five protected areas from Serbia, which has spatial area larger than 1000 ha; RAMSAR REGION – Within the list of regions having international significance according to the Ramsar Convention as of 2012; Emerald network – implemented within the EMERALD network of habitats and types.

LOCAL ECOSYSTEM SERVICES AND MAIN DRIVERS OF WATER QUALITY DEGRADATION IN KPR

Research on existing and selected ecosystem services provided by KPR was conducted in 2015, along with economic valuation of these ecosystem services in KPR (Stojnić et al., 2015). In recent years, extensive research has been conducted by numerous stakeholders, experts from academia, decision and policy makers and representative of local communities to determine the ecosystem services of key importance (Galambos et al., 2019; Ždero et al., 2020).
Detailed assessment, evaluation and prioritisation of ESS in KPR according to the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2018) is underway as a part of IDES activities. Preliminary results are given in Table 1.

Table 1. Ecosystem services provided by KPR

Category of ES	Provisioning ES	Regulating ES	Cultural ES
Types of ES	Cattle grazing	Flood protection	Recreation
	Water and groundwater use	Air purification and cooling	Tourism
	Livestock breeding	Water purification	Aesthetic importance
	Angling	Groundwater replenishment	Scientific and Research importance
	Hunting	Carbon sequestration	Cultural and Historical importance
	Use of reed as natural material	Pollination	Spiritual importance
	Commercial fishing	Control of invasive species	
	Collection of wild species (e.g. snails, mushrooms, leeches, medicinal herbs)		

Research under IDES objectives includes also characterization and evaluation of different governance and cost-effectiveness models for the KPR which include, beside others:

- water quality monitoring and control,
- follow-up of quantitative indicators of environmental effectiveness of targeted woodland planting,
- user guidance on quantifying the effectiveness of tree planting to reduce agricultural diffuse pollution to Danube watercourse,
- biodiversity promotion and implementation of actions to preserve it and make it sustainable on a long term basis,
- promotion and initial implementation of payments for ecosystem services (PES) schemes in KPR, etc.

Main drivers of the water quality degradation has been identified as: (a) lack of urban waste water treatment (unpurified waste water of the Novi Sad city is discharged directly into the Danube River upstreams of KPR); (b) waste water from septic tanks are also emptied into drainage canals constructed around settlement areas, and these canals are being discharged into KPR, causing further degradation to the water quality; (c) intensive forestry in the protected area also has negative impact on water quality. For better accessibility, forestry roads with culverts have been constructed in the floodplain that intersect the channels and oxbows, causing deadwood and driftwood accumulation in aquatic habitats, increased siltation and eventually habitat degradation and loss, directly impacting eutrophication and water quality deterioration.
Nevertheless, other pressures have also resulted in the degradation of the quality of the water. These are currently the drivers and threats of the KPR, but not limited to, that also need to be tackled by the IDES project:

1. Alteration to the natural water regime of the floodplain,
2. Period of the occurrence of floods and the duration of floods,
3. Drainage of wetlands for forestry,
4. Lack of projects for the water regime restoration,
5. Habitat loss and fragmentation,
6. Applications of pesticide to forests and agriculture,
7. Construction of roads and highways,
8. Unsustainable and illegal use of natural resources.

CONCLUSION

Rivers and floodplains, used from first human settlements, are known as hotspots of biodiversity and multi-functional ecosystems, with nutrient rich soils. Due to human activities, floodplains are significantly reduced in Danube region (Hein et al., 2016); remaining ones are, on the other hand, under pressure of high nutrient load that causes substantial algae growth, oxygen depletion, toxicity, accumulation of organic and toxic substances, etc. With new approach in management based on ecosystem services, developed IDES tool, and close communication with stakeholders across the Danube region, nutrient pollution in floodplains and Danube River can be decreased.
Together with water quality improvement, implementation of IDES project will expectedly mitigate conflicts, demonstrate synergies and co-create sustainable, efficient and integrative water quality management options. IDES approach is in the testing phase in pilot areas, including Koviljsko-petrovaradinski rit in Serbia. First results are promising.

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PROMOTING THE APPLICATION OF SMART TECHNOLOGIES IN AGRICULTURAL WATER MANAGEMENT IN BOSNIA AND HERZEGOVINA

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Abstract

The adoption of smart agricultural water management in Bosnia and Herzegovina (BiH) is becoming a priority due to overall increase of water demand by different sectors, pollution of the resources and impact of climate change, which resulted higher frequency and intensity of extreme weather events and loss of agricultural production. Therefore, the necessity to promote a more efficient and sustainable use of resources in agricultural sector is a must to stabilize agricultural production. In this context, a new project "Promoting the application of smart technologies in agricultural water management in Bosnia and Herzegovina - SMARTWATER" is funded by the European Commission (EC) under the Twinning HORIZON 2020 program. The project is coordinated by the University of Banja Luka with the aim to promote the application of smart technologies (cloud-based and remote sensing) in the agricultural water management. The project partners are University of Sarajevo (BiH), Mediterranean Agronomic Institute of Bari (Italy), Consejo Superior de Investigaciones Científicas (Spain), Instituto Superior de Agronomia (Portugal), and SYSMAN PROGETTI & SERVIZI SRL (Italy).

The project overall and specific objectives along with the adopted methodology and expected results are presented. The project activities focus on the reinforcement of networking, research and science and technology cooperation capacities of the University of Banja Luka (UNI-BL), the University of Sarajevo (UNSA) and other connected national institutions in the field of sustainable agricultural water management. The aim is to increase their competency and fund rising skills for a successful participation in the European Union (EU) Research Programs.

Key words: HORIZON 2020, Agricultural Water Management, Smart Technologies, Cloud based technologies, Remote Sensing monitoring, European Union (EU) Research Programs.

INTRODUCTION

The agricultural sector is of strategic importance for Bosnia and Herzegovina. The country is a net food importer (FAO, 2017) and agricultural production is mainly based on rainfed cultivation. The climate is semi-arid Mediterranean on the South and humid continental on the North. Most of the country experiences hot and arid summers, which limit agricultural production. Bosnia and Herzegovina has a relevant irrigation potential estimated at 74,000 ha. However, only 4,630 ha (6.3%) are equipped for irrigation (World Bank, 2012). The agricultural production has been seriously affected by severe droughts and drastic losses of agricultural production, with relevant socio-economic and political consequences. In the recent years (2007, 2011, 2012, 2015, 2017 and 2021) the situation of the agricultural sector has become aggravated due to climate change impact.

In the last few years, several scientific papers dealing with the issues of climate change impact on the variation in yield and water requirements of strategic crops in the Balkan area have been published (Stričević et al., 2014; Jancic et al., 2015; Mihailović et al., 2015; Stricevic et al., 2017). These studies revealed that climate change would contribute to an increase in irrigation demand and concluded that in the period up to 2030, the average yield will not be reduced significantly under rainfed cultivation. However, the increase in temperature and reduction in precipitation expected by the mid of the 21st century, will have a negative impact on yield and will increase irrigation water requirements (Zurovec et al., 2015; Knezević et al., 2018).

Sustainable agricultural water management requires reliable and easy-to-use methods to support real-time irrigation scheduling. This requires a comprehensive knowledge of weather, soil, crop and irrigation system characteristics to determine 'when' to irrigate and 'how much' water to supply in respect to the specific environmental conditions and management strategies. On-farm irrigation scheduling can be supported by means of several technical and scientific methods based on the evaluation of soil plant water status and/or on the simulation of crop soil water balance (McCarthy et al., 2011; Romero et al., 2012; Stambouli et al., 2012).

A number of European countries are devoting intense efforts since the turn of the 21st century to optimize the Water-Energy-Food nexus. In the agriculture of southern Europe, the most complete illustration of this nexus can be found in irrigation systems. Taking these challenges into consideration, many recent research works have focused on improving the energy efficiency of irrigation facilities, optimizing pumping stations and irrigation network design (Rodriguez-Diaz et al. 2009; Moreno et al. 2010; Lamaddalena and Khila, 2012; Zapata et al., 2017). Additional research efforts paid attention to the possibilities at the farm-level end-of-pipe: the irrigation emitter. As energy costs increase, there is a need to find ways to operate sprinkler systems (solid-set and sprinkler irrigation machines) at reduced pressure, without reducing the sprinkler spacing and maintaining high irrigation uniformity. Kincaid (1991), Robles et al. (2017) and Zapata et al. (2018) recently analyzed a reduction of the working pressure at the sprinklers from 300 to 200 kPa, concluding that the pressure reduction did not affect crop yield.

The new automated decision support system Bluleaf (Todorovic et al., 2016), which integrates the results of scientific achievements and technological innovations (software and hardware components) in the fields of crop water requirements and irrigation scheduling, on-field data acquisition, transmission and management, and application of web and app tools for real-time irrigation management, was already tested at several locations as in Southern and Central Italy, Malta and Lebanon. Its robustness has been confirmed and also its capability to save water and energy when compared to traditional irrigation practices (Abi Saab et al., 2019).

The Earth Observation (EO) - based methodologies for estimating K_{cb} and related crop growth parameters (e.g., fraction of vegetation cover) are already tested with Sentinel-2 data (Mateos et al., 2013; Pôças et al., 2015). Additionally, several models for irrigation scheduling and crop growth are in use and tested (calibrated and validated) under specific pedo-climatic conditions as SIMDualK$_c$ water balance model (Rosa et al. 2012) and AquaCrop (Steduto et al., 2009).

The integration of products derived from Sentinel-2 data and derived from irrigation scheduling and crop growth models will be further tested to provide timely-available information, throughout the crop cycle, to support irrigation management. Remote sensing data has been increasingly used for assessing several crops biophysical parameters, including leaf area index, fraction of vegetation cover, actual evapotranspiration, crop coefficients and leaf water potential (Paço et al., 2014: Pôças et al., 2015; Verrelst et al., 2015). Such remote sensing-derived parameters provide spatially and temporally distributed information about crops conditions, thus considering within field variability, and therefore greatly contribute to support management tasks in precision agriculture.

Finally, the concept of eco-efficiency is used to assess the ratio between the economic benefit and produced environmental impact, especially in terms of global warming potential (Todorovic et al., 2018). Hence, the adaptation measures could be seen also from the mitigation point of view in water management resources.

The reinforcement of research and science and technology capacity of BiH institutions to adopt innovative and sustainable water management strategies is of paramount importance in order to stabilize and improve agricultural production in the country. The modern strategies for sustainable agricultural water management aim to optimize the use of resources, while respecting the interest of numerous stakeholders in a complex context of interactions, overlapping of responsibilities, policies and legislation (EC, 2013; EC, 2014a,b; OECD, 2010).

The SMARTWATER project pursues sustainable agricultural water management strategies based on smart technological solutions and integration of technical (agronomic and engineering), socioeconomic and environmental issues. On one side, irrigation performance can be improved by adopting proper agronomic practices, such as the selection of crops/varieties and the cropping pattern, planning of sowing/planting date and growing cycle period, land/soil preparation, application of fertilizers and plant protection measures. On the other side, the performance of irrigation structures can be enhanced by implementing several engineering measures including reduction of water conveyance losses from withdrawal/storage to irrigation district/farm, on-demand-based design of water distribution network and adequate selection and design of on-farm/plot irrigation systems.

The main objective of SMARTWATER is to reinforce, or implement new, networking, research and science and technology cooperation capacities of the University of Banja Luka (UNI-BL), the University of Sarajevo (UNSA) and other connected national

institutions, in the field of sustainable agricultural water management, as well as to increase their competency and fund rising skills for a successful participation in the European Union (EU) Research Programs.
The UNI-BL, UNSA and other BiH institutions are particularly interested in reinforcing the networking and science and technology capacity for optimizing the use of water, land, energy and fertilizers; focusing on the development of modern irrigation methods and management practices; applying the latest technologies and tools for water management, promoting the climate change adaptation and mitigation strategies/measures and eco-efficiency as the main contemporary indicator of sustainability and balanced and rational use of natural resources. All these topics will be promoted by strengthening the involvement of early-stage researchers i.e., those who are at the beginning of their professional carrier and have not yet been awarded a doctoral degree.
The specific objectives of the project are the following:
a) Enhance the capacity building and human resources development of the UNI-BL, UNSA and other BiH institutions for research and science and technology improvement and cooperation in terms of sustainable agricultural water management, facilitating their access to competitive research funding;
b) Strengthen networking between UNI-BL, UNSA, the EU institutions and other BiH and regional (Balkan) institutions through staff exchange, joint workshops/conferences, research themes/studies and exchange of knowledge, data and experts on specific topics of agricultural water management;
c) Setting-up a smart scientific strategy in the field of sustainable agricultural water management for stepping up and stimulating scientific excellence and innovation capacity of UNI-BL, UNSA and other BiH institutions on the short and long-term basis;
d) Adoption/accomplishment of an effective smart communication/dissemination strategy for adequate promotion of twinning activities and ensuring the expected impacts at regional, national, EU and global level.
The achievement of the project objectives is planned through a series of twinning activities, which will be carried out within a period of 36 months. The monitoring of project achievements will be done through a set of clear and measurable indicators for each specific activity.

METHODOLOGY

The methodology adopted by the project includes a series of collaborative activities and measures designed to guarantee the achievement of the overall and specific objectives of the project related to the field of sustainable agricultural water management. Hence, SMARTWATER will focus on substantial stepping up of the research excellence and innovation capacity of UNI-BL, UNSA and other BiH research institutions, and on the sustainability of project results.
This requires improving the scientific capacities of early stage researchers and other personnel involved by: 1) creating an environment favorable to the creation of research/business partnerships and market research services; 2) facilitating the participation of BiH institutions in research and innovation networks; 3) improving the

capacity of BiH institutions to access national, international and EU funding; and 4) ensuring quality in science and technology performance and in the delivery of research and innovation goods.

To increase the scientific capacities of UNI-BL, UNSA and other BiH institutions on the thematic areas of agricultural water management, the project will organize:

- Three advanced specialized training courses abroad (Italy, Spain and Portugal) where participants (mainly early-stage researchers) from UNI-BL, UNSA other BiH institutions will be trained by the scientifically excellent partner institutions;
- Three post-graduate international Master of Science (two-year lasting) courses on topics related to agricultural water management addressing young early stage researchers from UNIBL, UNSA and other institutions, to give them the opportunity to accomplish MSc degrees;
- Three summer schools on the topics of sustainable agricultural water management combining scientific theory and practice with the acquisition of skills to use innovative technologies in water management;
- Three workshops targeting access to EU funding resources for research and innovation, and using a hands-on approach;

Summer schools will be open to all interested local professionals from agro-businesses, farming companies, decision makers, extension officers, agricultural high school teachers, etc. In this way, except for the transfer of knowledge, SMARTWATER will ensure the connection between actors from different agro-sectors and close the existing gap between the university/research, extension sector and farmers.

THE MAIN CHALLENGES

The main limitations towards a more efficient water use in agricultural sector in BiH include:

1) Lack of reliable and consolidated data concerning crop water requirements for different pedo-climatic conditions of the country;
2) Lack of data on quality control and the procedures for soil/weather/crop/management data acquisition and transfer from the fields to labs for elaboration and interpretation;
3) Lack of adequate IT tools (and trained experts) for monitoring/optimizing on-farm irrigation scheduling and agricultural water use;
4) Lack of implementation of research and technological development agendas on the performance of irrigation systems, optimization of water, energy and fertilizer use, and control of agricultural pollution.

EXPECTED IMPACTS

To strengthen networking, improve knowledge sharing and increase the participation of the BiH institution (coordinating and partners) in international scientific networks the project will:

- Establish an international network on sustainable agricultural water management with key institutions and researchers from the neighboring counties and the EU. Furthermore, SMARTWATER project will strengthen the relatively weak links between experts and researchers in the field of water management in BiH and those who already leaved the country and work abroad. The objective of the network is to establish joint research initiatives and enhance the exchange of research results and opportunities for cooperation in the area of sustainable agricultural water management.
- Establish joint experimental/demonstration fields and studies to support scientific research capacities on sustainable agricultural water management and related topics of particular importance to the specific pedo-climatic conditions of BiH.
- Support mutual exchange of scientists and research staff between the BiH and the EU partner institutions on the specific topics of interest for agriculture and water management.
- Identify a set of research questions to support development of research proposals, set up of students' projects and thesis, co-author teaching material and scientific publications, therefore facilitating the acquisition of skills on how to generate high-impact research and maximizing publication visibility within the scientific community.

The development of a new research proposal represents a final achievement of the project, which will guarantee its sustainability after the completion of the project activities. This new research proposal embraces all results achieved during the realization of the project (i.e. the results of experimental studies, MSc thesis and development of decision support system (DSS) for irrigation scheduling and satellite images elaboration). The setting-up of the smart national scientific strategy for stepping up and stimulating scientific excellence and innovation capacity of the BiH institutions on the short and long-term will provide a strong basis for the continuation of research and innovation initiatives after the completion of the project.

Accordingly, the project will:

- Create a multi-stakeholder dialogue platform to support exchange of knowledge and information and facilitate research/business partnerships. This will be done through two project meetings and several roundtables and public debates involving a wide range of stakeholders bearing an interest in sustainable agricultural water management and related issues.
- Establish a Scientific External Advisory Board (SEAB) for the periodical review and monitoring of the quality of the research coordination activities conducted by the different teams, and providing recommendations for future activities and for the development of the national scientific strategy.
- Design a modern and realistic national scientific strategy based on multi stakeholder dialogue and assessment of the present research and development situation in BiH, the EU and worldwide.

The approach of the consortium to strengthen the agricultural water management research area will be participative, involving a wide range of stakeholders, including researchers, water professionals, policy makers, private/business sector representatives, farmers and consumers. A trans-disciplinary approach will be ensured to account for all the multiple facets that characterize sustainable agricultural water management in the scope of the proposal and in the conditions of BiH.

Additional activities will be organized to further develop the research management and administration capacity. The specific training-capacity building on the practical application of BLULEAF DSS and elaboration of satellite data is foreseen during the advanced short courses and summer schools that will be organized. Moreover, the joint demonstration and experimental studies will be fully based on the testing of DSSs and specific app.

THE LINKS TO THE EU FRAMEWORK PROGRAMMES

The SMARTWATER project relates to the topic WIDESPREAD-03-2018: Twinning, as set out in the call H2020 WIDESPREAD 2018-2020, Spreading Excellence and Widening participation. The project addresses the specific challenges identified by the Twinning for improving the overall scientific and innovation capacity of low-performing associated countries by collaborating with internationally leading counterparts.
These challenges include: a) capacity building for research, science and technologies development and fund rising; b) networking and strengthening links with internationally leading research institutions in the EU countries; and c) setting of smart research strategy for the promotion of excellence and innovation in the field of sustainable agricultural water management.
The project will boost the research and science and technologies capacity of the UNI-BL, UNSA and other BiH institutions through a series of capacity building and human resources development actions like advanced training courses, joint MSc program, summer schools and research and innovation funding workshops. In this context, the project will particularly promote the involvement of early-stage researchers (ESR) and support their research and fund-raising capacities as well as those of other stakeholders interested to increase their competence in the field of sustainable agricultural water management.
The project addresses the networking gaps and deficiencies between the BiH institutions and leading EU partners. The project foresees a series of joint activities promoting networking, joint experimental/demonstration studies on specific research themes, smart water management tools, and exchange of knowledge and experts on specific topics of agricultural water management. SMARTWATER foresees the publication of joint research documents at international conferences and peer review journals. This will raise the research reputation of UNI-BL, UNSA and other BiH institutions as well as the research profile of ESR and other staff.
A technical assistance and expertise to improve the research and innovation systems of UNI-BL, UNSA and other BiH institutions and to delineate adequate research strategies and policies for the future will be provided. The strategy will follow the principles of sustainable development, actual research and science and technologies achievements, and responsible research and innovation process that will step up and stimulate scientific excellence and innovation capacity of UNI-BL, UNSA and other BiH institutions on the short and long-term basis. This will imply the engagement of a wide range of stakeholders, the design of a policy roadmap for decision makers and the establishment of a Scientific External Advisory Board for the review for existing strategy and monitoring of the quality of research conducted in the field of agricultural water management.

The participation in the EU Framework Programs is increasingly dependent on the research and science and technologies capacity, networking and staying connected with partners across the EU. SMARTWATER will approach the above challenges through the accomplishment of activities, which will help the fund rising capacity of the UNI-BL, UNSA and other BiH institutions.

CONCLUSION

The SMARTWATER project focusses on the reinforcement of networking and science and technologies capacities of BiH by involving researchers from other relevant institutions covering different regions and pedo-climatic conditions. Moreover, the SMARTWATER project will pursue the multi-stakeholders approach and will engage wider civil society and citizens to participate in the debate, definition and implementation of a research and innovation policy agenda and related activities.

A modern strategy for stepping up and stimulating scientific excellence and innovation capacity will be outlined. This strategy will endorse the sustainable development objectives in agricultural water management, which should be based on the principles of eco-efficiency, i.e. increasing the economic benefit of the agricultural sector while reducing negative environmental impacts. In this context, the principles of Responsible Research and Innovation (RRI) will be encouraged as a process of aligning research and innovation to the values, needs and expectations of society, which allows to identify and to deliver new eco-efficient solutions to the societal challenges.

Therefore, it is expected that the realization of the above-mentioned activities will create synergic effects in the enhancement of agricultural water management sector and effective application of innovative technologies in agricultural sector of Bosnia-Herzegovina.

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HISTORY OF THE FRENCH ASSOCIATION FOR THE STUDY OF SOIL (AFES)

www.afes.fr

Agnès Gosselin (secretary), Jacques Thomas* (chair), Denis Baize (treasurer), Christian Feller (past chair)

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Abstract

1934. Created by A. Demolon, the AFES is organized into 6 "technical sections" (Genesis, Physics, Chemistry, Biology, Soil Geography and Soil and Hygiene, Overseas) and 7 "regional sections" (North, Brittany, East, South, South-West, Massif Central, Overseas)
The *Bulletin de l'AFES* was published 4 times a year.
The war stopped the AFES in its tracks. Activity did not resume until 1947 (see number of members: 173 in 1934, 405 in 1939, then 145 in 1947).
1947 was the year of the "Conférence de Pédologie méditerranéenne" (Montpellier-Alger).
1963. The revue *Science du Sol* replaced the *Bulletin de l'AFES.*
1967. The study of the spatial distribution of soils allowed the publication of the first French Soil Map at 1:1,000,000 and led to the French Classification of Soils (CPCS, 1967).
The « Service d'Étude des Sols et de la Carte Pédologique de France" was created within INRA (Institut National de la Recherche Agronomique). This activity results in the *French Soil Reference System* (RPF), published in translation and widely distributed between 1987 and 2009.
Since **1967**, the activity is centered on the organization of 2 or 3 annual scientific sessions, accompanied by publications. Diversified themes are addressed.
The AFES grew and in **1991** had more than 852 members. The activity of the technical sections decreases, the regional sections remain dynamic (indoor meetings and field trips).
Activities 1992–2020:
<u>Communication, publications, scientific animation</u>:
1984. Creation of the *AFES Newsletter.*
1992. The journal *Étude et Gestion des Sols* (EGS), distributed in paper form, became electronic in 1997 (free access in 2013).
1994. *Science du Sol,* along with the Belgian and British reviews *Pédologie* and *Journal of Soil Science*, ceased to be published to support the joint launch of *European Journal of Soil Science*.
The sol-Afes web list (1711 subscribers in 2020) allows many online debates.
<u>Organization of congresses:</u>
1998. 14th World Congress of Soil Science, Montpellier.
"National Soil Study Days" (JES), biennial, since 1989.
"World Soil Day" (5 conferences since 2015),

Training

2003. Creation of the "Demolon Scholarships": awarded annually to thesis students (participation in international conferences).

1998. Year of the soil, AFES is very active.

2004-2008. ISIS ((Initiation of schoolchildren to soil via the Internet) project: AFES is involved in teaching about soils in secondary schools (distribution of 20,000 leaflets entitled "*Le sol, épiderme vivant de la Terre*")

2011. Creation of a "Recognition of competence in pedology" procedure awarded by a jury of AFES pedologists.

2012. 1st "AFES Webinar", currently 54 videos available.

2018. Birth of the "PromoSolsEduc" Working Group with teachers: a space for valorization and exchange of pedagogical sheets "soils".

Keywords: History of Afes 1934-2021, functioning, activities, communications, congresses, training

AFES[11] is a learned society created in 1934, and which, obviously, has evolved since that date. This article aims to summarize its history[12].

THE MAJOR STAGES: THE LIFE STORY OF A LEARNED SOCIETY, ANCHORED IN ITS TIME

AFES was created in 1934 by Albert Demolon (1881–1954), a scientist who dominated agricultural research between the two world wars. A precursor of the scientific approach, he introduced an objective, collective, experimental, repetitive, rational and normative attitude.

For Albert Demolon, the soil is not a simple support or chemical medium for plants; it is a living medium, the seat of almost permanent transformations through hydrolysis, the action of micro-organisms and all the living beings that make up an important part of the soil.

With Auguste Oudin, Director of the École Nationale des Eaux et Forêts, their ambition was to have pedology recognized as a science in its own right in France.

Albert Demolon remained president of the Association from 1934 to 1954.

The first objectives of AFES were: to support and promote the development of progress in the study of soil, to provoke, help and coordinate research and to popularize the application of their results, particularly in agricultural practice.

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[11] A glossary of acronyms is available in Appendix 2

[12] In this article, everything concerning the period 1934-1983 is borrowed from an article by Georges Pedro, published in 1984 on the occasion of the fiftieth anniversary of AFES: "Introduction. The French Association for the Study of Soil. Its role in the development of soil science in France (1934-1984)". pp. 19-40 In AFES ed. 1984, Livre Jubilaire du Cinquantenaire AFES-50. Paris, 349 pp.

AFES aims at creating a real community between persons or groups interested in the different branches of soil science and its applications and its consideration by related disciplines.

From 1934 to 1939

The AFES was then organized into 6 sections called "technical" on major themes:

I. Geology applied to the genesis of soils. Pedology in general. Soil classification and cartography. Regional study of soils. Forest soils. Peat soils. Mountain soils. Colonial soils, etc.
II. Soil physics. Climatology. Working the soil. Rural, civil and military engineering.
III. Soil chemistry. Fertilization, amendments, fertilizers.
IV. Soil biology.
V. Physical, botanical and economic geography.
VI. Soil and hygiene.

These technical sections are supported by 7 French Regional Sections, including a section entitled "Overseas". It is clearly later, in 1990, that a "Youth" section of the AFES will be created. The activity of these regional sections will diminish over the years to, unfortunately, almost disappear around 2010.
The Association grew rapidly and was very active during this start-up phase and had up to 405 members. Section 1 (Genesis) was the most active, based on a synthetic and naturalist vision of soil science: it contributed strongly to the diffusion of Pedology as a science in its own right. However, the momentum of this period was halted by the war. The AFES recovered slowly and with difficulty from this interruption, since its activity did not resume until 1947.

From 1947 to 1983

This period constitutes a phase of recovery and development.
The occasion was the organization, in 1947, of the "Conférence de Pédologie Méditerranéenne" (Montpellier-Alger). As mentalities had changed, the technical sections disappeared and the activity of the Association was essentially carried out through its Regional Sections, North-West, Massif Central and Algeria, then Burgundy, Alsace and South-West from 1960 on.
The Regional Sections carried out a large work of typological inventory of soils in different natural regions or “terroirs”, organized meetings with communications in the classroom or field trips, while the national activity was limited to the annual General Assembly in Paris, accompanied by one or two communications. This extremely fertile period, at the French level, on the intellectual level, was marked by several important events, including, in particular, the organization of the 6th World Congress of Soil Science in Paris in 1956, and the publication, from 1963 onwards, of a scientific journal "Science du Sol" which complements the regular bulletin of AFES. It has allowed to establish and deepen the general concepts of Pedology and to extend them to both

Earth Sciences and Agronomy. On a practical level, this resulted in the implementation and promotion of pedological mapping and classification operations (cartography of French soils at 1:1,000,000; creation within the framework of INRA of the Service d'Étude des Sols et de la Carte Pédologique de France (Soil Study Service and Pedological Map of France; French Classification of Soils, and CPCS, Soil science and Mapping Commission – 1967).
From 1967 on, the Association took on another dimension, mainly in terms of scientific sessions. Numerous topics are addressed, both pedological and applied. The actions of the AFES developed since then are detailed in the heading "actions" which can be consulted by following this link: https://www.afes.fr/presentation-actions/.
In 1984, AFES had 787 members.

From 1984 to 1997

During the fiftieth anniversary of the AFES in 1984, an exhibition on soils was produced. It toured France during AFES sessions or on the occasion of other congresses.
The AFES sessions are meetings on a scientific theme to exchange and report on the progress of each other's work. They take place 3 times a year (March, May and November) with, for each one, a time of presentations and a time in the field.
Working groups also exist: History of pedology, Epistemology, Sociology, International Association of Soil Science, Ecology and microbiology of soils, Humus.
AFES maintains regular links with soil science associations in other countries: Germany, Switzerland, Spain, Belgium, Poland, Russia, Greece, as well as those in African countries.
In the field of training, we should mention the following creations:
- in 1985, the creation of a "DEA (Diploma of Advanced Studies) national pedology",
- in 1990, at the University of Burgundy, a Diploma of Higher Specialized Studies (DESS) "Rural Areas and Development" largely focused on soil,
- in 1991, the request to AFES by the National Education Program Committee to participate in the reform of secondary education.

1990 marked the turning point for the AFES in terms of the environment. In February 1990, there was already talk of "global change"; on September 25, 1990, the scientific jubilee in honor of Stéphane Hénin concluded with a focus on environmental issues; on November 22–24, 1990, soil science was in the spotlight at the 108th congress of the Afas (French Association for the Advancement of Science) in Orléans, France, which was devoted to "Man and the Environment”.
In 1991, the AFES mobilized 852 members.
It was also in May 1992 that the subject of "Soil" was considered on a political level at the European level with a reflection on a "Soil Protection Policy - R(92)8" which aimed to have the "functions and services rendered by soils" recognized. This European project will not emerge again until 2021. All of this will be affirmed with the "Earth Summit" congress in Rio de Janeiro in 1992, and the activities of the AFES, including the content of its newsletter, are strongly marked by the words "environment", "sustainable agriculture", and "respect for the soil resource", which become recurrent themes. This was

followed by a dossier entitled "Terre, patrimoine commun" published in September 1992 by the Descartes Association.
The reflection on soil classifications was not abandoned. The old CPCS classification of 1967 is reworked to make way for a (French) reference system that meets more pragmatic objectives. Under the aegis of AFES and INRA (Institut National de la Recherche Agronomique) and coordinated by Denis Baize and Michel-Claude Girard, more than a hundred French and foreign soil scientists (138) participated in the construction of the reference system. A first edition of the Référentiel Pédologique (RP) was published in 1992, then completed in 1995, and revised and completed again in 2008.
During the years 1995–2000, a major turning point in AFES took place around the Internet and computer science and the development of networks. We can mention, in particular, the creation by Christian Walter, in September 1997, of the digital mailing list Sol-AFES.
In 1998, the first AFES website was created, initially hosted by INRA.

From 1998 to 2009

In 1998, France organizes the 16th World Congress of Soil Science in Montpellier.
In 1998, France organized the 16th World Soil Science Congress, and it was a Frenchman - Alain Ruellan - who became president of the International Soil Science Association (AISS) in 1994. The organizing committee of the congress was chaired by Marcel Jamagne and the scientific committee by Georges Pedro.
This congress was a great success and the AFES Newsletter n°48 of September 1998 carried essential information about the congress. There were 45 symposia, 2,505 participants including 674 French, 99 countries represented, 3 exhibitions, a pedological outing and various interventions in schools.
It was during this congress that Alain Ruellan proposed that the AISS become a scientific union: the International Union of Soil Science (IUSS). The statutes changed in 2001, and the structure of the IUSS differs greatly from that of the AISS. It is this structure that is still operational today.
Although 1998 was the Year of the Soil for France, it should be noted that the same year the subject "soil science" was removed from the secondary school curriculum.
From 1994 to 1999, Afes participated in numerous works on standardization issues.
2000: creation of the European Society of Soil Sciences (ESSS): a Eurosoil congress to be held between two IUSS world congresses.
Concerning the finances of AFES, the year 2000 corresponds to a strong decrease in subsidies from the Ministry of Agriculture (Directorate of Education and Research, Ministry of Agriculture, Food and Forestry).
In 2001, a "priority action plan" of AFES was envisaged and concerned: a new logo, the implementation of the "Recognition of skills in pedology", a reflection on the teaching of soil, and work on standardization.
AFES, a learned society, is gradually opening up to the professional world in order to respond to the challenges of society in terms of managing the planet. To this end, AFES set up "Personal and Educational Works" (TIPE) in agricultural colleges. The best works will be presented at the Journées d'Étude des Sols (JES);

In 2006 the statutes of AFES were revised and updated (modifications approved on April 3, 2007).
The period 2008–2010 is important for the strong activity of AFES in the field of secondary school education aimed at showing the importance of soils for nature and humanity and to convey to the general public the main concepts related to the role of soils in the environment and the need to protect them. The two main actors were Roland Poss and Alain Ruellan. There were thus:
- the translation and reorganization of an English brochure provided by the IUSS, followed by the distribution of 20,000 copies of the French version, under the title “Le sol, épiderme vivant de la Terre”;
- the publication, in 30,000 copies, of a booklet entitled “Soils for the Future of Planet Earth”, sponsored by various institutions;
- the development of an integrated SVT - physics chemistry - technology teaching program for the 6th and 5th grades, based in part on the theme of soils, within the framework of a multi-year experiment by the French Ministry of Education (general manager, E. Guyon, with several participants who are members of AFES under the coordination of R. Poss);
- a follow-up of the personal work (TPE) of students of 1st S of Montpellier with presentation of the best ones at the World Water Congress (September 2008);
- the realization, by Alain Ruellan, of a book for the general public on landscapes and soils, to be published in 2010 by IRD under the title “Des sols et des hommes. Un lien menacé”;
- a strong participation of AFES in the "International Year of Planet Earth" with the drafting of brochures, contacts with journalists from the written press or television in order to obtain programs on soils, etc.
In spite of the effervescence of the activities and for multifactorial reasons, the number of members is constantly decreasing from 800 members in 2000 to 467 members in 2007.

After 2009

AFES continues its recurrent and regular activities. We can mention:
- the biennial organization of the JNES (then the JES) and the annual organization of the World Soil Day (JMS),
- the presentation of webinar-type conferences under the direction of C. Walter and F. Feder. In 2021, there are 53 webinars available on the Vimeo channel and the AFES website;
- the " Formal recognition of competences in Pedology ", action led by D. Baize. To date, 19 people have been recognized as competent[13];
- support to PhD students to attend international congresses thanks to the "DEMOLON grants". Created in 2003, more than 50 scholarships have been awarded[14].

13 https://www.afes.fr/actions/reconnaissance-des-competences-en-pedologie/
14 https://www.afes.fr/actions/bourse-demolon/

The year 2015, decreed by the UN/FAO "International Year of Soil", is obviously important for AFES and French soil science in general. But it is also the holding of the COP 21 – Paris, a historic COP for major global issues. It is at this event that the French Minister of Agriculture is proposing the "4 for 1000" initiative, which places soil at the highest level of global issues.

Let us recall that the idea of this "4 for 1000" comes from a publication by our colleagues from INRA, Jérôme Balesdent and Dominique Arrouays[15].

Let us also recall that the FAO ambassador for the International Year of Soil (2015) was Claire Chenu, our eminent colleague from AFES.

Since 2015, AFES has been pursuing 2 new objectives in parallel:

- to define a common vocabulary repository for the scientific community,
- to define a complete vocabulary that can be understood by all those concerned by the "soil capital".

AFES TODAY, TO MEET THE CHALLENGES OF THE 21ST CENTURY

Objectives and actions

AFES is a learned society of associative status gathering professionals and researchers working on soils. It is the French branch of the International Union of Soil Science (IUSS), a partner of the Global Soil Partnership (GSP) and a forum for debate for the French soil science community. In 2021, it mobilizes less than 300 members, whereas the sol-AFES digital list has more than 1700 subscribers. How best to respond to the challenges facing society with regard to soils? This was the theme of the 2021 General Assembly. After a reflection on the place of learned societies "Understanding the mistrust of science. What are the stakes for a learned society?", debates between the members allowed to update the objectives of the AFES. An action plan resulting from these debates is currently being designed.

The association has a website: www.afes.fr.

The association promotes the study of soil in different ways: forums on its email lists, publication of a journal and books, participation of some of its members in working groups (e.g.: Recognition of Competences in Soil Science[16], Standardization of methods, or the "Prospective" working group of AllEnvi) and also through support actions towards young researchers such as the DEMOLON grants or the "young" list disseminating job offers in the sector[17].

The associative dynamics and the development of the association are also due to the capacity of its members to get involved in the governance of organizations carrying out complementary actions to AFES (Comifer, APCA, IUSS, RMT Sols et Territoires,

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15 Land use and carbon storage in French soils. An estimation of the annual net fluxes for the period 1900-1999 - C.R. Acad.Agric. 1999, 85, n°6, pp 265-277. Session of 19 May 1999 by Jérôme Balesdent and Dominique Arrouays.

16 https://www.afes.fr/actions/reconnaissance-des-competences-en-pedologie/

17 https://www.afes.fr/afes/les-listes-de-diffusion

RNEST ...). Administrators sit in various bodies: RNEST, CNB, Comifer, Cofusi, CSFD, IGCS.
AFES is also a stakeholder in French institutions and organizations concerned with soil issues: Afa, Afeid, Andhar, Apad, APBG, SFE.
AFES is represented in international organizations such as WCSS, GSS, WRB and has regular contacts with other European soil science associations.
In 2021, AFES is the founding vice-president of the Pyrenean Soil Alliance ASPir, a cross-border consortium that complements the global alliances of the GSP.
In recent years, AFES has developed a strong desire to broaden its audience through its various actions, in particular by involving more local elected officials and other decision-makers whose projects are decisive in the orientation of soil use, in particular by organizing its conferences in various French regions such as the World Soil Day (JMS), or the (biennial) Soil Study Days (JES).

Governance and operation
https://www.afes.fr/afes/fonctionnement/

The current Board of Directors (BOD) is composed of 18 people from various socio-professional backgrounds.
The President is supported by 6 vice-presidents, each in charge of a portfolio: Education, Legal Affairs, Youth and Communication, Research, Private Sector, Sustainable Soil Management.
In order to achieve the objectives of the Association, the Board of Directors has set up 8 working groups and 4 committees.
The working groups concern: Communication, World Soil Day (WSD), Soil Study Days (SSD), soil education (PromoSolsEduc), support for students (DEMOLON scholarships), Webinars-AFES, WRB (IUSS soil classification group), standardization of data and methods (Afnor-Iso)[18].
The commissions of reflection are interested in wetlands (ZH), the concept of "Zero Net Artificialization" (ZAN), Biodiversity, Soil Evaluation.

ACTIVITIES: WHAT IS AFES FOR?

https://www.afes.fr/wp-content/uploads/2020/11/Flyer-AFES-2020.pdf

Communicating to promote soil science
This is the purpose of the Soil Study Days (JES), the Webinars and the EGS journal which has been published for 28 years as well as the publications in which AFES participates.

Supporting young researchers

[18] This activity had already started in 1994 with a marked activity until 1999

With the Demolon Fellowships, the “Horizon-Jeunes” list and the support to training actions.

Communicate to facilitate the transfer of knowledge, in particular to decision-makers
This is the purpose of the website and the World Soil Day (JMS) organized each year with the FAO and the Parliamentary Club for the Study and Protection of Soils.

Facilitate the exchange of knowledge and the search for information and resources on soil
This is the objective of the website, the AFES newsletter, the work on the Pedological Reference System, the Recognition of Pedological Skills, the mapping of pedologists, but also the mailing lists. For example, the "Sol-Afes" list is made available to offer its subscribers a fast and free way to reach the soil science community, this mailing list allows online discussion, announcement of events or publications.
Created in 1997, it had 200 subscribers in 1998, 816 in 2004, 1550 in 2016 and 1711 in 2021. From April 2021, summaries of the discussions will be integrated into the "Afes letter".

Opening partnerships with other professional groups
This is in particular the role of the PromoSolsEduc project.
Initiated in 2019 with a survey of teachers in 5 regions, this operation is set up to facilitate the teaching of soil in all its facets by creating a network of teachers and experts.
The 2022 objectives are: to consolidate and animate the PromoSolsEduc network of teachers and trainers, to offer collaborative workshops, and to update a virtual resource and teaching sheet sharing center on the AFES website.

AFES PUBLICATIONS

https://www.afes.fr/publications/

Below is a list of publications that have been edited, co-published or carry the AFES logo (*). The presence of the AFES logo indicates an AFES participation in the work or a recommendation by AFES.

The Bulletin de l'AFES
This Bulletin was founded in 1949. It was published in mimeographed form until 1968 with 6 issues per year. It was then printed until 1972, when it was discontinued.

The journal « Sciences du sol »
This journal began to be published in 1963 at a rate of 2 issues per year until 1972, then 4 issues/year until 1984, the year in which M.-C. Girard was appointed editor-in-chief of the journal. In 1992, this publication is stopped because a discussion at the European level aims at regrouping several national reviews within a single review: European Journal of Soil Science (EJSS).

The first issue of EJSS was published in 1994 (Claire Chenu and G. Bourrie were on the editorial board). Initially, EJSS is supposed to be multilingual, with articles in French. But, in fact, very quickly the multilingualism disappeared and the journal is now exclusively in English.

The journal « Étude et gestion des sols » - EGS.

Following a survey, the AFES Board of Directors decided in 1992 to create the journal "Étude et gestion des sols". The aim was to provide a publication space for French-speaking soil scientists who were unfamiliar with English.

The first issue was published in July 1994; the journal become electronic and free in January 2013. The director of the publication is statutorily the president of AFES and current editor-in-chief is Dominique Arrouays[19].

2021: 28th year of publication.

The AFES Newsletter

The creation of the AFES Newsletter dates back to 1983, on the occasion of the Association's fiftieth anniversary, in order to chronicle the life of the Association, to circulate information among its members, and thus to maintain the dynamism of French soil science.

As of June 2021, 112 AFES Letters have been published.

Other publications

1984. Jubilee Book of the AFES. AFES, 349 pp.
1987. Podzols and podzolization. (D. Righi and A. Chauvel eds.), 231 p.*.
1990–2008. Le Référentiel pédologique (RP) - French soil designation system. The various editions of this work were coordinated by D. Baize:
- August 1990: the RP is presented at the 14th International Congress of Soil Sciences in Kyoto.
- 1992: first edition
- 1995: second edition (and translation into English).
- 2009: third edition
1998. Proceedings of the 16th World Soil Congress - Montpellier (France)
2007. Les Grands Sols du Monde. PPUR, Lausanne, 574 p. Co-publication of the book written by J.P. Legros. *
2008. Co-publication of 2 booklets: The soil, living epidermis of the Earth (R. Poss and A. Ruellan); Soils for the future of planet Earth (A. Ruellan and R. Poss) *
2011. Les grands paysages pédologiques de France, M. Jamagne, Quae éditions. 536 p.*
2013. co-publication of the Game of the 7 families " the hidden life of soils ". GESSOL program. *
2018. Surface covers of the Earth's continental spaces, by G. Pedro. AFES, 191 p.
2021: The origin of the world. A natural history of the soil for those who trample it, by M.-A. Selosse. *

[19] http://www.afes.fr/publications/revue-etude-et-gestion-des-sols/

APPENDICES

Appendix 1. List of presidents and general secretaries of the Association

Les présidents de l'Afes	Les Secrétaires généraux de l'Afes
1934–1954 A. Demolon	1934–1948 Maurice Lenglen
1954–1956 M. Lemoigne	
1956–1959 A. Oudin	
1959–1962 G. Aubert	
1962–1965 R. Chaminade	1948–1964 Pierre Boischot
1965–1968 J. Hebert	
1968–1971 S. Henin	
1971–1974 G. Barbier	1964–1972 A. Anstett
1974–1977 G. Drouineau	
1977–1979 P. Duchaufour	1972–1985 Jean Claude Begon
1979–1981 N. Leneuf	
1982–1986 G.Pedro	1985–1992 MC Girard
1987–1989 J. Boulaine	
1990–1992 A. Ruellan	
1993–1995 J.C. Remy	1993–2002 Micheline Eimberck
1996–1998 M. Jamagne	
1999–2001 M. Latham	
2002–2005 D. Tessier	2003–2008 J.P. Legros
2006–2008 R. Poss	
2009–2010 J.P. Legros	2008–2009 C. Collin Bellier
2011–2012 C. Feller	
2013–2015 D. Arrouays	2009–2013 Laurent Caner
2016–2018 C. Collin Bellier	2013–2015 Guilhem Bourrie
2019-2021 M. Brossard	2016–2017 Léa Beaumelle
2021– J. Thomas	2017– Agnès Gosselin

Appendix 2. Glossary of acronyms

A2.1. French organizations and tools

Ademe: Agence de la transition écologique
Afnor-Iso: Agence Française de NORmalisation produisant les normes « Iso »
AllEnvi: Alliance nationale de recherche pour l'environnement
APCA: Assemblée Permanente des Chambres d'Agriculture
BRGM: Bureau de Recherche Géologique et Minière
CEMAGREF: Centre d'Étude du Machinisme Agricole et du Génie Rural des aux et Forêts (institut de recherche publique)
CIRAD: Le Centre de Coopération Internationale en Recherche Agronomique pour le Développement.
CPCS: Commission de Pédologie et de Cartographie des Sols
CNB: Comité National de la Biodiversité
CNRS: Centre National de la Recherche Scientifique
Cofusi: Comité Français des Unions Scientifiques Internationales
Comifer: Comité Français d'Étude et de Développement de la Fertilisation Raisonnée
CSFD: Comité Scientifique Français de la Désertification
GESSOL: "Fonctions environnementales et GEStion du patrimoine SOL", programme de recherche initié par le ministère de l'Environnement
Gemas: Groupement d'Etudes méthodologiques pour l'analyse des sols: Association qui regroupe une trentaine de laboratoires d'analyses agro-environnementales sur tout le territoire Français
GEPPA: Groupement pour l'Etude des Problèmes de Pédologie Appliquée
GFHN: Groupe Francophone Humidimétrie et TraNsferts en Milieux Poreux.
IGCS: Inventaire, Gestion et conservation des sols
INRA: Institut National de la recherche agronomique
OMD: Objectifs du Millénaire pour le Développement
ONIC: Office National Interprofessionnel des grandes cultures.
ORSTOM: Office de la Recherche Scientifique et Technique Outre-Mer
Devenu en 1984 Institut Français de Recherche Scientifique pour le Développement en Coopération et en 1998 Institut de Recherche pour le Développement (I.R.D.).
RMT Sols et Territoires: Réseau Mixte Technologique Sols et Territoires
RNEST: Réseau national d'expertise scientifique et technique sur les sols

A2.2. Other French associations

fa: Association Française d'agronomie
feid: Association Française pour l'eau, l'irrigation et le drainage
Andhar: Association Nationale de Drainage et d'Hydraulique Agricole Responsable

pad: Association pour la Promotion d'une Agriculture Durable
APBG: Association des professeurs de biologie géologie.
SFE: Société Française d'écologie et d'évolution

A2.3. The days and actions of the AFES

JMS: Journée Mondiale du sol
JES: Journées pour l'Etude du sol
ISIS: Initiation des scolaires par Internet au sol (conférences dans les écoles en 2004 et 2005)

A2.4. International organizations

IUSS: International Union of Soil Science
GSP: Global Soil Partnership
WRB: World Reference Base for Soil Ressources
WCSS: World Congress of Soil Science
GSS: Global Soil Security

SOCIETAS PEDOLOGICA SLOVACA

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Abstract

The establishment of the Pedological branch of the Slovak Geographical Society at the Slovak Academy of Sciences was made in 1964 in Bratislava under leading of prof. Dr. Juraj Hraško. In this paper there are showed some significant milestones of historical development of Slovak Soil Science Society: a) establishment of the Slovak Soil Science Society in 1969; b) incorporation of this society into the Slovak Society of Agricultural, Forest, Food and Veterinary Sciences in 1973 as Pedological section; c) rename of the society on Societas pedologica slovaca (SPS) in 1990; d) new legal foundation as a civil association in 1995. President of Societas pedologica slovaca is Assoc. Prof. Dr. Jaroslava Sobocká, member of the Board is prof. Dr. Jozef Kobza. The seat of Societas pedologica slovaca is located at Soil Science and Conservation Research Institute in Bratislava. SPS is also included as a Pedological section for Slovak Society for Agricultural, Forest, Food and Veterinary Sciences at Slovak Academy of Sciences. SPS is a member of International Union of Soil Sciences (IUSS) and also a member of European Confederation of Soil Sciences Societes (ECSSS). The main aims of SPS are: to organize scientific groups for development of soil science and protection of environment, promotion of scientific results of pedological research, to support of soil policy and creation of new legislative measures, to support development of international relationships and international exchange of scientific information concernig soil science and landscape protection, to help young generation of researchers and scientists through educational and pedagogical activities, to support sustainable land use. The implementation of the main activities of SPS consits of lecturing, organizing seminars, conferences. After the division of former Czech-Slovak Republic – since 1993 year, we organize together with Czech Society of Soil Science international soil science conferences named „Pedologické dni" (Soil Science Days) alternately one year in Slovakia and second year in the Czech Republic with field excursions. There are representing their members and organizations at national and international level and cooperation between organizations in soil research and related topics, expert works and consultancy in soil science and soil conservation as well as development of publishing activities concerning the latest results of pedological research. SPS published the latest version of Morphogenetic soil classification system in Slovakia (2014). SPS has been publishing Proceedings named „Vedecké práce" of research and scientific works yearly, but currently, since the 1-July, 2021 these were changed on the International Journal PEDOSPHERE RESEARCH. Details for contributors are listed on the website www.pedosphereresearch.sk. More activities of SPS are listed on the website www.pedologia.sk.

Key words: Societas pedologica slovaca, history, current activities, Czech Society of Soil Science, International Union of Soil Sciences

INTRODUCTION

Comparing to other natural sciences, soil science is a very young science. In the contribution the soil science society's activities are presented since the foundation to the recent time. The establishment of the Pedological branch of the Slovak Geographical Society at the Slovak Academy of Sciences was made in 1964 in Bratislava under leading of Prof. Dr. Juraj Hraško. Some significant milestones of the Slovak Soil Science Society development were recognized like establishment of the Slovak Soil Science Society in 1969, incorporation of this society into the Slovak Society of Agricultural, Forest, Food and Veterinary Sciences in 1973 as Pedological section, rename of the society on Societas pedologica slovaca in 1990, new legal foundation as a civil association in 1995. In the paper a list of main activities (conference and seminars organization, pedological field excursions, international contacts) are presented.

HISTORICAL PERIOD

1750 – 1918

The first studies observing the soil from a scientific point of view occurred in Slovakia in the 2nd half of the 18th century. Matus Pankl, professor of Royal Academy in Bratislava (Academia Istropolitana) published first manual on agriculture. He paid much attention to soil properties in his Handbook of Agriculture (several editions: 1790 in Lat. with Latin - Slovak - German - Hungarian dictionary, 1793, 1797, 1810 all three in Lat., 1964 in Slovak.). He characterised the soil physical properties, explained the importance of soil texture and organic matter. He studied the organic matter mineralization and propagated a new manure approach.

At the same time Juraj Fandly (1750–1811) edited the Agricultural Encyclopaedia in 6 great volumes (Trnava, 1792), in which he also propagated the modern knowledge on soil properties and land management methods. The great advantage of this book, written in Slovak language, was that it could be understood by farmers and it was dedicated directly to them and the structure of the text was accommodated for this purpose.

Initiation of soil science as serious science in modern sense, in the territory of Slovakia, was dated to second half of 19th century. Dionýz Štúr (1827–1893), one of the best Slovak geologists, becoming later the director of the Imperial Geological Institute in Vienna, published his study „The influence of soil on the spatial variability of vegetation (1856–1858). This study, written in German, became the first study of the soils from the point of view of natural sciences. It became well-known at international level.

In the last decades of the 19th century several specialised agricultural schools were founded. The first one was opened in 1871 at Liptovsky Hradok. Later nine other agricultural schools were established, the last one in 1913. The agricultural school in

Košice was transformed to an Agricultural Academy, the first agricultural high school in Slovakia. These agricultural schools served as background of the first institutional base for soil research. However, the attention was paid mainly to manure and only a little attention was paid to the soil research.
Important role played Gregor Friesenhof (1840–1913), rich landowner, who belongs to founding members of Matica slovenska, the first Slovak scientific institution. He was interested in agro-meteorology and he initiated voluntary activities to educate farmers and to improve their life standard. He propagated cooperative farms, among farmers and despite he was of German-Russian origin in local journals he published papers about modernisation agriculture in Slovak language. His most successful achievement was the construction of new type of plough (plough of Nedanovce-Brodzany) and implementation of this new agricultural tool to daily use among Slovak farmers.
In the first decade of 20th century the agro-geological survey was organised by the Hungarian Royal Geological Institute at Budapest. This survey start only short time after the Russian geologist Vasilij Vasilievich Dokuchaev (1946–1903) formulated his definition of soil and the theory of soil genesis and zonality. He perceived the soil science as an independent scientific discipline. The agro-geological survey was the first soil survey in Slovakia. Unfortunately, it covered only part of the lowlands in West Slovakia. Leading personality was here Heinrich Horusitzky (1849–1929) – soil scientist and agro-geologist. The majority of the survey in this area he performed in 1902, 1903, 1905, 1908, 1909, 1912, and by Imrich Timko in 1904 and 1905. The soils were classified according to parent material and texture. Soil types were also mapped according to geological and hydro-geological soil characteristics. The soil parameters studied were analyzed by their relationship to productivity potential, as well as with respect to effective soil exploitation (sources of raw materials, rocks and water). Study works were edited and focused to rural country of Slovak regions: Trnava, Senec, Šurany, Komarno, Šturovo.
We must denote that Heinrich Horusitzky was dominant personality in the group of Hungarian soil scientists, with active international contacts and participated also at organization of the first soil science conferences organized in first years of 20th century in Budapest and Prague. In his group were active also Imrich Timko. Both Heinrich Horusitzky and Imrich Timko were of Slovak origin.
Another important soil scientist during the first decades of 20th century was Jan Lendvai-Lusnak (1881–1931). He studied humus, colloidal chemistry and soil capillarity. During the Austria-Hungarian period he lectured in several Hungarian universities. After establishment of Czech-Slovak Republic he was active within the State Research Institutes of Agriculture in Bratislava.

1918 – 1945

After the foundation of Czech-Slovak Republic in 1918, the soil science in Slovakia entered a period of fast development. Firstly, Slovak soil science was developing under rule of young generation of Czech soil scientists, as some pedologists active in Slovakia till 1919, emigrated to Hungary. The Czech soil scientists belonged to school of Josef Kopecky (1865–1935). In the state framework leading personality in Slovakia for several decades was Vaclav Novak (1888–1967).

In 1920 within the State Research Institutes of Agriculture (ŠVÚP) two institutes: for Agro-pedology and Bioclimatology (Bratislava, Košice) were established. They were first really scientific institutions for soil science with famous representants: František Kyntera (1897–1958, pedologist, agro-meteorologist), Peter Kučera and Karel Kohout. The mentioned soil scientists came from Bohemia, where the scientific life was much more free than in Slovakia under the Hungarian rule. Soon the first modern scientific studies in Slovak language was published by František Kyntera (1926, 1931), Karel Kohout (1928) and some other studies about Slovak soils were written in Czech language (Peter Kučera, 1935). František Kyntera is the author of first Map of Soil Types in Slovakia. He lived in Bratislava for some years but after Czech-Slovak state abolishment he returned to Prague where he worked until his death.

The research was running in several branches of soil science, such as soil physics, hydro-pedology and soil chemistry. A great advance was achieved in soil classification and soil genesis. The principles of genetic soil classification developed in Russia and reworked for Central European conditions in Germany, were applied also to soils of Slovakia. Few local soil surveys were performed. During this time a new generation of Slovak soil scientists such as Konštantín Nikitin, Ondrej Kožuch and Viktor Pecho-Pečner was educated. Konštantín Nikitin (1931) began with investigation of saline soils. Soon František Kyntera (1937) wrote the monograph on saline soils. It was the first Slovak book in pedology. Viktor Pecho-Pecner (1899-1978) represents Slovakian soil activities in thirties of 20th century. He was employed in the State Agricultural Research Institute (SVUP) in Bratislava (from 1938–1945 was the director of this institute). He studied and worked mainly in soil chemistry (nutrient dynamics, pH, soil colloids).

The promising development of soil science continued also in the 40-ties, despite the war conditions. In 1939, the Regional Agro-pedological Institute in Košice was moved after the occupation of this city by the Hungarians to Spišska Nova Ves. The leading personality among young Slovakian soil specialist became Ondrej Kožuch (1896-–1944). He implemented numerous investigations in several Slovakian regions – Spis, Gemer, Liptov, Orava, Turiec, Horehronie – occurring mainly in central and northern parts of Slovakia. He planned and arranged detailed soil survey of all Slovakian farmland. His most important works are: a) Soils of Slovakia and their Relationship to Cultivation of Agricultural Production (1943), b) Applied Soil Science (1944) and c) Plant Nutrition from the Soil (1946, 1951, both editions after his death).

Ondrej Kožuch was the most successful soil scientist of this period. Unfortunately, he was killed in the military action during the Slovak National Uprising which rose in summer 1944 against the occupation of Slovakia by German troops.

1945 – 1960

The end of the Second World War was a significant milestone in soil science development. Immediately after its end, new research activities began and new generation of pedologists became active. František Hroššo, Jozef Mrakič and Bohuslav Maláč became leading personalities in this period. In 1945 the "Geonomical Soil Survey" as a first large soil survey at national level started. In the period 1945–48 within this survey, the action "Liming Requirement on Soil of Czech-Slovak Republic" was carried out and focused to acid soils requiring liming. This survey covered mainly North and East Slovakia.

Successively after that (1949–1951) a new soil survey was organised to complete the results of the former surveys in those areas which were not covered. Thus, the first national soil survey, although not very detailed, but first time covering the whole area of the country was completed.
However, the further development of soil science was limited in 1950 by the administrative reorganisation of agricultural research. Both Regional Agro-pedological Institutes were closed and the soil research was split to several small working places, subordinated to various institutions such as the Academy of Sciences, the Central Testing Institute for Agriculture and the Agricultural and Forestry University in Košice.

Modern period (since 1960 until now)
On the beginning of this period the necessity arose to establish specialised scientific institution for soil science in Slovakia - the Laboratory of Soil Science in Bratislava in 1960. Later this institute worked under the name Research Institute of Soil Science and Plant Nutrition (RISSPN). Founder of the institute was Prof. Dr. Juraj Hraško. During next decades this institute underwent several transformations but although working under different names such as Soil Fertility Research Centre (SFRC) in second half of 80-ties, Soil Fertility Research Institute (SFRI) in 90-ties, and recently Soil Science and Conservation Research Institute (SSCRI), throughout the times it has been a leading research body specialised to soil science. Nowadays it belongs to National Agricultural and Food Centre in Lužianky near Nitra city.
Since the foundation of RISSPN as a solid institutional basis for the development of soil science, new generation of pedologists have been educated. It was much more numerous compare to earlier times. This allowed much better specialisation and many researchers (especially Juraj Hraško, Zoltán Bedrna, Michal Džatko, Emil Fulajtar, Bohdan Jurani, František Zrubec, Vladimír Linkeš, Cyprián Juráň, Pavol Bielek, Bohumil Šurina, Pavel Jambor, Ján Čurlik, Ján Karniš, Jaroslava Sobocká, Jozef Kobza, etc.) became a leading personalities each of them in different field.
Since 60-ties the soil science is developing also at several universities. At Comenius University soil geography was studied in 60-ties (Ľudovít Mičian). In 90-ties the Department of Soil Science was established here by group of researchers from SFRI under the leadership of Bohdan Jurani. At Agricultural University in Nitra, the agricultural aspects of soils were studied under the leadership of Soňa Sotáková, Konštantín Holobradý, Jozef Hanes, Anton Zaujec and their successors. At Forestry University in Zvolen, the forest soils, their genesis and soil erosion was studied by Rudolf Šály, Dušan Zachar, Rudolf Midriak, Eduard Bublinec and many other. All Slovak soil science research institutions work in mutual cooperation. For better exchange of information Slovak Soil Science Society (Societas pedologica slovaca) was established in 1992. It provides a communication forum for a whole pedological community in Slovakia.
Slovak pedologists were working in close cooperation with main specialists in Czech Republic such as Vladimír Kosil, Josef Pelíšek, Ján Němeček, Rudolf Vaculík, Alojz Prax, Josef Kozák, Pavel Novák and others. Close cooperation was maintained also with Russian soil science thanks to the personal contacts of several Slovak soil scientists who studied at Russian universities. At the end of 60-ties, they had intensive relations with soil science in Netherlands and several researchers from RISSPN studied in the Netherlands. Later, in 70-

ties and 80-ties the international cooperation was again limited to eastern countries. Since the beginning of 90-ties the research became much more diversified and the intensive cooperation especially with European countries and USA began.
The establishment of the Pedological branch of the Slovak Geographical Society at the Slovak Academy of Sciences was made in 1964 in Bratislava under leading of Prof. Dr. Juraj Hraško. Some significant milestones of the Slovak Soil Science Society development were recognized like a) the establishment of the Slovak Soil Science Society in 1969, b) incorporation of this society into the Slovak Society of Agricultural, Forest, Food and Veterinary Sciences in 1973 as Pedological section, c) rename of the society on Societas pedologica slovaca (SPS) in 1990, and d) new legal foundation as a civil association in 1995. Current president of Societas pedologica slovaca is Assoc. Prof. Dr. Jaroslava Sobocká in Bratislava. SPS is also included as a Pedological section for Slovak Society for Agricultural, Forest, Food and Veterinary Sciences at Slovak Academy of Sciences. SPS is a member of International Union of Soil Sciences (IUSS) and also a member of European Confederation of Soil Sciences Societes (ECSSS).

The main activities of SPS since 1960

- General Soil Survey of Agricultural Soils (1960 – 1970) in Slovakia as well as in Czech Republic;
- Land evaluation system where the land evaluation maps at a scale of 1: 5,000 were produced (1970 – 1980). The principles of subsidization and taxes in agriculture were deduced and the price of soil was determined on the base of the „pedo-ecological units“, the elementary mapping units of the land management maps. With the help of these maps the land use is planned, the crop rotation approaches are recommended; the rates of fertilisers are advised for individual parcels and crops;
- Since the beginning of 80-ties in Soil Science and Conservation Institute Bratislava, the Geographical Information System about the agricultural soils was created. It includes a huge amount of data and graphical interpretations (maps) about the soil cover. The system is computerised and actively working;
- Geochemical Atlas. Part V. Soils was developed and published by Ján Čurlík and Peter Šefčík (1990 – 1999);
- National Soil monitoring system in Slovakia in the network of 318 monitoring sites under coordination of Jozef Kobza has been running since 1993 until now, where the main indicators according to main threats to soil (soil contamination, soil acidification, soil salinization and sodification, decline in soil organic matter and available nutrients, soil erosion and soil compaction) are permanently monitored. Current results on actual state and development of soil properties including risk elements in Slovakia are permanently published in the end of every 5-year monitoring cycle;
- Monitoring of influence of Gabčikovo Hydro-work at Danube on the soil properties, especially the soil water regime, soil physical status and eventual salinization;

- Innovation of national soil classification and new classification was successfully introduced in cooperation of all relevant soil science working groups and at the platform of Slovak Soil Sience Society;
- Organizing of pedological conferences and seminars (every year together with Czech Society of Soil Science);
- Responsibility in research of soil science development, environment conservation, as well as in advisory service for agricultural practice using latest technology and innovation tools;

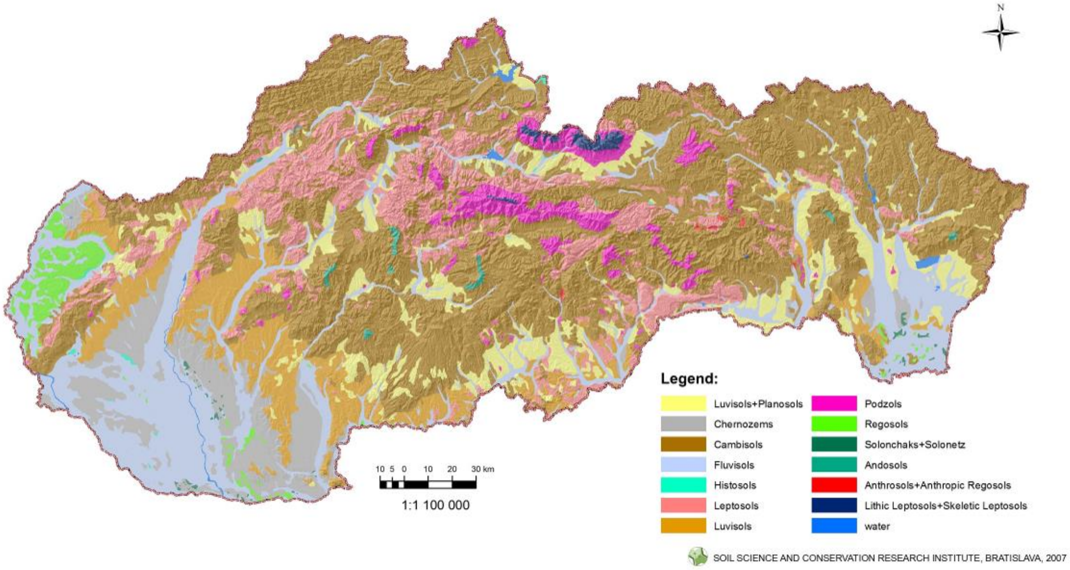

Figure 1 Soil map of Slovakia

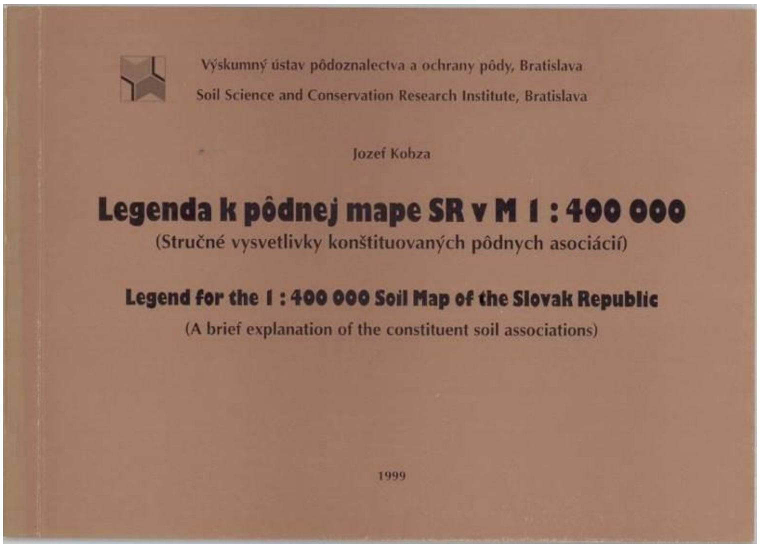

Figure 2 Legend for the 1: 400 000 Soil map of the Slovak Republic

- It is involved in several international research projects and is presenting an excellent centre for soil science in Europe;
- Many scientific books, papers and applied handbooks and brochures were published especially since second half of 90-ties last century, using own edition centre.

CONCLUSIONS

Most accounts of the history of soil science have focused upon development in Russia, America and Europe as a whole, but much less is known about the growth of the subject in small countries like Slovakia. Some broad phases can be distinguished:
1st - a pioneering phase (before 1918) characterized by isolated initiatives,
2nd - a development phases divided in two periods 1918–1945 and 1945–1960 when soil studies expanded rapidly in the context of agricultural and forest development,
3rd - a modern consolidation phase (since 1960 until now) when soil scientists largely enforced soil science development.
More information concerning Societas pedologica slovaca can be found on the website: www.pedologia.sk .

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ENHANCING MANAGEMENT OF CONTAMINATED SITES USING ENVIRONMENTAL MONITORING DATA AND PRELIMINARY RISK ASSESSMENT METHODOLOGY IN SERBIA

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Abstract

According to the Law on Soil Protection, the Cadastre of Contaminated Sites is a set of relevant data on endangered, polluted, and degraded soil. Serbian Environmental Protection Agency (SEPA) has been constantly working to improve the national methodology for collection, analysis and assessment of data on contaminated sites. The last updated database of the Cadastre shows that 309 potentially contaminated and contaminated sites have been identified and recorded on the territory of the Republic of Serbia. The main purpose of the Cadastre is to provide systematic data on sources of pollution such as the type, quantities, methods and location of discharges of pollutants into the soil, in order to implement preventive or remediation measures. Data collection is defined in more detail in the Rulebook on the content and manner of keeping the Cadastre of contaminated sites, type, content, forms, manner, and deadlines for data submission. Investigation of industrial sites suspected to be contaminated was a part of the GEF-funded project "Enhanced Cross-sectoral Land Management through Land Use Pressure Reduction and Planning" which is implemented by United Nations Environment Programme (UNEP) in close cooperation with the Ministry of Environmental Protection and SEPA in the period 2015–2019. The main goals of the Project were to provide the lacking methodologies, knowledge, and coordination mechanisms for sustainable and integrated management of soil as a natural resource. The Project also supported further development of the Cadastre of contaminated sites and preliminary analysis of selected 32 potentially contaminated sites. Field missions to the identified sites were conducted in 2016 with the purpose to identify receptors of pollution and potential exposure routes, previous land use, surface area, type and quantity of hazardous substances found at the location and in the surrounding area, soil and groundwater quality, as well as geological, pedological and hydrological features and to prepare and elaborate sampling programs, whereas the soil sampling itself took place in 2017 when 264 soil samples were analysed. Site specific environmental monitoring data and soil sampling results allowed performing the comparative analysis and application of preliminary risk assessment methodology that served to compile the relative risk-based priority list of contaminated sites. For this purpose, the Preliminary Risk Assessment Model for the identification and assessment of problem areas for Soil contamination in Europe – PRA.MS has been applied.

Keywords: Contaminated sites, Preliminary Risk Assessment, Remediation

INTRODUCTION

Investigation of 32 industrial sites suspected to be contaminated was a part of the GEF-funded project "Enhanced Cross-sectoral Land Management through Land Use Pressure Reduction and Planning" which is implemented by United Nations Environment Programme (UNEP) in close cooperation with the Ministry of Environmental Protection and SEPA in the period 2015 – 2019 (Vidojevic et al., 2016, 2017). The Project also received a contribution from the Italian Ministry of Environment, Land and Sea that enabled the development of Site Characterization Plans for two priority sites, in addition to the procurement of the laboratory analytical equipment, personal protective equipment and data storage server for SEPA as well as numerous study visits and opportunities for experience sharing with Italian expert institutions ISPRA, ENEA, ISS and INAIL (Falconi et al., 2018). The Project supports the development of a policy framework for integrated land use management and its implementation at local level.
The data and information for the selected 32 potentially contaminated sites collected from previous studies and through numerous consultations included: previous land use, type of industry, surface area, type and quantity of hazardous substances found at the location and in the surrounding area, soil and groundwater quality, as well as geological, pedological and hydrological features (Kukobat et al., 2018). The collected data are sorted and transferred to digital format in order to complete a database of contaminated sites. Field missions to the identified sites were conducted in the period September - December 2016 with the purpose to identify receptors of pollution and potential exposure routes, and to prepare and elaborate sampling programs, whereas the soil sampling itself took place in 2017 when 264 soil samples were analysed.

MATERIALS AND METHODS

The locations for soil sampling within 32 industrial sites were selected based on project criteria and existing data on the presence of contaminated land within the industrial complexes. Particular attention was given to abandoned locations. The visits and situation analyses of the locations lead to the conclusion that in most cases there is historical pollution within the complexes of enterprises that were, or are still state-owned (under bankruptcy, in the restructuring or privatization phase). In addition to the above form of ownership, a smaller number of enterprises has been privatized, or the locations have been fully or partly leased.
Soil samples were taken at each location as per the envisaged sampling plan (at depths of up to 0.5 m), in accordance with the situation in the field and the need for the samples to be as representative as possible. A number of samples have been taken outside the industrial complexes, in the immediate vicinity of vulnerable facilities, next to waste landfills or at lagoons for wastewater treatment.

The following parameters has been analysed in the total of 264 soil samples:
• Mechanical composition and chemical properties: pH, organic matter, $CaCO_3$ and total N,
• Content of heavy metals and metalloids: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), Zinc (Zn), as well as Mercury (Hg), but only in select samples,
• Organic pollutant content, hydrocarbons (C10-C40), polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides, and
• Asbestos and cyanide (only in select samples, in accordance with the plan of analysis).

Study area

In order to set priorities for detailed investigations and remediation, all locations have been sorted into 4 groups (I-IV) according to the:

- amount of data on the soil condition,
- concentrations of pollutants,
- types of pollutants,
- proximity of vulnerable facilities,
- activities on the given locations,
- size of the complex, and
- estimated scope of works.

Group I contain locations where, based on the available data, no contamination has been found and no remediation is proposed. In accordance with regulations, industry complexes need to establish soil monitoring.

Group II contain locations where, based on the available data, no remediation is proposed at this time. At the same time, in the majority of the tested locations the values of certain pollutants exceed the limit values multiple times which, in addition to establishing soil monitoring, requires expansion of testing, including sampling of surface and ground waters and plant matter.

Group III contain locations where contaminated soil was found and requires remediation (Figure 1).

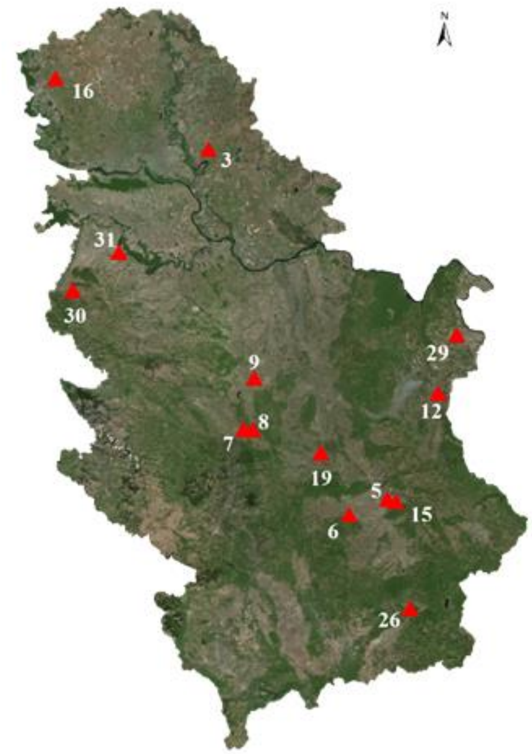
Group IV contain large industrial enterprises where certain parts of the complex require remediation.

The preliminary risk assessment methodology

Given that the sites within Group III were estimated as sites where urgent remediation activities are necessary, a model for preliminary assessment of risks to human health was used as a method for compiling the risk-based priority list. The selected model for prioritization is the PRA.MS methodology developed by the European Environmental Agency (EEA) in 2005. This model was developed to support the national, regional or local programs for the rehabilitation and remediation of contaminated sites (Altieri et al., 2004). The PRA.MS methodology is based on a scoring system of the relevant site parameters (Table 1) and factors grouped according to the *source-pathway-receptor* paradigm, adopted for the design of a conceptual model of locations and relative risk assessment.

According to this methodology, the "source" represents contaminated soil, while the human health exposure pathways are via groundwater (GW), surface water (SW), air

(AIR) and direct contact (DC) (Figure 2) (Falconi et al., 2005). Within the PRA.MS methodology it is also proposed a classification of locations according to the obtained relative risk and uncertainty factor values that was used to classify 14 selected locations in this study (Altieri et al., 2005).



No	Location name
3	Radijator AD, Zrenjanin
5	Electronics Industry, Niš
6	Non-ferrous metal factory, Prokuplje
7	Fabrika vagona AD, Kraljevo
8	Magnohrom, Kraljevo
9	Šumadija d.o.o., Kragujevac
12	Leather and Textile Processing Factory "Koža", Zaječar
15	Mechanical Engineering Industry, Niš
16	Battery Factory, Sombor
19	Chemical industry "Zupa" AD, Kruševac
26	Paper and packaging factory - lagoons, Vladičin Han
29	"Elixir" Mineral Fertilizer Industry Prahovo, Negotin
30	Viskoza, Loznica
31	"Zorka" non-ferrous metallurgy, Šabac

Figure 1. Map of 14 locations from Group III locations

Table 1. The parameters required for the calculations in the "tier 2" rank of the relative risk assessment

The parameters required for the "tier 2" rank of the relative risk assessment	
• toxicity of contaminants (risk phrases) • site area • disposal type • engineered containments • known releases of contaminants to sw, air, gw • lithology of the unsaturated zone • aquifer depth • slope • thickness and presence of the impermeable layer	• mean annual temperature, wind velocity, and precipitation • distances to nearest well, residential area, and surface water • groundwater and surface water use • land use at and off site • site accessibility • waste mass and volume • source area and volume • flooding return

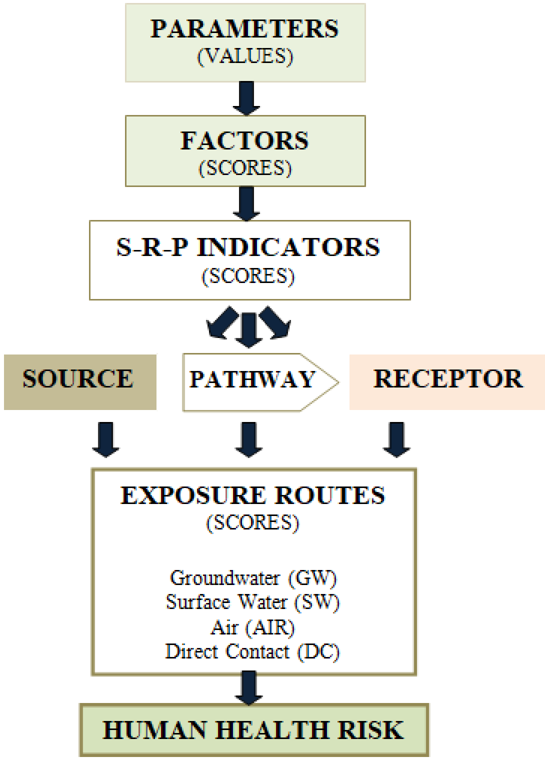


Figure 2. Scoring system and risk assessment algorithm of the PRA.MS methodology (modified after Quercia et al., 2006).

RESULTS AND DISCUSSION

Concentrations of contaminants identified at 14 locations within Group III were compared with the values from the Regulation on limit values for pollutants, harmful and hazardous substances in soil ("Official Gazette of the Republic of Serbia" No. 30/18 and 64/19) (Table 2).

After entering all parameters that are required for the calculations in the PRA.MS model (Table 2), the compiled priority list of 14 locations is shown in the Table 3 and listed according to the total risk values.

Table 2. Locations from Group III with identified contaminants that exceeded the remediation values

Location map number	Location name	SiteID	Exceed Limit values (LV)	Exceed Remediation values (RV)
3	Radijator AD, Zrenjanin	Rd-ZR	Cr, Cu, Zn, Ni, C10-C40	PCB
5	Electronics Industry, Niš	EI-NI	Cd, Cu, Ni, Pb, C10-C40	Pb
6	Non-ferrous metal factory, Prokuplje	Fom-PK	As, Cd, Cr, Cu, Ni, Pb, Zn, C10-C40, PAH	Cr, Cu, Ni, Zn, C10-C40
7	Fabrika vagona AD, Kraljevo	Fv-KV	As, Cd, Cr, Cu, Ni, Pb, Zn, PCB, PAH, C10-C40	As, Cu, Ni, Pb
8	Magnohrom, Kraljevo	Mgh-KV	As, Cr, Cu, Pb, Zn, Ni, C10-C40	As, Cu, Ni
9	Šumadija d.o.o., Kragujevac	Sum-KG	As, Cr, Cu, Zn, Ni, Cd, Pb, PAH, C10-C40	As, Cu, Zn, Ni
12	Leather and Textile Processing Factory "Koža", Zaječar	KTK-ZA	As, Cr, Cu, Ni, Pb, C10-C40	As, Cr, Pb
15	Mechanical Engineering Industry, Niš	Mi-NI	As, Cd, Cr, Cu, Ni, Pb, Zn, C10-C40, PAH, PCB	As, Cr, Cu, Ni, Pb, Zn
16	Battery Factory, Sombor	Fa-SO	As, Cd, Cu, Ni, Zn, Pb, C10-C40, PAH	Pb, C10-C40
19	Chemical industry "Župa" AD, Kruševac	HiZ-KS	As, Hg, Cd, Cr, Cu, Ni, Pb, Zn, C10-C40, PAH,	As, Hg, Cr, Cu, Ni, Pb, Zn
26	Paper and packaging factory - lagoons, Vladičin Han	Fp-VH	As, Cd, Cr, Cu, Ni, Pb, Zn, C10-C40	Cd
29	"Elixir" Mineral Fertilizer Industry Prahovo, Negotin	Ih-NG	As, Hg, Cd, Cu, Ni, Zn, C10-C40	As
30	Viskoza, Loznica	Vi-LO	As, Cd, Cu, Cr, Pb, Ni, Zn	As, Cd, Cu, Pb, Ni, Zn
31	"Zorka" non-ferrous metallurgy, Šabac	Z-SA	As, Cd, Cr, Cu, Ni, Pb, Zn, PCB, C10-C40	As, Cd, Cr, Cu, Ni, Pb, Zn, DDE/DDD/DDT, PAH

Table 3. The priority list of locations from Group III compiled in the PRA.MS model

No	SiteID	Relative risk and uncertainty factor values and risk classes				Ranked exposure pathways			
		Total risk value	Risk class (PRA.MS)	Total uncertainty value	Uncertainty factor class (PRA.MS	1st	2nd	3rd	4th
1	Fp-VH	41.7	High risk class	5.3	LOW UNCERTAINTY CLASS	SW	DC	GW	AIR
2	Vi-LO	41.0	High risk class	5.3		SW	DC	GW	AIR
3	HiZ-KS	40.0	High risk class	5.2		SW	DC	GW	AIR
4	Z-SA	32.6	Medium risk class	4.2		SW	DC	AIR	GW
5	Fom-PK	32.4	Medium risk class	6.9		SW	DC	GW	AIR
6	Fv-KV	31.8	Medium risk class	6.9		DC	SW	GW	AIR
7	EI-NI	31.4	Medium risk class	7.5		DC	SW	AIR	GW
8	Mgh-KV	30.7	Medium risk class	6.1		SW	DC	GW	AIR
9	Rd-ZR	29.6	Medium risk class	10.3		DC	SW	GW	AIR
10	Sum-KG	28.5	Medium risk class	7.1		SW	GW	DC	AIR
11	Ih-NG	27.6	Medium risk class	10.0		DC	SW	AIR	GW
12	Fa-SO	26.1	Medium risk class	10.6		DC	GW	SW	AIR
13	Mi-NI	24.8	Medium risk class	8.1		DC	GW	SW	AIR
14	KTK-ZA	24.4	Medium risk class	7.4		DC	GW	SW	AIR

GW – groundwater; SW - surface water; AIR – air; DC - direct contact

CONCLUSION

The results of the Project contributed to the development of the lacking methodologies, knowledge, and coordination mechanisms for sustainable and integrated management of soil as a natural resource. The priority list compiled based on the PRA.MS methodology can be further used for: planning the further site investigation strategies, enhancing the site monitoring, risk communication in the process of site management, decision-making purposes and allocation of resources for remediation projects.

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