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Microbiological and basic agrochemical properties of *Fluvisols* along the Western Morava basin

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Abstract

The most common type of soil in the valleys of large lowland rivers is *Fluvisol* or Alluvial soil. In order to determine the biogenity of this type of soil along the Western Morava basin, the representation of the total microflora, fungi, actinomycetes, ammonifiers, *Azotobacter* sp. and oligonitrophiles was examined. The samples were taken from soils used in the most common two different ways (plough fields and meadows). For that were used standard microbiological methods of inoculation a certain decimal dilution on appropriate nutrient media. No correlation was established between the number of examined groups of microorganisms and the way of land use, nor was there a correlation with chemical properties, primarily with pH and organic matter content. A good representation of *Azotobacter* sp., as an indicator of soil fertility, was found. Agrochemical analyses showed an acidic to neutral reaction, a low to medium percentage of organic matter, a very low to very high content of easily available phosphorus and easily available potassium.

Keywords: biogenity, *Fluvisol*, microflora

Introduction

Microorganisms are the most important biological component of the soil because with their enzyme systems they actively participate in the processes of decomposition of organic matter, the synthesis and decomposition of humus and the creation of easily available plant assimilatives (Milošević et al., 2003). The tolerance of microorganisms to pesticides and heavy metals allows certain genera and species to be used in soil bioremediation (Ajmal et al., 2021). Some microorganisms can be indicators of soil pollution with pesticides (Đurić at al., 2006; Verma et al., 2016). In addition, bacteria live in the rhizosphere that colonize the roots of plants and promote plant growth (PGPR) by synthesizing certain substances useful for plants such as phytohormones, facilitating the uptake of certain nutrients from the soil and protecting plants from diseases (Zahir et al. 2004; Cakmakci et al., 2006; Yazdani et al., 2009). By inoculating seeds with these bacteria before sowing, an increase in the yield of plant crops and an improvement in the microbiological properties of the soil are achived (Hajnal Jafari et al., 2012.). The abundance of individual groups of microorganisms is used as one of the indicators of general microbiological activity and potential soil fertility. A small number of certain groups of microorganisms (e.g. nitrogen fixers) indicates reduced biogenity, i.e. soil fertility (Milošević, 2008). Each type of soil has its own characteristic microbiocenosis and the method of land use can have a positive or negative effect on microbiological activity, which directly affects soil fertility (Marinković et al., 2018). The abundance and enzymatic activity of microorganisms are highest in the surface layer of the soil, in the phase of intensive plant grow, while at the end of the vegetation period, the abundance and enzymatic activity of microorganisms decrease. The abundance of microorganisms in the soil also depends on the presence and nature of organic matter, methods of processing, fertilization and plant cover (Bolton er al., 1984; Stamenov et al, 2016.). The number of microorganisms also depends on a number of abiotic factors such as pH, temperature, soil moisture, the presence of heavy metals, pesticides and other harmful substances (Jemcev and Đukić, 2000). It was established that the physical and chemical characteristics of the soil are the most important property that affects the number and activity of microorganisms (Marinković et al., 2008). Bacteria, actinomycetes and fungi are the most quantitatively represented in the soil, followed by representatives of algae and protozoa.

Fluvisol (alluvial soil) is a loose and porous soil of fluvial origin (Antić et al., 1990.). *Fluvisols* are formed by the deposition of river sediments and are formed along the courses of large lowland rivers. The process of their creation begins with erosion, and ends with deposition, that is, the creation of alluvial sediments. *Fluvisols* usually consist of different materials such as fine particles of silt and clay, or larger particles such as sand and gravel. The morphology of *Fluvisol* is characterized by very pronounced layering. The proportion of humus is mostly small, from 1-2%, and in sandy forms it is below 1%. According to their mechanical composition, they can be gravelly, sandy, loamy and clayey (Ćirić M.,1991.). The reaction of the environment is neutral to weakly alkaline in carbonate subtypes, and weakly acidic, rarely neutral in carbonate-free subtypes. These are fertile soils because periodic floods enrich them with organic matter and naturally fertilize them (Pekeč et al., 2012.). They are suitable for growing cereals, vegetables, fodder plants etc. In Serbia, they are most often used as plough fields for corn production or as meadows. *Fluvisols* occupy considerable areas in Serbia, it is estimated that there are about

500.000 ha. They extend in the valleys of lowland rivers such as the Danube, Sava, Morava, Tisa and others. Although *Fluvisols* are one of the most widespread soils in Serbia, little research has been done on them (Gajić et al., 2020).

Based on the above, basic agrochemical and microbiological analyses of 24 composite *Fluvisol* samples taken along the Western Morava basin, which separates Šumadija from the southern parts of the country, were performed at the Institute of Soil Science in Belgrade. The tested *Fluvisols* were used in plough field and meadow. The basic chemical characteristics were determined and the abundance of the basic physiological groups of microorganisms (total microflora, fungi, actinomycetes, ammonifiers, *Azotobacter* sp. and free nitrogen fixers) was examined in order to observe the general soil biogenity and thus fertility of the soil.

The aim of this research was to determine the correlation between the number of microorganisms and soil exploitation type, as well as the correlation between the number of microorganisms and the basic agrochemical properties of the examined soil type. The 24 localities along the Western Morava basin were selected. The presence of different groups of microorganisms in collected soil samples were analysed.

Materials and Methods

Along the Western Morava basin, 24 localities were chosen: 16 plough fields and 8 meadows. As the number and enzymatic activity of microorganisms is the highest in the surface soil layer (Marinković et al., 2008). Soil samples were taken aseptically from a depth of 0-30cm for microbiological and agrochemical analysis.

The basic parameters for assessing soil biogenity were: total microflora, total number of fungi, actinomycetes, ammonifiers, *Azotobacter* sp. and oligonitrophils. The number of examined microbial groups was assessed using the indirect method followed by plating of soil suspension on different selective media using decimal dilutions (10^{-1}-10^{-8}) (Pochon and Tardieux**,** 1962). The number of total microflora was determined on agar soil extract (Sarić, 1989). Fungi was determined on Chapek media (Sarić, 1989); actinomycetes on synthetic agar with sucrose according to Krasiljnikov (Govedarica and Jarak, 1996); ammonifiers in a liquid media with asparagine as a nitrogen source (Vojinović et al, 1966); *Azotobacter* sp. in a liquid nitrogen-free media according to Chan (Vojinović et al, 1966) and oligonitrophiles on a nitrogen-free media according to Fyodorov (Sarić, 1989).

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The pH of soil was determinedby pH-meter (in 1M KCl) according to SRPS ISO 10390. The content of soil organic matter was determined according to SRPS ISO 10694. Available P and K in the soil samples were determined by the Al-method (Riehm, 1958). The 0.1 mol L^{-1} ammonium lactate (pH = 3.7) was used as an extract. After extraction, K_2O was determined by a flame emission photometry and P_2O_5 by spectrophotometer after color development with ammonium molybdate and $SnCl_2$.

Results and Discussions

Results of basic agrochemical analyses of the examined *Fluvisol* soils are shown in Table 1. The reaction of tested samples (pH) was uneven and ranged from strongly acidic to neutral, with the largest number of samples showing a weakly acidic to neutral reaction, which is favourable from the aspect of the number and activity of soil microflora. It has been known that soil pH directly affects the mobility of nutrients by altering their accessibility for plants and the composition of soils microbial population (Tintor et al., 2009). Regarding the content of organic matter, which is important as a source of necessary carbon and energy, the largest number of samples showed a low to medium content, which is in accordance with literature data (Ćirić, 1991). The content of easily available phosphorus and potassium varied from very low to very high.

Table 2. shows the results of microbiological analyses of the tested fluvisol samples. The representation of the total microflora was quite uneven and ranged from 0.67×10^6 g^{-1} to 51.00×10^6 g^{-1} and was not correlated with pH and content of organic matter in the analysed samples. Previous researches carried out at the Institute of Soil Science in Belgrade have shown that the number of microorganisms in the soil is characterized by great dynamism in a relatively short period. Therefore, their number can change significantly because of the dynamics of soil temperature and humidity, as well as plant cover (Vojinović et al., 1990; Delić et al., 2005).

Table 1. Basic agrochemical properties of the examined Fluvisol soils

Type of soil usage	Location	pH (KCl)	Organic matter (%)	P_2O_5 ($mg10^{-2}g^{-1}$)	K_2O ($mg10^{-2}g^{-1}$)
PLOUGH FIELD	1	5.35	2.35	11.56	14.2
	2	3.9	3.10	9.22	21.8
	3	4.8	2.48	41.94	28.3
	4	3.9	3.04	2.62	21.4
	5	6.8	2.04	10.07	9.20
	6	6.7	2.46	17.88	22.20
	7	4.7	3.30	4.98	22.5
	8	6.8	2.24	19.13	19.00
	9	6.9	2.18	9.08	13.00
	10	6.9	2.30	15.1	12.00
	11	5.3	3.87	34.56	45.00
	12	5.9	3.22	11.20	27.00
	13	6.7	2.06	44.94	24.00
	14	6.7	1.39	27.55	11.80
	15	7.1	5.15	2.13	45.00
	16	5.85	1.85	3.71	13.60
MEADOW	1	4.45	2.97	0.71	16.10
	2	7	1.73	5.96	11.20
	3	6.25	2.84	32.44	36.60
	4	7.05	3.25	22.29	12.80
	5	7.1	1.07	46.6	2.56
	6	6.5	2.30	44.4	31.60
	7	5.7	3.98	4.03	23.20
	8	7.1	1.29	3.68	7.00

The representation of actinomycetes as very important transformers of organic matter in the soil also showed unevenness and ranged from 0.33×10^4 g^{-1} to $59.67\times10^4 g^{-1}$ and, as in the case of the total microflora, it was not correlated with the chemical properties of the samples. A slightly higher prevalence was observed in samples under meadow than under plough field crops.

As for fungi, as well as key microorganisms in the transformation of organic matter in the soil, it can be said that their representation was also uneven, but to a lesser extent than in the case of actinomycetes and ranged from 2.33×10^4 g^{-1} to 36.67×10^4 g^{-1}. Fungi, as acidophilic microorganisms, showed a greater abundance in samples with a lower pH than neutral.

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Table 2. Microbiological properties of the examined *Fluvisol* soils

Type of soil usage	Location	Total microflora ($\times10^6$)	Actinomycetes ($\times10^4$)	Fungi ($\times10^4$)	Ammonifiers ($\times10^5$)	*Azotobacter* sp. *MPN*	Oligonitrophiles ($x10^5$)
Plough field	1	41.00	18.33	22.00	45.00	95	75.33
	2	2.00	0.33	27.67	0.40	250	3.67
	3	6.33	1.33	16.00	9.50	15	26.67
	4	1.33	2.00	33.00	7.50	1400	59.33
	5	22.00	0.33	15.00	110.00	45	63.33
	6	7.33	40.00	5.67	4.50	95	47.00
	7	12.00	23.33	16.67	0.70	250	69.33
	8	14.00	17.00	9.67	25.00	250	55.00
	9	51.00	2.00	12.33	4.00	250	125.33
	10	45.00	0.33	16.00	1.40	95	104.33
	11	20.33	2.00	14.33	3.00	20	146.33
	12	44.33	26.67	7.67	110.00	45	151.67
	13	42.00	20.67	2.33	45.00	250	97.67
	14	8.67	36.33	13.00	1.50	250	23.33
	15	10.33	1.00	11.67	3.00	45	35.00
	16	18.67	27.33	10.00	45.00	250	38.33
Meadow	1	14.67	20.67	36.33	20.00	250	41.33
	2	0.67	25.00	6.00	0.70	450	22.00
	3	21.00	29.67	6.33	140.00	45	35.00
	4	26.00	18.33	13.00	4.00	150	40.67
	5	7.33	2.67	10.67	0.90	25	10.33
	6	33.00	26.33	5.67	25.00	250	58.00
	7	49.33	22.67	18.33	4.00	250	122.00
	8	22.00	59.67	11.67	15.00	150	82.33

Number of microorganisms was calculated per gram of absolutely dry soil. MPN: most probable number.

Ammonifiers, as decomposers of organic nitrogenous matter and as one of the most represented physiological groups of microorganisms in the soil, were poorly represented with the exception of samples 5 and 12 in plough field ($110,22\times10^5g^{-1}$) and sample No. 3 under the meadow ($140.00\times10^5g^{-1}$). This representation of ammonifiers can be said to be weak, considering that in chernozem type soil their number ca go up to 10^9 (Tintor et al., 2009; Marinković et al., 2018.). Not was the number of ammonifiers correlated with pH and organic matter content.

Azotobacter sp., the strongest associative nitrogen fixer and as an indicator of soil fertility, showed relatively good representation, both in samples under plough field and in samples under meadow. The number of *Azotobacter* sp. was relatively good, considering that according to researches in plough field its number was up to 10^3 (Kuzevski et al., 2011).

Oligonitrophiles, as fixers of atmospheric nitrogen to meet their own needs, also showed an uneven representation that ranged from 3.67×10^5 do $151.67\times10^5 g^{-1}$ and did not depend on the chemical properties of the examined soil. A large number of oligonitrophiles may indicate an unfavourable soil nitrogen regime (Marković and Veselinović, 1979).

Conclusion

The largest number of examined *Fluvisols* along the Western Morava basin showed slightly acidic to neutral pH, low to medium content of organic matter und uneven content of easily available phosphorus and potassium. The number of the examined groups of microorganisms was also uneven and did not depend on the chemical properties of the analysed samples. No difference in biogenity was observed between plough field samples and samples under meadows which are the most common ways of using *Fluvisol* in the Republic of Serbia.

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Mikrobiološke i osnovne agrohemijske osobine fluvisola duž sliva Zapadne Morave

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Izvod

Najzastupljeniji tip zemljišta u dolinama velikih ravničarskih reka je fluvisol ili aluvijalno zemljište. U cilju utvrđivanja biogenosti ovog tipa zemljišta duž sliva Zapadne Morave, ispitana je zastupljenost ukupne mikroflore, gljivica, aktinomiceta, amonifikatora, *Azotobacter* sp. i oligonitrofila. Uzorci su uzeti iz zemljišta korišćenih na najčešća dva različita načina (oranice i livade). Korišćene su standardne mikrobiološke metode zasejavanja određenog decimalnog razređenja na odgovarajuće hranljive podloge. Nije ustanovljena korelacija između broja ispitivanih grupa mikroorganizama i načina korišćenja zemljišta, kao ni korelacija sa hemijskim osobinama, pre svega sa pH i sadržajem organske materije. Utvrđena je dobra zastupljenost *Azotobacter* sp., kao indikatora plodnosti zemljišta. Agrohemijske analize su pokazale kiselu do neutralnu reakciju, nizak do srednji procenat organske materije, vrlo nizak do vrlo visok sadržaj lako pristupačnog fosfora i lako pristupačnog kalijuma.

Ključne reči: biogenost zemljišta, fluvisol, mikroflora

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Plodnost i sadržaj potencijalno toksičnih elemenata u zemljištu Mačve

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Izvod
Abstract

Ispitivanjem plodnosti zemljišta Mačve (fluvisol, humoglej i euglej, černozem, eutrični kambisol, pseudoglej, luvisol, vertisol) ustanovljeno je da dominiraju zemljišta povoljne reakcije za uspevanje većine kultura, ali oko 25% uzoraka, uglavnom na pseudogleju i luvisolu, ima nepovoljnu, jako kiselu reakciju. Sadržaj humusa je uglavnom srednji i visok, kao i rezerve azota. Utvrđen je nizak sadžaja fosfora u oko polovini uzoraka, a s druge strane u oko 10% uzoraka veoma visok sadržaj fosfora i kalijuma, kao rezultat osobina zemljišta i neodgovarajućeg đubrenja. Sadržaj potencijalno toksičnih elemenata (PTE) i vrednosti prirodnog fona su oko, ili ispod vrednosti za centralnu Srbiju. Ove vrednosti su ispod maksimalno dozvoljenih granica u domaćoj regulativi, sem Ni, čiji je sadržaj povećan u pojedinim uzorcima u aluvijumu reka Drine i Save i u zemljištu u neposrednoj okolini. Lokacije sa vrednostima iznad prirodnog fona i graničnih vrednosti u zakonskoj regulativi zahtevaju dodatnu analizu uticaja na životnu sredinu.

Ključne reči: plodnost zemljišta, potencijalno toksični elementi, Mačva

Uvod
Introduction

Mačvanska ravnica je najveća ravnica u užoj Srbiji, površine je oko 800 km^2. Prostire se između Save, Drine i Pocerine. Povoljni prirodni uslovi su doprineli da je ovo područje sa veoma razvijenom poljoprivrednom proizvodnjom.

Zemljišta ove oblasti proučavao je veći broj istraživača. Po navodima Tanasijevića i Pavićevića (1953) geološku podlogu Mačve čine deluvijalno-aluvijalni nanosi različitog sastava, natoloženi preko neogenih sedimenata. Nastali su pomeranjem toka Drine ka zapadu (oko 20-30 km), i toka Save ka severu (oko 7- 8 km), gde je Sava usekla svoje sadašnje korito u sremski lesni plato. Nanosi su sastavljeni od gline, ilovače i šljunka. U gornjem delu profila preovlađuje ilovača, a negde i šljunak, odnosno pesak. U središnjoj i severnoj Mačvi je iznad pomenutih nanosa nataložen sloj karbonatne lesolike ilovače ili lesa, koji je eolskim putem nanet iz Vojvodine, na kome je formiran černozem.

Na osnovnoj pedološkoj karti Srbije (list Šabac 1 i 2,Tanasijević i sar., 1961) vidi se da su u Mačvi formirani gotovo svi tipovi zemljišta karakteristični za ravničarske i brežuljkaste rejone: aluvijalno zemljište (Fluvisol), humoglej i euglej (Gleysol), černozem (Chernozem), eutrični kambisol (Eutric Cambisol), pseudoglej i ilimerizovano zemljište (Stagnosol, Planosol, Luvisol), smonica (Vertisol) (po klasifikaciji Škorić, Ćirić i Filipovski, 1985 i WRB, 2014).

Ispitivanje karakteristika zemljišta i stepena zagađenosti bilo je predmet većeg broja istraživanja (Mrvić i sar. 2009, Čakmak i sar., 2009, Dugonjić i sar., 2012; 2013). Na ovom području osnovni činioci koji utiču na zagađenje zemljišta su: nebezbedna proizvodnja i odlaganje stajnjaka, neregulisana kanalizaciona mreža za otpadne vode, nekontrolisana primena mineralnih đubriva i pesticida, odlaganje otpada, plavljenje i zabarivanje, deponija fabrike mineralnih đubriva „Zorka“ (UNEKO, 2015).

Predmet rada je utvrđivanje osnovnih osobina zemljišta, sadržaja i prirodnog fona potencijalno toksičnih elemenata u Mačvi, radi sagledavanje ograničenja zemljišta za intenzivnu biljnu proizvodnju.

Materijali i metode
Materials and methods

Terenski radovi su obavljeni 2013. godine. Uzeto je 96 površinskih uzorka zemljišta (0-25 cm), po grid sistemu na svakih 3,3 x 3,3 km. Pet poduzoraka čini prosečan uzorak. Uzorkovanje je obavljeno uglavnom na oranicama (95% uzoraka).

Laboratorijsko ispitivanje je izvršeno u Laboratoriji Instituta za zemljište. U pripremljenim uzorcima zemljišta utvrđeni su osnovni parametri plodnosti: pH u KCl, humus, lako pristupačni P i K, $CaCO_3$, standardnim metodama priznatim od strane JDPZ - današnje SDPZ (JDPZ, 1966). Ukupan („pseudo total“) sadržaj potencijalno toksičnih elemenata određen je spektrofotometrijski (ICP-OAS), posle kuvanja sa HNO_3 i H_2O_2, a žive iz istog ekstrakta, nakon pripreme hidridnim tehnikama na AAS.

Statistička analiza podataka je obavljena primenom osnovne deskriptivne statistike i metodom korelacije, na SPSS 10 programu.

Rezultati i diskusija

Results and discussion

Plodnost zemljišta

Soils fertility

Na području Mačve dominiraju zemljišta pogodne reakcije za uspevanje većine kultura (Tabela 1). Aluvijalno zemljište pored Drine i Save i severni deo pod humofluvisolom i černozemom, uglavnom je karbonatno, neutralne i slabo alkalne reakcije. Južnije su nekarbonatna zemljišta, kiselije reakcije - černozem u ogajnjačavanju (oko Klenja), humofluvisol zapadno od Šapca, eutrični kambisol. Oko 25% uzoraka, međutim, ima nepovoljnu, jako kiselu reakciju. To su najčešće uzorci na pseudogleju i luvisolu. Poznato je da jako kisela zemljišta imaju niz negativnih osobina koje ograničavaju normalno uspevanje biljaka: slabo izražena struktura i nepovoljne vodno-fizičke osobine, lošiji kvalitet humusa, debalans u ishrani biljaka, povećana rastvorljivost i toksičnost Al i većine štetnih elemenata, usporeni mikrobiološki procesi (Sikirić i sar., 2018; Dugalić i sar., 2022; Dugonjić i sar., 2022).

Tabela 1. Osnovni statistički parametri osnovnih hemijskih osobina zemljišta

Table 1. Basic statistical parameters of the basic chemical soil properties

Statistički parametri	pH u KCl	$CaCO_3$ %	Humus %	N %	P_2O_5 mg/100 g	K_2O mg/100 g
Prosek	5,72	1,95	3,33	0,20	13,34	23,61
Standardna devijacija	1,25	4,52	1,26	0,07	14,64	10,93
Minimum	3,70	0,00	1,26	0,10	0,20	8,38
Maximum	7,49	35,00	8,10	0,43	91,77	86,20
25%	4,53	0,00	2,56	0,15	4,78	13,72
50%	5,67	0,00	2,99	0,18	8,25	20,71
75%	7,04	1,66	3,66	0,22	15,34	35,55

Važan pokazatelj plodnosti zemljišta je sadržaj i kvalitet humusa. U ispitivanim uzorcima sadržaj humusa je od 1,26 do 8,10%. U malom broju uzoraka (oko 4%) sadržaj humusa je ispod 2%. Dominiraju zemljišta sa 2-3%, odnosno 3-5% humusa (48 i 38% uzoraka). Visok sadržaj iznad 5% je u 10% uzoraka, najčešće u aluvijumu oko Save i černozemu. S druge strane, pseudoglej ima od 1,5-3% humusa, u zavisnosti od načina korišćenja, što je povezano i sa sastavom humusnih kiselina (Dugonjić i sar, 2023). Rezerve azota su uglavnom dobre, u skladu sa sadržajem humusa.

Sadržaj pristupačnog fosfora u zemljištu je nizak u oko polovini uzoraka (do 10 mg/100 g). Posebno se izdvajaju uzorci na eutričnom kambisolu, pseudogleju i pojedini uzorci aluvijuma Drine. Nizak nivo fosfora je inače karakterističan za većinu zemljišta centralne Srbije (Čakmak, 2009). Poznato je da se fosfor, kako u jako kiselim zemljištima, tako i u karbonatnim, lako imobiliše i da se njegova koncentracija đubrenjem sporo povećava. Međutim, zabeležen je i veoma visok nivo fosora (iznad 30 mg/100 g) u oko10% uzoraka, u jako đubrenim baštama i oranicama.

Snabdevenost kalijumom je bolja. Nizak sadržaj (8-12 mg/100 g) je u oko 25% uzoraka, a ostali uzorci su srednje, visoko i vrlo visoko snabdeveni kalijumom, posebno u severnom delu na glinovitijem zemljištu, ili jače đubrenim površinama.

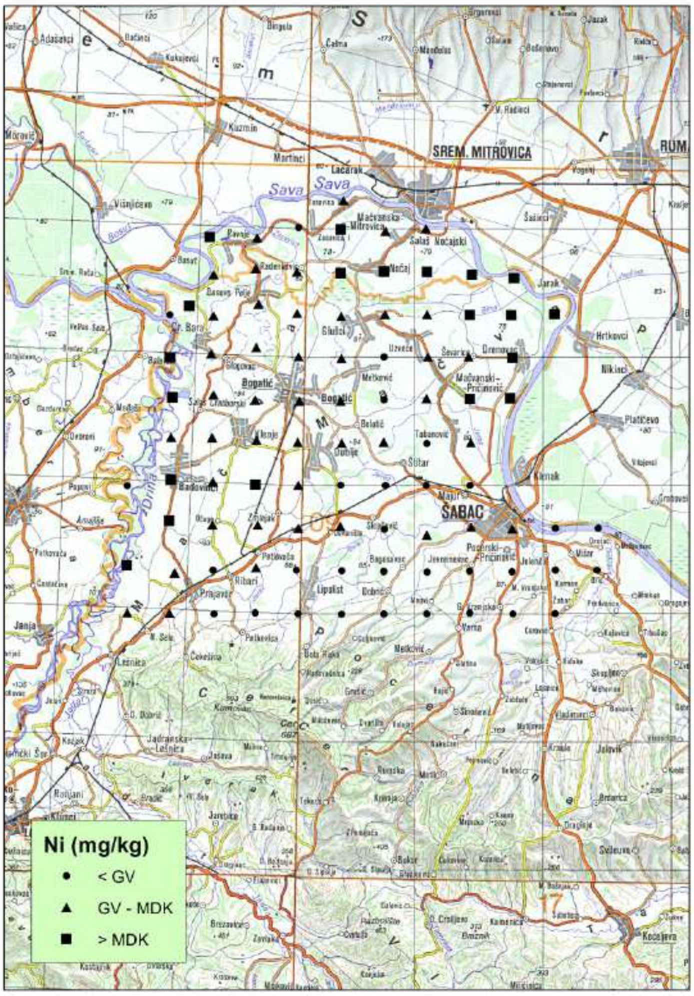
Potencijalno toksični elementi (PTE)
Potentially toxic elements (PTEs)

Analiziran je ukupan sadržaj sledećih elemenata: As, Cd, Cr, Cu, Hg, Ni, Pb, Zn (Tabela 2).

Tabela 2. Osnovni statistički parametri sadržaja potencijalno toksičnih elemenata (mg/kg)
Table 2. Basic statistical parameters of the content of potentially toxic elements (mg/kg)

Statistički parametri		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Prosek		6,29	1,52	46,13	23,30	0,01	51,43	24,36	75,61
St. dev.		3,06	0,63	12,60	7,58	0,04	23,45	11,17	27,11
Min		0,93	0,10	18,52	8,70	0,00	11,30	8,07	27,10
Max		14,72	2,73	92,55	43,40	0,35	100,90	70,00	253,20
Koef.varijacije %		48,69	41,29	27,32	32,52	266,50	45,60	45,86	35,85
	25%	4,40	1,07	38,48	17,45	0,00	32,50	17,33	62,85
	50%	5,73	1,66	43,62	22,90	0,00	43,95	19,75	71,65
	75%	7,78	2,02	53,70	29,02	0,02	69,80	28,87	86,50
	90%	11,53	2,21	62,34	32,16	0,04	88,40	40,09	100,37
	95%	**13,51**	**2,37**	**69,30**	**35,93**	**0,06**	**94,38**	**47,05**	**117,27**
	98%	14,19	2,66	79,95	41,52	0,08	99,20	66,32	134,70

Prosečne vrednosti PTE su oko ili ispod proseka za centralnu Srbiju (Mrvić, 2009) (Tabela 2). Sadržaj elemenata ne prelazi maksimalno dozvoljene koncentracije koje važe za poljoprivredno zemljište (MDK, Pravilnik, SG RS 23/1994), sem Ni. Sadržaj Ni je u oko 40% uzoraka od 50 - 100 mg/kg. To su uglavnom uzorci u aluvijumu reka Drine i Save i u zemljištu u neposrednoj okolini (eutrični kambisol, černozem) (Karta 1).



Karta 1. Sadržaj Ni u zemljištu na području Mačve

Map 1. Ni content in the soil of Mačva

Poređenjem sa graničnim vrednostima PTE u zemljištu (nekorigovanim, Uredba, SG RS 30/2018), vidi se da sadržaj elemenata u zemljištu Mačve ne prelazi remedijacione vrednosti, dok je u odnosu na granične maksimalne vrednosti (GV) sadržaj Ni i Cd veći u 68 i 80% uzoraka, Cu u 4% uzoraka, a Hg i Zn u po jednom uzorku.

Statistička analiza pokazuje da sadržaj Ni ima visoku korelaciju sa sadržajem Cr (0,861**), a srednju sa As, Cd, Cu, Pb (0,59-0,702**), što ukazuje na delom isto poreklo ovih teških metala (Tabela 3).

Ranija istraživanja pokazuju da se često u aluvijumu nalaze povećane koncentracije potencijalno toksičnih elemenata, a u nekim uzorcima pored naših reka - Velika Morava, Kolubara, Jasenica, posebno povećan sadržaj Ni (u manjoj meri i Cr, Pb i As), koji je pretežno geohemijskog porekla (Jakovljević i sar., 1997; Mrvić i sar., 2009; Antić-Mladenović, 2018).

Pored toga što se elementi geohemijskog porekla uglavnom nalaze u teže pristupačnim oblicima, u fluvijalnim zemljištima je rastvorljivost teških metala smanjena zbog težeg mehaničkog sastava i neutralne reakcije.

Tabela 3. Koralacija sadržaja PTE

Table 3. Correlation of PTE content

	pHuKCl	humus	As	Cd	Cr	Cu	Hg	Ni	Pb
As	,363**	0,15							
Cd	,278**	,313**	,393**						
Cr	,451**	,320**	,461**	,620**					
Cu	,429**	,428**	,556**	,789**	,642**				
Hg	,351**	0,136	,341**	-0,191	,222*	-0,096			
Ni	,616**	,372**	,680**	,688**	,861**	,702**	,350**		
Pb	,456**	,319**	,733**	0,193	,438**	,415**	,583**	,586**	
Zn	,354**	,414**	,427**	,600**	,431**	,713**	-0,023	,455**	,328**

Radi ocene rizika visokih vrednosti PTE na životnu sredinu i izrade programa rekultivacije, pored poređenja sa graničnim vrednostima u zakonskoj regulativi, treba poznavati i prirodne koncentracije elemenata, jer se time procenjuje stepen antropogenog zagađenja. Postoji veći broj metoda procene granice prirodnog fona elemenata. Jedna od najjednostavnijih je korišćenje procenta, najčešće 95%, za identifikaciju uzoraka koji odstupaju od „normalne varijacije prirodne koncentracije“ (Ander et al., 2013). U literaturi se navodi da su metodama [Mean +2Sdev] i TIF dobijene vrednosti prirodnog fona za različita zemljišta uglavnom na nivou 95-98% (Reinmann, 2018; Mrvić i sar., 2019).

Poređenjem ove granice (95%) za Mačvu (Tabela 2), sa vrednostima za centralnu Srbiju (Mrvić i sar., 2018) vidi se da su u Mačvi vrednosti As, Cr, Cu, Ni, Pb gotovo za polovinu niže, a za Zn slične. Poređenjem sa prirodnim fonom Zapadne Srbije - grafik (Čakmak i sar., 2018) vidi se da su vrednosti u Mačvi znatno niže za As, Cr, Hg, Ni, Pb, a slične za Cd, Cu i Zn. Prirodni fon za Mačvu je niži od MDK, sem Ni, čije se vrednosti približavaju 100 mg/kg. Lokacije sa vrednostima iznad prirodnog fona (5%) i graničnih vrednosti u našoj regulativi zahtevaju dodatnu analizu uticaja na životnu sredinu.

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Zaključak
Conclusion

Mačvanska ravnica je jedno od najznačanijih područja poljoprivredne proizvodnje u Srbiji. Na ovom prostoru formirana su različita zemljišta, boljih bonitetnih klasa - aluvijalno zemljište, humoglej i euglej, černozem, eutrični kambisol, pseudoglej i luvisol, vertisol.

U ovoj oblasti dominiraju zemljišta pogodne reakcije za uspevanje većine kultura, ali oko 25% uzoraka, uglavnom na pseudogleju i luvisolu, ima nepovoljnu, jako kiselu reakciju. Na kiselim zemljištima primena fiziološki alkalnih đubriva, kalcizacija sa humizacijom, uz kontrolu rastvorljivosti mikroelemenata, doprinose poboljšanju proizvodne vrednosti zemljišta.

Sadržaj humusa je uglavnom srednji i visok, kao i rezerve azota. Očuvanje i povećanje humusa, unošenjem organskog đubriva, zaoravanjem biljnih ostataka, promenom plodoreda, neophodno je zbog očuvanja kvaliteta zemljišta i prilagođavanja klimatskim promena, posebno u oblastima sa intenzivnom poljoprivrenom proizvodnjom.

Nizak, odnosno veoma visok sadržaj fosfora i drugih biogenih elemenata treba dovesti do optimalnih koncentracija adekvatnim normama đubriva, primenom sistema kontrole plodnosti zemljišta.

Prosečne vrednosti PTE su oko, ili ispod proseka za centralnu Srbiju. Sadržaj elemenata ne prelazi MDK, sem Ni, gde je u oko 40% uzoraka od 50 - 100 mg/kg. To su uglavnom uzorci u aluvijumu reka Drine i Save, i u zemljištu u neposrednoj okolini.

Prirodni fon elemenata (95%) je niži ili sličan vrednostima za zemljište Zapadne Srbije. Granice su ispod MDK, osim Ni, gde su blizu 100 mg/kg. Lokacije sa vrednostima iznad prirodnog fona i graničnih vrednosti u našoj regulativi zahtevaju dodatnu analizu uticaja na životnu sredinu.

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Fertility and content of potentially toxic elements in the soils of Mačva

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Abstract

By examining the fertility of Mačva soil (fluvisol, humogley, eugley, chernozem, eutric cambisol, pseudogley, luvisol, vertisol), it was found that the soils with a reaction which is favourable for growth of most crops dominate, but about 25% of the samples, mainly on Pseudogley and Luvisol, have an unfavourable, highly acidic reaction. Soil organic matter content is generally medium to high, as are the nitrogen reserves. A low content of phosphorous was found in about half of the samples, while in about 10% of soil samples, a very high phosphorous and potassium content was found, as a result of soil properties as well as inappropriate fertilization. The PTE content and natural backround values are around or below the values for Central Serbia. These values are below the maximum allowed limits in domestic regulations, except for Ni, whose content increased in some samples in the alluvium of the Drina and Sava rivers and in the soil in close vicinity. Locations with values above the natural background and limit values in the legal regulations require an additional analysis of the impact on the environment.

Keywords: soil fertility, potentially toxic elements, Mačva

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Prilog poznavanju nekih fizičkih i hemijskih osobina krečnjačkih zemljišta planinskog masiva Ozren

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Izvod
Abstract

Zemljišta obrazovana na krečnjacima zauzimaju veliku površinu u Srbiji, ali veoma malo podataka ima o njihovim osobinama. U ovom radu su prikazane fizičke i hemijske osobine posmeđenog kalkomelanosola i srednje dubokog kalkokambisola na planini Ozren. Na prevoju Vlasina odabran je lokalitet sa posmeđenim kalkomelanosolom pod prirodnom travnom vegetacijoma, a u blizini Ozrenskih livada odabran je lokalitet s kalkokambisolom pod prirodnom mešovitom šumom. Na navedenim lokalitetima iskopani su profili do matičnog supstrata iz kojih su po genetičkim horizontima uzeti uzorci u narušenom i nenarušenom stanju za laboratorijske analize. Određen je mehanički sastav, agregatni sastav i vodootpornost strukturnih agregata, gustina suvog zemljišta, ukupna poroznost, vazdušni kapacitet, vododrživa sposobnost, vodopropustljivost, pH vrednosti, sadržaj humusa, sadržaj fiziološki aktivnog fosfora (P_2O_5) i kalijuma (K_2O), hidrolitička kiselost, kapacitet adsorpcije katjona (CEC), suma razmenljivih baznih katjona, te stepen zasićenosti razmenljivim baznim katjonima. Humusno akumulativni horizont, A_{mo}, posmeđenog kalkomelanosola je praškasto glinaste teksture. Kambični $(B)_{rz}$ horizont oba zemljišta je glinovite teksture. A_{mo} horizont kalkomelanosola odlukuje se mrvičastom strukturom (0,5–5 mm) veoma visoke vodootpornosti. Ukupna poroznost, vazdušni kapacitet i vodopropustljivost oba zemljišta je visoka. Njihova vododrživa sposobnost je visoka. A_{mo} horizont kalkomelanosola se odlikuje visokim sadržajem humusa (>10%). Hemijska reakcija (pH u H_2O) A_{mo} horizonta je neutralna, dok je u $(B)_{rz}$ horizontima oba zemljišta umereno kisela. Oba zemljišta imaju visoke vrednosti CEC (>58 cmol kg^{-1}) i veoma su zasićena baznim katjonima (>95%). Posmeđeni kalkomelanosol je srednje do visoko obezbeđen K_2O, a kalkokambisol je srednje obezbeđen; dok su oba zemljišta veoma siromašna P_2O_5. Budući da ovo istraživanje pokazuje prilično povoljne fizičke i hemijske osobine istraženih zemljišta na ovom području zbog zadržavanja prirodne šumske i travne vegetacije, rezultati ovih istraživanja mogu pomoći u dubljem razumevanju ekologije zemljišta i očuvanju prirodnog biljnog pokrivača.

Ključne reči: kalkomelanosol/Calcomelanosols; kalkokambisol/Calcocambisols; vodootpornost strukturnih agregata/soil aggregate stability; vodni kapaciteti/water retention; organska materija u zemljištu/ soil organic matter; kapacitet razmenljivih katjona/cation exchange capacity

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Uvod

Introduction

Uticaj degradacije zemljišta na dobrobit ljudi i životnu sredinu predstavlja veliki izazov. Do značajnog pada kvaliteta zemljišta došlo je širom sveta zbog nepovoljnih promena u njegovim fizičkim, hemijskim i biološkim svojstvima, te zagađenja neorganskim i organskim hemikalijama. Postoji potreba za razvojem kriterijuma za procenu kvaliteta zemljišta kako bi se mogao pratiti napredak bilo koje korektivne mere. Trenutno ne postoje opšte prihvaćeni kriterijumi za procenu promena u kvalitetu zemljišta. Ovaj nedostatak onemogućava izradu smislenih programa upravljanja zemljištem. U ovom se radu ispituju glavna fizička i hemijska svojstva koja mogu poslužiti kao pokazatelji promene kvaliteta zemljišta u određenim edafskim uslovima. Predloženi pokazatelji uključuju dubinu zemljišta do sloja koji ograničava rast i razviće korena, kapacitet zadržavanja vode, zapreminsku masu, hidrauličku provodljivost, stabilnost strukturnih agregata, sadržaj organske materije, kapacitet katjonske izmene, pH i stepen zasićenosti baznim katjonima.

Prema podacima koje navode Dugalić i Gajić (2012) kalkomelanosoli u Srbiji zauzimaju površinu veću 250 000 ha, a kalkokambisoli preko 240 000 ha. Istražena zemljišta se obrazuju na jedrim krečnjacima i dolomitima. Kalkomelanosol nastaje neposredno kao primarna zemljišna tvorevina, a kalkokambisol evolucijom kalkomelanosola (Dugalić i Gajić, 2012) kada se humusno-akumulativni horizont razvije do 20–30 cm dubine. Izučavani kalkomelanosoli prema WRB (IUSS Working group, 2022) se mogu svrstati u referentne grupu zemljišta Leptosols, i to najčešće kao Mollic, Lithic i Rendzic, a ako su dublji od 25 cm (30 cm) dubine onda pripadaju najčešće Leptic Rendzic Phaeozems (Životić i sar. 2017). Kalkokambisoli se prema WRB najčešće mogu svrstati u Leptic Phaeozems, Leptic Umbrisols and Leptic Cambisols, i to najčešće kao Cambic Leptic Rendzic Phaeozems (Rhodic ili Chromic), Cambic Leptic Umbrisols (Chromic or Rhodic) ili Leptic Chromic or Rhodic Cambisols. Takođe, i Vertic i Luvic se mogu dodati kao primarne odrednice.

Ova zemljišta su kod nas proučavana uglavnom u okviru pedoloških studija pri izradi pedoloških karata (Tanasijević i sar. 1965; Tanasijević i sar. 1966; Pavićević i sar. 1968; Antonović i sar. 1974; Antonović i sar. 1975; Antonović i Mrvić, 2008). Kalkomelanosole i kalkokambisole pod prirodnom (travnom i šumskom) vegetacijom u Srbiji proučavali su i Živković i Pantović (1954). Takođe, ova zemljišta proučavali su i Knežević i Košanin (2004) u zajednicama planinske bukve na planini Ozren. U navedenim istraživanjima uglavnom je prikazan mehanički sastav i osnovne hemijske osobine zemljišta. Ni u jednoj od navedenih studija nema rezultata o agregatnom sastavu zemljišta i vodootpornosti strukturnih agregata, dok se samo u radu Antonović i Mrvić (2008) prikazuju neke vodno-fizičke osobine.

Planina Ozren se nalazi u jugoistočnoj Srbiji, južno od Sokobanje i čini jednu celinu sa planinnom Devicom. Ozrenski deo je nešto niži, kraći i ima više šume. Za razliku od Device koja je pretežno krečnjačka planina, na zapadnim delovima Ozrena su zastupljeni škriljci, dok se u centralnim i istočnim delovima pored dominantnog prisustva krečnjaka sreću i piroklasiti, konglomerati i glinci. Planina Ozren je jedna od najšumovitijih planina u Srbiji i poznata je kao vazdušna banja bogata ozonom. Na planini Ozren su najzastupljeni kalkomelanosoli koje Tanasijević i sar. (1965) nazivaju rendzinama. Pored rendzina, odnosno kalkomelanosola po nacionalnoj klasifikaciji (Škorić i sar., 1985), sreću se na velikim prostranstvima asocijacije kalkomelanosola i litosola na krečnjaku, dok se na manjim površinama sreću i rankeri, distrični kambisoli i kalkokambisoli. Kalkokambisoli su zemljišta nižih krečnjačkih terena u odnosu na kalkomelanosole, ali se na višem terenu sreću i u vrtačama, uvalama, na manjim zaravnima, odnosno u erozionim bazama koje se javljaju lokalno.

Cilj ovog rada je da se prikažu karakteristike dubljih zemljišta obrazovanih na krečnjačkim stenama, tj. kalkomelanosola i kalkokambisola pod prirodnom vegetacijom na planini Ozren.

Materijali i metode
Materials and Methods

Terensko istraživanje zemljišta je obavljeno u junu 2021. godine. Na oba tipa zemljišta iskopan je po jedan pedološki profil do matične stene. Celokupni terenski rad je izveden prema metodologiji Jugoslovenskog društva za proučavanje zemljišta (Filipovski i sar., 1967), i priručniku za opisivanje zemljišta (FAO, 2006). Profil kalkomelanosola je iskopan na prevoju Vlasina (43° 35' 42.99'' N, 21° 53' 1.81'' E, 940 m n.v.), na prirodnoj livadi koja se redovno kosi. Profil kalkokambisola iskopan je u blizini Ozrenskih livada (43° 37' 40.26'' N, 21° 52' 14.68'' E, 625 m n.v.), na zapadnim padinama vrha Orlovac (867 m n.v.), u listopadno četinarskoj šumi.

Iz horizonata oba profila su uzeti uzorci zemljišta u narušenom i nenarušenom stanju za određivanje fizičkih i hemijskih osobina. Po tri uzorka u nenarušenom stanju su uzeta iz

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analiziranih horizonata cilindrima Kopeckog zapremine 100 cm^3. Zbog veoma male dubine (3 cm) i velikog sadržaja nerazloženih organskih materija, kao i gustog korenovog sistema šumske vegetacije, uzorci nisu uzimani iz površinskog horizonta kalkokambisola.

U laboratoriji su određene sledeće fizičke osobine zemljišta, i to: mehanički sastav zemljišta, agregatni sastav zemljišta i vodootpornost strukturnih agregata, gustina suvog zemljišta (ρ_b), maksimalni vodni kapacitet (θ_s), retencioni (poljski) vodni kapacitet (θ_{fc}, –33 kPa), vlažnost trajnog uvenuća biljaka (θ_{pwp}, –1500 kPa), biljkama pristupačna vlaga (PAWC), brzina vodopropustljivosti (filtracija, K_{sat}), ukupna poroznost i apsolutni vazdušni kapacitet. Na uzorcima u narušenom stanju određene su sledeće hemijske osobine zemljišta: aktivna kiselost (pH u H_2O), razmenljiva kiselost (pH u 1M KCl), sadržaj humusa, hidrolitička kiselost (H), suma razmenljivo-adsorbovanih baznih katjona (S), totalni kapacitet adsorpcije katjona (CEC) i stepen zasićenosti bazama (V). Navedene fizičke i hemijske osobine zemljišta određene su standardnim postupcima (Gajić, 2005; Dugalić i Gajić, 2005). Sadržaji pristupačnog kalijuma (K_2O) i fosfora (P_2O_5) određeni su Al-metodom po Egner-Rejmu-Domingu (Минеев и сар., 2001).

Korišćenjem frakcija strukturnih agregata izdvojenih suvim i mokrim prosejavanjem izračunat je srednji maseni dijametar (MWD) i srednji geometrijski dijametar (GWD) jednačinama 1 i 2 (Gajić, 2005):

$$MWD = \sum_{i=1}^{n} \overline{Xi} \times Wi, \quad (1)$$

$$GMD = exp\left[\frac{\sum_{i=1}^{n} Wi \times ln\overline{Xi}}{\sum_{i=1}^{n} Wi}\right] \quad (2)$$

gde je $\overline{xi}$ srednji dijametar frakcije agregata i-te veličine (mm), w_i procentualni sadržaj frakcije agregata na situ i u odnosu na ukupnu masu uzorka.

Rezultati određivanja gore navedenih parametara označeni su kao MWD_d i GMD_d, odnosno MWD_{ws} i GMD_{ws}, gde se indeksi *d* i *ws* odnose na frakcija strukturnih agregata izdvojenih suvim,odnosno mokrim prosejavanjem. Veće vrednosti srednjeg masenog dijametra vodootpornih agregata (MWD_{ws}) ukazuju na veći stepen stabilnosti agregata, niži nivo erodibilnosti i manju opasnost od stvaranja pokorice (Gajić i sar., 2010).

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Rezultati

Results

Unutrašnja morfologija profila kalkomelanosola

The internal morphology of the calcomelanosols profile

Građa istraženog profila posmeđeng kalkomelanosola je A_{mo1}-A_{mo2}-$(B)_{rz}$-R (Slika 1). Humusno-akumulativni – A horizont je moličnog tipa, moćnosti oko 37 cm, u suvom stanju braonkasto crne boje (10YR 3/1), a u vlažnom stanju crne boje (10YR 2/1) i mrvičaste strukture. Kambični $(B)_{rz}$-horizont je i u suvom (10YR 5/3) i vlažnom stanju (10YR 4/3) zagasito žučkasto braon boje, graškaste strukture, moćnosti 13 cm.

Slika 1. Posmeđena crnica na krečnjaku
Figure 1. Brownized Black Soil formed on hard limestones

Mehanički i agregatni sastav kalkomelanosola

Particle size distribution of Calcomelanosols

Po mehaničkom sastavu humusni horizont ovog zemljišta spada u praškaste glinuše, a kambični $(B)_{rz}$-horizont u glinuše, što se vidi iz tabele 1. Mehanički sastav istraženog kalkomelanosola karakteriše dominantna zastupljenost frakcije gline čiji je sadržaj redovno veći od 50%, tačnije varira u intervalu 50,0–63,7%. Od izdvojenih mehaničkih frakcija najmanje učešće ima zbirna frakcija peska, tj. čestice veličine 2,00–0,05 mm (0,9–2,1%). Po dubini profila primećuje se osetnije kolebanje u mehaničkom sastavu, tj. sadržaju mehaničkih frakcija praha i gline, dok kod mehaničke frakcije peska to nije slučaj. Naime, zapaža se povećanje mehaničke frakcije gline s dubinom profila, što je posledica dehumizacije i posmeđivanja.

Tabela 1. Mehanički sastav frakcija sitne zemlje (< 2 mm) ispitivanih zemljišta

Table 1. Particle size distribution of the fine earth fractions (< 2 mm) of the investigated soils

Horizont/ Soil horizon	Dubina/ Depth (cm)	Mehaničke frakcije/ Particle size distribution (%)				
		Krupan pesak/ Coarse sand (0,2–2,00 mm)	Sitan pesak/ Fine sand (0,05–0,2 mm)	Prah/Silt (0,002–0,05 mm)	Glina/Clay (< 0,002 mm)	Teksturna klasa/Soil texture (USDA)
Posmeđeni kalkomelanosol / Brownized Black Soil formed on hard limestones						
A_{mo1}	0–12	1,1	1,0	46,9	51,0	praškasta glinuša/ silty clay
A_{mo2}	12–37	0,8	0,6	40,5	58,1	praškasta glinuša/ silty clay
(B)	37–50	0,2	0,7	35,4	63,7	glinuša/ clay
Kalkokambisol / Calcocambisol						
$(B)_{rz}$	6–36	2,0	4,8	39,6	53,6	glinuša/ clay

Tabela 2 prikazuje agregatni sastav kalkomelanosola pod prirodnim travnim pokrivačem. Udeo različitih frakcija strukturnih agregata pokazao je različite distribucijske obrasce po dubini istraženog profila. Najveći procenat ukupnih agregata čine mrvičasti agregati veličine 0,5–5 mm, zatim graškasti (5–10 mm) makroagregati, osim u površinskom delu humusno-akumulativnog horizonta, potom sledi frakcija strukturnih agregata veličine 0,5–0,25 mm, dok su najmanje zastupljeni mikroagregati (<0,25 mm) koji se još nazivaju i praškastim agregatima. Procentualni sadržaj mrvičastih agregata bio je najveći u površinskom delu A_{mo}-horizonta (A_{mo1}-horizont, 0–12 cm), 86,3%. U potpovršinskom delu humusno-akumulativnog horizonta (A_{mo2}-horizont, 12–37 cm) i kambičnom horizontu sadržaj tih agregata se naglo smanjuje i iznosi 52,8%, odnosno 60,0%. Udeo frakcije graškastih agregata bio je znatno manji u površinskom sloju dubine 0–12 cm (2,2%) nego u potpovršinskim horizontima (28,0–35,1%). Procentualni sadržaj megaagregata varira u intervalu 0,0–9,0%. Najmanju zastupljenost imale su frakcije strukturnih agregata veličine 0,5–0,25 mm (1,8–6,5%) i mikroagregati (1,3–5,1%). Sadržaj poslednje dve frakcije agregata se smanjuje sa povećanjem dubine istraženog profila. Znatnom udelu mrvičastih agregata u ukupnoj zemljišnoj masi doprineo je dubok, gusto razvijen vlaknasti korenov sistem travnate vegetacije.

Tabela 2. Zastupljenost frakcija strukturnih agregata (% mas) izdvojenih suvim prosejavanjem zemljišta
Table 2. Dry aggregate size distribution (mass %) of the investigated soils

Horizont/ Soil horizon	Dubina/ Depth (cm)	Frakcija strukturnih agregata/Aggregate size class (mm)								MWD_d[†] (mm)	GMD_d[††] (mm)
		> 10	10–5	5–3	3–2	2–1	1–0,5	0,5–0,25	< 0,25		
Posmeđeni kalkomelanosol / Brownized Black Soil formed on hard limestones											
A_{mo1}	0–12	0,0	2,2	23,4	30,0	30,7	2,2	6,5	5,1	2,36	1,30
A_{mo2}	12–37	9,0	35,1	33,7	11,0	7,5	0,6	1,8	1,3	5,46	1,91
$(B)_{rz}$	37–50	7,2	28,0	26,4	15,1	16,7	1,8	3,4	1,5	4,67	1,72
Kalkokambisol / Calcocambisol											
$(B)_{rz}$	6–36	32,9	32,7	20,9	6,8	4,5	0,4	0,9	0,9	7,49	2,21

[†] MWD_d – srednji maseni dijametar/mean weight diameter of air-dried aggregates, [††] GMD_d – srednji geometrijski dijametar/ geometric mean diameter of air-dried aggregates.

Rezultati istraživanja prikazani u tabeli 2 pokazuju veće vrednosti srednjeg masenog dijametra (MWD_d) i srednjeg geometrijskog dijametra (GWD_d) u podpovršinskim horizontima u poređenju sa površinskim A_{mo1}-horizontom, što je posledica dejstva korenovog sistema travne livadske vegetacije. Naime, najveće vrednosti MWD_d (5,46 mm) i GWD_d (1,91 mm) utvrđene su u A_{mo2}-horizontu gde se nalazi glavna masa korenovog sistema travne vegetacije. Veće vrednosti MWD_d i GWD_d ukazuju na bolju strukturu zemljišta podpovršinskih horizonata istraženog zemljišnog profila kalkomelanosola u poređenju sa površinskim A_{mo1}-horizontom.

Vodootpornost strukturnih agregata

Water-stable aggregate

Raspodela veličine vodootpornih strukturnih agregata kalkomelanosola prikazana je u tabeli 3. Rezultati pokazuju da je procentualno najzastupljenija frakcija vodootpornih strukturnih agregata veličine 2–1 mm (36,7–47,6%), zatim sledi frakcija mikroagregata <0,25 mm (16,4–20,0%), a potom frakcije agregata veličine 3–2 mm (16,6–17,7%), 1–0,5 mm (13,0–16,3%), >3 mm (3,6–10,5%), dok je najmanje zastupljena frakcija vodootporni agregata dimenzija 0,5–0,25 mm (1,6–2,7%). Udeli izdvojenih vodootpornih frakcija strukturnih agregata bili su slični po horizontima istraženog profila, izuzev udela agregata >3 mm kojih je u A_{mo1}-horizontu bilo za oko 2 do 3 puta više nego u podpovršinskim horizontima.

Brojčane vrednosti MWD_{ws} pokazuju da je vodootpornost agregata nešto veća u površinskom A_{mo1}-horizontu nego u podpovršinskim horizontima (Tabela 3). Rezultati naših istraživanja nisu pokazali značajnije razlike u brojčanim vrednostima GMD_{ws} po dubini istraženog profila. Brojčane vrednosti GMD_{ws} bile su slične, tj. varirale su u veoma uskom intervalu, 0,99–1,02 mm.

Tabela 3. Vodootpornost frakcija strukturnih agregata (% mas.) ispitivanih zemljišta

Table 3. Water-stable aggregate size distribution (mass %) of the investigated soils

Horizont/ Soil horizon	Dubina/ Depth (cm)	Frakcija strukturnih agregata/Aggregate size class (mm)						MWD_{ws}† (mm)	GMD_{ws}†† (mm)
		> 3	3–2	2–1	1–0,5	0,5–0,25	< 0,25		
Posmeđeni kalkomelanosol / Brownized Black Soil formed on hard limestones									
A_{mo1}	0–12	10,5	16,6	36,7	13,6	2,7	20,0	1,53	1,00
A_{mo2}	12–37	3,6	17,7	47,6	13,0	1,6	16,4	1,43	1,02
$(B)_{rz}$	37–50	4,7	16,8	42,4	16,3	2,0	17,8	1,40	0,99
Kalkokambisol / Calcocambisol									
$(B)_{rz}$	6–36	11,5	28,0	33,1	8,0	1,8	17,5	1,75	1,08

† MWD_{ws} – srednji maseni dijametar vodootpornih agregata/mean weight diameter of water-stable aggregates, †† GMD_{ws} – srednji geometrijski dijametar vodootpornih agregata/geometric mean diameter of water-stable aggregates.

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Fizičke osobine kalkomelanosola

Calcomelanosols physical properties

Fizičke osobine kalkomelanosola znatno variraju po genetičkim horizontima (Tabela 4). Gustina suvog zemljišta (ρ_b), poljski vazdušni kapacitet (VK), retencija vode pri pritiscima od –33 kPa i –1500 kPa i brzina vodopropustljivosti (K_{sat}), pokazuju da se A_{mo2}-horizont značajno razlikuje od kambičnog $(B)_{rz}$-horizonta po navedenim fizičkim osobinama. Brojčane vrednosti ρ_b (0,90 g cm^{-3}), poljskog vodnog kapaciteta (40,88%), količine biljkama pristupačne vode (25,18%) i brzine vodopropustljivosti (524,4 cm dan^{-1}) veće su u A_{mo2}-horizontu nego u $(B)_{rz}$-horizontu (0,85 g cm^{-3}, 38,48%, 5,34% odnosno 488,8 cm $danu^{-1}$). Međutim, veličine poljskog vazdušnog kapaciteta (27,68%), maksimalnog vodnog kapaciteta (68,56%) i vlažnosti trajnog uvenuća biljaka (15,70%) u A_{mo2}-horizontu su manje u poređenju sa vrednostima kambičnog horizonta u kojem navedene fizičke osobine imaju vrednosti 37,73%, 76,21% odnosno 33,14%.

Prema klasifikacijama koje navodi Gajić (2006), poljski vazdušni kapacitet, koji je pokazatelj aeracije zemljišta i brzine vodopropustljivosti je veoma visok u oba analizirana horizonta. Kapacitet pristupačne vode biljkama (θ_{pawc}), često se koristi kao pokazatelj kapaciteta zemljišta da zadržava i obezbedi vodu dostupnu biljkama je „idealan" u A_{mo2}-horizontu. U $(B)_{rz}$-horizontu istraženog kalkomelanosola ovaj vodni kapacitet je „loš ". Međutim, s obzirom na relativnu malu moćnost soluma ovog zemljišta ukupne rezerve pristupačne vode biljkama nisu baš mnogo visoke.

Tabela 4. Fizičke i vodno–fizičke karakteristike ispitivanih zemljišta

Table 4. Soil physical properties and water retention characteristics of the investigated soils

Horizont/ Soil horizon	Dubina/ Depth (cm)	ρ_b§ g cm^{-3}	VK† %	θ_s†† %	θ_{fc} %	θ_{pwp} %	θ_{pawc}‡ %	K_{sat}‡‡ cm day^{-1}
Posmeđeni kalkomelanosol / Brownized Black Soil formed on hard limestones								
A_{mo2}	12–37	0,90	27,68	68,56	40,88	15,70	25,18	542,4
$(B)_{rz}$	37–50	0,85	37,73	76,21	38,48	33,14	5,34	488,8
Kalkokambisol / Calcocambisol								
$(B)_{rz}$	6–36	1,29	13,06	52,21	39,15	33,33	5,82	938,4

§ – gustina suvog zemljišta/ bulk density, † – poroznost aeracije/ air-field porosity, †† θ_s – sadržaj vode pri saturaciji/ saturated water content, θ_{fc} – retencioni vodni kapacitet/ field capacity, i θ_{pwp} – vlažnost venuća/ permanent wilting point su definisani kao volumetrijski sadržaji vode u zemljištu na 0, –33 i –1,500 kPa vodnog potencijala, ‡ – ukupno pristupačna voda biljkama/ plant available water content (PAWC), ‡‡ – hidraulička provodljivost/ saturated hydraulic conductivity.

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Hemijske osobine zemljišta
Basic soil chemical properties

Hemijska reakcija zemljišnog rastvora je blago kisela do neutralna (Tabela 5). Vrednosti pH u H_2O (aktivna kiselost) nalaze se u rasponu od 6,58 do 7,19 pH jedinica, a u KCl (razmenljiva kiselost) od 5,73 do 6,38. Iz tabele 6. se vidi da se aktivna, razmenljiva i hidrolitička kiselost (1,04–2,94 cmol kg^{-1}) postepeno povećavaju sa povećanjem dubine profila, što je posledica pedogeneze. Sadržaj humusa u površinskih 37 cm (A_{mo}–horizont), varira od 10,66% do 11,44%, a u $(B)_{rz}$-horizontu je nešto manji – 6,98% (Tabela 5). Sa dubinom neznatno opada, što je svakako uslovljeno vegetacijom, jer koreni trava prodiru sve do krečne podloge, a delom i aktivnošću zemljišne faune koja intezivno meša površinske i dublje slojeve zemljišta (Slika 2).

Adsorptivni kompleks ispitanog kalkomelanosola je relativno visok (61,86–76,13 cmol kg^{-1}) (Tabela 6). Najveće vrednosti razmenljivo-adsorbovanih baznih katjona pokazuje najhumozniji deo humusno-akumulativnog horizonta (0–12 cm). Sadržaj razmenljivo-adsorbovanih baznih katjona u glinovitijem kambičnom horizontu je značajno manji u poređenju sa A-horizontom. Zasićenost baznim katjonima je iznad 95%.

Slika 2. Krtičnjaci na livadama prevoja Vlasina

Figure 2. Mole holes at the meadows of Vlasina pass

Tabela 5. Osnovne hemijske karakteristike ispitivanih zemljišta

Table 5. Basic soil chemical properties of the investigated soils

Horizont/ Soil horizon	Dubina/ Depth (cm)	pH u H_2O	pH u KCl	Humus %	K_2O mg 100 g^{-1}	P_2O_5 mg 100 g^{-1}
Posmeđeni kalkomelanosol / Brownized Black Soil formed on hard limestones						
A_{mo1}	0–12	7,19	6,38	11,44	19,37	1,34
A_{mo2}	12–37	7,17	6,30	10,66	19,67	0,91
$(B)_{rz}$	37–50	6,58	5,73	6,98	28,10	0,41
Kalkokambisol / Calcocambisol						
$(B)_{rz}$	6–36	6,63	5,76	3,76	13,66	0,39

U pogledu sadržaja hranljivih materija rezultati izvršenih laboratorijskih analiza potvrđuju pravilnosti koje su konstatovane i istaknute kod opisa plićih profila crnica, veliko bogatstvo u azotu, slabu obezbeđenost u P_2O_5, srednju i dobru obezbeđenost u lako pristupačnom K_2O. Povećanje sadržaja kalijuma po dubini profila verovatno je posledica povećanja frakcije gline.

Tabela 6. Osnovne karakteristike adsorptivnog kompleksa ispitivanih zemljišta

Table 6. Basic adsorptive characteristics of the investigated soils

Horizont/ Soil horizon	Dubina/ Depth (cm)	H† cmol kg^{-1}	S†† cmol kg^{-1}	CEC††† cmol kg^{-1}	V†††† %
Posmeđeni kalkomelanosol / Brownized Black Soil formed on hard limestones					
A_{mo1}	0–12	1,04	75,09	76,13	98,63
A_{mo2}	12–37	1,31	70,53	71,84	98,17
$(B)_{rz}$	37–50	2,94	58,92	61,86	95,25
Kalkokambisol / Calcocambisol					
$(B)_{rz}$	6–36	1,77	56,93	58,70	96,98

† H – hidrolitička kiselost/ hydrolitic acidity, †† S – suma baznih katjona/ sum of exchangeable bases, ††† CEC – ukupni kapacitet adsorpcije katjona/ total cation exchange capacity, ††† V – saturacija zemljišta bazama/ base saturation.

Morfološka građa kalkokambisola

Morphology of Calcocambisol

Morfološka građa profila istraženog kalkokambisola je O-A-$(B)_{rz}$-R (sl. 3). Podtipovi ovog zemljišta se izdvajaju prema pojavi procesa ilimerizacije na tipične i ilimerizovane kalkokambisole

(Škorić i sar., 1985). Istraženi profil pripada varijetetu srednje dubokih kalkokambisola. O-horizont je male moćnosti (oko 3 cm) i u vidu jezičaka se uvlači u humusno-akumulativni horizont. Čini ga slabo razloženo lišće listopadnog i zimzelenog drveća. Humusno-akumulativni horizont je takođe male moćnosti (3–6 cm), sivkasto žućkasto braon boje (10YR 4/2) u suvom stanju, a u vlažnom stanju braonkasto crne boje (10YR 3/2), rastresit, i zrnaste strukture. Na osnovu terenskog zapažanja, ispod humusnog horizonta obrazuje se kambični $(B)_{rz}$-horizont, zagasito crvenkasto braon boje u suvom (5YR 5/4) i u vlažnom stanju (5YR 4/4), težeg mehaničkog sastava u odnosu na A-horizont.

Slika 3. Morfološki izgled kalkokambisola

Figure 3. Morphology of Calcocambisol

Mehanički i agregatni sastav kalkokambisola
Particle size distribution of Calcocambisol

Prema mehaničkom sastavu kambični $(B)_{rz}$-horizont istraženog kalkokambisola pripada glinušama. Na osnovu prikazanih podataka u tab. 1 ovo zemljište se odlikuje visokim sadržajem frakcije gline, 53,6%. Na drugom mestu po procentualnoj zastupljenosti je frakcija praha – 39,6%, dok najmanji sadržaj ima zbirna frakcija ukupnog peska (čestice veličine 2–0,05 mm), 6,8%.

Rezultati istraživanja agregatnog sastava pokazuju da u ovom zemljištu najveći procentualni sadržaj imaju graškasti agregati veličine 0,5–5 mm (65,3%) i makroagregati (>10 mm) (32,9%). Sadržaji frakcija strukturnih agregata veličine 0,5–0,25 mm i mikroagragata (<0,25 mm) su manji od 1% (tab. 2). Veličine srednjeg masenog dijametra (MWD_d) i srednjeg geometrijskog dijametra (GMD_d) su prilično visoke – 7,49 mm, odnosno 2,21 mm. To nije iznenađenje s obzirom na veliki sadržaj mehaničke frakcije gline i humusa, i uticaja korenovog sistema drveća.

Što se tiče distribucije vodootpornih frakcija strukturnih agregata, iz podataka prikazanih u tab. 3, uočava se znatna dominacija frakcija veličine 2–1 mm (33,1%) i 3–2 mm (28,0%). Sa nešto manjim procentualnim sadržajem zastupljene su frakcije mikroagregata <0,25 mm (17,5%) i agregata >3,0 mm (11,5%). Najmanji sadržaj imaju vodootporni agregati veličine 1–0,5 mm (8,0%) i 0,5–0,25 mm (1,8%). Veličina MWD_{ws} i GWD_{ws}je 1,75 mm, odnosno 1,08 mm.

Fizičke osobine kalkokambisola
Calcocambisol physical properties

Fizičke osobine kalkokambisola prikazane su u tab. 4. Ovo zemljište, kao što se vidi, pokazuje umereno visok poljski vazdušni kapacitet (13,06%) kao i veoma visoku brzinu vodopropustljivosti (938,4 cm dan^{-1}). Pored toga, odlikuje se i umerenom zbijenošću (1,29 g cm^{-3}) i malim kapacitetom pristupačne vode biljkama (< 6% vol.), zbog visoke vlažnosti trajnog uvenuća biljaka (> 33% vol.) koja je uzrokovana visokim sadržajem frakcije gline (53,6%).

Hemijske osobine kalkokambisola

Calcocambisol chemical properties

Kambični horizont ovog zemljišta, kao što se vidi iz podataka, pokazuje neznatan stepen acidifikacije (tab. 5). Naime, hemijska reakcija u vodnoj suspenziji (pH u H_2O) je prema američkoj klasifikaciji (Dugalić i Gajić, 2005) neutralna, tačnije rečeno nalazi se skoro na granici između zemljišta slabo kisele i neutralne reakcije, dok je u kalijum-hloridu (pH u KCl) prema klasififikaciji Penkova (Dugalić i Gajić, 2005) takođe neutralna. Hidrolitička kiselost im takođe nije velika (1,77 cmol kg^{-1}), a zasićenost bazama iznosi 96,98% (tab. 6). Sadržaj adsorbovanih baznih katjona je veoma visok i iznosi 56,93 cmol kg^{-1}, kao i ukupni kapacitet adsorpcije katjona – 58,73 cmol kg^{-1}, što je povezano sa sadržajem mineralnih i organskih koloida. U poređenju sa kalkomelanosolom istraženi kalkokambisol ima nešto lošije hemijske osobine. Naime, karakteriše ga srednji sadržaj lako pristupačnog kalijuma, i veoma slaba obezbeđensot lako pristupačnim fosforom.

Diskusija

Discussion

Kalkomelanosoli se na krečnjacima Ozrena nalaze u različitim fazama razvoja. Naime, evolucija zemljišta na krečnjaku i dolomitu protiče u nizu sukcesivnih stadija, počinjući sa stadijumom organogenih crnica, preko organo-mineralnih crnica, stadijuma rudih šumskih zemljišta i završavajući se sa luvisolima na krečnjaku i sekundarno pseudooglejanim zemljištima. Karstni reljef doprinosi tome da su kalkomelanosoli po dubini profila veoma neujednačene dubine, pa je i to razlog što se na ograničenom malom prostoru često mogu naći gotovo svi razvojni stadijumi ovog zemljišta. Prema podacima sa pedološke karte kalkomelanosol spada u najrasprostranjenije zemljište na Ozrenu.

Kalkokambisol se pojavljuje na nižim terenima od kalkomelanosola, pre svega u sklopu posmeđenih kalkomelanosola, tako da on predstavlja samo dalji, mada ne završni deo ciklusa razvoja zemljišta na jedrom krečnjaku. Kalkokambisoli se mogu javljati i na višim terenim u asocijaciji sa kalkomelanosolima i tada najčešće zauzimaju ravne ili ulegnute forme reljefa krečnjačkih masiva, uvale, vrtače i kraška polja.

Mehanički sastav ispoljava značajan uticaj na fizičke, vodno-vazdušne, fizičko-mehaničke i toplotne osobine, oksido-redukcione uslove, adsorpcionu sposobnost, nakupljanje humusa i hranljivih elemenata u zemljištu. Naročito veliki uticaj ima na vodno-vazdušni, toplotni, hranljivi i biološki režim zemljišta (Dugalić i Gajić, 2012). Sa ekološkog stanovišta, može se reći da oba istražena tipa zemljišta u ovom radu imaju optimalne uslove za rast i razviće biljaka. Sadržaj mehaničke frakcije gline (< 0,002 mm) u solumu kalkokambisola ove studije činio je 51,0–63,7% ukupne mase zemljišta, što je znatno više od vrednosti (30,6–42,4%) koje su objavili Tanasijević i sar. (1965) i Knežević i Košanin (2004) (20,2 –34,0%) za smeđa zemljišta na jedrom krečnjaku planine Ozren. Naši rezultati o procentualnom sadržaju frakcije gline u posmeđenom kalkomelanosolu su slični onima koje su objavili Knežević i Košanin (2004).

Struktura zemljišta ima važan uticaj na edafske uslove i okolnu životnu sredinu. Ona je ključni faktor u funkcionisanju zemljišta, njegovoj sposobnosti da podržava biljni i životinjski svet, te umereni kvalitet životne sredine sa posebnim naglaskom na vezivanje ugljenika u zemljištu i kvalitet vode. Stabilnost agregata koristi se kao pokazatelj strukture zemljišta (Six i sar., 2000). Relativno visok procentualni udeo makroagregata (>2,0 mm) u istraženim tipovima zemljišta pod prirodnom šumom i prirodnom livadom planine Ozren mogao bi se pripisati njihovom visokom sadržaju organske materije, njenoj sporoj razgradnji, organo-mineralnoj kompleksaciji i neometanju zemljišta agrotehničkim merama. Pored toga, hidrofobnost u šumskom zemljištu (Buczko i sar., 2006; Mataix-Solera i Doerr, 2004) takođe je mogla zaštititi i poboljšati agregaciju zemljišta (Piccolo i Mbagwu, 1999) obrazovanjem većih makroagregata, povećanjem kohezivnosti i smanjenjem disperzije agregata (Bronick i Lal, 2005; Goebel i sar., 2005). Obilno korenje pod višegodišnjom livadskom i šumskom vegetacijom može pospešiti agregaciju vezivanjem čestica zemljišta ili mikroagregata (Daynes i sar., 2013) i dodavanjem organskog ugljenika u zemljište (Mapfumo i sar., 2002).

Stabilnost strukturnih agregata istraženih zemljišta, procenjena merenjem raspodele veličine agregata nakon mokrog prosejavanja, je pokazatelj stanja zemljišta i na nju uveliko utiče tip zemljišnog pokrivača, kao i druga svojstva zemljišta, i okolna sredina. Prema utvrđenim vrednostima MWD_{ws} oba istražena tipa zemljišta planine Ozren imaju stabilnu strukturu u vodi, koja se može klasifikovati kao odlična (Dugalić i Gajić, 2012). Prilično visoka vodootpornost strukturnih agregata oba zemljišta može se pripisati velikom unosu organske materije iz nadzemne biomase ispod šuma i prirodnih travnjaka (Blanco-Canqui i Lal, 2004) koja obezbeđuje malčirajući efekat i bolje stanište za mezo- i mikro-faunu i floru zemljišta za poboljšanje agregacije zemljišta.

Hidrofobnost je takođe mogla odigrati svoju ulogu u formiranju visoke vodootpornosti istraživanih zemljišta (Piccolo i Mbagwu, 1999). S druge strane, stabilni vodootporni agregati fizički štite organski ugljenik u zemljištu od mikrobne degradacije i povećavaju vreme njegovog zadržavanja u zemljištu (Daynes i sar., 2013; Stockmann i sar., 2013). Samim tim ako je agregatni sastav dobar i vodootpornost strukture visoka u većini slučajeva su i ostale fizičke i vodno-vazdušne osobine, pored ostalog, prilično dobre.

Struktura zemljišta je osnovno svojstvo za održavanje produktivnosti, očuvanje kvaliteta životne sredine i pružanje usluga ekosistema (Abiven i sar., 2009; Amézketa, 1999; Bronick i Lal, 2005). To je zato što je sposobnost zemljišta da prima, skladišti i provodi vodu, da se odupre stvaranju pokorice i eroziji zemljišta i obezbedi kruženje hranljivih materija (Kay, 1998) povezana sa strukturom zemljišta. Dok je struktura zemljišta heterogeni raspored čvrstog i poroznog prostora u određenom vremenu, strukturna stabilnost zemljišta ili stabilnost agregata odnosi se na sposobnost zadržavanja fizičkog rasporeda čestica, što rezultira šupljinama, kada su podvrgnute različitim stepenima stresa (Angers i Carter, 1996). Stabilnost agregata zemljišta koristi se kao pokazatelj postojanosti strukture zemljišta (Field i sar., 2004; Six i sar., 2000; Zhu i sar., 2009) i stanja zemljišta (Arshad i Coen, 1992; Hortensius i Welling, 1996).

Travnjaci imaju povećanu agregaciju koja proizilazi iz ekstenzivnog rasta korena, što može povećati međuagregatnu poroznost (Bodhinayake i Si, 2004). Velike korenske mase travnjačke vegetacije koje dostižu i do 85% ukupne biljne biomase pomažu razvoju biopora u travnjačkim zemljištima čime se povećava njihova ukupna poroznost (Greenwood i McKenzie, 2001; Bodhinayake i Si, 2004). Navedeni efekat u kombinaciji sa malim poremećajem zemljišta i nakupljanjem organske materije kontinuiranim izumiranjem korena može dovesti do intenzivnijeg stvaranja strukturnih agregata (Daynes i sar., 2013; Hirmas i sar., 2013).

Na osnovu prikazanih fizičkih karakteristika vidi se da su oba istražena tipa zemljišta dobro aerisana i propustljiva za vodu. Odlikuju se i prilično velikom sposobnošću da skladište i obezbeđuju biljke pristupačnom vodom. Cockroft i Olsson (1997) sugerišu, da je poljski vazdušni kapacitet od 15% potreban za zemljišta sa finom teksturom da bi se kompenzirale niske stope difuzije gasova i respiratorni zahtevi biološke aktivnosti. Prema navodima Gajić (2006), vrednosti utvrđene brzine vodopropustljivosti ispitivanih zemljišta su „idealne” za obezbeđivanje brze infiltracije i preraspodele pristupačne vode biljkama, smanjeno površinsko oticanje i eroziju zemljišta, te brzu drenažu viška vode. Međutim, vrednosti znatno iznad utvrđenih u ovom radu mogu podstaći ispiranje hranljivih materija i isušivanje zemljišta, što je povezano s činjenicom da su infiltracija i drenaža prebrzi da bi omogućili odgovarajuću sorpciju. Prilično povoljne fizičke i vodno-vazdušne osobine istraženih zemljišta verovatno su posledica odlične strukture istraženih tipova zemljišta planine Ozren.

U pogledu sadržaja humusa u kambičnom horizontu kalkokambisola, naši rezultati se razlikuju od rezultata do kojih su došli Tanasijević i sar. (1965), a slični su rezultatima koje su saopštili Knežević i Košanin (2004). Tanasijević i sar. (1965) su u svom radu utvrdili svega 1% humusa u kambičnom horizontu istraživanog kalkokambisola planine Ozren. Rezultati ostalih hemijskih osobina istraženih zemljišta su u manjem ili većem stepenu različite od rezultata gore navedenih istraživanja. Jedan od uzorka tome je što različiti tipovi vegetacije mogu uzrokovati značajne razlike u fizičkim, hemijskim i biološkim svojstvima zemljišta (Aon i Colaneri, 2001; Yifru i Taye, 2011; Tauqeer i sar., 2022a,b). Pored toga, tipovi vegetacije obično ispoljavaju dugotrajne uticaje na svojstva zemljišta (Li i sar., 2019).

Zaključak
Conclusion

Ovo istraživanje je izučavalo mehanički i agregatni sastav, kao i najvažnije fizičke i hemijske osobine kalkomelanosola i kalkokambisola, te njihovu ulogu u planinskom ekosistemu Ozrena. Podaci o istraživanim svojstvima svedoče o prilično dobrom fizičkom i hemijskom kvalitetu istraženih zemljišta. Na osnovu tih rezultata može se zaključiti da istraženi kalkomelanosol i kalkokambisol obezbeđuje povoljne ekološke uslove za rast šumskog drveća i travne vegetacije (livada). Osnovni činioci povoljnih ekološki uslova za rast navedene vegetacije u području istaživanja su prilično dobre osobine zemljišta koje utiču na vodni režim i pristupačnost vode biljkama, pre svega struktura zemljišta, a tu su i dubina, mehanički sastav i fiziografija soluma istraženih zemljišta.

Pored toga, naši rezultati pokazuju složeni međuodnos između analiziranih zemljišnih pokazatelja i njihov odnos sa drugim faktorima zemljišta i životne sredine. Međutim, potrebna je detaljnija studija koja će istražiti veći broj tipova zemljišta i njihovih profila da bi se ispitali ovi zamršeni odnosi radi boljeg razumevanja i upravljanja ograničenim prirodnim resursima u kontekstu povećane degradacije zemljišta, klimatskih promena i gubitka bioraznolikosti i usluga ekosistema, na istraživanom području. Nalazi iz ovog istraživanja omogućiće bolje razumevanje karakteristika zemljišta pod različitim načinima korišćenja zemljišta, što će biti od velike koristi upraviteljima zemljišta, uzgajivačima šuma i livada, i stručnjacima za zemljište.

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Contribution to the knowledge of the soils formed on limestones on the Ozren Mountain

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Abstract

Soils formed on limestones occupy large area in Serbia, but there is not a lot of information about their properties. This paper presents physical and chemical properties of the Brownized Calcomelanosols and Moderately-deep Calcocambisols of the Ozren Mountain. Brownized Calcomelanosols under natural grassy vegetation were investigated at the Vlasina pass, whereas Calcocambisols under mixed forests were investigated near the site "Ozrenske livade". Soil profiles were excavated up to the parent material, and disturbed and undisturbed soil samples were collected from soil genetic horizons. Following soil characteristics were determined: particle size distribution, soil structure and water resistance of structural aggregates, bulk density, total porosity, air capacity, water-holding capacity, water conductivity, pH, content of humus, available phosphorus (P_2O_5) and potassium (K_2O), hydrolytic acidity, cation exchange capacity (CEC), sum of exchangeable base cations, and base saturation. Humus-accumulative horizon (A_{mo}) of the Brownized Calcomelanosols has silty clay texture, whereas the cambic $(B)_{rz}$ horizon of both soils has a clay texture. The A_{mo} horizon of Calcomelanosols is characterized by fine to medium granular structure (0.5–5 mm) of very high water resistance. The total porosity, air capacity and water permeability of both soils is high. Their water-holding capacity is high. A_{mo} horizon of Calcomelanosols is characterized by a high humus content (>10%). Soil reaction in water of A_{mo} horizon is neutral, whereas in $(B)_{rz}$ horizons both soils are moderately acid. Both soils have high CEC (>58 cmol kg^{-1}) and base saturatation (>95%). Brownized Calcomelanosol is moderately to highly supplied with available K_2O, whereas Calcocambisol is moderately supplied; while both soils are very poor in available P_2O_5. Since this study presents quite favorable physical and chemical properties of the investigated soils due to the conservation of natural forests and grasslands, the results can help in a deeper understanding of soil ecology and the preservation of natural plant cover.

Keywords: Calcomelanosols; Calcocambisols; soil aggregate stability; water retention; organic matter; cation exchange capacity

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Influence of winter cover crops and different spring crops on soil structure indicators on Chernozem

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Abstract

The intensive form of agricultural production often leads to disruption of physical, chemical and biological properties of the soil. Therefore, in recent years there has been an increasing focus on research and finding ways to preserve the soil with management practices that support soil conservation. The research was conducted on the experimental field of the Institute for Field and Vegetable Crops Novi Sad on Rimski Šančevi. The experiment was set up as a randomized block design. The winter cover crops consisted of the combined intercrops: Triticale (×T*riticosecale* Wittm. ex A. Camus) and winter pea (*Pisum sativum* ssp. *arvense* L.) (T+P), solo winter fodder pea crop (*Pisum sativum* ssp. *arvense* L.) (P) and a control without winter cover crops (sole or mixtures)(Ø). The experiment with winter cover crops was divided into two blocks. In the first block, the winter cover crops were chopped and plowed, while treatments in the second block were mowed using a rotary mower and the fodder was removed for feeding ruminants. After ploughing and preparing the soil for sowing, sowing of spring crops (soybean, maize and sudan grass) was carried out on all varieties in the subsequent sowing period. This research aims to determine the influence of different types of winter cover crops and spring crops from subsequent sowing period on the physical properties of Chernozem with a special emphasis on soil structure. It was determined that values of MWD on the treatments where the mixture of cover crops (T+P plowed) ranged from 1.11 mm to 1.39 mm, which indicated a better aggregates stability compared to the control treatments where no cover crops were sown. Due to variable root morphology and water requirements, which may alter soil structure, it is required to pay more attention to the adaptation of management strategies through the use of cover crops as well as the selection of their mixes.

Keywords: cover crop, soil structure, soybean, maize, Sudan grass

Introduction

The intensive form of agricultural production often leads to disruption of physical, chemical and biological properties of the soil (Vojnov et al., 2019). In recent decades, the soil has been exposed to intense anthropogenic influence (Vojnov et al., 2020a). Modern understandings of the role of soil in sustainable agriculture start with harmonizing production with natural fertility and soil quality (Ćirić et al., 2014). Progressive soil degradation is not only the threat to the world's food supply, but it is also influencing global climate change (Steiner, 1996). According to Pagliai (2004), soil degradation processes present an immediate threat to both biomass and grain yields, as well as a long-term hazard to future crop yields. The Environmental Protection Agency (EPA) estimates that about 85% of the recorded erosion consequences in the Vojvodina province originate from wind erosion. In response to the more obvious soil degradation and loss of its fertility, the Food and Agriculture Organization (FAO) in 2015 declared soil a non-renewable resource indicating that it represents a priceless natural asset (Vojnov et al., 2019).

Soil structure is one of the most important physical soil properties and it is considered a key process of agro-ecosystem sustainability (Bronick and Lal 2005; Sarker et. al 2018; Shaheb et al. 2021). Achieving high and stable yields of cultivated plants strongly depends on soil structure. Soil with a good structure retains more accessible water for plants, reduces water losses and provides greater resistance to the formation of crusts (Belić et al., 2014b). In the Vojvodina province, Republic of Serbia the Chernozem soil type commonly has a good structure because of crumbly structural aggregates, but this can be changed due to inadequate soil management. Ćupina et al. (2011) point out that due to the reduced livestock production, and thus the lack of manure in the Republic of Serbia, it is necessary to make changes in agricultural production to preserve the fertility and quality of the soil. Many authors consider that the conventional method of soil tillage with the use of heavy machinery damages the soil structure, which worsened when working in wet soil with high soil pressure (Botta et al., 2010; Shaheb et al. 2021). Therefore, it is necessary to determine the new way of preserving soil physical properties in the modern agricultural practices. Also, the coverage of the soil during the winter period in Vojvodina which represent flat area, generally, is of great importance to mitigate the negative impact of wind erosion.

Due to reduced livestock, it is considered that cover crops can be an effective solution in reducing the lack of manure (Vojnov et al., 2020a, Vojnov et al., 2022). Cover crops in such a way can play a significant role in terms of preserving soil quality. Cover crops represent one crop, or a mixture of crops grown between two main crops (Ćupina et al. 2004, Vojnov et al. 2020). The use of cover crop mixtures can be an effective strategy for winter use cover crops because cereals and annual legumes complement each other very well (Ćupina et al., 2017). These characteristics have numerous annual fodder plants from the Fabaceae, Brassicaceae and Poaceae families thus they are used as cover crops (Ćupina et al., 2017; Vojnov et al., 2019; Vojnov et al., 2020b). Cover crop residues affect soil structure by reducing evapotranspiration i.e. plant stress during the dry period (Ćupina et al. 2007). Cover crops are also useful in preventing damage caused by erosion (Van Pelt and Zobeck, 2004; Blanco-Canqui et al., 2015). By establishing cover crops, the soil is protected because the plants used for this purpose bind soil particles with their root system, and their above-ground biomass prevents particles from being carried away from the soil surface (Ugrenović and Filipović 2017). Cover crops, like any other plant, can change soil physical and structural features, either directly through the creation of pores and aggregates by roots or indirectly through the input and decomposition of shoot and root residues (Kaspar and Singer 2011). Fast-growing crops with their above-ground biomass protect the soil from the negative impact of summer showers when large raindrops can form a crust when hitting the soil (Ćupina et al. 2007). Organic matter in the soil stabilizes the structural aggregates, makes the soil easier to cultivate, increases aeration, water and buffer capacity (Carter and Stewart, 1996). This research aims to determine the influence of different types of winter cover crops and spring crops from subsequent sowing period on the physical properties of Chernozem with a special emphasis on soil structure.

Materials and Methods

The research was conducted on the experimental field of the Institute for Field and Vegetable Crops Novi Sad, an Institute of national importance for the Republic of Serbia, on Rimski Šančevi (45°20' N, 19°51' E, 86 m). The experiment was set up on Chernozem soil type, subtype of Chernozem formed on loess and loess-like sediments, carbonate soil variety and moderately deep soil form. The experiment was set up as a randomized block design. The winter intercropping trial consisted of a joint crop of winter fodder pea (*Pisum sativum* ssp. *arvense* L.) and triticale (× *Triticosecale* Wittm. ex A. Camus) (T+P), a pure winter fodder pea crop (P) and a control without winter cover crops (sole or mixtures) (Ø). In the last decade of 2020 ploughing of cover crops and the control plot was performed. Ploughing of cover crops (sole or mixtures) utilized as sideration was done with a plow at a depth of 27 cm. At the beginning of June, maize, soybean and sudan grass were sown. Nitrogen fertilization was carried out with 50 kg N ha^{-1}. The experiment with winter cover crops was divided into two blocks. In the first block, the winter cover crops were chopped and plowed, while treatments in the second block were mowed using a rotary mower and the fodder was removed for feeding ruminants. Plowing of forage in the form of sideration (green manure) and seedbed preparation was carried out the day after mechanical termination.

Two plant species of winter cover crop were used in the experiment: triticale (×

Triticosecale Wittm. ex A. Camus - *NS Odisej*) (T) and winter fodder pea (*Pisum sativum* ssp. *arvense* L. - *NS Kosmaj*) (P) and 3 plant species in the subsequent sowing period: soybean (Glycine max - *NS Fortuna*), maize (Zea mays - *NS4051*), sudan grass (Sorghum Sudanese - *NS Sava*). Winter cover crop sowing was done in October at the optimal sowing period. Winter fodder pea was sown at an inter-row spacing of 30 cm and 2 cm deep, and in the first block of the plot, triticale was cross-sown with an Amazon grain seeder at an inter-row spacing of 12.5 cm. When combining T and P, the ratio of the seeds was 30:70, so that there would be no competitive effect of triticale over winter peas. During of flowering of peas and triticale, they were mowed and plowed.

After ploughingand preparing the soil for sowing, sowing of spring crops (soybean, maize and sudan grass) was carried out on all varieties in the subsequent sowing period. The sowing of the crops in the subsequent sowing period was carried out a few days apart after ploughing and soil preparation. Maize was sown in 4 rows with a distance of 75 x 23 cm, a depth of 5 cm, soybean in 6 rows with a distance of 50 x 3 cm, a depth of 4 cm, and sudan grass in 8 rows with an inter-row distance of 37.5 cm at a depth of 2 cm. During the growing season, two inter-row cultivations were applied for soybeans and maize, as well as hoeing. The soil was sampled in autumn before the harvest of crops from the subsequent sowing period.

Soil texture

In the Laboratory for Soil, Fertilizer and Plant Material Testing at the Department of Pedology and Soil Water Regime at the Faculty of Agriculture in Novi Sad, the soil texture was determined. Fractions of fine soil are determined by a combined method based on the different falling speed of particles in the liquid, which can be calculated by the Stockes' formula:

$$v = \frac{gr^2(\rho z - \rho v)}{\eta} \tag{1}$$

v - velocity of particle sedimentation (cm s^{-1})
r - particle radius (cm)
ρz - specific mass of soil particles (dispersed phase) ~2.65 g cm^{-3}
ρv - density of water (dispersed medium). At 20°C it is ~1 g cm^{-3}, and it changes with the addition of a peptizer.

η – water viscosity at 20°C is 0.01 paise. It changes rapidly under the influence of temperature changes.

To achieve peptization of mechanical elements, the soil samples were treated with sodium pyrophosphate.

Structural aggregates distribution - dry sieving

According to Savinov (1936), the dry sieving method is carried out as follows: 500 g of air-dry soil sample is sieved through a series of sieves with square holes of diameter 10, 5, 3, 2, 1, 0.5 and 0.25 mm, to obtain eight aggregate classes (>10, 10-5, 5-3, 3-2, 2-1, 1-0.5, 0.5-0.25 and <0.25 mm). Each class was then measured. The duration of sieving each sample is 1 minute.

The coefficient of structure (Ks) is used to assess the soil structure, which represents the ratio of the % of mesoaggregates (0.25-10 mm) and the sum of megaaggregates and microaggregates (>10 + <0.25 mm) (Gajić, 2006).

$$Ks = C / B \tag{2}$$

Where, C = mass of aggregate class from 0.25 mm to 10 mm; B = aggregate class mass >10 mm and <0.25 mm

According to this coefficient, soils with Ks above 1.5 have a good structure, those with values of 1.5-0.67 have satisfactory structure, and if Ks is lower than 0.67, the soil has an unsatisfactory structure (Veršinin 1958, cited by Belić et al., 2014).

Structural aggregates stability analysis - wet sieving

The wet sieving procedure is a method used to determine the aggregate stability. Weigh 100 g of air-dry soil and wet it on a sieve of 2000 µm, by immersing it in deionized water for 2 minutes. The 8000-2000 µm fraction was obtained by moving the sieve through the water for 2 minutes in a 3 cm up-and-down movement with 30 repetitions. The remaining aggregates on the sieve are transferred to an aluminum vessel with a stream of water. Aggregates that remained (<2000 µm) in the second vessel, which passed through the sieve, are transferred to the next sieve with a smaller diameter. The sieving is repeated with vertical movements (20 repetitions) for a sieve with a diameter of 250 µm and 10 repetitions for a sieve with a diameter of 53 µm. The rest represents the fourth - the smallest fraction. The resulting stable aggregates are dried in oven, and their mass is determined (Elliott 1986). With this procedure, four fractions of structural aggregates were separated (Ćirić 2014): large macroaggregates >2000 μm, small macroaggregates 2000-250 μm, microaggregates 250-53 μm, Silt and clay fraction <53 μm.

When determining the stability of structural aggregates, the following parameters were used: average weight diameter of particles MWD (mean weight diameter) and percentage of water-stable aggregates (% WSA) (Hillel 2004).

$$MWD = \sum_{i=1}^{n} \bar{x}iwi \quad (3)$$

Where, $\bar{x}i$ – average diameter of each soil fraction; wi – proportional share in the total mass of the sample of each of the soil fractions

Percentage of water-stable aggregates (%WSA):

$$\text{WSA (\% of soil >250 μm)} = \frac{WSA-S}{(Wag\ x\ k)-S}\ X\ 100 \quad (4)$$

Where, WSA – mass of water-resistant soil aggregates after drying in a dryer; Wag – total mass of soil samples (100 g); S – mass of coarse sand fractions (g); K – correction factor (total mass of all fractions after drying/mass of air-dry soil)

Results and Discussion

Soil Texture

The soil textural class was determined based on Serbian soil classification system (Belić et al., 2014b). All studied soils at 0-20 cm and 20-40 cm depths, is classified as loamy clay, which corresponds to the studied locality and soil type - Chernozem. From an agronomic point of view, the most favorable ratio of sand-silt-clay fractions is 35-40% – 35-40% – 20-30% (Ćirić, 2014).

Soil structure - dry sieving

Based on size, aggregates are divided into: megaaggregates (>10 mm), macroaggregates (10-0.25 mm) and microaggregates (<0.25 mm). In agricultural production, aggregates with a diameter of 0.25-10 mm are the most favorable for soil structure (Belić et al. 2014).

The results of dry sieving show that the soil samples grown on soybeans (Table 1), maize (Table 2) and sudan grass (Table 3) have the highest percentage of aggregates sizes >10 mm and 10-5 mm, and the lowest percentage of aggregates size < 0.25 mm. According to the data in Tables (1,2 and 3), mega-aggregates had the largest share individually (average values: soybean 38.8%, sudan grass 32.0% and maize 25.7%), and macroaggregates (10-5 mm) in total. In soybean crops, the highest percentage of megaaggregates was obtained when ploughing pea (P plowed 58.2%), in maize crops in the control variant without cover crops (Ø 40.6%), and in sudan grass when ploughing a mixture of triticale and pea (T+P plowed 39.2%). Macroaggregates are the most abundant in the size 10-5 mm in the control variant without cover crops in soybeans (Ø 27.7%), in maize when ploughing a mixture of cover crops (T+P plowed 26.7%), and in sudan grass when mowing pea (P mowed 30.2%). In terms of microaggregates (<0.25 mm), they were most represented in the maize crop when pea was plowed (P plowed 2.6%), and the least in the sudan grass crop when using a mixture of cover crops and ploughing or mowing them (T+P plowed, T+P mowed 1.1%).

Table 1. Percentage of structural aggregates and coefficient of structure in soybean crops

Crop type	Cover crop with their way of use	Aggregate content in %								
		Aggregate size class (mm)								
		>10	10-5	5-3	3-2	2-1	1-0.5	0.5-0.25	<0.25	Ks
Soybean	T+P plowed	38.8	24.0	12.4	7.4	9.2	4.9	2.0	1.3	8.2
	T+P mowed	25.4	23.3	17.0	10.2	13.8	6.5	2.2	1.5	10.6
	P plowed	58.2	20.4	6.3	3.6	4.9	3.1	1.5	1.4	7.6
	P mowed	32.1	25.6	13.4	7.9	10.4	6.1	2.7	1.9	11.5
	Ø	41.7	27.7	11.0	5.6	7.0	3.6	1.7	1.6	9.6
	x̄	38.8	24.0	12.4	7.4	9.2	4.9	2.0	1.3	9.3

Used symbols: T+P - triticale+pea, P - pea, Ø - control, x̄ - arithmetic mean, Ks - structural coefficient

Table 2. Percentage of structural aggregates and coefficient of structure in maize crops

Crop type	Cover crop with their way of use	Aggregate content in %								
		Aggregate size class (mm)								
		>10	10-5	5-3	3-2	2-1	1-0.5	0.5-0.25	<0.25	Ks
Maize	T+P plowed	18.4	26.7	18.0	11.0	14.8	7.5	2.5	1.2	10.1
	T+P mowed	28.5	25.1	14.7	9.5	11.2	6.2	2.8	2.0	12.3
	P plowed	22.1	20.2	13.5	9.3	16.5	11.2	4.6	2.6	16.2
	P mowed	18.9	19.1	15.5	11.1	18.3	11.3	4.1	1.7	12.7
	Ø	40.6	22.7	11.0	6.5	9.4	5.7	2.5	1.6	9.5
	x̄	25.7	22.8	14.5	9.5	14.1	8.4	3.3	1.8	11.8

Used symbols: T+P - triticale+pea, P - pea, Ø - control, x̄ - arithmetic mean, Ks - structural coefficient

Table 3. Percentage of structural aggregates and coefficient of structure in crops of sudan grass

Crop type	Cover crop with their way of use	Aggregate content in %								
		Aggregate size class (mm)								
		>10	10-5	5-3	3-2	2-1	1-0.5	0.5-0.25	<0.25	Ks
Sudan grass	T+P plowed	39.2	26.3	12.6	6.6	8.4	4.1	1.6	1.1	7.2
	T+P mowed	35.5	28.1	13.9	7.7	8.4	3.7	1.4	1.1	7.2
	P plowed	30.9	28.6	13.3	8.0	10.4	5.3	2.1	1.5	9.6
	P mowed	29.3	30.2	14.0	7.7	10.0	5.1	2.1	1.6	10.5
	Ø	25.2	23.7	14.9	9.5	13.5	7.7	3.5	2.0	13.1
	x̄	32.0	27.4	13.7	7.9	10.1	5.2	2.1	1.5	9.5

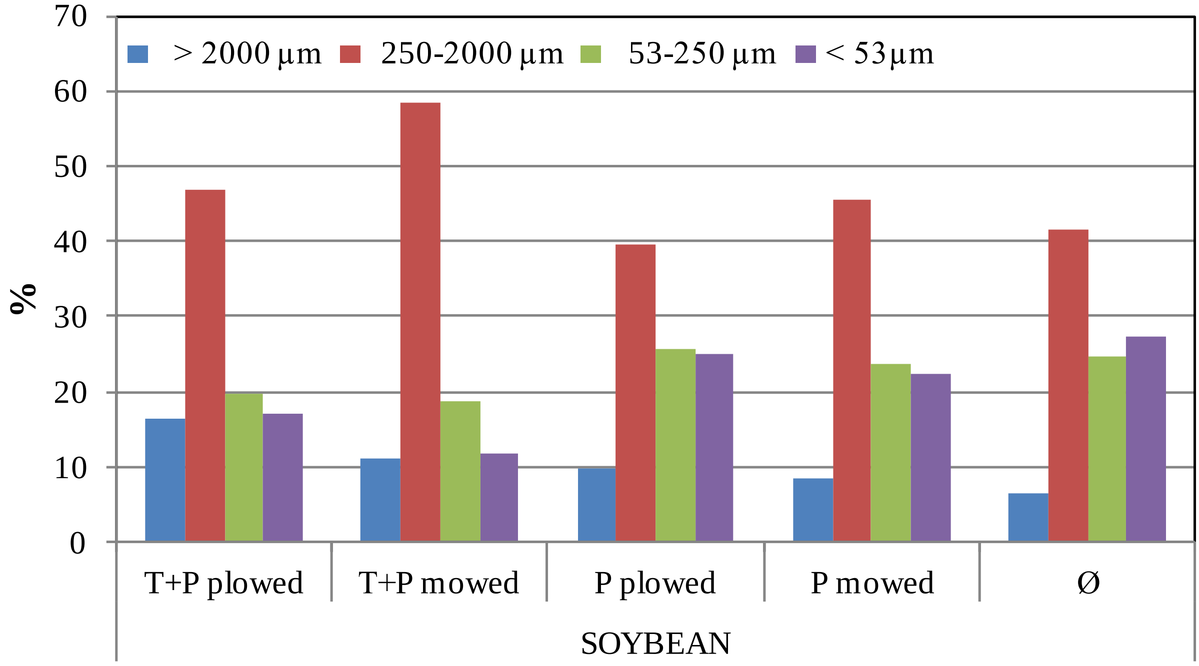
Used symbols: T+P - triticale+pea, P - pea, Ø - control, x̄ - arithmetic mean, Ks - structural coefficient

Regarding the coefficient of structure (Ks), according to Veršinin (1958), soil whose structural coefficient is greater than 1.5 is considered to have a good structure. According to the data from the preceding tables, it can be seen that Ks, in all cultivated crops and when applying all cover crop treatments, is greater than 1.5, which classifies the soil as having a good structure. The highest value of this coefficient was observed in maize when peas were plowed (P plowed 16.2), and the lowest in Sudan grass crops where a mixture of cover crops was used and ploughing or mowing was applied (T+P plowed, T+P mowed, Ks = 7.2). In the Sudan grass crop in the control treatment (Ø - 13.1) where no cover crops were used, a high value of this coefficient is observed due to the different tillage and soil management practices for this crop and the different types of root system compared to soybeans and maize. By comparing all the obtained values, it was noted that the highest Ks of the soil was after harvesting maize compared to soybean and Sudan grass.

During their research, in Ćirić et al. (2012) concluded that Ks is significantly correlated with the content of organic matter (OM) in the soil. The importance of OM in soil is attributed to its acting as a cementing agent and protecting the structure from degradation. Ploughing intercropping allows a greater amount of fresh organic matter in the soil and prevents nitrogen loss from the soil (Couëdel et al., 2018, Qin et al., 2013).

Soil structure - wet sieving

Soil aggregate stability strongly depends upon colloid content and cement materials (sesquioxides, polyuronides, polysaccharides, clay minerals, Ca-humates, and humic substances) and soil management/tillage practices. According to the division of aggregates obtained after wet sieving according to Ćirić (2014), the results showed that in soybean crops, the least aggregates were obtained in the fraction >2000 µm - large macroaggregates, and the most in the fraction 2000-250 µm - fine macroaggregates (Graph 1). In terms of microaggregates (250-53 µm) and silt and clay (<53 µm) in the same crop, the highest abundance is observed in the control variant where cover crops were not applied, and the lowest when mowing a mixture of triticale and pea (T+P mowed).

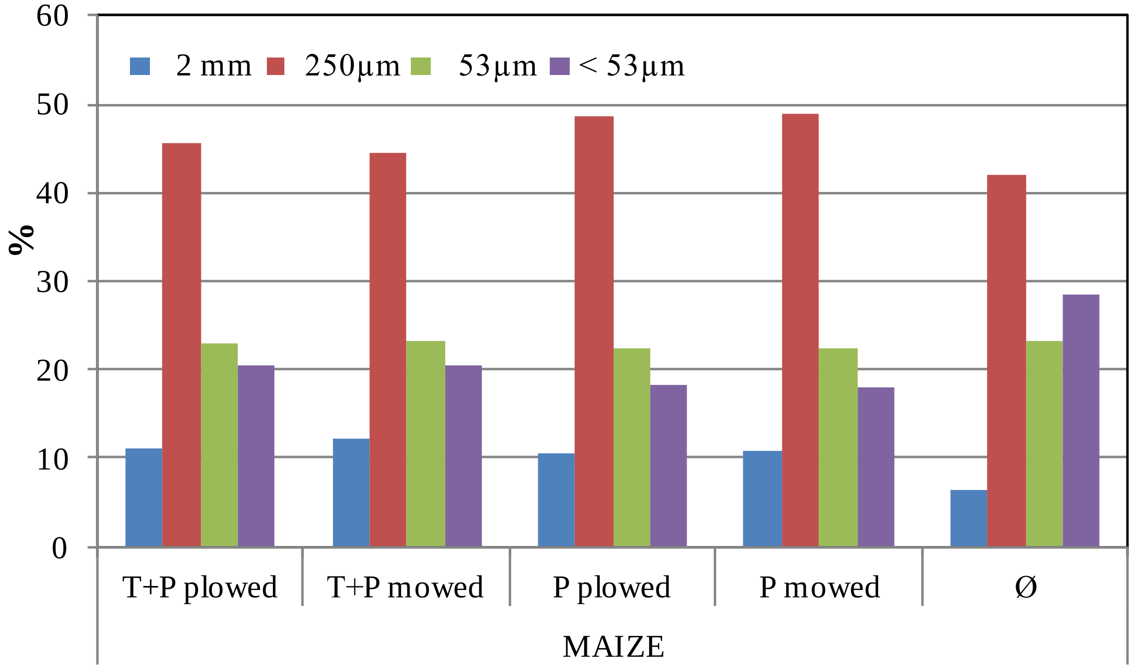


Graph 1. Content of structural aggregates in soybean crops

T+P p- Triticale+Pea (plowed); T+P m- Titicale+Pea (mowed); P – pea (plowed); P – pea (mowed); Ø - control

In the case of maize (Graph 2), the least aggregates were also obtained in the >2000 µm fraction - large macroaggregates, and the most in the 2000-250 µm fraction - small macroaggregates (highest abundance when ploughing pea (P plowed) or mowing peas (P mowed)). In terms of microaggregates, approximately equal values were obtained for all treatments.

The soil under the Sudan grass crop (Graph 3) is characterized by the highest prevalence of small macroaggregates during intercrop ploughing (T+P plowed, P plowed). There are also the least large macroaggregates as in the previous crops (especially in the control variant). Microaggregates are the most common on the treatments on which mixtures of cover crops (T+P) are mowed.

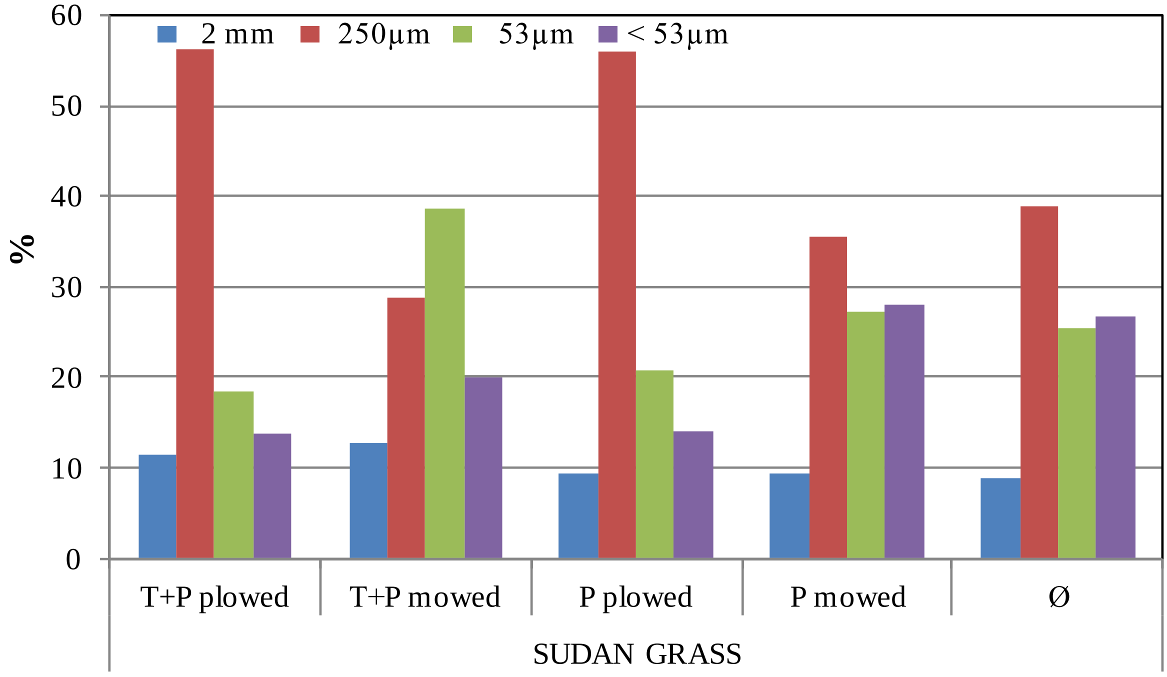


Graph 2. Content of structural aggregates in maize crops

T+P p- Triticale+Pea (plowed); T+P m- Titicale+Pea (mowed); P – pea (plowed); P – pea (mowed); Ø - control

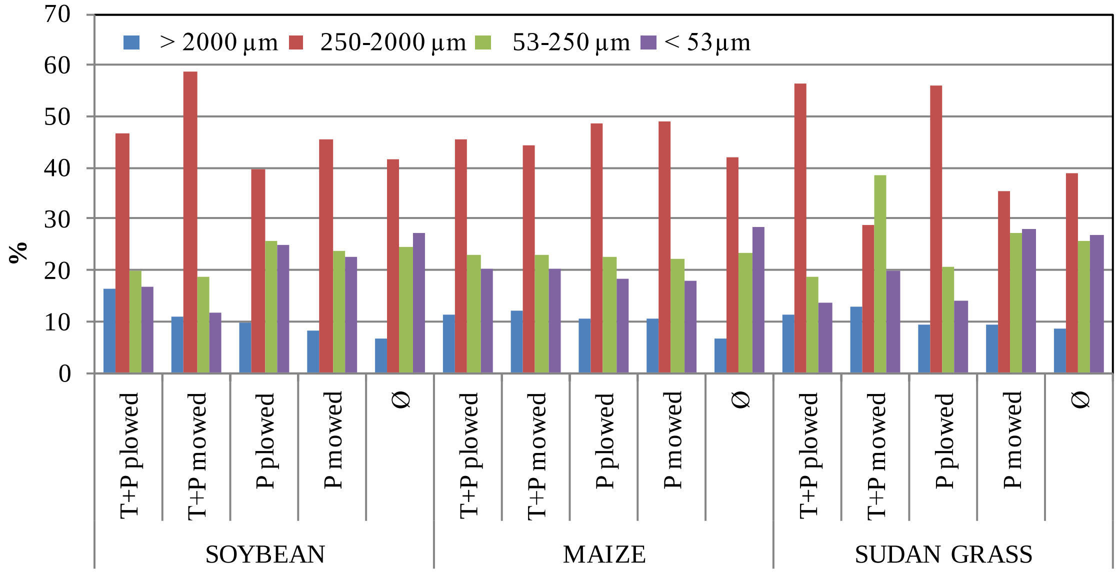
The soil under the Sudan grass crop (Graph 3) is characterized by the highest prevalence of small macroaggregates during intercrop ploughing (T+P plowed, P plowed). There are also the least large macroaggregates as in the previous crops (especially in the control variant). Microaggregates are the most common on the treatments on which mixtures of cover crops (T+P) are mowed.

To compare the previously obtained results of soybean, maize and Sudan grass crops and the use of different varieties of cover crops, Graph 4 shows the differences in the content of soil aggregates.



Graph 3. The content of structural aggregates in Sudanese grass crops

T+P p- Triticale+Pea (plowed); T+P m- Titicale+Pea (mowed); P – pea (plowed); P – pea (mowed); Ø - control



Graph 4. The content of structural aggregates of soybean, maize and Sudan grass in the 0-30 cm layer

T+P p- Triticale+Pea (plowed); T+P m- Titicale+Pea (mowed); P – pea (plowed); P – pea (mowed); Ø - control

The proportion of macroaggregates larger than 2000 µm was the lowest in all treatments. On the soil structure of the arable layer, the treatments T+P affected the highest percentage representation of macroaggregates larger than 2000 µm. The lowest macroaggregate content was recorded in the control varieties. Small macroaggregates (250-2000 µm) in all varieties made up the largest share concerning aggregates of other dimensions, while microaggregates (53-250 µm) were the most covered by the control variant in maize crops. Even though the assessment of the soil structure cannot be made only by considering the ratio of individual fractions of aggregates, the fact is that the largest proportion of aggregates dimensions of 0.25-7 mm provides the most favorable water-air soil properties (Belić et al., 2014).

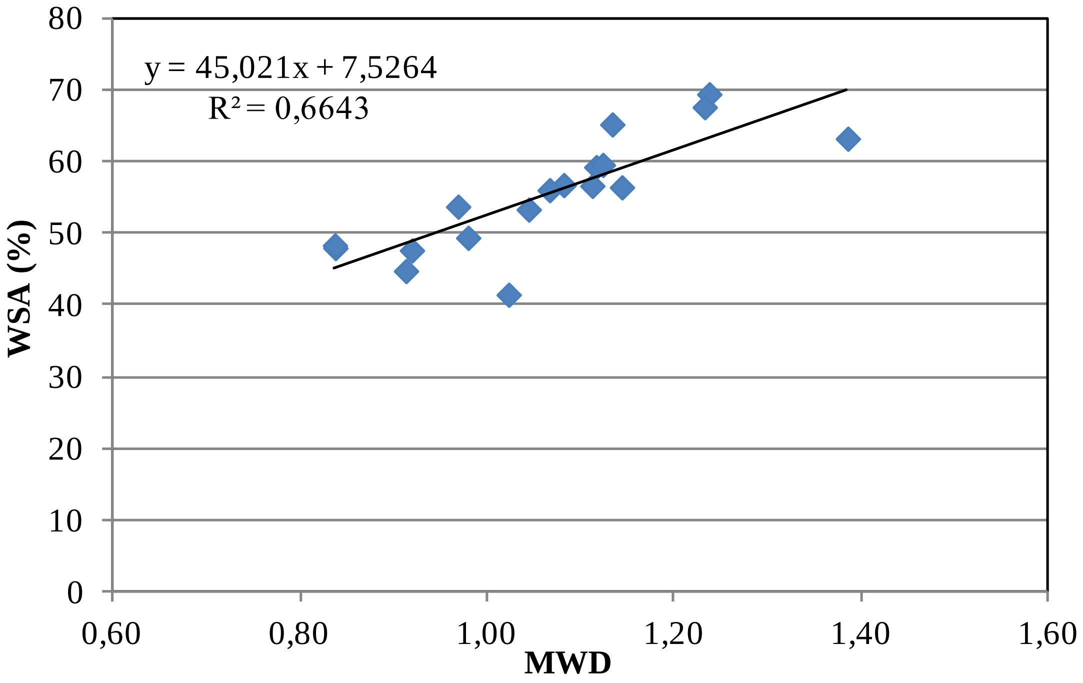
Table 4. Indicators of soil structure - MWD and WSA

Crop	Indicators of soil structure	Cover crops and their utilization				
		T+P plowed	T+P mowed	P plowed	P mowed	Ø
Soybean	MWD (mm)	1.39	1.24	0.98	0.97	0.84
	WSA (%)	63.3	69.51	49.45	53.8	48.02
Maize	MWD (mm)	1.11	1.14	1.12	1.12	0.84
	WSA (%)	56.71	56.5	59.33	59.63	48.38
Sudan grass	MWD (mm)	1.23	1.02	1.13	0.91	0.92
	WSA (%)	67.7	41.49	65.29	44.81	47.69

Used symbols: T+P - triticale+pea, P - pea, Ø - control, MWD - average diameter of structural aggregates, WSA (%) - percentage of waterproof aggregates

When comparing different types of cover crops, way of utilizing cover crops and types of crops grown in the subsequent sowing period, it is observed that the average diameter of the structural aggregates - MWD (Table 4) ranges between the minimum value of 0.84 mm, which shows that the given aggregates are class 2 - unstable (at control varieties - Ø soybean and maize, where cover crops were not used) and the highest value of 1.39 mm, which shows that the aggregates belong to class 4 - stable (for soybean crops - T+P plowed). Higher values of this parameter were observed when using a mixture of cover crops and their ploughing than when mowing and ploughing pea as an intercrop, and the lowest values of 0.84-0.92 mm were obtained in the control varieties (class 3 - medium stable) because no cover crops were used. Le Bissonnais (1996) states that MWD values from 0.8-1.3 mm make medium unstable soil characterized by medium appearance of soil crust, however, in our research on treatments T+G, where cover crops plowed, the values ranged from 1.11 to 1.39 mm, indicating a significantly better stability of structural aggregates compared to control treatments without cover crops.

Soil structure is usually expressed as the degree of overall stability of aggregates during gasification in water. According to Ćirić et al. (2012), MWD was related to the clay and silt content of the soil. When determining the percentage of water resistance of aggregates - WSA (%) (Table 4), the lowest results were also obtained in control varieties without cover crops (47.69% - Ø Sudan grass), and the highest value was determined in soybean crops when mowing a mixture of triticale and pea (T+P mowed - 69.51%). When comparing the methods of using cover crops, it is concluded that in soybean crops, the most water-resistant aggregates are found when using a mixture of cover crops and their mowing (T+P mowed 69.51%), in maize crops when ploughing or mowing pea (P plowed - 59 .33% and P mowed - 59.63%), and in the case of Sudanese grass crops when ploughing a mixture of cover crops (T+P plowed - 67.7%). In short-term research Castiglioni and Behrends Kraemer (2019) also found higher MWD values in soils on which cover crops were previously grown. Hermawan and Bomke (1997) point out that cover crops grown have a better effect on the soil structure after the spring tillage compared to land without cover crops. By looking at the average values of WSA % in our research, according to Kačinski (Shein et al., 2001), the examined soil is characterized by good (40-60%) to excellent stability (60-75%), especially on with T+P treatments after soybean cultivation. The lowest WSA % values were recorded at control plots without intercrops. The obtained results agree with other studies (Liu et al., 2005; Hoorman et al., 2009) where on the control treatments without cover crops values of WSA % were lower. Graph 5 shows the relationship between MWD - average diameter of structural aggregates and WSA (%) - percentage of water-stable aggregates. As the diameter of aggregates increases, their ability to resist gasification in water likewise increases. Šeremešić et al. (2012) state that the unfavorable structure of the arable layer also occurs as a result of tillage at unfavorable soil moisture, so monitoring the soil moisture and choosing a favorable moment of tillage is an important practice in quality plant production. The obtained results show that soil structure is a very complex parameter for the interpretation of which it is necessary to use different indicators to better understand its role.



Graph 5. Correlation of MWD and WSA

Conclusion

In the research it was determined that values of MWD on the treatments where the mixture of cover crops (T+P plowed) ranged from 1.11 mm to 1.39 mm, which indicated a better aggregates stability compared to the control treatments where no cover crops were sown. The lowest percentage of water- resistant aggregates - WSA (%) was observed on the control treatment (without cover crops). Based on the values of the coefficient of structure - Ks (7.2-16.2), it was determined that the analyzed soil after growing cover crops had a favorable structure. Therefore, it is necessary to pay more attention to the adaptation of management practices through the use of cover crops, as well as the selection of their mixtures due to different root morphology and the water requirements, which could affect the soil structure.

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Uticaj ozimih međuuseva i različitih jarih useva na strukturu zemljišta tipa černozem

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Izvod

Intenzivna poljoprivredna proizvodnja često dovodi do narušavanja fizičkih, hemijskih i bioloških svojstava zemljišta. Zbog toga je poslednjih godina sve veći fokus na istraživanju i pronalaženju načina za očuvanje zemljišta u savremenoj poljoprivrednoj praksi. Istraživanje je sprovedeno na oglednom polju Instituta za ratarstvo i povrtarstvo Novi Sad na Rimskim Šančevima. Ogled je postavljen kao randomizovani blok dizajn. Ogled sa ozimim međuusevima sastojao se iz združenog useva: tritikala (×*Triticosecale* Vittm. ek A. Camus) i ozimog graška (*Pisum sativum* ssp. Arvense L.) (T+P), čistog međuuseva – ozimi stočni grašak (*Pisum sativum* ssp. arvense L.) (P) i kontrole bez ozimih međuuseva (Ø). Ogled sa ozimim međuusevima bio je podeljen u dva bloka. U prvom bloku ozimi međuusevi su izmalčirani i zaorani, dok su tretmani u drugom bloku pokošeni rotacionom kosilicom i odneti sa parcele u vidu krme. Nakon oranja i pripreme zemljišta za setvu, izvršena je setva jarih useva (soja, kukuruz i sudanska trava) u naknadnom roku setve. Ovo istraživanje imalo je za cilj da utvrdi uticaj različitih vrsta ozimih i jarih useva iz naknadnog roka setve na fizička svojstva černozema sa posebnim akcentom na strukturu zemljišta. Analizom vrednosti MWD na varijantama sa zaoranim ozimim međuusevom tritikalea i graška kretale su se od 1,11 mm do 1,39 mm i imale su znatno bolju stabilnost strukturnih agregata u odnosu na kontrolne varijante bez međuuseva. S toga je potrebno više pažnje posvetiti prilagođavanju načina gazdovanja kroz upotrebu međuuseva, kao i izboru načina združivanja zbog različite morfologije korena gajenih biljaka i njihovog zahteva za vodom, što može uticati na strukturu zemljišta.

Ključne reči: međuusevi, struktura, černozem, kukuruz, soja, sudanska trava

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The History, Activities and Future Perspectives of the Serbian Soil Science Society

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Abstract

The future capacity of soils to support life on Earth is becoming questionable and in such a situation an important attention is given to soil science and land use–soil policy. This paper presents the historical overview, conducted activities and roles of the Yugoslav and Serbian Soil Science Society (SSSS) from its begining to recent days, as well as future plans. The material tackles the development of soil science in Serbia: foundation of the Soil Society, international cooperation, publication of the journal "Soil and Plant" and other publishing activities, structural organization of the Society, organization of congresses and symposia, and impact of the Society to overall well being by development of various programmes. It also highlights the coordination, consulting, and supporting role of the Society in preparation of the soil map of Yugoslavia. The role of SSSS today is aimed at the general scientific, cultural and educational development and benefit of the Republic of Serbia. The Society has its bodies, eight (nine) commissions, eleven sub-commissions and four working groups. In the coming period, the Society will continue its organizational, publishing, educational, and cooperation activities, but also strive to include soils and soil science among national priorities. The permanent legacy of the Society is the inclusion of soil at the core of policies that support environmental protection and sustainable development in line with new challenges.

Keywords: Serbian Soil Science Society, SSSS, Soil congresses and Symposia, Soil map of Yugoslavia, Soil and plant journal

The History of Serbian Soil Science Society

The Serbian Soil Science Society – SSSS (Srpsko društvo za proučavanje zemljišta – SDPZ) is the legal successor of the Yugoslav Soil Science Society – YSSS (Jugoslovensko društvo za proučavanje zemljišta – JDPZ). Therefore, giving the note about nowadays SSSS is not possible without taking into consideration the work of YSSS, as well with the initial work in the field of soil science from nineteen century up to the recent days, from the former Kingdome of Serbia and Yugoslavia, and after WWII Federal People Republic of Yugoslavia, later Socialistic Federative Republic of Yugoslavia, Federal Republic of Yugoslavia, and nowadays Republic of Serbia.

In Serbia, people were living for centuries depending on soil and its products, with a life strongly embedded in Bible (Gen, 1, 17-19): "Cursed is the ground because of you; through painful toil you will eat food from it all the days of your life. It will produce thorns and thistles for you, and you will eat the plants of the field. By the sweat of your brow you will eat your food until you return to the ground, since from it you were taken; for dust you are and to dust you will return." As such, the soils were sung for centuries in epic and lyric poetry, and the terms of vernacular pedology were developed well indicating the link of Serbs to soil, land and ground.

The first scientific and applied works on soils in Serbia date back to the ninetinth century. They are related to the establishment of the First State Economy in 1851, and then the Agricultural School in Topčider, Belgrade, in 1853. After the school was abolished, an agricultural and chemical experimental station was established in 1898. This was the site of the first fertilization experiments in Serbia, as well as as of first meteorological measurements, beginings in livestock breeding, production of seedlings, innovations in fruit and vine growing, and afforestation.

The first scientific and applicative works on soils in Serbia date back to the ninetinth century. It was related to the foundation of Agricultural school in Topčider, Belgrade, in 1853. This school became an agricultural and chemical experimental station in 1898. This school was a place for the first fertilization experiments in Serbia, as well as as of first meteorological measurements, beginings in livestock breeding, production of seedlings, innovations in fruit and vine growing, and afforestation. The school in Topčider is an ancestor of modern agricultural institutions in Serbia, as it spreaded the seeds of knowledge over the entire country, covering variuos scientific disciplines, and among them also soil science. In fact, later, in 1950, Institute of Soil Science was founded in Topčider.

The stronger development of soil sciences between two wars, in Kingdome of Serbs, Croat and Slovenian, and after Kingdome of Yugoslavia, were related to works of prof. Aleksandar Stebut from Belgrade, and prof. Mihovil Gračanin from Zagreb. Soil scientists of that period published first textbooks for universities and schools and also first monographs and soil maps, and took active participation in international soil events. These were the decades of vigorous early growth. During that time, in 1931, there was the first initiative from the Department of Pedology, from the Faculty of Agriculture in Belgrade, to organize Soil Science Society. However, this proposal was not realized because in 1931 was founded Geological institute at the country level, which had in its statute pedological department. This lasted until the end of second World War.

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After that, in 1946, there was a second initiative from the Pedological department in Zagreb, Croatia, but the organization of the Society stopped because also the organization of Internatianol Soil Science Society was stopped in those after war years. The first, foundation, meeting of Yugoslav Soil Science Society took place in Belgrade on November 8, 1953 (Tešić, 1954). This day was recognized as the foundation day of the Yugoslav Soil Science Society. The first president of the Society was Prof. Dr Stevan Nikolić. The Society was founded to enhance the national expertise in soil science and agricultural production, in accordance with ten–years country development programme. The major actvities of a new born Society were related to international cooperation and publication of the journal „Zemljište i Biljka“ - "Soil and Plant". International cooperation was organized via memebership in International Society of Soil Sciences, through participation in congresses, conferences, meetings, and knowledge exchange. The journal „Zemljište i Biljka“ - "Soil and Plant" was at the begining the forerunner of the Society, as it was officialy founded on December 8, 1951, at Consultation meeting in Zagreb, after the initiative of the Department for Agrochemistry and Pedology, from the Faculty of Agriculture, University of Belgrade. At the same meeting arose new and succesful initiative to found Yugoslav Soil Science Society. The first publications in „Zemljište i Biljka“ – "Soil and Plant" date back to 1952, one year before the official foundation of the Society. After the establishment of the Society, the journal actually became its "child" (organ). The role of the journal was to publish contributions in soil science and agriculture, both nationally and internationally. At the opening speech of the First meeting of the Society, the participants stated "that the Society should take care about the quality of the journal, which represents one of the organs of the Society, and should be devoted to its improvement". The foundation of Soil Society was greeted by Academic Council of Federative Public Republic of Yugoslavia, Serbian Geological Society, Council of the Faculty of Forestry in Belgrade, Serbian Geographical Society, and Serbian Biological Society. The initiative for the foundation of the Society was provided by a small group of pedologist and agrochemists, but the intention was further spread to wider array of scientific workers. At the first meeting, the Society organized republical sections and scientific committees, and it was decided to held the first Congress of Yugoslav Soil Science Society in 1955, in Portorož, Slovenia.

After the second world war, in 1946, Federal Ministry of Agriculture and Forestry gave an initiative to organize the first conference of pedologist of Yugoslavia, focused on the creation of soil map of Yugoslavia with comments. One of the decision of the conference was to create pedogenetic soil map of soil types in Yugoslavia in a scale 1 : 100,000 for the purpose of agricultural zoning and appropriate utilisation of modern agricultural mesures, in order to improve yields of agricultural crops. The initial soil survey and soil mapping work was not coordinated between the different Federal republics, and after the organization of Yugoslav Soil Science Society, its Commission for soil genesis, morphology, classification and cartography took a role of coordinator for soil surveys and mapping. In this period, an initial proposal to create soil maps in a scale 1:100 000 was left, and a decision to create maps in 1:50 000 scale was adopted. After several years, the work on soil map of Yugoslavia advanced, and after two to three decades the major part of the country was mapped. The coordinating role in creation of soil map of the republics of Yugoslavia is one of the greatest achievments of the YSSS during its lifetime. In Bosnia and Herzegovina, this work lasted for 23 years, and finaly finished in 1987 (Jakšić, 1988), whereas in some other republics the work was prolongued in another coming decades. The main reason was the revoke of the Fedaral fund for Scientific Work in 1971, and differences in financing institutions. The greatest effort in soil mapping in Serbia was carried out by Institute of Soil Science in Belgrade, Institute for Field and Vegetable Crops from Novi Sad, and Institute for Water Management in Belgrade.

The first Congress of YSSS was organized in 1955, in Portorož, Slovenia (Nikolić, 1955). During the venue, the annual assembly of the Society was held. The Congress brought the Resoulution, and one of the recommendations was to organise federal soil cartographic centre with a goal to create soil map of Yugoslavia. After the first Congress, the Society organized several consultations, courses and meetings, and also Fifth International Assembly of International Centre for Mineral Fertilizers in Belgrade, in 1956 – Consultations about microelements in agriculture, and fourth World Congress for Mineral Fertilizers in 1961, in Opatija (Croatia). The Society was very active as it has published under special issues several publications, and was a co-editor of the new journal "Agrochemistry", togheter with Society of enterpreneurs for production of products for chemigation of agriculture, and Society for Plant Protection of SR Serbia. Also, the active role of Society was noted in translation of international monographs, and publication of the edition "Stručna biblioteka agrohemije" ("Professional Agrochemistry Library").

The second Congress of YSSS was organized in Ohrid, Macedonia, in 1963 (Jelenić, 1963). This Congress brought the Resolution containing the guidelines for future development of soil science in Yugoslavia. Also, at this Congress was presented a proposal of Yugoslav Soil

Classification System, by Viktor Nejgebauer, Milivoj Ćirić, Georgi Filipovski, Arso Škorić, and Miodrag Živković (Nejgebauer et al., 1963). After the works of Aleksandar Stebut in the thirties and Mihovil Gračanin in the fifities of the 20th century, on soil classification, this was the first after WWII unified work of soil scientists from different republics of ex-Yugoslavia in regards to soil classification. The so called "Ohrid Classification" was a corner stone for the future development of soil classification in Yugoslavia. The resolution states that it is important to unify the work in the field of soil classification and mapping, soil nomenclature, and to create and publish soil maps with comments, and to organize this work via Federal Fund for Scientific Work. The other Commissions of the Socety had also fruitfull work and important conclusions. The overall decision was to organize working groups among all Commissions, which should develop working programmes and notify the problems which should be solved and discussed on the next Congress.

In that period, there was an active participation of the members of YSSS on VIII International Congress in Bucharest, in 1964. In 1965, YSSS actively participated in the organization of International seminar for correlation of soil map legend and soils of Balkan countries and Europe, under the supervision of FAO (Tešić, 1972). In 1965, the journal „Zemljište i Biljka" - "Soil and Plant" was transffered under the Union of Biological Societies of Yugoslavia, under basic Union's publications "Acta biolgica Yugoslavica", as Serie A, as the oldest journal of this serie. In 1965, Society starts with the publication of another important Serie: "Manuals for Soil investigations". The third Congress of YSSS was organized in Zadar, Croatia, in 1967 (Škorić, 1967). It was dedicated to actual problems of soils in intensive agricultural production, to soils with irregular water regime, and soils on karst. The period of begining weaknesses and stabilisation of institutions was left behnd, and the Society was able to cope with high number of important problems from all aspects of soil science, to discuss and solve them in the context of social requirements. After the third Congress, which was thematic in nature and not all commissions were represented, the working commissions were supplemented. The members of the Society were also enrolled in international activities via different working groups of International Union of Soil Sciences (IUSS). European working group for saline soils had a meeting in Novi Sad, Serbia, in 1968. Very important Symposium was held in Bečići, Montenengro, in 1969, devoted to developments and actual problems in soil investigations in Yugoslavia.

The fourth Congress of YSSS was held in Belgrade, in 1972, and it had the highest number of participants, as soil sciences developed very well in the past period (Jugoslovensko društvo za proučavanje zemljišta, 1972). In this period, there was a very sharp increase in promoted PhD and Magisters from educational institutions in Yugoslavia. The work on the Congress was organized via six Commissions of the Society.

The fifth Congress was organized in Sarajevo, Bosnia and Herzegovina, in 1976 (Jugoslovensko društvo za proučavanje zemljišta, 1976). The themes of the fifth congress were the soils of hilly-mountainous regions, intensive management of soils under drainage and irrigation practices, and soil protection.

The sixth Congress was held in 1980, in Novi Sad, Serbia (Jugoslovensko društvo za proučavanje zemljišta, 1980). The Resolution of the Congress reffered to the Problems of Soils under Intensive Management, to Intensification of Agricultural Production at Abnormal Soils, Soil and Land Evaluation, Soil Mapping and Soil Classification in Yugoslavia, and the Environmental Protection and Pedosphere.

The seventh Congress was organized in 1984 in Priština, Serbia (Antonović, 1984). The main topics were following: agricultural production in hilly regions, soil restoration, sustainable land management under field crops, orchards, vineyards, and forests, intensification of crop production under hydro-meliorative systems, and recultivation problems.

The eight Congress was organized in 1988, in Cetinje, Montenegro, with plennary lectures about soils in karstic regions (Jugoslovensko društvo za proučavanje zemljišta, 1988). This was the last Congress of YSSS in ex-Yugoslavia. Each of the events brought their resolutions and conclusions, future directions, and had very well organized excursions.

After the period of the dramatic events of the nineties, YSSS existed but only including active participation of institutions and scientists from Serbia and Montenegro. The ninth Congress was organized in 1997 in Novi Sad, Serbia (Dragović, 1997). The main topics of the Congress were management, arrangment and conservation of soils in 21^{st} century.

The tenth anniversary Congress was organized in Vrnjačka Banja, Serbia, in 2001 (Antonović, 2001) under the title "Soil and new concepts of soil management", with following sections: a) Genesis, classification, cartography and other areas, b) Soil fertility and agrochemistry, c) Soil biology, d) Irrigation, drainage, conservation and e) Soil protection and environment.

The following, eleventh, Congress was organized in Budva, Montenegro, in 2005 (Društvo za proučavanje zemljišta Srbije i Crne Gore, 2005) entitled as "Soil as a Resource of Sustainable

Development". The was the last congress organized togheter with Montenegrin side. In 2011, the Society was restructured and became Serbian Society of Soil Science.

The twelveth Congress was in Andrevlje, Serbia, in 2011 under the title: "Status and Prospectives of Soil Protection, Management and Use" (Sekulić, 2011).

The Serbian Society of Soil Science organized 13th congress in Belgrade, in 2013 (Saljnikov, 2013). This Congress was the first congress officially demarked as an International Congress. It was organized in four sessions: Plennary sesssion, Soil Use, Fertility and Management, Soil-Water-Environmental Protection, and Soil in Space and Time.

The next, fourteenth, Congress was organized in Novi Sad in 2017, and it was second international congress (Belić et al., 2017). It was entitiled as "Solutions and Projections for Sustainable Soil Management" and it had seven sessions.

The third international and 15th national Congress of the Society was organized in 2021, in Soko Banja, Serbia (Gajić et al., 2021). The congress in Sokobanja was organized at the time of COVID-19 Pandemic under the title: "Soils for Future under Global Challanges". It was organized as a hybrid one, with in-person and on-line presence. The participants from 40 countries were invloved in the work of the Congress, majority of them via internet because of the COVID–19 pandemic situation. The participants from Germany, Czech Republic, Poland, Italy, Bosnia and Herzegovina and Montenegro were present in-person. The representatives of British, French, Slovak and Spanish soil societies have presentations about the history, work and future activities of their societies. The topics of the Congress were Soil fundamentals, Soil-water-plant-atmosphere continuum, Soil degradation and soil and water conservation, and 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. This Congress was organized in the International Decade of Soils (2015–2024), proclaimed by IUSS in Vienna Soil Declaration on December, 7, 2015. In the declaration, IUSS recognized the key roles soils play in addressing major resources, environmental, health and social challenges currently facing humanity. Accordingly, the Congress in Sokobanja strived to emphasize the importance of soils through human effects on a landscape level, issues of soil security, role of the soils in climate change mitigation and adaptation, urbanization and sealing of soils, and soil awareness through integrated approaches emphasizing soil functions and services, soil protection and sustainable soil management for a more secured future.

The Society was reorganized in 2011, officially, and the main institutions involved in the work of the society since that time were Institute for Soil Sciences in Belgrade, Faculties of Agriculture from the University of Belgrade and Novi Sad, Faculty of Agronomy in Čačak, Institute for Field and Vegetable Crops from Novi Sad, Faculty of Forestry and others.

The fruitfull activities of the Society in the past period were mainly related to the development of the agricultural and other soil related sectors in the country. The activities of the Society were direct or indirect, but they significantly contributed to overall development and well being of the people. Therefore, an important activity of the Society from the first days of its existence, in addition to the coordinating, advisory and supporting role in the creation of Soil Maps of the former Yugoslav Republics, a very important role of the Society was the development of soil fertility control and the application of fertilizer programs. This work was initially given to Extension Services. The first meeting about this topic was organized in 1965 in Belgrade. Next important activity was related to coordination and support to soil fertility control and determination of harmfull and dangerous substances in soils.

The Society also organized Scientific Symposia about "Degraded soils and problems of their conservation". Nine Symposia were organised from 1975 to 1991. The first was in Peć (Serbia), in 1975, and the following Symposia were in Tuzla (Bosnia and Herzegovina), Lazarevac (Serbia), Lipica (Slovenia), Varaždin (Croatia), Oteševo (Macedonia), Novi Sad (Serbia), Žabljak (Montenegro), and the last one was in Tuzla (Bosnia and Herzegovina), in 1991. Since 1991, the Society recovered slowly and with difficulty from the above mentioned interruption. After 2011, the Society started to restore its activities referring to Symposia organisations. Therefore, the Commission for Soils and Environment organized symposia at Goč, in 2019 (Belanović Simić and Antić Mladenović, 2019) the Sub-Commission for Irrigation and dranage organized the Symposia in Vršac, in 2020 (Stričević and Pejić, 2020), a first hybrid-type event, during COVID-19 pandemic, and the Commission for Soils and Informative Technologies organised Symposia in Novi Sad in 2022 (Ćirić et al., 2022).

The next important role of the Society refers to publishing activities. In 2022, the journal „Zemljište i Biljka“ – "Soil and Plant" reached to volume 72. Nowadays, it is financed mainly be the Ministry of Science, Technological Development and Innovation of the Republic of Serbia. The most important editors of the journal were Prof. Dr. Stevan Nikolić, Prof. Dr. Đurđe Jelenić, Prof. Dr. Vladimir Mihalić, Dr. Gligorije Antonović and Dr. Elmira Saljnikov (current editor).

The Society has also published the Professional Journal Agrochemistry from 1959 to 1989, with 232 releases. The Society also published Manual for chemical methods in soil investigations (Bogdanović et al., 1966), Methods for microbiological investigations of soils and water (Tešić and Todorović, 1966), Methodology for soil survey and creation of soil maps (Filipovski, 1967), Methods for investigation of soil physical properties (Resulović, 1971). These manuals were published in sixties and seventies. Also, in that period was published a Monography Soils of Yugoslavia, and translated book on Utilisation and Improvment of Saline and Alkali Soils. In that period the Society had its newsletter. After the civil war in ex-Yugoslavia in ninethies there was a period of deintensified and changed work of the Society. The members of the Society were drastically reduced compared with the Former Yugoslavia.

In that after-war period, in 1997, the Society published Monograph about Methods in investigations and determinations of soil physical properties (Bošnjak, 1997). After that, there was a long period of "drought" in publishing activity of the Society, excluding the publications from congresses, symposia and issues of the journal. Finally, in 2022 was published a monograph about soil degradation (Belanović Simić, 2022).

Very important role of the Society is directed to international cooperation. The Society is member of International Society of Soil Science, since its beginings. The members of the Society were also members of the organs of International Society. Also, the Society was very active in the work of International Scientific Centre of Fertilizers (CIEC). Prof. Dr. Đurđe Jelenić was a president of CIE for almost twenty years, whereas at the postition of the Secretary were Prof. Dr Staniša Manojlović, Prof. Dr. Rudolf Kastori, and Prof. Dr Srđan Blagojević. After the civil war in ex-Yugoslavia, the Society was reconstructed, changed its name and renewed its membership in International Union of Soil Societies in 2018.

During its lifetime, the Society has gained great contribution from soil scientists from foreign countries. Also, the members of the Society participated in world soil congresses as well as foreign scientists participated in the congresses of the Society. In the period of ninethies the Sub-comission for Agro–Hydromelioration under the leadership of Prof. dr Jordan Milivojević was very active and organized tenths of international visits, especially in Israel, for the members of the Society and overall community. In order not to left behind the marvellious activities of some members of the Society, we decided to give a list (Table 1) of Presidents and Secretary Generals of the Society since its beginings.

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Table 1. Presidents and Secretary Generals of YSSS and SSSS (adopted from Manojlović et al., 1997 and revised)

Period	President	Secretary General	Society
1953–1955	Stevan Nikolić	Đurđe Jelenić	YSSS
1956–1957	Stevan Nikolić	Đurđe Jelenić	YSSS
1958–1959	Stevan Nikolić	Đurđe Jelenić	YSSS
1960–1961	Stevan Nikolić	Milan Todorović	YSSS
1962–1963	Stevan Nikolić	Milan Todorović	YSSS
1964–1965	Stevan Nikolić	Dobrivoje Aleksandrović	YSSS
1966–1967	Stevan Nikolić	Dobrivoje Aleksandrović	YSSS
1968–1969	Arso Škorić	Milan Todorović	YSSS
1970–1972	Živojin Tešić	Dobrivoje Aleksandrović	YSSS
1973–1974	Mirko Leskošek	Nikola Jović	YSSS
1975–1976	Husnija Resulović	Rastislav Korunović	YSSS
1977–1978	Dimitar Popovski	Rastislav Korunović	YSSS
1979–1980	Staniša Manojlović	Gligorije Antonović	YSSS
1981–1982	Budimir Fuštić	Gligorije Antonović	YSSS
1983–1984	Mustafa Dauti	Vladimir Hadžić	YSSS
1985–1986	Jakob Martinović	Miodrag Pejković	YSSS
1987–1988	Grujica Đuretić	Dragi Stevanović	YSSS
1989–1990	Dragoje Dušić	Dragi Stevanović	YSSS
1991–....			YSSS
1995–1997	Vladimir Hadžić	Stojan Stojanović	YSSS
1997–2001	Nebojša Protić	Jordan Milivojević	YSSS
2001–2005	Budimir Fuštić	Gradimir Vasić	SSSSM*
2007–2011	Petar Sekulić	Gradimir Vasić	SSSS
2011–2015	Srboljub Maksimović	Ljiljana Nešić	SSSS
2015–2019	Milivoj Belić	Dragan Čakmak	SSSS
2019–2023	Boško Gajić	Ljubomir Životić	SSSS

*in the period of 2003–2006 with the existence of Serbia and Montenegro, the name of the Society was Soil Science Society of Serbia and Montenegro (SSSSM) – Društvo za proučavanje zemljišta Srbije i Crne Gore (DPZSCG)

Serbian Soil Science Society today

In accordance with the provisions of Articles of the Law on Associations and Statute of the Yugoslav Soil Science Society of February 2, 1996, Assembly of the Yugoslav Soil Science Society on January 28, 2011, issued the Statute of the Serbian Soil Science Society. In the statute it is defined that Serbian Soil Science Society is a social organization and has the status of a legal entity, with rights, obligations and responsibilities stipulated by law and the issued Statute. The

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official address of the Society is Nemanjina 6, 11080 Belgrade–Zemun. The current president of the Serbian Society of Soil Science is Boško Gajić, PhD, Full Professor, whereas the Executive Secretary is Ljubomir Životić, PhD, Assistant Professor, both from the University of Belgrade, Faculty of Agriculture.To achieve its goals and tasks, the Serbian Soil Science Society perform several activities based on membership or other activities defined by law. The main activities based on membership are publishing, publication of the journal "Soil and Plants", publication of collections, monographs and books in the field of soil science, educational activities, and organization of scientific congresses, seminars, symposia, consultations, study trips in the country and abroad, courses, and lectures in the field of soil science.

The role of the Society is aimed at the general scientific, cultural and educational development and benefit of the Republic of Serbia. It continues to develop and realize all aspects of soil science. The mission of the Society is the promotion of soil sciences and application of new findings in the fields of agricultural and forestry production, and overall human and animal well being. Also, it assists teaching and scientific processes in education and academia and cooperate with other scientific societies in the country and abroad. General goals of the Society are related to development and enhancement of all areas of soil sciences. The multifold tasks of the Society are to encourage the practical application of scientific results and foster the advancement of young scientists, to serve as a base for scientific and professional cooperation of soil scientists in Serbia, to contribute to the economic development of Serbia, to foster cooperation between national and international institutitons and scientists, and to organize the exchange of scientific information and findings.

The bodies of the Society are the Assembly, Executive Board, President, Secretary General and Supervisory Board. The Society has eight commissions by its Statute from 2011, with additional Commission from the Assembly meeting in 2019. The Commissions are the following: Commission for soil physics, Commission for soil chemistry, Commission for soil biology, Commission for soil fertility and plant nutrition, Commission for soil genesis, classification and mapping, Commission for soil technology, Commission for soil mineralogy, Commission for soils and the environment, and Commission for Informative technologies and soils. There are following sub-commission in the Society: sub-commissions for salt-affected soils, soil micromorphology, conservation of soils and water, soil zoology, forest soil, land evaluation and assessment, soil remediation, soil cultivation, soil conservation, irrigation and drainage, and climatology and hydrology. The Society has the following working groups: working group for information system and land evaluation, working group for pedotechnology, working group for contaminated soil and groundwater, and working group for urban soils. The Society collects funds from membership fees, participation fees from meetings, voluntary contributions, donations, and sponsorships, gifts, from institutions and individuals, state budgets and other sources in accordance with the law. Serbian Soil Science Society is a member of the International Union of Soil Science, the Association of Agricultural and Food Technicians, the International Scientific Center for Fertilizers, the European Confederation of Soil Science Societies, and the Federation of Eurasian Soil Science Societies. The activities and services of the SSSS are accessible on the web site https://sdpz.rs/, which is regularly updated.

Future perspectives

Growing population pressures, industrialization and intensive use of soil exhaust natural resources and limit the performance of soil functions. The additional impacts of climate change and land use 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. In light of these, soil science again became a major component of each environmental science courses, given that soil plays a key role in elementary natural cycles. Accordingly, the role of Serbian Soil Science Society is again highlighted. The Society aims to contribute to the efforts focused on gaining insight into the impacts of current and future climate, economic, social and political changes on soil resources and the environment, in order to ensure their conservation and efficient use in the production of goods and services that will meet future human demands.

In the coming period the SSSS will continue hosting conferences, publish monographs and books, carry out educational activities, and organize scientific congresses, seminars, symposia, consultations, study trips, courses, and lectures in the field of soil science. The Serbian Society of Soil Science should continue to promote the cohesion and collaboration between soil science experts, but also should aim 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. In a sphere of education, the work of the Society should be focused on the organization of seminars, lectures and courses for younger generations, primary and secondary schools, in order to promote the importance of soils. In future period, it is of high importance to promote the soil as a key compartment for sustainable development and conservation of environmental quality.

In a scientific area, the future activities of the Society should be focused on renewal of its editions on manuals to investigate soils, on native language. Also, the journal „Zemljište i Biljka“ - "Soil and Plant" will have new numbers and the Society should give an effort to improve the rank of the journal. The work on national soil classification system and its improvement should be continued through Commission for soil genesis, classification and cartography. This group should also work on procedures to correlate World reference base for soil resources (WRB) and national soil classification system.

In the coming period, the Society should also create a leverage plan about how to create a framework for interaction with governmental representatives in the field of soil science, land management and other soil and land-related issues. The permanent legacy of the Society should be the inclusion of soil in the core of policies that support environmental protection and sustainable development, in accordance with new challenges. On one side, the increased climate variability, extreme climatic phenomena, torrential rains and floods are affecting the soils and their buffering capacity, and impeding the maintenance of productivity and biological diversity over the land, and thus triggering soil degradation of already threatened soil resources, whereas on the other side, soil and land sustainable management in less developed countries is an enemy of the economy, and is lacking in practices. These two factors together are multiplying their negative effects on soil resources and are required to be included in legal and institutional framework, so that their negative impacts are going to be reduced to desirable level. In this alarming situation, SSSS can be an alert or voice to listen, in order to improve economic benefit from the land, while at the same time protecting our environment and reduce energy consumption. Its role should be to set up soil and pedosphere in the centre of other Earth's spheres at the ‘’decision makers table’’, as the soils is a basic constituent of the terrestrial ecosystem, and it cannot be ignored like to be appeared in the past. The superficial consideration of soils received to date must change, and the role of the Society is to do that without letting these circumstances go by. Therefore, the Society must inform and change the perception of the entire society related to soil resources. After that, an increasingly committed society will contribute and change the course of events.

The Serbian Soil Science Society is a learned society and presents a forum for debate for the Serbian soil science community. The Society promotes the soil sciences via publication of a journal and books and it has a lot of space to conduct the promotion via actions towards young researchers and organization of World Soil Day, and land degradation day. In the future period, SSSS should stand for communication to facilitate the transfer of knowledge, communication to promote soil science, supporting young researchers, and opening partnerships with other professional groups.

To conclude, YSSS was an important contributor to the development of the ex-Yugoslavia. As its successor, the Serbian Soil Science Society should continue to fulfill the same tasks. Nowadays, we are growing, but we may be critical to ourselves and say that we are still in a phase of recovery and development. We should give our efforts to become the corner stone of the development and progress in the country.

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Istorijat, delatnost i budućnost Srpskog društva za proučavanje zemljišta

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Izvod

Sposobnost zemljišta da podrži život na Zemlji u budućnosti je pod znakom pitanja, i usled toga se sve više pažnje poklanja nauci o zemljištu i politici korišćenja zemljišta. U ovom radu je dat istorijski pregled, sprovedene aktivnosti i uloge Jugoslovenskog i Srpskog društva za proučavanje zemljišta (SDPZ) od njegovog nastanka do najnovijih dana, kao i budući planovi. Rad se bavi razvojem nauke o zemljištu u Srbiji i obuhvata: osnivanje Društva za proučavanje zemljišta, međunarodnu saradnju, izdavanje časopisa „Zemljište i biljka“ i druge izdavačke delatnosti, strukturnu organizaciju Društva, organizaciju kongresa i simpozijuma, uticaj Društva na sveobuhvatnu dobrobit preko razvijanja različitih programa. Takođe se ističe koordinaciona i savetodavna uloga Društva u pripremi pedoloških karata u republikama bivše Jugoslavije. Uloga SDPZ je danas usmerena na opšti naučni, kulturni i obrazovni razvoj i dobrobit Republike Srbije. Društvo ima svoje organe, osam (devet) komisija, jedanaest podkomisija i četiri radne grupe. U narednom periodu, Društvo će nastaviti sa organizacionom, izdavačkom, obrazovnom i kooperacionom delatnošću, ali i nastojati da zemljište i nauke o zemljištu uvrsti među nacionalne prioritete. Trajno nasleđe Društva je uključivanje zemljišta u srž politika koje podržavaju zaštitu životne sredine i održivi razvoj u skladu sa novim izazovima.

Ključne reči: Srpsko društvo za proučavanje zemljišta, SDPZ, Kongresi i simpozijumi, Pedološka karta Jugoslavije, časopis „Zemljište i biljka“.

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Acknowledgements: Acknowledgements of financial support, advice, and other kinds of assistance should be made before References section. The contribution of colleagues or institutions should also be acknowledged.

References

Authors are responsible for the accuracy of the references. Citations in the main text should be given by the surname and year of publication. For example, Winter (2012), Shnitzer and Amigo (2007), Ellies et al. (2005; 2009) or: (Winter 2012; Shnitzer and Amigo 2007). The references like “unpublished work” are not accepted. If the same author is cited more than once with all the paper being published in the same year, each subsequent paper should be indicated with the letter accompanying the year of publication in alphabetic order, i.e. 2010, 2010a, 2010b, etc. References list should be arranged alphabetically.

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