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Solutions and Projections for Sustainable Soil Management

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“SOLUTIONS AND PROJECTIONS FOR SUSTAINABLE SOIL MANAGEMENT”

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Classification of Rendzina soils in Serbia according to the WRB system

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ABSTRACT

According to soil classification system used in Serbia (Škorić, Ćirić and Filipovski, 1985) Rendzina is a soil *type* within the *order* of automorphic soils and the *class* of humus-accumulative soils with an Amo-AmoC-C-R profile, which is developed on parent rock containing more than 20% of calcareous material. Rendzinas are divided onto *subtypes* - according to the parent material: (i) marl, marly limestone and soft limestone, (ii) loess and loess like sediments, (iii) dolomite sand, (iv) moraine; on *varieties* - according to stadium of evolution: (i) calcareous, (ii) decarbonated, (iii) brunified, (iv) colluvial, and *forms* - according to texture and coarse fragments content. Throughout the world, the term Rendzina (and Pararendzina) is used to denote soils formed on different calcareous parent material and it generally corresponds with Rendzic Leptosol of the WRB soil classification system. Rendzinas on marl, marly limestone and soft limestone is the most widespread subtype in Serbia, and the aim of this study was to precisely classify it according to the WRB 2015 system.

Total of 29 Rendzina soil profiles from different parts of Serbia were studied. Field and laboratory investigations (soil depth, colour, coarse fragments, texture, structure, pH, soil organic carbon, base saturation) were determined using methods recommended by the WRB system (except for base saturation, where $BaCl_2$, pH 8.1, was used instead of NH_4OAc, pH 7).

According to soil classification system used in Serbia, from total of 21 soil profiles on soft limestone, 16 were calcareous variety (form: 8 loamy, low or medium skeletal and 1 clay, medium skeletal); 13 decarbonated variety (loamy, low skeletal); and 2 colluvial variety (loamy, low skeletal); and 8 profiles on marl of which 7 were calcareous variety (loamy, low or medium skeletal), and 1 profile was decarbonated variety (loamy, low skeletal).

According to WRB 2015 system, investigated Rendzinas were classificated to RSG of Leptosols (12 profiles), Regosols (10 profiles) and Phaeozems (7 profiles). Leptosols include Rendzinas with A-R soil profile, where continuous rock (10 profiles on soft limestone and 2 profiles on marl) starting ≤15-25 cm from the soil surface. For calcareous Rendzina variety, combinations of the principal qualifiers were: Rendzic, Rendzic Calcaric, and Skeletic Calcaric. The decarbonated variety matched the diagnostic criteria for the Eutric principal qualifier. The supplementary qualifiers for Leptosols were Loamic or Clayic, Aric and Humic.

Renzinas deeper than 25 cm, usually with A-AC-R soil profile, having a *mollic* diagnostic horizon were classified to RSG of Phaeozems. For calcareous Rendzinas variety, combinations of the principal qualifiers were: Rendzic Calcaric or Rendzic Skeletic Calcaric. The decarbonated Rendzinas variety only matched criteria for the Leptic principal qualifier. Loamic and Aric supplementary qualifiers were added to Phaeozems.

RSG of Regosols includes Rendzinas thicker than 25 cm, usually with A-AC-R soil profile, when surface horizon does not match diagnostic criteria of a *mollic* horizon (in slightly crushed samples a Munsell colour value of ≥3 moist, and ≤ 5 dry, and a chroma of ≥4 moist). Surface horizons were more than 20 cm deep (except for 2 profiles) and had over 0.6% (1.1-4.6%) *soil organic carbon*. For calcareous Rendzinas variety combinations of the principal qualifiers were: Leptic Calcaric or Leptic Skeletic Calcaric. For Colluvial Rendzinas variety (all calcareous) combination of the principal qualifiers was: Leptic Colluvic Calcaric. Loamic and Aric and/or Humic supplementary qualifiers were used for Regosols.

Soil depth caused the first differentiation between Leptosols and Phaeozems, and soil (moist) colour caused the second differentiation between Phaeozems and Regosols. Somewhat brighter soil colour of Rendzina/Regosols is a result of low soil organic matter content and/or high content of calcaric material in the fine earth.

KEY WORDS: limestone; marl; Leptosols; Phaeozems; Regosols.

INTRODUCTION

From its beginnings (Kubiena, 1953), the term Rendzina meant soils with A-C profile, developed on limestone and dolomites, while the term Parazendzina meant soils developed on silicate-carbonate substrates like: less, marl, fluvio-glacial material, alluvium, etc. In many national soil classifications even today, the terms Rendzina and/or Pararendzina are used to denote soils formed on different calcareous parent material (Avery, 1989; Florea and Munteanu, 2003; Němeček et al., 2001; Шишов et al., 2000; etc). The term Rendzina was used in the FAO soil maps of the world (FAO-UNESCO, 1974) since the establishment of World reference base for soil resources (WRB). According to the Revised legend of FAO soil map of the world (FAO, 1988) and all WRB editions from 1998. to 2015. (IUSS Working Group 2015), Rendzinas from many national soil classification systems belong to reference soil group (RSG) of Leptosols developed on calcareous rocks. According to other literature data (Krasilnikov and Arnold, 2009; Krasilnikov et al., 2013; Kyrylchuk, 2017; Shishkov and Kolev, 2014; Zagórski, 2010) correlation of Rendzinas with the WRB soil classification system is much more complex. Soils called Rendzinas correspond with Rendzic Leptosols in France, United Kingdom, Austria, Switzerland, Poland, Czech, Romania and Ukraine; Rendzic Leptosols or Rendzic Phaeozems in Germany, Slovakia, Hungary, Bulgaria, Cuba and Mexico. Soils called Pararendzinas correspond with Phaozems (Calcaric) in United Kingdom and Austria; Leptosol (Calcaric) in Czech; Leptosol (Calcaric), Regosol (Calcaric), Arenosol (Calcaric) and Phaeozem (Calcaric) in Germany; Rendzic Phaeozems and Umbrisols (Calcaric) in Poland; and Cambisols (Calcaric) and Phaeozems (Calcaric) in Slovakia.

According to soil classification system used in Serbia (Škorić et al., 1985) Rendzina is a soil *type* within the *order* of automorphic soils and the *class* of humus-accumulative soils with an Amo-AmoC-C-R profile. Rendzina includes soils developed on parent rock containing more than 20% of calcareous material (except soils with a A-R profile developed on hard pure limestone or dolomite, which are classified as a distinct soil type: Limestone-Dolomite Black Soil - Kalkomelanosol). Rendzinas are divided into *subtypes* - according to the parent material: (i) marl, marly limestone and soft limestone, (ii) loess and loess like sediments, (iii) dolomite sand, (iv) moraine; *varieties* - according to stadium of evolution: (i) calcareous, (ii) decarbonated, (iii) brunified, (iv) colluvial, and *forms* - according to texture and coarse fragments content.

As far as we know, available correlations of Rendzina soils in Serbia with WRB system (Đorđević and Radmanović, 2016; Dugalić and Gajić, 2012; etc.) are very superficial and generalized. The aim of this study was to precisely classify some Rendzinas soil profiles according to the WRB 2015 system (IUSS Working Group WRB, 2015).

MATERIAL AND METHOD

Total of 29 Rendzina soil profiles on marl, marly limestone and soft limestone (the most widespread subtype in Serbia) from different parts of country were studied. They were found at altitudes starting from 150 m near Lajkovac to 1200 m at the Sjenica-Pešter plateau. Most sites, i.e. those in Vojvodina, eastern Serbia, Šumadija region and Pirot and Bela Palanka environs in south-eastern Serbia, are located at up to 400 m asl. Altitudes exceeding 400 m were found in western Serbia, i.e. the Valjevo environs, while sites in the area of Niš in south-eastern Serbia were found at over 700 m al. Flattened areas at hill tops are used as arable land, while steep slopes are covered with forest and grass vegetation.

Field and laboratory investigations (soil depth, color, coarse fragments, texture, structure, pH, soil organic carbon, base saturation) were determined using methods recommended by the WRB system (FAO, 2006; Van Reeuwijk, 2002), except for base saturation, where $BaCl_2$ (pH 8.1) was used instead of NH_4OAc (pH 7).

RESULTS and DISCUSSION

Soil characteristics and diagnostic horizons, properties and materials are presented in Table 1 and 2. Soils classification according to system used in Serbia (Škorić et al., 1985) and WRB 2015 (IUSS Working Group WRB, 2015) are presented in Table 3.

According to Škorić et al. (1985), from total of 21 soil profiles on soft limestone, 16 were calcareous variety (form: 8 loamy, low or medium skeletal and 1 clay, medium skeletal); 13 decarbonated variety (loamy, low skeletal); and 2 colluvial variety (loamy, low skeletal); and 8 profiles on marl of which 7 were calcareous variety (loamy, low or medium skeletal), and 1 profile was decarbonated variety (loamy, low skeletal).

According to WRB 2015, all investigated soil profiles contain *soil organic carbon* and *mineral* diagnostic material and *continuous rock* as a diagnostic properties. All calcareous and colluvial varieties contain *Calcaric* diagnostic material, while in the decarbonated variety it is absent. M*ollic* is the single diagnostic horizon in 45% soil profiles. Surface horizons of other 55% profiles match all diagnostic criteria of mollic horizon except for the soil colour.

According to WRB 2015 system, investigated Rendzinas were classified as RSG of Leptosols (41% profiles), Regosols (35%) and Phaeozems (24%).

Leptosols include Rendzinas with A-R soil profile, where continuous rock (10 profiles on softy limestone and 2 profiles on marl) staring ≤ 15-25 cm from the soil surface. For calcareous Rendzina variety, combinations of the principal qualifiers are: Rendzic, for soils having *mollic* diagnostic horizon (≤20 cm depth) that directly overlies limestone containing ≥ 40% calcium carbonate equivalent; Rendzic Calcaric, for soil having *mollic* diagnostic horizon that directly overlies calcareous rock containing ≥ 40% calcium carbonate equivalent and having *calcaric* material (4.1% calcium carbonate equivalent) throughout between 20 and *continuous rock* (<25 cm); Calcaric, for soils having *calcaric* material (3-21.7% calcium carbonate equivalent) throughout between 20 cm and *continuous rock*. Decarbonated variety having an effective base saturation ≥95.7% in a layer ≥ 5 cm thick, directly above *continuous rock* match the diagnostic criteria for the Eutric principal qualifier.

Table 1
Characteristics of Rendzina soils on soft and marly limestone

Profile	Depth (cm)	Horizon	PM[a]	Colour (dry)	Colour (moist)	Coarse fragments (% by volume)	Texture[b]	Organic C (%)	Equivalent $CaCO_3$ (%)	pH in H_2O	Base saturation (%)	Diagnostic (WRB 2015)		
												horizons	properties	materials
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0-25	A		10YR3/2	10YR2/3	10.8	cl	4,9	4.1	7.8	ND[c]	*mollic*	-	*mineral, soc*[d]*, calcaric*
	<25	R	sol									-	*continuous rock*	-
2	0-20	A		10YR3/2	10YR2/3	3.7	cl	4.2	6.3	7.0	ND	*mollic*	-	*mineral, soc, calcaric*
	<20	R	sol									-	*continuous rock*	-
3	0-30	A		10YR3/2	10YR2/3	19.7	cl	2.9	9.4	7.7	ND	*mollic*	-	*mineral, soc, calcaric*
	<30	R	sosl									-	*continuous rock*	-
4	0-30	A		10YR3/2	10YR3/3	4.8	cl	2.8	2.9	7.7	ND	*mollic*	-	*mineral, soc, calcaric*
	30-40	AC		10YR6/3	10YR5/3	3.6	cl	1.3	3.1	7.9	ND	-	-	*mineral, soc, calcaric*
	<40	R	ll									-	*continuous rock*	-
5	0-20	A		10YR3/2	10YR2/3	4.7	cl	3.0	4.4	7.6	ND	*mollic*	-	*mineral, soc, calcaric*
	<20	R	sol									-	*continuous rock*	-
6	0-30	A		10YR3/2	10YR2/3	8.1	cl	3.0	5.5	7.5	ND	*mollic*	-	*mineral, soc, calcaric*
	<30	R	sol									-	*continuous rock*	-
8	0-30	A		10YR3/2	10YR3/3	2.3	cl	4.1	1.3	7.5	ND	*mollic*	-	*mineral, soc*
	30-45	AC		10YR6/3	10YR5/3	1.9	cl	1.6	1.6	7.7	ND	-	-	*mineral, soc*
	<45	R	sol									-	*continuous rock*	-
9	0-25	Ap		10YR4/3	10YR3/3	4.9	cl	1.4	1.8	7.7	ND	*mollic*		*mineral, soc*
	<25	R	sol									-	*continuous rock*	-
11	0-15	A		10YR4/3	10YR4/3	9.7	cl	4.6	17.5	7.6	ND	*mollic*		*mineral, soc, calcaric*
	<15	R	ml									-	*continuous rock*	-
16	0-20	A		10YR5/2	10YR3/4	6.6	l	4.5	51.8	7.6	ND	*mollic*		*mineral, soc, calcaric*
	<40	R	sol									-	*continuous rock*	-
19	0-25	Ap		7.5YR4/4	7.5YR4/4	16.1	cl	3.1	8.8	7.8	ND	-		*minaral, soc, calcaric*
	<25	R	sol										*continuous rock*	-
28	0-14	A		10YR5/4	10YR4/4	8.3	cl	2.0	14.4	7.7	ND	-	-	*mineral, soc, calcaric*
	14-30	AC		7.5YR8/2	7.5YR6/2	17.3	cl	0.3	21.0	8.1	ND	-	-	*mineral, soc, calcaric*
				10YR7/8	10YR6/4									
	<30	R	ml										*continuous rock*	-

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30	0-30	A		10YR5/3	10YR3/4	35.2	scl	4.1	17.1	7.6	ND	-	-	*mineral, soc, calcaric*
	<30	R	sol									-	*continuous rock*	-
31	0-40	Ap		10YR5/3	10YR4/4	7.8	cl	1.1	3.7	7.8	ND	-	-	*mineral, soc, calcaric*
	40-61	AC		10YR6/4	10YR6/3	10.6	cl	0.5	4.9	7.9	ND	-	-	*mineral, soc, calcaric*
	<61	R	sol									-	*continuous rock*	-
22	0-20	A		10YR3/4	10YR3/3	36.1	cl	5.3	12.3	7.5	ND	*mollic*	-	*mineral, soc, calcaric*
	20-30	AC		10YR6/2,3	10YR 4/2	46.7	cl	2.4	40.6	7.8	ND	-	-	*mineral, soc, calcaric*
	<30	R	sol									-	*continuous rock*	-
18	0-20	A		7.5YR4/3	7.5YR3/4	16.8	c	3.9	3.03	7.5	ND	-	-	*mineral, soc,calcaric*
	<20	R	sol									-	*continuous rock*	-
7	0-20	A		10YR3/3,2	10YR3/2	1.1	cl	3.3	0	7.1	95.6	*mollic*	-	*mineral, soc*
	20-35	A		10YR4/3	10YR3/4	0.6	cl	1.3	0	7.3	96.4	-	-	*mineral, soc*
	<35	R	sol									-	*continuous rock*	-
17	0-20	A		7.5YR6/4,6	7.5YR 4/6	18.4	cl	2.1	0	7.2	95.7	-	-	*mineral, soc*
	<20	R	sol									-	*continuous rock*	-
20	0-25	A		10YR3/4	10YR3/4	2.7	cl	4.6	0	7.4	98.0	-	-	*mineral, soc*
	<25	R	sol										*continuous rock*	-
21	0-30	Ap		10YR5/3	10YR4/4	1.8	cl	1.3	0	7.3	97.9	-	-	*mineral, soc*
	30-60	A		10YR6/3	10YR5/3	1.6	cl	0.9	3.2	7.7	ND	-	-	*mineral, soc, calcaric*
	<60	R	sol									-	*continuous rock*	
27	0-20	Ap		10YR4/3	10YR4/3	15.2	cl	1.9	6.7	7.7	ND	-	-	*mineral, soc, calcaric*
	20-40	Ap		10YR5/3	10YR4/3	6.7	cl	1.6	7.6	7.7	ND	-	-	*mineral, soc, calcaric*
	40-63	A		10YR5/3	10YR5/3	3.8	cl	1.2	7.8	7.8	ND	-	-	*mineral, soc, calcaric*
	<63	R	sol										*continuous rock*	

[a] PM-parent material: sol-soft limestone, sosl-soft sandy limestone, ll-loesslike loam with softy limestone, ml-marly limestone.
[b] cl-clay loam, l-loam, scl-sandy clay loam.
[c] ND-not detected.
[d] *soc-soil organic carbon.*

Table 2
Characteristics of Rendzina soils on marl

Profile	Depth (cm)	Horizon	PM[a]	Colour (dry)	Colour (moist)	Coarse fragments (% by volume)	Texture[b]	C (%)	$CaCO_3$ (%)	pH in H_2O	Base saturation (%)	Diagnostic (WRB 2015) horizons	Diagnostic (WRB 2015) properties	Diagnostic (WRB 2015) materials
14	0-25	Ap		10YR6/3	10YR4/6	24.0	l	1.8	43.9	7.7	ND[c]	-	-	*mineral, soc[d], calcaric*
	25-40	AC		10YR6/4	10YR4/6	11.2	scl	1.4	51.6	7.8	ND	-	-	*mineral, soc, calcaric*
	<40	C	m									-	-	-
24	0-25	Ap		10YR5/3,4	10YR4/6	15.0	scl	1.1	14.5	8.0	ND	-	-	*mineral, soc, calcaric*
	25-40	AC		10YR7/3,4	10YR7/3	37.9	sl	0.2	29.6	8.3	ND	-	-	*mineral, soc, calcaric*
	<40	R	sm									-	*continuous rock*	-
12	0-25	A		10YR6/2	10YR6/2	27.4	sl	3.3	21.7	8.0	ND	-		*mineral, soc, calcaric*
	<25	R	sm									-	*continuous rock*	
13	0-20	A		10YR5/2	10YR3/4	27.2	sl	4.3	14.8	7.7	ND	-	-	*mineral, soc, calcaric*
	20-40	AC		10YR6/4	10YR4/4	33.2	sl	1.3	16.9	7.9	ND	-	-	*mineral, soc, calcaric*
	<40	R	sm									-	*continuous rock*	-
15	0-20	A		10YR5/4	10YR3/4	31.5	l	4.6	18.1	7.8	ND	-	-	*mineral, soc, calcaric*
	20-40	AC		10YR6/4	10YR4/4	15.5	l	2.8	16.5	7.7	ND	-	-	*mineral, soc, calcaric*
	40-80	C		10YR8/2	10YR8/2							-	*continuous rock*	
	<80	R	m											
23	0-15	A		10YR5/2	10YR3/3	31.0	sl	3.8	27.1	7.6	ND	-	-	*mineral, soc, calcaric*
	15-30	AC		10YR6/3	10YR6/3	57.0	sl	0.8	37.9	8.4	ND	-	-	*mineral, soc, calcaric*
	<30	R	sm									-	*continuous rock*	-
29	0-20	A		10YR3/4	10YR3/4	27.5	scl	3.9	10.0	7.6	ND	-	-	*mineral, soc, calcaric*
	<20	R	cm									-	*continuous rock*	-
10	0-40	Ap		10YR4/2	10YR3/3	1.8	cl	2.0	0	7.0	94.2	*mollic*	-	*mineral, soc*
	40-55	AC		10YR4/3	10YR4/3	10.6	cl	1.1	ND	7.3	ND	-	-	*mineral, soc*
	55-60	C	lm									-	*continuous rock*	-
	<60	R												

[a] PM-parent material: m-marl, sm-sandy marl, cm-calcareous marl, lm-loesslike marly sediment with underlying limestone.
[b] l-loam, scl-sandy clay loam, sl-sandy loam.
[c] ND-not detected.
[d] *soc-soil organic carbon.*

Table 3
Classification of Rendzina soils

Profile	National classification - Variety; form	WRB 2015
	Subtype: on marl, marly and soft limestone	
1	Calcareous; loamy, low skeletal	Rendzic Calcaric Leptosol (Loamic)
2		Rendzic Leptosol (Loamic)
3		Rendzic Calcaric Phaeozem (Loamic)
4		Leptic Calcaric Phaeozem (Loamic)
5		Rendzic Leptosol (Loamic)
6		Rendzic Calcaric Phaeozem (Loamic)
8		Leptic Phaeozem (Loamic)
9		Rendzic Leptosol (Loamic, Aric)
11		Rendzic Leptosol (Loamic)
16		Rendzic Leptosol (Loamic)
19		Calcaric Leptosol (Loamic, Aric, Humic)
28		Leptic Calcaric Regosol (Loamic)
30		Leptic Calcaric Regosol (Loamic, Humic)
31		Leptic Calcaric Regosol (Loamic, Aric)
22	Calcareous; loamy, medium skeletal	Rendzic Skeletic Calcaric Phaeozem (Loamic)
18	Calcareous; clay, medium skeletal	Leptosol (Clayic, Humic)
7	Decarbonated; loamy, low skeletal	Leptic Phaeozem (Loamic)
17		Eutric Leptosol (Loamic, Humic)
20		Eutric Leptosol (Loamic, Humic)
21	Colluvial; loamy, low skeletal	Leptic Colluvic Calcaric Regosol (Loamic, Aric, Humic)
27		Leptic Colluvic Calcaric Regosol (Loamic, Aric, Humic)
14	Calcareous; loamy, low skeletal	Leptic Calcaric Regosol (Loamic, Aric, Humic)
24		Leptic Calcaric Regosol (Loamic, Aric)
12	Calcareous; loamy, medium skeletal	Calcaric Leptosol (Loamic, Humic)
13		Leptic Calcaric Regosol (Loamic, Humic)
15		Leptic Calcaric Regosol (Loamic, Humic)
23		Leptic Skeletic Calcaric Regosol (Loamic, Humic)
29		Leptosol (Loamic, Humic)
10	Decarbonated; loamy, low skeletal	Leptic Phaeozem (Loamic, Aric)

*According to coarse fragments content in % by mass (data not shown)

The supplementary qualifiers for Leptosols were Loamic or Clayic, Aric for soils being ploughed to a depth of ≥ 20 cm from the soil surface, and Humic for Leptosols which do not match criteria for the *mollic* diagnostic horizon but have 2.1-4.6% *soil organic carbon* in the fine earth fraction as a weighted average from soil surface to *continuous rock*.

Renzinas deeper than 25 cm, usually with A-AC-R soil profile, having a *mollic* diagnostic horizon were classified as RSG of Phaoezems. For calcareous Rendzinas variety, combinations of the principal qualifiers were: Rendzic Calcaric dominant and Rendzic Skeletic Calcaric in only one profile; Rendzic for soils having *mollic* diagnostic horizon (0-30 cm depth) that directly overlies limestone *continuous rock* or overlies *calcaric* material (AC transition horizon) both containing ≥ 40% calcium carbonate equivalent; Skeletic for soil having 41.4% (by volume) coarse fragments, avaraged from the soil surface to *continuous rock* and Calcaric for soils having *calcaric* material (5.5-40.6% calcium carbonate equivalent) throughout between 20 cm and *continuous rock*; and Leptic Calcaric for soil having limestone *countinous rock* starting ≤ 30 cm from the soil surface and *mollic* horizon (0-30 cm depth) overlies transitional AC horizon having 1.6-3.1% calcium carbonate equivalent (do not match criteria for a Rendzic qualifier). Decarbonated Rendzinas variety only matches criteria for Leptic principal qualifier, having limestone or marl *countinous rock* starting <30 cm from the soil surface. Loamic and Aric supplementary qualifiers are added to Phaeozems.

RSG of Regosols includes Renzinas thicker than 25 cm, usually with A-AC-R soil profile, when surface horizon does not match diagnostic criteria for a *mollic* horizon (in slightly crushed samples a Munsell colour value of ≥3 moist, and ≤ 5 dry, and a chroma of ≥4 moist). Surface horizons were more

than 20 cm deep (except for 2 profiles) and had over 0.6% (1.1-4.6%) *soil organic carbon*. For calcareous Rendzinas variety, combinations of the principal qualifiers are: Leptic Calcaric dominant and Leptic Skeletic Calcaric, in only one profile. For Colluvial Rendzinas variety (all calcareous), combination of the principal qualifiers are: Leptic Colluvic Calcaric. Leptic - continuous rock (soft limestone or marl) starting at <30-63 cm from the soil surface, Calcaric - *calcaric* material between 20 cm and *continuous rock* contains 3.2-51.6% calcium carbonate equivalent and Skeletic content 44% (by volume) coarse fragments, avaraged from soil surface to continous rock. Two profiles of Colluvial Rendzinas have colluvic material 60-63 cm thick, starting from the soil surface. Soils were found on foot slopes and the material is not of fluviatile, lacustrine or marine origin. Coarse fragments content decreasing with soil depth probably can be a result of colluvial origin of soils. Loamic and Aric and/or Humic supplementary qualifiers are used for Regosols.
According to literature data (Bašić, 2013; Krasilnikov and Arnold, 2009; Krasilnikov et al., 2013; Kyrylchuk, 2017; Nestory, 2007; Shishkov and Kolev, 2014; Zagórski, 2010) Rendzinas in most countries belong to Rendzic Leptosols, and, less, to Rendzic Leptosols or Rendzic Phaeozems.

Pararendzinas include soils on different silicate-carbonate substrates and their comparison is much more complex: most Phaeozem (Calcaric) or Rendzic Phaeozems, then Leptosol (Calcaric), and rarely Regosol (Calcaric), Arenosol (Calcaric), Umbrisols (Calcaric) and Cambisols (Calcaric). Cited authors made general comparison between national soil classifications and WRB system and there did not show numerical values of soil characteristics. Therefore, comparison of the obtained results with literary data is difficult. Rendzinas in Serbia (Škorić et al., 1985) correspond with Rendzinas in the world (except those developed on hard pure limestone and dolomite) and Pararendzinas (developed on loess and loess like sediments, dolomite sand and moraine, with A horizon thickness up to 40 cm). Obtained data comply with Krasilnikov et al. (2013) that 25 cm depth caused differentiation between Leptosols and Phaeozems. The principal qualifiers used for Leptosols comply with literature data (Krasilnikov and Arnold, 2009; Krasilnikov et al., 2013; Kyrylchuk, 2017; Shishkov and Kolev, 2014; Zagórski, 2010), while for Phaeozems along with Rendzic and Calcaric, Leptic was used for soils having limestone or marl *countinous rock* starting <30 cm from the soil surface and *mollic* horizon (0-30 cm depth) overlies transitional AC horizon having less than 40% (or 0%) calcium carbonate equivalent (does not match criteria for a Rendzic qualifier). Krasilnikov and Arnold (2009) classified Pararendzinas as Calcaric Regosols. Along with Calcaric principal qualifier, Leptic and Colluvic qualifiers were used. Soil (moist) colour caused the second differentiation between Phaeozems and Regosols. Somewhat brighter soil colour of Rendzina-Regosols is a result of low soil organic matter content and/or high content of calcaric material in the fine earth fraction.

The most of the investigated Rendzinas on soft limestone belong to Leptosols (48%), then to Phaeozems (28%) and Regosols (24%). The most of Rendzinas on marl and sandy marl belong to Regosol (63%), then to Leptosols (25%) and Phaeozems (12%). From the previous, it can be assumed that the marl parent material has affected soil colour of Rendzinas-Regosols.

Most of the investigated Rendzinas soil profiles belong to calcareous variety (79%), less to decarbonated (14%) and colluvial (7%). Calcareous Rendzinas correspond to Leptosols (43%), Phaeozems (26%) and Regosols (35%); decarbonated variety to Leptosols (50%) and Phaeozems (50%); and colluvial variety (calcareous too) to Regosols. Rendzinas varieties have influenced the principal qualifiers: Leptic is assigned to all varieties; Rendzic, Calcaric and Skeletic to calcareous variety (Calcaric to Colluvic variety too); Eutric only to decarbonated variety; and Colluvic only to colluvic variety.

Rendzinas forms according to soil texture correspond with WRB 2015 supplementary qualifiers. Rendzinas forms according to coarse fragments (% by mass) do not correspond with the Skeleic principal qualifier (% by volume).

This study did not include other three Rendzinas subtypes: on loess and loess like sediments, dolomite sand and moraine; and brunified variety. Their future classification according to the WRB 2015 system will give even more complex composition of the RSG, principal and supplementary qualifiers.

CONCLUSIONS

All investigated soil profiles contain *soil organic carbon* and *mineral* diagnostic material and *continuous rock* as a diagnostic property. *Mollic* is the only diagnostic horizon in 45% soil profiles.

According to WRB 2015 system, investigated Rendzinas were classified as RSG Leptosols (41% profiles), Regosols (35%) and Phaeozems (24%). In different combinations, some of next principal qualifiers were applied: Rendzic, Calcaric and Eutric for Leptosols; Rendzic, Leptic, Skeletic, and Calcaric for Phaeozems; and Leptic, Skeletic, Colluvic and Calcaric for Regosols. Loamic or Clayic, and sometimes Aric (for arable land) supplementary qualifiers were used for Leptosols; Loamic and sometimes Aric for Phaeozems; Loamic and sometimes Aric and/or Humic for Regosols.

Soil depth caused the first differentiation between Leptosols and Phaeozems, and soil (moist) colour caused the second differentiation between Phaeozems and Regosols. Somewhat brighter soil colour of Rendzina-Regosols is a result of low soil organic matter content and/or high content of calcaric material in the fine earth. Rendzinas varieties have influenced the choice of principal qualifiers for all three RSGs. Rendzinas forms according to soil texture correspond with WRB 2015 supplementary qualifiers, while forms according to coarse fragments do not correspond with the Skeleic principal qualifier.

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Mineralogical and geochemical properties of soils around Kuti Lake

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ABSTRACT

The subject of this study are the soils (calcomelanosol, calcocambisol and regosol) in the area of the Neretva River Delta around the Kuti Lake. The objective of this work was to determine geochemical and mineralogical properties of calcomelanosol, calcocambisol and regosol for better understanding weathering processes of source materials.

Chemical, mineralogical and geochemical analysis of the collected soils were carried out in order to determine their properties, such as soil reaction (pH), electrical conductivity, content of carbonates. Organic material was removed from the fraction <2 mm using two methods, H_2O_2, and NaOCl. Following that, the content of TOC was measured in order to determine the effectiveness of these two methods. The presence and importance of Fe-oxide was measured using the dithionite and oxalate treatment. Mineralogical characteristics were determined by the help of XRD. Sequential extraction analysis was made to determine the main binding site of trace metals in the soil, and evaluate their ability to evaluate the bioavailability and remobilisation. The analyses were performed according to the BCR procedure and proportions of elements were determined in four fractions: (1) carbonate, (2) the fraction of Fe-Mn oxide and hydroxide, (3) organic-sulphide, and (4) residual fraction. The following elements were measured: Cu, Mn, Zn, Co, Cd, Ni, Cr, Pb. The extracts obtained by dithionite treatment, oxalate and the sequential extraction analysis were measured by atomic absorption spectrometry.

Calcomelanosol and calcocambisol soils have slightly acid pH, while in regosol is slightly alkaline. Proportion of well crystallized is higher than poor crystallized Fe oxides. Phyllosilicates are dominant mineral phase in calcomelanosol and calcocambisol. Beside this mineral, quartz and mica minerals are also present in analysed soils. Most of analysed elements are bound to residual fraction. Cadmium has higher concentration in organic sulphide fraction.

KEY WORDS: calcomelanosol; calcocambisol; regosol; mineralogical and geochemical properties; Kuti Lake

INTRODUCTION

Geochemical and mineralogical properties of soils may give an insight into the influence of factors determining weathering rates. The investigate area is built of carbonate and dolomite rocks and flysch sediments. Regosol are formed mainly on unconsolidated parent substrate and marl, limestone and flysch. Regosol on flysch is widespread throughout the Adriatic region and islands (Bašić, 2013). Regosol development is totally influenced by the properties of parent material (Hristov, 2016). The main component that determine the soil reaction in these soils are carbonates (Hristov, 2014). Calcomelanosol occurs only on limestone or dolomite rocks. The dominant process of Calcomelanosol genesis is dissolution and leaching of calcium and magnesium. Calcocambisol is formed by dissolving calcite and/or dolomite and by accumulation of insoluble residue on stable relief positions protected from water and wind erosion (Bašić, 2013). Heavy metal retention by soils can be evaluated by investigating their partitioning among the various geochemical phases (Navas and Lindhorfer, 2005). The partitioning of metals in soils is element specific and depends on soil properties such as soil pH, organic matter, clay, and oxide concentrations (Brümmer et al., 1986). The subject of this study are the soils (Calcomelanosol, Calcocambisol and Regosol) in the area of the Neretva River Delta around the Kuti Lake. The objects of this research was: a) to determinate geochemical and mineralogical properties of Calcomelanosol, Calcocambisol and Regosol for better understanding weathering processes of parent materials and b) to study the mobility of selected heavy metals in investigated soils.

MATERIALS and METHODS

Field research was conducted in the area of Kuti Lake, which is located near Metković town in Croatia. The field research consisted of sampling and description of soils.

Three disturbed soil samples (0-25 cm) for laboratory analysis were collected from Calcomelanosol, Calcocambisol and Regosol soils. Soil samples were air-dried and passed through a 2 mm sieve for laboratory analysis.

Chemical, mineralogical and geochemical analysis of the collected soils were carried out in order to determine their properties, such as soil reaction (pH), electrical conductivity and content of carbonates. The presence of Fe-oxides was determined based on iron extractable with Na–dithionite–citrate bicarbonate (both well and poorly crystallized Fe-oxide phases; Fe_d) and iron extractable with ammonium oxalate (poorly crystallized Fe-oxide phases; Fe_o) after the method of Mehra and Jackson (1960). Mineral composition was determined using XRD analyses. Sequential extraction analysis of heavy metals was made to evaluate their bioavailability and remobilisation. The analyses were performed according to Rauret et al. (2001) and proportions of elements were determined in four fractions: (1) carbonate, (2) the fraction of Fe-Mn oxide and hydroxide, (3) organic-sulphide, and (4) residual fraction. The following elements were measured: Cu, Mn, Zn, Co, Cd, Ni and Cr. The extracts obtained by dithionite treatment, oxalate and the sequential extraction analysis were measured by atomic absorption spectrometry (AAnalyst 700, Perkin Elmer).

RESULTS and DISCUSSION

Table 1 present physical and chemical characteristics of Calcomelanosol, Calcocambisol and Regosol type of soils. Values of pH vary from 6.41 to 7.18. Calcocambisol and Calcomelanosols belongs to slightly acid while Regosol to slightly alkaline to neutral soil. Hamidovic et al. (2013) and Miloš and Bensa (2014) also reported similar pH values for Calcocambisol soils. Electrical conductivity is the highest in Calcomelanosol, and the smallest in Regosol, due to their geochemical and mineralogical properties. Carbonate content of investigated soils vary. Miloš and Bensa (2014) reported similar carbonate content for Calcocambisol soils. The highest proportion is determined in Regosol due to their source material. Fe_o/Fe_d ratio is low indicating prevalence of well crystallized iron oxides (Table 1). Merkli et al. (2009) found similar proportion of Fe oxides in Calcomelanosol and Calcocambisol soils. On the contrary, Mn_o/Mn ratio indicate prevalence of poorly crystallized Mn-oxides (Table 1).

Table 1

Physical and chemical properties of the investigated soils. Units for Fe are in mass.%, while for Mn are in mg/kg.

Soil type	pH (KCl)	EC (µS/cm)	$CaCO_3$ (%)	Fe_d	Fe_o	Fe_o/Fe_d	Mn_d	Mn_o	Mn_o/Mn_d
Calcomelanosol	6.67	171.2	0.57	3.80	0.67	0.18	737	591	0.80
Calcocambisol	6.41	124.2	0.78	3.90	0.71	0.18	694	561	0.81
Regosol	7.18	123.5	49.68	0.62	0.11	0.18	210	90	0.43

Phyllosilicates are dominant mineral phases in Calcomelanosol and Calcocambisol (Table 2). Both soil types contain chlorite and/or kaolinite as dominant phyllosilicate mineral phases while mica and mixed-layer clay minerals are subordinate. Regosol is dominated by calcite, while main phyllosilicates are mica, 14 Å phylosillicates and mixed-layer clay minerals. Raičević et al. (2016) found similar mineral composition of Calcocambisol and Calcomelanosol in their study. The similar mineralogical composition reported by Hristov et al. (2010) in their study of Regosols.

Table 2
Semi-quantitative mineral composition of the <2 mm fraction of soils. Legend: Q-quartz; Cal-calcite; Dol-dolomite; Pl-plagioclase; Kfs-pottasium feldspars; M-mica minerals; Gt-goethite; Hem-hematite; Kln-kaolinite; Chl-chlorite; 14 Å-14 Å phylosillicates; MM-mixed-layer clay minerals; AM-amorphous matter; + = mineral is present in the sample; ++-major mineral content (10-20 mass. %);+++-dominant mineral content (>20 mass. %);--mineral is not present in sample; ? = mineral is probably present in the sample but due to the low content and/or overlapping of diffraction peaks cannot be confirmed with certainty.

Soil	Qtz	Cal	Dol	Pl	Kfs	M	Gt	Hem	Kln	Chl	14 Å	MM	AM
Calcomelanosol	16	3	2	4	2	++	+ Gt and/or Hem		+++ Chl and/or Kln		?	++	++
Calcocambisol	15	-	-	?	?	++	+ Gt and/or Hem		+++ Kln and/or Chl		?	++	+/++
Regosol	11	50	-	2	?	++	?		?		++		+

The highest Mn concentration is determined in FEMN fraction of Calcocambisol (Fig. 1a). The similar values of manganese determined by Redžić et al. (2014) in their study of Calcocambisol. Total concentrations of Zn varies between 105.6 to 190.2 mg/kg (Fig. 1b). Total concentrations of 170 mg/kg of zinc is determined. Dvořák et al. (2003) measured similar concentrations of zinc in Calcocambisol. After RES fraction, Zn is bound to OR fraction. Zinc is bound to CARB fraction only in Calcomelanosol. Total concentrations of Co varies between 5.32 to 16.90 mg/kg (Fig. 1c). After RES fraction, Co is bound to FEMN fraction. Cobalt is bound to CARB fraction only in Regosol. The maximum Cd concentrations are determined in OR fraction (Fig. 1d). The Cd distribution for all fractions is same in Calcomelanosol and Calcocambisol. Total concentrations of Ni varies between 81 to 145 mg/kg (Fig. 1e). All samples show same trend of Cr in fractions (Fig. 1f). After residual fraction, chromium is bound to the organic fraction. This agrees with findings by Balasoiu et al. (2001) that reported high retention of Cr in organic fraction in soils.

Total concentrations of Cu varies between 52.27-54.80 mg/kg (Fig. 1g). After RES fraction, Cu is bound to OR fraction. Cu is bound to FEMN fraction only in Calcomelanosol. Pakuła and Kalembasa (2013) in Calcocambisol reported the highest concentration of Cu in the residual fraction, and the lowest in the carbonate fraction.

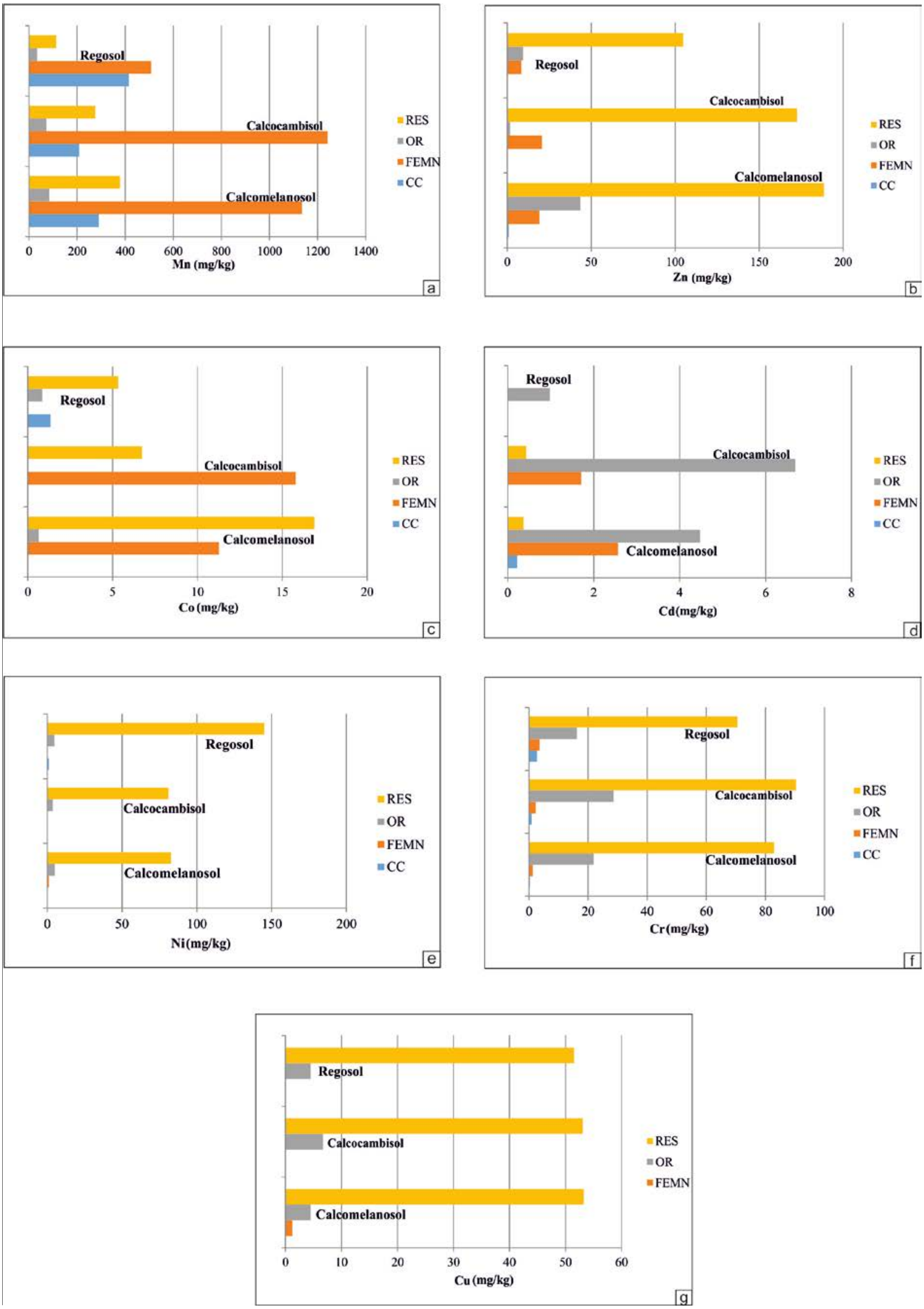

Figure 1. a) Distribution of Mn in fractions of soils; b) distribution of Zn in fractions of soils; c) distribution of Co in fractions of soils; d) distribution of Cd in fractions of soils; e) distribution of Ni in fractions of soils; f) distribution of Cr in fractions of soils; g) distribution of Cu in fractions of soils.

CONCLUSIONS

Calcomelanosol and Calcocambisol soils have slightly acid pH, while in Regosol is slightly alkaline to neutral. Fe_o/Fe_d ratio is low in all soil typed and indicates prevalence of well crystallized iron oxides. Both Calcomelanosol and Calcocambisol contain chlorite and/or kaolinite as dominant phyllosilicate mineral phases while mica and mixed-layer clay minerals are subordinate. Regosol is dominated by calcite, while main phyllosilicates are mica, 14 Å phylosillicates and mixed-layer clay minerals. Most of analysed elements are bound to residual fraction. Cadmium has higher concentration in organic sulphide fraction due to its affinity to organic matter which is in line with mineralogical composition. The metal retention in studied soils can be put in the following order: Calcocambisol>Calcomelanosol>Regosol.

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Copper accumulation and availability in Serbian smonitza soil

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ABSTRACT

Copper is one of the most essential trace element for plants and animals. The character of parent material has the greatest impact on the copper content in the soils. The artificially introduction in the soil of Cu is in various ways: by precipitation from the atmosphere (particularly in the vicinity smelting ferrous metal), using a variety of waste sludge, as well as beneficial to the agricultural materials (fungicides-"Bordeaux mixture", a spreader, solid and liquid manures). Thus leads to the contamination of soil, when the total content of Cu exceeds the limit value of 100 mg/kg. When the Cu of natural origin in the plot, it is for the most part is bonded in the crystal lattices of the minerals and in attached form on oxides of Mn, Fe, and Al. The characteristics of Cu is to be stronger than the other trace elements (Mn, Zn) associated in a complex with an organic substance, leading to the occurrence of the lack of available Cu to the plants in the soil very rich in organic matter (peat soil). Available forms for plants in the soil has at least a copper (Cu in solution and adsorbed on the colloid exchangeable). In the case of the artificial introduction of Cu in the plot, due to the tight attachment with an inorganic or organic materials, lags far behind the most part in the upper soil horizon and its contents were significantly reduces the depth.

The aim of this work is detailed examination of the state of copper in Serbia Smonitzas and giving score to this type of soil in relation to plants supply with this element.

The investigations were conducted on Vertisols (Smonitza) type of soil taken from the Ap horizon at ten different localities in Serbia: (1) Milutovac, (2) Priština, (3) Trnava, (4) Rekovac, (5) Vranje (Neradovac), (6) Zaječar, (7) Bela Crkva, (8) Blace, (9) Salaš and (10) Kragujevac. The sub-samples were air-dried, crushed in a porcelain mortar with a pestle to 1 mm particle size, were determined the chemical and physical soil properties by common analyzing methods, in use in our country in preparation for a greenhouse experiment designed to determine plant availability of Cu in soil.

The pseudo-total content of copper was determined by atomic adsorption spectrophotometry after digestion of soil samples with conc. HNO_3 and then treated with H_2O_2. The content of the available copper was determined by AAS spectrophotometry, after the extraction from soil with different extraction techniques: 0,1N HCl, 0.005M DTPA and 1N NaOAc.

In addition a vegetation experiment in pots was performed in Vertisol soils taken from 10 above mentioned locations. The plants were followed 45 days in controlled laboratory conditions. Water was added to obtain optimal humidity. After 45 days the plants were dug up, rinsed with destiled water, and dried at room temperature in a dryer at t=70ºC. The dried plants were ground into a powder and content of Cu in oats was determined by AAS method, after digestion with tri-acid mixture HNO_3, $HClO_4$ and H_2SO_4. According to recorded content of the total Cu in the analyzed Smonitzas one can speak of its natural, geochemical origin, as found from the mean value of 36.9 mg/kg for the meadows and 29.8 mg/kg for the arable land, as well as the value of the total of the Cu individual samples, with some variations, are within normal values for unpolluted soil. The content available copper, based on three different extraction techniques, showed that the test smonitzas accomplished by the limit values, according to Ankerman, 1977, high and very high levels. That says it all about the high provision to a very affordable Cu tested Smonitza and in this regard there will not be problems in growing plants in these lands. Based on the results of state of the trace elements Cu in Serbia Smonitzas the following conclusion can be made that in the test Smonitzas total Cu content ranged from 17 to 74 mg/kg.
KEY WORDS: smonitzas, cooper, extraction, oats

INTRODUCTION

Copper is one of the most essential trace element for plants and animals. The character of parent material has the greatest impact on the copper content in the soils. The artificially introduction in the soil of Cu is in various ways: by precipitation from the atmosphere (particularly in the vicinity of smelting ferrous metal), using a variety of waste sludge, as well as beneficial to the agricultural materials (fungicides-"Bordeaux mixture", a spreader, solid and liquid manures). This leads to the contamination of soil, when the total content of Cu exceeds the limit value of 100 mg/kg.

Naturally occuring Cu in the soil is for the most part bonded in the crystal lattices of the minerals and in attached form on oxides of Mn, Fe, and Al. The presence of Cu should be more pronounced than other trace elements (Mn, Zn). The fact that it readily makes complexes with organic substances leads to the lack of available Cu in the soil rich in organic matter (peat soil). The most common forms of Cu in soil solutions are soluble organic chelates of this metal.

The behavior, phyto bioavailability and toxicity of Cu are influenced by its species, and are not a function of its total concentration (Allen, 1993). Several soil properties control the Cu solubility and thus bioavailability such as pH, oxidation and reduction potential, soil organic matter (SOM), soil texture, mineral composition, temperature, and water regime.

The mobility of Cu is especially reduced in the presence of large mineral colloids with Fe–Al-oxyhydroxide coatings, by oxyhydroxide particles of Al, Mn, Fe, and by organic matter (Kabata-Pendias and Sadurski, 2004). Dissolved organic matter has a great affinity to fix Cu and thus to inhibit its sorption in soils. These phenomena are attributed to the formation of soluble Cu-organic complexes (Zhou and Wong, 2003). Determination of the chemical forms of the trace elements related to soil indicates their potential mobility and availability to the plants. The total content of trace elements in the soil do not show a good correlation with their biological availability, but these data are useful for legislation which evaluate soil contamination. Single or sequential methods are being used to assess the potential of affordable and available fraction of trace elements in the soil.

In the case of the artificial introduction of Cu in the soil, due to the tight attachment with an inorganic or organic materials, lags far behind the most part in the upper soil horizon and its contents were significantly reduces depth (Delas, 1963). Ninkov et. al. (2010) has noted that of the Vojvodinian vineyard soils are contaminated with the cooper due to long-term intensive application of copper based fungicide. The highest concentration of Cu 336 mg kg^{-1} was noted in surface layer of soil, which is three times the value of maximum allowable concentration MAC (100 mg kg-1). It is especially unfavourable that 23 % of all analysed vineyard soils surface layers are in critical concentration zone (>60 mg kg-1) and 33 % exceed maximum allowable concentration MAC.

The total Cu concentration in Vertisols of the region of Turkey varied from 33.54 to 73.40 mg kg^{-1}. Apparently, the total cooper concentrations were highest in the surface horizon and lowest in the lower horizon. Also, higher DTPA extractable concentrations Cu are found in the surface horizon and decreased with depth. The values of Cu ranged from 4.14 to 8.93 mg kg^{-1} (Cumhur Aydinalp and Malcolm Cresser, 2003).

The study of the condition of useful micro-elements in the soil was started a few decades ago in our country. Results for total and available contents of micro-elements, their dynamic in the soil, determination methodology as well as border values of their availability were presented in papers of numerous authors (Bogdanović et al., 1973; Jakovljević et al., 1983; Jakovljević i Blagojević, 1997; Milivojević 2003, Milivojevic et al., 2012, 2013). It was concluded that the investigation on this area should be expanded and intensified.

The aim of this work is detailed examination of the state of copper in Serbia Smonitzas and giving score to this type of soil in relation to plants supply with this element.

MATERIAL AND METHOD

Samples were taken from Vertisol (WRB Clasification 2014, 2015) in the Ap horizon at ten different locations in Serbia: 1) Milutovac, 2) Priština, 3) Trnava, 4) Rekovac, 5) Vranje (Neradovac), 6) Zaječar, 7) Bela Crkva, 8) Blace, 9) Salaš and 10) Kragujevac (Fig.1, Table 1). Sub-samples were taken from arable land and meadow ecosystems, from a depth of 0 to 20 cm, after which they were air-dried and crushed in a porcelain mortar up to particles of 2 mm in size. The research area is under various vegetables small grains (wheat, rye, barley oats).

The basic physical and chemical properties of soil were determined using standard methods (Soil. Sci. Yug., 1966). Soil pH was determined in a suspension with water and 1M KCl mixture, with the ratio of soil/solution 1:2.5 after a 0.5 – hour equilibration period, using a pH metre pH-TAR MA 5705 (Iskra, Kranj, Slovenia).; the organic content was determined using the humus method by Kotzmann, the available P_2O_5 and K_2O content was determined using the Al method by Egner-Riehm, cation exchangeable capacity (CEC) was determined using the method with 1 M NH_4OAc, pH 7, and particle size distribution was determined by a pipette method (YSSS, 1966).

The total content of Cu was determined by atomic adsorption spectrophotometry (AAS, model Perkin–Elmer 3300/96, MHS-10) (Krishnamurty et al., 1976), after digested soil samples with conc. HNO_3 and then treated with H_2O_2. The content of the available Cu was determined by AAS spectrophotometry, after the extraction with different reagents 0.1 M HCl (McKeague, 1978), 0.005 M DTPA (Lindsay and Norvell, 1978), and acid solution of NaOAc (Tessier et.al., 1979).

Extraction with 1M NaOAc. An amount 10 g of soil sample were added to 80 ml 1M NaOAc adjusted to pH 5.0 with acetic acid and agitated for 5 h at room temperature and then filtered using Whatman No. 42 filter paper.

Extraction with 0.1 M HCl. Weighted 10 g of soil sample into in plastic containers and overflow with 100 ml of solution 0.1 M HCl, then shaking on a rotary shaker for 1 hour and filtering.

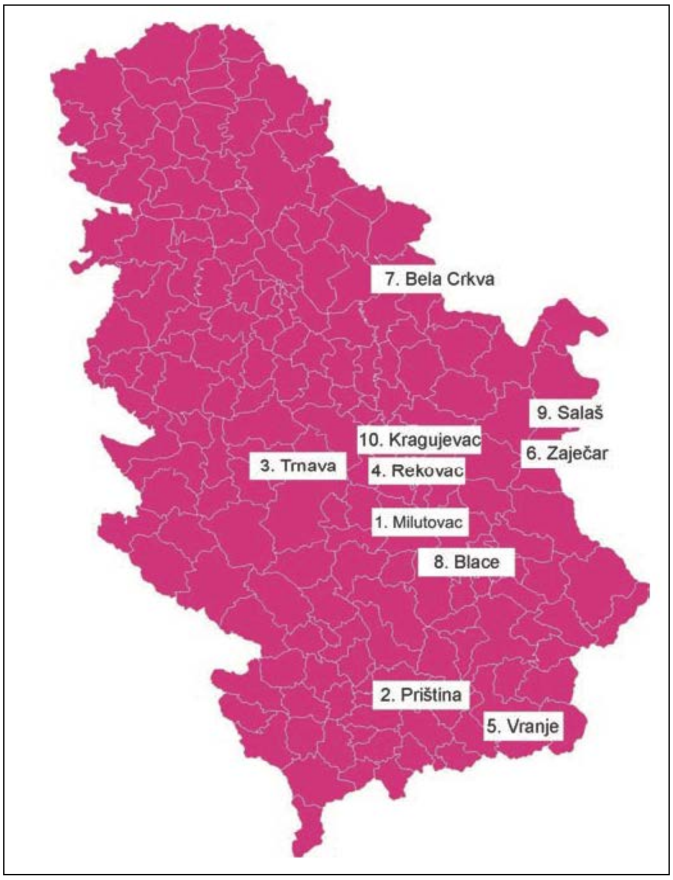

Figure 1 Geographical location of the investigated soil samples in the Republic of Serbia

The DTPA extractable metal content was determined using a mixture of 0.005 mol L^{-1} DTPA, 0.01 mol L^{-1} $CaCl_2$, 0.1 mol L^{-1} triethanolamine (TEA) with pH adjusted to 7.3 with mol L^{-1} HCl solution. An amount of 10 g of soil sample was weighted into a 125 mL flask, and shaken for 2 h at room temperature using a magnetic shaker with 20 m of DTPA extracting solution. The extracts was filtered and diluted to 100 ml with ultrapure water.

In addition a vegetation experiment in pots was performed in Vertisol taken from 10 abov mentioned locations. Soil samples, taken from arable land and meadows from a depth of 0-20 cm first air dried, ground and the size of particles of soil samples used in the vegetation experiment was determined. The experiment was conducted using “Slavuj” oats (*Avena sativa* L) cultivated with 15 seeds per pot u triplicate; after two weeks the plants were thinned to ten seedlings per pot. The plants were followed 45 days in controlled laboratory conditions. Water was added to obtain optimal humidity. After 45 days the plants were dug up, rinsed with destiled water, and dried at room temperature in a dryer at t=70ºC. The dried plants were ground into a powder. For total heavy metal concentrations in plant samples, 1 g of samples was taken into a 100-ml cid washed beaker and 15 ml of tri-acid mixture (70 %) high purity HNO3, 65 % $HClO_4$ and 70 % H_2SO_4; (5:1:1) was added (Allen et al. 1986). The mixture was then digested at 80 °C till transparent solution was achieved. After cooling, the digested samples were filtered using Whatman No. 42 filter paper and the filtrate was diluted to 50 ml with deionised water. Determination of Cu in the filtrate was achieved by atomic absorption spectrophotometer Perkin-Elmer 3300/96, model MHS-10 (Perkin-Elmer, Santa Clara, California, USA). Quantification was carried out using appropriate calibration curves obtained for standard element solutions in the same acid matrix. All hemicals used in the sample treatments were of ultrapure grade. The glassware was cleaned prior to use by being soaked overnight in 10% v v^{-1} HNO_3 (Suprapur, Merck) and rinsed with Milli-Q water.

Table 1
Sampling locations

Location	Latitude (North)	Longitude (East)	Altitude (m.a.s.l.)	Tecture classes	
				Arable land	Meadow
Milutovac	43º 41' 10"	21º 07' 22"	272	medium clay	light clay
Priština	42º 39' 52"	21º 09' 54"	652	heavy clay	medium clay
Trnava	44º 11' 00"	20º 46' 00"	299	medium clay	heavy clay
Rekovac	43º 51' 25"	21º 05' 29"	629	heavy clay	heavy clay
Vranje	42º 30' 10"	21º 52' 26"	368	medium clay	medium clay
Zaječar	43º 54' 15"	22º 17' 05"	343	medium clay	heavy loam
Bela Crkva	44º 53' 10"	21º 25' 01"	272	medium clay	medium clay
Blace	43º 17' 26"	21º 17' 05"	389	medium clay	medium clay
Salaš	44º 06' 23"	22º 18' 35"	234	medium clay	medium clay
Kragujevac	40º 00' 51"	20º 54' 42"	173	medium clay	medium clay

Determination of the heavy metals in the filtrate was achieved by atomic absorption spectrophotometer Perkin-Elmer 3300/96 model MHS-10 (Perkin-Elmer, Santa Clara, California, USA).

The data were statistically analyzed using the SPSS 20.0 statistical software package to calculate average, standard deviation, Student's *t*-test, Pearson's correlation coefficient and level of significance. Level of significance was calculated at $^{*}p<0.05$ and $^{**}p<0.01$.

RESULTS and DISCUSSION

Basic characteristic of examined Vertisol of Serbia are given in Table 2. The reaction of soil was found to range in a fairly wide interval of pH values from acid to weakly alkaline reaction (from 4.60 to 6.9 in N KCl). The content of humus was considerably varying, ranging from 2.00 to 5.6% (weakly humus to humus soils), being unaffected by land use. In addition, the content of available phosphorous also ranged in a wide interval. Thus, on the Vertisol under meadow, the content of available P ranged from 0.8 to 17.8 mg/100g, whereas on those under field, its content ranged from 0.6 to 28 mg/100g supplied with this element. In contrast to the available phosphorous, the soils were found to be rich in potassium (19.0-59.6 mg/100g). In addition, these soils indicated a high cation exchange capacity and, by mechanical composition, could be defined as medium to heavy clay soils. The above-mentioned average values of the investigated properties proved to be very much the same for the arable land and for the meadow. According to the content of mechanical fractions (sand, silt, clay), these soils are in medium and hard clay soils.

Results of the study of the total content of Cu in the analyzed Smonitzas (Table 3) indicates its natural, geochemical origin, as found from the mean value of 29.8 mg/kg for the arable land and 36.9 mg/kg for the meadow, as well as the value of the total content of Cu individual samples, with some variations, are within normal values for unpolluted soil. High to very high levels he content of available copper, based on three different extraction techniques, showed that the tested smonitzas rich the limit values according to Ankerman, 1977. The high level of available Cu in tested Vertisols makes them suitable for growing plants in these lands.

According to the results of the t-test (Table 3) between the available cooper contents in the tested Vertisols, no statistically significant differences in the distribution of cooper between the arable land and meadows was found.

Table 2
Examined physical-chemical characteristics of Vertisols in Serbia

Soil characteristic	Arable land			Meadow		
	Mean	Range	Standard deviation	Mean	Range	Standard deviation
pH (H_2O)	7.11	5.8–8.1	0.91	6.9	5.6-8.1	0.9
pH (KCl)	6.0	4.6-6.9	0.93	5.8	4.7-7.0	0.9
Humus, %	3.3	2.5-4.0	0.49	3.5	2.0-5.6	1.1
P_2O_5 mg/100 g	7.7	0.6-28.0	8.83	4.2	0.8-17.8	5.0
K_2O mg/100 g	34.4	19.0-59.6	11.8	31.1	20.4-53.5	10.4
CEC meq/100g	25.1	15.5-31.5	5.57	23.8	16.9-34.7	6.6
Sand, %	29.6	21.4-36.0	4.80	32.2	22.3-50.5	9.0
Silt, %	24.6	18.8-31.2	3.61	22.8	11.9-29.4	5.6
Clay, %	45.8	33.5-54.4	7.25	44.9	28.9-64.3	11.1
Silt + Clay, %	70.4	64.0-78.6	4.8	67.7	49.5-77.7	9.0
t-test arable land:meadow	NS	NS	NS	NS	NS	NS

NS-application of the student t-test showed that there is no statistical signicance between the examined characteristics of field and meadow

The results of the experiments pots out in oats plants with soil samples from the mentioned locations and from the non-fertilizer treatment (control) are shown in the Table 4. Plant yields (dry weight) ranged between 5.43-10.31 g/pot, and average values were 7.01 g/pot for arable land and 7.58 g/pot for meadows. Because of the wide interval variation there were not found significant differences between the used as arable land and meadow.

Table 3
Content of Total and Available Copper (Means, Standard Deviaton and Interval mg/kg) in Observed of Vertisos in Serbia

Mode of soil utilisation	Total Cu	Available Cu		
		0.1 N HCl	0.005 M DTPA	NaOAc
Arable land	29.8±9.8	4.1±1.6	3.1±1.5	0.7±0.2
	17-49	2.4-4.8	1.8-6.8	0.5-1.3
Meadow	36.9±18.5	7.0±6.3	5.7±5.7	1.7±1.8
	18-74	1.6-19.7	2.3-17.4	0.5-6.3
t-test arable land:meadow	NS	NS	NS	NS

NS-there are no statistically significant differences

The average content Cu in the tested plants grown on the control group was 10.77 mg/kg (range 9.8-11.7 mg/kg) for arable land samples, and 10.99 mg/kg (range 9.7-11.8 mg/kg) for meadow samples. It is also concluded that the oat shoot uptake was 75.50 mg/kg (58.6-87.6) g/pot for arable land of soil, and 83.30 mg/kg (63.69-113.41) g/pot of soil for meadow. The obtained values for Cu content in oat plants correspond to the optimal levels (5-25 mg/kg) for this plant (Westfall et al., 1990).

For Cu concentration in plant dry weight and its amounts taken out there were not found significant differences between arable land and meadow.

Table 4
Yield, content and uptake of Cu in oat shoots from the control of Cultivated Plants (Oat), Cu Content in Plants and Outtake of Cu by Yield (Means, Standard Deviation and Interval)

Mode of soil utilisation	Out DM yield ($g\ pot^{-1}$)	Cu content in plant ($mg\ kg^{-1}$)	Cu outtake by plant Yield ($g\ pot^{-1}$)
Arable land	7.01±0.86	10.77±0.56	75.50±9.92
	5.43-7.96	9.8-11.7	58.6-87.6
Meadow	7.58±1.2	10.99±0.91	83.30±14.03
	5.53-10.31	9.7-11.8	63.69±113.41
t-test arable land.meadow	NS	NS	NS

A state of Cu in the studied Vertisols can be found out through mutual correlation between total and available contents of Cu as well as as between the different forms of available contents (Table 5). First, very high correlation was found between total content Cu (HNO_3) and its available forms (0.1 N HCl, 0.005 M DTPA and 1 N NaOAc). Second, the available values of Cu are interconnected in a strong cumulative bond, regardless of the different extraction means. These data indicate that Cu in Vertisols of Serbia is of natural, geochemical origin, and that all three applied methods for determination of available Cu in the soil can be equally used regarding to soil types of Vertisols.

Table 5
Correlation Coefficient between Total and Available Cu Contents in Observed Soils

	Total Cu	Available Cu (0.1N HCl)	Available Cu (DTPA)	Available Cu (1N NaOAc)
Total Cu	-			
Available Cu (0.1 NHCl)	0.88**	-		
Available Cu (DTPA)	0.84**	0.96**	-	
Available Cu (1 N NaOAc)	0.76**	0.94**	0.94**	-

**- significant at 0.01 probability level

In addition, for the explanations of the origin of copper in the soil, the correlation coefficients between different forms of Cu in soils their various chemical and physical properties of the soil are also important (Table 6). A very small number of correlations were found between total Cu and silt (r = -0.44 *) as well as between available Cu (1 M NaOAc) for total sand (r = 0.54 *) and silt (r = 0.54 *).

Table 6
Correlation Coefficients between Different Forms of Cu Contents in Observed Soils and their Chemical and Pphysical Properties

	pH		Humus	Available		CEC	Total sand	Silt	Clay
	H_2O	KCl		P_2O_5	K_2O				
Total Cu	/	/	/	/	/	/	/	-0,44*	/
Available Cu (0.1N HCl)	/	/	/	/	/	/	/	/	/
Available Cu (DTPA)	/	/	/	/	/	/	/	/	/
Available Cu (1N NaOAc)	/	/	/	/	/	/	0,54*	0,54*	/

*Significant at the 0.05 probability level

These data indicate that none of the tested soil properties significantly affected the different forms of available Cu content. This indicates the geochemical origin of Cu and the smaller influence of the pedogenetic processes on its state in Vertisol of Serbia. Similar results on Smonitza soil in the Sumadija region were also found (Milivojevic et al., 2012, 2013). At the end, there is significant correlation between Cu concentration in plants and its amounts taken out according to the content of its forms in soil and chemical and physical properties of soils.

There was a correlation, but not large, between Cu concentration in plants and total Cu content (r = 0.48*) in the tested soil. This could be expected because the content of available Cu in the soil, using method that give limit values (0.1 M HCl, DTPA), were high or very high. Under such conditions, the oats planted the required quantities of copper and among them there were no differences and pronounced effects of various properties of the soil. This is another proof that the smonitza type soil in Serbia well accumulate copper, one of the most important microelement for plant nutrition and exhibit favorable fertility.

CONCLUSIONS

Based on the presented results on the state of the Cu micro element in the smonitze soil of Serbia, the following conclusions can be made:

In the tested soil, normal, geochemical contents of total copper in the range 17-74 mg/kg were found. The three methods used for determination of available Cu in the soil can be used equally because the obtained results showed strong mutual correlations according to the content of total Cu.

The uptake of Cu in oat plants was uniform, and the found content was optimal. This indicates a satisfactory amount of available copper for plant nutrition in the investigated Smonitza soil of Serbia.

Literature

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Soil distribution in Bregalnica river basin and its importance for agricultural production

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ABSTRACT

This paper is a result of many years of field and laboratory research of the soils in Bregalnica river basin, spread out on 428.323,45 ha, ranging from 150 to 1932 m above the sea level in order to gain a better understanding of the productive capacities of the soils and measures for their improvement. The filed research of the soils has been done according to methods described by (Filipovski G et al, 1967). In laboratory, the following analyses have been carried out on the soil samples: hygroscopic moisture; mechanical composition; pH of the soil solution; humus content and total nitrogen; content of carbonates; available nutrients P_2O_5 and K_2O. The mechanical composition and chemical properties of the soils have been determined by standard methods described by (Bogdanović et al, 1966), (Mitrikeski & Mitkova, 2001); (Resulović et al, 1971), (Džamić et.al.1996).This area is very heterogeneous, with numerous relief forms, with different expositions and inclinations, and with great differences of altitude. Additionally, there are several geological formations of a very heterogeneous petrographic-mineralogical composition and climate-vegetation zones. Long-term effects from human involvement should also be noted. The vast diversity of the factors required for soil formation in this area is the reason for the formation of many different soil types as well as the lower taxonomic units. These types of soils are characterized by different properties (chemical, physical, physical-mechanical, productive). Therefore, they have varied effects on agricultural production. There are 16 (sixteen) different soil types distributed in the Bregalnica river basin together with a considerable amount of subtypes, varieties and forms. Soils of lake terraces and of undulated hilly relief are prevalent in this river basin: 202.097,50 ha, or 47.19% of the whole. Mountain soils cover 188.764,00 ha (44.08%), whereas soils of the plains occupy 25.236,32 ha (5.88%) of the area. Finally, soils of colluvial fans occupy the least surface - 12.225,63 ha (2.85%).

KEY WORDS: soil types, Bregalnica river basin

INTRODUCTION

This area (Bregalnica river basin) is very heterogeneous, with numerous relief forms, with different expositions and inclinations, and with great differences of altitude. Additionally, there are several geological formations of a very heterogeneous petrographic-mineralogical composition and climate-vegetation zones. Long-term effects from human involvement should also be noted. The vast diversity of the factors required for soil formation in this area is the reason for the formation of many different soil types as well as the lower taxonomic units.

The soils in the area also appear in the complexes that are presented on the soil (pedological) map. These types of soils are characterized by different properties (chemical, physical, physical-mechanical, productive). Therefore, they have varied effects on agricultural production.

In this paper are presented the main aspects of the soil geography. The agrotechnical and meliorative measures are determined based on the properties and processes of the various soil types found in this area with the goal of improving their productive capacity to further increase agricultural production.

MATERIAL AND METHOD

The filed research of the soils has been done according to methods described by (Filipovski G et al, 1967). In laboratory, the following analyses have been carried out on the soil samples: hygroscopic moisture; mechanical composition; pH of the soil solution; humus content and total nitrogen; content of carbonates; available nutrients P_2O_5 and K_2O.

The mechanical composition and chemical properties of the soils have been determined by standard methods described by (Bogdanović et al, 1966), (Mitrikeski & Mitkova, 2006); (Resulović et al, 1971), (Džamić et.al.1996).

RESULT AND DISCUSSION

1.Geography of soils

1.1. Distribution of soil types and complexes

The formation, the distribution and the soil properties in this area are in close co-relation with the environmental conditions, i.e. the soil genesis conditions, such as the geographical position and the relief, the hydrography, the parent material, the climate, the vegetation, the time period and the human factor. The soil (pedologic) map (picture 1), (picture 2 and 3) together with Table 1 on the distribution of the soil types, differentiates the following properties in the geography of soils.

In the catchment area of the Bregalnica river, there are 16 (sixteen) soil types and a number of subtypes, varieties and forms. The total area of this region is 428.323,45 ha.

Depending on the dominant influence of individual soil forming factors, most part of the areas are covered with soils that also demonstrate climate – vegetation zoning (Chromic Luvisols on saprolite, Cambisols, Humic Eutric and Umbric Regosols, Albic Luvisols), which is also combined with the influence of other soil forming factors (parent material, relief). Some of the soils demonstrate strong lithogenous character (Leptosols, Regosols, Humic Calcaric Regosols, Vertisols), whereby the influence of other factors (relief) is also significant. Some of the soils have topogenous – hydrologic origin, related to the consequences of the erosion processes (Fluvisols, Gleysols, Fluvisols-Colluvial Soils). Lately, due to the newly planted seedlings (orchards, vineyards), some of the soils also have antropogenous origin (Aric Regosols). The papers of Mitkova T, et. al. (2015) and Filipovski G, (2015), address these conditions in details.

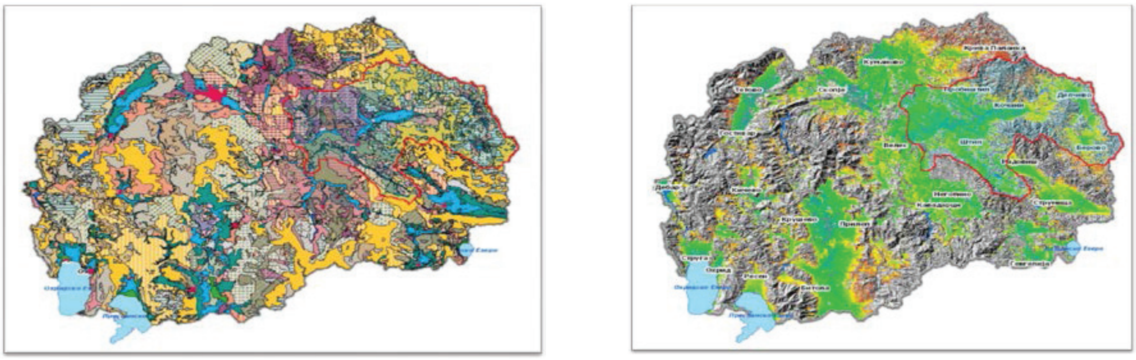

Figure 1 and 2. Soil map - Soil types and complexes distribution in the catchment area of the Bregalnica river (http://www.maksoil.ukim.mk/masis/)

Table 1 contains data on the soil types and complexes distribution according to the relief forms in the catchment area of the Bregalnica river in ha and %. It can be seen from the Table that the soils spread on lake terraces and of undulated hilly relief dominate in the catchment area and cover an area of 202.097,50 ha, or 47.19% of the area, followed by the soils spread on mountainous terrains with 188.764,00 ha, or 44.08%. The soils on plains and sloping terrains (colluvial fans) cover small areas (25,236.32 ha, or 5.88% and 12.225,63 ha or 2.85% of the area).

Table 1
Soil types and complexes distribution in the catchment area of the Bregalnica river (ha and %)

	Symbol	ha	%
SOIL TYPES AND COMPLEXES (WRB Soil Classification)			
I. SOILS OF THE PLAINS			
1. Fluvisol	J	16438,94	3,84
2. Gleysol	G	210,07	0,05
3. Mollic Vertic Gleysol	Gm	407,42	0,09
4. Fluvisol	J/K	1695,7	0,39
5. Fluvisol+ Gleysol	J/G	1204,21	0,28
6. Solonetz+ Solonchak	Z/S	2199,57	0,51
7. Urbisol	Urb	3080,41	0,72
Total		25.236,32	5,88
II. SOILS OF COLLUVIAL FANS			
1. Fluvisol (Colluvial Soils)	K	12.225,63	2,85
III. SOILS OF LAKE TERRACES AND OF UNDULATED HILLY RELIEF			
1. Regosol	R	39750,82	9,28
2. Humic Calcaric Regosol	Rz	14073,57	3,28
3. Vertisol	V	19054,99	4,45
4. Chromic Luvisol on saprolite	Lc	15244,55	3,56
5. Aric Regosol	ATa	1031,47	0,24
6. Humic Calcaric Regosol+ Regosol	Rz/R	16574,22	3,87
7. Chromic Luvisol on saprolite+ Humic Calcaric Regosol+ Regosol	Lc/Rz/R	2981,58	0,70
8. Regosol+ Vertisol	R/V	7564,61	1,76
9. Humic Calcaric Regosol+ Regosol+ Vertisol	Rz/R/V	1176,78	0,27
10. Vertisol + Humic Calcaric Regosol	V/Rz	7242,28	1,69
11. Chernozem + Humic Calcaric Regosol	C/Rz	1029,45	0,25
12. Chernozem+ Humic Calcaric Regosol+ Vertisol	C/Rz/V	9924,63	2,32
13. Chromic Luvisol on saprolite+ Regosol	Lc/R	20518,34	4,79
14. Chromic Luvisol on saprolite+ Albic Luvisol + Regosol	Lc/La/R	750,9	0,17
15. Chromic Luvisol on saprolite+ Albic Luvisol	Lc/La	1144,51	0,27
16. Vertisol+ Regosol+ Leptosol	V/R/E	23862,74	5,57
17. Vertisol+ Chromic Luvisol on saprolite+ Regosol	V/Lc/R	9216,62	2,15
18. Albic Luvisol	La	5264,27	1,23
19. Albic Luvisol + Regosol	La/R	5691,15	1,33
Total		202.097,50	47,19
IV. MOUNTAIN SOILS			
1. Leptosol	E	2886,24	0,67
2. Humic Eutric and Umbric Regosol	Lm/U	35499,49	8,29
3. Cambisol	B	72361,03	16,9
4. Cambisol+ Regosol	B/R	27650,21	6,46
5. Cambisol+ Leptosol+ Regosol	B/E/R	7173,47	1,67
6. Humic Eutric and Umbric Regosol+ Leptosol	Lm/U/E	116,12	0,03
7. Cambisol+ Humic Eutric and Umbric Regosol	B/Lm/U	1076,79	0,25
8. Humic Eutric and Umbric Regosol+ Regosol+ Leptosol	Lm/U/R/E	13979,67	3,26
9. Humic Eutric and Umbric Regosol+ Regosol	Lm/U/R	17916,76	4,18
10. Regosol+ Leptosol	R/E	10103,85	2,36
Total		188.764,00	44,08
Total area of this region		428.323,45	100,00

The plain terrains are mostly covered by Fluvisols (16.438,94 ha or 3,84%), while the percentage of other soils is under 1%. The sloping terrains are mostly covered by Fluvisols (Colluvial Soils) (12.225,63 ha or 2,85%). The undulating-hilly terrains and the lake terraces are mostly covered by Regosols (39.750,82 ha or 9,28%), followed by Vertisols (4,45%), Chromic Luvisols on saprolite (3,56%) and Humic Calcaric Regosols (3,28%), as well as Albic Luvisols with 5264,27 ha or 1,23%. Most of the mountainous terrains are covered with Cambisols (72.361,03 ha or 16,9%) and Humic Eutric and Umbric Regosols (35.499,49 ha or 8,29%), as well as Leptosols with 2886,24 ha or 0,67%.

The erosion processes, i.e. the human factor are strongly reflected in the geography of the soils in the area. The area of soils that occurred from erosion processes (Leptosols, Regosols, Fluvisols-Colluvial Soils and their complexes) is more than 25% of all areas and unfortunately, the spreading process for these areas is still active.

The individual terrain forms differ from each other by their terrain, geological structure, their climate – vegetation and hydrographic conditions and by the degree of anthropogenization. This is reflected on the geography of soils and their properties, as well as on the degree of their utilization and the measures that need to be undertaken in the agricultural production of the area.

1.2. Common properties of the soils according to terrain (relief) forms

Common properties of the soils on the mountainous terrains. The soils spread on mountainous terrains cover 188.764,00 ha, or 44,08% of the area. These are: Leptosols, Humic Eutric and Umbric Regosols, Cambisols, as well as their complexes, in combination with Regosols. Their common properties are: a) very pronounced erosion processes; b) weak chemical weathering resulting in shallow solum over some substrates, and lack of deep regolith and poor clay content; c) absence of carbonate, pronounced acidification (weaker in the soils over acidic rocks than in the basic rocks); d) absence or very poor textural differentiation of the solum; e) clearly expressed changes in the soil properties and the intensity of some processes as the altitude increases; f) clearly expressed dependence of the soil properties from the substrate: soils over acidic rocks contain less clay, they are more acidic and are less texturally differentiated, unlike the soils formed over basic rocks, g) absolute domination of the silicate over the carbonate substrate.

Common properties of the soils from the lake terraces and of undulated hilly relief. The following soil types are present on this terrain form: Regosols, Humic Calcaric Regosols, Vertisols, Chernozems, Chromic Luvisols on saprolite and Albic Luvisols. The occurrence of these types of soils is in close co-relation with the substrate, the relief, the climate-vegetation conditions and the degree of erosion. The soils on this terrain (relief) form have the following common properties: a) very pronounced erosion (occurrence of Regosols and erosion of horizon A or part thereof, in the soils with A-C, A-(B)-C and A-E-B-C profile type); b) absence of compact rocks as substrate and soil genesis over clastic sediments, resulting in deep solum and physiologically active profiles; c) greater presence of clay resulting from the substrate or the argilogenesis within the profile; d) presence of smectites in some soils (Vertisols, Vertic Chromic Luvisols on saprolite) arising mainly from the substrate and partially from the soil genesis, and in relation to that, deterioration of the physical properties of the soils; e) occurrence of textural differentiation at some soils (Vertisols and Albic Luvisols), and in relation to that, deterioration of the physical properties; f) greater presence of the silicate – carbonate substrate in the soil genesis, in comparison to the substrate of the mountainous terrains; g) relative dryness of the soils (which is lower at the lake terraces), caused from insufficient quantity of rainfalls, surface water flow and very deep underground water; e) insufficient quantity of humus and nutrients (especially N and P); f) relatively good chemical properties (the high content of carbonates of Humic Calcaric Regosols and the acidity of the Albic Luvisols are an exception).

Common properties of soils from sloping terrains. These terrains are covered with Fluvisols (Colluvial Soils), which are characterized by: a) horizontal and vertical (according to depth of profile) heterogeneity in the mechanical and mineral-petrographic composition; b) low content of clay, drainage, dryness, good aeration; c) poor humus content, insufficient stability of the aggregates; d) good chemical properties with insufficient nutrient elements; e) increasing the finer particles by descending to the lower parts of the cones (“fans”); g) short duration of soil genesis (the youth of the soils); h) unregulated water regimen (floods and sedimentation of coarse material).

Common properties of the soils of the plains. Fluvisols with varying degrees of gleyzation are present in the flat bottom deep in the profile and the Gley soils (Gleysols and Mollic Vertic Gleysols) have the following characteristics: a) the appearance of non-saline underground waters at different depths; b) the appearance of a physiologically deep profile; c) gleyzation at the bottom of the profile; d) a significant amount of organic matter (especially in Gleysols), where it is of hydromorphic origin; e) occurrence of unregulated water regimen (floods, riverbad erosion, deposition of coarse sediments, regeneration of fertility by application of fine sediment); g) absence of texture differentiation of the profile (no occurrence of (B) or Bt horizons); h) favorable physical and chemical properties.

The occurrence of Halomorphic soils (Solonchak and Solonetz) on small areas (total 2199,57 ha or 0,51%) is characteristic of these terrains in the area. Their formation is related to the presence of salts in the sediments, drier climate conditions and relief-topographical conditions in which there are shallow and saline underground waters.

1.3. Soil significance according to relief forms for agricultural production in the area

The properties (mechanical composition and chemical properties) of individual soils formed in the area are described in detail in the papers of Mitkova T, et.al. (2015), Filipovski Gj, (2015) and Filipovski Gj, (2015a). Here, together and according to relief forms, we will explain their significance for agricultural production in the area, the measures for improving their productive ability will be explained in the conclusions.

In mountain reliefs, part of the Humic Eutric and Umbric Regosols is under summer pastures, a smaller part under forests, and a small part is cultivated. Fields are mostly abandoned, and some produce potato and seed material for it, then rye and oats, and at lower altitudes some fruit trees are cultivated. As for the use of Cambisols, it can be said that they have the greatest significance for forestry, because they produce and then exploit most of the wood mass in our country. By deforestation some of these soils are converted into pastures or into now abandoned fields. A very small part is cultivated, used as fields, and a smaller part as pastures. Potatoes are most commonly cultivated field crops, some forage field crops can be successfully grown, as well as crops for green fertilization. Some of these soils can be successfully turned into artificial grasslands. Several fruit crops can be successfully grown (chestnut, walnut, plums, apples, pears, raspberries, blackberries, ribes).

Among the soils formed on lake terraces and of undulated hilly relief, Chernozems, Vertisols and Humic Calcaric Regosols are characterized by greater productivity in comparison with Regosols, Chromic Luvisols on saprolite and Albic Luvisols. Depending on the conditions for irrigation these soils have heterogeneous use. Field crops, vegetable crops, forage crops, industrial crops, vineyards, orchards are cultivated on them.

Fluvisols (Colluvial Soils) are significantly less productive than Fluvisols (with which they border. They are less sorted, do not have a flat relief, have higher impact from drought, contain less nutrients, do not supply water from groundwater.

In the plain terrains of the area, Fluvisols are of the greatest significance for agricultural production. This is due to the favorable physical and chemical properties, the deep solum, the provided conditions for irrigation and the presence of available forms of P_2O_5 and K_2O. They provide relatively high yields of all agricultural crops. Mollic Vertic Gleysol and Gleysols are potentially fertile. The former have good chemical properties, but poor physical properties, and the latter have relatively good properties, but have shallow underground waters, occasional floods at some sites, anaerobic conditions and due to this, poor nitrification.

CONCLUSIONS

There are 16 (sixteen) different soil types distributed in the Bregalnica river basin together with a considerable amount of subtypes, varieties and forms. They are formed on four relief forms (plain terrains, sloping terrains, mountain terrains and undulating-hilly terrains and lake terraces) that have different significance for agricultural production. In order to increase their productive ability, the following joint measures should be undertaken according to relief forms:

- *Joint measures for soils from mountain terrains*: (protection from erosion, fertilization with organic and mineral fertilizers, proper tillage, liming if necessary);
- *Joint measures for soils from lake terraces and undulating-hilly terrains*: (deep tillage, humization: organic fertilizers and phytomeliorations, intensive use of mineral fertilizers N and P_2O_5, and for plants that need potassium during the entire year and for obtaining much higher yields and K-fertilizers, anti-erosion measures, proper irrigation method);
- *Joint measures for soils from sloping terrains*: (anti-erosion protection measures, irrigation, humization, intensive use of mineral fertilizers);
- *Joint measures for soils from plain terrains*: (regulation of the water regimen, lowering of the level of underground water-drainage, tillage and creating a deep fallow, fertilization with mineral and organic fertilizers with previous soil fertility control, proper irrigation).

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THE IMPACT OF AGRICULTURE ON THE CAMBISOL SOIL DEVELOPED IN THE AREA OF THE VELIKA GORICA WELL FIELD

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ABSTRACT

Increased concentrations of anions and cations, as well as potentially toxic metals in the agricultural soils developed in the area of water field Velika Gorica can present problem from the standpoint of environmental risk. The subject of this study is the Cambisol soil developed on the area of the Velika Gorica water well field. The objective of this research was to determine the main soil properties and soil accumulation or mobilisation of potentially toxic metals and ions in Cambisol under agricultural activities.

Physical, mineralogical and geochemical analysis of the collected soils were carried out in order to determine their properties, such as soil reaction (pH), electrical conductivity, carbonate, organic and mineralogical content and grain size distribution. Sequential extraction analysis was made to determine the main binding site of potentially toxic metals in the soil. The analyses were performed according to the BCR procedure and proportions of elements were determined in four fractions: (1) carbonate, (2) the fraction of Fe-Mn oxide and hydroxide, (3) organic-sulphide, and (4) residual fraction. The following potentially toxic metals were measured: Cu, Cd, Zn and Pb. The analysis of anions and cations (Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, NO_2^- and SO_4^{2-}) were made using ionic chromatography.

The analysis showed that the concentrations of potentially toxic elements (Cu, Cd, Zn and Pb) as well as cations and anions (Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, NO_2^- and SO_4^{2-}) are significant in a layer of up to about 80 cm. Their concentration decreases beneath the specified depth as a result of particle size distribution, dominated by silt and clay that determine a lower permeability of the soil. Surface samples showed increased element concentrations, as well as the influence of agricultural activities.

Even though influence of agricultural activities is recognized, all results show that impact is decreasing after approximately 80 cm depth.

KEY WORDS: agricultural activities, unsaturated zone, potentially toxic metals, cations and anions, Cambisol

INTRODUCTION

Increased concentrations of major anions and cations, as well as potentially toxic metals, in the agricultural soils developed in the area of well field Velika Gorica, can cause soil and water contamination.

One of sources of contamination by potentially toxic metals are agricultural inputs (animal manure and artificial fertilizers). Phosphorus (P) fertilizers are sources of potentially toxic metals, which are used in agricultural systems (Nziguheba and Smolders, 2008). Copper and zinc are substantially added to soils by agricultural practices (Bonten et al., 2008) and are widely used as fertilizers and stimulants of animal growth (Schipper et al., 2008).

Apart from potentially toxic metals, load of cations and anions from agricultural sources can present risk for groundwater contamination. Agriculture is the main diffuse nitrogen source (Wendland et al., 2009). Inorganic nitrogen fertilizers are applied to increase the immediate availability of nitrogen for plant growth (Balderacchi et al., 2013). Potassium is an essential and major nutrient for crop production (Zhang et al., 2011). Manure contain potassium in their compounds and excessive load of this parameter to agricultural soil can cause very high concentrations of this element in soils and groundwater.

Therefore, the objective of this research was to determine the main soil properties and soil accumulation or mobilisation of potentially toxic metals and major ions in Eutric Cambisol FAO (2006) under agricultural activities.

MATERIALS and METHODS

Field research was conducted in the area of Velika Gorica well field (45°43'41''N; 16°01'40''E), which is located west of the Velika Gorica City in Croatia. The field research consisted of borehole drilling, sampling, description of the pedological profile and recognition of the soil horizons (A-Bw-C).

Five disturbed soil samples for laboratory analysis were collected from soil horizons. Soil particle size distribution was determined by the pipette method with sieving and sedimentation after dispersion with sodium pyrophosphate, and interpreted according to FAO (2006). Soil pH was measured in a calcium chloride solution with a 1:2.5 soil to solution ratio (ISO 10390, 2005). Particle size distribution was determined by sieving and pipette methods. Carbonate content was determined by the volumetric method (ISO 10693, 1995) while organic matter was determined using hydrogen peroxide solution. Determination of anions and cations (Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, NO_2^- and SO_4^{2-}) on the previously frozen soil samples was performed using the method of ion chromatography (ICS-90).

Different binding sites of trace elements in selected soils were analysed using sequential extraction. Sequential extraction scheme was used according to Rauret et al. (2001) and it gave four fractions: acid (bound to carbonates-CARB), reducible (bound to iron and manganese oxides, hydroxides and oxyhydroxides-FEMN), oxidisable (bound to organic matter and/or sulphides-OR/SUL) and residual (total dissolving using aquaregia-RES). All the reagents used in the extraction procedures were of analytical grade. The resulting solutions were analysed by flame atomic absorption spectrometry (AAnalyst 700, Perkin Elmer).

RESULTS and DISCUSSION

Table 1 presents physical and chemical characteristics of Eutric Cambisol. Texture of analysed soil profile is mainly silt, in some parts silt loam. The highest proportion of sand is determined in C horizon, and the smallest in Bw horizon. Values of pH varied from 6.88 to 7.19, which represent uniformity with the depth. Change in pH values along the soil profile can be associated with a change of carbonates, while alkalinity of the soil can be related to the presence of magnesium and calcium carbonates (Jašaragić-Rako, 2015). The highest percentages of organic matter were determined in A and C horizons, while with increase of depth this values decrease.

Table 1
Physical and chemical characteristics of investigate soil profile.

Soil horizon	Depth (cm)	$CaCO_3$ (%)	OM (%)	pH ($CaCl_2$)	Granulometric composition		
					Sand (%)	Silt (%)	Clay (%)
A	0-20	7.5	8.06	6.88	2.42	87.43	10.15
Bw	20-40	14.3	11.46	7.1	1.8	89.54	8.65
	40-60	19.4	4.6	7.19	1.46	87.59	10.95
	60-80	13.8	4.07	7.16	2.72	84.97	12.32
C	80-100	7.2	12.72	7.14	4.77	82.00	13.23
	100-120	5.3	3.77	7.14	3.84	89.78	6.37

Table 2 presents distribution of the major anions and cations in the soil profile according to the results of ion chromatography. Cations and anions have higher concentrations to 80 cm depth, while after are decreasing. Very high concentrations of chlorides and calcium could be the consequence of agricultural activity.

The highest concentrations of cations in studied soil were determined in Bw horizon (40-60 cm), with exception of potassium (Table 2). Carbonate content of Bw horizon is in line with calcium and magnesium concentration due to substitution of these cations. The lowest concentrations of cations were determined in C horizon, with exception of sodium. The potassium concentration in analysed soil varied from 46 mg/kg to 163 mg/kg (Table 2). The calcium varied from 2152 mg/kg to 3599 mg/kg. Sedlář et al. (2014) determined approximately 1743 mg/kg of calcium concentrations in Cambisol. Magnesium varied from 508 mg/kg to 813 mg/kg. Loide (2004) in his research of cations determined approximately 650 mg/kg of magnesium concentrations in Cambisol. Ammonium content in analysed soil varied between 38 mg/kg to 64 mg/kg.

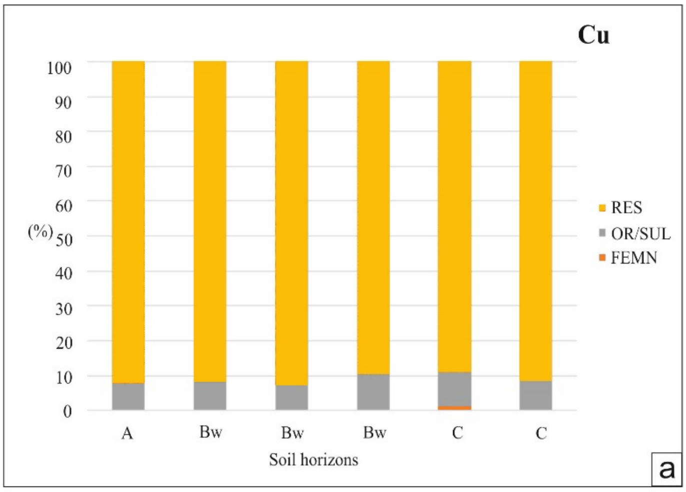
The highest concentrations of anions in studied soil were determined in A and Bw horizons (Table 2). Sulphates varied from 61 mg/kg (C horizon) to 117 mg/kg (Bw horizon). The highest chloride concentrations (4140 mg/kg) were determined in Bw horizon which correspond to calcium concentration. Nitrates varied from 48 mg/kg (C horizon) to 235 mg/kg (Bw horizon) (Table 2). Nitrate showed decreasing trend with soil depth. The same trend was reported by Bubalo et al. (2014) during their research of nitrate concentration through soil depth.

Table 2
Distribution of major cations and anions by depth. All units are in mg/kg.

Soil horizon	NO_3^-	Cl^-	NO_2^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
A	164.11	302.87	57.83	90.49	241.13	63.81	162.57	587.25	2496.26
Bw	234.91	1668.41	57.79	117.20	253.28	39.40	67.92	739.38	3117.69
	173.65	4140.04	0.00	85.57	435.26	56.47	102.13	813.68	3598.69
	95.34	239.16	39.04	73.27	271.15	46.69	94.87	578.96	2518.98
C	48.41	289.07	0.00	60.55	241.99	42.88	46.34	508.16	2151.49
	50.90	897.19	0.00	67.21	287.67	38.08	57.29	517.50	2169.68

The sequential chemical analysis resulted in diverse distribution of sequenced fractions in Eutric Cambisol. The average proportion of Cu fraction in soil horizons was arranged in the following decreasing orders: RES (89-93%) > OR/SUL (7-70%) > FEMN (0-1) > CARB (0) (Fig. 1a). The distribution of Cu to different fractions is the result of various soil processes and the equilibrium of these processes, which depend on soil physical-chemical conditions and crop cultivation (Adriano, 2001). The highest proportion (93%) of Cu in the analysed soil was detected in the residual fraction in A horizon (Fig. 1a). The second highest enrichment of Cu is in OR/SUL fraction. Kaasalainen and Yli-Halla (2003) studied behaviour of metals in soils and concluded that the concentrations of Cu in oxidizable fraction were higher in the A horizons than in the deeper horizons.

The average proportion of Zn fraction in soil horizons was distributed in the following decreasing orders: RES (78-86%) > FEMN (7-11%) > OR/SUL (6-10%) > CARB (0-4%) (Fig. 1b). Kabala and Singh (2001) in their study found same orders of Zn fractioning in Cambisol.



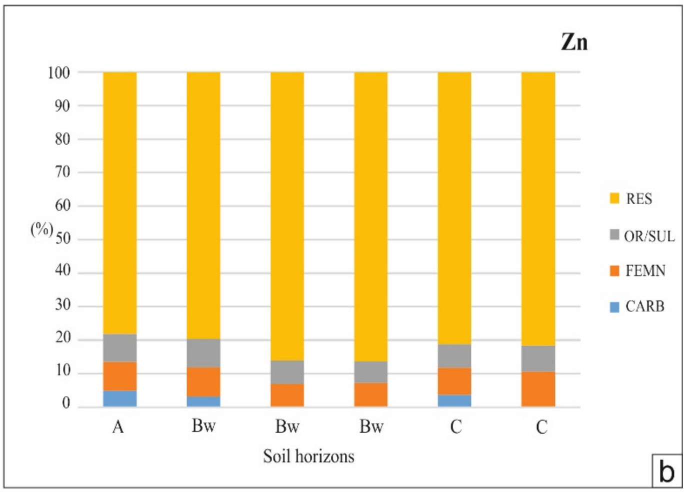


Figure 1. a) Distribution of copper in fractions in soil profile; b) distribution of zinc in fractions in soil profile

CONCLUSIONS

Physical and chemical properties and element concentrations of Eutric Cambisol in area of well field Velika Gorica (Croatia) was investigated. The highest proportion of clay is determined in C horizon, which is in correlation with the highest organic matter for this depth. Values of pH varied from 6.88 to 7.19, which represent uniformity by changing with depth.

The sequential chemical analysis presented diverse distribution in sequenced fractions of investigated soil. The average proportion of Cu fraction in soil horizons was arranged in the following decreasing orders: RES (89-93%) > OR/SUL (7-70%) > FEMN (0-1) > CARB (0). The average proportion of Zn fraction in soil horizons was distributed in the following decreasing orders: RES (78-86%) > FEMN (7-11%) > OR/SUL (6-10%) > CARB (0-4%).

The highest concentrations of cations in studied soil were determined in Bw horizon (40-60 cm), with exception of ammonium. Carbonate content of Bw horizon is in line with calcium and magnesium concentration due to substitution of these cations. The lowest concentrations of cations were determined in C horizon, with exception of sodium. The highest concentrations of anions in studied soil profile were determined in A and Bw horizons. Nitrate showed generally decreasing trend with soil depth.

Values of soil pH and calcium concentration are in line. Even though influence of agricultural activities is recognized, all results show that impact is decreasing after approximately 80 cm depth. The results from this study show impact of agricultural activities until approximately 80 cm soil depth.

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Ways of improving reed meadow in Aral region

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ABSTRACT

During the formation of the new relations in agriculture the main contract intensification of animal feed in the Republic of Kazakhstan all forms of agro-industrial complex, must provide every cattle with a sufficient amount of guaranteed quality forage in all seasons of the year. In todays market condition the main way of increasing the base of forage is increase productivity of soil where the forage is planted, growing cheap and full forage from these places.

There are such kind of places with much reed thickets in Kyzylorda in our republic. These agricultural places produce ran vegetable oil which considered as the most important southern reed. The total area of reed thicket in the Republics of the Commonwealth of Independent States is 5 million hectares, and its mass is about 40 million ton. According to the information of some scientists reed thickets in Kazakhstan contains from 1.8 to 3 million hectares.

However, in the last 30-40 years because of the men regulation of the flow of rivers and building water constructions destroy reed places for plowing cereal and vegetable crops, reed growing areas are in disaster, the inventories of raw materials are reducing.

That's why land using for agriculture especially researching reed thickets in detail and effectively in Economy is topical nowadays.

The decision of these problems will be increasing reed productivity. Growing forage in Aral region is very important. Problem of forage bases enhancing forage crop productivity and crop rotation has been considering to nowadays. The amount of mineral fertilizers and pesticides has been using while mechanization of large-scale land reclamation works and agro-technical measures there we face some expenditure. In the southern irrigated lands feed and silage is made from corn. Their quality is depend on preparing succulent forage (silage).

Theoretical and technological basis of producing silage is done according to the collective farms. Reducing of cattle, much expenditure in sown area, the lack of agricultural machinery demands new research.

Quality of hay biological fertility, grass harvest time, gathering and keeping technology changes according to the rainy weather and crop rotation. Identifying biological fertility of food in winter, in a crisis season to feed the cattle with quality hay, save them and obtain high yield is the practical importance of the scientific research.

Regulation of the flow of the Syrdarya river, drying of valley, desertification of land area, decrease of the amount of reed meadow to 20-28 times, decline of strong forage to 2.4 times leads soil salting.

However, the creation of a strong forage base and possibility of industrial use of reed thickets in farm is not used enough.

KEY WORDS: Syrdarya, animal feed, irrigated lands, biological fertility, quality hay.

INTRODUCTION

In the light of the emergence of new relations in agriculture, the guaranteed provision of livestock for animals of all economic entities of the agro-industrial complex of the Republic of Kazakhstan with high-quality fodders and in sufficient quantities in all seasons of the year is a prerequisite for intensifying fodder production.

The main reserve in strengthening the fodder base in modern market conditions is the increase in the productivity of natural forage lands, the receipt of full-fledged and cheap fodder on these lands. One of such vast areas in the republic in the Kyzylorda region are reed beds. The main dominant of these lands is the southern reed, which is of great economic importance, as a vegetable raw material for integrated agricultural use and industrial processing.

The total area of cane thickets in the CIS is 5 million hectares, and its annual growing mass is about 40 million tons. The area of reed thickets, according to various scientists, in Kazakhstan is from 1.8 to 3 million hectares.

However, over the past 30-40 years, as a result of intensive economic activities, regulation of river flow, the construction of various water management structures, the plowing of reed meadows for cereals and vegetable crops, the areas under the reed are catastrophically declining and their raw material reserves are decreasing. In this connection, the problem of the comprehensive study of natural lands, especially of reed meadows and their rational use for the needs of the national economy, is acute.

The solution of these problems is especially important in the environment of the environmentally unfavorable region of the Aral Sea region, where the increase in feed production should be carried out first, due to the all-round increase in the productivity and rational use of natural fodder land.

Flow regulation of Syr Darya River in the region led to the irretrievable drying up of its delta, desertification of the territory, a decrease in flooded reed hayfields by 2.0-2.8 times (from 600-700 to 250-300 thousand hectares), a 2.4-fold decrease in the yield of roughage, as well as increased secondary salinization of the soil, and a shortage of water resources.

The potential uses of cane thickets are not sufficiently utilized in the region in order to create a solid feed base for livestock and industrial use in the national economy of the republic.

Due to the prevailing circumstances, the problem of providing livestock with feeds became more and more difficult. Therefore, the goal of finding the most acceptable ways to increase the yield of reed thickets. The research tasks were put specifically to the measures to create highly productive haymaking with various methods of superficial and radical improvement.

The Reed southern has enormous potentialities, adapts to extremely diverse soil and climatic conditions, including growing on heavy clayey solonchak soils. The cane thickets are a stable one-species community, it increases the area due to vegetative and seed renewal.

One above-ground shoot can contain up to 50 thousand germinating seeds in a panicle, which under favorable conditions swell and begin to grow after 48 hours. Reed continues to develop even with surface amelioration of meadows - disking, flooding with water for 15 -30 days and provides a high plant mass without the expense of labor and funds.

A huge area of reed thickets, creating a peculiar microclimate determines the composition of the accompanying vegetation and fauna. They are not only a habitat for animals and birds, but they also serve as protection against enemies and unfavorable weather conditions, as well as food and a place for breeding.

The good heat-insulating, physico-mechanical and chemical properties of cane stems, as well as their cheapness, make it possible to use it widely as local building materials, as cane shields, mats, facades, insulating boards, sheets of dry plaster, roofing, flooring, facing tiles , shapes and beams.

The feed value of reed in a timely harvest for hay and silage is satisfactory. Hay, harvested before the reed flowering, contains 12.1% protein, 35.8% extracted substances and 38.6% fiber. The nutritional value of this hay is 36.5 fodder units.

Nowadays reed is widely used as pasture forage, as well as for hay making and silage preparation. In pastures, cattle often prefer it to all other herbs in the spring, because at this time the reed contains a lot of sugars and tastes sweet. It gives a huge mass of hay sufficient nutrition, provided that the terms of mowing are respected. Silage made from cane is of good quality and is not inferior in quality to the silage from the stems of sunflowers.

However, with many positive qualities, the reed southern has an extremely unfavorable characteristic for livestock farms that is its instability to grazing and haymaking. With annual summer mowing (as well as grazing), it quickly degrades - becomes short, small and gradually falls out of the grass stand. The replacing plants are less valuable food - low-productive, poorly eaten or even harmful to livestock.

MATERIAL and METHOD

Studies on the creation and improvement of fodder in the floodplain of the river. The Syr Darya were conducted for four years - 2013 – 2016. The main object of research was reed beds.

When developing technological methods for improving the grass stand of reed thickets aimed to create highly productive hayfields, we were guided by the works of the founders of fodder production and meadow management -. Williams 1, I.V. Larina 2, N.G. Andreev3, as well as special techniques compiled by the authors' groups: "Technique of experimental work on hayfields and pastures"; "Methodology of field experiments with fodder crops" and many other sources.

In the process of research, we have generalized and critically analyzed the extensive experimental materials of domestic and foreign authors on various issues of the improvement of reed thickets.

At all stages of the experimental research, we followed the basic requirements: observance of the principle of a single distinction, i.e. observance of the unity of all the conditions of cultivation, except for one studied, the compulsory setting of experiment on sites homogeneous by climate and soil.

The experimental work was carried out by setting up the field experiments by the method of ordinary repetition in 2-fold repetition in time. Repeatability of the same options - 3 - 4-fold. The area of experimental plots was 200 - 300 m^2. All the experimental crops were irrigated twice at the end of May and the middle of July, with an irrigation rate of 700 m3 per hectare. Two field experiments were set up.

Experiment 1. Effect of soil treatment on yield of reed hayfields.

Scheme of the experiment:
1. Without tillage (control);
2. Disk harrowing with BDT - 2,2 to a depth of 10 - 12 cm, in two tracks;
3. Disc harrowing with BDT - 7.0 to a depth of 17 - 18 cm, in two tracks;
4. Plowing with PM-4 - 3,5 with a skimmer to a depth of 20 - 23 cm.

Before processing the field with disk, a cane was burned on the site. Therefore, plowing was carried out from two sides so that the fire did not spread to other areas.

The processing of the turf of the reed meadow facilitated the penetration of air into the root layer of the soil, and its main purpose is cutting the rhizomes of the reeds, which greatly increases the stalk on the unit area.

After processing for the purpose of crushing the top layer of the soil, harrowing of the soil with the "Zig-Zag" harrows and packing of the ring-shaped skating rinks ZKK-6A was carried out.

RESULTS and DISCUSSION

The results of the research showed that by establishment of an effective method of presowing soil cultivation against the background of the optimal dose of fertilizer application and irrigation regime, it is possible to regulate the growth and development of reed southern and thereby increase the productivity of jelly cane cenoses.

It has been established that with deep loosening, the vegetative renewal of the southern reed is due to the growth of the vertical rhizomes and to the intergrowth sprouts become independent plants.

On the discarded plants, the reed plants were better scraped, had powerful plants compared to the control and plowed land.

The greatest number of plants were planted 192-203.5 plants and shoots (293 - 366.2 plants), before harvesting was in the plots with loosening disk implements (BDT-2.2, BDT-7.0), and the smallest number (175, 2 plants) and 225 stems in the dumping of soil at a depth of 20-22 cm.

Differences in the growth and development during cane vegetation, depending on the surface treatment of the soil, has an effect on the productivity and formation of the yield of reed hayfields.

The growth of reed southern in different years occurs in mid-April, depending on the course of the onset of the warm period. So, in 2013, the cane growth was recorded on the 10th, in the next 2014 - on the 16th and on the third year also on the 10th of April. On 2014, the growth in the third year after treatment was observed on 12 April.

Further, the growth and development of the reed southern, as well as the accumulation of the above-ground mass, occurs as the temperature increases and continues until August.

The average height of the reed plants and average daily increments, depending on the processing of the turf of the reed meadow have been recorded. In the phases of tillering, which usually occurs in mid-May; tubing - the middle of June, sweeping - the second decade of July and flowering - the twentieth of August.

A distinctive difference in plant height, according to the average daily gain in all growth variants and over the years, was not found, although some preference should still be given to plants growing on the disk tilled plots. If we compare the linear growth of cane in different species, then its highest stems were on the plots disked on - 201.7 and 233.0 cm, while on plowing 183.7 and control - 196.7 cm.

Also, in the phases of the development of the reed, depending on the processing of the reed meadow, the number of leaves was considered and their feeding area was determined.

A considerable increase in the leaf area was observed on the deep loosening with disk, compared in the plots without tillage (control), and when the soil was plowed, A decrease in the leaf surface of the reed was observed due to the natural drying and yellowing of leaves of the whole plant. This leads to a weakening of the photosynthetic activity of reeds and a decrease in the rate of accumulation during the growing season.

The smallest accumulation of dry mass during the vegetation period under plowing is was due to the fact that on these plots growth and development of the cane leaf surface occurred at a significantly low rate, as a result of smaller size the leaves compared to the deep loosening of 17-20 cm with disk BDT-7.0.

The results showed that with deep loosening by disk implements the photosynthetic activity of the cane plants improves and the number of leaves, width and length, the number of nodes increases compared to the (control).

This tendency was also observed on the variants where plowing to a depth of 20-23 cm was carried out. The low productivity of reeds was due to the conditions of the Kyzylorda region that has heavy clay and saline meadow-bog soils form large clumps during plowing, which requires additional costs for their destruction, because the bulk of the reed rhizomes fall into the lower horizon of the soil at a depth of 15-20 cm.

As a result, vegetative regeneration is weak, only 1-2 shrubs were formed. High air temperature and strong winds contribute to the desiccation of the upper arable horizon, because of which the growth and development slows down considerably, the photosynthetic activity of the southern cane weakens.

Our results showed that the plowing during the vegetation period, a decrease in the number of leaves (1-2 pcs) in cane, the length of the internodes is shortened by 1 to 2 cm width and length, of leaf were the same or insignificant increased than in the plots without processing (control).

Such an advantage in terms of morphological indices - the number of leaves, the area of the leaves, the average daily gain, the mass of 10 plants, including the mass of leaves - in the variants where disking was carried out had a positive effect on the overall productivity of reeds.

For the life of the reed thickets, the natural aging of plants has infinitely small value. The main role in their development have the conditions of their existence and rational ways of use. Separation of thickets of cane by types based on the age sign, as suggested by Krivitsky (5), we consider biological unreasonable. The decrease in the production of plant matter in a particular reed community is more likely to worsen the conditions of existence than the regular aging.

Our observations on the reed showed that the onset of the same phenological phase in this plant is stretched for two to three, and sometimes four weeks, depending on the climatic conditions, especially the air temperature, lack of moisture and the water-food regime of the soil. With limited supply of water the reed almost always ends its cycle of development and fruiting occurs earlier despite a low growth.

In unfavorable years, as in 2014, the development phase was delayed by 5-7 days, and in the plots where deep loosening with the disk BDT-7.0, the onset of individual phases of cane development (flowering, 14th - 16th leaf) proceeded earlier for 3 - 4 days.

As was noted, the determination of the yield of green and dry mass of the reed plants was carried out in the experiment for a period of three years after soil cultivation. The yield of cane basically depends on the moistening of the soil and the occurrence of groundwater. The yield was significantly influenced by soil cultivation. The positive effect of disking was clearly traced when characterizing the morphological features of the reed. These positive indices contributed to an increase in the yield of cane in these variants throughout the years of recording yields (Table 1 and 2).

Table 1
The yield of cane in the south, depending on the processing of the reed meadow, q / ha Bookmarks for 2013
Bookmarks for 2013

Options experience	Years of Accounting						Amount		Average		Addition	
	2013		2014		2015							
	green mass	dry mass	green mass	dry mass	green mass	dry mass	green mass	dry mass	green mass	dry mass	dry mass	dry mass
Without treatment, (control)	143,3	40,2	174,0	48,8	145,3	41,5	462,6	130,5	154,2	43,5	-	-
Disking to a depth of 10-12 cm	185,0	53,5	196,2	54,9	191,0	54,5	572,2	164,9	190,7	55,0	36,5	11,5
Disking to a depth of 17-18 cm	210,3	58,8	218,3	61,1	217,2	60,8	645,8	190,7	215,2	60,2	61,0	16,7
Plowing n depth 20-23 cm	175,0	50,0	148,1	41,4	181,0	51,7	504,1	143,1	168,0	47,7	13,8	4,2
LSD 0.95		8,3		9,8		10,1						

Table 2
The yield of cane in the south, depending on the processing of the reed meadow, q / ha
Bookmarks for 2014

Treatments	Years of Accounting						Amount		Average		Addition	
	2014		2015		2016							
	green mass	dry mass	green mass	dry mass	green mass	dry mass	green mass	dry mass	green mass	dry mass	green mass	dry mass
Without treatment, control	152,3	42,6	178,3	49,9	183,7	51,4	514,3	143,9	171,4	48,0	-	-
Disking to a depth of 10-12 cm	191,5	53,6	205,4	57,5	224,7	62,9	622,6	174,0	207,2	58,0	35,8	10,0
Disking to a depth of 17-18 cm	205,6	57,6	229,3	64,2	241,3	67,6	676,2	189,4	225,4	63,1	54,0	15,1
Plowing on depth 20-23 cm	182,3	51,0	196,2	54,9	214,7	59,3	593,2	165,2	197,7	55,1	26,3	7,1
Nsr 0.95		8,3		9,8		10,1						

The average yield of cane is about 150 tonnes of green mass, in our experience at the control it was 15and 171.4 t / ha, and the dry weight – 43,5 and 4,8-0 t / ha. The yield of cane on the disked site (BDT - 2,2 and BDT - 7,0), respectively, in 2013 - 190,7 and 215,2 t / ha and in 2014 - 207,2 and 225,4 t / ha . In the plowing plots - 168.0 and 197.7 t/ha. The additions in the disking variants were 36.5 and 61.0 for the green mass in 2013, 11.5 and 16.7 t/ ha for dry matter, and in 2014 respectively, 35.8 and 54.0 and 10.0 , 0 and 15.1t/ha.

CONCLUSION

Based on experimental studies of four years, studying the improvement of reed haymaking and previewing the literature sources, the following conclusions are made:

1. By burning old plants with subsequent processing of the area with disk BDT-2,2 and BDT-7,0 and plowing PN-4-35, the yield of haymaking can be increased. Disking to a depth of 10 - 12 cm and 17 - 18 cm provided an average yield of 199 and 220 t / ha of green mass, respectively, and 57 and 62 t / ha of hay, respectively.
2. The harvest of reed mass in various phases of its development showed that by changing the time of mowing it is possible to obtain not lower than usual with mowing in generally accepted terms, but of much better quality. Thus, when the cane was mowed during the tubing period, its yield averaged 141 t / ha of green mass.

Literature

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Reclamation methods and their outcomes in Serbian mining basins

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ABSTRACT

The reclamation plan is introduced in the early planning phase of exploitation of mineral deposits by the national Law on mining and geological research. This way the reclamation practice is joint and adapted to the excavation and ore processing technology in order to achieve more efficient, low cost and sustainable solutions. However, reclamation activities in Serbian mining basins are still considered poorly applied in practice. Non-selective deposition of overburden material, sporadically coupled with improper technical reclamation, aggravates and slows down the process of biological reclamation and the improvement of physical, chemical and biological characteristic of underlying Technosols. Besides, management of reclaimed land and further maintaining of reclaimed surfaces often remains questionable. During previous decades, although interrupted with periods of economic crisis, certain efforts have been made towards improving the reclamation practice. Short and long-termed outcomes of reclamation activities are achieved so that some examples of good practice may be displayed. This is particularly reflected in the development of ecosystem processes in artificially created ecosystems, including the development of the soil cover and the increase of biodiversity. The objective of this paper is to give a review of the reclamation methods used in practice and the outcomes of biological reclamation activities in some of the most important mining basins in Serbia, on base of which the basic guidelines and directions for the adequate management measures can be given in order to enhance the successful outcomes in future reclamation activities.

Identification of relevant publications, technical reports and unpublished sources was undertaken prior to their systematic review. The results and the conclusions of relevant studies are summarized and interpreted in order to answer the research questions.

Methods of reclamation in large mining basins in Serbia are described within context of ground preparation, use of artificial covers or topsoil cover, prevailing type of biological reclamation, and additional scientific researches. Agricultural and silvicultural approach to biological reclamation of mining sites largely dominates in Serbia, often being coupled with ameliorative approach. As a consequence of reclamation measures, content of nitrogen and organic matter in Technosols overly increased in reclaimed areas, and their biogenity has generally been improved. Systematic monitoring of reclaimed areas may provide information on soil and vegetation development that could significantly contribute to the quality of future reclamation activities.

KEY WORDS: reclamation, outcomes, management, good practice

INTRODUCTION

Mining operations are temporary land use activities. In order to minimize the impact to the local environment after the end of mining operations a mine reclamation plan is required. Reclamation techniques include technical and biological processes. Technical reclamation covers landscape shaping and levelling, drainage control measures, stabilization measures and topsoiling. The main objective of biological reclamation process is the establishment of diverse artificial ecosystems most suitable for designed post-mining land use. Successful biological reclamation restores the natural capital of biota and productivity of land, which have been previously destroyed by mining operations (Sheoran et al, 2010).

According to the The Law of Mining and the Geological Explorations (Official Gazette 101/2015) after the exploitation of mineral resources company is obliged to carry out reclamation of the land according to the project study. The reclamation plan is introduced in the very early planning phase of of mineral deposits exploitation, which enables that the reclamation technology can be adapted to the excavation and ore processing technology in order to achieve more efficient and lower cost solutions. The project documentation for the performance of the reclamation work is regularly made, but the projects are still poorly applied in practice. Due to the periods of economic crisis, lack of financial resources often caused discontinuities in reclamation processes, or the absence of proper management measures. In addition, the information on the results of reclamation efforts is often missing, or it is partial and incomplete (Ranđelović, 2015, Stanković et al,2015).

One of the basic preconditions for the biological reclamation is the adequate ground preparation. Landfilling is still subordinate to the technological process of exploitation and not the biological reclamation process. To ensure the optimal condition for reclamation success, biological reclamation needs to be strongly adjusted to the technical part of ground preparation.

Non-selective deposition of overburden material is a common practice in Serbian mining basins (e.g. Bor, Majdanpek, Kostolac, Kolubara). In his way, the surface ground remain heterogeneous, creating a variety of different conditions over a relatively small surface that often compromises the biological reclamation efforts and success. Physical, chemical and biological properties of extracted material are main obstacles for a successful reclamation. If the topsoil layer has been preserved, soil cover preparation is more efficient than in the case of non-selective deposition. However, Ličina et al. (2017) suggest that preserved surface soil layer, used for topsoiling in biological reclamation, should be previously tested on the excess of heavy metals, especially if the agricultural reclamation is going to be applied.

Biological reclamation of mine wastes can be described in terms of three different basic approaches (Hester and Harison, 1994):

a) agricultural / silvicultural - agricultural crops or forest plantations are established using conventional or specialized techniques.

b) ameliorative - achieving optimum conditions for plant growth by improving the physical and chemical nature of mine wastes using organic matter, fertilizers or specialized industrial products. The most suitable species commercially available are sown on to the wastes with modified properties.

c) adaptive - selection of the most suitable species and cultivars to meet the extreme conditions of mine wastes. This approach is simple but is constrained by the availability of the seed banks and lead-time in producing commercial seed from promising natural or artificially selected plant material.

The objective of this paper is to present a review of the reclamation methods used in practice and the outcomes of biological reclamation activities in some of the most important mining basins in Serbia. The outcomes reflected in Technosol development, microorganism and vascular plant diversity indicating a degree of ecosystem function and productivity, which are highly influenced by prevailing abiotic and biotic conditions of specific mine basin.

This paper also aims to answer following questions: What is the prevailing type of biological reclamation in most important Serbian mining basins? What are the main changes that arise upon the biological reclamation? Are there any new directions emerging in nowadays reclamation practice in Serbia?

Summarizing the findings of diverse researches and reports on biological reclamation state and process creates a base of which the basic guidelines and directions for the adequate management measures can be given in order to enhance the successful outcomes in future reclamation activities.

MATERIAL and METHOD

Identification of relevant publications, technical reports and unpublished sources was undertaken prior to their systematic review. The results and the conclusions of relevant studies are summarized and interpreted in order to answer the research questions.

RESULTS and DISCUSSION

Reclamation practice in Serbia has been developing in last couple of decades, reaching its peaks during 80`s of previous century. Reclamation practice was closely connected with economic development and it was also heavily influenced by economic crisis in the country. So far, rather low percentage of reclaimed area out of total deposited area has been obtained in Serbian large mining basins (Table 1).

Table 1
Total deposited area, reclaimed area and percentage of reclaimed area out of total deposited area in Serbian mining basins (according to Vujić et al, 2005 and National Strategy for Sustainable Use of Natural Goods and Resources, 2012)

Mining basin	Total deposited area (ha)	Reclaimed area (ha)	Percentage
Kolubara	3 580.6	1150.8	32.14
Kostolac	1 435	462.1	32.20
Bor	827.7	112.7	13.6

Reclaimed land is managed either by the operational units within the mining companies, either by separate companies (public entities) with a purpose of land reclamation and managing. The organizational type influences the way reclaimed land is managed and treated. In Kolubara mining basin special operational units are conducting reclamation work and they also permanently manage post-exploitation land. In Kostolac mining basin this role belongs to a public company „Reclamation and greening". The reclaimed land is in a public ownership, and state and local governments has obligation to provide financial support and other measures for effective land management and other management measures based on the sustainable development of the area (Živanović- Miljković and Džunić, 2013).Operational unit within Mining Basin Bor and Institute for Mining and Metalurgy Bor as a public institution are currently managing the mine waste and flotation tailings areas in Bor. There is no special treatment of reclaimed areas in this mining basin, which largelz influence their size, quality and effectiveness.

The reclamation works and post-mining land use change in largest mining basins in Serbia needs to be accompanied with ownership transformation, e.g. returning the land to the previous owners, transfer of land for profit or non-profit purposes (Živanović- Miljković and Džunić, 2013).

Kolubara coal mining basin

The first reclamation efforts in Kolubara mining basin began in the 1950's (Šmit and Veselinović, 1997). A total of 845.14 ha of deposited area in Kolubara mining basin has been reclaimed by the end of 2016., out of which 738.24 ha underwent forest reclamation, and 106.9 ha agricultural reclamation (Report on the state of the environment in MB Kolubara d.o.o., 2016). Few decades of experimenting with crops, fruits and forest plantations, as well as application of diverse agro-technical measures, has nowadays brought to a valid recommendations for successful reclamation of Kolubara deposits.

Agricultural reclamation process consists of substrate preparation, fertilization, sowing and care measures. However, if preserved surface soil layer is going to be used in agricultural reclamation, Ličina et al. (2017) suggest a prior metal assessment as a component of a future rehabilitation policy for topsoil in food and fodder production in Kolubara mining basin. First phase of agricultural reclamation consists of grass and legumes, which improves fertility of Technosols. In later phases diverse crops (wheat – *Triticum* sp., corn – *Zea mays*, alphalpha – *Medicago sativa*, and sunflower – *Helianthus* sp.) and fruits (apples – *Maluspumila*, pears – *Pyrus* sp., and plums – *Prunus* sp.) are planted. Agricultural products from Kolubara mining basin are annually sold on market. However, evaluation of economic parameters for success of agricultural reclamation showed that high level of agricultural profitability cannot be expected in the case of Kolubara mining basin, according to the investigations of Zlatić et al (2000). Forest reclamation in Kolubara mining basin started in 1957, but intensive reclamation efforts began from 1973, when first forest nursery was formed on the Technosol in Baroševac (Šmit and Veselinović, 1997). The technology of establishing forest plantations consisted of adding peat in a planting hole, or using seedlings with baled roots in order to provide favourable conditions for the development of root system. First tree species used in reclamation of this area were the species previously used in similar programs: Austrian pine (*Pinus nigra)*, lime (*Tilia* sp.), ash (*Fraxinus* sp.), larch (*Larix europaea)* and black locust (*Robinia pseudoacacia).* At later stages, other tree species such as oak (*Quercus* sp.), alder (*Alnus glutinosa*), Douglas fir (*Pseudotsuga menziesii),* maple (*Acer* sp.) etc. were used. Results of multidisciplinary research on this forest stands showed that great number of autochthonous deciduous species and fast-growing conifers can be used in reclamation of Kolubara mine deposits (Šmit and Veselinović, 1997). Technosol soil texture is one of the major factors that determine the choice of tree species (Šmit and Veselinović, 1997). The profitability of wood production in Kolubara Technosols depends upon tree species and site quality (Zlatić et al, 2000). According to Resulić et al, 2013, agrochemical properties of tested Technosols under different forest cultures showed increased pH, lower humus and total nitrogen content, higher level of available phosphorous and similar or lower value of available potassium compared to the control pseudogley soils, which represents natural autochthonous soils of Kolubara basin (Table 2).

Table 2
Agrochemical properties of Technosols and pseudogley soil under different forest cultures (taken from Resulić et al. 2013)

Locality	Species	pH	Humus (%)	N (%)	P2O5 (mg/100g)	K2O (mg/100g)
Technosol 1	*Pinus nigra*	5.5	1.48	0.1	8.2	15.4
Technosol 2	*Quercus robur*	6.5	1.26	0.13	6.8	22.6
Technosol 3	*Alnus incana*	6.5	2.1	0.05	2.1	13.6
Technosol 4	*Pseudotsuga menziesii*	5.75	1.35	0.12	3.7	27.8
Technosol 5	*Larix decidua*	5.9	2.67	0.10	3.6	16.5
Technosol 6	*Tilia* sp.	5.9	1.12	0.06	2.5	15.2
Control site - pseudogley	*Pinus nigra*	4.55	3.15	0.16	2.7	23.4

According to Miletić (2004), one of the main limiting factor for the growth and development of the forest trees on the reclaimed mine soils in Kolubara mining basin is the lack of nitrogen. Consequently, the best improvements of Technosols characteristics were achieved by nitrogen-fixing species *Alnus glutinosa* and *Robinia pseudoacacia* (Miletić, 2004; Miletić et al, 2009). Based on the results of a various investigations on the reclaimed areas in Kolubara, it is recommended that the future reforestation works should be based on formation of mixed deciduous-coniferous or mixed deciduous forest stands, in order to enhance their ecological values and effects they produce on the surrounding environment (Šmit and Veselinović, 1997).

Investigation of soil microorganisms in Technosols under forest stands showed that biochemical processes and organic matter turnover has been established. The higher content of soil microorganisms by their main physiological groups has been obtained under deciduous stands compared to the coniferous stands at the reclaimed areas (Miletić et al, 2005). Similar results are obtained by Đorđević et al. (2014), which have found increased number of soil microorganisms in the 7 year old birch tree stands, compared to a 16 year old silver pine tree stands. Total number of soil microorganisms in the investigated Technosols has been reached the average levels for natural soils.

New approaches to biological reclamation in Kolubara mining basin are confined to the individual scientific studies on small plots. Research on short-rotation forest plantations for biomass production was established in Kolubara mining basin in order to revile proper species and optimal solutions for the establishment of short-rotation plantations that may produce the greatest amount of biomass for energy production. In 2006.experimental plots with *Larix europaea (larch)*, *Pseudotsuga menziesii (*Douglas fir*)* and *Populus* sp. seedlings were established at Field “D”(Dražić et al, 2008), while in 2008. experimental plot with *Robinia pseudoacacia* seedlings was established at Field “B” (Danilović et al, 2013). Preliminary results showed that deciduous species, especially poplar, achieved better growth compared to the coniferous trees at current stage of development (Dražić et al, 2011; Dražić, 2017). However, continuous monitoring until the end of rotation period is needed for the proper conclusions to be made. These investigations have been partially coupled with amelioration measures, where waste sludge (generated in the process of coal processing) and ash (product of the wood combustion) were successfully used as manure for tree plantations (Dražić et al, 2017).

Similar approach has been undertaken by creating experimental plots with perennial grass *Mischantus x giganteus.* In 2011.experimental fields of *Mischantus x giganteus* for biomass production emerged in “Tamnava West Field”. The results of this experiment suggested that the development and production rate of *Mischantus x giganteus* highly depends on fertility of Technosol and application of adequate agrotechnical measures. When properly applied, it becomes possible to achieve results on degraded Technosols close to the ones obtained on natural soils (Aranđelović et al, 2014).

Kostolac coal mining basin

Reclamation works in Kostolac mining basin started in 1970`s. Up to 2011th, total of 704 ha has been reclaimed, out of which 432 ha have been afforested, while 235 ha were under agronomic cultures (Miloradović-Đorđević et al.,2014).

Forest reclamation was predominantly undertaken at the landfill slopes of open-pit mines “Ćirikovac”, “Kostolac”, “Klenovnik” and “Drmno” (Figure 1). Main tree species used for afforestation at this mining basin are *Robinia pseudoacacia*, *Populus* sp. and *Pinus nigra*. Agricultural reclamation is confined to flat areas, and is sporadically been coupled with topsoiling (Figure 2). First phase of agricultural reclamation includes sawing of rapeseed (*Brassica napus*), which is afterwards used as a green manure in process of soil preparation for supporting cultivation of grasses and crops. Investigations of potential of annual agricultural species for reclamation of mine waste deposits at “Drmno” reflected the accumulation of heavy metals (especially Ni and Cr) in underground and aboveground parts of plants (*Lactuca sativa*, *Fragaria vesca*, *Brassica napus*, *Zea mays*, *Medicago sativa*) and the possibility for their transfer to animals and humans via food chains, which makes them unsuitable for reclamation of this area (Ličina et al, 2007).

Figure 1. Two-year old black locust plantations on landfill slopes of „Drmno“ mine

Figure 2. Topsoil placement upon preparation for agriculture reclamation in „Drmno“ mine

Technosols reclaimed with poplar become richer in nitrogen and potassium, followed by formation of humus-accumulative horizon. After 5 years of reclamation with rapeseed, legume and grasses initial acidity of Technosols decrease, contents of humus and nitrogen increase, as well as the contents of available potassium. State of 25 year-old forest and agricultural Technosols in “Ćirikovac” mining field showed increased content of humus and total nitrogen, as well as the decrease in content of $CaCO_3$ in comparison to a non-reclaimed deposits (Table 3).The highest differences in terms of humus, total nitrogen and available phosphorous and potassium content were obtained under agricultural areas as a consequence of fertilization application and other agrotechnical measures.

The best condition and health status so far have been achieved by usage of black locust (*Robinia pseudoacacia*). Technosols of older black locust stands are characterized by regular turnover of organic material with formation of humus (Đorđević—Miloradović et al, 2014). Increased biogenity and development of ecosystem processes on reclaimed areas has regularly been followed by increased biodiversity. Over 300 species of herbaceous plants was found to inhabit reclaimed areas in mine “Ćirikovac” (Đorđević—Miloradović et al, 2014).

Table 3
Agrochemical characteristic of non-reclaimed mine waste deposits and 25 years old Technosols under different reclamation types (according to Đorđević—Miloradović et al, 2014)

Reclamation type	pH_{KCl}	Humus (%)	$CaCO_3$ (%)	N (%)	P_2O_5 (mg/100 g)	K_2O (mg/100 g)
Non-reclaimed area	7.5	1.67	4.99	0.02	5.4	27.9
Spontaneously revegetated area	7.4	2.28	4.18	0.09	5.36	21.3
Forests of *Pinus nigra*	6.9	2.31	4.11	0.11	5.12	19.1
Forests of *Populus sp.*	7.1	3.15	4.05	0.13	5.31	18.5
Agricultural areas	7.2	3.71	4.1	0.185	7.81	26.3

New approaches to biological reclamation in Kostolac Mining Basin have been implemented in previous years. Amelioration of Technosols by zeolite and coal dust prior to agricultural reclamation has been proved to improve it's characteristics by introducing new amounts of organic carbon, nitrogen, phosphate and potassium (Grubišić, 2011; Đorđević—Miloradović et al., 2014). In 2016.a plantation of fast- growing *Paulownia tomentosa* was established on 3.5 ha of landfill slopes at "Drmno" mine in order to investigate the potential of this species for the biomass production.

Bor copper mining basin
Reclamation of mine wastes and flotation tailings in Bor copper mining basin has started in late 1970's. Due to the severe heavy metal and metalloid pollution of air, soil and water in Bor area, forest reclamation has been predominantly applied for the purpose of environmental protection and erosion control. Afforestation efforts have been carried out on mine wastes and flotation tailings in mines "Bor" and "Veliki Krivelj" during 1979-1986. and 1992-1997., with species *Robinia pseudoacacia* (Figure 3), *Betula pendula*, *Quercus* sp., *Pinus nigra*, and *Carpinus* sp. (Milijić, 1997). Agricultural reclamation has been carried out during 1994-1995. on flotation tailings in Veliki Krivelj with rapeseed (*Brassica napus*) and rye (*Secale cereale*).

Table 4
Chemical characteristic of Site 1 - Non-reclaimed mine waste sites with native vegetation, Site 2 - Afforestated Technosols on mine wastes under *Robinia pseudoacacia* stands, Site 3 - Afforestated Technosols on flotation tailings under *Robinia pseudoacacia* stands (according to Ranđelović et al, 2014)

Mine wastes	pH_{H2O}	C (%)	N (%)	P_2O_5 (mg/100g)	K_2O (mg/100g)
Site 1	3.91 - 8.32	1.35	0.03	6.1	15.8
Site 2	5.6 - 7.85	1.04	0.6	7.6	19.5
Site 3	4.5 – 7.55	2.57	0.2	13.3	20.4

Technology for biological reclamation on deposited mine wastes consisted of providing favourable conditions for the development of roots by adding peat in a planting holes. Biological reclamation was preceded by topsoiling on flotation tailings sites in mines "Bor" and "Veliki Krivelj" (Figure 4). Investigation of Ranđelović (2010) showed that initial stages of pedogenesis, represented by accumulation of organic material and nitrogen in surface layers of Technosols occurred under black locust stands,but also in the non-reclaimed areas colonized by spontaneous native vegetation (Table 4). However, there is no formation of humus-accumulative layer neither a formation of structural aggregates in surface in investigated areas (Lilić, 2015), except in flotation tailing sites that have been topsoiled prior to biological reclamation. However, due to the constant exposure to aeropollution, Technosols of flotation tailings show degradation of soil structure in comparison to the surrounding natural soils (Lilić, 2015).

Despite the fact that the total content of soil microflora is generally low due to the presence of metal pollution, especially copper and arsenic (Ranđelović, 2010; Lilić, 2015), the transformation process of organic matter under the black locust stands has been established. The ratio of the number of soil microorganisms in diverse physiological groups (fungi, actinomyces, oligonitrophiles, ammonifiers and total microbes) reflects that the major part of the organic matter decomposes to the end-products. Synthesis of humus out of the inter-products of organic matter decomposition is slow and the further decomposition of the synthesized humic substances to the end products is either very slow, or was not identified (Ranđelović, 2017). Total of 105 vascular plants, which count as approximatelly 3.3% of total flora of Serbia, have been identified in black locust stands at Bor mine wastes and flotation tailings (Ranđelović, 2009).

Figure 3: Black locust stand on Bor mine waste slope

Figure 4: Reclaimed flotation tailings with topsoil and herbaceous species

Recent reclamation efforts have been made in 2008. at "Veliki Krivelj" mine wastes, where 10 ha were planted with black locust and Siberian elm *(Ulmus pumila).*Evaluation of reclaimed surfaces in "Veliki Krivelj" reviled that Siberian elm was not able to survive present environmental conditions, while the black locust showed different survival rates (16-95%), depending on a site conditions and reclamation technology (Žikić et al, 2017). In the area of Bor copper mine wastes, species selection and maintaining measures have proved to be a very important question for success of biological reclamation.

New approaches to biological reclamation in Bor mining basin include selection of plant species for future reclamation and investigations for the purpose of phytoremediation. During 2008. and 2009. experimental plots at Bor flotation tailings were tested with with meliorated and sterile substrates and chosen tree and grass species. The best results in a first year upon establishment were achieved with the species planted in the fertile soil layer placed upon the flotation deposit, and on the mixture of soil and flotation tailings deposit. Black locust, European ash *(Fraxinus excelsior)* and sycamore (*Acer pseudoplatanus)* showed the best survival rate, growth, and physiological vitality (Dožić et al., 2010). This research has confirmed that it is possible to use a wider number of tree species in the reclamation of the Bor mine basin. Investigations of phytoremediation potential of native and cultivated species in the area of Bor mine wastes have also been conducted. Marić (2014) and Ranđelović (2015) concluded that certain native and cultivated plant species show possibilities for significant uptake of main pollutants in the area, such as copper, arsenic or lead in their underground or aboveground parts. Species such as *Dactylis glomerata*, *Vicia sativa*, *Festuca ovina*, *Taraxacum officinale*, *Calamagrostis epigejos* and *Agrostis stolonifera* can therefore be used in future reclamation projects dealing with phytoremediation issues.

CONCLUSIONS

Although wider biological reclamation of mine wastes in Serbia started six decades ago, there is still not enough attention paid to this process, which largely depends on the economic and political trends. Prevailing attitude is that a reclamation is consider to be a long-term and costly solution, and not an legal obligation to return the land into previous or similar to previous state prior to excavation. After the processes of reclamation, the issue of further land management and land use is often not properly solved.

Agricultural and silvicultural approach to biological reclamation of mining sites largely dominates in Serbia, sporadically being coupled with ameliorative approach. Adaptive approach is still not considered as a viable alternative in reclamation of Serbian mining basins.

Content of nitrogen and organic matter in Technosols generally increase in reclaimed areas and the content and diversity of soil microorganisms has also been improved, aiming at enhancing organic matter turnover and nutrient cycling in artificially created ecosystems. Diversity of herbaceous species follows the development of forest- or agroecosystems on reclaimed areas.

Scientific institutions carry out experiments in order to find efficient and cheaper, or even profitable reclamation solutions. Modern reclamation efforts are directed toward gaining biomass for energy production (coal mining basins Kolubara and Kostolac), or investigating a potential for phytoremediation (metalliferous mining basin Bor).

In order to create stable foundation for the application of biological reclamation, certain recommendation and guidelines can be met:

●Landfill practice and technical reclamation solutions should be closely related and more adapted to biological reclamation process, and this conjunction should become usual in project practice. Selective deposition of overburden would significantly influence the success of biological reclamation, improving the starting condition for vegetation development.

● Systematic monitoring of reclaimed areas is needed in order to gain comprehensive information on soil and vegetation development, which will lead to new knowledge and directions for successful reclamation. Adaptive management, which synthesizes scientific and management approach through continual monitoring and iterative project cycle is often a proper method for sustainable management of reclaimed areas.

● Further researches with ameliorative approach are needed in order to gain cost-effective and more productive reclamation solutions. Phytoremediation experiments should be directed toward practical application in selected mining basins. Species selection and maintenance measures of artificially created ecosystems on reclaimed areas should be carefully planned, having in mind future resilience and adaptation of these ecosystems to ongoing climate changes.

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EFFECTS OF FERTILIZATION ON YIELD AND SOME TRAITS OF TAKOVČANKA CULTIVAR OF WINTER WHEAT

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ABSTRACT
Investigations were carried out during the 2008/2009 and 2009/2010 year on stationary field trial, which was established in 1970 on the experimental field of the Center for Small Grains in Kragujevac. The objective of this study was to investigate the influence of mineral nutrition on the yield of winter wheat varieties Takovčanka. Trials were included control and six fertilization variants with different combinations of NPK fertilizers.
Investigation where showed a considerable variation of grain yield which were in dependence from mineral nutrition. The highest grain yields were the highest with mineral fertilizer in the combined 80 kg/ha N and 100 kg/ha P_2O_5 (2.945 t/ha). Over the two-year period, all investigated treatments of wheat achieved the highest average 1000-grain weight in the combined 80 kg/ha N and 100 kg/ha P_2O_5 (41.40 g).
Analysis of variance was found highly significant effect of years on 1000 grains weight and test weight, and significant effect of years on grain yield. Different combinations of fertilization had the most highly significant influence on all characters, except for test weight.
Positive correlations were observed between grain yield and 1000-grain weight in all years. Grain yield were significantly positively correlated with 1000-grain weight only in the 2008/09 ($r=0.40^*$) and 2009/10 ($r=0.38^*$).
KEY WORDS: fertilization, yield, quality, wheat

INTRODUCTION
Wheat productivity and grain quality in Central Serbia are governed by a range of factors, notably climate, soil, genetics and crop nutrition (Đekić et al., 2015). Soil acidity in wheat fields in Central Serbia has become a severe problem that leads to a significant decline in grain yield and quality of wheat (Đekić et al., 2013). Several factors are decisive in increasing wheat yields: the cultivar, cultural practices, agroecological conditions, local climatic and soil characteristics, mineral nutrition and adequate protection from plant diseases, pests and weeds.

Mineral nutrition of wheat grown on acid soil reaction is specific. The crucial importance play equilibred nutrition by nitrogen and phosphorus with higher impact of phosphorus nutrient. Mineral fertilizers play a vital role towards improving crop yields but one of the main constraints in achieving proven crop potential is imbalanced use of nutrients, particularly low use of P as compared to N. The optimum rate of P application is important in improving yields of most crops (Đekić et al., 2014; Jelić et al., 2013, 2014). In Serbia, farmers use only nitrogen fertilizers for fodder crops while the use of P fertilizer is negligible. These crops are usually grown on marginal lands. Hence, the production is low and quality is poor. The absence of record yields indicates that an answer could be sought in soil, the main substrate for field crop production. Additionally, the major previous small grain crops also suffer from negative nutrient balance. The use of incomplete production technology in previous decades had definitely affected the potential and actual soil fertility.

The objective of this study was to evaluate the effect of different fertilization systems on the grain yield and quality of wheat grown on a vertisol soil. The study was also aimed at optimizing fertilization for maximum profitability in the future wheat production of Central Serbia.

MATERIAL and METHOD

Experimental design and soil conditions

The study was carried out in a stationary field trial involving fertilization over a two years period from 2008/09 to 2009/10. Plot size was 50 m^2. The wheat cultivar used in the experiment was Takovčanka, the dominant cultivar in the production region of Serbia. This investigation included an untreated seven variants of fertilization: 1-control, 2-80 kg/ha N, 3-60 kg/ha P_2O_5, 4-80 kg/ha N, 60 kg/ha P_2O_5, 60 kg/ha K_2O, 5-80 kg/ha N, 100 kg/ha P_2O_5, 60 kg/ha K_2O, 6-80 kg/ha N, 100 kg/ha P_2O_5 and 7-80 kg/ha N, 60 kg/ha K_2O. A non-fertilized variant served as a control. Total amounts of phosphorus and potassium fertilizers and half the nitrogen rate are regularly applied during pre-sowing cultivation of soil. The trial was set up in a randomized block design with five replications. Fertilization was regular and followed a long-time scheme.

The crop was harvested at full maturity. Grain yield (t/ha) was harvested and reported at 14% moisture. Two parameters of grain quality, namely test weight (kg/hl) and 1000-grain weight (g) were analysed. Thousand grain weight was determined using an automatic seed counter.

The trial was set up on a vertisol soil in a process of degradation, with heavy texture and very coarse and unstable structure. The humus content in the surface layer of soil was low (2.22%). Soil pH indicated high acidity (pH in H_2O 5.19; pH in KCl 4.27), nitrogen content in soil was medium (0.11-0.15%), while the content of available phosphorus ranged from very low (1.7-2.9 mg/100 g soil) in the N variant to very high (26.9 mg P_2O_5/100 g soil) in the NPK variants of fertilization. Available potassium contents was high, ranged from 19.5 to 21.0 mg K_2O/100 g soil.

On the basis of achieved research results, the usual variational statistical indicators were calculated: average values, standard error and standard deviation. Statistical analysis was made in the module Analyst Program SAS/STAT (SAS Institute, 2000).

Agroecologial conditions

This study was conducted over a three-year period in the Šumadija region, Central Serbia, on a Vertisol soil, at Kragujevac location, 173-220 m a. s. l. (**44° 22′ N, 20° 56′ E**), in a temperate continental climate having an average annual temperature of 11.5°C typical of Šumadija districts in Serbia and a rainfall amount of about 550 mm. The data in Table 1 for the investigated period (2008-2010) clearly indicate that the years in which the researches were conducted differed from the typical multi-year average of Kragujevac region regard the meteorological conditions.

The average air temperature in 2008/09 was higher by 1.48°C and 2009/10 was higher by 1.01°C. The sum of rainfall precipitation in 2008/09 was higher by 13.0 mm, where the sum of rainfall in 2009/10 was 616.2 mm higher than the average of many years and with a very uneven distribution of precipitation per months. Spring months April, May and June in 2009/10 were surplus of precipitation, what affected unfavorable on the crops. During the April in 2009/10 it was 142.2 mm of rainfall, what was 90.7 mm more compared with the long term average. During the month of June in 2009/10 it was 196.7 mm of rainfall, what was 117.4 mm more compared with the long term average.

Table 1

Mean monthly air temperature and precipitation (Kragujevac)

Year	Months										Average
	X	XI	XII	I	II	III	IV	V	VI	VII	
Mean monthly air temperature (^oC)											
2008-09	13.1	8.5	4.4	2.3	2.0	6.8	13.4	17.8	20.2	22.5	11.1
2009-10	11.7	8.8	2.6	0.9	3.2	7.2	12.1	16.5	20.2	23.1	10.63
Long term Average	11.8	5.6	1.9	0.6	2.0	6.2	11.2	16.2	19.4	21.3	9.62
The amount of rainfall (mm)											
2008-09	31.3	30.6	29.7	57.7	76.9	40.3	16.8	46.0	137.8	25.2	492.3
2009-10	102.6	77.5	194.2	57.0	150.5	43.3	142.2	116.7	196.7	14.8	1095.5
Long term Average	47.5	50.0	49.5	36.8	33.9	43.5	51.5	64.8	79.3	62.5	479.3

RESULTS and DISCUSSION

Based on the analysis of variance, it can be concluded that are significant differences in grain yield regarding the year of investigation (F_{exp}=5.926*) and highly significant differences at thousand grain weight

(F_{exp}=31.029**) and test weight (F_{exp}=13.219**). Highly significant differences in grain yield (F_{exp}=3.295**). and thousand grain weight regard the fertilization of investigation (F_{exp}=3.126**). Also, the effect of the interaction of the year x fertilization on the grain yield and 1000-grain weight was significant. Investigations of year x fertilization interactions present the important basis for the further more successful growing, breeding and zoning of wheat (Table 2).

The study showed that the highest grain yields were achieved in variant with 80 kg/ha N and 100 kg/ha P_2O_5 among investigated fertilization variants. Usage of fertilizers and certain amendments on extremely acid soils in certain years, particularly those less favorable for production, almost certainly had different effects on grain filling, resulting in diverse relationships between productive and qualitative traits. Presented results confirm the opinion of many authors that the traits analysed are genetically determined, but strongly modified by the nutrient status and weather conditions (Đekić et al., 2014; Jelić et al., 2013).

Nitrogen, phosphorus and potassium application, particularly on acid soils poorly supplied with these nutrients, has a high effect on the grain yield of oats and other cereal crops (Browne et al., 2006; Jelić et al., 2013; Mohr et al., 2007; Rashid et al., 2007). The present results confirm the opinion of many authors that the traits analysed are genetically determined but are strongly modified by the nutrient status of the environment and weather conditions (Đekić et al., 2013, 2014, 2015; Jelić et al., 2013, 2014).

Table 2
Analysis of variance of the tested parameters (ANOVA)

Effect of years on the traits analysed				
Traits	Mean sqr Effect	Mean sqr Error	F(1. 68)	p-level
Grain yield (t ha^{-1})	5.9230	0.999448	5.92629*	0.017547
1000-grain weight (g)	192.0629	6.189863	31.02862**	0.000000
Test weight (kg hl^{-1})	118.8206	8.988586	13.21905**	0.000534
Effect of fertilization on the traits analysed				
Traits	Mean sqr Effect	Mean sqr Error	F(6. 63)	p-level
Grain yield (t ha^{-1})	2.94104	0.89269	3.294601**	0.006970
1000-grain weight (g)	23.43923	7.49743	3.126300**	0.009566
Test weight (kg hl^{-1})	3.31590	11.27221	0.294166	0.937530
Effect of the year x fertilization interaction on the traits analysed				
Traits	Mean sqr Effect	Mean sqr Error	F(6. 56)	p-level
Grain yield (t ha^{-1})	3.1830	1.08435	3.12547**	0.01025
1000-grain weight (g)	10.1015	2.21925	3.52931**	0.00155
Test weight (kg hl^{-1})	6.2350	9.8914	0.63035	0.70529

The grain yield of wheat significantly varied across years, from 1.321 t/ha to 3.445 t/ha in 2008/09, from 1.320 t/ha to 2.445 t/ha in 2009/10. Grain yield was the highest in the combined treatment 6 (80 kg/ha N and 100 kg/ha P_2O_5) with mineral fertilizer NP (2.945 t/ha). Results clearly show that yield components were significantly affected by fertilization (Table 3), the lowest values for grain yield and yield components were obtained in the untreated control.

Thousand grain weight of wheat significantly varied across years, from 39.44 g to 42.72 g in 2008/09, from 34.16 g to 40.08 g in 2009/10. In the first year of the study, the highest average value of 1000-grain weight achieved the 6 (80 kg/ha N, 100 kg/ha P_2O_5) and 2 (80 kg/ha N) treatments (42.72 and 42.58 g). In the second year, the highest average value of 1000 grain weight achieved the 6 (80 kg/ha N, 100 kg/ha P_2O_5) treatment (40.08 g).

Table 3 presents average values for grain test weight across years and treatments. All testing fertilization variants had test weight greater than 68 kg/hl, except for control and 3 variants (60 kg/ha P_2O_5). During the first year achieved the highest test weight at 7-treatment (70.08 kg/hl), followed by 4 and 5 (69.32 kg/hl and 69.63 kg/hl), while the lowest test weight was the 3-treatment 60 kg/ha P_2O_5 (66.26 kg/hl).

In the second year of investigations, the test weight of 80 kg/ha N, 100 kg/ha P_2O_5 was the highest with 71.89 kg/hl, while the slightly lower test weight was obtained from control (71.85 kg/hl). The average two-year value of test weight were the highest at 7 and 6-treatments (70.61 kg/hl and 70.44 kg/hl). Grain test weight showed a very significant dependence on year (Table 3). In all years, the use of different treatments induced a significant increase in grain test weight.

Table 3
Grain yield, 1000-grain weight and test weight of winter wheat

Traits	Fertilization	2008/09 $\bar{x}$	2008/09 S	2008/09 S_X	2009/10 $\bar{x}$	2009/10 S	2009/10 S_X	Average $\bar{x}$	Average S	Average S_X
Grain yield, (t ha^{-1})	1-Control	1.321	0.690	0.308	1.320	0.504	0.225	1.321	0.570	0.180
	2	2.696	0.982	0.439	2.157	1.051	0.470	2.426	1.000	0.316
	3	2.167	0.844	0.377	1.970	0.505	0.226	2.068	0.664	0.210
	4	3.132	1.038	0.464	1.819	0.553	0.247	2.476	1.046	0.331
	5	2.938	1.204	0.538	2.273	1.273	0.569	2.606	1.220	0.386
	6	3.445	1.124	0.503	2.445	0.558	0.250	2.945	0.989	0.313
	7	3.160	1.160	0.519	2.410	0.617	0.276	2.785	0.961	0.304
1000 - grain weight, (g)	1-Control	39.44	1.880	0.841	34.16	4.127	1.846	36.80	4.109	1.299
	2	42.58	0.950	0.425	38.80	1.075	0.481	40.69	2.210	0.699
	3	40.36	1.328	0.594	37.42	1.453	0.650	38.89	2.031	0.642
	4	42.18	0.680	0.304	38.84	3.017	1.349	40.51	2.711	0.857
	5	42.38	0.789	0.353	38.12	2.018	0.902	40.25	2.670	0.844
	6	42.72	0.661	0.296	40.08	3.140	1.404	41.40	2.552	0.807
	7	40.70	2.734	1.223	39.75	2.137	0.956	40.22	2.367	0.748
Test weight (kg/hl)	1-Control	67.79	2.070	0.926	71.85	1.456	0.651	69.82	2.725	0.862
	2	68.93	1.635	0.731	71.33	3.339	1.493	70.13	2.783	0.880
	3	66.26	4.050	1.811	71.49	3.001	1.342	68.87	4.347	1.374
	4	69.32	3.381	1.512	70.53	2.806	1.255	69.92	2.998	0.948
	5	69.63	4.131	1.847	71.00	3.763	1.683	70.31	3.795	1.200
	6	68.99	3.836	1.716	71.89	3.976	1.778	70.44	3.988	1.261
	7	70.08	2.696	1.206	71.15	2.124	0.950	70.61	2.357	0.745

Table 4 shows the correlation coefficients between the traits analysed during 2008-2010 years. Positive correlations were observed (Table 4) between grain yield and thousand grain weight in all years. Testing the correlation coefficients between grain yield and test weight of wheat (Table 4) was found positive and significantly correlated between in 2008/09, but negative and low correlations between in 2009/10. However, thousand grain weight were significantly positively correlated with grain yield only in the first year ($r=0.40^{*}$) and second year ($r=0.38^{*}$). The results suggest that grain yield and quality formation is affected by both genetic and environmental factors (Đekić et al., 2015).

Table 4
Correlations among the analysed traits over two years (2008-2010)

Traits	Correlations in 2008/09: Grain yield, t/ha	1000-grain weight, g	Test weight, kg/hl	Correlations in 2009/10: Grain yield, t/ha	1000-grain weight, g	Test weight, kg/hl
Grain yield (t ha^{-1})	1.00	0.40^{*}	0.36^{*}	1.00	0.38^{*}	-0.11^{ns}
1000-grain weight (g)		1.00	0.06^{ns}		1.00	-0.01^{ns}
Test weight (kg hl^{-1})			1.00			1.00

Table 5 shows the correlation coefficients between the studied fertilization treatments and analysed traits. Positive correlations were observed between grain yield and thousand grain weight in all treatments. Negatively and strong correlations were observed between thousand grain weight and test weight in the unfertilized control ($r=-0.87^{**}$) and treatment 80 kg/ha N ($r=-0.72^{**}$).

Table 5 Correlation coefficients for the analysed traits across treatments

	Grain yield (t ha^{-1})	1000-grain weight (g)	Test weight (kg hl^{-1})
Correlations between the traits analysed in the unfertilized control			
Grain yield (t ha^{-1})	1.00	0.34^{ns}	-0.23^{ns}
1000-grain weight (g)		1.00	-0.87^{**}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analysed in the 80 kg/ha N			
Grain yield (t ha^{-1})	1.00	0.30^{ns}	-0.28^{ns}
1000-grain weight (g)		1.00	-0.72^{**}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analysed in the 60 kg/ha P_2O_5			
Grain yield (t ha^{-1})	1.00	0.53^{ns}	0.20^{ns}
1000-grain weight (g)		1.00	-0.44^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analysed in the 80 kg/ha N, 60 kg/ha P_2O_5, 60 kg/ha K_2O			
Grain yield (t ha^{-1})	1.00	0.59^{ns}	-0.33^{ns}
1000-grain weight (g)		1.00	-0.11^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analysed in the 80 kg/ha N, 100 kg/ha P_2O_5, 60 kg/ha K_2O			
Grain yield (t ha^{-1})	1.00	0.44^{ns}	0.06^{ns}
1000-grain weight (g)		1.00	-0.27^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analysed in the 80 kg/ha N and 100 kg/ha P_2O_5			
Grain yield (t ha^{-1})	1.00	0.41^{ns}	0.19^{ns}
1000-grain weight (g)		1.00	0.07^{ns}
Test weight (kg hl^{-1})			1.00
Correlations between the traits analysed in the 80 kg/ha N and 60 kg/ha P_2O_5			
Grain yield (t ha^{-1})	1.00	0.11^{ns}	0.14^{ns}
1000-grain weight (g)		1.00	0.45^{ns}
Test weight (kg hl^{-1})			1.00

The present results confirm the of many authors that the traits analysed and their correlations are genetically determined but are strongly modified by the nutrient status of the environment and weather conditions (Đekić et al., 2014; Jelić et al., 2013). Đekić et al. (2016) stated positive correlation between grain weight and grain yield.

CONCLUSIONS

Environmental conditions such as weather and soil and fertilization have a significant effect on grain yield and quality in wheat. Grain yield shows a tendency to increase in the years having a higher total amount and better distribution of rainfall during critical plant development stages. Based on the gained results from two-year investigation on seven treatments fertilization, it can be concluded that the highest yield achieved the treatments of two mineral elements N 80 kg/ha and P 100 kg/ha (2.945 t/ha) and 80 kg/ha N and 60 kg/ha P_2O_5 (2.785 t/ha) have achieved satisfactory results, while the poorest results were achieved by the control (1.321 t/ha).

Statistically were significantly different between of year on the grain yield and highly significantly different between of year on the 1000 grain weight and test weight. Effect of fertilization on the grain yield and 1000 grain weight were highly significantly.

Seed yield significantly and positively correlated with 1000 grain weight both in 2008/09 and 2009/10 ($r=0.40^{*}$ and $r=0.38^{*}$, respectively). Negatively and strong correlations were determined between 1000-grain weight and test weight in control and 2 treatment.

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Consecutively two years treated sewage sludge applications: effect on corn and second crop wheat yield and some soil properties of sandy clay soil

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ABSTRACT
In this study, effect of consecutively two years treated sewage sludge (TSS) applications on corn and second crop wheat yield and some soil properties of sandy clay soil (Typic Xerortent) were investigated. The field study was conducted in 20 plots in a randomized-block design with four replications and five different applications including control, mineral fertilizer, treated sewage sludge 12.5 $Mg.ha^{-1}$, 25.0 $Mg.ha^{-1}$, 37.5 $Mg.ha^{-1}$ as dry matter during 2011-2012 in Menemen-İzmir, Turkey. Corn (*Zea mays* L. var. ZP 737) and wheat (*Triticum durum* L. var. Ege 88) were sown as the first and second crop respectively. During the experiment, soil samples were taken five times in two years. Consecutively two years increasing TSS applications to sandy clay soil resulted in significantly increased total biomass and grain yield of corn according to the control. The highest grain yield of wheat as second crop was found with the highest TSS application. Increasing treated sewage sludge aplications were significiantly increased total N, plant available P and K, total salt, $CaCO_3$, OM content and CEC of sandy clay soil as average of 5 sampling periods. However, It was found that, there is no statistical relationship between TSS levels and pH values of soil samples of 1st, 2nd, 3th and 5th periods when compared with the control. It can be recommended that 37.5 $Mg.ha^{-1}$ TSS as dry matter can be added for improving plant nutrients and soil properties of sandy clay soil under Mediterranean climate, which are characterized by low OM content and high pH.
KEY WORDS: corn, sandy clay soil, sewage sludge, soil properties, wheat.

INTRODUCTION
Agricultural recycling of organic wastes is an interesting solution since it enables a reduction of the quantities of mineral fertilizers applied and an improvement of organic matter (OM) content of soil. Treated Sewage Sludge (TSS) is an ultimate product of municipal wastewater treatment plant and highly enriched in OM. Sewage sludge as an uncalled for product of wastewater treatment proses the challenge to society of disposing of it, but at the same time gives us the opportunity of beneficial use by closing the cycle of nutrients: sludge derived from agricultural activity must return to soil if a sustainable and ecologically sound management of these materials is desirable (Sequi et al. 2000). At present the major ways of disposing of sewage sludges are deposition, landfill and incineration, only part of the sludges are used in agriculture. Where sludge is to be used on land, it is usually stabilised by mesophilic anaerobic digestion, or aerobic digestion and then treated with polymers and mechanically dewatered using filter presses, vacuum filters or centrifuges. Other treatment processes for sludge going to land include long-term storage, conditioning with lime, thermal drying and composting. As municipalities upgrade waste water treatment systems and public opinion and legislation discourages disposal of organic materials in landfills, biosolids are projected to become increasingly available for agricultural use. Organic materials can differ considerably in terms of the extent to which they increase soil organic matter contents and alter soil physical and chemical properties (Barker et al. 2000). Sewage sludge may contain significant amounts of N, P and trace elements. The use of sewage sludge has been recommended to improve the chemical and physical properties of soil (Wong and Su 1997; Debosz et al. 2002). The beneficial effects of using sludge on agricultural soils have been proven by numerous researchers (Wong and Su 1997; Aggelides and Londra 2000; Benitez et al. 2001; Selivanovskaya et al. 2001; Debosz et al. 2002). The use of biosolids as agricultural soil amendments and fertiliser replacements is also relatively well researched (Cogger et al. 2004; Correˆa 2004; Tarraso´n et al. 2008; Delibacak et al. 2009a), and fertiliser advice is available for these materials (Defra 2010). TSS contains macronutrients, trace elements and heavy metals. These attributes potentially make TSS an excellent fertilizer at very low cost for agricultural land in Turkey which is generally rich in lime, low in OM. However, special care should be taken with respect to micronutrients and heavy metals so as not to introduce excessive amounts of these elements, which could have an adverse effect on the environment, especially when soil is acidic

(Delibacak et al. 2009a; Mercik et al. 2003, Pascual et al. 2004). The purpose of this work has been to evaluate the effect of consecutively two years municipal TSS doses applications on the corn and second crop wheat yield and N, P, K content and some soil properties of sandy clay soil during five different periods in two years.

MATERIAL and METHOD

Experimental site

The experiment was conducted at the research field of Aegean Agricultural Research Institute in Menemen plain, Izmir, Turkey (38°56′87.96″-38°56′91.02″N; 27°03′57.52″-27°03′58.61″E) (Figure 1). The experimental site is in the Western Anatolia region of Turkey, where the Mediterranean climate prevails with a long-term mean annual temperature of 16.8 °C. Long-term mean annual precipitation is 542 mm, representing about 75% of rainfalls during the winter and spring, and the mean relative humidity is 57%. Long-term mean annual potential evapotranspiration is 1,570 mm (IARTC, 2012). The investigated soil is characterized by sandy clay texture with slightly alkaline reaction and classified as a Typic Xerortent (Soil Survey Staff, 2006). Some selected properties and total heavy metal concentrations in the experimental soil and TSS used in the experiment are given in Table 1 and 2.

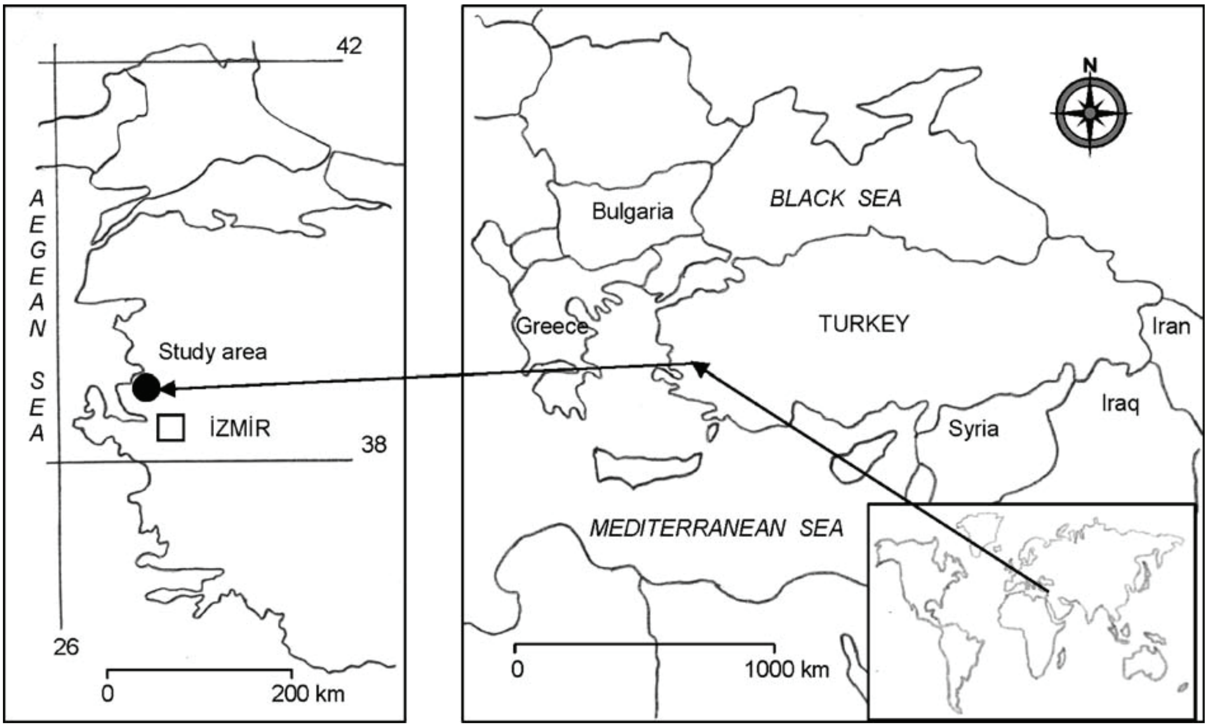

Figure 1. Location of study area

Table 1

Some selected properties of experimental soil.

Sand	(%)	43,84	pH	(Saturation paste)	7.71
Silt	(%)	16.44	Pb[1]	mg/kg	16.40
Clay	(%)	39.72	Cu[1]	mg/kg	17.28
Texture		Sandy clay	Zn[1]	mg/kg	46.10
Salt	(%)	0.165	Cd[1]	mg/kg	0.76
$CaCO_3$	(%)	0.63	Cr[1]	mg/kg	15.00
Org. matter	(%)	1,53	Ni[1]	mg/kg	24.68

[1]: Total

Table 2
Some selected properties and total heavy metal concentrations of treated sewage sludge used in the experiment.

EC	dS/m	16,35	Fe[1]	%	1,14
$CaCO_3$	(%)	10,24	Cu[1]	mg/kg	268,8
Org. matter	(%)	70,32	Zn[1]	mg/kg	1335
Org. C	(%)	40,79	Mn[1]	mg/kg	298,6
N[1]	(%)	5,33	B[1]	mg/kg	035,2
P[1]	(%)	1,33	Co[1]	mg/kg	014,2
K[1]	(%)	0,68	Cd[1]	mg/kg	004,1
Ca[1]	(%)	3,74	Cr[1]	mg/kg	250,6
Mg[1]	(%)	0,68	Ni[1]	mg/kg	115,4
Na[1]	(%)	0,59	Pb[1]	mg/kg	199,4

[1]Total

Field experiment
The field study was conducted in 20 plots in a randomized-block design with four replications, during 2011-2012. The plot dimensions were 3 m width and 3 m length. The TSS used in the experiment was obtained from the wastewater treatment plant of Metropolitan Region, Izmir city. It may produce around 600 t (moist basis) sewage sludge per day. Calcium oxide was added to raise the efficiency of the dewatering process of sewage sludge. In addition, the SS produced presented a pH varying between 10 and 13, what increased the pathogen control and decreased the heavy metal availability by added calcium oxide. TSS was added to the experimental soil under investigation at the rates of 12.5 t.ha^{-1}; 25.0 t. ha^{-1}; 37.5 t.ha^{-1} as dry matter on July 14, 2011. Also 150 kg N, 150 kg P_2O_5, 150 kg K_2O ha^{-1} (1000 kg ha^{-1} 15.15.15. composed fertilizer) were applied to the only mineral fertilizer plots at the same time and mixed with soil to 15 cm depth. Corn grains were sown with seeding machine on rows 18 cm and in rows 70 cm apart. Drip irrigation was provided when required. Harvest of corn was done manually on November 17, 2011. Wheat grains were sown with seeding machine on November 22, 2011 to 5 cm of soil depth as second crop. Also 80 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} (400 kg ha^{-1} 20:20:0. composed fertilizer) were applied only to the mineral fertilizer plots at the same time and mixed with soil to 15 cm depth before wheat seeding. Wheat was harvested with machine on July 10, 2012. Second year, again TSS was added to the experimental soil under investigation at the rates of 12.5 t.ha^{-1}; 25.0 t. ha^{-1}; 37.5 t.ha^{-1} as dry matter on July 14, 2012. Also 150 kg N, 150 kg P_2O_5, 150 kg K_2O ha^{-1} (1000 kg ha^{-1} 15.15.15. composed fertilizer) were applied to the only mineral fertilizer plots at the same time and mixed with soil to 15 cm depth. Corn grains were sown with seeding machine on July 18, 2012. Harvest of second year's corn was done by hands on November 1, 2012.

Soil sampling and analyses
During the experiment, soil samples were taken from the center of each plot in five different periods (1st, August 11, 2011-3 weeks after sowing of corn; 2nd, November 17, 2011-after corn harvest; 3rd, July 11, 2012-after wheat harvest; 4th, August 7, 2012-3 weeks after sowing of second year corn; 5th, November 1, 2012- after corn harvest of second year). The samples were air-dried and sieved using 2-mm sieve. All analysis were done in these sieved soils. Particle size distribution of experimental soil was determined by the Bouyoucos hydrometer method (Bouyoucos 1962). Total salt, OM concentration, $CaCO_3$, pH, total P, K, Ca, Mg, Na, Fe, Cu, Mn, Zn, Cd, Cr, Co, Ni, Pb and B concentrations of TSS were all determined according to Page et al. (1982). Some properties (total salt, OM concentration, $CaCO_3$, pH) of the soil were also determined according to Page et al. (1982). Cation exchange capacity (CEC) of experimental soil was determined according to Chapman (1965). Total N content of soil and TSS were determined using a modified Kjeldahl method (Bremner 1965). Available P in soil was determined by the Mo blue method in $NaHCO_3$ extract (Olsen et al., 1954). Available Available Ca, Mg, K and Na were analyzed with 1N NH_4OAc extract method. Ca, K and Na were determined by flame emission spectrometry and Mg was determined by flame atomic absorption spectrometry (AAS) (Kacar 1994). Fe, Mn, Zn and Cu were extracted using DTPA (diethylene triamine pentaacetic acid) solution (Lindsay and Norwell 1978). The concentrations of these elements in the extracts were determined by AAS (AOAC 1990).

Statistical analysis
Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 17 (SPSS 17.0 2008). Tukey test was used to find if differences in the treatments were significant at P≤0.01 or P≤0.05 (Steel and Torrie, 1980).

RESULTS and DISCUSSION

Influence of TSS applications on yield of corn and second crop wheat grown in sandy clay soil

Influence of TSS applications on total biomass and grain yield of corn grown in sandy clay soil are given in Table 3 and Table 4, respectively. The increasing TSS rates significantly increased 1st and 2nd year and average of total biomass and grain yield of corn in the experiment. Antolı´n et al. (2005) stated that the yield of barley increased in sludge and mineral amended plots in comparison to unamended plots. This increased grain yield was primarily due to increased ear number per unit of area. The higher yields in sludge-treated crops are usually attributed to an improvement in the soil conditions, by the supply of additional C from the sludge (Navas et al. 1998; Christie et al. 2001). The highest grain yield of wheat as second crop was found with the highest TSS application. Hernandez et al. (1991), Jamil et al. (2004), Jamil et al. (2006) and Tamrabet et al. (2009) reported that sewage sludge increased the grain yield and straw production of wheat. They mentioned that the maximum yields in both grain and straw were obtained at 40 Mg ha^{-1} of sewage sludge application. Al-Mustafa et al. (1995), Singh and Singh (1999), Al Zoubi et al. (2008) and Ailincăi et al. (2010) also mentioned highest increase in the grain and straw yield of wheat treated with sewage sludge.

Table 3

Influence of treated sewage sludge (TSS) applications on total biomass yield of corn grown in sandy clay soil (Tukey: P≤ 0,01: P≤ 0,05)

Applications	Average of 1st and 2nd. year yield (Mg.ha^{-1})	1st year yield (Mg.ha^{-1})		2nd year yield (Mg.ha^{-1})		
Control	31.65 c[1]	34.45 c	A[2]	28.85 b	A	
Fertilizer	33.61 c	36.83 c	A	30.38 b	B	*
12.5 Mg.ha^{-1}TSS	37.87 bc	44.54 bc	A	31.20 ab	B	**
25.0 Mg.ha^{-1}TSS	46.44 ab	56.00 ab	A	36.87 ab	B	**
37.5 Mg.ha^{-1}TSS	49.08 a	58.83 a	A	39.33 a	B	**
	**	**		**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for years.

Table 4

Influence of treated sewage sludge (TSS) applications on grain yield of corn grown in sandy clay soil (Tukey: P≤ 0,01: P≤ 0,05)

Applications	Average of 1st and 2nd. year yield (Mg.ha^{-1})	1st year yield (Mg.ha^{-1})		2nd year yield (Mg.ha^{-1})		
Control	3.31 b[1]	3.66 c	A[2]	2.95 b	A	
Fertilizer	4.81 b	6.33 bc	A	3.28 b	B	*
12.5 Mg.ha^{-1}TSS	5.24 b	6.52 b	A	2.96 ab	B	*
25.0 Mg.ha^{-1}TSS	7.60 a	8.73 ab	A	6.48 a	B	*
37.5 Mg.ha^{-1}TSS	8.68 a	11.04 a	A	6.33 a	B	**
	**	**		**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for years.

Influence of TSS applications on grain yield of second crop wheat grown in sandy clay soil are given in Table 5.

Table 5

Influence of treated sewage sludge (TSS) applications on grain yield of second crop wheat grown in sandy clay soil (Tukey: P≤ 0,05)

Applications	Control	Fertilizer	12.5 Mg.ha^{-1}TSS	25.0 Mg.ha^{-1}TSS	37.5 Mg.ha^{-1}TSS
Grain yield of second crop wheat (Mg.ha^{-1})	1.161 b[1]	1.888 ab	1.697 ab	1.961 ab	2.233 a

[1]Significant differences between treatments at * P≤ 0,05 level indicated by different letters.

Influence of TSS applications on total N, plant available P and K content of sandy clay soil

Influence of TSS applications on total N content of sandy clay soil is given in Table 6.

Table 6
Influence of treated sewage sludge (TSS) applications on total N content of sandy clay soil
Total N (%) Tukey:P≤ 0,01

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	0.076 c[1]	0.108 b	A[2]	0.080 b	AB	0.081 a	AB	0.068 d	AB	0.042 b	B	**
Fertilizer	0.091 bc	0.118 b	A	0.090 b	A	0.092 a	A	0.113 bc	A	0.044 b	B	**
12.5 Mg.ha^{-1}TSS	0.094 bc	0.118 b	A	0.109 b	A	0.091 a	A	0.101 cd	A	0.050 ab	B	**
25.0 Mg.ha^{-1}TSS	0.113 b	0.146 b	A	0.119 ab	AB	0.095 a	BC	0.143 ab	A	0.062 ab	C	**
37.5 Mg.ha^{-1}TSS	0.147 a	0.222 a	A	0.153 a	B	0.106 a	C	0.164 a	B	0.089 a	C	**
	**	**		**				**		**		

Significant differences between treatments at ** P≤ 0,01 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

The increasing TSS rates significantly increased total N concentration of the average of 5 sampling periods of soil compared with the control. Total N concentration in the soil decreased particularly in the 3th and last (5th) period because of the plant uptake of N in soil. 4th period's total N concentrations of soil samples were increased by second year application of TSS. Brofas et al. (2000) stated that N concentration increased with sludge applications. Bozkurt and Cimrin (2003) determined that sewage sludge applications increased the total N concentration about five-fold at the highest sludge rate. White et al. (1997) found that N mineralization potentials were significantly higher at high sludge rates. Magdoff and Amadon (1980) estimated that 55% of organic N in sludge incorporated in soil was mineralized during the first year. Under optimum laboratory conditions at a temperature of 35 °C, 55 to 95% of the organic N was mineralized in a 24-week period. The rate of mineralization is a function of the amount of the sludge added to soil. A good N balance is a critical factor in any land application program. Over application of N can result in groundwater contamination. Under application can lead to less than optimum crop yields and consequently to farmer dissatisfaction. It is important that sufficient sludge is applied to obtain optimum crop response without excessive NO_3-leaching. Further investigation is needed to develop more precise methods for balancing N from different sludge types and for varying soil conditions.

Influence of TSS applications on plant available P content of sandy clay soil is given in Table 7.

Table 7
Influence of treated sewage sludge (TSS) applications on plant available (extractable with $NaHCO_3$) P content of sandy clay soil
Available P (mg.kg^{-1}) Tukey:P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	32.38 d[1]	45.87 d	A[2]	26.40 c	B	32.79 c	AB	32.21 d	AB	24.64 d	B	*
Fertilizer	53.89 c	75.27 c	A	33.30 c	C	57.16 ab	AB	59.32 c	AB	44.39 cd	BC	**
12.5 Mg.ha^{-1}TSS	59.22 c	75.21 c	A	54.75 b	AB	44.00 bc	B	68.05 c	A	54.09 c	AB	**
25.0 Mg.ha^{-1}TSS	80.31 b	108.49 b	A	61.55 b	C	55.07 ab	C	93.13 b	AB	83.31 b	B	**
37.5 Mg.ha^{-1}TSS	111.97 a	156.18 a	A	102.71 a	B	75.32 a	C	119.97 a	B	105.69 a	B	**
	**	**		**		**		**		**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Applications of increasing TSS rates significantly increased the plant available P concentrations of soil in 5 different soil sampling periods according to the control. In the course of time, depending on decomposition of OM and using of plant available P in soil by produced plants, the effect of TSS rates on plant available P concentrations in soil decreased especially in the 3th and last (5th) period. 4th period's plant available P concentrations of soil samples were increased by second year application of TSS. White et al. (1997) and Brofas et al. (2000) also reported a remarkable increase in plant available P in soil after the application of sewage sludge. Another study showed that P concentrations increased more than six-fold from control to the highest application rate plots (Sullivan et al. 2006).

Influence of TSS applications on plant available K content of sandy clay soil is given in Table 8.

Table 8
Influence of treated sewage sludge (TSS) applications on plant available K content of sandy clay soil
Available K (mg.kg^{-1}) Tukey:P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	170.07 c[1]	174.84 c	A[2]	168.11 a	A	165.82 a	A	172.55 b	A	169.01 b	A	
Fertilizer	204.65 ab	235.45 b	A	202.23 a	AB	186.30 a	B	218.02 ab	AB	181.46 ab	B	*
12.5 Mg.ha^{-1}TSS	183.31 bc	184.16 bc	A	172.99 a	A	170.96 a	A	204.51 ab	A	183.91 ab	A	
25.0 Mg.ha^{-1}TSS	203.95 ab	228.46 bc	A	185.17 a	AB	169.46 a	B	223.56 ab	AB	213.10 ab	AB	**
37.5 Mg.ha^{-1}TSS	224.48 a	298.40 a	A	192.92 a	BC	174.29 a	C	240.79 a	B	215.98 a	BC	**
	**	**						**		**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Increasing TSS rates significantly increased available K concentration of the average of 5 sampling periods of soil compared with the control. Delibacak et al. (2009a) found that, plant available K increased with TSS rates from 340 mg kg^{-1} in the control plots to 419 mg kg^{-1} with the 90 Mg ha^{-1} application rate. On the other hand, Martı´nez et al. (2003) noted that, plant available K concentrations in soil were low and did not increase significantly with biosolid treatments compared with the control.

Influence of TSS applications on some properties of sandy clay soil
Influence of TSS applications on pH of sandy clay soil is given in Table 9. It was found that, there is no statistical relationship between TSS levels and pH values of soil samples of 1st, 2nd, 3th and 5th periods when compared with the control. pH values of experimental soil is higher than 7. It is recommended that soil pH should be maintained above 6.5 for sludge amended soils (Henning et al. 2001). Smith (1994) noted that optimal pH value for growth of the majority of plants was between 6.5 and 7.0. The soil pH is also one of the major factors controlling the availability of heavy metals.

Table 9
Influence of treated sewage sludge (TSS) applications on pH of sandy clay soil
pH Tukey: P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	7.57 ab[1]	7.76 a	A[2]	7.71 a	A	7.23 a	B	7.49 ab	AB	7.65 a	A	**
Fertilizer	7.37 b	7.48 a	ABC	7.53 a	A	7.18 a	BC	7.17 b	C	7.50 a	AB	*
12.5 Mg.ha^{-1}TSS	7.58 a	7.54 a	AB	7.85 a	A	7.31 a	B	7.53 a	AB	7.67 a	AB	**
25.0 Mg.ha^{-1}TSS	7.57 ab	7.58 a	A	7.73 a	A	7.41 a	A	7.44 ab	A	7.69 a	A	
37.5 Mg.ha^{-1}TSS	7.56 ab	7.47 a	B	7.82 a	A	7.43 a	B	7.45 ab	B	7.64 a	AB	*
	*							*				

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Influence of TSS applications on total salt content of sandy clay soil is given in Table 10.

Table 10
Influence of treated sewage sludge (TSS) applications on total salt content of sandy clay soil
Total salt (%) Tukey:P≤ 0,01

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	0.131 c[1]	0.139 c	AB[2]	0.109 a	AB	0.079 a	B	0.170 c	A	0.156 c	A	**
Fertilizer	0.161 c	0.160 bc	AB	0.106 a	B	0.093 a	B	0.228 c	A	0.220 c	A	**
12.5 Mg.ha^{-1}TSS	0.170 c	0.173 bc	AB	0.126 a	B	0.089 a	B	0.244 c	A	0.220 c	A	**
25.0 Mg.ha^{-1}TSS	0.232 b	0.240 ab	B	0.129 a	C	0.090 a	C	0.336 b	A	0.364 b	A	**
37.5 Mg.ha^{-1}TSS	0.299 a	0.305 a	B	0.173 a	C	0.089 a	C	0.463 a	A	0.465 a	A	**
	**	**						**		**		

Significant differences between treatments at ** P≤ 0,01 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

The increasing TSS rates significantly increased total salt concentration of the average of 5 sampling periods of soil compared with the control. The highest total salt was found with the highest

(37.5 $Mg.ha^{-1}$) TSS level. Mineralization of organic materials increases soil total salt content. But, by the time mineral matters taken by plants as plant nutrients and salt level of soil dicreased.

Influence of TSS applications on $CaCO_3$ content of sandy clay soil is given in Table 11.

Table 11

Influence of treated sewage sludge (TSS) applications on $CaCO_3$ content of sandy clay soil

$CaCO_3$ (%) Tukey:P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	0.62 c[1]	0.52 b	AB[2]	0.51 b	B	0.71 a	A	0.72 b	A	0.65 b	AB	**
Fertilizer	0.64 c	0.54 ab	A	0.62 ab	A	0.74 a	A	0.68 b	A	0.64 b	A	
12.5 $Mg.ha^{-1}$TSS	0.71 bc	0.53 ab	B	0.71 ab	AB	0.77 a	A	0.83 ab	A	0.72 ab	AB	**
25.0 $Mg.ha^{-1}$TSS	0.79 ab	0.70 ab	A	0.71 a	A	0.82 a	A	0.89 ab	A	0.84 ab	A	
37.5 $Mg.ha^{-1}$TSS	0.85 a	0.77 a	AB	0.74 a	B	0.87 a	AB	0.96 a	A	0.93 a	AB	*
	**	**		*				*		**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

The increasing TSS rates significantly increased $CaCO_3$ content of the average of 5 sampling periods of soil compared with the control. It can be said that High $CaCO_3$ content of TSS (10.24%) increased $CaCO_3$ content of soil.

Influence of TSS applications on CEC of sandy clay soil is given in Table 12.

Table 12

Influence of treated sewage sludge (TSS) applications on cation exchange capacity (CEC) of sandy clay soil

CEC (meq/100g) Tukey: P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods									
		1		2		3		4		5	
Control	24.79 b[1]	25.27 a	A[2]	25.453 a	A	23.91 a	A	24.76 ab	A	24.57 ab	A
Fertilizer	24.80 b	25.18 a	A	25.85 a	A	24.36 a	A	24.26 b	A	24.37 b	A
12.5 $Mg.ha^{-1}$TSS	25.70 ab	25.54 a	A	26.44 a	A	25.02 a	A	25.41 ab	A	26.07 ab	A
25.0 $Mg.ha^{-1}$TSS	26.23 ab	26.17 a	A	26.81 a	A	25.49 a	A	26.11 ab	A	26.57 ab	A
37.5 $Mg.ha^{-1}$TSS	26.75 a	26.76 a	A	27.08 a	A	26.15 a	A	27.01 a	A	26.72 a	A
	**							*		*	

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

It was found that, increasing TSS rates significantly increased CEC of the average of 5 sampling periods of soil compared with the control. Ahmed et al. (2010) determined that use of sewage sludge in soil showed higher nitrogen and phosphorus contents than the control soil, but a similar content of CEC. On the other hand, Alcantara et al. (2009) observed that the concentrations of phosphorus, nitrogen, sulfate, and CEC, organic carbon were positively correlated with sewage sludge dose applied to the soil.

Influence of TSS applications on organic matter content of sandy clay soil is given in Table 13.

Treatments of increasing TSS levels significantly increased OM content of soil samples all periods and average of 5 periods except for 3th period. In the course of time, depending on decomposition of OM in soil, the effect of TSS levels on OM concentration in soil decreased especially in the 3th period. Because of second year application of TSS, OM content of soil samples increased again in 4th and 5th periods. Analogously to our study, Delibacak et al. (2009b) found out an increase in the concentrations of OM in soil caused by increasing doses of sewage sludge introduced to soil.

Table 13
Influence of treated sewage sludge (TSS) applications on organic matter (OM) content of sandy clay soil
OM (%) Tukey: P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	1.362 b[1]	1.54 b	A[2]	1.43 b	A	1.32 a	A	1.32 b	A	1.18 b	A	
Fertilizer	1.343 b	1.54 b	A	1.41 b	A	1.26 a	A	1.31 b	A	1.17 b	A	
12.5 $Mg.ha^{-1}$TSS	1.628 bc	1.85 bc	A	1.80 ab	AB	1.41 a	AB	1.71 ab	AB	1.35 bc	B	*
25.0 $Mg.ha^{-1}$TSS	1.904 ab	2.26 ab	A	2.02 a	AB	1.52 a	B	1.93 a	AB	1.77 ab	AB	**
37.5 $Mg.ha^{-1}$TSS	2.145 a	2.79 a	A	2.12 a	B	1.70 a	B	2.18 a	B	1.91 a	B	**
	**	**		**				**		**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

CONCLUSIONS

Consecutively two years Increasing TSS applications to sandy clay soil resulted in significantly increased total biomass and grain yield of corn according to the control. The highest grain yield of wheat as second crop was found with the highest TSS application. Increasing treated sewage sludge aplications were significiantly increased total N, plant available P and K, total salt, $CaCO_3$, organic matter content and CEC of sandy clay soil as average of 5 sampling periods. However, It was found that, there is no statistical relationship between TSS levels and pH values of soil samples of 1st, 2nd, 3th and 5th periods when compared with the control. pH values of experimental soil is higher than 7. It can be recommended that 37.5 $Mg.ha^{-1}$ TSS as dry matter can be added for improving plant nutrients and soil properties of sandy clay soil under Mediterranean climate, which are characterized by low OM content and high pH. Sewage sludge application to agricultural land has been a widely accepted practice during recent years. Its use in agricultural land is promoted because it is considered that it will solve not only the problem of disposal but also will increase productivity in agriculture. Further investigations are necessary to quantify the fertiliser replacement value of plant nutrients. In particular, accurately characterising the P fertiliser replacement value of sewage sludge will become an increasingly important issue for effective P recycling in agricultural production and food security in future as geological P reserves are depleted and P fertiliser costs increase. At levels above the agronomic recommended rate, however, the potential for negative externalities may be quite substantial. Monitoring the soil periodically for nutrient levels would be prudent to avoid any excess levels on N or other plant nutrient. More continuous long-term experiments are needed to improve the understanding of the effects of sewage sludge on soil fertility and crop yield to contribute to the development of sustainable agricultural practices. However, negative effects of sewage sludge such as elevated heavy metal levels resulting from the usage of sewage sludge must also be taken into consideration. Sewage sludge containing pathogenic organisms should be handled and applied in a proper manner to reduce the risks to human and animal health. Finally, the application of TSS to soil must obey the limited regulations. After the analysis of sewage sludge and soil, a governmental permission is needed to apply them to agricultural lands in Turkey.

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Effect of nitrogen fertilization on soybean plant heigh in arid year

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ABSTRACT

Soybean (*Glycine max* (L.) Merr.) is the most important legume for food production. Soybeans, in Serbia, in the last years, are grown on 180,000 ha to 200,000 ha. Several-year-old soybean yields were about 2.5 kg ha^{-1}, in average. The year 2016 had the record yield of 3.5 kg ha^{-1}. Growth of soybean production was registered in Serbia, primarily due to increase of its production area and also because of its yield increase. High yields will be reduced when deficit in essential nutrients and precipitation are present. The aim of this investigation was to estimate the effect of seed inoculation and fertilization on plant height in soybean variety, in arid year.

In dry years, fertilization has a significant effect on increasing the soybean yield and mitigate the effects of drought. In tested year, for the production of soybean, it is recommended the use of 150 kg ha^{-1} of CAN, directly with the sowing, if it is not applied microbiological fertilizer - NS Nitragin, or use of 100 kg ha^{-1} of CAN, if it is inoculated with NS Nitragin before seeding.

KEY WORDS: soybean, pseudogley, morphological characteristic, NS Nitragin, CAN

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is the most important oilseed and livestock feed crop, which accounts for 58% of the total world oilseed production and 69% of protein meal which is consumed by livestock. According to the Food and Agricultural Organization data (FAO, 2015), soybean is cultivated worldwide, generating 276,406,003 tonnes, of which almost 30% is obtained in the United States of America. Worldwide, the economic value of soybean is 119,516 million US dollars, owing to the versatile use in many fields of industry. As well as making a contribution to the alleviation of some chronic diseases (Kahraman, 2017), soybeans is an essential source of dietary protein, oil and minerals for humans and animals.

Several challenges of soybean production need to be overcome for soybean production to sustain the predicted global population growth rate. The current yield increase rate is of 1.3%, but, required increase is around 2.4% for satisfaction of demands by 2050 (Ray et al., 2013; Rocha et al., 2015).

Soybeans in Serbia, was grown on 180,000 ha in 2016 (on 201,470 ha in 2015). Several-year-old soybean average grain yields in Serbia were 2.5 t ha^{-1}, and variation of 1.9 t ha^{-1} (2015) and 3.5 t ha $^{-1}$ in 2016, etc. Soybean crop, yielding 2.5 t seed, takes out from the soil, per hectare, about 125 kg nitrogen, 23 kg phosphorus, 101 kg potassium, 22 kg sulphur, 35 kg calcium, 19 kg magnesium, 192 g zinc, 866 g iron, 208 g manganese and 74 g copper per hectare from the soil (Tandan, 1989). Growth of soybean production was registered in Serbia, primarily due to increase of its production area and also because of its yield increase.

Nitrogen is one of the major nutrients that are required for soybean growth and development. Nitrogen is reported to promote the vegetative growth of plants and increase assimilation by making more available area for photosynthesis area (Bangar et al., 2000; Ghadir Mohammadi et al., 2015; Popović et al., 2011).

Nitrogen is the plant nutrient that is often most limiting to efficient and profitable crop production. At plants, inadequate supply of available N frequently results in plants that have slow growth, depressed protein levels, poor yield of low quality produce, and inefficient water use. Nitrogen-stressed plants often have greater disease susceptibility compared with properly nourished plants. However, excessive N can be detrimental for crop growth and quality, in addition to causing undesirable environmental impacts. Unlike other plant nutrients (like P and K), there is no universal or widely used soil test for prediction of the amount of supplemental N required to meet the crop's need. Instead, the need for N supplementation is typically based on yield expectations, field history, and measurement of residual NO^{3-}. Nutrients in commercial fertilizers are generally soluble, so their availability to plants is quite predictable. However, most organic N sources require mineralization (conversion to inorganic forms) before they can be used by plants. Environmental factors such as soil temperature, pH, moisture, and management practices such as tillage intensity all impact the rate of availability of N from organic sources (Mikkelsen and Hartz, 2008).

Soybean has a high demand for nitrogen due to high protein content in the seed (about 40% and about 15% N). Nitrogen is, in nature, a predominant ingredient of air (78%), and most organisms can not directly use it. Soybean as a legume is able to provide nitrogen through the process of N fixation, biological relationship between soybean and soil bacteria *Bradyrhizobim japonicum.* N fixation provides up to 75% of the total required nitrogen. Soybean plants assimilate a large amount of nitrogen (about 330 kg N ha^{-1} for a yield of 4 t ha^{-1}) during vegetation period, and the amount of N adopted in a plant adopted is highly correlated with the soybean seed yield (Ohyama et al., 2013; Popović et al., 2013, 2016a), as well as with the chemical composition of soybean grains (Salvagiotti et al., 2008, Đukić et al., 2010; Popović et al., 2013; 2016a). Soybean plants obtain nitrogen from three sources (Gai et al., 2016); (1) nitrogen derived from biological N_2 fixation by root nodule; (2) soybean`s requirenment for nitrogen can be fulfilled by soil nitrogen. High levels of nitrogen in soil inhibit symbiotic N_2 fixation and under these conditions, soil provides the majority of the plant's needs for nitrogen (Streeter, 1988). Conversely, N_2-fixation supplied the majority of the plant's requirements for nitrogen under conditions of low level of nitrogen in soil; and (3) nitrogen from applied fertilizer. For optimum soybean yield, it is necessary to use both biological N_2-fixation and apsorption of nitrogen uptake by soybean roots (Harper, 1974; 1987). Applying of nitrogen fertilizer in soybean crop is based on the plant nitrogen needs during seedling development prior to nodule formation that is crucial to the growth and development of soybean (Harper 1974; Hatfield et al. 1974). Hardy et al. (1971) reported that N_2-fixation began 14 days after planting only when soybean had cultivated under optimum temperature and moisture conditions, while a small amount of nitrogen fertilizer at planting might be beneficial for early vegetative growth. In the study by Bergersen (1958), it was pointed out that nitrogen applied before sowing was beneficial to soybean growth, given that soybean root nodules were not formed until at least 9 days after soybean emergence. Additionally, starter nitrogen fertilizer can supply plant with nitrogen until biological N_2-fixation begins by the root nodule (Touchton and Rickerl, 1986; Popović, 2010; Popović et al., 2013; 2016a).

High yields will be reduced when deficit in essential nutrients and precipitation are present. The aim of this investigation was to estimate the effect of seed inoculation and fertilization on plant height in soybean variety, in arid year.

MATERIAL and METHOD

Small plot field trial was carried out in order to investigate the influence of fertilizer calcium ammonium nitrate (CAN) on soybean plant height, at the site of Brčko, on pseudogley type of soil. Field experiments were conducted in arid year, using a randomized complete block design, with three replications. The main plot area was 10.8 m^2. The soybean variety Bačka, maturity group 0, was tested. Density of crops was the same for all variants and amounted to 500,000 plants per hectare. During experiment a standard technology for growing soybean was applied, (Stevanović et al., 2016; Popović et al., 2017) excluding studied factors. Sowing was done at beginning of April.

The following factors were examined:

(1) Fertilization: There were four variants of the applied doses of CAN:

- (a) 0 kg ha^{-1} – control;
- (b) 50 kg ha^{-1}
- (c) 100 kg ha^{-1}
- (d) 150 kg ha^{-1}

(2) Inoculation of the seed was:

- (a) with NS Nitragin
- (b) without NS Nitragin.

Researches were conducted with the aim to investigate the effect of nitrogen fertilization and NS Nitragin on the plant height of soybean. Just before sowing, according to the anticipated fertilization plan, the CAN fertilizer was applied and the seed was inoculated by microbiological biofertilizer - NS Nitragin. After 120 days growing under these conditions, the plants were analysed in terms of morphological characteristic of soybean, plant height of soybean. The results are processed by mathematic-statistical method of analysis of variance and evaluation of the difference by LSD test.

Soil properties

Soybean can be grown on a wide variety of well drained soils, but thrives best on a clay and loam soil type. Soybean prefers a slightly acid soil (pH 6.0-6.5). However, it grows quite well on calcined clay soils (pH 7.5) if the free lime level is not too high. Soybean is rated as a moderately salt-tolerant crop and the reported threshold of salinity threshold is about 5 dS m^{-1} (Qiu and Chang, 2010).

The experiment with soybean was carried out on a pseudogley soil, in Brčko (φ N 44°52′, λ E 18°49′, 98 m. s. l.), Bosnia and Hercegovina, Pic. 1. and 2. Soil at a depth of 30 cm was low in humus (2.88%), very acidic (pH in H_2O 4.30), low in carbonat soil (0.60 %, $CaCO_3$) and at medium level for Al–K_2O (15.00 mg/100 g soil) and P_2O_5 (24.50 mg/100 g soil), Popović et al., (2017). Dissolubility and accessibility of microelements in the soil is mostly influenced by pH reaction of soil, content of organic matter, mechanical composition of the soil (quantity of clay fraction), content of calcium carbonate and accessibility of phosphorus in the soil. Production value of pseudogley is small and on such soil of low production value, soybean can be successfully grown only with application of melioration measures along with adequate regime of fertilization which is compatible to the need of soybean on pseudogley (Glamoclija et al., 2015).

Picture 1. Locality in Brčko in Bosnia and Herzegovina

Picture 2. Soybean

Meteorological data of the experimental area

Soybean is classified as the warm-season crop it is cultivation now extends from the tropic to 52°. The major commercial production of soybean is between 25 ° N and 45° lantitude and altitudes of < 1000 m. Soybean is a temperature-sensitive crop and is usually grown in environments with temperatures between 10 ^{0}C and 40 ^{0}C during the growing season (Qui and Chang, 2010).

Soybean achieves the best production in monsoon climate, warm and humid climate, with high relative humidity (Popović at al., 2015a, 2015b). In our production conditions, at summer, occurrence of drought is frequent (Tatić et al., 2016, Vidić et al., 2016).

In this study, from the meteorological station of the Brčko, B&H, meteorological data for soybean growing period were obtained. The climatic data for the growing period in Brčko are shown in Figure 1. During the vegetation period (April - September) in arid year, there was total precipitation of 167 mm, and average temperature of 19.90 ^{0}C. Multi-year average for temperature was 17.60 ^{0}C and 438.3 mm for precipitation.

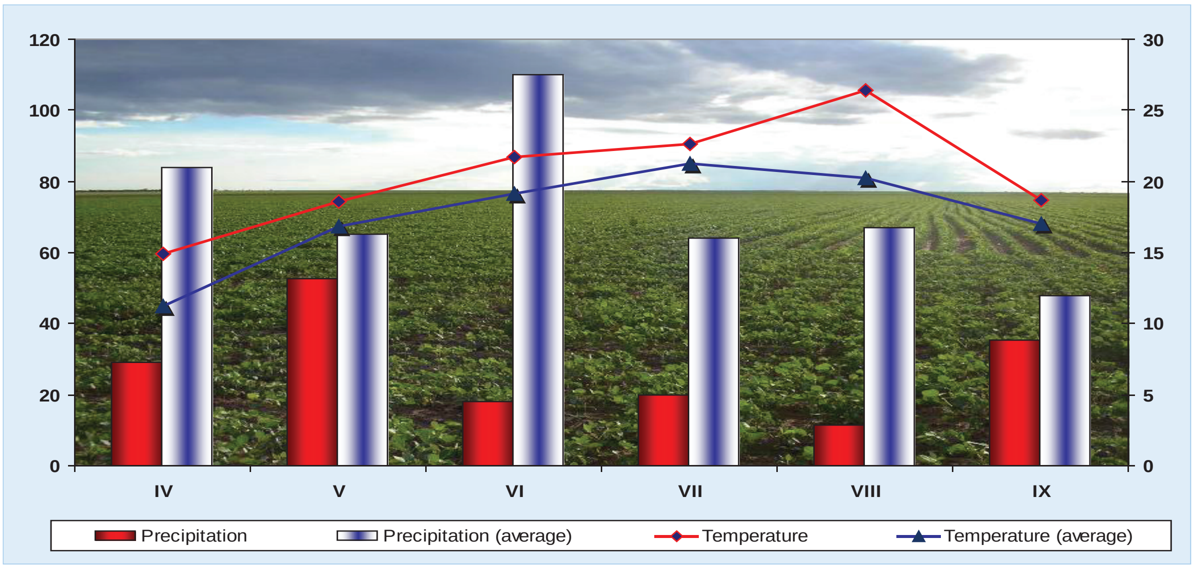

Figure 1 Meteorological data for vegetation period of soybean production

For successful production of soybeans is necessary that plants have enough moisture. The amount of precipitation needed for soybeans growth is 450 mm. The total amount of precipitation in tested year, in the vegetation period of soybean was 167 mm and it was less soybean need, which is 283 mm. In tested arid years, due to deficit of precipitation, a soybean yield was decrease.

RESULTS and DISCUSSION

The results showed that the use of fertilizers significantly increased height of soybean (P<0.05) plants in a dry year, Table 1.

Table 1
Effect of nitrogen fertilization and seed inoculation on soybean plant height (cm)

Fertilization of soybean, kg ha^{-1}	Seed inoculation				
	Without seed inoculation	With seed inoculation	$\overline{X}$	Std. Dev.	Std. Err.
Control, 0	50.81	53.51	52.16	1.54	0.63
50	54.93	55.00	54.97	0.40	0.17
100	54.00	**56.31**	**55.16**	1.31	0.53
150	**56.52**	51.67	54.10	2.68	1.09
Average	**54.07**	**54.12**	**54.09**	1.99	0.41
Std. Dev.	2.21	1.84	-	-	-
Std. Err	0.63	0.53	-	-	-

Parameter		CAN	NS Nitragin	CAN x NS Nitragin
LSD	0.5	0.527	0.372	0.745
	0.1	0.728	0.515	1.039

Use of fertilizer had a statistically significant effect on plants height while the inoculation of seed had no statistical significance. In variant with application of 150 kg ha^{-1} of CAN and without inoculation of seed and in the variant with 100 kg ha^{-1} of CAN and inoculation of seed with the microbiological biofertilizer NS Nitragin soybean plants height were larger than in other variants, Table 1 and 2, Figure 2.

Table 2
ANOVA for tested parameter

Effect	SS	Degr. of Freedom	MS	F	p
Intercept	70229.37	1	70229.37	379396.1	0.000000
NS Nitragin	0.02	1	0.2	0.1	0.747637
CAN	33.77	3	11.26	60.8	0.000000
NS Nitragin *CAN	54.16	3	18.05	97.5	0.000000
Error	2.96	16	0.19		

Table 3
Correlations coefficients for tested parameter

Variable	Plant height	CAN	NS Nitragin
Plant height	1.00	0.34	0.02
CAN	0.34	0.02	1.00

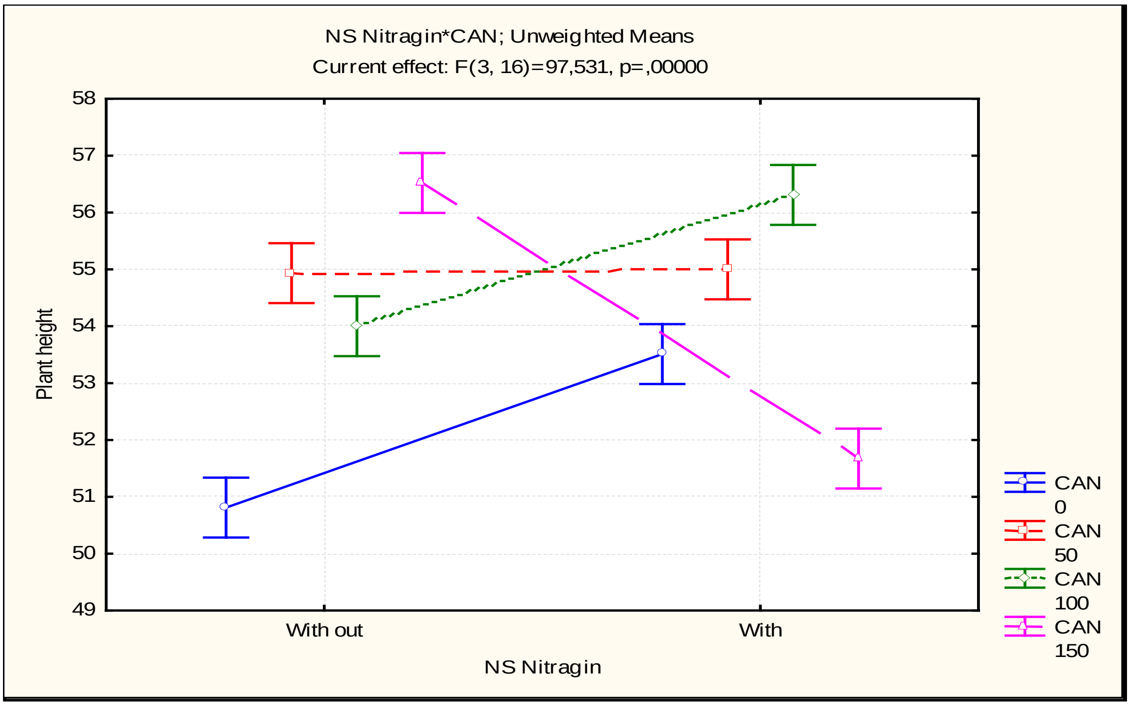

Figure 2 The influence seed applications of NS Nitragin of soybean plant height

Drought is a limiting factor for soybean production (Popović et al., 2015a; 2016a-c). In dry years, fertilization has a significant effect on increasing the soybean yield and mitigate the effects of drought. In tested year, for the production of soybean, it is recommended the use of 150 kg ha^{-1} of CAN, directly with the sowing, if it is not applied microbiological fertilizer - NS Nitragin, or use of 100 kg ha^{-1} of CAN, if it is inoculated with NS Nitragin before seeding, Figure 3.

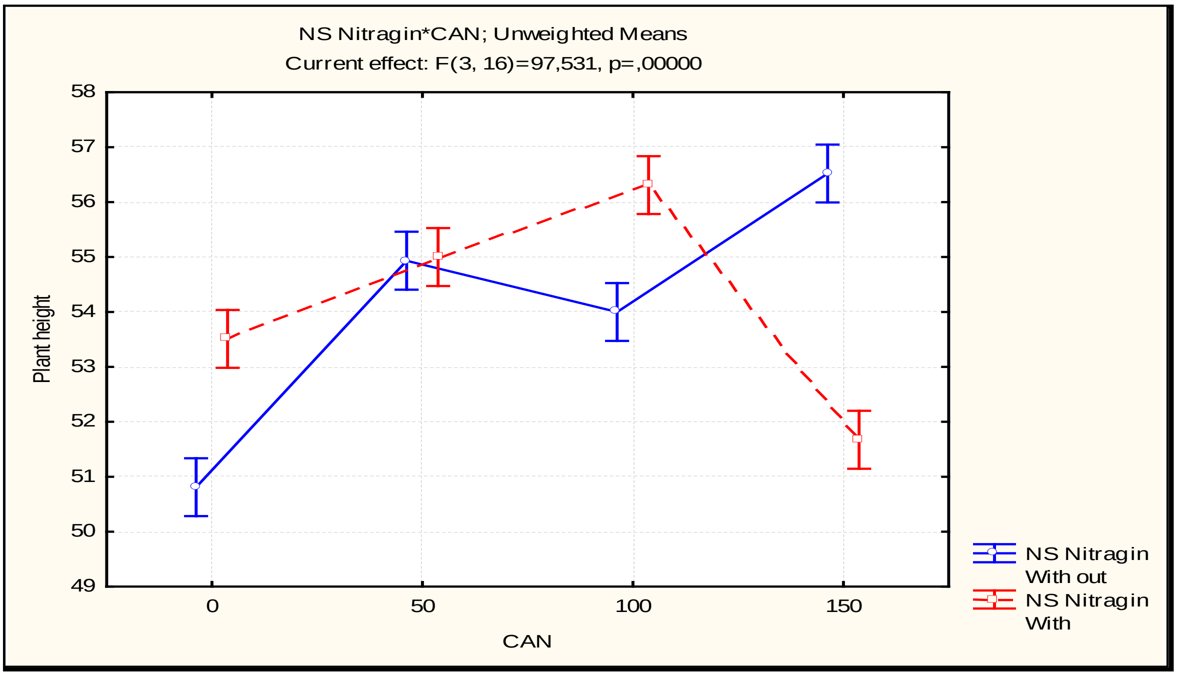

Figure 3 The influence of different scheme of CAN fertilizers applications of soybean plant height

Positive, nonsignificant correlation was achieved between plant height and applied amount of CAN fertilizer (r = 0.34), Table 3.

Table 3
Correlations coefficients for tested parameter

Variable	Plant height	CAN	NS Nitragin
Plant height	1.00	0.34	0.02
CAN	0.34	0.02	1.00

Previous studies dealing with this issues confirmed positive effect of fertilization on plant height. Soybean production is directly influenced by many environmental factors. Many researchers have extensively examined the effects of nitrogen fertilizer on soybean crops. Among these, nitrogen fertilization can affect on soybean growth and soybean grain yield (Popović, 2010; Đukić et al., 2010; Popović et al., 2012; 2013; 2014; Tatić et al., 2016). Nitrogen is one of the most important nutrients affecting soybean grain yield (Dong et al., 2010). Gai et al. (2017) in their research indicated that applying nitrogen as starter is necessary to increase soybean yield in Sangjiang River Plain in China. Muchow and Sinclair (1986) reported that nitrogen input was a “major constraint” to high soybean yield based on analysis of crop stimulation. Maximum grain yield was obtained at intermediate level of nitrogen application each year in our study. Results from this study proved that excessive or insufficient nitrogen fertilizer was not beneficial to an increase in grain yield of soybean, and intermediate level of starter nitrogen fertilization (N50) increased grain yield.

The research conducted by Starling et al. (1998) for soybean following corn in southern Alabama indicated that grain yield and plant growth were higher when nitrogen fertilizer was applied as starter. Furthermore, their study suggested that early application of starter nitrogen fertilizer had significant effects on soybean grain yield. In addition to soybean grain yield, starter fertilizer-N increased plant height and biomass.

The excessive use of these fertilizers results in adverse environmental effects, changes the ecological balance of the soil, and making plants even more susceptible to this abiotic and biotic stress. Nitrogen is an important biogenic element and and gives main contribution to high yield, but the nitrogen fertilizers are large polluters of soil and water (Glamočlija et al., 2015; Vasileva, 2014; 2017; Vasileva et. al., 2017; Maksimović et al., 2017) and long term use of large quantities of chemical fertilizers leads to a decline in crop yields and soil fertility. Therefore, it is necessary to conduct soil quality analyzes and to approach the proper application of nitrogenous nutrients. These studies are important because they give the answer about soybean need for nutrients, in the arid years, the soil pseudogley.

CONCLUSIONS

These studies give the answer about soybean need for nutrients, in the arid years, the soil pseudogley.

Applied nitrogen fertilizer CAN significantly affected tested parameter of soybean plant ($P<0.05$).

The use of fertilizer was statistically significant for soybean plants growth in a dry year, at pseudogley soil. Inoculation with seed the NS Nitragin, had not significant effect.

The highest plants height of soybean was in the variant with the application of 150 kg ha^{-1} of CAN and without inoculation of seed.

In the variant with 100 kg ha^{-1} of CAN and in inoculation of seed with microbiological biofertilizer NS Nitragin soybean plants were higher than in other variants.

Our results proved that, it is necessary to apply a 100 kg ha^{-1} of CAN before sowing seed on pseudogley soil.

Inoculation of soybean seed with the bio-fertilizer NS Nitragin and application of 100 kg of CAN before seeding is recommended.

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The influence of foliar treatment with selenium on nitrogen content in barley

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ABSTRACT

Under certain conditions to use foliar fertilizer is more economical and efficient than conventional methods due to the fact that foliar treatment can be the most effective for the correction of irregularities of mineral nutrition of plants. In conditions of drought and high salt content, the efficiency of foliar treatment is higher than the fertilizer into the soil. It is connected with the "delivery" of the necessary nutrients directly to the leaves and a relatively quick absorption (e.g. 0.5–2 h for nitrogen; 10-24 h for potassium), regardless of root activities and the presence of moisture in the soil. Foliar treatment of plants can be used to mitigate the deficit of macro - and micronutrients. It is known that the growth and development of plants is under the control of endogenous regulatory systems, among which are hormonal and trophic systems. Selenium is an important component of trophic system involved in the regulation of growth. Selenium acts as a stimulator of growth and nutrition for plants, improving their growth and yield and increasing the content of total nitrogen in grain, and has an antistress effect under conditions of low temperature and a few other unfavourable environmental factors.

Greenhouse pot experiments were carried out under natural conditions of the photoperiod, temperature, and illumination in the spring–summer period during several years in a greenhouse (Moscow State University). Spring barley (Hordeum vulgare L.) was grown on soddy-podzolic soil with different level of mineral nutrition under conditions of drought and a few other unfavourable environmental factors. We used natrium selenite with selenium concentrations of 0.01 and 0.05%.

All selenium concentrations using via leaves have a positive effect on the growth of the amount of total and protein nitrogen in the grain in conditions of normal level of plant nutrition (N100P100K100). A high dose of mineral fertilizers, N200P200K200 (0.05% Se), enhances the entry of the element into the grain, but has a negative effect on the formation of biomass and reduces the nitrogen content. The selected concentrations of selenium (0.01% and 0.05 %) caused a significant accumulation of this element in the grain, in the straw – two times less. Therefore, we can talk about physiological barriers that control the flow of Se in the productive organs of the plant but at high concentrations don't demonstrate such action. The analysis of amino acid composition of the samples explains the increase in non-protein nitrogen. In content of essential amino acids (threonine, valine, methionine, isoleucine, phenylalanine, histidine, arginine) were not observed significant changes. Under conditions of high level of NPK the protective properties of Se have been shown. They are represented in the synthesis of specific amino acids in the composition of enzymes (SeCys & SeMet) involved in the synthesis of secondary metabolites.

KEY WORDS: selenium; foliar treatment; plant nutrition; amino acids; protein nitrogen

INTRODUCTION

The foliar treatment with sodium selenite as the most effective procedure [1, 2] can be used to saturate the barley grain with this element relating to its deficiency in soddy-podzolic soils [3]. It is well known that selenium (Se) is a vital element for animals and humans, its deficiency or excess leads to multiple physiological abnormalities in the body [4]. The study of the role of selenium and its functions in the cultivation of barley in field and pot experiments allowed to establishing its effect on the absorption of nutrients and the relationship with nitrogen [5]. Nitrogen nutrition is largely considered as the main factor influencing the concentration of crude protein in plants. Moreover, its content in the grain depends on the timing and ways of nitrogen fertilizers usage (it increases if we use nitrogen closer to flowering, not during vegetation period) [6, 7]. The nutritional value of protein is associated mainly with its amino acid composition. The proteins of barley often found the lack of at least one of the essential amino acids. For example, in barley seeds often reduced the content of threonine, tryptophan and especially lysine [8]. Selenium can be an alternative element to sulphur for the formation of amino acids selenocysteine and selenomethionine in plants, especially under conditions of sulphur deficiency. The correlation between selenium and sulfur can be traced in the plant metabolism.

MATERIAL and METHOD

The greenhouse pot experiments were carried out at the Department of agrochemistry and plant biochemistry, Lomonosov Moscow state University at natural conditions of photoperiod, temperature and light. During the growing season field capacity 60 % was maintained, the temperature was higher than a multiyear average by 1 - 5^oC. Soddy-podzolic loamy soil was used with the following agrochemical characteristics: humus, % - 3,4; pH Kcl - 5,9; P_2O_5, mg/kg - 200; K_2O, mg/kg – 70; Se, µg/kg – 200. 175 - 200 µg/kg of selenium represents the upper bound marginal sufficiency, according to the assessment of the level of availability of soil selenium, proposed by and Tan J. [2]. Seeds of spring barley Raushan (Hordeum L.) were sown in 12 pieces on a vessel with the following thinned to six plants with 4 times frequency. Nutrients were added as aqueous salts - NH_4NO_3, KCl, $Ca(H_2PO_4)_2 \cdot H_2O$ with two doses (0,1 and 0,2 g active substance /kg).

Variants of experiment are:

$N_{100}P_{100}K_{100}$,
$N_{100}P_{100}K_{100}$ + 0,01 % Se;
$N_{100}P_{100}K_{100}$ + 0,05% Se;
$N_{200}P_{200}K_{200}$,
$N_{200}P_{200}K_{200}$ + 0,01 % Se;
$N_{200}P_{200}K_{200}$ + 0,05% Se.

On the 42nd day (the phase of of tillering completion) the plants were treated with a sodium selenite solution in 0.01 and 0.05 % concentrations of selenium by a hand spray (volume was 2.5 ml/vessel).

Total and protein nitrogen were determined by Kjeldahl method [9], selenium was determined by modified way of fluorometric analysis. The method is based on wet combustion with a mixture of nitrogen and perchloric acids, the recovery of Se^{+6} to Se^{+4} and condensation of selenous acid with 2.3-diaminonaphtalene with the formation of a fluorescent complex – piazoselenol. We used a Hitachi fluorimeter MPF-2A (Japan). The content of amino acids was determined at the amino acid analyzer L8800 Hitachi (Japan) [10]. Statistical processing of results was carried out using programs Statictica 6.0 module ANOVA.

RESULTS AND DISCUSSION

The formation of high level of nutrients in the soil in the experiment influenced the morphology of the emerging plants significantly. The weight of unproductive green mass in the phase of tillering increased in the variant $N_{200}P_{200}K_{200}$ in comparison with the variant $N_{100}P_{100}K_{100}$. In the result, the mass of straw increased from 8.4 to 11.6 g, and the grains mass decreased from 6.2 to 3.0 g (table. 1). The positive effect of selenium is manifested indirectly through the impact on the structure of barley. Grain weight increased by 40 % and straw weight decreased by 26% in variant $N_{200}P_{200}K_{200}$ + 0,05% Se.

Table 1

Weight of grain and straw under treatment with p selenium at different levels of mineral nutrition

Variants	Grain, g	Straw, g
N100P100K100	6,2	8,4
N100P100K100 + 0,01 % Se	5,9	8,8
N100P100K100 + 0,05% Se	6,0	7,6
N200P200K200	3,1	11,6
N200P200K200 + 0,01 % Se	3,6	10,3
N200P200K200 + 0,05% Se	4,3	8,6
LSD	0,98	1,96

Selenium accumulation in the grain is an important indicator in our studies. Its content was low in the control samples without treatment with sodium selenite. Considering that the maximum permissible level (MPL) in barley is 800 µg/kg [1], treatment with 0.05 % selenium leads to increased content in grain (4012 - 4091µg/kg). Without foliar treatments high background of mineral nutrients (N200P200K200) promotes greater intake of selenium in plants. In straw the concentration increases from 64 to 178 in average, in grain from 89 to 197 µg/kg. However, in case of sodium selenite treatments the effect, depending on the level of mineral nutrition (use of NPK) was not discovered. The selected concentrations of selenium (0.01% and 0.05 %) caused a significant accumulation of this element in the grain, in the straw – two times less. Therefore, we can talk about physiological barriers that control the flow of Se in the productive organs of the plant but at high concentrations don't demonstrate such action (see figure 1,2).

Significant changes in the barley crop and the concentration of selenium in plants were accompanied by significant changes in the accumulation of nitrogen in grain and straw. The percentage of total nitrogen depended on the level of nutrition (NPK level) and the doses of selenite concentrations used via leaves. The highest concentration of Se - 0.05% will be discussed further to track contrast changes. Treatment with selenium (0,05 %) showed a significant decrease in the content of total nitrogen in the straw by 11 % (N100P100K100 + 0.05% Se) and by 28 % (N200P200K200 + 0,05 % Se) compared to untreated variants. The content of selenium in the grain increases by 14 and 40%, respectively, at the same variants (figure 3,4).

The quantity of protein nitrogen does not change under the action of the selenium (its changes are connected only with the additional dose of NPK - N200P200K200). For this reason, the portion of protein nitrogen in the grain is reduced in variants with application of selenium (by 80 %), due to the increase of non protein nitrogen compounds.

The analysis of amino acid composition of the samples explains the increase in non-protein nitrogen (table 2). The amount of amino acids is increased by 1167 mg/100 g in the variant N100P100K100 + 0,05 % and by 844 mg/100 g in the variant N200P200K200 + 0,05 % in comparison with variants without selenium treatments. In content of essential amino acids (threonine, valine, methionine, isoleucine, phenylalanine, histidine, arginine) were not observed significant changes. However, there were significant decrease from 950,3 to 637,3 mg/100 g in the content of the deficient amino acid lysine in the variant with application of selenium at a high level of mineral nutrition (N200P200K200). This is accompanied by an increase in the content of glutamine from 2264 to 2748 and glycine from 426 to 556 mg/100 g (N100P100K100).

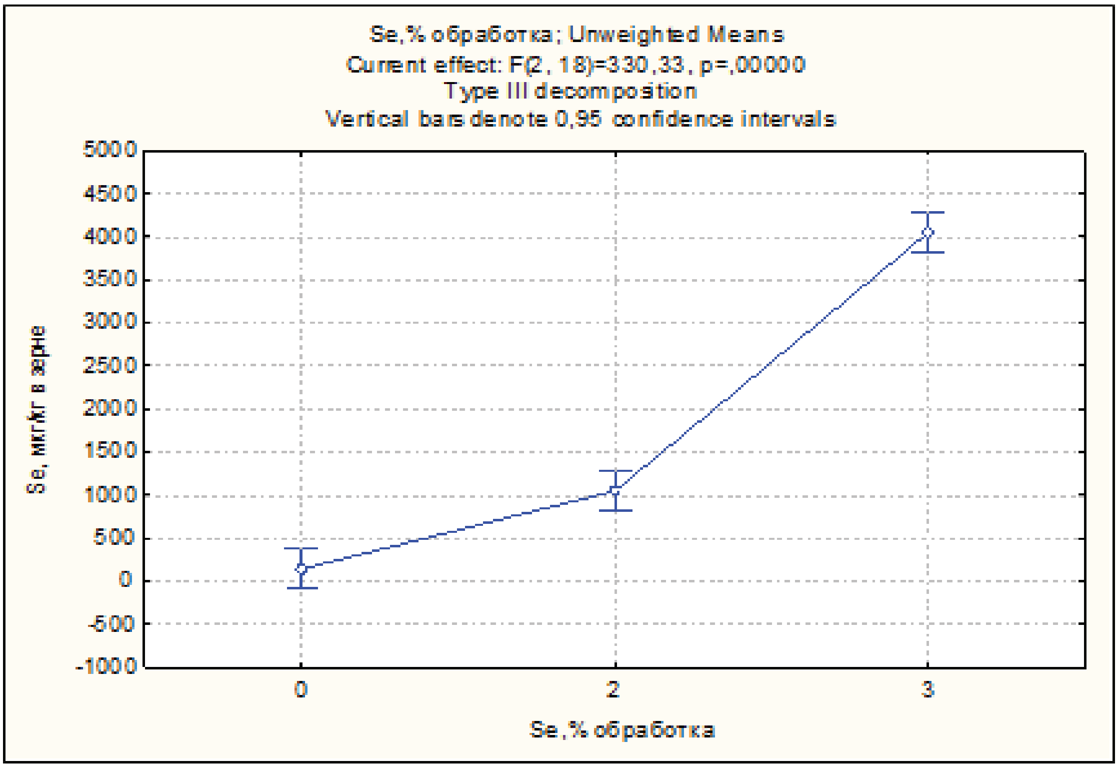

Figure 1. The changes of selenium content in grain depending on the doses of selenium taken for treatment (0 – 0%Se; 2 – 0,01%Se; 3 – 0.05% Se)

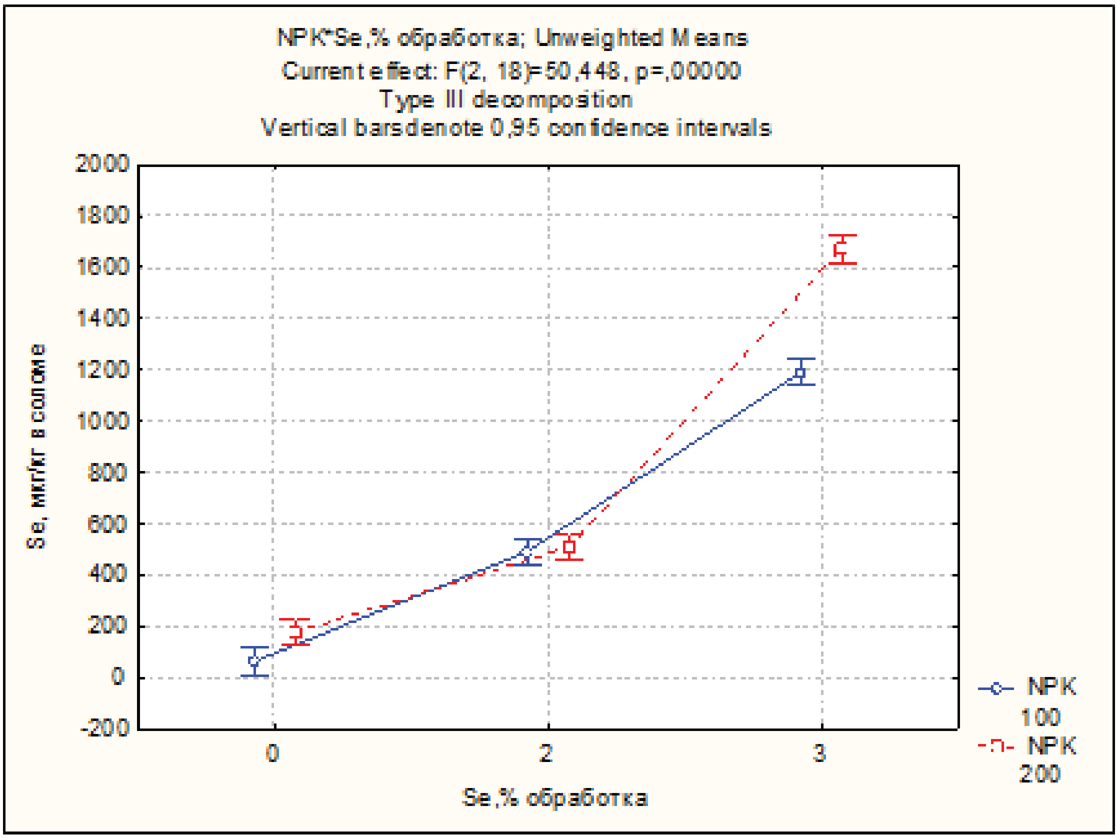

Figure 2. The changes of selenium content in straw, depending on the doses of selenium taken for treatment (0 – 0%Se; 2 – 0,01%Se; 3 – 0.05% Se) and the NPK level

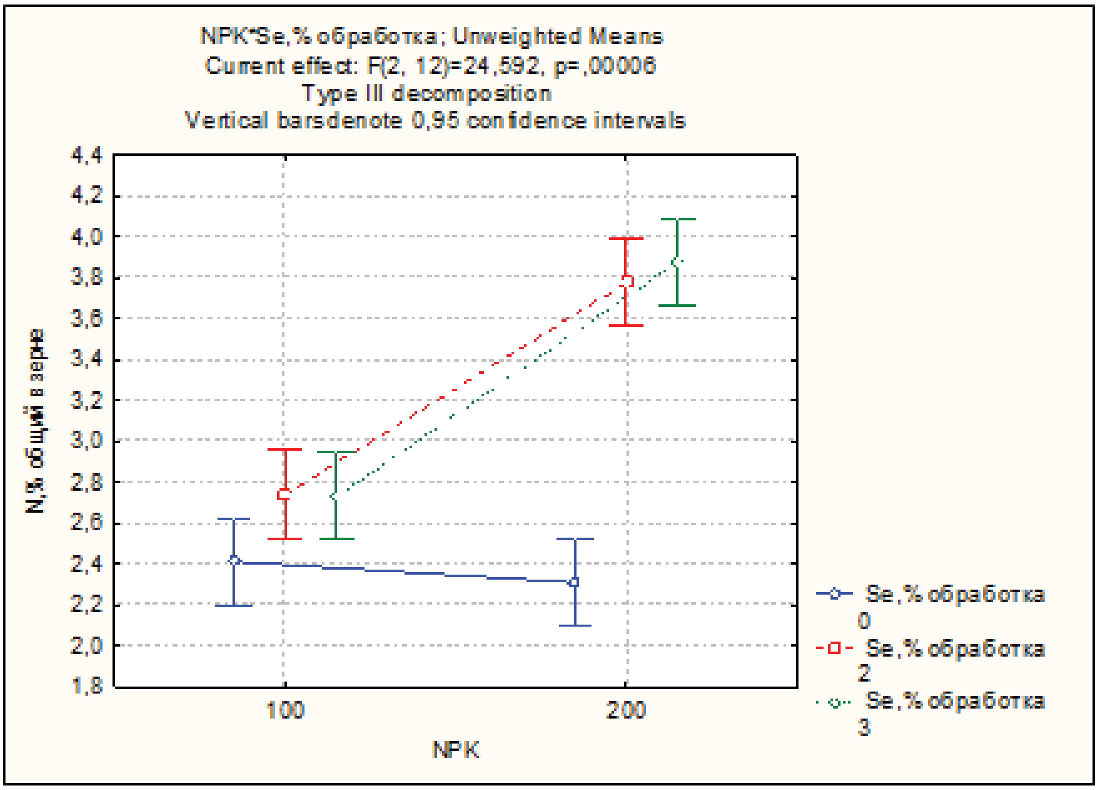

Figure 3. The changes of nitrogen content in the grain depending on treatment with selenium (0 – 0%Se; 2 – 0,01%Se; 3 – 0.05%Se)

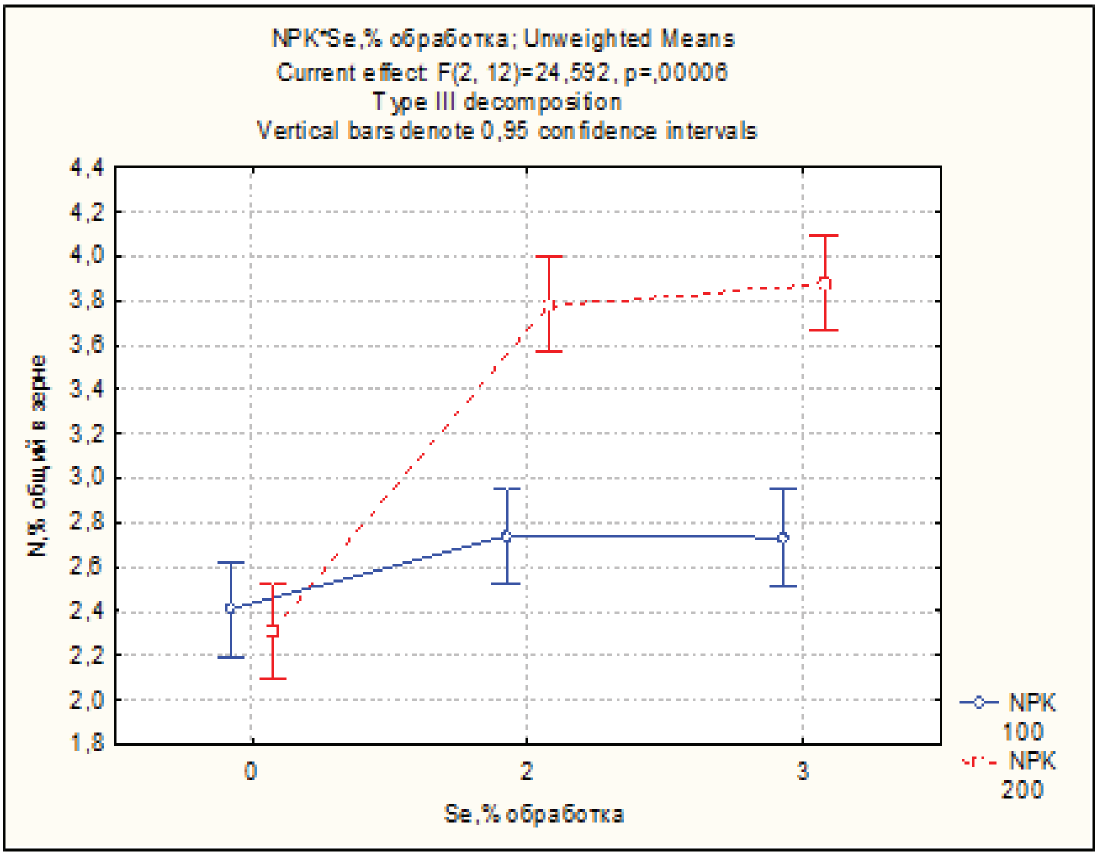

Figure 4. The changes of nitrogen content in the grain depending on the level of NPK

Table 2
The composition and amino acid content in grain and straw of spring barley

amino acids	mg in 100 g of grain				mg in 100 g of straw			
	N100P100K100		N200P200K200		N100P100K100		N200P200K200	
		+0,05% Se		+0,05% Se		+0,05% Se		+0,05% Se
Asp	479,4	614,0	1066,4	1172,0	271,4	311,5	278,4	381,8
Thr	312,5	361,4	627,8	652,9	125,0	141,1	141,4	174,1
Ser	440,6	554,7	822,8	953,4	145,7	158,8	170,2	217,1
Glu	2264,0	2748,4	5673,6	5912,7	409,6	517,8	483,6	654,6
Pro	1651,3	1555,3	2561,0	2669,7	175,6	479,3	403,7	1264,4
Gly	426,4	556,0	716,3	793,0	171,0	193,8	209,2	255,3
Ala	433,6	526,0	754,1	845,8	190,4	231,2	221,0	295,1
Val	417,0	461,2	917,9	996,9	156,6	192,7	179,3	228,3
Cys	58,3	116,1	0,2	4,9	5,6	5,6	18,8	22,5
Met	93,9	99,9	189,3	186,8	32,5	43,6	35,1	59,1
Ile	300,5	323,9	663,3	680,2	106,3	127,5	110,7	163,1
Leu	679,9	719,9	1282,2	1285,1	206,9	242,3	246,7	327,2
Tyr	224,5	82,9	366,2	367,3	67,0	79,0	99,8	114,3
Phe	482,4	530,1	1091,1	1214,0	138,3	169,7	154,4	250,9
Lys	375,8	438,8	950,3	637,3	121,2	151,5	159,2	226,6
His	239,5	274,8	364,1	433,1	43,1	49,4	70,3	93,4
Arg	489,6	573,2	960,5	1046,1	127,9	162,0	154,7	205,4
Sum	9369	10536	19007	19851	2494,3	3256,8	3136	4933

The content of amino acids responsive to plant stress increases significantly with increasing doses of major mineral nutrients (NPK): proline – from 1651,3 to 2561,0 and phenylalanine – from 482,4 to 1091,1 mg/100 g. Their contents increased on variants N200P200K200 after treatment with selenium. At variants N100P100K100 the content of proline decreased, and phenylalanine increased. with the exception. The content of cysteine at the double dose of fertilizer variants (N200P200K200) is significantly reduced (from 58,3 to 0.2 mg/100 g) compared to N100P100K100, and in case with selenium treatments increases by 116,1 and 4.9 mg/100 g, respectively.

CONCLUSIONS

1. Foliar treatment with trace elements (Se) is focused on biofortification of the plants. However, the positive effect on grain quality depends on concentration of selenium. This element can accumulate in plants at concentrations exceeding the MPL.
2. The effect of sodium selenite depends on the level of mineral nutrition (NPK) in soil.
3. Under conditions of high level of NPK the protective properties of Se have been shown. They are represented in the synthesis of specific amino acids in the composition of enzymes (SeCys & SeMet) involved in the synthesis of secondary metabolites.

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Land Degradation Neutrality in Serbia

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ABSTRACT

Land degradation neutrality (LDN) is defined as a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales. This concept is a part of sustainable development goal 15 of the UN Agenda for Sustainable Development. Target 15.3 aims to combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world by 2030. The achievement of this target is measured through indicator called “Proportion of land that is degraded over total land area”. United Nations Convention to Combat Desertification (UNCCD) endorsed SDG target 15.3 and the concept of land degradation neutrality as a strong vehicle for the implementation of the Convention. Countries are invited to formulate voluntary targets to achieve LDN. UNCCD provide guidance for formulating national voluntary targets and facilitate utilization of the UNCCD indicator framework. Republic of Serbia has ratified Convention in 2007 and actively works on LDN target setting process. This paper aims to present: (a) the basic principles of LDN concept, (b) global datasets provided by UNCCD, (c) SWOT analysis for the country, and (d) to discuss possible national datasets and further activities related to LDN.

Indicator “Proportion of land that is degraded over total land area” is measured by means of three sub-indicators: land cover, land productivity and soil organic carbon. This indicator framework could be broaden with national indicators by decision of the country. Country has been provided by global data on land cover from European Space Agency (ESA). Land productivity dynamics (LPD) dataset was prepared by Joint Research Centre of the European Commission, while soil organic carbon (SOC) dataset was provided by ISRIC. Watershed boundaries are provided from FAO GAUL network. Net area change as a result of comparison between two periods for land covers change and SOC, while LPD is obtained as a trend for the 15 years period.

ESA land cover data are given for the two epochs, around 2000 and 2010. These data indicate the loss of 3,800 ha of forests and their conversion to croplands or shrubs. National datasets on land cover exist but their utilization is constrained with the necessity to have dataset for two period of time and to have regular acquisition of future data which are necessary for further analysis and monitoring. Land productivity dynamics data indicated that 5% of the Serbian territory has negative trends in land productivity for the period 1998-2013. There are no national data on LPD obtained according to LDN concept. Soil organic carbon for the country indicates average content of 82.2 t/ha. National data on SOC stocks exist in the databases of relevant institutions but the problems in their utilization are related to the fact that they are sometimes very old, rarely geo-referenced, and obtained by various analytical and terrain procedures. Hence, global data on SOC stocks do not present real country situation, while national SOC stocks data should be systematized to be confident. Indicator analysis at watershed level has recognized the watersheds of Great Morava, Tisa, Sava 3 and South Morava and Nisava rivers, as four watersheds which present 50% of degraded areas according to the proposed methodology. These watersheds should be prone to detailed analysis of around 20 potential hotspots are found in the country. LDN baseline is not yet decided on a country level. Global land cover and land productivity dynamics data will be used until we obtain national data for these indicators. SOC national data should be systematized and used instead of global data. Further activities in LDN target setting process are related to the establishment of LDN baseline, analysis of land degradation trends and drivers, and suggestion of possible national voluntary targets and associated measures at the country, local and/or watershed level. The inclusion of national indicators should be further discussed. LDN concept should be strongly lead by the Government of Republic of Serbia. Hence, Serbian UNCCD NAP document should be finalized, adopted by the Government and LDN embedded into the NAP.

KEY WORDS: LDN; indicators; soil degradation; Serbia

INTRODUCTION

Life on our planet depends on the sustainable use of environmental resources. Plants provide food for humans and animals and society rely on agricultural production for their survival and livelihoods

(UNEP, 2015). Forests cover around 30% of the Earth's surface and are important sources of clean air and water. Nowadays, rates of land degradation and ecosystem loss are increased. Arable land is being lost at 30 to 35 times the historical rate (UNEP, 2015). Land degradation and desertification appear more and more as a result of extreme weather conditions and inappropriate land use. The destruction of habitat has lead to a concern to over 22% of species which are at the risk of extinction (UNEP, 2015). These effects are sawn much easier in the poorest and vulnerable societies. On the other side, increasing population has lead to an increasing demand for natural resources. All these problems are part of the land degradation neutrality concept which strives to achieve balance between sustainable land use, restoration and rehabilitation of habitats, and processes of land degradation. Therefore, land degradation neutrality (LDN) is defined as "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales. The LDN initiative grew out of the concept of Zero Net Land Degradation, which was promoted by the UNCCD (2012), as discussed in recent scientific literature (Chasek et al., 2015; Tal, 2015; Stavi and Lal, 2015). LDN concept is a part of sustainable development goal 15 of the UN Agenda for Sustainable Development. Target 15.3 aims to combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world by 2030 (UNCCD, 2016). The achievement of this target is measured through indicator: ''Proportion of land that is degraded over total land area''. LDN should be understood as a no net loss approach concept. It aims to maintain or enhance land based natural capital comparing to reference state. Therefore, it is important to correctly define reference state, also called baseline. The twelfth session of the Conference of Parties of the United Nations Convention to Combat Desertification (UNCCD), in October 2015, endorsed SDG target 15.3 and the concept of land degradation neutrality (LDN) as a strong vehicle for the implementation of the Convention. All the country Parties are invited to formulate voluntary targets to achieve LDN. UNCCD provide guidance for formulating national voluntary targets and facilitate utilization of the UNCCD indicator framework. Republic of Serbia has ratified Convention in the year 2007 and actively works on LDN target setting process. LDN TSP requires government leadership and stakeholder engagement which is all fulfilled through organization of national working group on LDN TSP. This paper aims to present: (a) the basic principles of LDN concept, (b) global datasets on three sub-indicators, and (c) SWOT analysis for the country. It also aims to discuss about possible national indicators and national voluntary targets throughout the framework of identified hotspots of land degradation.

MATERIAL and METHOD

The indicator ''Proportion of land that is degraded over total land area'' is measured by means of three sub-indicators: land cover, land productivity and soil organic carbon. LDN is achieved if the land-based natural capital measured and validated by the three sub-indicators is maintained or enhanced between the baseline period (t_0) and future monitoring period (t_1). This indicator framework could be broadening with national indicators by decision of the country. The baseline period depends on the current situation and conditions in the country. It should be calculated by estimating the average value of three sub-indicators across the 10-15 year period, unless otherwise stated by country. The indicators should be computed using official, comparable and standardized national data sources. Global data sources should be used if there is a lack of potential national data. The last situation is characteristic of many countries. Country has been provided by UNCCD with global data on land cover, soil organic carbon and land productivity and they are presented below.

Land cover refers to the observed physical cover of the Earth's surface (IPCC, 2003). This fundamental surface parameter helps with the interpretation of other two sub-indicators. Changes in land cover provide a first indication in vegetation alteration, habitat fragmentation or land conversion. Land cover could be obtained from Earth observations and the use of FAO land cover meta language (LCML) is recommended (FAO, 2016). A proposed hierarchical classification is based on level 1 IPCC (2006) categories and level 2 FAO LCML (United Nations, 2014) categories. Global data on land cover and land cover change were provided by European Space Agency. The European Space Agency's Climate Change Initiative Land Cover dataset (CCI-LC) has global coverage and spatial resolution of 300 m. Three epochs are available centered around 2000, 2005 and 2010. The 37 CCI-LC classes are aggregated into the level 2 classes. In the Tab. 1 are given Level 1 and 2 categories.

Table 1
IPCC (Level 1) and FAO LCML (Level 2) land use categories used in LDN TSP

Level 1	Level 2
Forest Land	Forest tree cover
Grassland	Pasture and natural grassland
	Shrubland, bushland, heathland
	Sparsely vegetated areas
	Natural vegetation associations and mosaics
Cropland	Medium to large fields of rain-fed herbaceous cropland
	Medium to large fields of irrigated herbaceous cropland
	Permanent crops, agriculture plantations
	Agriculture associations and mosaics
Wetlands	Open wetlands
Settlements	Urban and associated developed areas
Other Land	Barren land
	Permanent snow and glaciers
Water bodies (inland water bodies, coastal water bodies, sea)	

Changes in land cover may be characterized as positive or negative depending on national or local circumstances. Negative critical transitions are generally conversions from natural or semi natural land cover classes to cropland or settlements or from forest land to other land cover classes, as well as urbanization. The interpretation of changes in land cover is ultimately the responsibility of national and local authorities which can explain why changes are evaluated to be positive (gains) or negative (losses) in the given context.

Land productivity is defined as total above-ground net primary productivity (NPP) calculated as the energy fixed by plants minus their respiration. Measuring unit for land productivity are tones of dry matter per hectare per year (t DM/ha/year). Land productivity captures relatively fast changes in the system. For the purpose of LDN TSP land productivity dynamics (LPD) dataset prepared by Joint Research Centre of the European Commission is used as a global data source. This dataset has been obtained after elaboration of SPOT vegetation normalized difference vegetation index (NDVI) observations in the period 1998-2013 composited in 10-days intervals at the spatial resolution of 1 km. LPD set provides five qualitative classes of land productivity trends. These classes are not quantitative but rather qualitative. They are qualitatively combined measure of the intensity and persistence of negative or positive trends and changes in the photo-synthetically active vegetation cover over the observed period. LPD depicts trajectories of long-term seasonal dynamics and departures from it. Land productivity baseline is actually the trend in land productivity. The LPD dataset is useful for assessing land degradation, for practical LDN target setting as well as for further monitoring. Dynamics of land productivity refers to the variation in primary productivity of a stable land system between different years and growth cycles as a function of natural or partially human induced adaptation and resilience to diverse environmental conditions and human intervention. LPD dataset is stratified by means of the 6 main land cover categories. Following classes of land productivity dynamics are defined: ''declining productivity'', ''early signs of decline'', ''Stable, but stressed'', ''stable (not stressed)'' and ''increasing productivity''.

Carbon stocks above and below ground refer to the quantity of carbon in a pool. It is expressed in tones of carbon per hectare. Soil organic carbon (SOC) is going to be use instead of total carbon stocks until the later becomes operational. SOC is an indicator of overall sol quality, important for nutrient cycling, water holding characteristics and aggregate stability and soil structure. Coarse estimates of SOC could be produced with modeling techniques. Soil organic carbon dataset was provided by ISRIC – World Soil information for SOC stocks to a reference depth of 30 cm. SOC is presented in 250 m grids. It is computed using data on SOC content, gravel content, bulk density and soil thickness following the equation below:

$$SOC\ (t \cdot ha^{-1}) = 100 \cdot SOC\ (\%) \cdot BD\ (t \cdot m^{-3}) \cdot (1 - CF\ (\%vol.)) \cdot D\ (m)$$

Where: SOC – soil organic carbon stock (t/ha), BD – bulk density (g/cm^3), CF – volume of coarse fragments (%), D – depth of soil layer (0.3 m).

ISRIC soil grids could be more accurate if sharing more data on soil profiles. Interpretations of SOC trends are positive when SOC stocks values increase, or they may be negative when SOC stocks values decrease, unless it is defined otherwise by country. SOC reflects slower changes in the system.

The Republic of Serbia has been also provided with watershed boundaries from FAO GAUL network in order to perform calculations on watershed level. Twenty one watersheds cover 99.9% of the territory of the country. Net area change in km^2 is given as a result of comparison between two periods for land cover and SOC stocks, while LPD is explained as a trend for the 15 years period. The utilization of global data should carry out after their evaluation and validation, and comparison with national datasets.

RESULTS and DISCUSSION

ESA land cover data are given for the two epochs around year 2000 and 2010. These data indicate the loss of 3800 ha of forests and their conversion to croplands or shrubs. The change in net area of six main land cover classes is given in Table 2 and presented spatially on Figure 1.

Table 2

The surface of six main land use/cover categories in the Republic of Serbia for the period 2000 and 2010, and the difference between these two epochs

Land Use/Cover Category	Area (2000) (km^2)	Area (2010) (km^2)	Net area change (2000-2010) (km^2)
Forest	31996	31959	-38
Shrubs, grasslands and sparsely vegetated areas	2929	2947	18
Croplands	48668	48688	20
Wetlands and water bodies	823	823	0
Artificial areas	4135	4135	0
Bare land and other areas	12	12	0
Total	88563	88563	

National data on land cover exist and have somehow better resolution. Their utilization is constrained with the necessity to have dataset for two periods of time and to have regular acquisition of future data which are necessary for further analysis and monitoring. CORINE land cover (CLC) dataset exist for the year 2006 and 2012, but complete dataset do not exist for both periods. CLC has 44 classes of land cover in nomenclature, 25 hectares minimum mapping unit, and 100 meters minimum mapping width. For the purpose of LDN TSP, this dataset should be converted into IPCC and FAO LCML land use/cover classes. Unfortunately, the use of these datasets is currently constrained with the possibilities to compare land use/cover between two or more epochs. Also, these epochs do not coincide with the epochs of ESA dataset provided by UNCCD. Next release of CORINE LC dataset will be compared with 2012 dataset, and then these data area going to be compared with ESA dataset. This should be done for monitoring purposes.

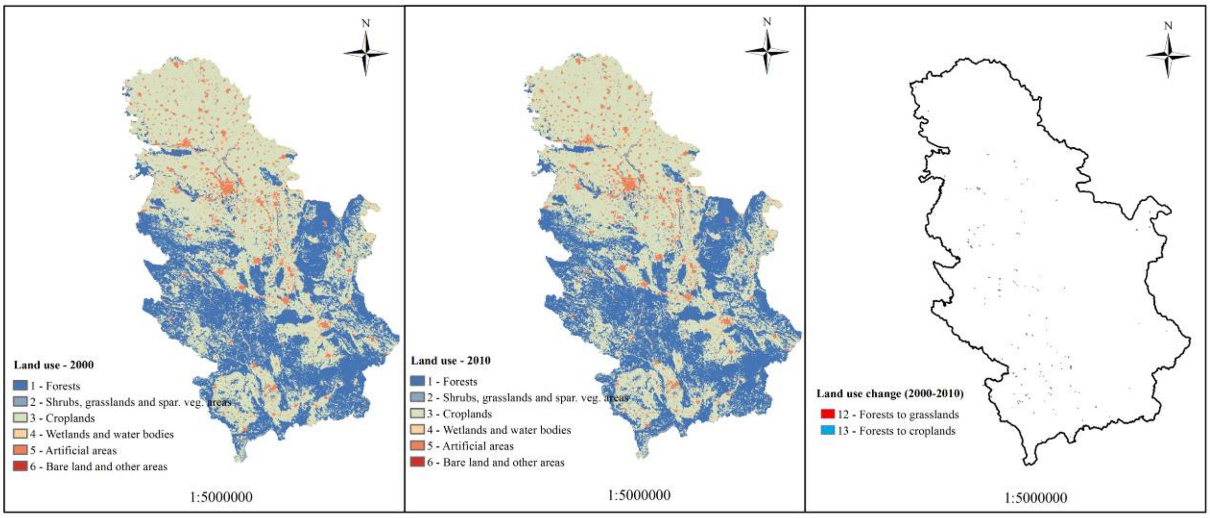

Figure 1. Map of six main land use categories in the Republic of Serbia for the centered years 2000 and 2010, as well as the map of land use change for these two epochs

Land productivity dynamics data indicate decline in land productivity on 24900 ha, while early signs of decline and stable but stressed areas cover 451200 ha. Totally, 5% of the Serbian territory has negative trends in land productivity (classes 1-3). There are no national data on LPD prescribed according to LDN concept. The results of LPD for six main land cover classes are given in Table 3. Croplands had much higher decline in land productivity dynamics (total for classes 1-3) compared with forest land. Around 7.84% of croplands has negative trend (LPD classes 1-3) in LPD, while there is 0.85% of forests that have negative trend in LPD, and 3.97% of shrubs, grasslands and sparsely vegetated areas. The map of LPD for the Republic of Serbia is given in Figure 2. There is no national data on LPD obtained with LDN TSP methodology.

Table 3
Net land productivity dynamics in the Republic of Serbia for the six main land use classes for the obtained as a trend for the period 1998-2013

Land Use/Cover Category	Net land productivity dynamics (km^2)					
	Declining	Early signs of decline	Stable but stressed	Stable not stressed	Increasing	No Data
Forest	4	49	219	2299	29381	7
Shrubs, grasslands and sparsely vegetated areas	10	16	91	254	2576	1
Croplands	173	1260	2385	14434	30415	21
Wetlands and water bodies	6	9	21	268	465	53
Artificial areas	53	118	343	1580	2039	3
Bare land and other areas	3	0.4	1	4	3	0.2
Total land area (%)	0	2	3	21	73	0
Total (km^2)	249	1452	3060	18838	64878	85

Soil organic carbon map for the whole area in the year 2000 indicate average content of 82.2 t/ha for the entire territory of the Republic of Serbia. SOC content is the highest in forests, at 95.9 t/ha. SOC stock for six main land use classes is presented in Table 4. SOC data provided by ISRIC are obtained with modelling techniques and with a small amount of measured data used for modelling. Therefore, these data are sometimes overestimated or underestimated, if compared with existing SOC data in the country.

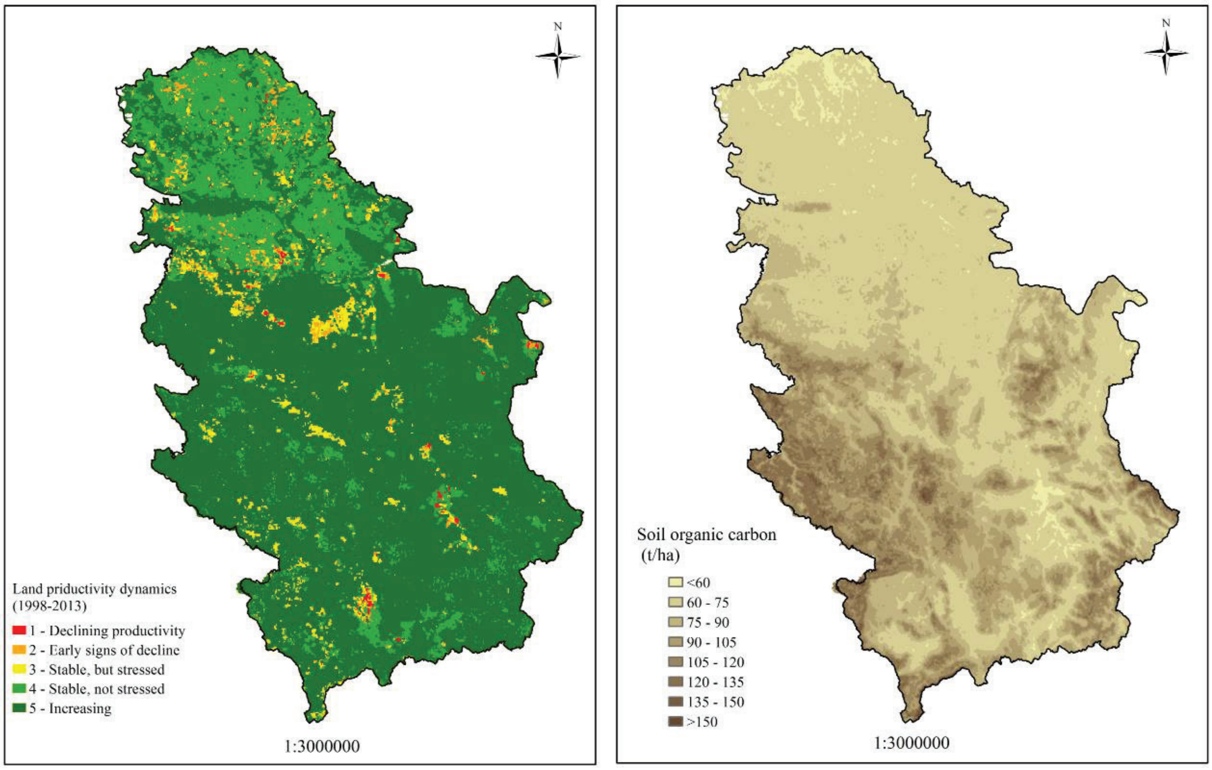

Figure 2. Maps of land productivity dynamics and soil organic carbon stocks for the Republic of Serbia obtained from the global datasets

National data on SOC stocks exist in the databases of relevant institutions,, but the problems in their utilization are related to the fact that they are sometimes very old, rarely geo-referencized, and obtained by various analytical and terrain procedures, which do not correspond to the methodological approach of LDN TSP, and nevertheless, some of the steps in calculations are based on assumptions, and not on a basis of measurements.

Also, it is very important to say that SOC data were mainly not obtained from SOC campaigns, but rather from the campaigns that had different purposes. Therefore, we have baseline SOC data obtained from global datasets (Figure 2), which are centered on year 2000. Changes in SOC for the two periods of time are given on a basis of IPCC methodology, which is related to land cover change. These are very crude assumptions. Hence, we do not have good quality SOC data for the baseline period. Global SOC map of Serbia should be corrected using good quality national data obtained according to the methodology and including data for the period of last 10-15 years. Global data on SOC stocks do not present real situation, while national SOC stocks data should be systematized in order to be presented spatially and be confident.

The Republic of Serbia has been also provided with watershed boundaries from FAO basins network in order to perform calculations on watershed level. Sub-indicators analysis at watershed level has recognized the watersheds Great Morava, Tisa, Sava 3 and South Morava and Nisava, as four watersheds, which present 50% of totally observed degraded areas according to methodology, and 45% of the Serbian territory. The boundaries of watersheds should also be further discussed since they do not correspond to official used boundaries. Therefore, this analysis should be conducted by different manner. Table 5 presents data for 21 watersheds in Serbia obtained from FAO basins network. These watersheds cover 99.9% of the entire country territory.

Table 4
Soil organic carbon stocks in the Republic of Serbia provided by ISRIC for six main land use categories centred on year 2000

Land Use/Cover Category	Soil organic carbon (2000) (t/ha)
Forest	95.9
Shrubs, grasslands and sparsely vegetated areas	94.7
Croplands	73.8
Wetlands and water bodies	69.7
Artifical areas	69.6
Bare land and other areas	82.3
SOC average (t/ha)	82.2

Each country could use additional national indicators to assess land degradation by its own decision. We share the opinion that the methodology for determination of trends in LPD could be constrained if irrigation sector is not observed separately. For this purpose irrigation cadastre should be created for the country level and the areas under agricultural water management could be monitor separately.

Hotspots:
The analysis of degraded areas by means of trends in sub-indicators has indicated around 20 potential hotspots in the country (Figure 3). These hotspots were identified by means of presence of more adjacent spatially aggregated pixels of LPD classes 1-3. It is very difficult to collect information on land degradation types on these areas, although trends were identified. The biggest hotspots are located on agricultural areas, mainly with arable land use in Northern Vojvodina, Pomoravlje, and Central Sumadija regions. The farmers do not identify any change in land quality except that they recognize drought as a threat to crop production. Moreover, farmers do not link droughts to land degradation. Hence, if the soil management and crop production practices are not organized in sustainable manner, then the problems of land degradation could slowly appear. Thus, it is difficult to identify land degradation types on these areas, as well as the drivers of land degradation, but lack in sustainable management practices could be the cause. More notable than other bad practices, are production in monoculture, burnt of residues, soil compaction, use of fertilizers without application of manure, and bad irrigation management, which all causes soil structure deterioration and damage to soil physical and chemical properties. The use of pesticides decreases soil biodiversity. Nevertheless, in some cases LPD methodology was found to be incorrect, i.e. presence of greenhouses and glasshouses, and higher presence of artificial areas and infrastructure object. Hence, we need to explore more the LPD methodology and to be more familiar with it, in order to analyze and elaborate data by ourselves. We need an access to methodology. The causes of negative trends in LPD on pastures in lowlands and highlands could be only potentially related to overgrazing, but also to joint effects of droughts and extreme rainfall events. Overgrazing in Serbia is not very often, since livestock number is decreasing rapidly. Anyway, the utilisation of pastures with lower intensity could also cause negative changes in LPD. Possible hotspots with pasture and meadow land use are found on flat terrain in Banat region and on Zlatibor and Maljen mountains, as well as on Pester plateau. The negative trends of LPD in forests were not found to be strong. We expect that these data will be different after next LPD monitoring since in the meanwhile, the forest were prone to extreme colds and droughts. Negative trend in LPD was found also in the areas around cities, such as Belgrade, Sabac, Pristina and Novi Pazar, and the cause for this trend could be intensive urbanization, which was not identified as land use change by global data. Possible hotspots were identified also around Kostolac, Lazarevac and Obrenovac power plants, and industrial zone around Prahovo, Eastern Serbia. The last one could be related to environmental pollution.

Watershed analysis:
Great Morava River watershed accounts for 16.2% of degraded area of the country based on sub-indicator approach. Almost 80000 ha of this watershed has negative trend in LPD and/or SOC. Tisza River watershed has almost 70000 ha of degraded area, while Sava 3 watershed is at the third place with more than 55000 ha of degraded areas.

Table 5
Serbian watersheds from GAUL network; watershed area (km2), degrading area in watershed (km2), sum of total degraded area (%), degraded area in watershed (%), total degraded area at the country level (%), and the ratio of watershed area to degraded area

Watersheds	Watershed area (km^2)	Degrading area: LPD + SOC (km^2)	Cumulative sum national area (%)	Degraded area in watershed (%)	Total degraded area in country (%)	Watershed area /Degraded area
Great Morava	11967.5	768.6	13.6	6.4	16.2	15.6
Tisza	8920.4	698.9	23.8	7.8	14.7	12.8
Sava 3	3598.1	551.1	27.8	15.3	11.6	6.5
South Morava-Nisava	14471.0	363.2	44.3	2.5	7.6	39.8
Sitnica-Drenica-Lab	4016.3	353.3	48.9	8.8	7.4	11.4
Sava 4	2495.0	294.6	51.7	11.8	6.2	8.5
White Drin	4535.7	290.5	56.9	6.4	6.1	15.6
Drava 2	3402.5	239.8	60.7	7.0	5.0	14.2
Rzav-Moravica-West Morava	4755.0	238.5	66.2	5.0	5.0	19.9
Tamis	3296.3	206.7	69.9	6.3	4.3	15.9
Kolubara	3618.9	193.0	74.0	5.3	4.1	18.8
Ibar	3809.2	136.2	78.3	3.6	2.9	28.0
Drina	5783.2	116.4	84.9	2.0	2.4	49.7
Timok	5918.7	108.0	91.7	1.8	2.3	54.8
Dunav	1636.7	84.5	93.5	5.2	1.8	19.4
West Morava	3072.4	70.6	97.0	2.3	1.5	43.5
Vardar	1292.4	21.6	98.5	1.7	0.5	59.8
Black Drin	66.1	13.6	98.6	20.6	0.3	4.9
Dunav 2	378.5	4.6	99.0	1.2	0.1	82.5
Sava 2	104.7	2.2	99.1	2.1	0.0	48.5
Struma	715.1	1.4	99.9	0.2	0.0	529.7

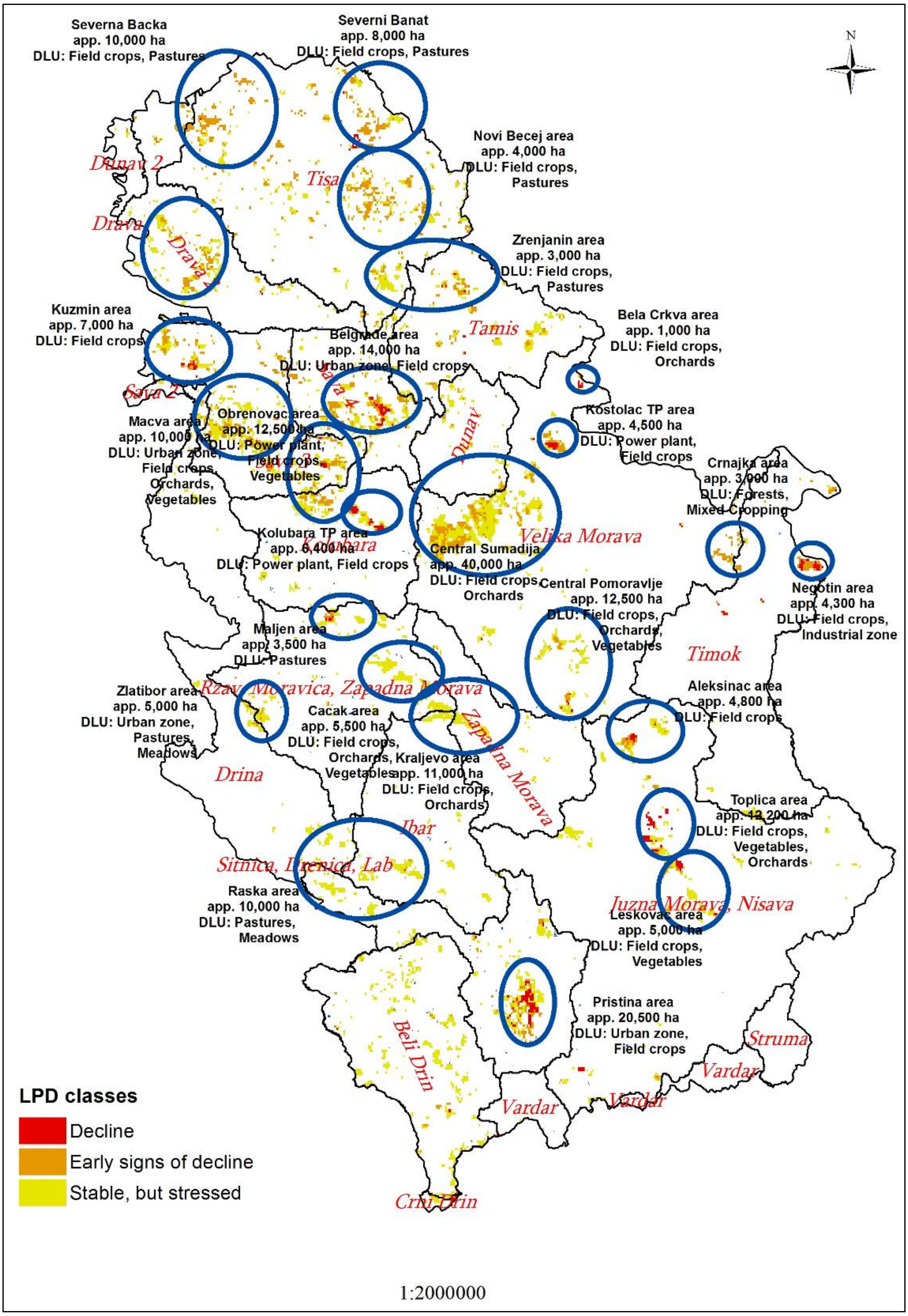

Figure 3. National map of possible hotspots with LPD classes 1-3 and sub-basin boundaries

South Morava/Nisava and Sitnica/Drenica/Lab watersheds have both more than 35000 ha of degraded areas. The first four mentioned watersheds cover almost 50% of total degraded area in the country, almost 240000 ha. Ratio between watershed area and degraded area is the lowest in the case of Sava 3 watershed, only 6.5, which implies that this watershed is the most vulnerable to land degradation. All the presented results are obtained after the analysis of global datasets.

SWOT analysis:

LDN TSP is concept that should be strongly involved into national politics. The LDN related legal and institutional framework can be assessed by analyzing its strengths, weaknesses, opportunities and threats (SWOT) including UNCCD NAP. The strengths and weaknesses are considered as internal factors controlled by Government, whereas opportunities and threats are considered as external factors, which require the mobilization of a broader range of stakeholders. The SWOT analysis includes identification of relevant documentation, review of the NAP, compilation of LDN synthesis report, with the main elements appearing to be strengths, weaknesses, opportunities and threats, discussion on the report, and SWOT validation by national working group. SWOT analysis provides better understanding of legal and institutional framework, link LDN concept to NAP, and identifies measures to achieve LDN.

The major strengths in institutional in legal framework are related to: (a) clearly identified directions of NAP and (b) its linkage to strategy of sustainable use of national resources, which takes into account Rio+20 UN Conference on Sustainable Development, (c) NAP political and institutional support via scientific community, (d) LDN TSP inclusion into NAP, (e) laws and strategies that mostly cover environment, (f) existence of Law on Soil as a natural resource, (g) the well-structured organization that govern the process, (h) recognition of land degradation problems by Ministry of Environmental Protection, (i) foundation of Centre for monitoring and control of desertification and degradation processes of soils, (j) high level of visible degradation problems.

The most important weaknesses are related to: (a) the fact that NAP alignment is not yet started, (b) non efficient system of funding to support soil interventions, (c) short term for implementation of the NAP, (d) nonexistence of long-term activities in combating land degradation, (e) not established indicator system for the assessment and monitoring of land degradation, (f) lack of institutional and political support and financial resources, (g) low level of local communities involvement, (h) lack of coordinated actions among sectors and actors, among sectorial and cross/sectorial issues, (i) lack of critical look to the projects and measures already implemented, as well as low transfer and dissemination of results, (j) no assessment of land degradation impact on economy, (k) low political awareness about degradation problems, and (l) low level of visible degradation problems.

A plenty of opportunities exist from LDN TSP. The major opportunities are related to: (a) well-structured NAP, (b) possibility to use data and indicators from LDN activities for adaptation policies and measures at national level, (c) targeted mobilization of financial and technological resources, (d) development of infrastructure for NAP implementation, (e) development of relevant regulations, laws, and normative related to land degradation, (f) support of LDN activities from environmental institutions, (g) development of new technologies and tools to support LDN, (h) new insights into agro climatic indicators, (i) specific attention by stakeholders and media on soil degradation, (j) possibilities to find financial resources for the activities from international organizations, (k) design of an integrated monitoring and evaluation system at national or local level, (l) design of intervention plan on local level, (m) partnership building, (n) organization of training programs, (o) development of LDN economic index, mechanisms for efficient information exchange, (p) increased commitment to address environmental problems, (q) engagement of different national, regional and international actors in restoration of degraded land, and (r) share of scientific research information, advanced technologies and best practices.

Possible threats are related to: (a) lack of regulations about combating land degradation, (b) often delays in the elaboration of draft legal acts, discussions and approval procedures, (c) impact of potential changes in the global and national economies, (d) an ongoing decrease in funds for research in the environmental sector, (e) competition with other environmental hazards for funding, (f) lower management efficiency in multi-sectorial approach, (g) increasing urbanization and soil sealing, (h) high incidence of floods and droughts, impact of climate change and natural disasters, (i) the lack of awareness of the importance of land degradation.

LDN baseline:

Since LDN is achieved when land-based natural capital measured and validated by the three sub-indicators is maintained or enhanced between the baseline period (t_0) and future monitoring period (t_1), it is important to bring decision on LDN baseline and reference period. Currently, the situation with national datasets on sub-indicators in the country is following: (1) land cover/land use data should be initially used from global datasets, until new epochs on national datasets appear, (2) land productivity dynamics should be used from global sources until national capacities to determine this indicator strengthen, (3) SOC data should also be used from global sources with very high caution on their quality and accuracy, until the national data on SOC become available from systematized official datasets and SOC campaigns, (4) irrigation cadastre do not exist.

National voluntary targets and measures:

The decision on country national voluntary targets and associated measures should be carried out after the analysis of trends in sub-indicators, types of land degradation, and the analysis of indirect and direct drivers of degradation. As a result of analysis, national voluntary targets and associated measures should be stated. It should be stated that national voluntary targets often depend on country ambition. At this state of knowledge, adopted targets are related to collection of national and on-field data on sub-indicators. This should be conducted through official soil monitoring in the Republic of Serbia and systematization of all existing country SOC data into one database. Soil issues should be more addressed in the elementary and high schools, while degradation problems could be bring to higher level at University. Therefore, soil monitoring and education are two voluntary targets. Strengthening national capacities in elaboration of remotely sensed data and access to the methodology to determine LPD is another target. A special attention should be given to possible detected hotspots, where the economical assessment of measures and gains could also be defined.

Future perspectives:

LDN concept is superficially simple, but there are wide arrays of opportunities related to its implementation that should be taken into account. The concept of LDN has some very important insights relevant to its implementation. Firstly, neutrality assessment must consider changes in the available land quantity and quality, or to express as the severity of degradation and land area involved (Kust, 1997; Savich et al., 2003; UNCCD, 2012, 2014a; EC JRC, 2014). The ecosystem-based approach is promoted through two pathways of action (Kust et al., 2017): (i) addressing current and future land degradation and (ii) redressing past degradation (Colls et al., 2009; IUCN, 2009; Vignola et al., 2009; Uy and Shaw, 2012; Girot et al., 2013; WWF, 2013; Aronson and Alexander, 2013; Kust and Andreeva, 2014; Schipper et al., 2014; UNCCD, 2014b, 2014c; Reid, 2015). Spatial and temporal scale of land degradation is considered in LDN concept, while land quality is observed through its productivity, functions, ecosystem services and their resilience, health… Also, LDN recognizes the different uses of land and considers various approaches and methodologies to reach the LDN target. It monitors changes in land area and therefore reference state should be stated for further evaluation and assessment. LDN requires an enabling environment in which all stakeholders participate and accept responsibility and voluntary commitments (Kust et al., 2017).

Land tenure is recognized as an indirect driver of land degradation. We share the opinion that in Serbia pilot project about LDN TSP should be conducted on state soils, the soils rented for agricultural activities to private companies. We suggest monitoring of the quality of these soils and application of law on soil protection.

CONCLUSION

LDN is a new paradigm reflecting the inter-related aspirations and demands of land-related sustainable development goals (Kust et al., 2017). Human-induced land degradation as a result of unsustainable management requires ongoing compensation measures to support land resource potential. Nevertheless, successful land management (SLM) practices can also improve land resources. Therefore the LDN state can serve as a target for SLM and overall indicator for the success of SLM. Therefore, LDN is a modeling game related to the space where we are living.

LDN baseline is decided on a country level. Currently, in the Republic of Serbia, we are going to use data on land cover, land productivity and SOC from global sources. In the forthcoming period, of four years, when LDN concept is going to be embedded into NAP officially, a plan is to collect data on sub-indicators, and to compare and/or change global data sets with national datasets. CORINE land cover dataset could be used and compared to previous epoch for the whole territory. Nevertheless, we do not neglect ESA land cover datasets neither. These data should be compared with CORINE LC data. Land productivity dynamics dataset may become more accurate in future period compared with the previous one. This opinion relies on the fact of improved resolution of images. We expect an access to the methodology and a possibility to elaborate remotely sensed data ourselves. SOC data could be systematize in the future 4-year period and SOC stocks campaign could be organized through the network of the soil monitoring of the Republic of Serbia. We expect gaps between different datasets and timeline. This is a disadvantage of this methodology. Therefore, the idea to monitor LDN in forthcoming period will be prolonged or limited due to data systematization and collection, and time steps.

Further activities in LDN target setting process are related to the analysis of land degradation trends and drivers and their mapping at a country level, especially on the areas identified as potential hotspots. The suggestion of possible national voluntary targets and associated measures at the country, sub-national, regional or watershed level, should become realistic after these serious analyses. Soil monitoring, systematization of existing SOC data and access to LPD methodology are three national voluntary targets related to collection of data about sub-indicators, whereas, education about land degradation is related to raise of awareness on land degradation and soil issues. Monitoring program on state soils could be another voluntary target. The inclusion of national indicators, such as irrigated areas, should be further discussed since these area behave diversely than rainfed areas, especially from the point of view of remote sensing proxies. LDN concept should be strongly lead by government and therefore, the idea to promote LDN firstly on state soils is a cornerstone of this concept. Who could actually better protect the land than the state? Serbian UNCCD NAP document should be finalized and aligned, and LDN TSP should be embedded into NAP.

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Arsenic Content and Distribution in Agricultural Soils of Vojvodina Province, Serbia

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ABSTRACT

Arsenic (As) is metalloid designated as a pollutant in the environment due to its harmful effects on biota. Sources of arsenic soil contamination originate from both indigenous and anthropogenic inputs, including atmospheric deposition (mining, industry, dumpsites). In addition, As has been used in agriculture as a component of different agrochemicals. Contamination of groundwater with arsenic is a global issue. Arsenic in drinking water can affect human health; it is considered as one of the most prominent environmental causes of cancer mortality in the world. The content and retention of As in soils, as well as the other heavy metals, is highly dependent on the physicochemical properties of the soil. Vojvodina Province in the northern part of Serbia represents its most important agricultural area. The aim of this study was to determine the content and distribution of As in agricultural soils, its spatial distribution in different geomorphological units and soil types of Vojvodina Province, and to establish permanent monitoring. A grid superimposed on Vojvodina soil by means of a GIS tool has divided study area into 4 × 4 km units, each representing an area of 16 km^2. Total number of 1,370 bulked soil samples (0-30 cm depth) were taken from agricultural land. The samples were analysed for pseudototal content of As_T (after MW digesting the soil in $_{cc}HNO_3$ and H_2O_2) and available contents of As_{EDTA} (EDTA extraction). The concentrations of As were determined by ICP-OES. Basic soil properties were determined according to standard methods at the Laboratory for Soil and Agroecology of the Institute of Field and Vegetable Crops, Novi Sad, accredited according to the standard ISO/IEC 17025 (2005). The software used for the mapping and spatial analysis was ESRI ArcGIS Geostatistical Analyst 10. All statistical analyses were performed using the data analysis software system Statistica for Windows, version 13.2 (Dell 2015). The obtained results of As_T were within interval 1.0–31.4 mg kg^{-1}. The average concentration of As was 8.4 and 0.4, with median 8.3 and 0.3 mg kg^{-1} for pseudototal and available content, respectively. Only four samples were above 25 mg kg-1 for AsT, which is the national legislative threshold. These samples belong to the District of Srem, South Banat and two samples are from the South Bačka District. It was found that As_T content is negatively correlated with pH value and $CaCO_3$ and positively correlated with organic matter contents in soil. The effect of different soil particle size on availability of As was proven; availability decreases with higher proportion of clay and slit. As spatial distribution indicated, the majority of Vojvodina Province area has geochemical origin of As. Based on As concertation along geomorphological units, As_T is higher on mountains (10.4) and lower on the sandy area (5.6 mg kg^{-1}) with statistical difference among the other units. Oppositely, As_{EDTA} is higher on sandy area (0.6) and lower on the mountains (0.3 mg kg^{-1}), which proves effect of organic matter and clay on As availability. Average values of As_T concentrations according to the soil types coincides with main geomorphological units where soils have been formatted. As_T is higher in cambisol (10.9) and lower in arenosol (4.8 mg kg^{-1}). Average values of As in chernozem, most frequent soil type in Vojvodina, was 8.6 and 0.4 mg kg^{-1} for pseudototal and available content, respectively. The obtained results show that measured levels of As in the soil are not limiting factors for safe food production in Vojvodina. The results emphasize the importance of knowing the spatial determinants of geomorphological units and soil types in establishing a permanent monitoring.
KEY WORDS: soil, arsenic, heavy metals, geomorphological units

INTRODUCTION

Arsenic (As) is a metalloid, designated as a pollutant in the environment, due to its harmful effects on biota. Arsenic is an element and is a naturally occurring mineral found widely in the environment. Arsenic enters the environment naturally through ground water, mineral ore and geothermal processes. Sources of arsenic soil contamination originate from both indigenous and anthropogenic inputs, including atmospheric deposition (mining, industry, dumpsites). In addition, As has been used in agriculture as a component of different agrochemicals (ATSDR, 2009).

The toxicity of arsenic is partly related to its form, valence state, solubility, rate of absorption and elimination from the body. Inorganic arsenic is generally more toxic than the organic one. Arsenic is non-soluble in water but its compounds arsenite and arsenate are highly soluble.

Among all the possibilities of arsenic entering the food chain, arsenic contamination of rice (*Oryza sativa* L.) endangers the global food security and human health (Meharg et al., 2009; Seyfferth et al., 2014, Neumann et al., 2017). In flooded paddy soil, arsenic is mobilized through reductive dissolution of arsenic bearing iron(III) oxides. Climate warming could alter availability and plant uptake of arsenic, because soil warming increases arsenic availability in the Rice rhizosphere (Neumann et al., 2017).

Contamination of groundwater with arsenic is another global issue. The natural occurrence of arsenic in groundwater constitutes a major setback in the provision of safe drinking water to millions of people in Asia and worldwide (Amini et al., 2008; Thakur et al., 2011). Arsenic in drinking water can affect human health; it is considered to be one of the most prominent environmental causes of cancer mortality in the world (Shrivastava et al., 2014).

In Vojvodina, 800,000 people drink water with arsenic (mostly in Central Banat), in Hungary 1,800,000 people (Dalmacija et. al, 2010).

The content and retention of As in soils, as well as the other heavy metals, is highly dependent on the physicochemical properties of the soil (Adriano, 2001).

Vojvodina Province in the northern part of Serbia represents its most important agricultural area, therefore, soil protection is of crucial importance for economic development of the Vojvodina Province.

The aim of this study was to determine the content and distribution of As in agricultural soils, its spatial distribution in different geomorphological units and soil types of Vojvodina Province, and to establish permanent monitoring.

MATERIAL and METHOD

Study area

Vojvodina is the autonomous province in Republic of Serbia and occupies the area between 44^{o} 38' and 46^{o} 10' northern latitude and 18^{o} 10' and 21^{o} 15' eastern longitude. Vojvodina is situated in the south-eastern part of the Pannonian (Carpathian) Basin, the plain that remained when the Pliocene Pannonian Sea dried out. Consequently, Vojvodina is rich in fertile loamy loess soil. Regarding the distribution of soil types, as much as 60% of the Vojvodina Province soil is chernozem, which is considered ideal for crop production due to physical and chemical properties. Other fertile soil types with considerable areas include hydromorphic black soils (16%), and the alluvial soils (9%) (Skoric et al., 1985). Out of the total area of the Vojvodina Province (21,506 km^2), the agricultural land takes 16,940 km^2 or 80%. Vojvodina is a typical rural region in which ploughed land and gardens cover 90% of the agricultural land (STAT. YEARB. SERB., 2015). More than 60% of this lowland area is covered by loess and loess-like sediments at terraces and loess plateaus (Markovic et al., 2008). Beside four lowland geomorphological units (sandy area, loess plateaus, upper Pleistocene, alluvial terraces and alluvial plains), the most distinctive landforms of the Vojvodina region are two mountains: Fruška Gora Mountain, which is situated between the Danube and Sava rivers, and Vršac Mountains, which are located in the south-eastern part of the region close to the border with Romania (Fig. 3).

The climate of Vojvodina is moderate continental, with cold winters and hot and humid summers, wide range of extreme temperatures and unequal distribution of rainfall per months, which leads to different aridity types. The mean annual air temperature is 11.1°C and the annual amount of precipitation is about 600 mm (Hrnjak et al., 2013; Tosic et al., 2014). Potential vegetation is mostly replaced by crops at lowland zone. Forest vegetation is limited to narrow belts close to the rivers, Deliblato sandy area and two mountains. Vojvodina has a population of about 2 million inhabitants (about 27% of Serbia's total).

Sample collection and processing

A grid superimposed on Vojvodina land by means of a GIS tool GIS ArcView 10 has divided the land of the Vojvodina into 4 × 4 km units, each representing an area of 16 km^2 (Fig. 1). Samples were taken from the defined spots of agricultural land, or the centre of each quadrant using GPS manual receivers (GPS receivers Trimble GPS GeoXH 3000, Trimble GPS Juno SC, Terrasync Professional software). In case a sample could not be taken from the centre of a quadrant for any reason, the correction sampling was performed at the nearest corresponding location, up to 500 m away from the defined spot, rarely up to 1,000 m away (Fig. 1). If the defined spots were in the urban area, the samples were taken from urban gardens and garden plots.

Total of 1,370 bulked soil samples were taken during the period 2011-2013. The topsoil samples were taken from 0-30 cm soil layer. This depth was chosen as the most active zone of field crops root systems. The samples were taken using a soil drill agrochemical probes and stored in polyethylene bags. Samples were stored in cold (+4°C) during transport. One composite sample represented 10-15 subsamples from random points within about 300 m^2 grid in each sampling site. The initial quantity of samples was approximately 1.5 kg. The soil samples were air-dried at the room temperature, milled and sieved to <2 mm particle size, in accordance with ISO 11464 (2006).

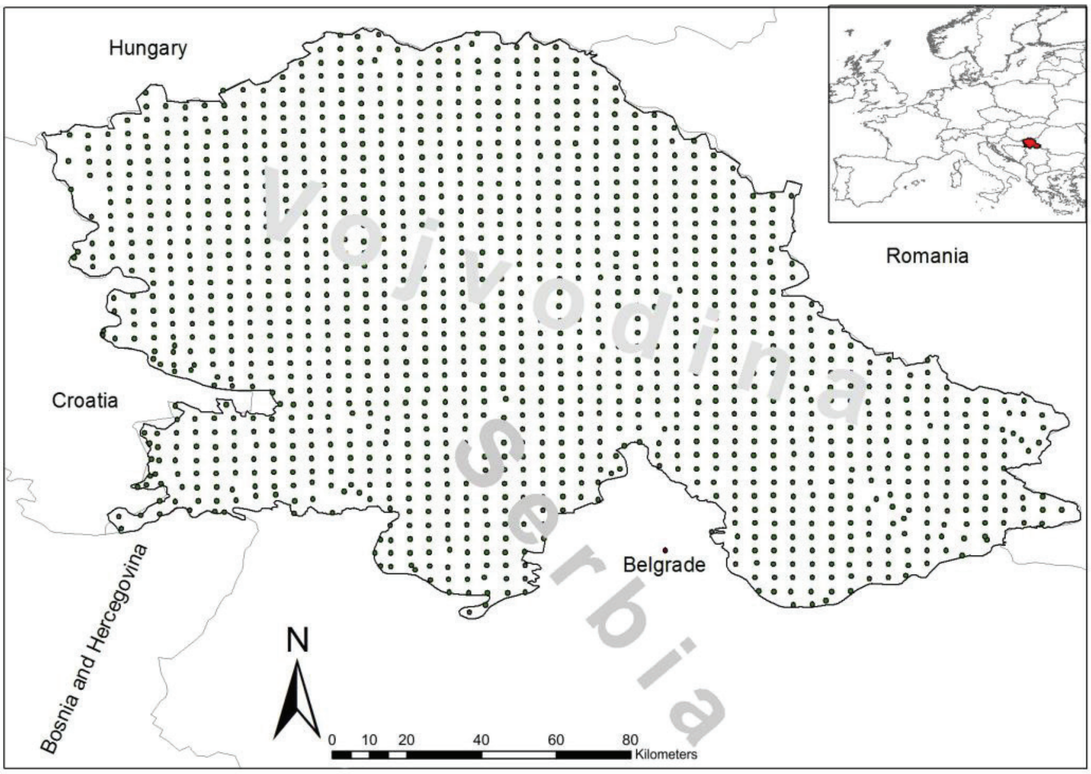

Figure 1. Layout of 1.370 taken soil samples

Laboratory analyses

All laboratory analyses were performed at the Laboratory for Soil and Agroecology of the Institute of Field and Vegetable Crops, Novi Sad, accredited according to the standard ISO/IEC 17025 (2005).

The pH value in 1:5 (V/V) suspension of soil in 1 mol/L KCl was determined using glass electrode according to ISO 10390 (2010). The carbonate content ($CaCO_3$ content) was determined according to ISO 10693 (1995) by volumetric method. The organic matter content was measured by oxidation using the sulphochromic oxidation method by ISO 14235 (1998). Readily available phosphorus (P_2O_5) and available potassium (K_2O) were extracted by ammonium lactate extraction (AL method by Egner and Riehm, 1960), and measured by the means of spectrophotometry and flame photometry, respectively. Particle size distribution was determined in the <2 mm fraction by the pipette method (Van Reeuwijk, 2002). The size fractions were defined as clay (<2 µm), silt (2-20 µm), fine sand (20-200 µm) and coarse sand (200-2,000 µm).

The samples were analysed for "pseudo-total" contents of As (e.g. As_T) after digesting the soil in concentrated HNO_3 and H_2O_2 ($5HNO_3$: $1H_2O_2$, and 1:12 solid:solution ratio) by stepwise heating up to 180°C using a Milestone Vario EL III for 55 min. The concentration of elements was determined by ICP-OES (Vista Pro-Axial, Varian) in accordance with US EPA method 200.7:2001. Quality control was periodically carried out with reference materials ERM CC 141 and deviations were within ±10% of the certified values. Available As concentrations (e.g. EDTA-extractable As_{EDTA}) were determined by the EDTA extraction protocols for IRMM BCR reference materials CRM 484: 5 g soil/50 ml EDTA concentration 0.05 mol/L pH=7.00.The concentration of available As was determined by ICP-OES (Vista Pro-Axial, Varian).

Geochemical mapping

The GIS mapping technique was used to produce the spatial distribution maps of arsenic concentrations in Vojvodina Province soil. The software used for the mapping and spatial analysis was ESRI ArcGIS Geostatistical Analyst 10. The arsenic concentration was interpolated with the geostatistical analyst using a spatial interpolation method of inverse distance weighting (IDW) from ArcGIS 10. Grid used 4 × 4 km units with available input points.

Statistical analysis

Parameters of descriptive statistics (minimum, maximum and mean value, median value, standard deviation, coefficient of variation and percentiles) were shown for arsenic content (mg kg^{-1}) in agricultural soils of Vojvodina Province. All statistical parameters were shown in tables and box-plots graphs. The significance of the differences in the arsenic content between the geomorphological units and soil types were determined using the Duncan multiple range test ($p \leq 0.05$). In order to confirm the relationship among content of arsenic and different chemical traits, a Pearson's correlation analysis was applied to dataset. All statistical analyses were performed using the data analysis software system Statistica for Windows, version 12 (Dell 2015).

RESULTS and DISCUSSION

Arsenic concentration in soil

The obtained results of As_T were within interval 1.0-31.4 mg kg^{-1}. The average concentration of As was 8.4 and 0.4, with median 8.3 and 0.3 mg kg^{-1} for pseudototal and available content, respectively. (Fig. 2). Variation coefficient value CV (31.2%) for As_T points out medium heterogeneity of tested soil samples (Fig. 2). The obtained average concentrations of As suited to concentration for non-contaminated soils which ranged from 0.1 to 10 mg kg^{-1} (Kabata-Pendias and Pendias, 2001).

Based on the GEMAS project, median As concentrations in an aqua regia extraction determined by ICP-MS were 5.7 mg/kg for the agricultural land (Ap horizon, 0–20 cm) (Tarvainen et al., 2013). In present study, median value was higher than EU median value and suited with median value in the agricultural soils of southern Europe, which amounted to 8 mg kg^{-1}. The dominant feature is the southern margin of the former glacial cover seen in the form of a sharp boundary between northern and southern European As concentrations. Based on the GEMAS, the As content in grazing land (0–10 cm) from Vojvodina Province area was within 5.75 and 9.68 mg kg^{-1} (Tarvainen et al., 2013).

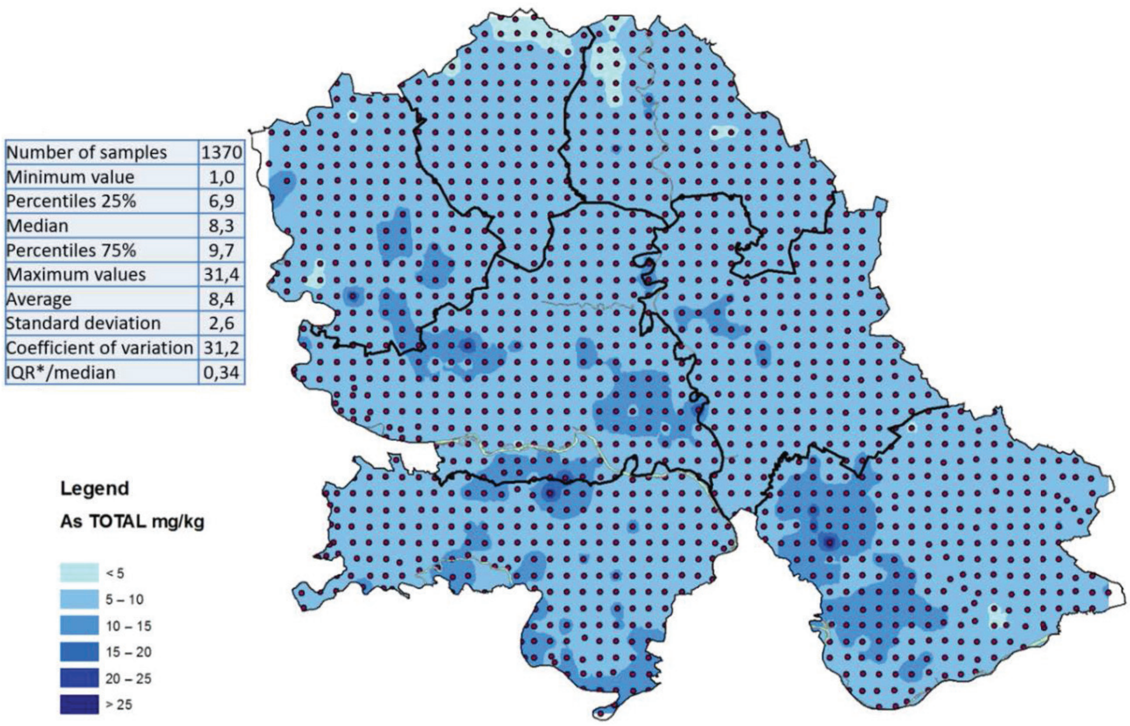

Figure 2. Spatial distribution of arsenic with statistical summary of total content (mg kg^{-1}) in agricultural soils of Vojvodina Province

Table 1
Correlation coefficients between total, available content of arsenic and basic physicochemical soil properties, for observed samples of agricultural soils in Vojvodina

	As_T [mg kg^{-1}]	As_{EDTA} [mg kg^{-1}]
pH KCl	-0.089**	-0.030
pH H_2O	-0.058	-0.025
$CaCO_3$[%]	-0.112**	-0.119**
OM [%]	0.117**	0.046
N_T[%]	0.097**	0.018
AL-P_2O_5[mg/100g]	-0.031	0.209**
AL-K_2O [mg/100g]	0.037	0.144**
Clay [%]	0.176**	0.013
Slit [%]	0.398**	-0.075*
Fine sand [%]	-0.340**	0.015
Coarse sand [%]	-0.024	0.063*
As_T[mg/kg]	1.000	0.053
As_{EDTA}[mg/kg]		1.000

* p<0.05; ** p<0.01

According to the established correlations shown in Table 1, As_T was found to be significantly negatively correlated with pH value (in KCl) and $CaCO_3$ content and significantly positively correlated with organic matter contents and total nitrogen content in soil. Available content of As_{EDTA} was significantly negatively correlated with $CaCO_3$ content.

Available content of As_{EDTA} was significantly positively correlated with nutrients (easily accessible phosphorus and potassium), which indicates that this element can be introduced in the soil using mineral fertilizers.

Clay fraction was in significant positive correlation (r=0.176) with As_T content, while was not in significant correlation with As_{EDTA} content. Silt fraction content was in significant positive correlation (r=0.398) with As_T content, while silt fraction content was in significant negative correlation (r=-0.075) with available As_{EDTA} content (Tab. 1). Fine sand fraction was in significant negative correlation (r=-0.340) with As_T content, while coarse sand fraction was in significant positive correlation (r=0.063) with As_{EDTA} content (Tab. 1). Based on established correlations, the effect of different soil particle sizes on availability of As was proven. Availability decreases with higher proportion of clay and slit and opposite, availability increases with higher proportion of sand. In general, clay particulates present negative charge, tends to undertake sorption of cations, and they are associated with As retention in soil (Hooda, 2010).

Only four samples were above 25 mg kg^{-1} for As_T, which is national maximum allowable concentration (MAC) for agricultural soils as prescribed by the laws of the Republic of Serbia (OG 23/94, 1994). These samples belong to the District of Srem, South Banat and two samples are from the South Bačka District.

Arsenic concentration in soil along geomorphological units

Based on As concentration along geomorphological units (Bukurov, 1972), As_T is higher on mountains (10.4 mg kg^{-1}) and lower on the sandy area (5.6 mg kg^{-1}) with statistical difference among the other units (Fig. 3, 4). Oppositely, As_{EDTA} is higher on sandy area (0.6 mg kg^{-1}) and lower on the mountains (0.3 mg kg^{-1}), which proves effect of organic matter and clay on As availability.

As spatial distribution indicated, the majority of Vojvodina Province area has geochemical origin of As. Regarding the pedogenesis of Vojvodina soils, the relief is the dominant factor compared to the other pedogenetic factors. Alluvial plains and mountains have higher geological and pedological diversity, unlike sandy areas, loess plateaus, Upper Pleistocene and alluvial terraces (Zivkovic et al.,1972).

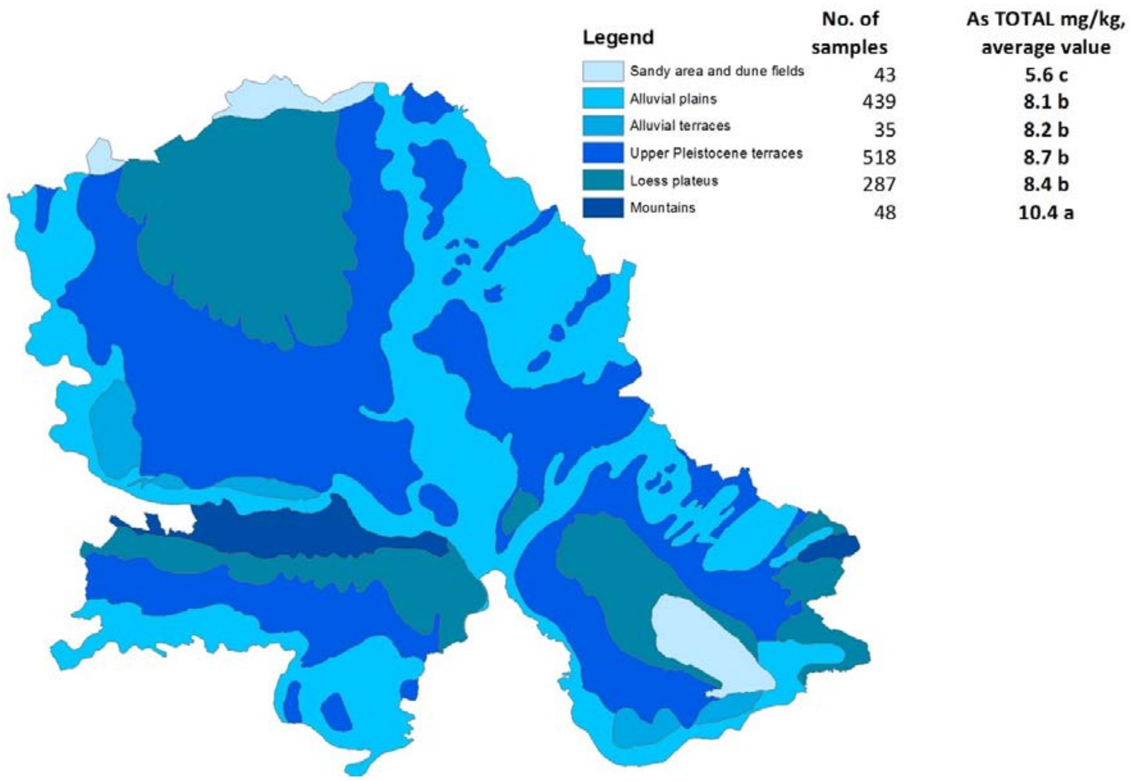

Figure 3. Spatial distribution of arsenic along geomorphological units with statistical summary of pseudototal content (mg kg^{-1}) in agricultural soils of Vojvodina Province, values are marked with same letter do not differ statistical significance for the level of importance α=5% (according to the Duncan multiple range test)

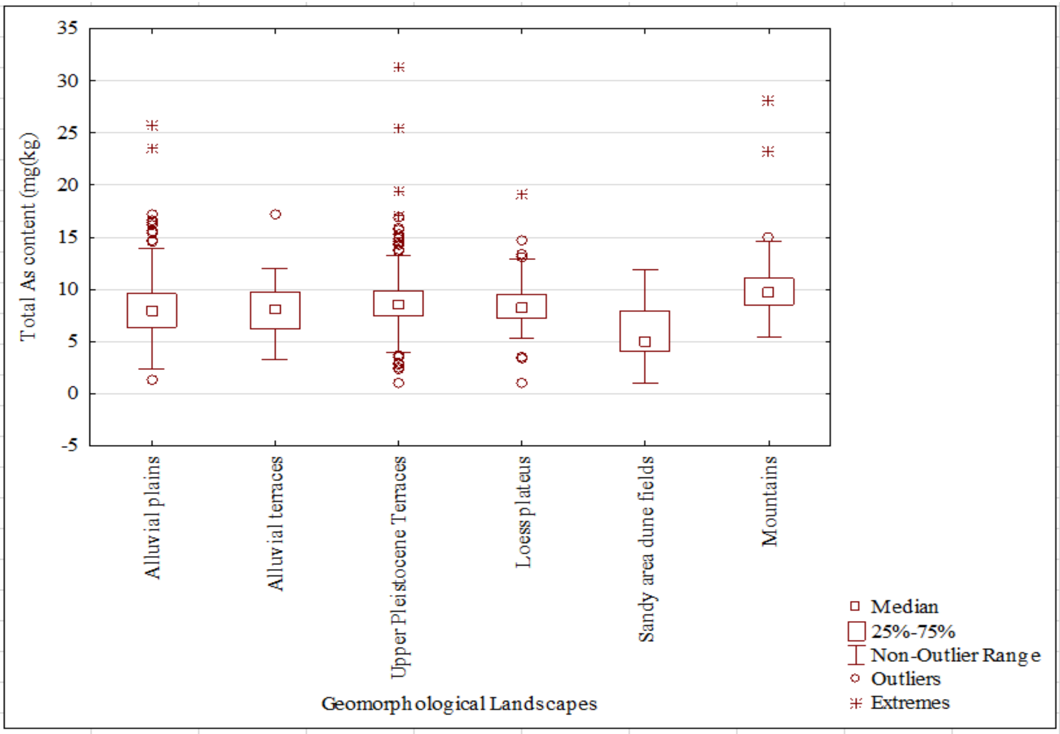

Figure 4. Box-plot graphical display of pseudototal arsenic content (mg kg^{-1}) along geomorphological units of Vojvodina Province

Arsenic concentration in soil along different soil types

The distribution of As in soils varies with soil type, depending on the nature of the parent material. Average values of As_T concentrations according to the soil types coincide with main geomorphological units where soils had been formatted.

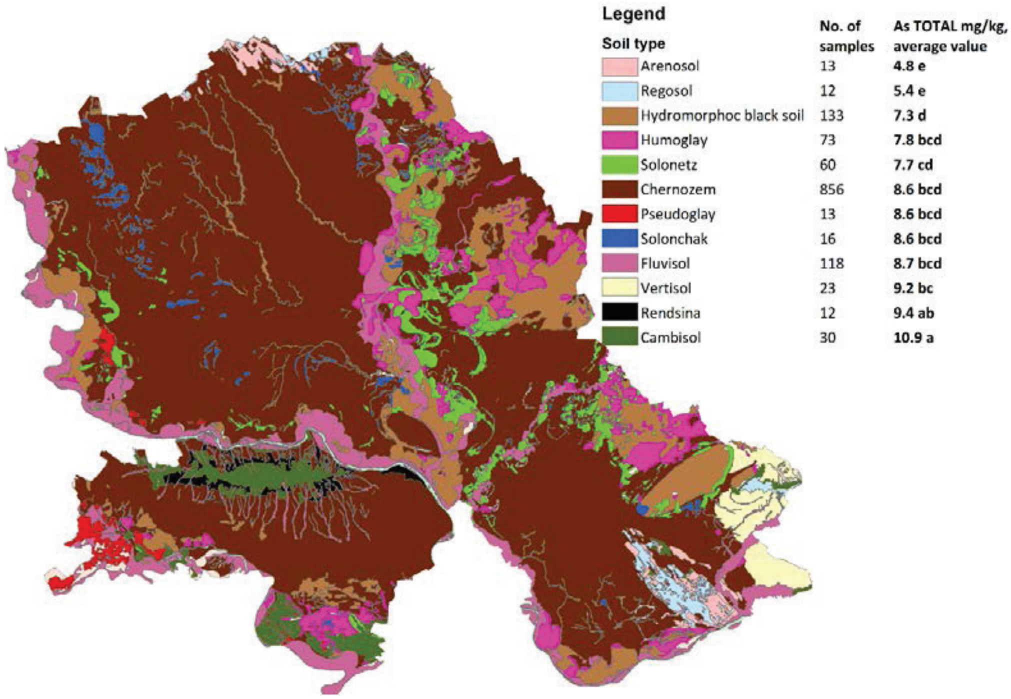

Figure 5. Spatial distribution of arsenic along different soil types with statistical summary of pseudototal content (mg kg^{-1}) in agricultural soils of Vojvodina Province

As_T is higher in cambisol (10.9 mg kg^{-1}) which is typical soil type on mountains and lower in arenosol (4.8 mg kg^{-1}) which is typical soil type on sandy area (Fig. 5,6).

According to established statistical difference between soil types, weakly developed soils arenosol and regosol are separated into one group (Fig. 5).

Generally, comparing the survey of As content in different soil types in soils of central Serbia (Mrvić et al., 2013), distribution of As content along soil types is similar, but in present study higher concentration was established.

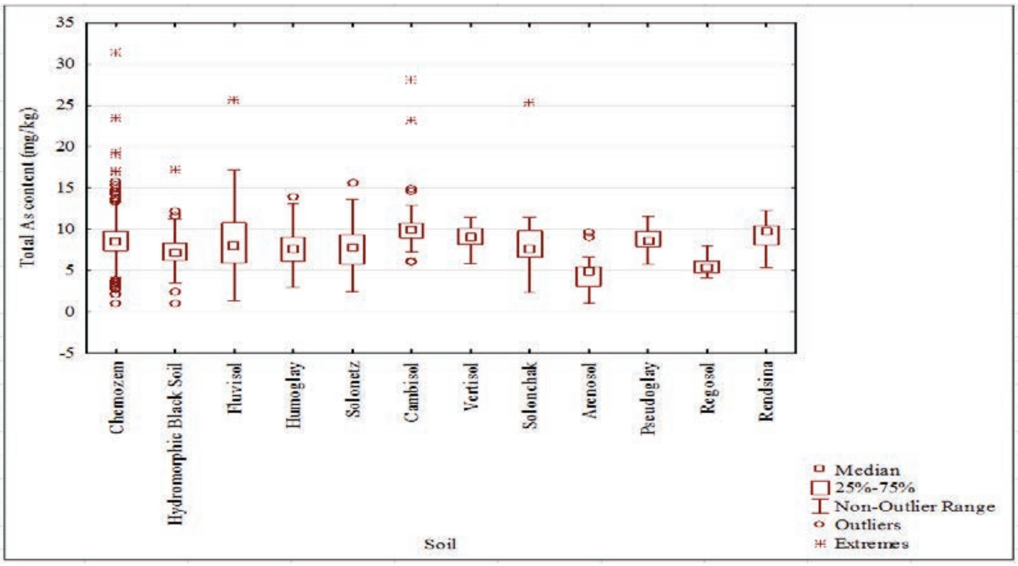

Figure 6. Box-plot graphical display of pseudototal arsenic content (mg kg^{-1}) along soil types of Vojvodina Province

Average values of As in chernozem, most frequent soil type in Vojvodina, was 8.6 and 0.4 mg kg^{-1} for pseudototal and available content, respectively. Median value was 8.5 mg kg^{-1} for As_T pseudototal content, which is much higher than reported median value for central Serbia area of 4.7 mg kg^{-1} (Mrvić et al., 2013).

CONCLUSIONS

The average concentration of As in agricultural soils of Vojvodina Province was 8.4 mg kg^{-1} for pseudototal content which suited to concentration for non-contaminated soils.

Based on established correlations, the effect of different soil particle sizes on availability of As was proven. Availability decreases with higher proportion of clay and slit.

As spatial distribution proved, the majority of Vojvodina Province area has geochemical origin of As.

The obtained results show that measured levels of As in the soil are not limiting factors for safe food production in Vojvodina. The results emphasize the importance of knowing the spatial determinants of geomorphological units and soil types in establishing a permanent monitoring.

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Management of Contaminated Sites in the Republic of Serbia

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ABSTRACT

The paper shows the way of managing the sites on which the presence of localized soil contamination has been confirmed, and implementation of the rehabilitation and remediation process in the Republic of Serbia. Localized contamination is linked to the areas of increased industrial activity, inadequately organized dumpsites, mineral extraction sites, military warehouses and areas in which accidents have occurred.

Since 2006 Serbian Environmental Protection Agency started creation of National Cadaster of contaminated sites. Data for Cadaster is collected from Local Governments and industry's based on the Questionnaire for Determination of Contaminated Sites with the instruction for completing. The Cadaster provide systemized data on pollution sources such as type, amount, manner and place of discharge of pollutants into the soil, so the measures of prevention, rehabilitation and remediation can be implemented. There are two technical guidelines for identification, addressing and remediation of industrial environmental hotspots:

1. Questionnaire for identification of contaminated sites. The questionnaire consists of general information about a site, and specific information depending on the type of contamination on the site. The most important data include the amount of pollution, the physical condition of the polluter and the period of pollution/dumping/production, while the industrial and commercial sector specify the type of industrial/commercial activities or facilities that produced the pollution, as well as the number of employees for certain periods of production. At the base of the data about a possible influence of contamination on human health and/or the environment, an additional estimation related to potential hazard to human health and/or the environment should be performed.

2.Classification system with criteria for the assessment of the status of highly threatened environment, the status of threatened environment and establishes criteria for the identification of restoration and remediation priorities (Official Gazette of RS, No. 22/2010). However, the classification system is too complicated and there is not sufficient administrative and financial capacity to implement it.

Article 34 in the new Law on Soil Protection (Official Gazette of RS, No. 112/2015), describes the basis for developing the methodology for creation of the “Cadaster of contaminated sites”. According to the Law, "Cadaster of contaminated sites" is a database of polluted, endangered and degraded soils and it's an integral part of Soil information system which is maintained by the Environmental Protection Agency. In line with this and other laws, state organizations, local authorities and polluters are obliged to provide information about the quality and state of the soil to the Environmental Protection Agency.

In the territory of the Republic of Serbia 709 sites containing potentially contaminated and contaminated sites were identified. By division into main types of localized sources of soil contamination, in 2016 as well as in the previous years, the largest share in the total number of sites have municipal waste landfills with 31.17%.Out of the total number of 709 sites recorded in the Cadaster, 557 sites are registered and 152 are estimated. According to the *List of potentially soil polluting activities* in Annex II of the Proposal for a Directive of the European parliament and of the council establishing a framework for the protection of soil and amending (Directive 2004/35/EC), sites such as former military sites, petrol and filling stations, dry cleaners, waste water treatment installations and pipelines for the transport of dangerous substances are not included in Cadaster. Out of 709 sites, 478 are in need of investigation or still to be investigated and 103 are currently under investigation. There are 93 sites in need of remediation and 564 sites might need remediation. In the period 2008-2015 the Ministry of Agriculture and Environmental Protection issued approvals for 91 projects for rehabilitation and remediation. In 2015, the Ministry adopted the Rulebook on the methodology for the development of projects of rehabilitation and remediation (Official Gazette of RS, No. 74/2015).

KEY WORDS: Cadaster, Contaminated sites, municipal waste landfills, investigation, rehabilitation and remediation.

INTRODUCTION

Soil is a conditionally renewable natural resource that is expected to meet increasing needs for food, fiber and fuel production under the pressures of urbanization and infrastructure building. Soil is also supposed to provide key ecosystem services. The main characteristic of soil is fertility - presence of substances (water, mineral and organic substances, oxygen) necessary for plant growth and development. Providing primary production in terrestrial ecosystems, the soil ensures around 99% of global food supply for human race and is the prerequisite for survival of life on Earth (FAO, 2007). From that reason it is necessary to maintain its main functions and quality. Soil is a disappearing resource. Almost 1000 m^2 of agricultural land and areas of natural land disappear each year in the European Union, being converted into artificial surfaces (Prokop et al., 2011). More and more soils are under the pressure of degradation and as a result, ecosystem services are less and less provided. Soil degradation may be defined as a group of processes caused by human activity, which prevent present and future capacities of soil as the condition of survival of life on Earth (Sekulić et al., 2003). When the functions and quality of the soil are impaired once, its regeneration may be very difficult and expensive. Soil is one of the most important natural resources and is an invaluable good group or individual.

Monitoring of the condition of land is performed by systematic observation of indicator values, in other words, by monitoring negative impacts on the soil, as well as the state, measures and activities undertaken with the view to reducing such impacts and raising the quality level of the soil and the entire environment. Soil protection is ensured by measures of systematic soil quality monitoring, by using soil degradation risk assessment indicators, as well as by implementing land rehabilitation programs aimed at mitigating the impacts of contamination and degradation of land space, caused either by natural factors or by human activity.

The establishment of systematic monitoring of the soil condition in the Republic of Serbia is legally based on the Law on Environmental Protection (“Official Gazette of RS” No. 135/2004, 36/2009, 36/2009 - other law, 72/2009 – other law and 43/2011– Decision of SC and 14/2016), Law on Soil Protection („Official Gazette of RS“, No.112/2015), Law on Agricultural Land (“Official Gazette of RS” No. 62/2006,65/2008 – other law and 41/2009) and has been harmonized with the objectives defined in the national programs and strategies National Program of Environmental Protection (“Official Gazette of RS”, No. 12/2010) and the National Strategy of Sustainable Development of the Republic of Serbia (“Official Gazette of RS”, No. 57/2008), as well as the Action Plan for Implementation of the Sustainable Development Strategy (“Official Gazette of RS”, No. 22/2009) (Vidojević et al., 2015). The basis for land monitoring is the Regulation on the program for systematic monitoring of the soil quality, indicators for evaluation of soil degradation and methodology for preparation of remediation program (“Official Gazette of RS”, No. 88/2010). The Regulation has been harmonized with the recommendations provided in the Proposal for a Soil Framework Directive-COM (2006)232. Restoration and remediation priorities are identified on the basis of the Regulation which establishes criteria for the assessment of the status of highly threatened environment, the status of threatened environment and establishes criteria for the identification of restoration and remediation priorities (“Official Gazette of RS“, No. 22/2010). The Regulation on the content and method of management of the environmental protection information system, on the methodology, structure, common bases, classes and levels of data collection, and on the content of publicly released information (“Official Gazette of RS”, No. 112/2009) provided a basis for drafting the Rulebook on the National List of Environmental Protection Indicators (“Official Gazette of RS”, No. 37/2011). The National List of Indicators contains the methodology of Data Collection, the Manner and Time Frames for Submitting Data, Information, Indicators and Reports in the Information System. In the National List of Indicators there is a set of land indicators providing systematic information on the land condition, changes of land use and factors of soil degradation. One of listed indicators is “Management of Contaminated sites in the Republic of Serbia”. The indicator shows the way of managing the sites on which the presence of localized soil contamination has been confirmed, and implementation of the rehabilitation and remediation process. Localized contamination is linked to the areas of increased industrial activity, inadequately organized dumpsites, mineral extraction sites, military warehouses and areas in which accidents and soil contamination have occurred.

Since 2006 Serbian Environmental Protection Agency (SEPA) started creation of National Cadastre of contaminated sites. Data for Cadastre is collected from Local Governments and industry's based on the Questionnaire for Determination of Contaminated Sites with the instruction for completing. The Cadastre provide systemized data on pollution sources such as type, amount, manner and place of discharge of pollutants into the soil, so the measures of prevention, rehabilitation and remediation can be implemented. There are two technical guidelines for identification, addressing and remediation of industrial environmental hotspots:

(1) Questionnaire for identification of contaminated sites. The questionnaire consists general information about a site, and specific information depending on the type of contamination on the site. The most important data include the amount of pollution, the physical condition of the polluter and the period of pollution/dumping/production, while the industrial and commercial sector specify the type of industrial/commercial activities or facilities that produced the pollution, as well as the number of employees for certain periods of production. At the base of the data about a possible influence of contamination on human health and/or the environment, an additional estimation related to potential hazard to human health and/or the environment should be performed.
(2) Classification system with criteria for the assessment of the status of highly threatened environment, the status of threatened environment and establishes criteria for the identification of restoration and remediation priorities (Official Gazette of RS, No. 22/2010). However, the classification system is too complicated and there is not sufficient administrative and financial capacity to implement it.

MATERIAL and METHOD

Article 34 in the new Law on Soil Protection (Official Gazette of RS, No. 112/2015), describes the basis for developing the methodology for creation of the “Cadastre of contaminated sites”. According to the Law, "Cadastre of contaminated sites" is a database of polluted, endangered and degraded soils and it's an integral part of Soil information system which is maintained by the SEPA. In line with this and other laws, state organizations, local authorities and polluters are obliged to provide information about the quality and state of the soil to the SEPA.

Investigation of potentially contaminated industrial sites

Investigation of potentially contaminated industrial sites is a part of the GEF-funded project "Enhanced Cross-sectoral Land Management through Land Use Pressure Reduction and Planning" which is implemented by United Nations Environment Programme (UN Environment) in close cooperation with the Ministry of Environmental Protection (MoEP) and SEPA in the period 2015-2018. The project is implemented in three Components: 1. Enabling institutional, policy and scientific environment for long-term integrated land use management; 2. Landscape-level management of natural resources in Serbia; and 3. Capacity building, awareness raising and sharing learned lessons with main stakeholders and wider public based on sustainable monitoring system. The project aims at providing the lacking methodologies, knowledge and coordination mechanisms for sustainable and integrated management of soil as a natural resource. It supports the establishment of state, provincial and local networks for land use and soil quality monitoring strengthen administrative capacities and contributes to enhanced cooperation among institutions dealing with land degradation issues. The project further on supports development of a Cadastre of contaminated sites and of a policy framework for integrated land use management and its implementation at local level. In addition to MoEP and SEPA, the following professional and scientific institutions provide support for Project implementation: Provincial Secretariat for Urbanism and Environmental Protection, Institute of Soil Science Belgrade, Institute of Field and Vegetable Crops Novi Sad, Public Health Institute of Belgrade, Geological Survey of Serbia, and Republic Hydrometeorological Service of Serbia.
In the first phase of the Project, 32 potentially contaminated sites have been selected in accordance with project criteria from the Cadastre managed by the SEPA. Data and information on previous land use, type of industry, surface area, type and quantity of hazardous substances at the location and on the surrounding area, soil and groundwater quality, as well as geological, pedological and hydrological features were collected from previous studies and though numerous consultations. Collected data are sorted and transferred to digital format in order to complete a database of contaminated sites. Field missions to identified sites were conducted in the period September-December 2016 with the purpose to identify receptors of pollution and potential exposure routes, and to prepare and elaborate sampling programs. In 2017, soil sampling is being conducted on 32 industrial sites.
The expected result of the project is to compile a list of prioritized sites for remediation based on conducted research and a preliminary assessment of the risks to human health and the environment on selected sites. For this purpose, project team has applied Preliminary Risk Assessment Model for the identification and assessment of problem areas for Soil contamination in Europe - PRA.MS. The PRA.MS model is based on the scoring criteria in order to rank sites for the identification of problem areas, using the Source-Pathway-Receptor paradigm in the design of the conceptual model, where contaminated soil or waste disposed on/into soil represents a source.

RESULTS and DISCUSSION

In the territory of the Republic of Serbia 709 sites containing potentially contaminated and contaminated sites were identified. Out of the total number of 709 sites recorded in the Cadastre, 557 sites are registered and 152 are estimated. According to the List of potentially soil polluting activities in Annex II of the Proposal for a Directive of the European parliament and of the council establishing a framework for the protection of soil and amending (Directive 2004/35/EC), sites such as former military sites, petrol and filling stations, dry cleaners, waste water treatment installations and pipelines for the transport of dangerous substances are not included in Cadastre. Currently, 103 sites are under investigation, 478 sites are in need to be investigated. According to the Cadastre, remediation is completed on 52 sites, 93 are in need to be remediated and 564 sites might need remediation. In the period 2008-2015 the MoEP issued approvals for 91 projects for rehabilitation and remediation. In 2015, the Ministry adopted the Rulebook on the methodology for the development of projects of rehabilitation and remediation (Official Gazette of RS, No. 74/2015). By division into main types of localized sources of soil contamination, in 2016 as well as in the previous years, the largest share in the total number of sites have municipal waste landfills with 31.17% (Figure 2).

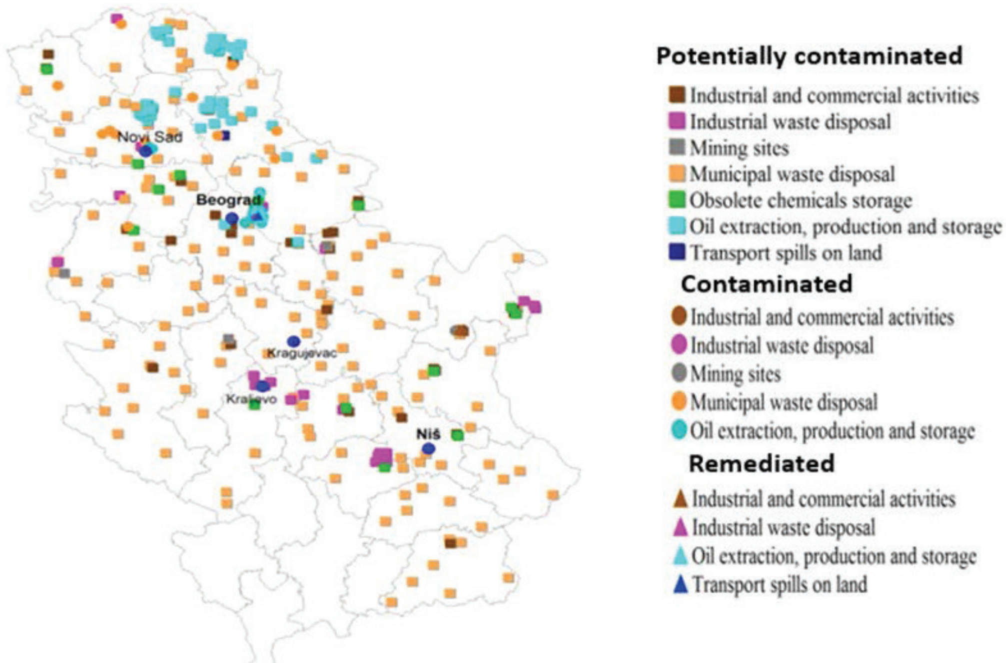

Figure 1. Locations from the Cadastre according to the status based on the research

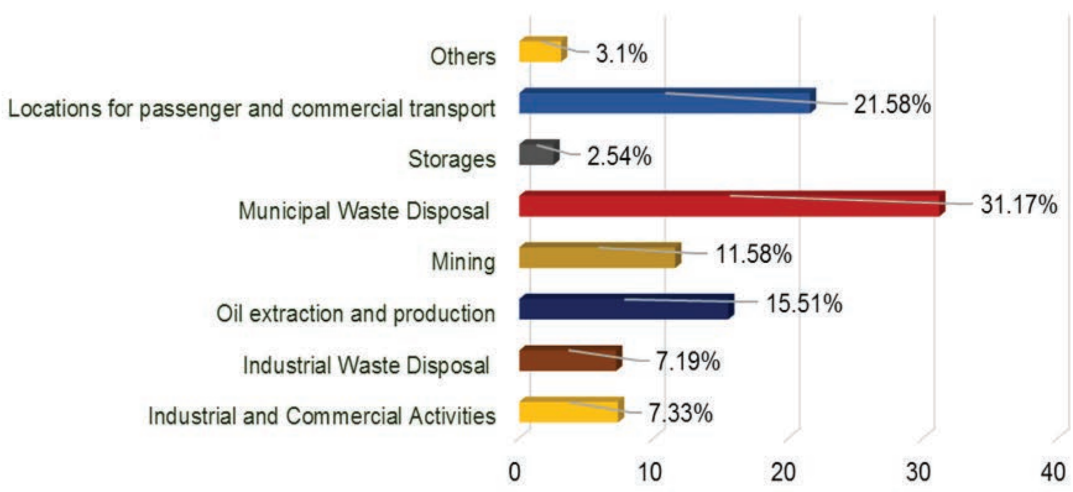

Figure 2. Breakdown of activities causing local soil contamination (%)

In the period 2013-2016, the Provincial Secretariat for Urban Planning, Construction and Environmental Protection conducted a survey of the quality of soil near landfills in 28 municipalities in the Autonomous Province of Vojvodina. A total of 143 samples taken from a depth of maximum 1 m were analysed. On the basis of the results it can be concluded that in the vicinity of the surveyed municipal waste landfills, the limit and remedial values for the soil have been exceeded ("Official Gazette of the RS", No. 88/2010). Concentrations of Cd and PAHs are increased, while the remedial value in the small number of samples was exceeded for Pb, Ni, Zn, Cu, Cr, Hg, and As (Figure 3).

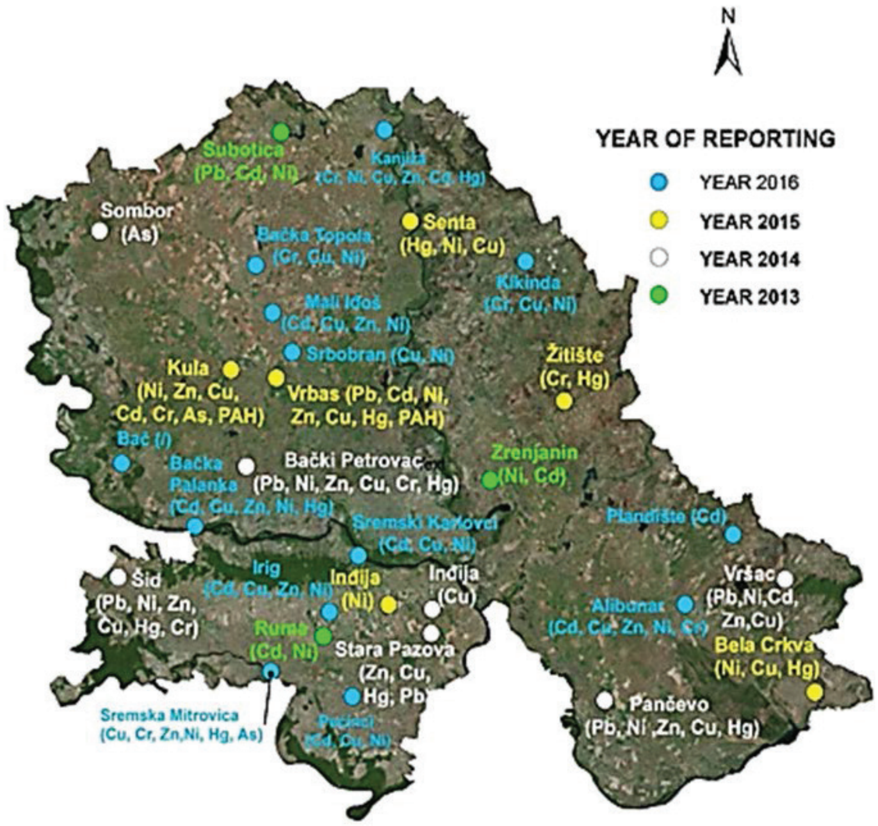

Figure 3. Locations of tested landfills and hazardous and harmful substances which exceeded the limit and remedial value in the period 2013-2016

CONCLUSIONS

Taking into consideration the current state of the soil in the Republic of Serbia, it is necessary to apply science and technology in order to improve the existing methodology for sustainable and integrated land management as a natural resource. As one of the most important step in prevention of land degradation is well organized management of contaminated sites. Prevention of land degradation is currently limited due to the lack of comprehensive data. The Cadastre of contaminated sites is precisely that bridge between complete lack of data and information of the status of certain locations and the establishment of their good management. According to the data from Cadastre of contaminated sites managed by the SEPA, it can be concluded that preliminary studies are conducted at most of the identified potentially contaminated sites in Serbia. The greatest number of registered sources of localized soil pollution are related to municipal waste disposal sites, oil extraction, production sites and industrial and commercial activities. However, the data collected so far are not at the same level of quality at different locations, therefore it is not possible to estimate a comparable level of pollution at different potentially contaminated and contaminated sites. Additional and more detailed surveys are needed in order to update the Cadastre and the results from these surveys will be used for creation of National priority list for restoration and remediation of most polluted localities. Also, by strengthening administrative capacities, it contributes to greater cooperation between institutions dealing with land management issues through reduction and planning of pressure reduction on land. By exchanging experiences in the implementation of good practices in the management of degraded land and the prevention of soil loss, the pressure on natural ecosystems is reduced it affects food safety and, consequently, the safety of human health.

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Impacts of fertilization and liming on yield of grassland biomass and chemical reaction of Rekultisol

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ABSTRACT

The research of biological phases of soil reclamation by seeding the grassland has been conducted on the Deposol at internal disposal area for overburden from Raskovac open pit in Stanari coal mine (Republic of Srpska, Bosnia and Herzegovina). The aim of this survey refers to implementation of biological phase of reclamation and improvement of technogenic soil fertility, type Rekultisol. The survey task refers to measurement of impact of fertilization and liming on yield of biomass grassland and chemical properties of forming Rekultisol. The survey expended through three-year period (2011–2013). Three grass-leguminous mixtures and one grass mixture have been studied; altogether four treatment of various doses mineral fertilizer and lime. The research covers the selection of treatment with the most productive green mass and impact of chemical reaction of Rekultisol. Statistical analysis of measuring quantitative properties of vegetable mass has been conducted by method of ANOVA, 3x4x4. The sandy-loam Deposol at the beginning of research had unfavorable physical and chemical properties. The applied treatments and interactions bear impact on measuring quantitative properties of researched mixtures and chemical properties of Rekultisol. The TDS-3 mixture had the biggest green mass production (25.8 t/ha) in 2013. Techno-pedogenesys process in three years has resulted in forming Rekultisol with improved chemical properties with initiated process of humification and mineralization regarding to the initial Deposol. The application of liming caused the increase of pH of Rekultisol. The biological reclamation in researched agro-ecological conditions has been successfully conducted by seeding grasslands, raising selected species in grass-leguminous mixtures and application of optimal agromeliorative measures.
Key words: technosols, reclamation, grass-leguminous mixture, soil pH.

INTRODUCTION

Main objective of the reclamation of degraded areas, caused by open pit mine exploitation of the ore reserves, is to establish the management functions on these newly created technogenic soils (technosols). The main task of all these man-built terrestrial ecosystems is to stabilize and revive production and ecological functions of a technogenic soil, ie Deposol (the surface layer of the disposal area for overburden).

The fertility of the Deposol and most other types of technogenic soils (e.g. mine soils) is usually low. The concentration of the Deposol with the basic biogenic elements (N, P and K) is within or below the minimum concentrations (Dvurechensiy and Seredina, 2015; Pivić et al., 2011; Sheoran et al., 2010; Marković, 1996; Veselinović, 1995; Coppin and Bradshaw, 1982; Antonović et al., 1978). In addition to the deficit of nutrients, technogenic soils have low content of pedobi'os and organic matter, and poorly developed adsorptive complex (Rasulić et al., 2005). Shukla et al. (2004) states the following disorders in technogenic soil: loss of aggregate and soil structure, decrease in soil C concentration, increase in volume, and decrease in porosity.

The results of the past physical and chemical analyzes of Deposol at disposal area for overburden at the Stanari mine found that they have favorable physical - mechanical but unfavorable chemical properties (Malić, 2015; Malić i Marković, 2012; Malić, 2010). The same authors state that, based on the content of organic matter, the researched Deposol belongs to the class of low and medium content, while there is no pure humus and nitrogen. According to the content of P_2O_5 and K_2O in the Deposol, they are classified as very poorly secured by these elements. The Deposol is characterized by a non-carbonate substrate, a strong unsaturation with base cations, a medium and highly acidic chemical reaction. The fact that the composition of organic matter is very low makes this one of the biggest problems in Stanari Deposols.

A significant part of the agricultural reclamation refers to the establishment of artificial grassland. Studies on the methods of grassland establishment in the reclamation process and potential yields have started in 2008 at the Deposols of Raškovac open pit external disposal area in Stanari (Malić and Lakić, 2011).

Pioneer species in agricultural reclamation include species from the families of Poaceae and Fabaceae. Seeding grasslands establishment through seeding grass-leguminous mixtures and pure cultures of certain grass species is significantly present at mine in Bosnia and Herzegovina, Serbia and abroad. Since the earliest reclamation works in the USA, a vast expanse of recultivated areas has been under seeding meadows and pastures (Thorne, 2010, Skousen and Zipper, 2010, Lyle, 1987, Vogel and Berg, 1968). Normally, most commonly sown species during reclamation process are grasses (family Poaceae) because they are producing a large amount of biomass and quickly adapt to specific and harsh environmental conditions. For biological reclamation most commonly used grass species are from the following genus: *Poa*, *Festuca*, *Lolium*, *Panicum*, *Agrostis*, *Phleum*, *Dactylis* (Malić and Lakić, 2011, Smith et al., 2002). Participation of leguminous in mixtures depends on the type and characteristics of Deposols used for reclamation. In addition to the potential yields of forage and hay, multiple significance of all types of grasslands is reflected in the changes of basic physical, chemical and biological properties of Deposol by increasing its fertility.

MATERIAL and METHOD

The coal basin Stanari is located between 44°40' and 44°50'N and 17°45' and 18°00'E, in the northern part of the Republic of Srpska and Bosnia and Herzegovina. Research on biological reclamation of a direct type was carried out in an experimental field (GPS Coordinates: y = 6.486.822.33; x = 4.957.645.63; altitude 220 m a.s.l) at the internal disposal area for overburden of the excavation from the surface mine Raškovac in the lignite coal basin Stanari: "EFT - Mine and Thermal Power Plant Stanari". The survey was conducted in a three-year period (2011-2013). Part of the disposal area for overburden site where the experimental field is located was formed during 2010.

The three-factorial experiment was set by the random block method in four repetitions. The experiment plots area is 10 m^2 (5 x 2 m). The distance between the plots is 50 and 80 cm, and between the blocks is 1 m. Plots are without inclination.

The first factor of research is year (factor A), with three treatments. The second factor is diferent grass and leguminous species in mixtures (factor B), with four treatments. The third factor is agromeliorative measures (fertilization, liming and mulch, factor C), with four treatments (Table 1).
Statistical analysis of the measured results yield green mass has been conducted by the ANOVA method, 3x4x4. Establishment of the seeding grassland was carried out during the spring sowing period in 2011. Seeding rate amounted 45 kg/ha. When the crops reached their maximum growth, mowing – lawn mulcher was performed.

Table 1
Treatments three-factorial trial

Factors	Treatments			
Factor A (three years)	a_1 (2011)	a_2 (2012)	a_3 (2013)	
Factor B (three grass-leguminous mixtures and one grass mixture)	b_1 (TDS-1): *Festuca arundinacea* Schreb. 25%, *Festuca rubra* L. 20%, *Dactylis glomerata* L. 10%, *Phleum pratense* L. 10%, *Trifolium repens* L. 10%, *Trifolium pratense* L. 10%, *Medicago sativa* L. 10%, *Poa pratensis* L. 5%			
	b_2 (TS-2): *Festuca arundinacea* Schreb. 40%, *Festuca rubra* L. 20%, *Poa pratensis* L. 20%, *Dactylis glomerata* L. 10%, *Phleum pratense* L. 10%			
	b_3 (TDS-3): *Festuca rubra* L. 50%, *Poa pratensis* L. 30%, *Lotus corniculatus* L. 10%, *Trifolium repens* L. 10%			
	b_4 (TDS-4): *Dactylis glomerata* L. 30%, *Phleum pratense* L. 30%, *Lotus corniculatus* L. 20%, *Arrhenatherum elatius* (L.) Mert. et Koch. 20%			
Factor C (four agromeliorative measures)	c_1: $N_{90+54+54}P_{90}K_{90}$	c_2: $N_{60+54+54}P_{90}K_{90}$ + 8 t/ha $CaCO_3$	c_3: $N_{60+40,5+40,5}P_{60}K_{60}$	c_4: $N_{90+40,5+40,5}P_{90}K_{90}$ + wheat straw mulch

The third factor (C) represents dosages of mineral fertilizer (pure nutrients) applied during sowing date (doses: $N_{90}P_{90}K_{90}$, $N_{60}P_{90}K_{90}$ and $N_{60}P_{60}K_{60}$) and spring supplementation with nitrogen fertilizer two time (doses: N_{54+54} and $N_{40,5+40,5}$). The mineral fertilizer used before sowing was NPK 15:15:15, and during supplementation it was KAN (27% N). Limestone was added during the primary tillage of the Deposol (treatment c_2). After the sowing, wheat straw in the form of mulch was used on treatment c_4.

The determination of the researched types of technogenic soil was carried out according to Resulović and Čustović (2007), and the WRB classification (2014). According to the soil classification in Bosnia and Herzegovina, the newly discovered soil mines belong to the class of technogenic soils (types Deposol and Rekultisol). Deposol represents the type of surface layer of the disposal area for overburden before the beginning of the biological phase of the reclamation. Rekultisol is a layer of soil where reclamation measures have been carried out and the initial processes of humification and mineralization begin. The researched Deposol and formed geogenic Rekultisol are of a silicate subtype. According to the WRB classification (World Reference Base for Soil Resources, 2014), these soils are determined as technosols (Epiarenic and silicit material).

Geological series of roof coverings or overburden of coal layer on the surface mine Raškovac at the Stanari mine are mostly mixed sandy-pebbles, and clay zones and layers. These materials represent poorly bound and unbound sediments. The roof cover thickness varies from 10 to 60 m. The sandy material is a quartz mineralogical composition and of such low fertility when it enters the composition of the parent substrate (Okiljević and Marković, 2005). Bentonite clay is the second building material of the roof of the coal layer. The basic components of bentonite clay are: montmorillonite, kaolinite, ylit.

For the purposes of laboratory pedological research, the average samples of the Deposol were taken before the study at the beginning of 2011, and the samples of Rekultisol at the end of the vegetation in 2013. The samples were taken from a depth of 0-20 cm. The analysis of the Deposol included the examination of the following parameters (Table 2): content of organic matter (dry burning method at 550 ^oC), humus (Tjurin method), soil reaction (pH) in H_2O and 1M KCl (electrometrically combined electrode in pH-metre), total N (semimycro Kjeldahl method), plant available P and K (AL-method). At the end of the research in 2013 year, the pH value was again analysed. The classification of Deposol and Rekultisol based on the chemical reaction was carried out according to Živković (1991) for pH in H_2O, and according to Šefer-Šahtašabel for pH in KCl.

Table 2
Results of the analysis of chemical properties of Deposol

Number of sample	pH		Organic matter	Humus	Total N	AL - P_2O_5	AL - K_2O
	H_2O	KCl	(%)	(%)	(%)	mg/100g soil	
1	6.2	4.9	2.1	0.0	0.0	0.0	1.3
2	5.8	4.5	1.2	0.0	0.0	0.5	2.2
3	5.2	4.0	1.6	0.0	0.0	0.6	2.7

The basic climate indicators (precipitation and air temperature) in the researched five-year period are shown in the following tables (Table 3 and 4).

Table 3
Monthly quantities of precipitation for the period 2011-2013 (mm)

Years	Months												Σ
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2011	63	37	32	21	76	42	71	26	13	44	14	111	550
2012	86	70	4	129	154	44	44	18	80	130	77	142	978
2013	78	115	130	43	180	100	54	33	123	38	160	2	1056
$\bar{x}$	76	74	55	64	137	62	56	26	72	71	84	85	861

Table 4
Average monthly and average annual air temperature for the period 2011-2013 (^oC)

Years	Months I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	$\bar{x}$
2011	0.8	0.7	5.3	11.3	15.32	20.1	22.4	22.5	19.0	11.5	4.9	5.7	11.6
2012	3.4	-1	9,3	12.6	16.4	22	24.4	22.9	17.7	12.7	10.7	2.7	12.8
2013	4.5	4,2	7.1	14.7	13.7	23.3	22.3	22.4	15.4	13.2	8.9	3.7	12.7
$\bar{x}$	2.9	1.3	7.2	12.8	15.1	21.8	23.03	22.6	17.4	12.5	8.2	4.03	12.4

RESULTS and DISCUSSION

Three-year-long research and applying of the intensive agrotechnical measurements in the implementation of the biological phase of reclamation (by the dominance of the anthropogenic factor) resulted in formation of the Rekultisol as the thin surface layer of the technogenic soil. The researched Rekultisol is formed in the process of the direct reclamation while the lawn forming.

The crops were mulched so the dry mass stayed on the Deposol surface in the process of reclamation. Table 5 shows the average values of the green mass of the first swaths, the results of the variance analysis, and the Lsd test. The identified interaction effects are given in Figure 1 and 2.

Table 5
Average yield of green mass in t/ha, in the first swath (measurements: 13 July 2011, 30 May 2012 and 03 June 2013)

Treatments basic factors			Factor B (mixtures) b_1	b_2	b_3	b_4	$\bar{x}_C$
Factor A (years) a_1 (2011)	Factor C (agromeliorative measures)	c_1	3.7	2.9	3.8	4.3	3.67
		c_2	2.7	3.2	4.5	3.1	3.37
		c_3	1.6	2.8	5.2	2.6	3.05
		c_4	3.9	4.0	5.7	3.8	4.35
		$\bar{x}_B$	2.9	3.2	4.8	3.4	3.6
a_2 (2012)	Factor C (agromeliorative measures)	c_1	12.7	10.8	15.5	12.6	12.9
		c_2	10.2	10.7	17.3	13.1	12.8
		c_3	13.2	15.2	16.8	11.9	14.3
		c_4	16.7	13.6	17.2	10.7	14.5
		$\bar{x}_B$	13.2	12.6	16.7	12.07	13.6
a_3 (2013)	Factor C (agromeliorative measures)	c_1	22.3	19.1	22.9	16.2	20.1
		c_2	20.6	21.6	32.1	29.2	25.8
		c_3	22.9	16.1	27.4	16.2	20.6
		c_4	23.6	17.5	20.8	18.6	20.1
		$\bar{x}_B$	22.3	18.6	25.8	20.05	21.7
	$\bar{x}_{BC}$		12.8	11.5	15.7	11.8	12.98

ANOVA		A	B	C	AxB	AxC	BxC	AxBxC
$F_{calc.}$		311.48**	10.72**	1.06^{-}	1.71^{-}	3.43**	1.93**	1.08^{-}
Lsd	0.05	1.41	1.63		2.83		3.27	-
	0.01	1.86	2.15		3.73		4.3	-

With the researched mixtures, yields during the research were very variable in some of the treatments. Particularly large differences in yield are noticeable by years of research. The results in Table 5 indicate the increase of the average yield of the green matter during the survey. The average value of yield of the green mass in the first year was 3.6 t/ha, in the second 13.6 t/ha and in the third one was 21.7 t/ha of green mass. The analysis of the variance shows the statistically significant influence of the basic factor of the year (A), different mixtures (factor B), and as well as the interactions of factor A and C (year x agromeliorative measurements) on the achieved results, while the interaction of relations B and C (mixture x agromeliorative measure) is significant. The factor of a year with three treatments had a consonant statistical statistical significant impact on the green mass. yield. The reason for this is different amount of precipitation during the spring growth of grass and legumes, which was 97 mm for the period April-May in 2011, in 2012 198 mm, and in the last year of the survey it was 280 mm.

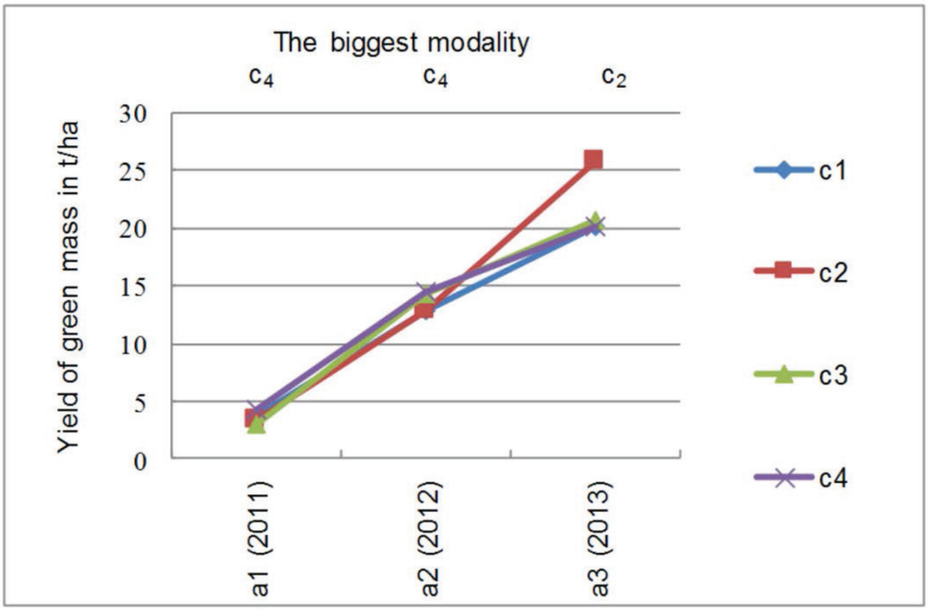

Figure 1. Interactive effects of research year (factor A) and agromeliorative measures (factor C) on the yield of green mass in t/ha

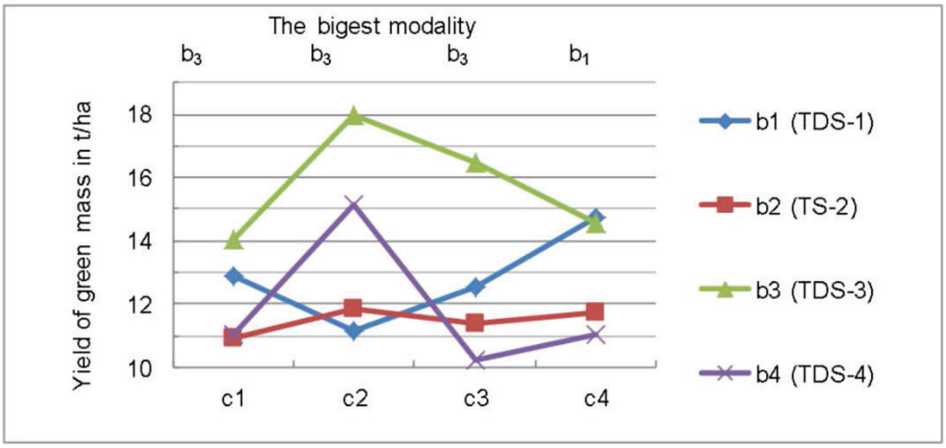

Figure 2. Interactive effects of mixtures (factor B) and agromeliorative measures (factor C) on the yield of green mass in t/ha

The analysis of the interaction effect of the years x agromeliorative measure (A x C) on the average values of yield of green mass of the first swath shows that in the first and second year there is no statistical significance between the treatment of agromeliorative measures on the yield of the green mass and the deviations of the tendencies of the modality are random. The great deviations considering the first two years appeared in the third year of the study, with the average value of the maximum yield of the green mass of all mixtures from the treatment c_2 showed a significant difference comparing it to the yield from other treatments. It means that the effect of calcification which was applied has been influenced by the increasing intensity.

From the graph relating to the interaction, the changes in the modalities of the average values of the yield results of the green mass in the first crop are noticed due to the interaction of factor B and C treatment. Particularly large changes in the yields are present in grass-leguminous mixtures (TDS-1, TDS-3 and TDS-4) in combination with treatments of agromeliorative measures c_2, c_3 and c_4. The differences of the maximum average yield of green matter between the treatment b3 and the yield of the green mass of treatment b_1 and b_2, at the treatment c_2, are statistically significant. At the treatment c_3 yield with TDS-4 mixture decreases, while the differences between treatments b_3 and b_1 are significant at the level of 5%, and the yield differentials in treatment b_2 and b_4 are significant at level of

1%. At the treatment of c_4, yield of TDS-3 mixture decreases, and TDS-1 is the most suitable formulation.

The maximum average yield of green matter in the second two years of the survey (17.3 t/ha in 2012 and 32.1 t/ha in 2013) was measured in the combination of the b_3c_3 treatment. The least variation of the yield is evident for the TS-2 mixture on all treatments of factor C, which is the result of seedling of grass species only.

The measured values of green mass yield match the results of previous research with the type of *Festuca arundinacea* Schreb. on the deposit of the outlying landfill of Raškovac, where Malić and Lakić (2011) state the maximum yield of 19.5 t/ha of green mass in the first swath at the dose of fertilizer N35+80P100K150. Lower values of the green mass of grass-leguminous mixtures are also reported by Grandt and Lang (1958), who achieved an average yield of *Medicago sativa* L., with more grass species of 8.4 t/ha, in three years of direct reclamation of Deposols in Illinois. The same authors report the yield of the green mass of the mixture *Lotus corniculatus* L. and grass of 8.1 t/ha, with a mixture of other legumes and grasses, the yield of 5.4 t/ha was measured. Moreover, with the mixture of *Lespedeza bicolor* Turcz. and grass, the yield of 4.6 t/ha was measured. Measured production of green mass of the mixture *Trifolium repens* L. and grass is 7.1 t/ha and *Trifolium pratense* L. and grass 5.1 t/ha. The measured yields of green mass in direct reclamation are significantly lower than the potential of these species in the production of green fodder (Malić, 2015). The main reason for this is the difference in the fertility of natural soils and Deposols. So, for example, the mixture of *Medicago sativa* L. and *Dactylis glomerata* L. can achieve a maximum yield of green matter of 98.8 t/ha on natural soil (Jovanović, 1963). The average yield of green matter in the mixture of *Medicago sativa* L. with perennial grasses of 56.38 t/ha is given by Tetarić et al. (1985), which represents a higher yield than the results obtained by the study. After forming the Rekultisol and establishing the permanent purpose of the technogenic surface, the use of formed lawns can be in the function of producing fodder.

The process of pedogenesis of the technogenic soil starts immediately after the completion of the digestion deposit on a single landfill, and in this way the technogenic base substrate influences the course of the reclamation. The extent and intensity of the applied agro-technical measures are interrelated with the time of the reclamation, which together affects the properties of the re-cultivated land. Beginning of the pedogenesis of the Deposol at the investigated site overlaps with the completion of the discharge of the discovery on this part of the internal landfill site Raškovac, which was carried out in late 2010. The results of the analysis of the chemical reaction of the Rekultisol at the end of the study are shown in Table 6. The possibility of raising the pH value is an important activity in the reclamation of deposits from the surface mine Raškovac, which are mostly acidic reactions.

Based on the value of the results of the analyzed chemical properties of the Rekultisol of all the average samples given in Table 6, an improvement in the pH value was observed, comparing to the values of the results in the testing of the Deposol before the start of the biological reclamation (Table 2).

The values of the active reactive reaction (pH in H_2O) of all the samples in Table 6 enter the interval from strongly acid to weak alkaline chemical reaction of the soil. The value of the pH of the sample 1 represents the soil of a highly acidic reaction. According to the sample values no. 4, 5, 7, 8, 11, 13 and 16 in these combination treatments, the Rekultisol is determined in the category of moderate or moderate acid reaction. Examined samples include all treatments with grass-leguminous mixtures (TDS-1, TDS-3 and TDS-4). As far as factor C is concerned in these samples, samples with treatments c_1, c_3 and c_4 are present. Rekultisol with the values of the pH within samples 3, 9, 12 and 15 is classified as low acidity. In this case, there was no significant change in pH compared to the applied treatments in the study. Neutral and weak alkaline reaction was determined in samples 2, 6, 10 and 14, or on parcels under treatment c_2 where calcification was performed at a dose of 8 t/ha of $CaCO_3$.

The values of the substitution reaction of Rekultisol (pH in KCl) in Table 6 assign samples 1, 4, 5, 7, 8, 11, 13 and 16 to the category of very acidic reaction. Samples 3, 12 and 15 are the categories of moderately acidic reaction. The values of pH in the sample 2, 6, 9, 10 and 14 categorize the Rekultisol into the soil of a slightly acidic reaction. Comparing the results of this division and the division of the pH into H_2O, the samples 2, 6, 10 and 14, in which the acidity is the lowest (ie, the highest pH), are the same treatment of factor C. In these treatments, calcification is applied, and the pH value in the KCl moved from 6.2 to 6.6, and belong to the category of poorly acidic reactions.

Table 6
Analyses of pH of Rekultisol at the end of 2013 year

Number of sample	Treatments	pH H_2O	KCl
1	b_1c_1 (TDS-1, $N_{90+54+54}P_{90}K_{90}$)	5.3	4.2
2	b_1c_2 (TDS-1, $N_{60+54+54}P_{60}K_{60}$ + 8 t/ha $CaCO_3$)	7.5	6.5
3	b_1c_3 (TDS-1, $N_{60+40,5+40,5}P_{60}K_{60}$)	6.3	5.0
4	b_1c_4 (TDS-1, $N_{90+40,5+40,5}P_{90}K_{90}$ + mulch)	5.9	4.8
5	b_2c_1 (TS-2, $N_{90+54+54}P_{90}K_{90}$)	5.6	4.3
6	b_2c_2 (TS-2, $N_{60+54+54}P_{60}K_{60}$ + 8 t/ha $CaCO_3$)	7.5	6.5
7	b_2c_3 (TS-2, $N_{60+40,5+40,5}P_{60}K_{60}$)	6.0	4.6
8	b_2c_4 (TS-2, $N_{90+40,5+40,5}P_{90}K_{90}$ + mulch)	5.7	4.8
9	b_3c_1 (TDS-3, $N_{90+54+54}P_{90}K_{90}$)	6.2	6.9
10	b_3c_2 (TDS-3, $N_{60+54+54}P_{60}K_{60}$ + 8 t/ha $CaCO_3$)	7.5	6.6
11	b_3c_3 (TDS-3, $N_{60+40,5+40,5}P_{60}K_{60}$)	5.8	4.9
12	b_3c_4 (TDS-3, $N_{90+40,5+40,5}P_{90}K_{90}$ + mulch)	6.2	5.1
13	b_4c_1 (TDS-4, $N_{90+54+54}P_{90}K_{90}$)	5.9	4.8
14	b_4c_2 (TDS-4, $N_{60+54+54}P_{60}K_{60}$ + 8 t/ha $CaCO_3$)	7.2	6.2
15	b_4c_3 (TDS-4, $N_{60+40,5+40,5}P_{60}K_{60}$)	6.1	5.0
16	b_4c_4 (TDS-4, $N_{90+40,5+40,5}P_{90}K_{90}$ + mulch)	5.9	4.9

According to Malić and Marković (2012), the partial increase of the pH value of the Deposol in the reclamation process at the Raškovac mine deposit was also achieved in previous researches of agricultural reclamation, where calcification was applied. An increase of pH in KCl from 4.12 to 6.46 with the previous application of 15 t/ha of hydrated limestone is indicated by Kovačević et al. (2011), which corresponds the results on treatments where calcification is applied. The same authors note the decrease of pH in KCl in the case of meliorative fertilization with phosphorus and potassium, without the use of calcification. In a study of the pedological changes on the laparotid substrate during the thirty-two-year period, Mujačić (2013) states that the pH in H_2O had an insignificant decrease of value, which is 7.7. The possibility of successful calcification in the reclamation process of Deposol using limestone materials is cited by Sheoran et al., 2010.

CONCLUSIONS

Based on the results of the research of the biological reclamation of deposits of landfill deposits from the surface mine Raškovac, Stanari, the establishment of a shadowed lawn with the sowing of grass-leguminous and grass mixtures, with the application of agromeliorative measures, concludes the following:

(1) The chemical properties of the investigated Deposol are characterized by the non-carbonate and non-humus substrate, the strong unsaturation of the base cations, the medium and highly acidic chemical reaction, the low content of organic matter and basic biogenic elements.

(2) The ecological conditions during the research, together with the anthropogenic factor (through the applied agro-technical measures), have had an impact on the growth and development of grass and legumes in the mixtures, as well as on the changes in the surface layer of the investigated technogenic soil.

(3) The highest average yield of green mass in the first three-year period (4.8 t/ha, 16.7 t/ha and 25.8 t/ha) was measured with the TDS-3 mixture.
(4) The least average yield was measured in 2011 with mixture TDS-1 (2.9 t/ha), in 2012 with the mixture TDS-4 (12.07 t/ha) and in 2013 with mixture TS-2 (18.6 t/ha).
(5) Under the influence of intensive implemented measures of biological reclamation on the Deposol, which was affected by technopedogenetic processes, the condition of the recultivated soil was conditioned as well as the type of Rekultisol, which on the basis of the analysis indicates the increase in the pH value.
(6) The values of the Rekultisol reaction in the treatment samples with applied calcification at the dose of 8 t/ha of $CaCO_3$, measured in H_2O, are in the category of neutral and poorly alkaline reaction, and the ones measured in KCl are in the category of poorly acidic reactions.
(7) Calcification gives positive results in the investigated agroecological conditions, with regular fertilization with mineral fertilizers.
(8) Anthropogenic impact is of the crucial importance for the time that is necessary for formation and the established technological fertility of the Rekultisol, which means, application of intensive reclamation measures and agro-technology, which, depending on the time period, and climate factors, work on the technogenic parent substrate.

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Microbiological and basic agrochemical properties of soil near the lead melting plant in the place of Zajača

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ABSTRACT
In 2015 the Soil Institute performed soil analyses near the lead melting plant at Zajača in order to establish its negative effects on soil quality.
Sixteen profiles and semi-profiles were opened at various distances from the melting plant and samples were taken from the surface soil. Agrochemical and microbiological properties of tested soils were determined by using standard laboratory methods.
There was moderate biogenity of analyzed samples that is most cases was lower in the immediate vicinity of the melting plant. At a greater distance from the melting plant, the number of microorganisms was higher. Smaller biogenity of tested samples in the immediate vicinity of melting plant could be a result of increased lead pollution. As far as agrochemical characteristics of the tested soil were concerned, medium to high humus content was established, poorly acidic to neutral reaction, very low to easily availability of phosphorus and medium availability of potassium.
KEY WORDS: biogenity, lead melting plant, pollution

INTRODUCTION
Zajača is an inhabited place near the town of Loznica in the district of Mačva. There is an antimony and lead mine at Zajača that was opened in 1877 and the lead melting plant. The mine and melting plant were privatized in 2006 and since then production of crude lead has been multiplied. Due to their operation, water and air pollution was increased in Zajača and this has led to the increase in the level of lead in children's blood.

Microorganisms are the most important biological soil components as they actively take part in the processes of organic matter degradation with their enzyme systems as well as in the synthesis of humus and creation of available plant assimilative (Milošević et al., 2003). Tolerance of microorganisms to pesticides and heavy metals allows that some crops and cultivars are used in soil bioremediation. Apart from this, there are bacteria that live in rhizosphere and colonize plant roots and promote plant growth (PGPR) by synthesizing specific substances useful for plants, facilitate uptake of nutrients from soil and protect plants from diseases (Glick, 1995, Zahir et al. 2004, Cakmakci et al., 2006). Number of specific groups of microorganisms is used as one of the indicators of general microbiological activities and potential soil fertility. Small number of specific groups of microorganisms (i.e. diazotrophs) indicates lower biogenity, or soil fertility (Milošević, 2008). Each type of soil has its own characteristic microbiocenosis and the manner in which soil is used could positively or negatively affect microbiological activity and this is directly reflected on soil fertility (Tintor et al., 2009). Numerousness and enzyme activity of microorganisms are the highest in the surface soil layer, in the phase of intensive growth of plants whereas at the end of vegetation period numerousness and enzyme activity of microorganisms get lower. Number of microorganisms in soil also depends on the presence and nature of organic matter, treatment method, manure, plant cover and a number of abiotic factors like pH, temperature, soil humidity, presence of heavy metals, pesticides and other harmful materials (Vojinović et al., 1982). It was established that physical-chemical characteristics of soil are the most important property influencing the number and activity of microorganisms (Milošević et al., 2007, Marinković et al., 2008). Most represented in soil in quantity are bacteria, actinomycetes and then come fungi, algae and protozoa. Heavy metals getting to the surrounding environment, as a result of man's activities, are one of the most dangerous pollutants of biosphere. They may cause an exchange of total numerousness and compositions of soil microorganism types that are the most significant soil biological component (Jemcev and Đukić, 2000).

Proceeding from the above, in order to establish the harmful effect of the melting plant on the quality of the surrounding soil, the Institute of Soil Science in Belgrade, in 2015, performed agrochemical and microbiological analyses of 16 representative samples from the soil layer of profiles and semi-profiles opened along the whole basin of the Štira river at various distances from the melting plant. Numerousness of fundamental functional and physiological groups of microorganisms was tested (total microflora, fungi, actinomycetes, ammonifiers, azotobacter and free diazotrophs) that indicate general biogenity and, thus, soil fertility.

MATERIAL and METHOD

Numerousness of microorganisms is the highest in the soil surface layer (Marinković et al., 2008). This is why soil samples from 16 selected localities were taken aseptically for microbiological analyses from the depth of 0-25 cm. The following agrochemical analyses were performed on the prepared samples: pH in H_2O, humus contents and easily available forms of phosphorus and potassium with Al-method.

Basic parameters for the evaluation of soil biogenity were the following: total microflora, total number of fungi, actinomycetes, ammonifiers, azotobacter and oligonitrophils. Number of microorganisms was established with standard microbiological methods of introducing a specific quantity of soil suspensions on appropriate culture media by using decimal dilutions (10^{-1}-10^{-8}), (Pochon and Tardieux, 1962). Numerousness of total microflora was determined on agarized soil extract, fungi on Chapek medium, actinomycetes on synthetic agar with sucrose by Krasiljnikov, ammonifiers on liquid medium with asparagine as a source of nitrogen, azotobacter on liquid nitrogen-free medium with mannitol by Chan and oligonitrophils on medium by Fiodorov.

Six profiles were excavated in the field (P) and 10 semi-profiles (SP). Closest to the melting plant were P2, SP3, SP1, P1, SP2 and SP9. At a greater distance were opened SP4, SP7 and P5, whereas at the greatest distance from the melting plant were SP8, SP6, P4, SP10 and P3.

RESULTS and DISCUSSION

Reaction of tested soil ranged from very acidic to neutral. Most profiles showed slightly acidic to neutral reaction. Humus content was medium to high in the largest number of samples. The composition of easily available phosphorus was very uneven and ranged from very low to high although it was very low in the majority of tested samples. As far as easy availability of potassium was concerned, it was medium in the majority of samples.

Table 1
Basic agrochemical properties of tested soil

Profile and semiprofile	pH in H_2O	Humus	P_2O_5	K_2O
P1	5.90	4.68	0.73	11.71
P2	6.50	6.64	31.02	12.90
P3	5.20	5.83	0.48	21.22
P4	6.65	3.11	0.41	6.17
P5	4.50	3.92	3.80	13.3
P6	4.20	6.79	0.87	11.71
SP1	7.35	5.88	15.76	16.07
SP2	4.45	5.13	1.67	14.88
SP3	4.20	5.83	7.63	20.82
SP4	7.10	6.85	0.10	23.20
SP5	7.20	7.52	22.9	19.63
SP6	4.60	3.47	0.87	12.90
SP7	4.30	3.07	0.68	12.90
SP8	6.30	7.17	3.03	40.00
SP9	5.50	5.69	2.23	20.03
SP10	5.05	4.75	1.07	12.90

Results of the analyses performed showed that numerousness of total microflora varied from 0.33-43.67 x 10^6/g of absolutely dry soil. The biggest biogenity was shown by profiles and semi-profiles that were at the greatest distance from the melting plant and those were P3, SP4 and SP8. The smallest total number of bacteria was shown by P5, SP7 and SP10 that were at the smallest distance from the melting plant.

Following bacteria, fungi and actinomycetes were mostly widespread in soil and they play a very important role in mineralization of organic matter in soil, both fresh and humificated. The number of fungi varied from 1.33-70.67x10^4/g of absolutely dry soil and it was not in correlation with the distance from the melting plant.

As far as actinomycetes were concerned, their numerousness varied from 0.33-37.67 x10^4/g of absolutely dry soil and the largest number of profiles and semi-profiles showed the smallest established number of 0.33 x 10^4/g of soil and this means an exceptionally low numerousness of those important humification agents.

Numerousness of ammonifiers as indicators of contents of nitrogen organic compounds varied from 0.3-45.00 x 10^5/g of absolutely dry soil and it was not in correlation with the distance from the melting plant.

Table 2
Number of microorganisms per gram of absolutely dry soil

Profile and semi profile	Total microfora (x10^6)	Acinomy-cetes (x10^4)	Fungi (x10^4)	Ammonifiers (x10^5)	*Azotobacter* MPN	Oligo-nitrophils (x10^5)
P1	11.67	1.33	14.33	1.5	4	38.67
P2	11	2.67	7.00	9.5	4	46.67
P3	43.67	0.67	15.00	0.3	0	10.67
P4	7.33	0.33	3.33	0.9	4	21.67
P5	1.00	0.33	24.67	2.5	4	6.00
P6	2.33	0.33	20.33	4.5	0	15.00
SP1	12.67	37.67	13.00	45	9	24.00
SP2	11.67	0.33	27.67	7.5	0	13.00
SP3	4.33	0.33	64.33	4.5	4	17.33
SP4	38.33	9.33	9.00	9.5	45	64.67
SP5	22.00	22.00	6.33	20	25	93.33
SP6	5.00	0.33	70.67	0.6	9	16.67
SP7	1.33	0.33	31.33	1.5	4	4.67
SP8	28.33	3.00	26.33	3.5	4	126.00
SP9	8.00	0.33	1.33	0.4	4	5.67
SP10	0.33	1.00	16.33	0.9	4	16.33

Azotobacter, as the strongest associative fixator of atmospheric nitrogen and as an indicator of soil fertility was poorly present in tested samples with an exception of semi-profiles SP4 and SP5 which was one of those which were at the largest distance from the melting plant.

Apart from azotobacter, free aerobic diazotorphic action can be performed by bacteria of the species *Pseudomonas*, *Bacillus*, *Azospirillum*, *Beijerinckia* and *Derxia*. Their numerousness in tested soil was uneven and ranged from 4.67-126.00x10^5/g of absolutely dry soil. Most present was SP8 that was at the same time the semi-profile at the largest distance from the melting plant.

According to the results obtained, it was established that samples with increased humus content showed greater numerousness of the total number of microorganisms as other physiological groups. Positive correlation was established between the number of microorganisms and acidity, or soil pH. Samples with reaction close to neutral showed greater numerousness of total microflora, actinomycetes and other groups of microorganisms whereas fungi as acidophilus microorganisms were more represented in samples with lower pH value or with acid content. Results point to moderate soil biogenity of the tested area.

CONCLUSIONS

Microbiological analyses of soil samples at different distances from the lead melting plant at Zajača showed moderate biogenity which, with the largest number of groups of microorganisms and in accordance with expectations, was smaller in the immediate vicinity of the melting plant. At a greater distance, biogenity was larger and it could be a result of increased lead concentration in soil in the immediate vicinity of the melting plant. Agrochemical analyses of tested samples showed a medium to high content of humus, slightly acid to neutral reaction, very low availability of easily available phosphorus and medium availability of potassium. Correlation was established between agrochemical and microbiological properties.

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Intensity ratio of Ca and Sr migration from sod-podzolic sandy soil ameliorated with conversion chalk (modelling of leaching processes)

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ABSTRACT

The stable strontium is the element of the 3rd class of danger (GOST 17.4.1.02.83). Moving from the soil into plants and then animals and humans the ions of Sr replaces Ca in the bone tissue. This leads to the various diseases of bones and joints. Strontium gets into the soil when using a strontium-containing fertilizers and ameliorants. There are simple and double superphosphates: (1.5 and 0.26% of Sr, respectively); phosphate rock (0.47% Sr); azofoska (0.20% Sr); phosphogypsum (>3.5% Sr), conversion chalk (1.5% Sr), etc. The maximum permissible concentration (MPC) of Sr in soils and plants has not been developed, therefore, to assess the quality of plant products the Ca/Sr ratio was used. The optimal ratio of Ca/Sr in plants is 160/1 and more. If there is a reduction of this ratio up to 80 and lower the plants are considered hygienically defective. The Ca/Sr ratio in plants is dependent on Ca/Sr in the soil. However, the differences in the intensity of leaching of the studied elements will lead to changes the Ca/Sr ratio in soils and subsequently in plants. The objectives of this study were to compare the intensity of leaching of Ca and Sr with multiple drenching the sod-podzolic sandy loam soil limed by conversion chalk; to study the extent of leaching of stable Sr from soils with different humus content; to evaluate the role of root excretions of plants in strontium migration in the soil and to develop a mathematical model describing time migration of calcium and strontium.

Objects of the research were two acidic soddy-podzolic soils of light granulometric composition (humus – 3.02 and 1.76%; pH_{KCl} 4.1 and 4.2; Hy – 5.4 and 5.6 $mmol_c$/100 g of soil, Sr – 135 и 112 mg/kg). The migration ability of Ca and Sr in a sod-podzol sandy loam soil double-limed with conversion chalk was studied in the model experiment in columns. Height of soil layer in column was 17 cm. Before packing into columns, the soil was limed with chalk till the full dose of hydrolytic acidity and composted during 30 days at a temperature of 28°C. Leaching was conducted with a calculated amount of moisture corresponding to the annual rainfall. According to the calculations for a single wash a 400 ml of water was used. After 8 washings, the soil was removed from the columns, limed again, composted for a month and subject to 8 washes. The experiment was repeated five times. The total contents of calcium and strontium in the native soil were determined on X-ray fluorescence spectrum analyzer, the contents of Ca and Sr in washing waters – on atomic absorption spectrophotometer.

It was found that after 8 washes, corresponding to the annual amount of moisture percolating through the topsoil, the proportion of leachable calcium chalk was 54 and strontium ~25% of the applied quantity. After the repeated liming and 16 washes the total metal loss was equal to 43 and 23%, respectively. The level of humus content in soils has a significant influence on the migration of strontium. From the soil with low humus content, for the 8 washes, the total loss of Sr amounted to 41 % of the applied amount. Uptake of strontium by wheat, depending from the treatment, was 0.50% and 0.27% from the amount of Sr applied with chalk. The plants have a deterrent effect on the value of the loss of strontium from leaching. The loss of strontium elution ranged from 11.6 to 13.9%, which is 1.8-2.2 times lower than in the experiment without plants. Probably, the binding of strontium contributes to the low molecular weight organic substances allocated in the root system. The mathematical models adequately describing the dynamics of the process of leaching of calcium and strontium after the first and second liming were developed.

KEY WORDS: conversion chalk, liming, calcium, strontium, migration, modeling

INTRODUCTION

The stable strontium is the element of the 3rd class of danger (GOST 17.4.1.02.83). Moving from the soil into plants and then animals and humans the ions of Sr replaces Ca in the bone tissue. This leads to the various diseases of bones and joints. Sources of strontium in the agroecosystem are meliorate and fertilizers made from phosphate rock (phosphorites and apatites of different fields), where Sr is isomorphic impurities. There are simple and double superphosphates: (1.5 and 0.26% of Sr, respectively); phosphate rock (0.47% Sr); azofoska (0.20% Sr); phosphogypsum (>3.5% Sr), conversion chalk (1.5% Sr), etc.

The maximum allowed concentration (MAC) of Sr in soils and plants has not been developed, therefore, to assess the quality of plant products the Ca/Sr ratio was used. The optimal ratio of Ca/Sr in plants is 160/1 and more. If there is a reduction of this ratio up to 80 and lower the plants are considered hygienically defective (Mineev, 1989). The Ca/Sr ratio in plants depends on Ca/Sr in the soil. However, the differences in the intensity of leaching of the studied elements will lead to changes the Ca/Sr ratio in soils and subsequently in plants. The objectives of this study were to compare the intensity of leaching of Ca and Sr with multiple wetting of the soddy-podzolic sandy loam soil limed by conversion chalk; to study the extent of leaching of stable Sr from soils with different humus content; to evaluate the role of root excretions of plants in strontium migration in the soil and to develop a mathematical model describing the migration time of calcium and strontium.

MATERIAL and METHOD

1. *Experimental site*. The two acidic soddy-podzolic soils of light granulometric composition were studied. Two sites were chosen for the experiment: 1st soil was sampled under natural perennial meadow and 2nd soil– under forest.

2. *Ameliorant*. Strontium containing conversion chalk (CC) was used as an ameliorant in the experiment. It is a byproduct of the process of nitrogen fertilizer production. Conversion chalk is a white powder, with a fine-grained structure and low moisture content (1-1,2 %). The analyses of granulometric composition showed that the bulk (99,8%) of the granules of CC are presented by the particle size < 0.25 mm. Due to the crystalline structure the chalk has excellent physical properties – it does not clod, retains flowability when stored in adverse conditions, easily applied to soil, has a high neutralizing ability (90 % $CaCO_3$) and contains nitrogen and phosphorus. The concentration of Ni, Cu and Zn is small and does not pose a threat to contamination of plants. Among the potentially toxic to plants elements the CC contains fluorine (0.3%) and strontium (1.5%). The fluorine in chalk is presented by poorly water-soluble compound (CaF_2). Strontium in chalk is presented in a carbonate form ($SrCO_3$), which become soluble when released into the acidic soil.

3. *Design of the experiments No. 1 and No. 2.* The migration ability of Ca and Sr in the soils two times limed with CC, was studied in the three model experiments in columns. The model experiments No. 1 and No. 2 studied the effect of different humus content in soddy-podzolic soils on the migration ability of Sr using the separatory funnels. The experiments No. 1 and No.2 included two treatments each in 5 replications: treatment 1- control (washing of native soil), and treatment 2- washing of limed soil. Height of soil layer in the columns was 17 cm. Weight of the soil – 350 g. The packing density – 1,0-1,1 g/cm^3.

4. *Methods.* Before packing into funnels, the soil was limed with chalk till the full dose of hydrolytic acidity and composted during 30 days at a temperature of 28°C. The washing was conducted with a calculated amount of distilled water corresponding to the annual rainfall. The calculations based on the following data: 1) annual rainfall in the North-West of Russia is 600 mm (Rode, 1965; Pestryakov, 1977); 2) for plant transpiration and evaporation from the soil surface is consumed about 400 mm (Pestryakov, 1977).

Thus, 200 mm of precipitation annually percolates through the soil layer. The amount of water needed for a single washing of column, was calculated by the formula:

$$V = \frac{\pi * r^2 * 200}{1000}$$

where π = 3.14;
r – the radius of the column, mm;
1000 – conversion into ml.

According to the calculations for a single wash a 400 ml of water was used.

After 8 washings, the soil was removed from the columns, limed again, and composted for 30 days followed by 8 more washings. The total contents of calcium and strontium in the native soil were determined on X-ray fluorescence spectrum analyzer, the contents of Ca and Sr in washing waters – on atomic absorption spectrophotometer.

To study the role of root secretions in the migration of strontium a model experiment No. 3 with 1st soil was set up. The model experiment No. 3 was conducted in columns with a diameter of 7 cm; soil height in the column was 25 cm; weight of soil 800 g. The packing density was 1.0-1.1 g/cm^3. The preparation of the soil before the experiment was the same as in the experiments No. 1 and No. 2, but the soil was limed in a dose corresponding to 0.75 Ha.

5. *Design of the experiment No. 3*. The scheme of the experiment No. 3 included two treatments: treatment 1 - soil with 4 plants of wheat; treatment 2 –soil with 6 plants of wheat, with three replications for each treatment. The washing was started after the emergence of plant shoots, and included 8 washings. The amount of distilled water for one washing was 400 ml. The experiment lasted 2.5 months. Wheat was harvested in the phase of maturation. Analysis of plant material was carried out without separation of the plants in vegetative and generative organs. Before analysis, the plants of all 3 replications were combined, accordingly to the treatments, and digested with a mixture of concentrated nitric and hydrochloric acids (1:3) at a ratio of 1 g of plants per 10 ml of mixture of acids. After completion of the experiment the soil of the experiment No. 2 was extracted by acetate-ammonium buffer (pH 4.8) and analyzed for strontium content in layers: 0-5 cm; 5-15 cm and 15-25 cm.

6. *Statistics*. Statistical data processing included the development and evaluation of statistical significance of the linear (on estimated parameters) and empirical non-linear dependencies. The construction of linear dependencies for unknown parameters was performed by means of linear regression analysis (least squares method). Calculations were performed in MS Excel (Yakushev et al., 2003; Bure, 2007).

RESULTS and DISCUSSION

The main physico-chemical characteristics of studied soil were: humus – 3.02 and 1.76%; pH_{KCl} 4.1 and 4.2; Hy – 5.4 and 5.6 $mmol_c$/100 g of soil, Sr – 135 и 112 mg/kg.

a. Experiments No. 1 and No. 2.

- ***Control:***

The results showed that the amount of the leached elements was influenced by their initial content in the soil and the volume of the leaked moisture. The maximum calcium content in the control treatment was in the filtrate of the 1st stage of observation. The total loss over 8 washings was high and amounted to 70.2 mg (Table 1).

The repeated composting of soil of the control treatment did not result in increased migration of calcium. The content of calcium in the washed water of the 2nd stage of observations was less than at the 1st stage.

The high migration ability of calcium in native soil is explained by the large supply of water-soluble compounds formed after mineralization of root residues of herbs, as well as poor ability of the soils with light granulometric composition to hold the bases.

To build the model (No. 1) of calcium migration from soil of the control treatment (without liming) the data of all 16 washings were logarithmized and a linear regression analysis was applied. It was shown that after the logarithm the use of a polynomial of 6th degree is applicable for descriptions of the numerical data. At the same time the statistical significance at 5% level and very good quality of approximation of the obtained data (R^2 = 0.94, F = 24.9) was ensured. As a result, the model No.1 has the following form:

$$y_1(t) = \exp(12{,}282 - 13{,}017t + 5{,}266t^2 - 0{,}9755t^3 + 0{,}09079t^4 - 0{,}00415t^5 + 0{,}00007t^6) \quad (1),$$

where y_3 (t) is the amount of calcium in control treatment (mg).

Figure 1 shows the results of migration of Ca from not limed soil.

Table 1
The calcium and strontium concentration in soil leachates, mg

Washes	Ca		Sr	
	liming CC	control	liming CC	control
		1-st liming		
1	79,8	40	1,2	0,12
2	39,0	2,2	0,4	0
3	38	1,4	0,5	0,04
4	28,5	8,0	0,4	0
5	26,4	4,0	0,4	0
6	21,0	7,6	0,4	0
7	19,8	4,8	0,3	0
8	13,8	2,2	0,2	0
Σ	266,3	70,2	3,8	0,16
		2-nd liming		
9	33,2	1,98	0,7	0
10	15,4	1,80	0,42	0
11	17,4	1,30	0,41	0
12	12,9	1,17	0,48	0
13	11,8	0,98	0,36	0
14	11,6	0,71	0,34	0
15	11,4	0,59	0,35	0
16	10,0	0,4	0,32	0
Σ	123,7	8,93	3,38	0
Total	390,0	79,13	7,18	0,16

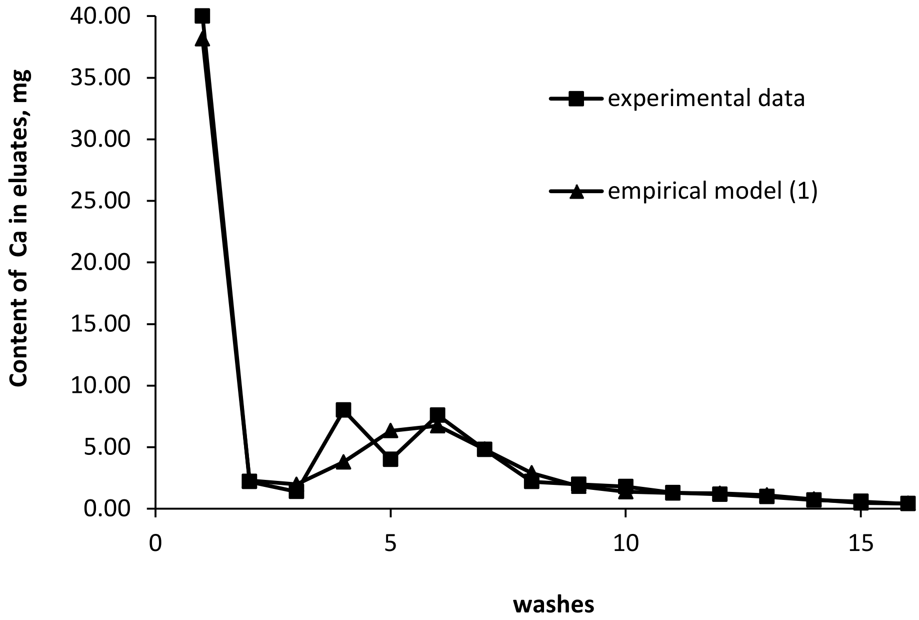

Figure 1. Dynamics of leached calcium in control treatment
In liming treatment, the loss of calcium from the soil because of the washing is increased. This is consistent with the results of other authors obtained in field and laboratory experiments (Yakovleva, 2012; Litvinovich, 2015).

The total amount of calcium leached from reclaimed soil in 8 washings amounted to 266 mg, which is 3.8 times more than in the control (Table 1). If the amount of mobile Ca in native soil doesn't depend on the added ameliorant, then the amount of leached Ca from the conversion of chalk was 54%.

To represent the dynamics of Ca losses in the first 8 washes after the 1st liming was produced by taking the logarithm of the data the first 8 washes and the method of linear regression analysis a polynomial of the 3rd degree was developed, and then the inverse transformation was applied. As a result, the model No.2 has the following form:

$$y_2(t) = \exp(5{,}0977 - 0{,}93045 \cdot t + 0{,}168846 \cdot t^2 - 0{,}0114 \cdot t^3) \quad (2),$$

where $y_2(t)$ is the amount of leached Ca after the 1st liming (mg).

The polynomial of the 3rd degree describes the data after taking the logarithm (R^2 = 0.97, F = 49.9). The coefficient of determination and F-statistics testified about the statistical significance of the constructed model on the standard significance level of 5% and very good quality of approximation.

The second liming contributed to an increase in loss of calcium in the washing. If the last portion of the filtrate of the 1st stage of the experiment the concentration of calcium was equal to 33.1 mg/l, then after the 2nd liming it increased to 85 ± 24 mg/l. In the filtrates of 9-16 washings, the calcium concentration was decreasing gradually and by the end of the experiment was 26.8 ± 6.5 mg/l.

Similarly, as for the 1st stage, after taking the logarithm of the original data by linear regression a polynomial 3rd degree also was constructed then the inverse transformation applied. As a result, the model No.3 has the following form:

$$y_3(t) = \exp(4{,}1621 - 0{,}8811 \cdot t + 0{,}1575 \cdot t^2 - 0{,}00957 \cdot t^3) \quad (3),$$

where $y_3(t)$ is the amount of Ca leached after the 2nd liming (mg).

The polynomial of the 3rd degree describes the data after taking the logarithm (R^2 = 0.91, F = 14.3). The coefficient of determination and the value of F-statistics confirms the statistical significance of the constructed model on the standard significance level of 5% and the very good quality of approximation.

The constructed models No. 2 and No. 3 is shown in Fig. 2. For construction of the model (3) it was assumed that the model is built only for the 2nd stage, so the countdown began from 1.

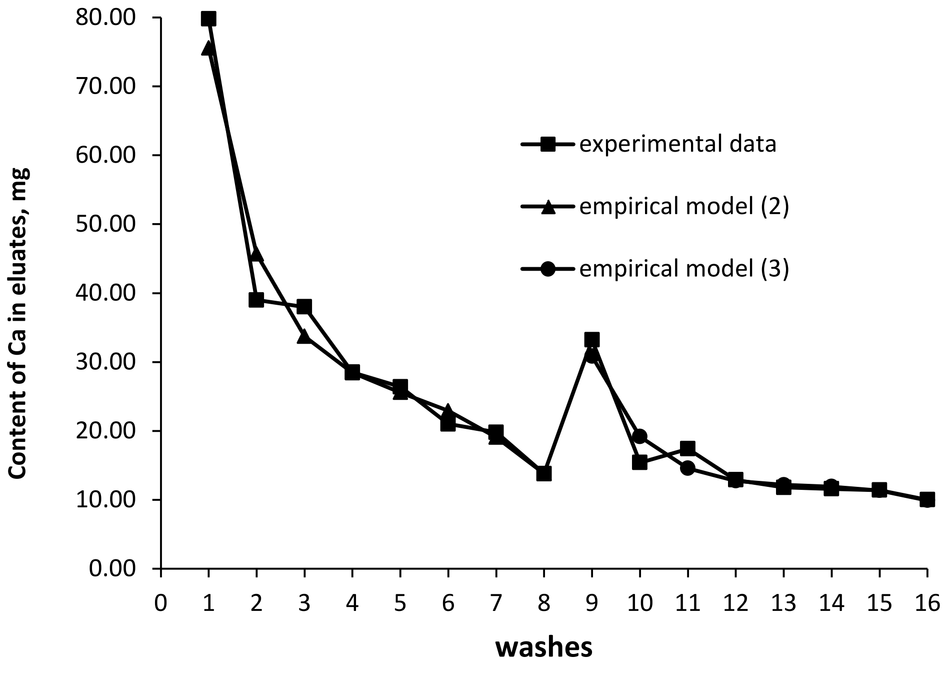

Figure 2. The leaching of calcium after the first and second liming

Thus, from the given values of the determination coefficients and Fisher statistics it follows that the models No.2 and No. 3 adequately describe the dynamics of the process of leachates of calcium after the 1st and 2nd liming, with a rather high quality of the approximation of the experimental data.

Complete removal of the mobile strontium from the soil of the control treatment was achieved to the 3rd stage of observations (Table 1). Obviously, the reserve of mobile compounds of strontium in the native soil is small and is only 0.12% of the total content.

Artificial enrichment of soils with strontium by liming with conversion chalk led to its increased migration. Strontium was detected in all portions of the filtrate, and the maximum concentration was found in the filtrate of the 1st stage of observation. With increase of the volume of leached water the content of strontium in the filtrate was reduced, and by the 8th stage of observation it amounted 0.4 ± 0.1 mg/L. The eluvial losses of strontium of conversion chalk for the 8 washings amounted only 25% of the added amount, comparing to calcium. While the level of maximum permissible concentration of strontium, as determined for waters (7 mg/l), doesn't exceed in any of the filtrates.

- ***Treatment 2 (liming)***:

In the model of leaching of strontium after the 1st liming (6) the same scheme was applied. After taking the logarithm of the data of 1st to 8th washings a linear regression analysis was done. A 4th degree polynomial with statistical significance at 5% and very good quality of approximation (R^2 = 0.94, F = 12.1) was applied. The inverse transformation resulted in the model No. 4:

$$y_4(t) = \exp(2{,}2215 - 2{,}9118 \cdot t + 0{,}94478 \cdot t^2 - 0{,}1248 \cdot t^3 + 0{,}005595 \cdot t^4) \quad (4),$$

where y_4(t) is the amount of Sr after 1st washing (mg).

After taking the logarithm of the data of 9th to -16th washings a linear regression analysis was done. Here a polynomial of 5th degree was applied, which provided statistical significance level of 10% and a very good quality of the approximation (R^2 = 0.965, F = 11.1). The inverse transformation resulted in the model No. 5:

$$y_5(t) = \exp(2{,}4587 - 4{,}7944 \cdot t + 2{,}5287 \cdot t^2 - 0{,}6093 \cdot t^3 + 0{,}06767 \cdot t^4 - 0{,}0028 \cdot t^5) \quad (5)$$

where y5 (t) - the amount of the Sr after the 2nd washing (mg).

Models No. 4 and No. 5 adequately describe the dynamics of the process of leaching of strontium after the 1st and 2nd liming, with high quality of approximation of experimental data.

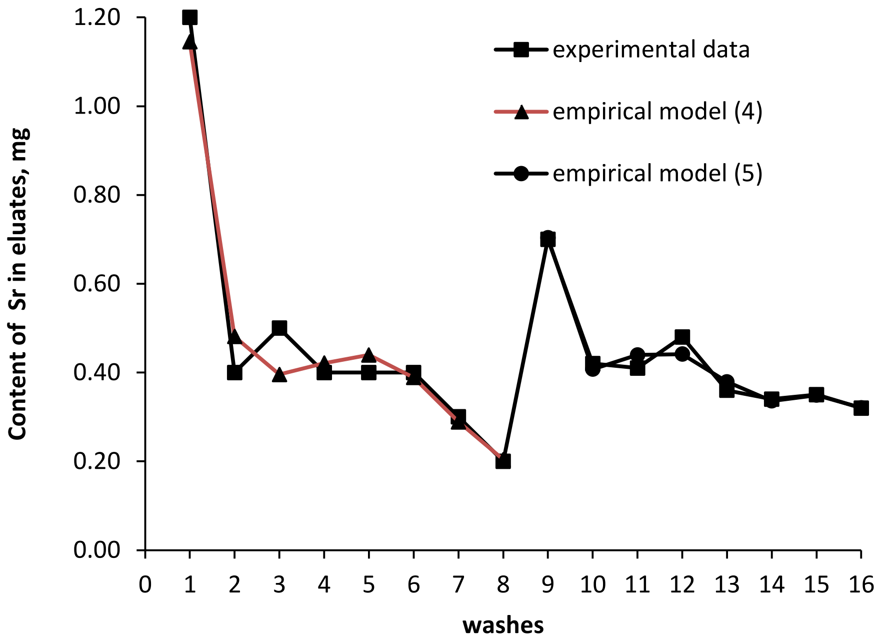

Figure 3. The leaching of strontium from soil No. 1 after the first and second liming

The total amount of calcium leached from the conversion of chalk for 16 washings was 311 mg (43%), and strontium – 7.02 mg (23%). Obviously, this is caused by the differences in bond strength of Ca and Sr with the absorbing complex of the soil. This conclusion is confirmed by the data of several studies. The experiments on desorption of metals from soils showed that the strontium is fixed stronger than calcium (Heald, 1960). After analyzing the data on the content of water-soluble and exchangeable forms of calcium and strontium in all horizons of the profile of leached Chernozem, Goltsev and Aleksakhin, (1969) found a similar pattern. In our studies, it was shown that Sr in the soil is fixed in the first fraction of humic acids (Litvinovich, 2013). The theoretical calculations performed based on determination of thermodynamic characteristics of the exchange adsorption of calcium and strontium (Polyakov, 1960), also testified in favor of these results. Ryzova (1965), has established the possibility of a non-exchange capture of strontium by a number of minerals, while calcium is absorbed only in the exchange form. The weak capacity of the humus to keep calcium from humid areas also indicated in works of Ponomaryova et al. (1980). A higher rate of leaching of soil calcium, compared to strontium in our experiment may be associated with different solubility of carbonates of alkaline earth metals in the composition of chalk (Goltsev and Aleksakhin, 1969), because the solubility of $CaCO_3$ two times greater than the solubility of $SrCO_3$.

To build the model of joint leaching of Ca and Sr the ratio of the amount of leached calcium relative to the amount of leached strontium. The results are presented in Table 2.

Table 2
The ratio of calcium to a strontium concentration in the leachates

Wash	Ca/Sr	Wash	Ca/Sr
1st liming		2nd liming	
1	66,50	9	47,43
2	97,50	10	36,67
3	76,00	11	42,44
4	71,25	12	26,88
5	66,00	13	32,78
6	52,50	14	34,12
7	66,00	15	32,57
8	69,00	16	31,25

The result of a data calculation served for the construction of the model No. 6, which characterizes the dynamics for all washes (1 – 16), representing a simple pair regression. Model No. 6 has a statistical significance at 5% and satisfactorily approximates the entire data set (R^2 =0,789; F=52,3):

$$y_6(t) = 85{,}724 - 3{,}84 \cdot t \tag{6}$$

where y_6 (t)- the ratio of leached Ca to leached Sr.

Model No. 6 adequately reflects the dynamics of the studied indicator ie. the ratio of the amount of leached Ca to the amount of leached Sr (Fig. 4). There is a trend to significant decrease of the indicator for each of the sixteen washes.

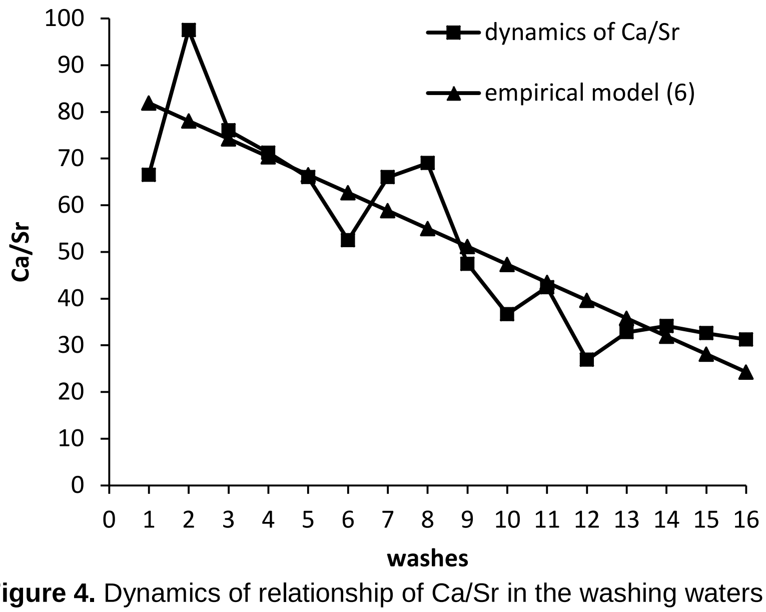

Figure 4. Dynamics of relationship of Ca/Sr in the washing waters

In the model of leaching of Sr from limed by conversion chalk soil 2, the assumption was that the process of the removal of Sr is divided into two phases: the first phase (1 – 6 washes) is an intensive non-linear dynamic over time, the second phase is stable with virtually no change of numerical values over time. The mathematical model (7) describing the dynamics of the amount of leached Sr from soil 2 on the interval (1 – 6 washes) is:

$$y_9(t) = \exp(1{,}86 - 2{,}03 \cdot t + 0{,}66 \cdot t^2 - 0{,}069 \cdot t^3) \quad (7)$$

Table 3 presents the data on the amount of Sr leached from soils with a high (soil 1) and low (soil 2) humus content in 8 washes. The total metal loss over the entire period of the experiment from the soil 1, limed with CC was 3.8 mg, from soil 2 – 6.1 mg, which corresponds to 25 and 41% of leached Sr from the applied chalk. Consequently, the soil humus content has a significant influence on the migration of the studied element. In soils with a high humus content, the migration ability of Sr is reduced. This gives grounds to assume that Sr is fixed in the composition of humic substances or their derivatives.

Table 3
The amount of leached strontium, mg

Wash	Soil No. 1		Soil No. 2	
	Control	liming 1Hy	Control	liming 1Hy
1	0,12 ± 0,03	1,2 ± 0,2	0	1,5 ± 0,3
2	0,04 ± 0,01	0,4 ± 0,1	0	1,0 ± 0,2
3	0	0,5 ± 0,15	0	0,8 ± 0,2
4	0	0,04 ± 0,015	0,09 ± 0,02	1,1 ± 0,3
5	0	0,04 ± 0,01	0,04 ± 0,01	0,8 ± 0,15
6	0	0,04 ± 0,009	0,02 ± 0,004	0,3 ± 0,07
7	0	0,03 ± 0,01	0,02 ± 0,004	0,3 ± 0,06
8	0	0,02 ± 0,004	0,03 ± 0,005	0,3 ± 0,06
$\sum$	0,16	3,8	0,2	6,1
%	0,12	25	0,18	41

b. Experiment No.2 (Plant uptake)

The presented model experiments did not consider the factor of biological uptake of Sr by plants. The results of the experiment with wheat showed that Sr is present only in the leachates of the first two observations. The total amount of Sr removed from the soil amounted to 2,97 and 3,56 mg in the two treatments, respectively. The share of washed Sr from the CC in the experiment with plants was significantly less than in the experiment without plants and was 11.6 and 13.9 %, respectively to the treatments. Consequently, plants had an inhibiting effect on the migration of strontium. The weak capacity of the Sr to move is evidenced by the layer-by-layer soil analysis after harvesting of plants. The concentration of exchange-absorbed Sr, recovered by acetate-ammonium buffer with pH 4,8, has aligned character. That is, the multiple washing didn't result in the displacement of the Sr in the lower part of the columns.

The results of studying the chemical composition of plants showed that uptake of the metals by wheat plants depended on the sowing rate of the plants (Table 4).

Table 4
Yield (g/column) and chemical composition of wheat plants, mg/kg air-dry mass of plants

Treatment	Yield	Ca	Sr	Ca/Sr
4 plants	1,7	4820	76	63,4
6 plants	2,0	3300	34	97,0

In the treatment with 4 plants the vegetative mass of wheat was characterized by a higher level of accumulation of Ca and Sr than in the treatment with 6 plants. The removal of Sr by wheat, depending on the treatment, was only 0.50 and 0.27 % from the amount of applied chalk. Thus, the sharp decrease in the loss of Sr from the soil in the wheat planted treatments can hardly be explained only by the root uptake of this element.

c. Leachate analyses

During the experiments, we noticed that the leachates from the soil without plants were colorless, while in the experiment with plants the leachate had a straw-yellow color. This prompted us to analyze the composition of the leachates on the presence of organic matter (Table 5).

Table 5
Carbon content in washings, µg

Washing	Treatment	
	4 plants	6 plants
1	21,47 ± 2,8	29,3 ± 4,5
2	11,00 ± 2,4	20,9 ± 7,1
3	10,10 ±1,2	9,2 ± 3,0
4	12,03 ± 1,2	9,1 ± 4,6
5	10,10 ± 1,3	6,7 ± 1,2
6	16,5 ± 1,6	8,9 ± 1,6
7	5,20 ± 0,4	8,1 ± 1,7
8	7,10 ± 0,5	7,9 ± 0,2
Σ	93,5	100,1

The results of the leachates study indicate that the moisture was enriched by water-soluble organic matter (WSOM). The most enriched was the first portion of filtrate. Total losses for the entire period of observation were: 93,5 and 100,1 µg, that is a much lower than the amount of leachable Sr. Therefore, the WSOM root secretions couldn't affect the movement of Sr in the soil of experiment. However, the total volume of organic substances released by the root system of wheat over the entire period of the experiment, is likely to be much larger than their amount removed with percolating moisture. The composition of organic substances excreted by plants include low molecular weight organic acids, vitamins, enzymes, amino acids, ie., the compounds, many of which are strong complexing agents (Ivanov, 1973). Therefore, it is appropriate to assume that a sharp reduction of leached Sr at the treatments with grown plants caused by the fact that secreted by roots of wheat organic compounds bind ions of strontium in the composition of the hardly soluble organo-mineral complexes.

CONCLUSIONS

It was found that after 8 washes, corresponding to the annual amount of moisture percolating through the topsoil, the proportion of leachable calcium from the chalk was 54 and strontium ~25% of the applied quantity. After the repeated liming and 16 washes the total metal losses were equal to 43 and 23%, respectively. The level of humus content in soils has a significant influence on the migration of strontium. From the soil with low humus content, for the 8 washes, the total loss of Sr amounted to 41% of the applied chalk amount. Uptake of strontium by wheat, depending from the treatment, was 0.50% and 0.27% from the amount of Sr applied with chalk.

The plants had an inhibiting effect on the losses of strontium from leaching. The losses of strontium ranged from 11.6 to 13.9%, which is 1.8-2.2 times lower than in the experiment without plants. Probably, the binding of strontium occurs due the low molecular weight organic substances allocated in the root system. The mathematical models adequately describing the dynamics of the process of leaching of calcium and strontium after the first and second liming were developed.

Given the competitive nature of calcium and strontium translocation into the plants, with advanced rates of leaching of Ca from the plow layer compared with Sr one should expect the narrowing of Ca/Sr ratio in soils during chalk dissolve and, as a result, the deterioration in the quality of crop production.

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Soil Awareness Raising, Soil Information and Regional Cooperation for Sustainable Management of Soil Resources – the Links4Soils Project

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ABSTRACT

The plenary contribution points-out and discusses the importance of soil awareness rising and the suitability of soil information for better management and protection of soil, for sustainable development in other words. A self-reflection of a 'soil person' that deals with soils, land uses, soil quality and soil information for decades, reveals the fact that soil science is still not successful enough in conveying the product of soil research (soil information) to a variety of end-users. At the same time it discusses recent global and regional soil awareness rising – very much needed activities that are too often (or traditionally?) neglected by soil experts, scientists.
The contribution presents the EU Links4Soils Interreg project that aims to mitigate sustainable soil management gaps by improving the systematic applicability of the Soil Protection Protocol of the Alpine Convention. In particular, it focuses on linking (soil) experts and decision makers, creating a trans-border community dedicated to the soil protection (Alpine Soil Partnership), collection of existing regional and national soil data to generate user-friendly and applicable soil information, transfer of soil knowledge and best soil management and protection practices to policymakers and other stakeholders, and promotion of efficient soil protection strategies (Alpine Soil Platform). The Links4Soils project aims to be an example of regional and transborder cooperation in sustainable soil management and protection in an environmentally specific area (Alps) of six EU countries, and to act as a regional initiative / extension of the Global and European Soil Partnership, important soil protection activities coordinated/lead by the FAO.
KEY WORDS: sustainable soil management, Interreg, Alpine Soil Partnership, GSP, ESP

INTRODUCTION

Soil awareness rising

International soil protection activities & partnerships
The awareness on soil being the key natural resource that enables life of terrestrial ecosystems was relatively poorly recognised in the past. The countries had (and many of them still have) a poor attitude to the soil. The unsustainable soil management was tolerated and consequently caused soil and environmental degradations. The damages are not reflected only as local economic burdens but also as desertification of a global extent and a significant contribution to the negative climate change effects. In the final extent, the unsustainable soil management significantly contributes to the hunger in the world and ultimately to the international refugee problem as well as growing international tensions[1]–[4].
And yet, something is moving! Due to the overlooked but exceptional importance of soil for life, prosperity and sustainable development, the United Nations – FAO [5] initiated and took a lead in a series of international soil awareness activities. The December 5th was declared as a World Soil Day [6], and year 2015 as an International Year of Soils 2015 (IYS2015[7]. The International Union of Soil Sciences IUSS [8] declared International Decade of Soils 2015-2024 [9] to extend soil awareness activities and programmes.
The activities of the FAO, IUSS in several other international organizations are continued and harmonized within the Global Soil Partnership (GSP) initiative [10]: The GSP includes continental / regional partnership that follow the same goals. The European Soil Partnership (ESP)[11] adapts and conveys GSP activities to the Europe with important organisational and financial support of the European Commission [12].

The Global and European Soil Partnership
Is a global, FAO-lead initiative / programme towards better protection and sustainable management of world's soil resource. The GSP mandate is to: improve governance of the limited soil resources of the planet in order to: assure healthy and productive soils for a food-secure world; support the capacities to provide soil ecosystem services and functions; all in accordance with the sovereign right of each state over its natural resources. The GSP should become an interactive and responsive partnership.
The aim of the European Soil Partnership is to bring together the various scattered networks and soil related activities into a common framework, open to all institutions and stakeholders willing to actively contribute to sustainable soil management in Europe. Cooperation, data harmonization, standardization, exchange of experience, important political background, awareness rising, and other activities are embedded within the five ESP pillars of action: i) Soil management, ii) Awareness rising, iii) Research, iv) Information and data, and v) Harmonization.

Sub-regional partnerships
The GSP and the ESP are opened to sub-regional soil partnership. The ESP includes the sub-regional Eurasian Soil Partnership that unites entire Russia (European part and Siberia), Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkey, Turkmenistan, Ukraine and Uzbekistan.

Sub-regional soil awareness rising activities

Soil awareness rising in Alps and some European countries
Individual countries in Europe already promote soil protection and sustainable soil management for several years. In Austria for instance, they have developed well organised *Bodenforum / Bodenplattform* [13]. Some EU countries' environment protection agencies [14], [15] including the European Environment Agency [16], ministries and organizations such as the European Land and Soil Alliance (ELSA)[17], are increasingly raising awareness for better soil management and protection in Europe.
In the context of a specific region such as Alps, the soil awareness rising is initiated within the Links4Soils[18] Alpine Space project. Two important activities aims to contribute to the better implementation of the Alpine Soil Conservation Protocol [19], a legislation ratified by all parliaments of the Alpine Countries but Swiss: i) the establishment of the Alpine Soil Partnership (ASP) and ii) the elaboration of the Alpine Soil Information and Decision Support Platform.

Soil awareness rising in Slovenia
The soil protection in Slovenia is not sufficiently addressed. The proportionate loss of the best agricultural soils (agricultural land) e.g. due to motorway construction in last twenty years, expanding urban areas with dense sealing [20]–[23], hot spot and dispersed soil contamination [24], [24]–[27] are considered the most serious soil threats in Slovenia. Other soil threats such as soil organic matter depletion in agricultural soil is not as promoted as a problem which causes increased droughts, accelerated erosion and reduced soil fertility is recognised merely by individual soil experts. The introduction of sustainable soil management and rational land-use practices and better soil protection in Slovenia require adequate public and political attention and raised soil awareness in media, other disciplines as well as decision-making institutions at state and regional / municipality level.
Within the International Year of Soil 2015 several activities were carried out in Slovenia. The IYS2015 logo was translated and widely used, web page created; soil calendar elaborated [28], leaflet and soil-photo exposition organised. Under the Ministry of Environment and Spatial Planning the logo *Soils in environment* was developed, six soil-environment posters were designed. The Post of Slovenia have issued a soil-stamp to celebrate the IYS2015.

Soil information for sectoral needs

Soil is a cross-sectoral topic
Soil is a true cross-sectoral topic. In agriculture it is traditionally considered as valued natural resource that basically defines land capabilities for the agricultural production. The food and fodder quantity and quality, the possibility to grow energy crops and industrial biomass, at a first place depend on the soil properties – the agricultural soil quality. The sustainability of the agricultural production is largely linked to the preservation of soil fertility. In the forestry sector the situation is similar: the biomass (fibre, wood) production is nowadays better linked to soil properties and recently to the forest

ecosystem management. In relation to the drinking water management soil in an important ways defines the water retention, filtration, groundwater quality, flood prevention and potential flood mitigation measures. The planning and infrastructure development address soils to assess soil bearing capacity, physical properties, waterlogging and ponding areas, slope mass stability, etc. Natural disaster prevention, e.g. against land sliding and severe erosion, is focusing on soils. The nature conservation has started to link the above ground biodiversity and soil properties as well as soil biodiversity itself as an important gene pool. The archaeologists traditionally study soil to better understand and reconstruct the artefacts. Defence, among others, focuses to e.g. land trafficability. The soil as a CO_2 sink / source, the C-pool and the soil C-sequestration capacities are in a prime focus of national and international politics and research community. Very likely, the ultimate focus on soils is driven by the World's and national climate change mitigation needs, strategies and activities.
An interesting question: *Is sustainable development possible without sustainable soil management and protection?* is quite easy to answer. Not really.

Cross-sectoral needs vs available soil information
The aforementioned needs and soil–related activities in a large extend depend on adequate, well interpreted and focused soil information. Here, we need to underline the difference between the soil data ('raw' soil data such as soil profile datasets) and interpreted, purpose-driven information adapted to sectoral needs or individual soil management activities.
The soil experts, researchers and professors of soil science, have to better cope with interesting phenomena. Within the soil science community, in general, we are aware about the applicability of soil information not only in the agricultural and forest sector but in other sectors as well. Yet, the understanding of soil experts about the difference between raw soil data and soil information, applicable by an end-user, typically non-soil expert, seems not to be sufficiently recognised.
We have to recognize better that the 'raw' soil data (physical and chemical properties of soil horizons, soil profile datasets; pedological maps with soil names; soil mapping units' polygons -, etc.) is familiar to soil experts and barely understandable or not understandable at all to other sciences and disciplines; not to say public authorities and decision makers. The users need soil information in terms of thematic (soil) maps, land suitability maps, (soil) vulnerability maps, etc.
And probably an important introductory conclusion would be: *There is no sustainable soil management without widely available, quality, focused, and applicable soil information, and without a soil expertize.*

The questions for the soil scientists / experts
What we (soil scientists, soil experts) actually deliver; soil data or soil information? Who are the end-users of soil information; by whom and what for the soil information is needed? What matters to soil experts and what to end-users? What kind of soil information is primarily needed in different sectors? Is available / provided soil information appropriate; is it focused and understandable to users / decision-makers? Are soil data / information technically adapted and applicable?
Existing soil data and information is to a large extent adapted to agricultural and forestry needs. But how appropriate it is for other purposes; e.g. for designing practical climate change adaptation measures, rational urban planning, improvement and protection of ground-water resources, biodiversity protection, natural resource management, etc.? The suitability and applicability of soil information to meet the needs of other sectors is still insufficiently addressed.
To which extent is soil science and soil expertise present in decision making processes in other sectors? How come the soil-related issues in other sectors are not tackled by soil scientists bit the non-soil experts. How successful is soil science in linking to other disciplines, other natural sciences? Can we improve knowledge-transfer to our 'customers'? The soil experts and scientists, should question ourselves how successful we are in providing soil knowledge / soil information to non-experts, end-users, typically decision-makers?
The intention of this paper is to remind soil experts and soil scientists on the in the importance of raising soil awareness for better management and protection of soils; to reflect / convey some global soil protection initiatives, to present and link regional soil awareness activities to the global context. An important aim of the paper is to remind and self-reflect the soil science about the difference between soil data and soil information, to justify the raise the importance of adequate; end-user adapted and focused soil information. So, the important message is explained in the Introductory.
At the end, the paper aims to present the soil information and soil awareness rising activities carried out within the Links4Soils – an Interreg Alpine Space project.

MATERIAL and METHODS

The Alpine Soil Platform [29] has been developed and maintained using the WordPress concept management system based on the PHP and MySQL and the Shaka PT theme developed by the ProteusThemes. The system integrates important plugins: WPML Multilingual CMS, Contact Form 7, Duplicator, Yoast SEO, and the MailChimp.
The eSOIL[30] and the eTLA [31] soil web GIS developed by the Agricultural Institute of Slovenia are based on the Giselle web GIS engine developed by the Sinergise d.o.o., Ljubljana, Slovenia.

RESULTS and DISCUSSION

Soil protection in Alps

Why Alps? Alps are to a large extent specific area with specific soil threats. Alpine ecosystems are under increased pressure due to human influence and climate change effects. Soil is the basis of Alpine ecosystems; it is a fundamental natural resource especially in the vulnerable Alpine Region. The mountain soils are (highly) vulnerable and exposed to increased threats such as erosion, land-sliding, and acidification. The mountain soil management practices are quite diverse in different Alpine countries although we are all facing similar soil threats and management challenges. The diversity of management practices; approaches and legislation require local adaptations and 'fine-tuning' of sustainable soil management activities, yet having a common goal in mind: a sustainable soil management and protection as well as cross-border cooperation and mitigation of soil degradation and soil related-threats.
Alpine soils perform key ecosystem services (ESS) that enable human well-being, ecosystem functioning and contribute to the biodiversity. The importance of sustainable Alpine soil management is being recognised yet it is insufficiently implemented mainly due to its crosscutting function, fragmented governance structures, diverse sectoral needs, lack of targeted soil information and applicable management tools.
Soil Conservation Protocol of the Alpine Convention. Through the sustainable management and protection of soil the project aims to enhance the sustainable management of alpine environment, considerably contribute to the performance and resilience of key soil ecosystem services. The soil management and protection is provided for the framework of the Alpine Convention Soil Conservation Protocol (SCP), which aims *"[to] safeguard the multifunctional role of soil based on the concept of sustainable development. To ensure sustainable productivity of soil in its natural function, as an archive of natural and cultural history and in order to guarantee its use for agriculture and forestry, urbanism and tourism, other economic uses, transport and infrastructure, and as a source of raw materials."* The AC Soil Conservation Protocol has still not been successfully implemented. Among the important reasons is the lack of applicable soil information adapted to user needs and environmental threats, knowledge of sustainable ecosystem management, as well as applicable and best-case soil management practices.

The Links4Soils project – our way to raise awareness and improve soil information for sectoral use

The project aims to overcome these gaps by linking Alpine soil knowledge, end-users and experts, elaborate sectoral soil information, create best-case practices and promote soil management. By this, it enhances the applicability of the AC Soil Conservation Protocol and contributes to the protection, conservation and connectivity of Alpine ecosystems. The project links expertise and governance on various levels and sectors to jointly develop and implement sustainable Alpine land management policies / strategies. Main project outputs are: a) The Multi-stakeholder Alpine Soil Partnership that joins forces of experts and authorities to introduce soil protection in land management practices and promotes Alpine-wide cooperation on soil protection & ESS management; b) The Alpine Soil Information and Decision Support Platform encourages stakeholders from cross-cutting sectors like forestry, agriculture, spatial planning to benefit from the first Alps-wide soil information system that includes an expert Soil Consultancy Service, sectoral best-case practices etc. in order to integrate them into local and regional management and planning. The outputs, built on common interest of public authorities (e.g. soil, environmental protection, planning,) as well as Alpine and EU org. (AC, EUSALP AG 6,EC-JRC), will be integrated to ESDAC and linked to international organisations or NGOs for durability after the project. The soil protection in Alps is pushed by the bottom-up policy and actions that will be transferred to (trans)-national levels, as required by AC SCP and EUSALP.

Ten Links4Soil partners come from Slovenia (lead, 2), Austria (3), Germany (2), Italy (2), France (1).
Main Links4Soil project goals are: i) to review, develop and share good soil management practices; ii) to link users and soil experts in a community (Alpine Soil Partnership) committed to sustainable soil management; iii) to support cross-border cooperation on soil protection and management in Alps, iv) To initiate comparable cross-border soil information, and v) to raise awareness on Alpine soils.
Links4Soils project activities and work-packages are: M – Project Management; T1 – Alpine Soil Partnership; T2 – Strengthening Alpine Soil Management Information Sources; T3 – Sustainable soil and ecosystem service management implementation in case studies; T4 – Capacity Building and Knowledge Transfer, and C – Communication.
The overall objective of the project are to: i) encourage and enhance the management and protection of Alpine soils, ii) strategically link soil knowledge to daily work of end-users & experts using the ESS concept, iii) improve local management and the local/regional applicability of the AC Soil Conservation Protocol. The Links4Soils strongly enhances trans-border management and safeguarding of soil resources. It supports ecological connectivity of Alpine ecosystems by linking local/regional authorities committed to better soil management.

Project results: The Alpine Soil Partnership (ASP)

The Alpine Soil Partnership (ASP)
The ASP is a voluntary community committed to sustainable soil management and protection in Alps. The ASP follows the umbrella GSP/ESP soil protection activities with an important difference. It is not planned to inherit the hierarchical top-down approach but the opposite – bottom-up approach. The ASP activities and short term goals are adapted to regional and local needs of different sectors: agriculture, spatial planning, forestry, natural disaster prevention, climate change adaptation & mitigation, etc.
The ASP members are/will be authorities (local and regional governments, municipalities), national/regional agencies (e.g. environment protection, sectoral agencies, national data centres, etc.) Soil & soil-related experts national soil science societies, soil research institutions, universities, individual soil experts and (soil) consultancies and companies (e.g. soil remediation, planning…), NGOs, and individual citizens.
The main ASP activities (will) tackle all Alpine stakeholders committed to sustainable land management and environment protection. Analysis/recommendations for an improved implementation of soil protection, implementation of AC Soil Conservation Protocol and ESS management are applicable by all Alpine soil and land management stakeholders. Outputs, carefully elaborated to enable wide repeatability &transferability, are transferred during ASP meetings; by NGO's, awareness rising and WPC5 Web-Platform (A53). The ASP members are committed:

- To cooperate on soil protection (national and intl. level) in Alps.
- To practice and promote sustainable soil management and protection (in cont. 'SMP').
- To develop and exchange best SMP practices in Alps.
- To give political support to widely introduce SMP practices on national and int.. level.
- To act towards a better implementation of the Soil Conservation Protocol* of the Alpine Convention.
- To raise awareness on importance of soils in Alps.

The Alpine Soil Information and Decision Support Platform
The 'Platform' is designed to become a knowledge-driven website, established to become a comprehensive source of soil expertise and soil information. When completed, it will serve as a new overarching information platform that will promote tools for decision support and capacity building, a soil management consultancy service, best practice examples and soil data collection. An important part of the Platform is dedicated to the cross-sectoral case study best practice soil management solutions that can be transferred into local / regional management plan in other countries and regions.

Main functionalities of the 'Platform'
Information on soils, soil ecosystems services, and soil functions*:* Platform is designed to help making soil-related decisions for different sectors: planning, agriculture, forestry and environment protection. The **best practices** section presents tools and methods for soil management, cross-border dissemination & exchange of soil information and know-how. The practices are organised using sectoral approach again: mainly spatial planning, forestry, agriculture, nature protection and tourism (skiing). **The access to national Alpine soil data and soil information systems is given through the** Public Alpine soil data web GIS (a prototype, initial development at the time). When the project will

be completed, the web GIS and the datasets are transferred to the EC JRC European Soil Data Centre for further development, maintenance and the formation of the Alpine Soil Information System (ALPSIS). **The ASP member information node** will serve ASP members as a communication tool.

The importance of national languages
The soil protection and management at local and regional level would not be effective if not available in national language(s). The possibility to exchange knowledge and best practices in national language is expected to largely contribute to the successful implementation. According tor to belief of project partners the top-down approaches in foreign (mainly English) language are (much) less efficient because of the language barrier, no matter how fluent the English is spoken in local/regional environments. The Links4Soilpartners will support to the development of national Alpine soil web pages which will be designed as source of data and information, and best practices for regional/local authorities.

CONCLUSIONS

The intermediate results and aims of the herewith presented Links4Soils project is the way some partners of from six Alpine countries decided to go and to explore. It is not a recipe but a report what the international group of soil experts and end-users is doing to promote soils and raise awareness outside of the soil science. We are aware that a single international project is simply not enough; the Links4Soils project can be considered as just ‘brick in the wall’ of global/international soil protection and soil awareness rising activities.

Soil information

The soil science has to provide soil information, not (measured) soil data. Different sectors need focused, adapted, tailored and applicable soil information. Soil information needs to be available, online or effectively disseminated in another way. Soil science / soil experts, have to reach and to talk to, and to cooperate with other end-users and decision-makers. Besides agriculture and forestry, planers, environment protection, ground water experts, and other users need the support of soil science although the latter is not widely recognised.
Besides the data collection itself, soil science has to (primarily?) focus on soil data interpretation suitable for end users / sectoral needs, dissemination of soil information, and support of ‘customers’ in different sectors. This not an easy tasks will largely contribute to the better soil management and protection, to sustainable development and better climate change mitigation in other words.

Regional soil management and protection approaches

Specific regions (no matter the Alps or the Pannonian Basin) face to a certain extent specific soil threats and, consequently, environmental and soil management challenges. Soil science, experts and ‘customers’ can benefit from a cross-border cooperation and exchange of: soil knowledge, soil protection activities, soil monitoring strategies, soil management practices, and the cross-border harmonization of soil information. Here, a clear explanation has to be given: it is hard to harmonize soil data collection and datasets cross-border or at international level. The quantity of legacy data is often simply too large, datasets different, data structures too complex and diverse, and differences in soil analytical procedures simply too significant. But what can be done is better regional cooperation of soil experts, and soil science societies.

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Assessing nitrogen balance in crossborder agricultural watershed area- a GIS study

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ABSTRACT

Slovenia is considered as nitrate vulnerable area since 2001 and therefore groundwater pollution prevention activities based on the EC Nitrates Directive have to be implemented on the whole territory. In the catchment of the Kučnica border river between Austria and Slovenia, problems associated to the river quality appeared as a result of point (e.g. wastewater treatment plants) and diffuse contamination (e.g. agriculture). The purpose of our research was to analyse existing nitrogen load from agricultural activities and to prepare a draft of best agricultural practice measures to improve chemical and ecological status of the river Kučnica.

The analysis of available spatial data was made to identify areas of individual agricultural holdings (GERK) and areas of different land use in the Kučnica water body area. For the selected farm holdings fertilization and crops data for 2013 were obtained to calculate the N balance for each agricultural parcel using the OECD-Eurostat methodology in a GIS model. The methodology is based on a calculation of the net balance between the amounts of N applied into the soil by the agricultural activities and the amounts of N discharged from the agricultural land. The N input to the soil was calculated from the amount of mineral fertilizers, manure applied, biological fixation of nitrogen with legumes, deposition of atmospheric nitrogen, other organic fertilizers, seed and planting material. On the other hand the withdrawal of N was defined by the amount of harvested crops, volatization and potential leaching.

The N balance surplus was estimated on 73 % of investigated agricultural land. Surplus up to 50 kg N/ha was typical for 25 % of agricultural land. For the most areas (37 %) surpluses between 51 and 100 kg N/ha were estimated while 11 % of agricultural land identified features surpluses above 100 kg N/ha. Largest N surpluses were estimated for fertilization of grain maize, wheat, vegetables and legumes. Survey analysis showed that N inputs in 2013 were consistent with the requirements of the EU Nitrates Directive for 93 % of agricultural land surfaces. Most often breaches of the N input thresholds were estimated for barley, wheat and oil pumpkins fertilization. The spatial approach of the potential N surplus assessment identified areas of possible environmental pollution with N from agricultural sources and individual agricultural holdings where the agricultural practices should be adjusted to reduce N contamination of water and air.

KEY WORDS: nitrogen balance; agricultural land; EU Nitrate Directive; GIS modelling

INTRODUCTION

Slovenia is considered as nitrate vulnerable area since 2001 and therefore groundwater pollution prevention activities based on the EC Nitrates Directive (Council Directive 91/676/EGS of 12 December 1991) have to be implemented on the whole territory.

In the catchment of the Kučnica border river between Austria and Slovenia, problems associated to the river quality appeared as a result of point (e.g. wastewater treatment plants) and diffuse contamination (e.g. agriculture).

Activities implemented in this project were based on the Regulation on the protection of waters against pollution caused by nitrates from agricultural sources (Official Gazette no., 113/09, 5/13), which in accordance to the Nitrates Directive (Council Directive 91/676/EGS of 12 December 1991) defines nitrogen (N) limit values from agricultural sources into the soil and measures to reduce and prevent water pollution caused by nitrates from agricultural activities.

The basis for the preparation of measures for agricultural activity in the field of fertilization in the River Kučnica water body (WB) area was the calculation of the N balance in agricultural activity, carried out according to the OECD-EUROSTAT methodology at a local level (Sušin et al., 2009, 2011a, b, 2012), considering real data on mineral and organic fertilizers consumption in 2013.

The purpose of our research was to analyse existing N loads from agricultural activities. N loads were evaluated based on data processing of N inputs and outputs in agriculture and were calculated for a single farm parcel and individual crops for year 2013. We used real data gathered by farm advisory service through a survey for farm holdings where increased risk for nitrate leaching was estimated. Based on the results a set of measures in agricultural activity was prepared in order to improve ecological and chemical status of river Kučnica.

MATERIALS and METHODS

Methodology was developed for the River Kučnica WB, one of the 155 surface water bodies in Slovenia which is located in the NE part of Slovenia on the border with Austria (Goričko region). It covers an area of 2,045.6 ha, only 0.1 % of the territory of the Republic of Slovenia. The main watercourse is 23 km long river Kučnica.

Analysis of agriculture and land use

Status of agriculture on investigated area was examined by analysing available spatial data. Identification of individual farm holdings, farm parcels (AAMRD, 2013) and different land uses (MAFFS, 2013) with associated area calculations were carried out.

An important indicator of the N load from agriculture is also the amount of N excreted from livestock manure at the farm holding level. Slovenian regulation (Official Gazette no., 113/09, 5/13) determines that yearly input of N from livestock fertilizers at farm holding level should not exceed 170 kg N/ha on agricultural land in active use (ALU). Due to this limitation the actual load of N from livestock fertilizers on ALU was assessed using the database GOVEDO (AIS, 2012) and a livestock number (AAMRD, 2012), as well as data on livestock manure trade between individual farms.

The farm survey with criteria for respondents

In order to obtain realistic data for N balance on each farm parcel we conducted a field farm survey. Since the total area of River Kučnica WB had 248 agricultural holdings (ARSKTRP, 2013), the survey was carried out only on selected agricultural holdings, which were determined according to the factors that potentially have the greatest impact on the ecological and chemical status of (surface) waters. Farm holdings were chosen for the survey by considering indicators such as:

(1) the structure of farm parcel, which was calculated from vector layer UKREPI 2013 (AAMRD, 2013);
(2) the quantity of N excreted at the annual level of a farm holding, which was calculated from the GOVEDO database (AIS, 2012) and data on number of livestock at farm holding level (AAMRD, 2012).

The following criteria were used to select individual farms:

(3) the N load from livestock fertilizers at farm holding level exceeding 170 kg N/ha (restriction of the Nitrates Directive);
(4) more than 2 ha of farm parcels surfaces within River Kučnica WB and at the same time more than 90 kg N/ha of livestock fertilizers at a farm holding level;
(5) additional criterion was more than 5 ha of maize within River Kučnica WB.

The survey was divided into five sections: A/ farm type and owners data, farming orientation, storage capacities status, B/ livestock farming methods, C/ farm sewage types, D/ storage capacities and E/ crops and fertilization data.

Nitrogen balance calculation in agriculture

The calculation of the N balance in agriculture was carried out on the basis of the OECD-EUROSTAT methodology that is based on the calculation of the difference between the amount of N applied into the soil in agriculture (N input) and the amount of N taken from agricultural land (N output) (6).

(6) N balance (kg/ha) = N input (kg/ha) – N output (kg/ha)

N input was consisted of mineral and livestock fertilizers input data (in kg/ha, gathered through survey), biological fixation of N with legumes (assessed from comparative expert assessments in EU countries in kg/ha), deposition of the atmospheric N (raster layer from EMEP model in size 50x50 km), seeds and planting material (estimated on the basis of average N content and sowing norms in kg/ha). It was estimated that the quantities of other organic fertilizers applied in the area (e.g. compost, sewage sludge, etc.) were negligible and therefore not used in total N input calculation.

N output was represented by harvested crops, grassland and other bulky fodder. The quantity of the harvested N yield was calculated on the basis of the yield data obtained from the survey and on the basis of average N content in the crops.

Collected N input and output data were transferred in the ArcGIS 9.3 Arc Info software that was used for the spatial assessment of the N balance (kg/ha) and production of the N balance map for the entire River Kučnica WB area. The results of N balance in kg/ha were classified into 7 classes (Table 1).

Table 1
Distribution of N balance results into classes.

Class	*1*	*2*	*3*	*4*	*5*	*6*	*7*
N balance (kg/ha)	*<= 0*	*1 - 50*	*51 - 100*	*101 - 150*	*151 - 200*	*201 - 250*	*> 250*

As potentially the most problematic agricultural areas, from water protection point of view, the fields where N balance in 2013 exceeded 150 kg N/ha were defined.

Nitrogen input into soil by fertilization
Data on N input by fertilization on individual farm parcels, collected through the ground-survey, were evaluated on the basis of the Slovenian regulation (Off. Gazette RS, 113/2009, 5/2013) stating that the limit values for N input into the soil for fertilization purposes of certain types of crops should not exceed the values defined in the Annex to the Slovenian regulation (Off. Gazette RS, 113/2009, 5/2013). Limit value was defined as the amount of N that can be put into soil for each crop in the form of mineral and organic fertilizers and in the irrigation of plants during the preparation of soils for sowing to harvest and for permanent crops and meadows in a period of one calendar year. This analysis was used to check whether farmers respected the restrictions of N input into soils by fertilization.

RESULTS and DISCUSSION

The state of agriculture and land use in River Kučnica WB
The land use analysis showed that in the River Kučnica WB 60.6 % of total 2,045.6 ha area is represented by agricultural land, out of which 1,015.4 ha were subsidized, which represented 82 % of all agricultural land. There were 248 farm holdings in River Kučnica WB, with a total area of 1,015.5 ha. There were 145 farms with less than 2 ha of farm parcel (59 % of all farms) covering only 10 % of all farm parcels. 53 farms had more than 5 ha of land (21 % of farms) covering 76% of all farm parcels. Despite the smaller number of farms larger than 2 ha their land covered most (90%) of all farm parcels in River Kučnica WB.

Agricultural land use on farms was consisted mainly of fields and gardens (850 ha / 83.7 %) and in smaller extent of meadows (131.8 ha / 13%) ha), vineyards (22.1 ha / 2.2 %), extensive or grass orchards (8 ha / 0.8 %), intensive orchards (2.8 ha / 0.3 %) and other permanent plantations (0.7 ha / 0.1 %).

Yield structure on farm parcels was consisted of 35 different crops where the most represented were grain maize (336 ha), wheat (236 ha), permanent grassland (132 ha) and barley (99 ha) and they represented 79 % of all farm parcel.

Land use analysis on River Kučnica WB showed that in 2013 the largest area was covered by fields and gardens (901.1 ha / 44 %), forest (711.3 ha / 35 %) and permanent meadows (198.3 ha / 10 %). The rest of land use (11 %) was represented by built and related land, abandoned agricultural land in spontaneous afforestation, extensive orchards, vineyards, trees and shrubs, intensive orchards untreated farm land, water, other permanent crops, greenhouses, marsh meadows, agricultural land overgrown with forest trees.

The analysis of the N load from livestock fertilizers
Analysis of the extracted N from livestock fertilizers in 2012 showed that 194 farm holding out of 248 were dealing with livestock fertilizers. Average load of N from livestock fertilizers on a farm parcel was relatively small (68 kg N/ha) as it didn’t reach even half of the permissible annual load of N (170 kg N/ha) based on the Slovenian regulation (Off. Gazette RS, 113/2009, 5/2013). Most farm holdings (59 %) had N load less than 50 kg N/ha and additional 22 % of them less than 90 kg N/ha. For two farm

holdings we detected exceeded permissible N load from livestock fertilizers at a farm parcel level. (Table 2).

Table 2
Distribution of N load from livestock fertilizers (kg N/ha) on farm parcels.

Farm parcels	N load from livestock fertilizers kg N/ha					
(ha)	< 50	50-90	90-130	130-170	> 170	SUM
< 1	4	1				5
1 - 2	21					21
2 - 5	39	10	2	1		52
5 - 10	35	7	11	3		56
10 - 20	8	11	7	3	2	31
> 20	7	13	6	3		29
SUM	114	42	26	10	2	194
Percentage (%)	59	22	13	5	1	100

Farm survey results

Taking into account the criteria 34 farm holdings with 613 land parcels and 24 different crop productions were included in the survey. At the level of River Kučnica WB they represented 53 % of all farm parcels (534.6 ha) and 70 % of excreted N from livestock fertilizers.

The analysis of farm holding respondents showed that 56 % of them were farming in an integrated way and bound breeding (53%) was dominated for the domestic animal husbandry. 82 % had a septic tank with a waterproof bottom (a concrete bottom) and 15 % of them were connected to the public sewage system which was positive in terms of environmental pollution prevention. 30 % of storage facilities for livestock manure were built or renovated more than 10 years ago.

The largest share in terms of crop production had maize for grains (37.4 %) and wheat (23.0 %), which together with permanent grassland, barley, oil pumpkin, vine, silage maize, triticale and clover grass mixture presented 95 % of all cultivated areas of farm holding respondents.

The nitrogen balance

The results of N balance assessment showed the negative N balance for 27 % of the agricultural land included in the survey. The N balance surplus was estimated on 73 % of the agricultural land. A surplus up to 50 kg N/ha was estimated for 25 % of agricultural land and a surplus of between 51 and 100 kg N/ha for most areas (37 %). The N balance surplus over 100 kg N/ha was estimated for 11 % of agricultural land (Figure 1).

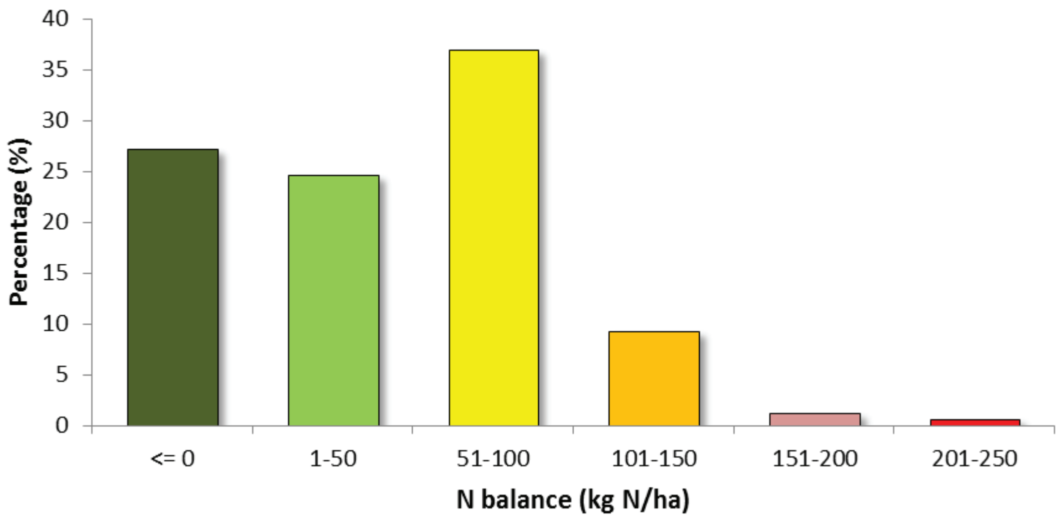

Figure 1. N balance distribution according to farm parcels area (in %).

The analysis of N balance according to individual crops showed relatively large differences between individual groups. In grain maize, the N balance surplus above 50 kg N/ha was estimated on 63 % of the area, with a predominance (49 %) of the N surplus between 51 and 100 kg N/ha. The same applied to wheat (57 %), while barley had a surplus of up to 50 kg N/ha. On permanent grassland, the N balance was mostly negative (97 %), which can be attributed to the relatively modest fertilization of permanent meadows and in particular large N output by crop harvest (Figure 2). From the point of environmental pollution, it is interesting that the large N balance surplus (above 200 kg N/ha) is typical for the outdoor production of vegetables as well as clover-grass and grass-clover mixtures. Farmers often use to too much fertilizers for vegetables, whilst regarding large N balance surpluses for clover-grass and grass-clover mixtures farmers do not take into account the relatively large amount of biological fixation of N with the help of symbiotic bacteria on the roots of the legumes.

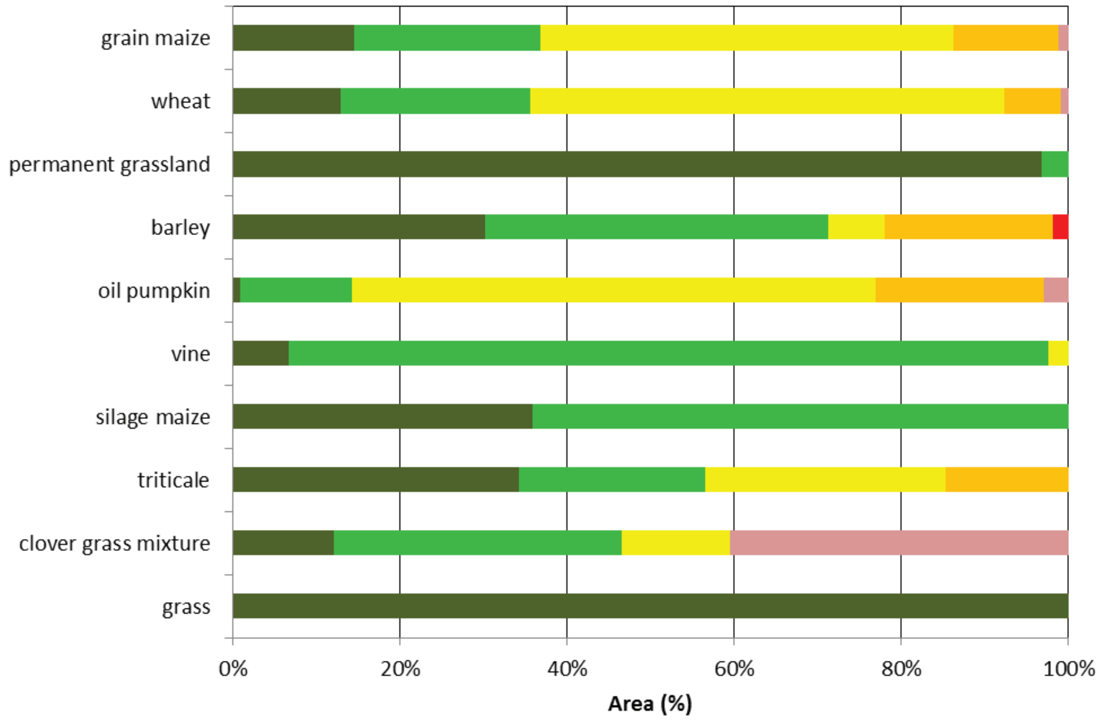

Figure 2. Distribution of N balance by individual crops that present 95 % of the area.

The analysis of N balance showed that the surpluses above 150 kg N/ha were typical for 3 farm holdings with 11 farm parcels on which 7 different crops were cultivated (vegetables, grain maize, barley, wheat, oil pumpkin, clover-grass mixture and potatoes).

Estimated N balance tabular data were transferred into ArcGIS 9.3 program in order to create vector layer data. The result was N balance map for River Kučnica WB area estimated for each farm parcel of farm holdings included in the survey (Figure 3). Spatial analysis showed that all farm parcels with extreme excess of N (above 150 kg N/ha) were in the middle flow of river Kučnica in Goričko area under settlements Fikšinci and Gerlinci.

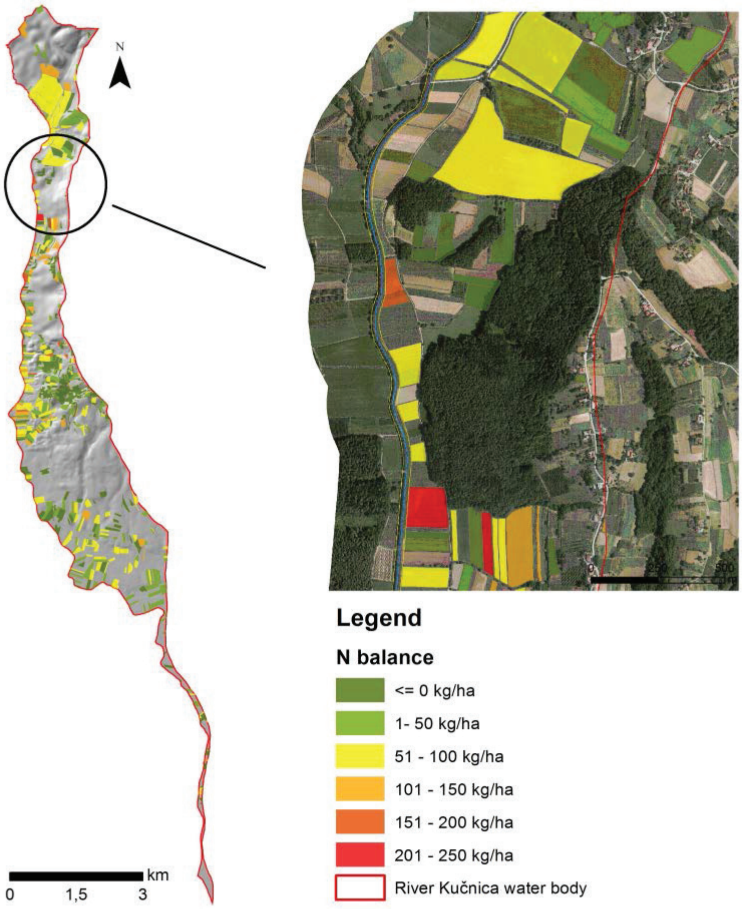

Figure 3. N balance map for farm land in River Kučnica WB (left) with a zoomed segment (right).

Nitrogen input into soil by fertilization

Based on a survey result regarding single crop fertilization it showed that N input by fertilization in 2013 was largely in line with the requirement of the Slovenian regulation (Off. Gazette RS, 113/2009, 5/2013) in terms of limit values of the N input into soils. On 572 out of 613 investigated farm parcels crop fertilization was compliant with the Slovenian regulation (Off. Gazette RS, 113/2009, 5/2013), which represented 93 % of them. Limit values for N input into soils were exceeded on 9 farm holdings with 41 farm parcels in total (7 % of farm parcels). Most frequent violation of the N input limit value was estimated for cereals (barley and wheat) and oil pumpkins.

CONCLUSIONS

The analysis showed some favourable results, based on which we could conclude that agriculture in the area of River Kučnica WB is already partly oriented towards an environmentally friendly farming method. These positive indicators are as follows:

(1) the load of agricultural land in use with N from livestock fertilizers was relatively low (68 kg N/ha), while exceeded limit value of 170 kg N/ha was estimated only in case of two farm holdings;
(2) the vast majority of agricultural land (82 %) was included in the recording system in 2013, which means that they applied for a subsidy that year and already implemented some agro-environmental measures;
(3) most of farm holdings (56 %) were farming in an integrated way, which is more favourable in terms of water pollution protection than conventional production;
(4) the vast majority of farm holdings (82 %) had a tidal septic tank with a watertight bottom (paved bottom).

On the other hand, the study showed that livestock fertilizer storage facilities were relatively old, as only 30% of buildings have been built or adapted less than 10 years ago. In terms of environmental

pollution, point sources of pollution are much more dangerous than the dispersed use of fertilizers on agricultural land, as there is a large amount of nutrients in a small area like manure storage facilities.
The analysis of the N balance in 2013 showed that the N balance surplus was estimated on 73 % of the investigated agricultural land. If N balance surpluses up to 50 kg N/ha can still be considered acceptable (25 % of them), we cannot claim this for just under half of all farm parcels (48 %) investigated. This is especially true for 11 % of all farm parcels, where we detected more than 100 kg/ha of the N balance surplus.
A more detailed analysis of N surpluses by individual crops showed that the most common surpluses were in case of the dominant two agricultural crops (grain maize and wheat) between 51 and 100 kg N/ha. Interestingly, the N surplus was significantly lower in the fertilization of silage maize (less than 50 kg N/ha). In the future, more attention should be paid to N fertilization in terms of vegetables and clover-grass and grass-clover mixtures for which we estimated largest N surpluses.
Individual crops were mostly fertilized according to the requirements of the Nitrates Directive (Council Directive 91/676/EGS of 12 December 1991). Nevertheless, in the case of 9 farm holdings we estimated exceeded limit values of N input into the soil by fertilization, mostly for cereals (barley and wheat).
For a correct interpretation of the N balance results it is important to be aware, that the OECD-EUROSTAT methodology does not take into account some important factors, which also affect the actual N surplus in the soil. In this context, we should mention in particular the losses of N from soils by denitrification and the release of ammonia (NH_3) and nitrous oxide (N_2O) from the stables, during the storage of livestock fertilizers and fertilization. Because of this, the N balance surplus in soil was actually lower in 2013. Additionally, the N in the year of use is not fully utilized (the multi-annual utilization of manure from N is about 70 %), which means that the total N surplus is not in this case completely left to the environment (including waters!). A part of the N from stable manure is in the form of organically bound N still available for plants in the upcoming years, which is mainly provided by favorable conditions for the mineralization of organic matter in the soil.
Our analysis proved to be suitable for N balance assessment and was mainly used as a tool to determine the relevant ratios of the N balance surpluses among the agricultural plants and individual areas in the River Kučnica WB. This, however, enabled us to develop appropriate general and more specific measures to further reduction of contamination risk of the river Kučnica with N from agriculture.
General measures (principles of good agricultural fertilization, 15 m buffer belt along the river Kučnica and education of farmers in terms of water protection due to the use of N in agriculture) and specific measures (additional overview of the facilities for livestock manure storage, education on the topic of fertilization of legumes, prevention of surface outflow of nutrients into rivers, implementation of the N balance calculations to the consulting service, optimization of the use of appropriate mineral fertilizers according to the actual needs of plants and preparation of appropriate expert material) should be coordinated from the local Agricultural Advisory Service and in this case partners on the other side of the state border (Austria), which also extends to River Kučnica WB.

Acknowledgements

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Mapping potential truffle growing areas in Slovenia – an opportunity for additional agricultural crop

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ABSTRACT

Truffles are a group of underground fungi well known in gastronomy and one of the most markets esteemed food. The tradition of truffle harvesting in Slovenia was already described in the Scopoli's Kranjska flora in 1772. Due to the small number of random finds, the truffles are (wrongly?) considered as rare fungi. Nevertheless, the truffles can be foound in soils along entire temperate climate zone of Slovenia with higher frequency and diversity in areas with warmer climate. Traditional harvesting of truffles takes a substantial time, experiences and specially trained animals, dogs mainly. Some Mediterranean countries such as Spain, France and Italy, have developed a high profitable activity – the Trufficulture (nursery growing truffle production, processing, and marketing). In Slovenia, the trufficulture is still undeveloped and a highly marginal activity that deserves to be assessed as an additional agri-touristic activity and a potential source of income for Slovenian farmers.

The aim of the study was to identify soil and environmental factors that significantly define the areas with (high) natural truffle-growing suitability and to create a map/spatial database of potential growing areas for Tuber Aestivum. The map was derived from a model which process spatial soil and environmental information as well as soil analytical data from 21 Tuber Aestivum sites in Slovenia.

The contribution presents the map and the web GIS application of Tuber Aestivum growing suitability potential of Slovenia which is estimated to the 27 % of the country territory. Out of this area, the most suitable for truffles are sub Mediterranean and low Dinaric Karst landscapes. The extent and location of this areas can be identified as a basic decision support information to estimate trufficulture potential for a successful establishment of truffle nurseries and development and introduction of the trufficulture.

KEY WORDS: trufficulture, truffles, *T. Aestivum,* GIS, decision support, multi criteria evaluation method

INTRODUCTION

Truffles, the underground fungi, are well known in gastronomy and one of the most market esteemed foods. The truffle consummation in Europe is about 2,300 years old tradition firstly mentioned by Treofast in the Ancient Rome. After the decline in Middle ages, the truffle picking tradition in Europe rise again with the Pope Clement (1305 - 1134), and especially later in the Renaissance period (Piltaver and Ratoša, 2006). The truffle picking tradition in Slovenia was described in the Scopoli's Flora Carniolica in 1772. Due to the small number of random findings the truffles are still wrongly considered as rare (Breitenbach in Kränzlin, 1984). On the contrary, the findings suggest truffles to be widespread along the entire temperate climate zone with higher frequency and diversity in areas with warmer climate (Piltaver in Ratoša 2006). There are significant differences between several truffles species. The *T. aestivum* par example, has a wide ecological and geographical range and a southern distribution boundary in North Africa (Chavelier and Frochot 1997a; Hall et. Al. 2007).

The traditional harvesting of wild truffles is time-consuming; it requires experience and specially trained animals, dogs mainly. In the past decades some Mediterranean countries (mostly France, Italy and Spain) invested significant resources to study natural environmental parameters of truffle growing conditions and have been relatively successful for some truffle species (Piltaver and Ratoša, 2006). They managed to utilize the knowledge by turning it into viable economic activity – the trufficulture (nursery growing truffle production, processing, marketing and sale).

In Slovenia the trufficulture is not yet recognized as a business opportunity and an additional agricultural activity although the trufficulture could become a profitable especially in areas less favourable for traditional agriculture (LFA areas). The reason for low interest of farmers is probably relatively high investment for a truffle farming, to establish truffle nursery on one and unsecure and unpredictable success in terms of profitable yield on the other hand. On top of that, the first yield can be harvested after a relatively long period; after 6 to 10 years on average. The lack of adequate promotion, knowledge on truffle growing conditions, absence of truffle nurseries selling certified inoculated species largely contribute to the practically non-existing trufficulture in Slovenia.

The article presents an initial research, a first step to evaluate the natural potentials for trufficulture development in Slovenia. It explains the method for assessment of natural conditions for natural truffle growing areas in Slovenia. The research is focused on three types of truffles: i) the summer truffle (T*uber aestivum*), ii) the white truffle (*Tuber magnatum*), and iii) the winter or Perigord truffle (*Tuber melanosporum*). The main aim of the research was to define the most important soil and landscape properties which contribute to the truffle growth potentials in different landscapes and climates of Slovenia. The results are evaluated soil properties – indicators that determine truffle growth potential and the visualization/map of potential natural growing areas in Slovenia for summer truffle (T*uber aestivum*). The map was derived by multi criteria evaluation method/processing of spatial soil and environmental information as well as soil analytical data from 21 *Tuber Aestivum* sites in Slovenia.

MATERIALS and METHODS

Soil survey and analysis

Thirty two known and representative truffle growing sites around different pedo-climatic conditions of Slovenia, selected by the recognised expert Mr. Andrej Piltaver, the mycologist from the Institute for Systematics of Higher Fungi (ISHF), were investigated. The *T. aestivum* was found at twenty one growing sites, the *T. magnatum* at nine sites and *T. melanosporum* at two sites[1] only.

On each individual location the land use, terrain properties (altitude, exposition, and slope) were observed and data about the average annual air temperature and average annual precipitation collected (climate maps from Environmental Agency of Slovenia, data from period 1971 – 2000). At each site soil was sampled in upper layer (0 – 10 cm depth), the same depth where the truffles grow. Chemical and physical analysis of soil samples were carried out in the laboratory of the Agricultural institute of Slovenia where the pH in KCl (ISO 10390:2005), plant available phosphorus , potassium, magnesium (all AL extraction), total nitrogen (ISO 14255:1998), the organic matter content (ISO 14235:1998), coarse particles > 2 mm (ISO 11277:1998), texture (ISO 11277:1998), exchangeable Ca (NF X31-108), exchangeable Mg (NF X31-108), exchangeable K (NF X31-108), exchangeable Na (NF X31-108) and exchangeable H (own method[2]) were measured. The content of carbonates as $CaCO_3$ (ISO 10693:1995) were measured in the laboratory of Biotechnical Faculty, University of Ljubljana. The soil measurements data and environmental factors were processed using the descriptive statistics indicators and the ANOVA analysis. The collected data enabled an insight to ecological and natural growing conditions of the *T. aestivum*, *T. magnatum* and marginally of the *T. melanosporum* in Slovenia.

Defining natural growing areas of T. aestivum in Slovenia

The map of potential *T. aestivum* growing sites was elaborated using the weighted linear combination method as a part of the multi-criteria evaluation process (MCE) which differentiates between two types of evaluation criteria (spatial covariates):

i) constraints, which are absolute or Boolean values and are used as limitation of considered alternatives (in our case that means criteria defining areas that are unsuitable for *T. aestivum* growth); and

ii) continuous factors or relative criteria that have a role of increasing or decreasing the suitability for a certain property (in our case criteria which increase or decrease the potential for T. aestivum growth) (Eastman, 1997).

The entire evaluation of truffle growing locations utilized and combined soil data with expert knowledge and the literature information. It enabled us to define the most important ecological criteria for *T. aestivum* natural growing sites. All spatial covariates were processed and converted into a covariate layers in a raster format using the uniform spatial resolution of 12.5 m.

The evaluation method was implemented in GIS with eight main separate steps: 1. Soil data standardization; 2. Relief data standardization; 3. Climate data standardization; 4. “Host plants” data standardization, 5. Defining the constraints; 6. Evaluation of abiotic criteria; 7. Evaluating of biotic criteria; and at the end, 8. The final GIS algebraic processing to create a raster database of indicating the potential *T. aestivum* growing areas. The raster processing was written in the ESRI AML code (Arc

[1] Since the *T. melanosporum* was found only on two sites the statistics weren't carried out.
[2] exchangeable H measured in extract of $BaCl_2$

Macro Language) and processed in the ArcInfo Workstation module, a part of the ArcGIS ArcInfo 9.3 package.
The map was evaluated and tested on the 21 actual growing sites of *T. aestivum*.

The GIS evaluation model and processing steps
Criteria used as multi criteria evaluation factor
In step one key soil criteria (n=8) considered were the soil pH, organic matter content (%), CN relationship, calcium carbonate content (%), content of sand, silt, clay (%) derived from the Digital soil map of Slovenia 1:25.000. In step two the topography covariates (n=3) were standardized; the slope (°), curvature, and the amount of solar radiation, which we evaluated from exposition (°) and slope (°) data. These criteria were choosen based on literature (Chavelier and Frochot 1997a; Hall et. Al. 2007; Stobbe et. Al. 2012; Ricard. J. M., 2003), suggestion of mycologist and truffle expert Mr Andrej Piltaver, the results of soil samples, climate and topography parameters from T. aestivum growing sites and available spatial data. All topographic data were derived from the DEM 12.5 m resolution. The data used in third step for climatic covariates (n=2) were the average annual air temperature map (°C), average annual precipitation map (mm) both provided by the Environmental Agency of Slovenia for the period 1971– 2000. The mycorrhizal plant presence layer as a group of biological criteria (step four) was evaluated from forest composition map provided by the Slovenia Forest Service. The data on key truffle mycorrhizae species *Prunus avium, Quercus, Salix, Carpinus betulus, Ostrya carpinifolia, Tilia platyphyllos, Tilia cordata, Populus* were reconsidered and integrated in the model. Since forest composition map was not enough accurate or some mycorrhizae species were missing we evaluated their presence using also the land use data (Land use, 2012). The distance from forest edge layer was derived and assumed the high suitability for *T. aestivum* also on agricultural land at the forest edge and descending till 10 m distance.

Criteria used as MCE constraints
As constraint criteria next data was used; mountainous climate (H) from climate classification map for Slovenia (Ogrin, 1999) which is more detailed version of the Köppen climate classification, areas above 1000 m (DEM 12.5), areas with no presence of mycorrhizae species (wet and acidic sites) or non-suitable land use (sealed areas etc.), data of flood areas from Environmental Agency of Slovenia, areas with no soil and non-carbonate soils from Digital soil map of Slovenia 1:25.000.

Standardization
For covariates used as factor standardization processes were applied. The cell values in original units were reclassified to relative values indicating the suitability for the *T. aestivum* (0 equals not suitable, 100 highly suitable). For the continuous type of environmental covariates the fuzzy standardization process was used. Mathematical functions were derived from expert knowledge defined curves using the Geogebra software. All constraint criteria raster layers were combined into the single constraint layer with cell values 1 as *T. aestivum* growing potential exist, and 0 - no growing potential for the *T. aestivum*.

Weighted overlay
Soil, topography and climatic factors (abiotic factors) were weighted using the analytical hierarchical process (AHP) (Eastman, 1997). The consistency of covariate weights was checked by the calculation of the consistency ratio. The land suitability for *T. aestivum* was calculated using the equation:

$$SI = \sum_{i=0}^{n} W_i * X_i * \prod C_j$$

where; SI = suitability index for *T. aestivum*, W_i = weight for factor i, X_i = standardized value for factor i, C_j = constraint.

For the areas with no constraints the final SI was calculated by combining the SI layer of abiotic covariates with SI from presence of truffle mycorrhizae plant species layer (biotic covariates) in the weighted 60 : 40 ratio.
The result of the model was indication of the land suitability for the *T. aestivum*, in other words the potential black truffle growing area in Slovenia.

RESULTS and DISCUSSION

The results of statistical analysis of observed soil, relief and climate parameters at 30 truffle growing sites are presented in the lower table (Table 1). The statistical analysis for the *T. melanosporum* was not carried out due insufficient number (2) of locations of *T. melanosporum* identified.

Summary of ecological criteria of T. aestivum natural growing sites

In general, most growing sites had alkaline (pH >7.2) and neutral acidity (pH > 6.5). Only four sites had pH < 6.5 that all belong to the *T. aestivum*. *T. aestivum* sites had significantly ($p<0.05$) lower average soil pH values than *T. magnatum* and wider range with higher variation of soil pH values. The study from Hungary *T. aestivum* growing sites showed the pH value ranges between 5.2 - 8.5, which is similar to our findings (Csorbai Gogan et. al., 2012). The soil acidity at both *T. melanosporum* sites from our study is alkaline and therefore conditions are more similar to *T. magnatum*. The pH in KCl from *T. melanosporum* growing sites in France ranged between 7.1 - 7.7 (Ricard, 2003).

The average value of accessible magnesium (MgO) is significantly higher for *T. aestivum* with higher range and variation than the *T. magnatum* sites. According to the accessible Mg (MgO), the *T. melanosporum* sites (5.4 mg/100g and 7.8 mg/100g) are more similar to the *T. magnatum* locations.

The total N in soil at growing sites is in general very low and significantly higher at T. aestivum sites with average of 0.4 %. The *T. melanosporum* sites have similar conditions to the *T. aestivum* with total N value of 0.46 % and 0.35 %.

Soil organic matter content (%) is significantly higher at *T. aestivum* sites with the average of 8.5 % than at *T. magnatum* sites with the average of 4.5 %. The soil organic matter at *T. aestivum* sites from Hungary ranged between 0,7 - 5,6 % (Csorbai Gogan et. al. 2012). Samples from *T. melanosporum* sites from our study had 8.7 and 6.6 % soil organic matter and is similar to *T. aestivum* sites. According to Lefevre et. al., 200, the soil organic matter at *T. melanosporum* sites does not exceed 8 %.

According to high base saturation, the soils are classified as eutric. The average V value for T. aestivum is 84 % and is lower than the average V value at *T. megnatum* growing sites (96 %) and *T. melanosporum* sites (V value for both samples is 94 %).

Truffles prefer soils with high stone content which has been confirmed in our study as well. The average content of soil particles > 2 mm at *T. aestivum* sites was 19 % and is higher than at *T. magnatum* sites where average is 13.3 %. T. melanosporum sites had the highest quantity of rock fragments (46 % and 74 %). That could be one of the strongest arguments to promote truffle cultivation in high soil stoniness areas which are frequently less favourable for traditional agriculture.

The soil carbonate content is one of the most important factors affecting the truffle growing land suitability. In general, truffles require calcaric soils. Low carbonate content soil is often a limiting factor for truffle growth. The results of our study proved that *T. magnatum* and *T. melanosporum* need high carbonate soils for their growth. The minimum for *T. magnatum* was 12.8 % and the average is 29.2 %. On the other hand, the carbonate content for *T. aestivum* is significantly lower with average of 6.0 %. Surprisingly, the *T. aestivum* was found in the North-East of Slovenia on non-carbonate soils.

The assumption that *T. magnatum* grow in areas with significantly warmer climate than *T. aestivum* was confirmed in our study. Very similar rule applies to *T. melanosporum* climate conditions. *T. Magnatum* is much more sensitive to lower air temperatures (3.4 to 5.1 °C) than the *T. Aestivum* (-1.1 – 4,4 °C). *T. magnatum* and *T. melanosporum* were found only on one part of the Slovenia with temperate humid climate with hot summers (Cfa according to Köppen). Since these are areas located near warm Mediterranean Sea it seems logical that significance of elevation and slope parameters is lower at *T. magnatum* sites. *T. magnatum* is often found on moist but well drained soils and active down-slope mass movement areas where soil is constantly renewed by denudation and affected by colluvial processes from upper slopes (Bragato et al., 2004).

Table 1
Results of statistical analysis of soil, climate and relief parameters for T. aestivum and T. magnatum. Since numerus of T. melanosporum sites was 2, the statistics were not calculated. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05.

Parameter group	Parameter	Units	Summer truffle (*T. aestivum*) n = 21					White truffle (*T. magnatum*) n = 9						
			MIN	MAX	AVERAGE	STD	CV	MIN	MAX	AVERAGE	STD	CV	p value	
soil	pH in KCl		4.9	7.6	6.9	0.7	10	7.3	7.8	7.6	0.1	2	0.007	**
soil	Phosphorus (P_2O_5)	mg/100g	1.2	103.0	15.7	29.0	185	0.7	3.1	1.4	0.8	53	0.155	
soil	Potassium (K_2O)	mg/100g	9.5	48.0	26.2	8.3	32	17.0	29.0	22.9	3.8	16	0.262	
soil	Magnesium (Mg)	mg/100g	4.6	84.0	34.5	25.4	73	2.9	7.4	5.6	1.7	30	0.002	**
soil	N (total)	%	0.2	0.9	0.4	0.2	45	0.1	0.4	0.2	0.1	31	0.005	**
soil	Organic matter	%	2.7	18.3	8.5	4.2	50	1.9	7.6	4.5	1.7	38	0.010	**
soil	C/N		9.1	13.5	11.1	1.3	11	9.7	12.2	10.8	1.0	9	0.585	
soil	Total basic cation (S)	mmol+/100g	17.5	64.0	46.0	15.3	33	41.5	55.0	46.3	3.8	8	0.956	
soil	CEC (T)	mmol+/100g	28.0	75.6	53.2	14.2	27	43.2	58.5	48.2	4.4	9	0.312	
soil	V value	%	62.5	95.9	84.8	10.5	12	94.0	97.9	96.1	1.0	1	0.003	**
soil	Clay (< 2 um)	%	17.9	37.7	29.5	6.0	20	14.4	32.8	24.7	7.3	30	0.072	
soil	Silt (2 - 50 um)	%	40.4	70.0	53.5	7.5	14	51.4	67.6	57.3	4.9	9	0.170	
soil	Sand (50 - 2000 um)	%	9.9	34.9	17.0	5.7	33	8.1	31.3	18.0	7.5	42	0.712	
soil	Soil particles >2 mm	%	6.4	30.7	19.0	6.3	33	4.5	23.0	13.3	5.1	38	0.023	*
soil	Carbonates $CaCO_3$	%	0.0	26.7	6.2	8.7	141	12.8	45.2	29.2	8.7	30	5.81E-06	***
climate	Average January temperatures	°C	-1.1	4.4	0.7	2.1	291	3.4	5.1	4.1	0.6	14	4.04E-05	***
climate	Average July temperatures	°C											2.54E-04	***
climate	Average annual temperatures	°C	8.1	12.7	10.1	1.5	14	11.5	13.4	12.4	0.6	5	1.06E-04	***
climate	Average annual precipitation	mm	921	1364	1265	95	8	1149	1423	1286	94	7	0.583	
relief	Elevation	m	97	758	353	167	47	22	391	141	120	85	0.002	**
relief	Slope	°	4.1	35.4	14.9	8.6	58	0.7	14.6	4.8	4.7	98	0.003	**

The map of natural potential for T. aestivum growing areas

The result of the multi criteria evaluation process was the GIS layer showing natural land suitability for *T. aestivum* growths in Slovenia with range of values called suitability index between 0 and 100. The areas which received 0 values are interpreted as areas with no natural potential for growth of T. aestivum and higher suitability index means higher potential and also higher probability to find the T. aestivum. For the presentation the map was resampled from original 12.5x12.5 m resolution to 1x1 km resolution to avoid massive truffle harvesting and damage to the forest. The resampling has been done by using 1x1 km flowing filter where suitability index from raster cells under filter where summed. In general, the most of Slovenian areas has no potential for T. aestivum growth (73 % or 14,763 km^2), but still there are quite surprisingly large areas of suitable areas (28 % or 5,500 km^2). Out of suitable areas there are 2,400 km^2 or 12 % (43.6 % out of suitable) of areas with truffle growing suitability index larger than 80, which mean highly suitable areas (Figure 2).

The map presents most areas in North-East Slovenia, which is part of Western Pannonian Basin, as not suitable for *T. aestivum*. The limiting factor in this area is non-carbonate parent material. Silicate alluvial gravel, sandy deposits in the river plains and non-carbonate sandstones in the hills. Other large basins in the Central Slovenia (ex. Ljubljana Basin, Novo mesto Basin, Savinja Basin, Celje Basin), were mostly identified as non-suitable. The Brkini area seems to be unsuitable due to Dystric Cambisol formed on a non-carbonate sandstone bedrock (Figure 1).

Mountain areas of Alps and High Dinaric Plateaus (Snežnik, Javorniki, Hrušica, Nanos, Trnovski gozd, Velika gora, Goteniška gora) are unsuitable. The limiting factor here are harsh climate conditions, which limit truffle grow potential due to low temperatures (Figure 1).

All other areas in Slovenia in general, features at least some natural *T. aestivum* growing potential. The fragmentation of suitable areas is much higher than in case of non-suitable areas. The largest area with very high *T. aestivum* growing suitability can be identified in the South - West Slovenia. Those are the areas of Low Karstic Plateaus, Plains and Hills of Mediterranean landscapes (ex. Karst). Very suitable are also large parts of Low Karstic Plains and Hills of Dolenjska region in South-East and East Slovenia.

The data and map lead to the conclusion that ecological conditions for *T. aestivum* are favourable widespread so that very suitable areas for *T. aestivum* can be found in areas of Slovenia which are so far not known as traditionally truffle growing areas (Figure 1).

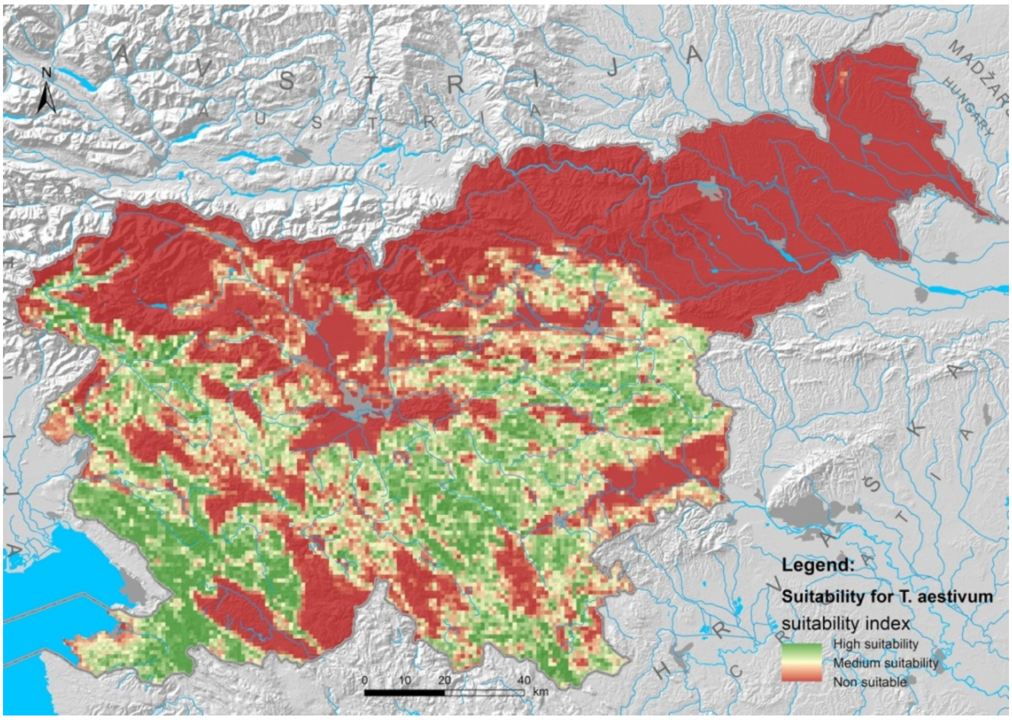

Figure 1. Map of *T. aestivum* potential growing area in Slovenia

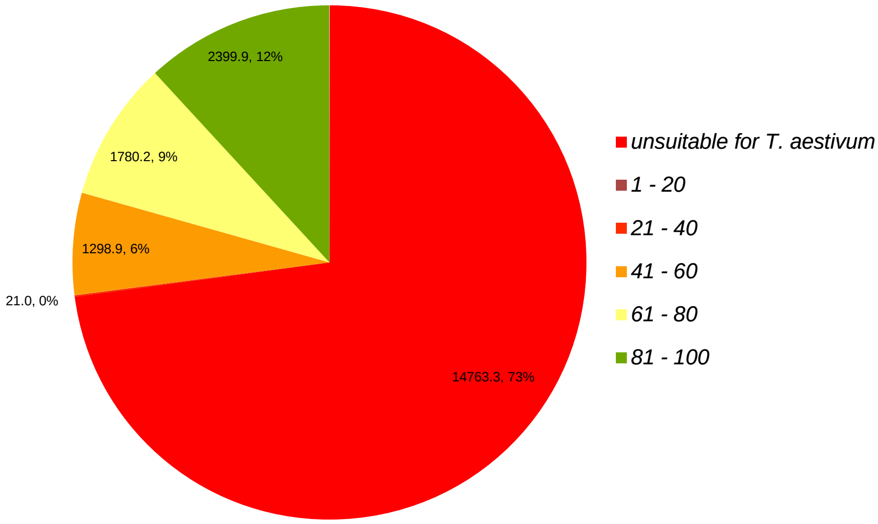

Figure 2. Land suitability for *T. aestivum* growth
(represented by suitability index: higher index means higher suitability).

The Truffle growing potential map was evaluated at all 21 observed growing sites of *T. aestivum* in Slovenia. The prediction power of the model is satisfactory. Out of 21, 17 sites showed some suitability according to the map and 4 growing sites fell under unsuitable area. From 17 growing sites we got the average of 84 points of suitability index with quite low variability-coefficient of variation is 16 % (Figure 3, Figure 4, Figure 5).

The map was evaluated also on the field mostly near Ljubljana by truffle expert. Using the map which was included in Truffle Web GIS viewer he found the new truffle growing sites (Figure 6).

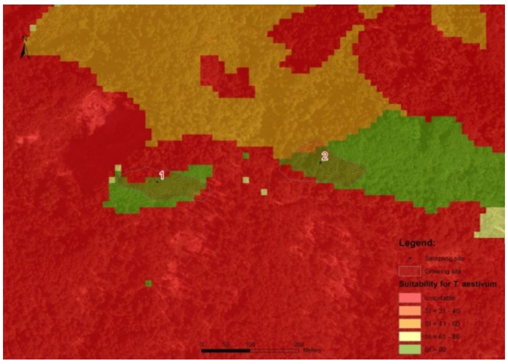

Figure 3. Map of potential *T. aestivum* growing site at the actual growing site near Ljubljana; an example of a good prediction.

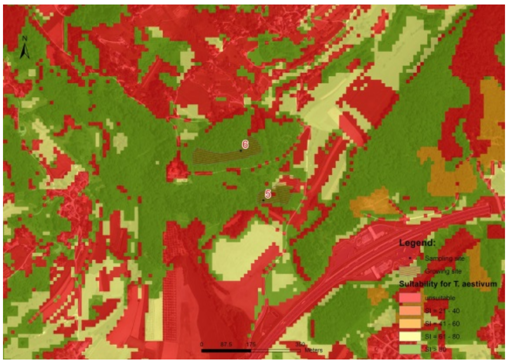

Figure 4. Map of potential *T. aestivum* growing site at the actual growing site at Low Dinaric Platoes and Hills of Dolenjska region in South - East Slovenia; an example of a good prediction.

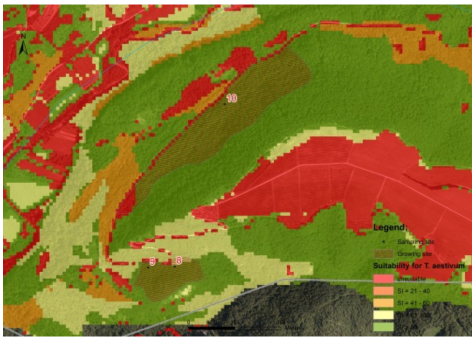

Figure 5. Map of potential *T. aestivum* growing site at the actual growing site near Dragonja river in South - West Slovenia; an example of a good prediction.

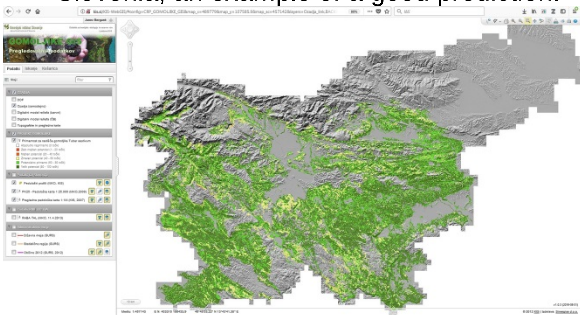

Figure 6. Truffle Web GIS viewer with *T. aestivum* potential growing areas in Slovenia.

CONCLUSIONS

T. aestivum, T. magnatum and T. melanosporum ecological growing conditions differ. For the most observed soil, relief and climate parameters *T. magnatum and T. melanosporum* conditions are similar but they both differ from the *T. aestivum* sites. Soil samples from *T. aestivum* sites had significantly lower average pH, V value and carbonate content than T. magnatum. The accessible magnesium (MgO) in soil, soil organic matter, content of soil particles > 2 mm, climate parameters and relief parameters were on average significantly higher for *T. aestivum* sites than for *T. magnatum* sites. The results indicate wide ecological and therefore also geographical range of T. aestivum in comparison to *T. magnatum* and *T. melanosporum* which are less tolerant and were found only on calcaric soils in South - East Slovenia which has temperate humid climate with hot summers.

The result of a spatial multi criteria evaluation process is the map of *T. Aestivum* potential growing areas in Slovenia. According to the map 27 % of Slovenia features some natural potential for *T. aestivum* growth of which 2,399.9 km^2 or 43.6 % are highly suitable areas. Since the numerus of *T. eastivum* sites was low (21 growing sites) and the fact that the map can be only compared to true or false value (*T. aestivum* exists or not) the quantitative evaluation was not carried out. After the qualitative evaluation of the map on all 21 observed growing sites of *T. aestivum* in Slovenia the prediction of the model can be described as satisfactory. Still, the probability of the high suitable areas is over-estimated by the model elaborated. The main reasons are: the lack of data presenting the main environmental conditions determining/affecting truffle growth, accuracy of available spatial data used as the input criteria of the model, equation and weights used in the standardization process, need further refinement. The accuracy of the soil data from soil map of Slovenia 1:25.000 and the climatic maps (1x1 km) is probably too low to elaborated highly-precise map as well. More accurate and high-resolution input data can improve the prediction power of the model. Even though, the map proved itself useful to truffle experts and pickers and a good support to determine the potential truffle growing areas.

Ecological conditions for the *T. aestivum* are wide enough so that very suitable areas can be found in parts of Slovenia which are not known as traditional truffle growing areas. Therefore, the potentials for truffle cultivation should be explored also in non-Mediterranean part of Slovenia. There, the truffle cultivation could become a source of an additional income in the areas marginally suitable for traditional agriculture and agro-tourism.

Acknowledgements

The authors would like to thank all participating in the study, especially to mycologist and truffle expert Mr Andrej Piltaver for his important contribution, participation to the field work and evaluation of the T. aestivum growing areas map of potential. Authors thank the Central laboratory of Agricultural institute of Slovenia for analysis of soil samples. Also we are grateful to the leader of the project prof. dr. Dušan Jurca and dr. Nikica Ogris from the Forest institute of Slovenia for preparing forest data.

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Estimation of soil organic carbon stock in the Republic of Serbia

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ABSTRACT

Spatial distribution of soil organic carbon (SOC) was investigated in the soils of the Republic of Serbia. Organic carbon stocks were estimated for soil layers 0-30 cm and 0-100 cm. The database included a total of 1,140 soil profiles. Soil map of the Republic of Serbia was adapted to the WRB classification and divided into 15,437 polygons (map units). We calculated the SOC stock values for each reference soil group based on mean values of SOC at 0-30 and 0-100 cm and their areas. Based on the size of the reference groups, total area of the Republic of Serbia, and the mean SOC values for each reference group, we calculated the total SOC stocks.

Database was established in the period 2009-2011. Presently, the database includes a total of 1,140 soil profiles which involve 4,335 horizons. Data that comprise the database for analytical study were collected in the period 1962-2010. Using Soil Map of Serbia, areas of the main WRB reference soil groups were defined. Total values of organic carbon stocks for these reference groups were calculated on the basis of the mean values of organic carbon content at 0-30 cm and 0-100 cm and the area of each reference group. The database does not contain the results for organic carbon stocks in the following reference groups: Anthrosol, Calcisol, Histosol, Phaeozem, Podzol and Umbrisol. For the calculation of organic carbon stocks in these groups, we used values which represented the arithmetic means for all reference groups at 0-30 cm and 0-100 cm expressed in t ha^{-1}.

The calculated data indicated that there existed a great variability in the content of organic carbon among the reference soil groups. The largest SOC stocks for the soil layers 0-30 cm were found in Cambisol 194.76 x 10^{12} g and Leptosol 186.43 x 10^{12} g, and for the soil layers 0-100 cm in Cambisol 274.87 x 10^{12} g and Chermozem 230.43 x 10^{12} g. The highest mean values of organic carbon content were found in the reference group Leptosol - 151.33 t ha^{-1} and 178.95 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively. The analysis of the coefficients of variation indicated that the mean values were not sufficiently representative for that group (CV > 50%). The lowest mean values of organic carbon content were found in the reference group Arenosol - 41.78 t ha^{-1} and 96.03 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively. The analysis of the coefficients of variation showed that the mean values were sufficiently representative for this group (CV <50%). The research showed that the values of organic carbon content had highest variability in the reference groups Leptosol and Regosol.

The result obtained on the basis of the compound area of the reference soil groups and the area of the Republic of Serbia (77,474 km^2) indicated that the organic carbon stocks at 0-30 cm and 0-100 cm were 705.84 x 10^{12} g and 1,159.55 x 10^{12} g, respectively. The mean values for the main reference groups were 89.60 t ha^{-1} and 145.69 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively. The map of organic carbon distribution per soil type, at 0-30 cm, showed that largest organic carbon stocks were present in Central Serbia (southern part). In the north of the country, in Vojvodina Province, the region with the most intensive agricultural production, the organic carbon content at 30 cm was mostly low, amounting to 1.93%. The most common soil type in this part of the country is Chernozem, which covers 57.9% of the area. The values of organic carbon content for this reference group, at 30 cm, ranged from 7.89 to 133.51 t ha^{-1}, with the mean value of 73.82 t ha^{-1}. The organic carbon content at 100 cm ranged from 24.21 to 341.37 t ha^{-1}, with the mean value of 168.20 t ha^{-1}. The obtained values indicated that Chernozems have a greater depth of the humus horizon (Ah), which went up to 100 cm, then Cambisols with the humus horizon up to the depth of 60 cm. The compilation of data on organic carbon stocks and its distribution in the different soil reference groups is the first step in the evaluation and monitoring of changes of organic carbon stocks in the soils of Serbia.

KEY WORDS: Soil organic carbon stocks, Republic of Serbia, Soil Map, Leptosol, Arenosol

INTRODUCTION

Soil plays an important role in the carbon cycle on Earth. Except for carbonate rocks, soil is the largest terrestrial carbon reservoir whose size ranges between 1,400 x 10^{15} g (Post et al., 1982) and 1,500 x 10^{15} g of carbon (Batjes, 1996). This amount is about twice the size of atmospheric carbon or three times the amount contained in terrestrial vegetation (Milne et al., 2006). The global soil carbon pool is about 2,500 Gt (10^{15} g) (1,550 Gt of SOC and 950 Gt of soil inorganic carbon) (Lal, 2004). In most soil types (except for calcareous ones), carbon is typically contained in organic compounds, i.e., in the form of organic carbon (Batjes & Sombroek, 1997). This suggests that changes in organic carbon stocks in the soil (increases or decreases) may be of global significance and they may mitigate or exacerbate climate changes. In addition to soil organic carbon having a positive impact on climate changes, proper land management aimed at raising the level of organic carbon can increase the productivity and sustainability of agricultural ecosystems (Cole et al., 1997).

To evaluate the role of soil in carbon cycling, it is necessary to estimate organic carbon stocks (Yang et al., 2007). Such assessment is necessary from the points of both, environmental protection and agricultural production.

This paper presents an assessment of organic carbon stocks in the soils in the Republic of Serbia. The assessment was based on long-term research data and data from Soil Information System of Environmental Protection Agency (Vidojević & Manojlović, 2010). Estimation of organic carbon stocks in the soil is important for the Republic of Serbia for several reasons. Of the total territory of the Republic of Serbia, 65.6% are agricultural land and 32% are forest land (State of Soil in the Republic of Serbia for 2012, 2013). Considering the vital importance of organic carbon for the functioning of ecosystems, its effect on soil structure and soil water capacity, and its role in numerous chemical and physical soil properties, it is important to establish its baseline status in order to be able to monitor its variations over time. In the case of agricultural soils in the Republic of Serbia, the mean value of organic carbon up to the depth of 30 cm was found to be 68.99 t ha^{-1}, or 1.58%, which is considered as low (1-2%) (Vidojević et al., 2014). In the most frequent soil types under forest ecosystems in Central Serbia, eutric ranker (humic silicate soil), eutric cambisol and distric cambisol, the average content of organic carbon in the surface layer (0-20 cm, organic and mineral layers included) was 5.77 kg m^{-2} (Kadović et al., 2012). Statistically significant differences in the variations of organic matter content over time can be obtained only when an adequate database is available (Sleutel et al., 2003; Van Meirvenne et al., 1996).

MATERIAL and METHOD

According to its geographic location and natural characteristics, Republic of Serbia is a Central European, Balkan, Pannonian and Danubian country. In administrative terms, Republic of Serbia is comprised of Central Serbia and two autonomous provinces: Vojvodina (21,506 km^2) and Kosovo and Metohija (10,887 km^2).

Large heterogeneity in geological substrate, climate, vegetation cover and soil fauna had resulted in the formation of a large variety of soil types. Accordingly, the area of Serbia was divided into nine edaphic-climatic regions (Vidojević & Manojlović, 2007). Each region includes several soil types whose combination defines the general characteristics of these regions. Spatial distribution of soil organic carbon (SOC) was investigated in the soils of the Republic of Serbia. Organic carbon stocks were estimated for soil layers 0-30 cm and 0-100 cm. The database included a total of 1,140 soil profiles. Database was established in the period 2009-2011. Data that comprise the database for analytical study were collected in the period 1962-2010. Soil map of the Republic of Serbia was adapted to the WRB classification and divided into 15,437 polygons (map units). All polygons were divided into eighteen WRB groups. Table 1 shows the areas and proportion of the Reference Soil Groups in the Republic of Serbia according to the WRB classification.

Table 1.
Soil groups in the Republic of Serbia according to the WRB classification

Reference Soil Group Code		Area	
		ha	%
AT	Anthrosol	11,519	0.15
AR	Arenosol	55,836	0.72
CL	Calcisol	27,284	0.35
CM	Cambisol	2,168,581	27.99
CH	Chernozem	1,369,962	17.68
FL	Fluvisol	586,221	7.57
GL	Gleysol	484,545	6.25
HS	Histosol	442	0.01
LP	Leptosol	1,231,952	15.90
LV	Luvisol	219,583	2.83
PH	Phaeozem	72,840	0.94
PL	Planosol	429,472	5.54
PZ	Podzol	34,313	0.44
RG	Regosol	168,689	2.18
SC	Solonchak	25,022	0.32
SN	Solonetz	85,858	1.11
UM	Umbrisol	13,093	1.69
VR	Vertisol	644,689	8.32
Total		**7,747,401**	**100.00**

The database does not contain the results for organic carbon stocks in the following reference groups: Anthrosol, Calcisol, Histosol, Phaeozem, Podzol and Umbrisol. For the calculation of organic carbon stocks in these groups, we used values which represented the arithmetic means for all reference groups at 0-30 cm and 0-100 cm expressed in t ha^{-1}.

We calculated the SOC stock values for each reference soil group based on mean values of SOC at 0-30 and 0-100 cm and their areas. Organic carbon stocks in soil (SOC t ha^{-1}) were calculated on the basis of the values of SOC g kg^{-1}, bulk density and soil depth applying the following formula:

$$SOC(t\ ha^{-1}) = \frac{SOC(g\ kg^{-1})}{1000000} x depth(m) x$$

$$BD(Mgm^{3}) x 10000(m^{2}ha^{-1}) x 1000(kgMg^{-1})$$

The formula was derived after the method of Evrendilek & Wali (2001):
(1) soil weight (kg ha^{-1}) = depth (m) x bulk density (Mg m^{-3}) x 10,000 (m^{2} ha^{-1}) x 1,000 (kg Mg^{-1})
(2) SOC stocks (Mg ha^{-1}) = (g SOCkg^{-1}/1,000,000) x soil bulk (kg ha^{-1})
Organic carbon stock at 0-30 cm per reference group was calculated according to the following formula:
SOC 30 cm (t) = Σ {(ẋ) mean value of organic carbon content per reference soil group at 0-30 cm (t ha^{-1}) x area occupied by reference group (ha)}
Organic carbon stock at 0-100 cm was calculated according to the following formula:
SOC 100 cm (t) = Σ {(ẋ) mean value of organic carbon content per reference soil group at 0-100 cm (t ha^{-1}) x area occupied by reference group (ha)}

RESULTS and DISCUSSION

The calculated data indicated that there existed a great variability in the content of organic carbon among the reference soil groups. The largest SOC stocks for the soil layers 0-30 cm were found in Cambisol 194.76 x 10^{12} g and Leptosol 186.43 x 10^{12} g, and for the soil layers 0-100 cm in Cambisol 274.87 x 10^{12} g and Chermozem 230.43 x 10^{12} g. The highest mean values of organic carbon content were found in the reference group Leptosol - 151.33 t ha^{-1} and 178.95 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively (Vidojević et al., 2015). The analysis of the coefficients of variation indicated that the mean values were not sufficiently representative for that group (CV > 50%). The lowest mean values of organic carbon content were found in the reference group Arenosol - 41.78 t ha^{-1} and 96.03 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively. The analysis of the coefficients of variation showed that the mean values were sufficiently representative for this group (CV <50%). The research showed that the values of organic carbon content had highest variability in the reference groups Leptosol and Regosol. Table 2 shows soil organic carbon content (SOC) and SOC stocks in the major WRB soil groups in the Republic of Serbia

The mean values for the main reference groups were 89.60 t ha^{-1} and 145.69 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively (Vidojević et al., 2015).

Table 2.
Soil organic carbon content (SOC) and SOC stocks in the major WRB soil groups in the Republic of Serbia

RSGC	n	0-30cm					0-100 cm				
		SOC content t ha^{-1})				SOC stock (Tg)	SOC content (t ha^{-1})				SOC stock (Tg)
		Mean	Min	Max	SD		Mean	Min	Max	SD	
AT	-	-	-	-	-	1.03	-	-	-	-	1.68
AR	101	41.78	3.72	101.90	20.04	2.33	96.03	10.06	308.66	47.07	5.36
CL	-	-	-	-	-	2.44	-	-	-	-	3.97
CM	319	89.81	20.44	347.62	53.35	194.76	126.75	25.74	398.43	62.79	274.87
CH	216	73.82	7.89	133.51	21.86	101.13	168.20	24.21	341.37	57.88	230.43
FL	97	70.80	23.27	173.25	28.21	41.50	154.70	34.91	444.03	71.87	90.69
GL	38	85.01	6.29	221.33	37.47	41.19	168.75	92.96	436.43	83.61	81.77
HS	-	-	-	-	-	0.04	-	-	-	-	0.06
LP	211	151.33	11.06	527.22	96.95	186.43	178.95	11.06	658.40	127.33	220.46
LV	32	83.31	56.41	146.62	27.75	18.29	123.20	79.12	223.87	38.08	27.05
PH	-	-	-	-	-	6.53	-	-	-	-	10.61
PL	41	61.61	14.29	162.74	27.05	26.46	109.88	43.44	232.14	38.83	47.19
PZ	-	-	-	-	-	3.07	-	-	-	-	5.00
RG	12	93.74	26.51	298.43	87.08	15.81	160.88	26.51	425.53	157.98	27.14
SC	9	48.00	14.90	100.42	22.97	1.20	102.13	32.11	178.76	40.95	2.56
SN	29	71.09	30.66	126.48	24.39	6.10	126.74	55.68	215.89	33.95	10.88
UM	-	-	-	-	-	1.17	-	-	-	-	1.91
VR	35	71.09	33.25	129.26	21.08	45.83	156.34	58.26	275.29	53.58	100.79

RSGC: Reference Soil Group Code; **n**: Number of soil profiles in the database; **SD**: Standard deviation

The map of organic carbon distribution per soil type, at 0-30 cm, showed that largest organic carbon stocks were present in Central Serbia (southern part), predominantly in the reference group Leptosol (Figure 1). In that reference group, the content of organic carbon at 0-30 cm ranged from 11.06 to 527.22 t ha^{-1}, with the mean value of 151.33 t ha^{-1}. At 0-100 cm, the values ranged from 11.06 to 658.40 t ha^{-1}, with the mean value of 178.95 t ha^{-1}. The soils in this reference group are shallow, so that the values of organic carbon content to the depth of 100 cm represent in fact the value for the entire profile. The reference group Cambisol occupies the largest area in Central Serbia (37.76%). The values of organic carbon content for this reference group, at 0-30 cm, ranged from 20.44 to 347.62 t ha^{-1}, with a mean value of 89.81 t ha^{-1}. The coefficient of variation was 59.40%. The values of organic carbon content at 100 cm ranged from 25.74 to 398.43 t ha^{-1}, with the mean value of 126.75 t ha^{-1}. The coefficient of variation was 49.54%. In the north of the country, in Vojvodina Province, the region with the most intensive agricultural production, the organic carbon content at 30 cm was mostly low, amounting to 1.93%. The most common soil type in this part of the country is Chernozem, which covers 57.9% of the area. The values of organic carbon content for this reference group, at 30 cm, ranged from 7.89 to 133.51 t ha^{-1}, with the mean value of 73.82 t ha^{-1} (Vidojević et al., 2016, 2017). The organic carbon content at 100 cm ranged from 24.21 to 341.37 t ha^{-1}, with the mean value of 168.20 t ha^{-1}. The obtained values indicated that chernozems have a greater depth of the humus horizon (Ah), which went up to 100 cm, then Cambisols with the humus horizon up to the depth of 60 cm.

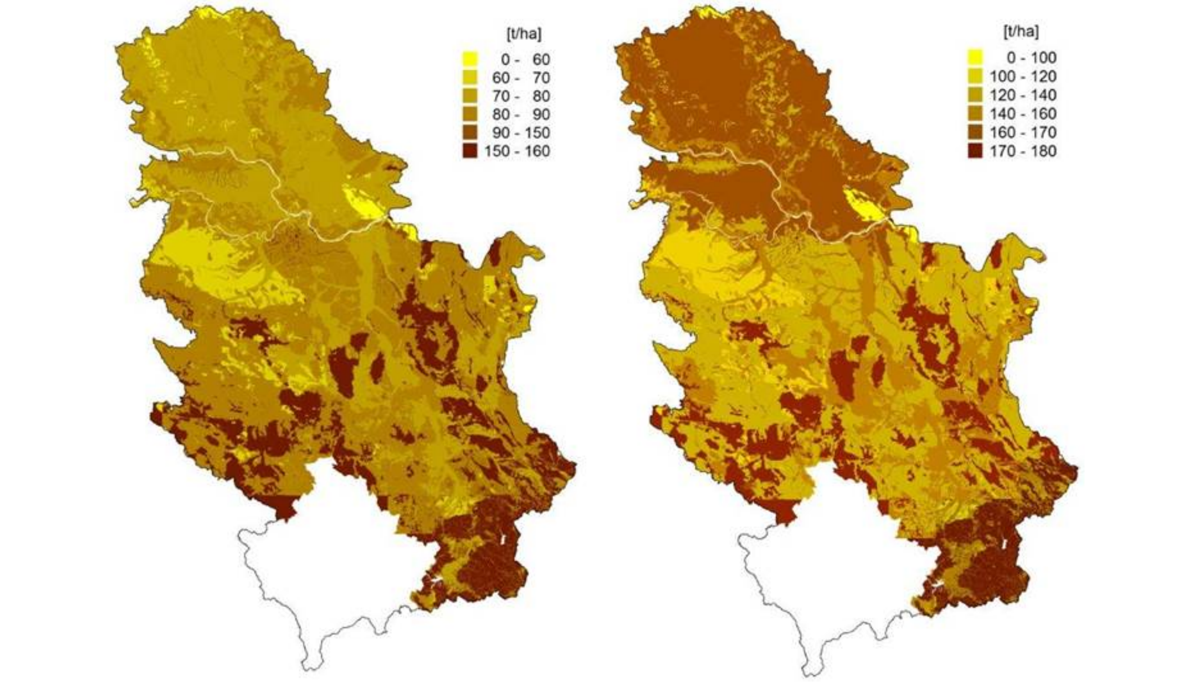

Figure 1. SOC stocks distribution by soil type, to the depths of a) 0-30 cm and b) 0-100 cm (Vidojević et al., 2015)

Chernozem and Gleysol, the two most common soil reference groups in Vojvodina Province, which occupy 76.03% of the area, were found to have larger organic carbon stocks than Cambisol, the most common soil reference group in Central Serbia. The Chernozem soil in Russia was reported to contain 290 t ha^{-1} of organic carbon at 0-100 cm (Mikhailova & Post, 2006), while a study in Bulgaria showed 142 t ha^{-1} (Filcheva et al., 2002). Chernozem in Vojvodina Province, which had developed on loess terraces, has the mean organic carbon content of 151 t ha^{-1} at 0-100 cm (Belić et al., 2013).

CONCLUSION

According to the analysis of the soil map, the soils of Serbia were found to store 705.84 x 10^{12} g (Tg) of organic carbon at 0-30 cm and 1159.55 x 10^{12} g (Tg) at 0-100 cm. The spatial distribution of organic carbon stocks and its variability is caused by various factors, such as clay content, land use pattern, altitude, and climate. In general, the distribution of the content of organic carbon at 0-30 cm showed higher values in Central Serbia, where forestland occupied a larger area than agricultural land. Republic of Serbia has a variety of soils which differ in profile structure and depth. In the case of the reference soil groups with the profile depth less than 100 cm, the content of organic carbon was still presented for the depth of 0-100 cm although it was not true for the actual situation.

This study is the first comprehensive assessment of organic carbon stocks in the soils layers 0-30 cm and 0-100 cm done in the Republic of Serbia. The compilation of data on organic carbon stocks and its distribution in the different soil reference groups is the first step in the evaluation and monitoring of changes of organic carbon stocks in the soils of the Republic of Serbia.

Literature

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The dependence of soil organic matter and crop productivity in maize monoculture

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ABSTRACT

Monoculture is cropping system that is still using on the broadest areas for maize production in Serbia and in the world. This technology has many disadvantages, due to the negative impact on environment, with increased inputs of agro-chemicals and lower yields achieved. However, some measures (like application of farmyard manure and bio-fertilizers that decompose crop residues) could improve maize productivity and restore soil fertility, even in negative agro-ecological conditions. Soil organic matter plays an important role in maintenance of soil fertility, contributing to carbon cycling in the soil.
The hybrid ZPSC 684 Ultra (in order to conduct perennial grass weed control with the application of cycloxydim) was grown in long-term monoculture during period 2012-2016. The soil type at the experimental field is slightly calcareous chernozem with 53% sand, 30% silt, 17% clay and soil structure is silty clay loam with pH 6.9 and moderate drainage. The trial included application of farmyard manure in the amount of 60 t ha^{-1} (M) in 2011, 2014 and trial without manure application (MØ). The application of bio-fertilizer Bioplug (for crop residues decomposition) is the second factor with three levels: application in amount of 2.5 l ha^{-1} (BF1), 5 l ha^{-1} (BF2) and without it (BFØ). Mineral fertilizer application included NPK in autumn (N:P:K= 15:15:15, 1709 kg ha^{-1}) and Urea (320 kg ha^{-1}) in spring (MF), and control - without mineral fertilizers. Soil organic matter (from 0-30 cm layer) was determined at the beginning of vegetation every year and maize grain yield was measured after harvesting.
Soil organic matter varied across seasons and experimental variants from 1.08% (combination MØ-BF2-control) up to 5.58% (in combination MØ-BFØ-control), both in 2016. Averagely, higher soil organic matter was determined in trial with manure, as well as BFØ and control. Grain yield also expressed significant variations under the influence of year, mineral fertilizer and interactions year x bio-fertilizer, year x mineral fertilizer, bio-fertilizer x mineral fertilizer and interaction of all three treatments, but mainly in treatment without manure application. In treatment with manure, only year and its interaction with bio-fertilizer and mineral fertilizer showed significant impact on grain yield variability. The highest values of grain yield were achieved in 2014, as a season with the lowest average monthly temperature and the highest precipitation amount, as well as BF2 and MF treatments, particularly in the part of trial with manure application. The significant and negative correlations between soil organic matter and maize grain yield exist in MØ and M treatments, with notice that the highest yield values were achieved when soil organic matter is in range 2.5-4.5% (MØ treatment) and 2.5-5% (M treatment). This means that improved mineralisation, as in BF2 treatment, in combination with mineral fertilizers and particularly manure application reflects positive on maize yielding potential, even in meteorologically unfavourable seasons, like 2012. Manure partially diminishes the influence of other factors, such as application of mineral and bio-fertilizer. It could be concluded that soil organic matter and its mineralisation plays an important role in expression of maize yielding potential. Low organic matter, or its high values reveals negatively on maize yielding.
KEY WORDS: Maize monoculture; grain yield; soil organic matter; bio-fertilizer

INTRODUCTION

Monoculture is cropping system that is still using on the broadest areas for maize production in Serbia and in the world. This technology has many disadvantages, due to the negative impact on environment, with increased infection by diseases and pests, weed spreading, increased inputs of agro-chemicals and lower yields achieved (Kovačević, 2003).

However, some measures (like application of farmyard manure and bio-fertilizers that decompose crop residues) could improve maize productivity and restore soil fertility, even in negative agro-ecological conditions. It is shown that inputs of organic fertilizers increases soil water retention, nitrogen retention, and availability of essential mineral elements after decomposition, thus improving soil quality (Yadav et al., 2013). Such soils represents good quality medium for crops growth through improved uptake of mineral nutrients and water, enhanced root growth, and increased grain yields. El Sheikha (2016) also recommends the integrated use of organic manure and mineral fertilizers in sustainable agriculture as an important measure for making of healthy soil environment for long time. The significance of this measure could be purported by application of bio-fertilizers, which improve soil fertility by increased bioavailability of mineral nutrients and improved root growth.

Organic and bio-fertilizers play an important role in maintenance of soil organic matter, as main factor that contributes to carbon cycling in the soil. Intensive production, which involves application of various fertilizers, is connected to higher crop yields, inducing increase in root mass, green biomass and grain yield. Such conditions facilitate plant mediated mineralisation of soil organic matter, thus increased availability of mineral nutrients (Murphy et al., 2017), when compared to extensive production, where level of soil organic matter remains stable, i.e. mineralisation is pronounced in the lesser extent. This means that not only the soil status affects crop productivity, but also crop has significant impact on soil fertility. Martínez-Alcántara et al. (2016) established that, besides the increase in soil organic matter, soil exchangeable P and Mg and decreased nitrate concentration animal-based fertilizer increased biomass and quality of citrus trees, when compared to plant-based fertilizer and especially in comparison to commonly used mineral fertilizer.

The aim of this study was to examine the impact of manure, mineral fertilizers and bio-fertilizer application on soil organic matter level and maize grain yield and their interdependence in long-term monoculture.

MATERIAL and METHOD

The hybrid ZPSC 684 Ultra (in order to conduct perennial grass weed control with the application of herbicide cycloxydim) was grown in long-term monoculture during period 2012-2016. The soil type at the experimental field is slightly calcareous chernozem with 53% sand, 30% silt, 17% clay and soil structure is silty clay loam, with pH 6.9 and moderate drainage.

The trial included application of farmyard manure in the amount of 60 t ha^{-1} (M) in 2011, 2014 and trial without manure application (MØ). The application of bio-fertilizer Bioplug (for crop residues decomposition) is the second factor with three levels: application in amount of 2.5 l ha^{-1} (BF1), 5 l ha^{-1} (BF2) and without it (BFØ). Mineral fertilizer application included NPK in autumn (N:P:K= 15:15:15, 1709 kg ha^{-1}) and Urea (320 kg ha^{-1}) in spring (MF), and control - without mineral fertilizers. Soil organic matter (from 0-30 cm layer) was determined at the beginning by the loss-on-ignition method (Magdoff et al., 1996) of vegetation every year and maize grain yield was measured after harvesting.

Significant differences between treatments means were determined by the Fisher's least significant difference (LSD) test at the 0.05 probability level. Interdependence between the maize grain yield and soil organic matter were processed by regression analysis.

Meteorological conditions:

Observed period was characterised with great variations in monthly average temperatures and precipitation sum (Table 1). Among years, 2012 and 2015 had higher average temperatures, with peaks observed during July and August of 2012 (27.1 and 26.2 °C, respectively) and 2015 (26.4 and 25.7 °C, respectively). The same months of both years were also low in precipitation amounts (4.8 mm in August 2012 and 7.2 mm in July 2015). The highest precipitation amount was noted in 2014 (192.5 mm in May), the year that also had the lowest average temperature (18.6 °C).

Table 1
Average monthly air temperatures and precipitation sums for vegetative period (April-October) from 2012 to 2016 at Zemun Polje

Month	IV	V	VI	VII	VIII	IX	X	Aver./Sum
Year	Average temperatures							
2012	14.4	17.9	24.6	27.1	26.2	22.1	15.4	21.1
2013	14.9	19.7	21.9	23.8	23.7	16.9	15.3	19.5
2014	13.7	17.4	21.1	23.2	22.6	18.0	14.1	18.6
2015	12.9	19.1	22.1	26.4	25.7	20.2	12.4	19.8
2016	15.3	17.6	23.0	24.2	22.3	19.4	11.2	19.0
Aver.	14.2	18.3	22.5	24.9	24.1	19.3	13.7	19.6
	Precipitation sum							
2012	56.2	58.5	14.8	19.8	4.8	20.7	41.3	216.1
2013	14.9	93.9	37.8	16.0	12.7	70.1	21.9	267.3
2014	84.8	192.5	71.2	187.4	41.0	75.6	56.6	709.1
2015	19.7	97.8	31.1	7.2	56.0	73.6	65.1	350.5
2016	51.9	47.4	107.4	33.6	43.2	36.6	60.3	380.4
Aver.	45.5	98.0	52.5	52.8	31.5	55.3	49.0	384.7

RESULTS and DISCUSSION

Soil organic matter varied across seasons and experimental variants from 1.08% (combination MØ-BF2-control) up to 5.58% (in combination MØ-BFØ-control), both in 2016 (Figure 1). Averagely, higher soil organic matter was determined in trial with manure (about 0.38% higher in relation to trial without manure), as well as BFØ (about 0.10% and 0.03% higher in comparison to BF1 and BF2, respectively). This means that manure and crop residues contribute to the soil enrichment in organic matter, as it was expected. Martínez-Alcántara et al. (2016) find that animal-based fertilizer enriches soil with organic matter and exchangeable mineral nutrients in higher degree than plant-based fertilizer and particularly to mineral fertilizer. Also, the higher average value of organic matter was determined in control, of about 0.15% higher in relation to MF treatment, implying that intensive production with added mineral fertilizers increases mobilization of mineral nutrients from soil organic matter and their uptake by crops, thus increasing crop productivity (Murphy et al., 2017).

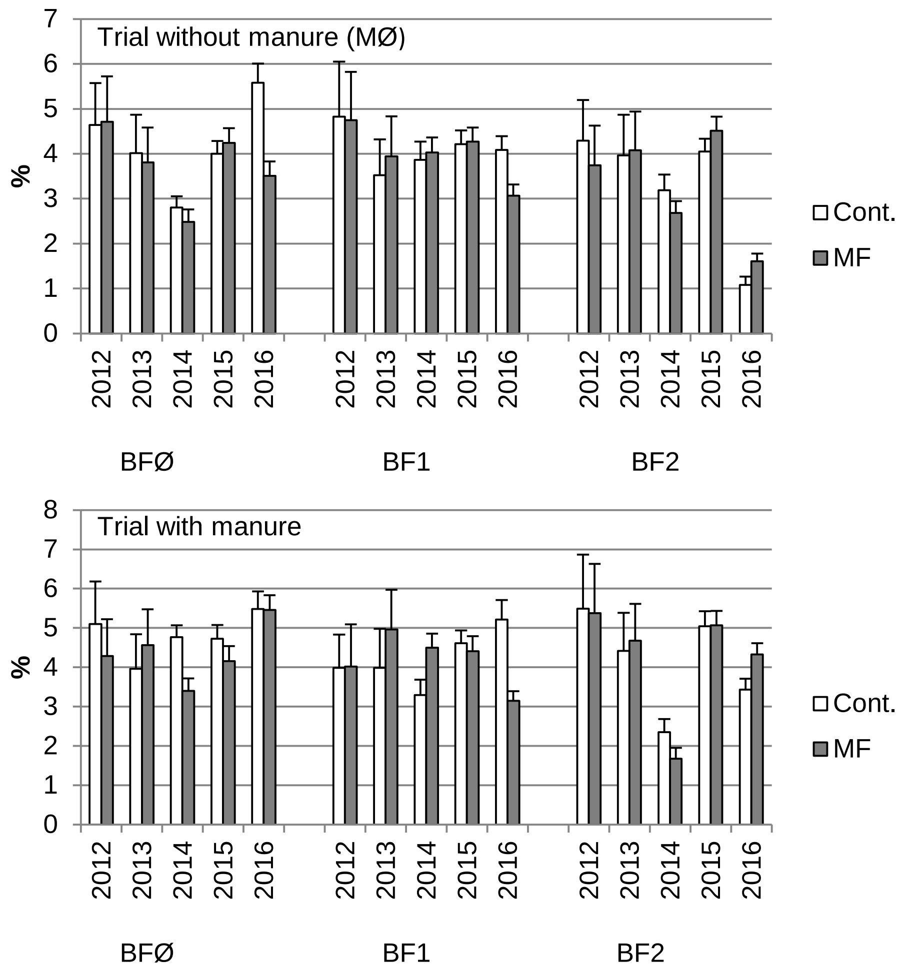

Figure 1. Variation of soil organic matter in treatments without manure (MØ) and with manure (M) application, with different bio-fertilizer levels (BFØ – without bio-fertilizer, BF1 – application in amount 2.5 l ha^{-1}, BF2 – application in amount 5 l ha^{-1}) and mineral fertilizer (control – without mineral fertilizers, MF – NPK + Urea). Bars present average ± standard deviation.

Maize grain yield varied significantly under the influence of year, mineral fertilizer and interactions year x bio-fertilizer, year x mineral fertilizer, bio- x mineral fertilizer and year x bio- x mineral fertilizer in both parts, with exception of mineral fertilizer and bio- x mineral fertilizer interaction in trial with manure application (Table 2). In treatment with manure, only year and its interaction with bio- and mineral fertilizer showed significant impact on grain yield variability.

The highest values of grain yield were achieved in 2014, as a season with the lowest average monthly temperature and the highest precipitation amount, as well as in BF2 and MF treatments, particularly in the part of trial with manure application. This proved that high availability of mineral nutrients, either from mineral or organic fertilizer (manure or facilitated by mineralisation with bio-fertilizer), as well as increased soil water retention in trials with organic fertilizer application increases maize yielding potential (Yadav et al., 2013). El Sheikha (2016) emphasized that the combined use of manure and chemical fertilizers is necessary to maintain healthy soil environment in the long run and what is more application of bio-fertilizers improves usage of mineral fertilizers.

The significant and negative correlations between soil organic matter and maize grain yield exist in MØ and M treatments, with notice that the highest yield values were achieved when soil organic matter is in range 2.5-4.5% (MØ treatment) and 2-5% (M treatment). This means that improved mineralisation, as in BF2 treatment, in combination with mineral fertilizers and particularly manure application reflects positive on maize yielding potential, even in meteorologically unfavourable seasons, like 2012. Manure partially diminishes variations in gain yield, i.e. the differences caused by the influence of other factors, such as meteorological factors, application of mineral and bio-fertilizer. Ahmad et al. (2008) underlined that combination of organic and bio-fertilizer expressed the highest effectiveness on soil aggregate stability, N and P uptakes by maize crop, with reduction in the rate of water loss from the soil, thus increasing grain yield, when compared to the application of sole organic, or bio-fertilizer and full doze of mineral fertilizer. The importance of organic fertilizers application is also reflecting through increased mineral elements bioavailability, increased number of beneficial soil microorganisms, reduced pathogen population, lowered down bulk densities, having as a consequence improved soil quality, crop growth and yielding potential (Ahmad et al., 2008).

Table 2
Effect of manure (MØ – without manure, M – with manure application), bio-fertilizer (BFØ – without bio-fertilizer, BF1 – application in amount 2.5 l ha^{-1}, BF2 – application in amount 5 l ha^{-1}) mineral fertilizer (control – without mineral fertilizers, MF – NPK + Urea) on maize grain yield in period 2012-2016.

	Year	MØ				M			
		BFØ	BF1	BF2	Aver.	BFØ	BF1	BF2	Aver.
Control	2012	3.01	3.06	3.63	3.23	3.58	5.43	6.11	5.04
	2013	5.87	5.55	6.08	5.83	6.79	8.06	8.10	7.65
	2014	7.36	6.73	7.28	7.12	9.31	10.26	11.11	10.23
	2015	3.98	4.18	5.63	4.60	5.61	6.12	7.54	6.42
	2016	5.14	5.89	6.49	5.84	5.77	7.61	7.06	6.81
	Aver.	5.07	5.08	5.82	5.33	6.21	7.49	7.98	7.23
MF	2012	4.26	5.59	7.01	5.62	3.92	5.57	7.08	5.52
	2013	7.56	8.36	9.43	8.45	7.12	8.15	9.50	8.26
	2014	11.14	11.55	10.82	11.17	12.02	12.08	11.80	11.97
	2015	6.66	7.91	8.98	7.85	7.03	8.32	9.45	8.27
	2016	7.05	6.25	7.01	6.77	5.64	6.71	6.49	6.28
	Aver.	7.33	7.93	8.65	7.97	7.15	8.17	8.86	8.06
Average	2012	3.63	4.33	5.32	4.43	3.75	5.50	6.59	5.28
	2013	6.72	6.96	7.76	7.14	6.96	8.10	8.80	7.95
	2014	9.25	9.14	9.05	9.15	10.67	11.17	11.45	11.10
	2015	5.32	6.04	7.30	6.22	6.32	7.22	8.50	7.35
	2016	6.10	6.07	6.75	6.31	5.71	7.16	6.78	6.55
Aver.		6.20	6.51	7.24	6.48	6.68	7.83	8.42	7.64
LSD 0.05		Year	BF.	MF.		Year	BF.	MF.	
		2.21	2.64	2.30		2.04	2.73	2.78	
		Y x BF	Y x MF	BF x MF	Y x BF x MF	Y x BF	Y x MF	BF x MF	Y x BF x MF
		2.31	1.70	2.31	1.81	1.99	2.00	2.74	2.07

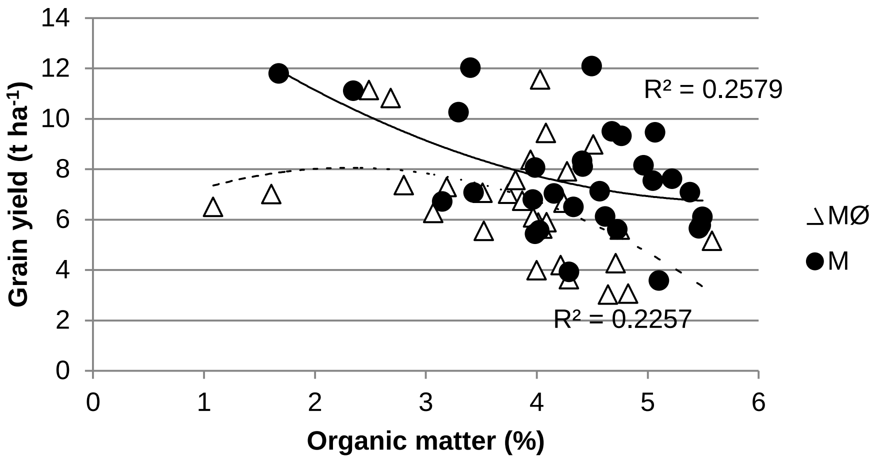

Figure 2. Interdependence between maize grain yield and soil organic matter in treatments with manure (M) and without manure (MØ) application.

CONCLUSIONS

Soil organic matter and its mineralisation play an important role in expression of maize yielding potential. Low organic matter, or its high values reveals negatively on maize yielding. The application of different fertilizer combinations affects status of soil organic matter, as well as maize grain yield. Combination of mineral and bio-fertilizer reflects positively on soil organic matter accumulation, as well as on grain yield increase, particularly in trial with manure application. This combination guarantees grain yield stability, even in meteorologically unfavourable seasons. Irrespective that monoculture is still adverse cropping system, the stable and high yields, with maintaining of soil organic matter could be established by proper fertilizers combination.

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Ethical aspects of soil quality

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ABSTRACT

Soil is defined as a non-renewable natural resource, since the processes of its degradation have been so accelerated in the past decades that they by far exceed the speed of pedogenic processes. By the 1990s, soil was mainly studied from the aspect of productivity, after which the focus moved in the direction of preservation of its functions for the purpose of providing ecosystem services. Soil quality assessment plays a major role in deciding on the land use. With the increase in human population and urbanization land has become a limited resource and a deficient "commodity" (Acuña et al., 2015). Therefore, human society, which is not the only party involved in the use and share of that space on Earth, has to address the problems of degradation caused by human activities and the nature of relating dynamics. This natural wealth that is entrusted to us for care requires a moral obligation, not only because of our interest, but also because of the soil itself, since people are morally responsible for its condition (Jonas, 2004). It also means searching, not only for the well-being of humans, but for the benefit of all other communities for which the care for soil and its inhabitants has to be included in the concept of the human wealth.

Ethical responsibility, in terms of care for arable land, is, above all, not a technical issue concerning farmers, agronomists and soil scientists. Looking for the humanistic perspective, Arnold (2007) emphasizes that soil science is at the same time in the field of ecology and economics. However, in addition to ethics, which is an important moderator of soil conservation efforts by the power of its principles, many aspects of other sciences play an important role in highlighting the true importance of soil science. We are warned of future problems in a statement that "if the preservation and rational use of soil resources are not significant enough for societies in the next few decades," then irrational use can lead to a "tragedy of the commons"; if, however, this compromise is focused on planetary sustainability, then we get a golden opportunity to convey the knowledge and wisdom of soil science.

The aim of this paper is to point out the importance of soil quality assessment for making decisions on the use of land according to the concept of soil security and the respect of moral principles. This further imposes numerous questions: How far can the inadequate use of soil be justified and what can justify it besides the belief that it is necessary to provide enough food for the growing human population? Can the acquisition of profit justify different anthropogenic pressures that cause soil degradation?

KEY WORDS: soil quality, land management, soil ethics, ethical aspects

INTRODUCTION

Soil is the basis of environmental sustainability, as besides providing support services to terrestrial ecosystems, it is important for different human activities, and is an important part of natural heritage. The basic focus of soil studies from the aspect of productivity has moved towards studies aimed at improving ecosystem services based on the interaction between soil and other ecosystem components from local to global scale (Feller, et al., 2010). Sustainable soil use, i.e. land use is recognized as the key to preserving natural resources and meeting the needs of people for the "good life" of the present era. The concept of soil quality developed from the land quality concept, since soil quality should be the basis of land management (Schjønning, et al, 2004). The link between these concepts of soil and land study is very important, since management measures can potentially improve the quality of soil and water (Bouma, et al., 1998). Soil quality assessment and method of soil management have over time become the basic indicators of sustainable land management (Karlen, et al, 1997). In the context of the intensive use of soil resources to provide the necessary amount of food for the growing human population, the concept of soil quality is the applied science, i.e. the application of principles and processes, which are the key to the sustainable land management (Carter, et al., 1997). The development of the soil quality concept resulted in the defining of indicators and inventory of soil conditions. Further, the integral role of soil in global proportions, was seen through the concept of soil security. The basic reasons for the introduction of the concept of soil security are to incorporate scientific achievements in the field of soil research into sustainable development policies. The role of soil in the provision of ecosystem services has been scientifically established. However, although in scientific circles this has been known for more than two decades, it has not yet clearly entered the instruments of sustainable development policy (Koch et al., 2013).

The concept of sustainable soil development includes all dimensions of global existential issues, that is, the approach is multidimensional and multidisciplinary, and it is necessary to differentiate the optimal state of the soil, the present state of the soil, and find solutions for efficient soil use. It is possible to answer these questions and find solutions in the concept of soil security, because the key to the solution in a holistic approach is – soil security, that is, the inclusion of ecology and economics in determining the value of the non-renewable resource of soil, but also social sciences, in order to better understand the relationship between the society and basic soil functions within land.

The question arises whether a modern man has the awareness of the fact that soil is a natural wealth that it is entrusted to us for care and demands a moral obligation, not only because of our interests, but because of the soil itself and because people are morally responsible for its condition. This further leads us to numerous questions: How and to what extent can the inadequate use of soil be justified, with the explanation that it is necessary to provide enough food for a growing human population, or can the need for profits justify different anthropogenic pressures that cause soil degradation?

SOIL QUALITY and SUSTANABLE LAND MANAGEMENT

In terrestrial ecosystems, soil is the critical, regulatory and dynamic basis both for management and use measures, as well as for natural processes. A critical and growing global problem is soil degradation, which reduces soil quality, thereby reducing the services provided by soils to ecosystems (Lal and Stewart, 2010). For the provision of ecosystem services in conditions of climate change, meeting the needs for increased food production and clean water, it is necessary to maintain soil functions. It is particularly important to increase the regeneration of soil functions after a certain stress (resilience) and increase its capacity to restore its basic processes important for the provision of ecosystem services and functions by reducing anthropogenic impacts (Lal, 2010).The degree of basic degradation processes depends on many factors, including the way of land use and management, and the causes of soil degradation are social, cultural and political parameters, including institutional support, land ownership, market access and the level of education (Lal, 2010). Anthropogenic causes greatly affect the intensity and degree of a specific degradation process, and if the population is poor and discouraged, it moves its focus towards survival until the next day, rather than planning and securing resources for future generations.

It is clear that, in the conditions of a growing human population and, therefore, the need for safe food, water and energy, the focus on soil processes is of extreme importance. Thus agricultural production that is not in accordance with ecological principles and principles of sustainability should be considered as a segment of the ecological process or cycle, but with long-term potentially negative implications. Agricultural production is one of the major causes of soil degradation, first of all, physical degradation, erosion and loss of organic matter (Lal,2010, Belanović Simić, 2017). On the other hand, agricultural production depends on the quality of soil. Soil quality assessment is not easy considering the fact that it cannot be defined by universal criteria, but as the capacity of the soil for certain functions. Increasing the awareness of the importance of soil quality and improving future policies include: development of a continuous network for monitoring the current status of soil and its quality, including the quality of the soil and the objectives of the soil functions in the legislation, the study of tools for the precise and simpler determination of soil quality and the implementation of soil management strategies to enable the repair of soil quality as well as the inclusion of the ethical aspect.

From the perspective of soil conservation, different acceptable measures are introduced that lead to the soil conservation and good agriculture practices and environmental protection. UN NRC (1981) pointed to these challenges, stating that if soil scientists are striving for the concept of sustainable agriculture then they will have to agree on the significance of sustainability with clear strategies and tasks of restoring degraded ecosystems (Miller and Wali, 1995).

The renewal and maintenance of the basic natural functions of soils will provide an answer to the global issues of environmental sustainability. However, certain soil functions in response to global issues are in some cases synergistic, while in others they are antagonistic. Thus, the quantity, quality and availability of safe food are in the function of the circulation of nutrients, retention of water and physical stability of the soil, as well as protection from pollution, while at the same time they contribute to the provision of clean water. However, when plants are used as biofuels for achieving energy stability, the same soil functions as for food production are important, but they are not synergistic. Soils have been used to produce, besides food, other uses which will reduce the availability of agricultural production, while the demand for food production is increasing. Lal and Stewart (2010) induced that is necessary to identify soil and development of management practices of plantations, which is important for the success of the emerging biofuel industry. In support of this are the analysis of the use of soil for energy plantations from the ethical aspect (Gamborg et al., 2012).

For soil as a critical resource and the preservation of its quality, the wider social community should show readiness and take responsibility by implementing the adopted concepts (sustainability, quality and soil security). The assessment of soil quality is of particular importance for making decisions on land use according to the concept of soil security.

LAND ETHICS

It is well-known that civilizations had collapsed when they ignored the need to maintain soil quality and preserve its functions (Lal, 2010), while on the other hand, they had survived if those developed the spirituality and significance of the idea of sustainability (Montgomery, 2006). Does our soil condition tell us about our civilization?

It is imperative for people to "live a good life" and achieve it with an economic and technological development that has direct or indirect environmental impacts in general. The anthropogenic impact, and the extent to which it affects the environment, and therefore also soil quality, depends on the awareness of the society, its technologies and the degree of development of their spiritual being.

Aldo Leopold created the term LAND ETHICS in the book *A Sand County Almanac* (1949). In this book he wrote that there is a need for "new ethics" apropos "An ethics that deals with people's relations towards soil, animals and plants that grow on it." Leopold's ethical approach describes that the land ethics changes the role of Homo sapiens from the owner (taker) of the land into an ordinary member and its inhabitants, which implies the respect for all members, and the community as a whole (Kadović and Belanović Simić, 2017).

The need for a "good life" characterizes capitalist economic development which leads to a reduction in habitats for plant and animal species, air and water pollution, climate change and toxic waste accumulation as a load for future generations (Martin-Schramm et al., 2003). According to the same authors, environmental degradations are the products of: population growth, increased consumption, development of the technologies which are continuously causing the degradation of natural ecosystems, economic and political systems which encourage degradation and anthropocentric standpoint towards nature.

Des Jardins (2006) shows the impacts on the environment using the formula:

$$U = P \times I \times T.$$

where: U (environmental impact) depends on the population (P), consumption and abundance (I) and technology (T).

In the framework of the Earth Charter, which was signed in 2000, ethical framework was defined for making a fair, sustainable and peaceful global society in the 21st Century. Engel (2007) lists 6 basic ways for soil ethics to contribute to the formation of a just, sustainable and peaceful global society:

(1) The care about land is an example of the necessity of jointly solving the social and environmental issues of our planet;
(2)soil integrity is a *sine qua non* of ecological and biosphere integrity;
(3) soil management is an essential component in agreements made between generations;
(4) the need for precautions in the way we deal with soil, given the limited nature of our scientific and practical understanding of how to protect and restore soil, demonstrates the importance of the precautionary principle;
(5) soil conservation requires a "common but differentiated" approach to our cultural as well as economic and technological capacities for the care of the land; and
(6) The evolutionary and spiritual solidarity that we experience with the Earth through soil is a powerful naturalistic foundation for our ultimate dedication to sustaining life on the planet.

The imbalance between people and natural resources has negatively affected ecosystem services, which are essential for the well-being of not only human life, but also other forms of life on the planet. The main causes of these problems are the lack of quality systems for managing soil and water resources and land resources in general that lead to the unsustainable use (explotation) of natural resources (Lal, 2010, Kadović and Belanović Simić, 2017).

Nowadays, more than ever before, in addition to water and air, soil has a central importance for human society and for the support of the life functions of the ecosystem. The revitalization of soil requires serious social, scientific and ethical approaches, and in the conditions of the growing human population the focus of agriculture is on the systems of high quality food production (Franzlubbers and Haney, 2006). The efficiency of anthropogenic control of the agroecosystem is an open debate, where the soil quality of these ecosystems depends on anthropogenic activities. When considering the management of ecosystems, it is necessary to harmonize the engineering approach and ethical issues.

The basic engineering problem (challenge) lies in the need for a better understanding of interactions in an ecosystem (for example, unsuccessful afforestation), while ethics are mainly in the anthropocentric approach to ecosystem management.

Gregorich and Carter (1997) describe that environmental problems might be best viewed by confronting the basic challenges of human values.

In agriculture, it is ethically challenging to achieve sustainable agriculture and define a problem that conflicts with other moral obligations.

Grimm (2005) states that moral principle “do-not-harm” can serve as a fundamental aspect in sustainable agriculture.

According to this, a time and a place are irrelevant, it is important not to endanger the human population, which implies the application of the technology of conserving natural resources with regulation of the size of the human population.

In this regard, Des Jarden (2006) set up the question:

Is there any morally desirable target of the growing human population?

If so, what are the philosophical bases for establishing this goal; and

What kind of policies should be supported in order to achieve it?

Are human beings obliged to refrain from having children?

Do people in the industrial countries of the world spend too much?

Is it unfair that the richest 16% of the world's population consume 80% of world resources?

Do people in the industrial world have direct moral obligations towards the poor in the world?

Does the current generation have the responsibility to save resources for future generations?

Are we obliged to avoid technologies such as nuclear energy that could put future generations at risk?

Energy plantations can negatively affect soil quality, but a significant increase in the use of energy from biofuels is expected by 2020 (Lal and Stewart, 2010). Also, the use of biofuels poses two ethical issues (Gamborg, 2012):

(1) bioenergy products compete directly or indirectly with food production, which may result in numerous social issues;
(2) the production of biofuels directly or indirectly leads to deforestation and other land use changes, which may have negative effects on GHG emissions.

The key to the solution by Koch et al. (2013) is in a holistic approach – soil security, that is, the inclusion of ecology and economics in determining the value of the non-renewable soil resource, but also social sciences, in order to better understand the relationship between society and basic soil functions within land.

In the United States, in accordance with various federal laws, punishment measures were imposed for corruption where land was used in a non-ethical manner (Salkin, 2014, Salkin and Ince 2014). From this point of view it is clear that it is of special importance, the public interest and responsibility for natural resources, so it is necessary that the ethical aspect has to be included in our laws. Also, ethical trade is very important, started under sponsorship of Soil Associations. Under this term, initiatives include (Crucefix, 1998):

(1) organic agriculture,
(2) sustainable forest management,
(3) fair trade, and
(4) ethical sourcing by wholesalers and retailers).

INSTEAD of a CONCLUSION

Soil quality assessment is of great importance when deciding on the land use, primarily in agriculture and forestry, in the management of contaminated areas. In modern agricultural production, soil conservation systems are observed through the concept of soil quality, because in addition to the expected yields, the goal is also to preserve soil functions for the provision of ecosystem services.

However, the development of strategies for improving and strengthening soil functions is unconceivable without the human aspect, that is, without looking for a humanistic perspective. Nowadays, soil science is being considered simultaneously between the fields of ecology and economics, but many aspects of other sciences, primarily sociology, as well as law and ethics, play a key role in the study and transfer of knowledge and wisdom of soil science. Soil ethics includes ways in which soil can be viewed as an integral component in systems that involve valuation processes, rather than the past practice of viewing it as the object of value.

The use, management and conservation of soils imply a whole range of decisions that are preceded by the question of what is the right thing to do in order to achieve sustainability. These questions point to technical considerations on practical objectives and directives, but also the legal and ethical need to express, specify and justify human goals and aspirations.

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Abundance of azotobacter in the soil of natural and artificial grasslands

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ABSTRACT
Free nitrogen-fixing bacteria of which the most important are the bacteria of the genus *Azotobacter,* make an important contribution by providing nitrogen to plants and increasing nitrogen content of soil. The presence of azotobacter in soil is a prominent indicator of its biogenity. In this paper, the abundance of azotobacter was assessed in the soil from 10 sites, whereby 5 samples were taken from the natural soil and 5 from artificial grasslands. Studied soil samples were characterized by relatively low pH, so that the abundance of azotobacter was low. It was determined that there was the decrease in the number of azotobacter with increasing acidity of the soil, although the difference is not at the level of statistical significance in all cases. The highest abundance of azotobacter was recorded in the soil from natural grassland, while the lowest (0.125 - log number) was registered in the soil from the planted grassland which pH (KCl) value was 4.16. The results of this study show that the content of organic matter as an energy source for metabolism of microorganisms and chemical properties of the soil, especially the pH of the soil, are limiting factors which influence the abundance and activity of the bacteria of this genus.

INTRODUCTION
Rhizosphere is a dynamic system that is characterized by physical, chemical and biological properties and its biological component is composed of plant roots and rhizosphere microorganisms. They occupy the soil under the direct influence of root secretion, participate in the transformation of organic and inorganic compounds in the soil and provide plants with assimilates. Microorganisms, with their enzymatic systems, participate in 60-90% of the total metabolic activity in soil (Lee, 1994). The abundance of microorganisms ranges from tens to hundreds of billions in one gram of absolutely dry soil. Microbiological properties are an important indicator of soil fertility (Nannipieri et al., 2003). Free nitrogen-fixing bacteria, of which the most important are the bacteria of the genus *Azotobacter,* make an important contribution by providing nitrogen to plants and increasing nitrogen content of soil. Depending on the prevailing conditions in the soil, azotobacter may fix 50–80 kg ha^{-1} of nitrogen from the air. Besides binding atmospheric nitrogen, azotobacter produces biologically active substances: auxins, gibberellins, pyridoxine, biotin and nicotinic acid (Dobbelaere et al., 2003). *Azotobacter chroococcum* produces an antibiotic which inhibits the growth of several pathogenic fungi in rhizosphere thereby decreasing seedling mortality (Subba Rao, 2001). *Azotobacter* reacts to minimal changes in soil conditions by reducing their numbers, which is why it can be used as an indicator of soil quality. Acidic reaction of the environment has a negative effect on the activity and abundance of azotobacter since these bacteria prefer a highly productive neutral soil (Govedarica and Jarak, 1995). The number of *Azotobacter* sp. is used as the indicator of biological value of the soil. The population of azotobacter is generally low in the rhizosphere of the crop plants and in uncultivated soils. A very acidic environment shows a negative effect on the growth of azotobacter (Kološenko, 1981). These nitrogen-fixing bacteria are important for soil fertility and agriculture.

The aim of this investigation was to examine the abundance of azotobacter in the acidic soil of natural and artificial grasslands.

MATERIAL and METHOD
The number of azotobacter determined in soil samples from natural and artificial grasslands. In August of 2016 samples from 0-25 cm layer from 10 different sites were collected whereby 5 samples from the natural soil and 5 from artificial grasslands. All sites are located in the territory of Kruševac. The chemical properties of the soil were determined by standard methods in the chemical laboratory of the Institute for Forage Crops Kruševac (Table1). Biological activity of the soil (biogenity) was monitored

on the basis of the presence of azotobacter. The abundance of azotobacter was assessed using the fertile drops method on the Fiodorov medium The inoculation was done using the 0.2 ml of soil suspension diluted by 10^{-2}. The incubation lasted for 48 h at 28 °C. The number of grown colonies was calculated per 1 g of absolutely dry soil (Jarak and Đurić, 2006).

The results were processed with STATISTICA 8.0 computer program. The significance of the difference between the investigated treatments was determined upon the analysis of variance, i.e. LSD test.

Table 1
The chemical composition of the studied soil

The samples	Type of grassland	pH H_2O	pH KCl	Total nitrogen %	P_2O_5 mg/100g	K_2O mg/100g	Humus %
N1	natural	7.34	6.51	0.318	38.99	20.04	4.75
A1	artificial	6.89	5.90	0.224	6.40	11.06	3.09
N2	natural	6.69	5.71	0.198	25.40	33.38	2.24
N3	natural	6.18	5.31	0.127	5.00	14.80	1.76
A2	artificial	6.59	5.46	0.244	8.40	26.66	2.88
N4	natural	6.16	5.22	0.289	3.50	55.46	4.35
A3	artificial	5.52	4.93	0.099	7.2	17.68	1.40
N5	natural	6.09	5.12	0.348	0.80	12.31	4.65
A4	artificial	6.04	5.06	0.160	38.00	32.56	4.83
A5	artificial	5.06	4.16	0.275	2.00	25.68	3.83

RESULTS and DISCUSSION

The results of chemical analyses show that the pH value ranged from strongly acidic 4.16 to 6.51, which is on very border of the low acidic to neutral. Also, soil samples differed between each other by the amount of nitrogen, humus, potassium and phosphorus (Table 1). Each type of soil had characteristic microbiological properties processes that can be affected by various biotic and abiotic factors (Govedarica et al., 1997). The abundance and diversity of microorganisms in the soil is influenced by the physical and chemical properties of the soil, such as acidity, quantity and type of organic matter, air-water regime and thermal regime, structure and mechanical composition of the soil, etc. (Jarak and Čolo, 2007). The most studied, in our conditions, are free aerobic nitrogen fixing microorganisms of the genus *Azotobacter* (Milošević et al., 2003).

The results of the study show that azotobacter was highest in the soil of a natural grassland - N1 which pH was at the border of slightly acidic to neutral (Table 1 and 2). This soil was well supplied with nutrients. A similar number of azotobacter has been found in soils of some higher acidity below sown - A1 and natural grasslands - N2. There were no statistically significant differences between these three samples and they formed a homogeneous group. *Azotobacter* sp. is actively multiplying in cultivated soils, which are rich in organic matter, calcium, phosphorus, and moistand have a pH is above 5 (Djukić et al., 2007).

According to the Fisher test, two other homogeneous groups were determined. The number of azotobacter in soils from natural grassland - N4 and from sown grassland - A3 do not show any statistical significance difference. Also, there was no statistical difference between these two samples and sample from the sown grassland - A2. Simultaneously, samples from natural grassland N4 and from sown grassland - A3 did not show any statistically significant difference in the number of azotobacter compared with soil samples from the natural grassland - N5. The abundance of this group of nitrogen fixers is one of the most important soil fertility indicators (Marinković et al, 2007).

Table 2
The number of azotobacter (log of number) in different soils

The samples	Type of grassland	The number of azotobacter
N1	natural	1.761 [a]
A1	artificial	1.738 [a]
N2	natural	1.686 [a]
N3	natural	1.528 [b]
A2	artificial	1.057 [c]
N4	natural	1.013 [c, d]
A3	artificial	0.991 [c, d]
N5	natural	0.881 [d]
A4	artificial	0.515 [e]
A5	artificial	0.125 [f]

Note: Mean values with the same superscript(s) are not significantly different according to Fisher's LSD test ($p < 0.05$)

In general, the abundance of azotobacter in the investigated soils was very small. Acidic soil had unfavorable properties of poor and physiologically active nutrients and an unsatisfactory air - water regime, so that the presence of azotobacter in these soils was very low or even absent (Milinčić and Jarak, 2008). Anđelković et al. (2011) recorded a very low abundance in the soil of increased acidity (4.97 pH (KCl) on which the alfalfa was grown experimentally. However, Milošević et al. (2007) recorded the absence of azotobacter in the soil of natural grasslands of the acidic reaction at the different altitudes and different chemical composition.

Microorganisms as a biological component are good indicators of soil quality because they respond quickly to changes in the soil ecosystem, so microbiological activity can be used for the determination of soil fertility (Milošević et al, 1999).

CONCLUSIONS

Physical and chemical characteristics of the soil are the most important properties that affect the activity of microorganisms. Based on the obtained results it can be concluded that, in the soils of natural and sown grasslands from the studied sites, characterized by elevated acidity and generally sufficient amounts of nutrients, the abundance of azotobacter was low. Because of such chemical characteristics of the examined soils the presence of azotobacter, even in a small number, is very important and points to the need for the determination of species of this genus and the isolation of these microorganisms as they are tolerant to the acidic reaction of the environment and can be applied in agricultural production.

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Soil fertility of Rogozna mountain

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ABSTRACT
Mountain Rogozna is located in the southern part of the country, between Raska, Novi Pazar and Kosovska Mitrovica municipalitices, surrounded by the rivers Ibar, Raska and Jošanica. The part of the mountain is located in central Serbia, and the other part in the province of Kosovo. The geological composition of this area is very diverse, presented by igneous rocks - ultramafic, dacite-andesite, and quartz latite with pyroclastic rocks, as well as by sedimentary rocks - shale and marl with the diabase-chert and flysch formations (sands, alevrolytes and marl). Ranker type of soil dominates on Rogozna, while on steep slopes there were formed regosol, and rarely there can be found a deeper cambic soil. The largest number of the stage of soil development is found under andesite, which occupies the largest area and the various forms the relief. The paper presents the results of basic soil properties and content of heavy metals on the part of Mt. Rogozna belonging to central Serbia, aimed to determine the status and differences in soil fertility by the geological substrates.
The soil samples (about 30) were taken from surface horizon (0-25cm), according to the grid system at a distance of 3.3 x 3.3 km. Composite sample consists of five individual samples taken at the corners and in the center of the square with a side length of 10m. The most number of samples were taken in meadow, 6 samples in forest, 2 samples in arable land, and 1 in orchard. In the prepared soil samples the following parameters were determined: pH in nKCl (1: 2.5) - electrometrically; $CaCO_3$ - volumetrically with Scheibler calcimeter; humus – were calculated from the content of organic C (CNS analyzer); accessible phosphorus and potassium – by Al method (Egner-Riehm). Heavy metals content ("pseudo totals") - by boiling with HNO_3 and H_2O_2 and spectrometric determination (ICP-OAS). The investigated soil has a different reaction depending on the substrate on which it was formed. The rankers on quartz latite and dacito-andesite have a strongly acidic reaction, the soils on ultrabasic rocks is weakly acidic, and on flysch are in the range from acidic to neutral. Lack of phosphorus occurs in soil on all substrates. The values of heavy metals are generally at the level common for this type of soil. The soils on ultrabasic rocks are outstanding because they naturally rich in Ni, Cr, and other heavy metals. In addition, in comparison to the average in Serbia, the soil on all the substrates has a slightly higher average concentration of Pb (59-93 mg kg^{-1}), probably due to the abundance of substrate by ores of Pb and Zn, and possibly due to human influence.
KEY WORDS: fertility; heavy metals; Rogozna; geological substrate.

INTRODUCTION
Mountain Rogozna is located in the southern part of Serbia, in the triangle between Raska, Novi Pazar and Kosovska Mitrovica, surrounded by the rivers Ibar, Raška and Jošanica. The area of this mountain is about 72000 ha, and about half is in central Serbia, and the other part in the province of Kosovo. Mt.Rogozna belongs to the middle-high mountains, with the highest peak of 1504 m (Crni Vrh).

Antonovic and Nikodijevic (1969) have written of the factors of soil formation and soil properties of the Rogozna area. The relief is very fragmented, intersected with many rivers that have deep valleys. The climate is mountainous, with an average annual temperature of 5.1-5.6 ˚C and precipitation about 900 mm.

The geological composition of this area is very diverse, presented by igneous rocks (ultramafic, dacite-andesite, and quartz latite with pyroclastic rocks), as well as by sedimentary rocks (shale and marl with the diabase-chert) and flysch formations (sands, alevrolytes and marl). The Mt.Rogozna is known for the minerals of lead and zinc, which were exploited in the middle ages. The Pb-Zn is concentrated in contact zones and cracks in ultramafites, volcanics, slates and other rocks (Urošević et al., 1973).

According to Antonovic et al. (1969) ranker type of soil dominates on Rogozna (Leptosol, WRB, 2014) while on steep slopes there were formed regosol (Leptic Regosol), and rarely there can be found a deeper cambic soil (Haplic Cambisol).

In 80% of the terrain, dominated shallow soils, less developed, usually A-C, less frequently the A-AC-C, and only exceptionally A- (B) –C type. The largest numbers of the stages of soil development are found under andesite, which occupies the largest area and the various relief forms.

This area is interesting because in a small area there are various geological substrates, which influence on the properties of the soil, especially on content of microelements and heavy metals, which are little examined.These paper presents more recent results of basic soil properties and heavy metals content on the part of Mt. Rogozna belonging to southern Serbia, aimed to determine the status and differences in soil fertility and potential pollution on various geological substrates.

MATERIAL and METHOD

The soil samples (30) were taken from surface horizon (0-25cm), according to the grid system at a distance of 3.3 x 3.3 km, during September and October 2010. The soil samples belong to the soils type Ranker and Rendzina (Leptosol and Rendzic Leptosol, WRB, 2014). Composite sample consists of five individual samples taken at the corners and in the center of the square with a side length of 10m. The 21 samples were taken in meadow, 6 in forest, 2 in arable land, and 1 in orchard (Figure 1).

Laboratory research was carried out at the Laboratory in the Institute of Soil Science in Belgrade. In the prepared soil samples the following parameters were determined: pH in nKCl (1: 2.5) - electrometrically; $CaCO_3$ - volumetrically with Scheibler calcimeter; humus - were calculated from the content of the organic C (CNS analyzer); accessible phosphorus and potassium - by Al method (Egner-Riehm-Domingo). Heavy metals content ("pseudo totals") - with HNO_3 and H_2O_2 and spectrometric determination (ICP-OAS).

Descriptive statistics and corelation method were used for statistical data analisys.

Background limit of elements have been determined by [Median ± 2MAD] method (Reimann et al., 2005).

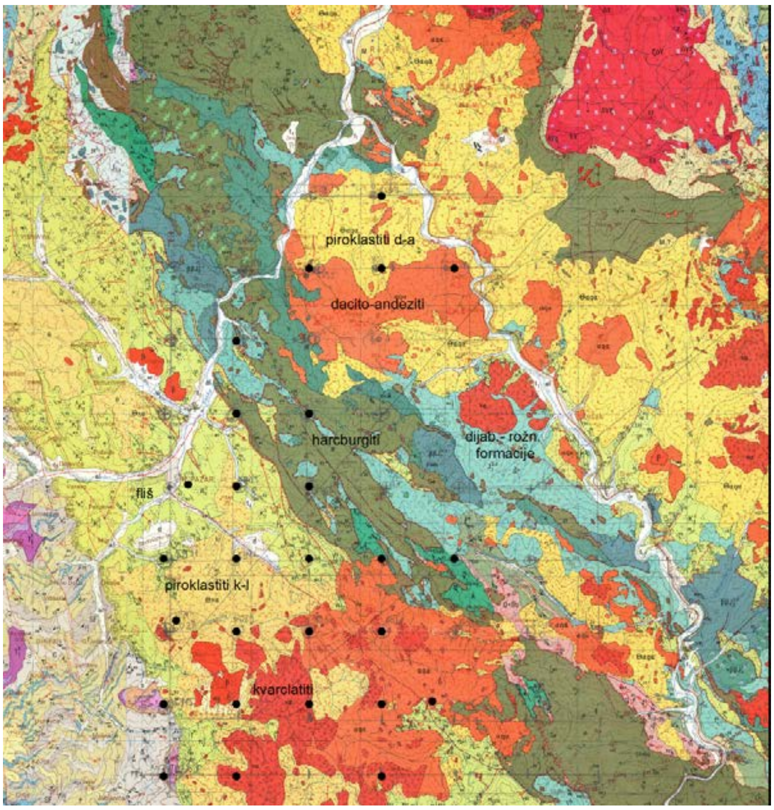

Figure 1.- Geological composition with samples location at Mt. Rogozna

RESULTS and DISCUSSION

Basic chemical properties

The soil samples belong to the soils type Ranker and Rendzina (Leptosol and Rendzic Leptosol, WRB, 2014).

In research area dominated medium and weakly acid soils (50 and 25% of the samples). The content of humus is medium and high (Džamić and Stevanović, 2014), which is associated with the soil usage (about 90% of the samples are taken from grassland and forest). The content of available phosphorus is very low (up to 6 mg/100g in 84% of samples), except on fertilized surfaces, and potassium is usually medium and high (above 12 mg/100g in 75% of samples).

Soil characteristics vary depending on the parent substrate, as well as other factors - vegetation, relief, and fertilizer application.

The soils on quartzlites and dacites-andesites have similar properties. Quartzlatites and dacites belong to a group of acidic magmatic rocks, and andesites to transitional rocks. Acidic rocks, compared to transitional, have more quartz, alkaline feldspat and less Fe-Mg silicates and alumosilicates. However, according to Urosevic et al. (1973) the dacito-andesites rocks of Mt.Rogozna are similar to quartzlatites, because they are highly altered. In addition, the volcanic eruption of quarclatite and dacito-andesites is accompanied by the eruption of pyroclastic rocks (tuffs, conglomerates), which are often mixed together, resulting in a material different from that of pure andesite or quartzlatite.

The reaction of the soil on these substrates is high to medium acid. Antonović (1969) determine in some profiles on the Mt. Rogozna samples with neutral reaction, because some of the andesite parties contain certain quantities of lime. The humus content is medium and high, with an average value around 5%. The soil are poor supplied with phosphorus, usually up to 5 mg/100g, and content of potassium is mostly medium and high, which indicates that the soil is naturally rich in this element.

Table 1
Basic soil fertility properties - statistic parameters

Geological supstrate (number of samples)	pH uKCl	Humus %	P_2O_5 mg/100g	K_2O mg/100g	$CaCO_3$ %
Quartzlatite (10)					
Minimum	3.9	2.3	0.1	5.8	0.0
Maximum	5.2	7.4	4.7	29.4	0.0
Mean	4.7	4.9	2.4	15.6	0.0
Median	4.9	5.3	2.1	14.6	0.0
Dacito-andezite (9)					
Minimum	4.2	3.9	0.1	15.9	0.0
Maximum	5.7	6.3	10.6	42.0	0.0
Mean	4.9	5.1	3.0	27.5	0.0
Median	5.0	5.2	2.5	25.4	0.0
Flysch (6)					
Minimum	5.2	4.6	1.8	17.4	0.0
Maximum	7.1	7.6	91.4	42.0	6.8
Mean	6.4	5.9	27.0	31.1	1.3
Median	6.7	5.7	13.3	33.3	0.0
Hacburgite (5)					
Minimum	5.7	6.0	1.2	9.2	0.0
Maximum	6.1	8.5	3.5	42.0	0.0
Mean	5.9	7.5	2.6	20.7	0.0
Median	5.9	8.0	3.2	11.0	0.0
All (30)					
Minimum	3.90	2.30	0.00	5.80	0.0
Maximum	7.10	8.50	91.40	42.00	6.8
Mean	5.37	5.55	8.12	23.51	1.3
Median	5.20	5.69	3.16	22.75	0.0
Stand.deviation	0.84	1.53	17.79	11.75	1.25
CV %	15.6	27.6	219.1	50.0	498.0

Ranker on ultrabasic rocks (harzburgites)(Mollic Leptosol) is a weakly acid (pH in KCl have value around 6). The soil reaction and the elements content are influenced by the composition of the rocks, which contain less than 45% of silicon (SiO_2), do not contain mineral quartz and feldspate, than Fe-Mg minerals, predominantly olivine and pyroxene. The soil is well supplied with humus (above 6%), because the samples are taken under the forest and grass vegetation, which also affected the lower erosibility of the humus horizon. The phosphorus content is very low (up to 3.5 mg/100g), and potassium is weak to high (over 9 mg/100 g).

Ranker on ultrabasic rocks, despite the favorable reaction and high percentage of humus, is infertile soil because it is poorly supplied with macroelements, humus decomposition is slow, has a shallow active layer insufficient for the development of plant roots, low water accumulation capacity and pronounced aridity (Antonović et al., 2000; Yao-Tsung Chang, 2013). A particular problem is the unfavorable Ca: Mg ratio - the molar ratio is less than 1, so there is a lack of Ca in the plant nutrition (Kabata-Pendias, 2001).

The soil on the flysch has the most uneven performances because the geological substrate consists of various materials - sandstone, alevrolites and marls. Properties also depend on cement material that connects clastic sediments. The reaction of the soil is from medium acid to neutral. Several samples have carbonates, belongs to the Rendzina type. The content of phosphorus have large variations, from low to high (on fertilized surfaces). Potassium content is medium and high.

Microelements and heavy metals

In addition to the basic characteristics of the soil, it is also important to determine the content of potentially harmful elements, especially at agricultural areas.

The concentration of microelements and heavy metals in soil of Mt. Rogozna depends primarily on the composition of the geological substrate, the anthropogenic pollution from traffic emissions and particles from the industry in Novi Pazar, Kosovska Mitrovica, and the mining complex Trepca.

Table 2

Content of microelements and heavy metals in soil (mg kg^{-1}) – statistic parameters

Geological supstrate (number of samples)	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Quartzlatite (10)								
Minimum	2.3	0.1	4.7	5.2	0.0	3.0	15.9	12.4
Maximum	12.2	0.8	31.3	27.1	0.3	18.6	79.5	43.8
Mean	6.4	0.3	15.2	16.7	0.1	9.8	64.2	30.5
Median	5.7	0.3	13.0	17.2	0.1	10.1	66.7	29.7
Dacito-andezite (9)								
Minimum	2.9	0.1	4.1	11.8	0.0	3.4	51.3	21.3
Maximum	18.1	1.3	63.9	52.5	0.2	36.3	167.0	51.3
Mean	10.1	0.4	31.8	18.5	0.1	12.0	94.0	32.5
Median	10.6	0.2	31.0	14.4	0.1	4.1	76.1	27.5
Flysch (6)								
Minimum	6.1	0.4	10.9	18.2	0.0	11.8	41.7	31.1
Maximum	24.5	1.0	37.2	30.0	0.3	56.5	86.9	56.4
Mean	10.9	0.6	24.7	22.6	0.2	24.9	65.7	42.6
Median	9.2	0.6	24.5	21.7	0.1	21.0	67.9	40.5
Harzburgite (5)								
Minimum	2.9	0.1	64.0	16.7	0.0	83.2	67.5	29.1
Maximum	12.1	0.3	522.3	64.1	0.1	688.4	267.9	136.4
Mean	6.5	0.2	310.0	31.3	0.1	445.0	126.6	59.6
Median	3.2	0.1	416.1	22.1	0.1	486.5	102.4	35.7
All (30)								
Minimum	2.30	0.1	4.05	5.16	0.0	2.95	15.9	12.4
Maximum	24.50	1.3	522.33	64.05	0.33	688.43	267.9	136.35
Mean	8.40	0.345	71.12	20.83	0.11	86.00	83.8	38.40
Median	7.15	0.275	26.62	19.20	0.08	14.13	73.3	32.8
Stand.deviation	5.22	0.34	132.86	12.04	0.08	184.12	46.16	21.68
CV-coeff.variation	62.2	99.6	186.8	57.8	75.9	214.1	55.1	56.5
Central Serbia average content (Mrvić et al. 2009)	11	0.80	48	27	0.12	58	40	48
MAC	25	3.00	100	100	2.00	50	100	300

The average values of the elements in all samples show that, in relation to the soils of central Serbia (Mrvić et al., 2012), soils of Mt.Rogozna have the lower or the same content of most elements, except Cr, Ni, and Pb. Elements Cr and Ni are found in concentrations above the MAC in most soil samples on harzburgite, and Pb in several soil samples on harzburgite and on dacite-andesites. The high correlation between Ni and Cr (R = 0.835 **) indicates the same origins, while the relationship between other elements is weaker (R≤0.54), but for certain elements statistically significant (As-Pb **, As-Hg **, As-Zn *, Zn-Cu **).

Regarding to heavy metals content, the soil on ultrabasic rocks (harzburgites) is separated, with significantly higher concentrations of Cr and Ni, which generally exceeds the MAC - average of 310 and 445 mg kg^{-1}, reaching 522 and 688 mg kg^{-1}respectively. In these soils, there is a slightly higher concentration of Zn, Cu, and Pb compared to the rest samples.

It is known that high levels of Ni, Cr, Co, Fe, and Mg occur in the soil on ultrabasic rocks. According to Mrvic et al. (2009) in the soil on ultrabasic rocks of central Serbia, the content of Ni is usually from 300-1500 mg kg^{-1}, and can reach 1900, and for Cr are in 100-700 mg kg^{-1}range, and can reach 1200 mg kg^{-1}, and those are mainly areas under forest and grass vegetation. Nickel and other metals originating from a geochemical source are most commonly found in highly accessible forms, related to silicates, oxides, and sulfides, while in anthropogenic pollution they are mostly predominantly metallic (Kabata-Pendias, 2001). However, in soils with a very high total content of Ni the content of available forms can be high. According to Jakovljevic and Stevanovic (2004), the average content of the total Ni in the serpentines of Zlatibor is 1456 mg kg^{-1}, and an available Ni 181 mg kg^{-1} (in DTPA), while in most of the grass Ni concentration is above the normal values for quality animal feed. According to Đorđević et al. (2005), in various rankers on serpentines rock mobile Ni (extracted 1M HCl) ranged from 261-557 mg kg^{-1}. According to Adriano (2001) on the soil on ultrabasic rocks, the harmful effects on the plants have more Ni than Cr, since Cr is less soluble. Chromium occurs in soil more often in primary minerals, more resistant to decomposition, so the concentration in the plant, especially in the above-ground part of plants, is usually low.

In addition to ultrabasic rocks, also in the soil on all substrates there is a slightly higher concentration of Pb compared to the average values for Serbia, average 59-93 mg kg^{-1}. The area of Mt.Rogozna is rich in Pb and Zn ores, which are located at the contact with different rocks and in rock cracks, especially in dacite-andesite, and there were also mines of these metals. The influence of the emission of Pb (and other pollutants) from the car exhaust gases, the Mining-chemical-metallurgical complex of Trepca etc. is not excluded.

As anthropogenic pollution can be expected in this area, the background limit of elements is calculated using the empirical method [Median + 2MAD] (Reimann et al., 2005). For Ni and Cr (CV> 100) log-transformed data was used and for other elements natural value was employed. Since the soil in harzburgite differs significantly from others by the content of Ni and Cr (to a lesser extent Pb), the background limit of these elements with the exclusion of soil on harzburgites is also calculated (tab. 3).

Table 3
Background limit of trace elements (mg kg^{-1})

	Elements	Median		MAD*		[Median+2MAD] Background concentration		Num. samples > [Median+2MAD]
		Natural	Log10	Natural	Log10	Natural	Anti-log	
All supstrates	As	7.15		3.40		13.95		3
	Cd	0.28		0.22		0.725		4
	Cr	24.58	1.39		0.327		110.53	4
	Cu	19.20		4.80		28.80		4
	Hg	0.075		0.036		0.147		7
	Ni	14.13	1.15		0.348		70.28	7
	Pb	73.30		10.48		94.25		6
	Zn	32.80		7.68		48.15		5
Without harzburgite	Cr	21.05		10.3		41.6		3
	Ni	11.9		7.35		26.6		3
	Pb	71.80		8.95		89.7		4

*MAD - median of the absolute deviations from the data's median

The Table 3 shows that in some points the concentration of elements is above the calculated background limits. In these locations, more detailed testing of possible anthropogenic pollution should be carried out.

The natural content boundaries for Cr and Ni of 41.6 and 26.6 mg $kg^{-1}$are more suitable for soils on flysch, dacite - andesite and quartzlatite. The background limit for Cr and Ni for soil on harzburgites are probably similar to the measured values, because they are the primarily geochemical origin, since the values are similar to those common for the soil on the ultrabasic rocks.

CONCLUSIONS

Rankers on various substrates have different properties, and thus the convenience for the growth of plants, especially meadow grasses, which dominate here. The highly acidic reaction of the soil, which occurs on quartzlatites and dacite-andesite, may be a limiting factor for the growth of some plants, especially from the genus Leguminosae. The lack of phosphorus was observed in the soil on all substrates. The application of calcification and phosphatization on these soils gives good results.

Regarding the increased content of heavy metals, rankers on ultrabasic rocks are naturally rich with Ni, Cr, and other heavy metals. In these soils, it is necessary to increase the intake of macroelements N, P, K, as well as Ca fertilizers, and the appropriate selection of cultures, without the nickel accumulator plants (especially from the family Brassicaceae, genera: Allyssum, Thlaspi, Pseudosempervirum, Brassica).

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SOIL FERTILITY AND PRODUCTIVITY IN THE MUNICIPALITY OF PRIBOJ

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ABSTRACT
Agrochemical evaluation of soils in the municipality of Priboj is a part of the macroproject "Soil fertility control and content of harmful and dangerous substances in the soils of the Republic of Serbia", financed by the Serbian Ministry of Agriculture and Environmental Protection. The results obtained serve as a basis of evaluation of the soil productivity and potential contamination by harmful and dangerous substances. This is of special importance in the moment when due to economic crises and the closure of an industrial plant FAP, population has taken up agricultural production, as the only alternative, regardless of many limitations of hilly and mountainous terrain. Therefore, it would be more than useful to investigate the possibilities of organic and health food in this region, particularly bearing in mind that this region is ecologically clean environment.
The soil samples were taken from the depth of 0-25 cm by grid system in grid network with 3.3 km distance between the plots (from agricultural land, pastures and forests). The following laboratory analyses were performed: pH_{KCl} electrochemically, % of $CaCO_3$ volumetrically, % of hummus and % of N by CNS Analyser, available P_2O_5 and K_2O by AL method by Egner-Riehm. The total heavy metal contents, that is, the harmful substances: As, Cd, Cr, Cu, Ni, Pb and Zn were determined by digestion with HNO_3 and H_2O_2, and by inductively coupled plasma atomic emission spectroscopy (ICP-AES). The results were statistically processed by descriptive statistics and correlation analysis.
The results obtained showed that 2/3 of soils in the Priboj municipality are acid or very acid, while 1/3 of the territory are mild acid soils. Since the soil samples usually derived from hilly and mountainous terrain, the hummus content was very high, $CaCO_3$ was not detected; available phosphorus was low or very low, while available potassium was high or very high. Among harmful elements evaluated, in low number of samples, that is on small area of the municipality, elevated concentrations of Cd, Cr and Ni were detected (usually around maximum allowed concentrations - MAC).
KEY WORDS: soil fertility; acid soils; harmful substances; municipality of Priboj

INTRODUCTION
Soil fertility is defined as the ability of soil to meet the plant needs for nutritive elements, a sufficient amount of water, air and heat (Kauričev et al.,1982). In other words, fertility means favourable soil chemical and physical properties for normal growth and development of plants.

Besides appropriate soil acidity and favourable physical properties, for optimal plant growth and development, a sufficient (optimum) concentrations of essential elements (including some heavy metals) are required. However, if their concentrations exceed these values, toxic effects can be expressed (phytotoxicity), which is typically reflected in reduced biomass, chlorosis of the leaves (reduction rate of photosynthesis), inhibition of root growth, and morphological alterations. In this way, heavy metals affect crop yield and soil fertility directly. It should be noted that phytotoxicity is primarily associated with the non-essential metals and metalloids such as As, Cd, Pb and Cr, which usually have a very low toxicity threshold. There are some plants, the so-called accumulator plant, which are resistant to very high concentrations of heavy metals and harmful elements, and their cultivation at the locations with very high content of these elements is recommended.

The soil contamination by pollutants and generally environment contamination (heavy metals and potentially harmful elements), has considerably increased with the development of intensive agriculture, mining, and energy and traffic. In the soil, pollutants come from different sources: the air (by gas emission from technological processes, fossil fuel burning, car emissions, biomass burning or farms, etc.), rivers and underground waters, as well as flood water and as one of the most important sources of solid pollution, industrial and home garbage. Adriano (2001) referred that production and metal processing release the significant amount of heavy metals on global level (Zn, Pb, Cu, As, Cd, Se, Mn, Sb, Sn, Hg, V), while mines the most Pb, and other elements in smaller amounts.

Excessive use of pesticides and fertilizers can be a significant source of pollution. In the long term experiments in chernozem soils, fertilization increased some heavy metals (Cu, Ni, Pb, Cd) significantly (Ubavića et al., 1995). Andersson (1979) reported that in the crude phosphates, Zn content can be very high (50-1450 mg/kg), and other elements such as Cd, As, Cr, Pb, Hg, Ni can be also found in the larger amounts, where Cd represents the greatest danger, due to its easy uptake by plants. Excessive use of nitrogen fertilizers leads to nitrate accumulation in the soils, which causes environmental problems and adversely affects the health of humans and animals (Corre and Breimer, 1979).

In the municipality of Priboj, with large truck manufacturer (FAP) already closed, almost no major industrial sources of pollution exist. The factory for plastic production (Polyester) can be considered one of the potential sources of soil contamination, which can be a source of organic or inorganic pollution.

As a part of a long-term macroproject "Soil fertility control and content of harmful and dangerous substances in the soils of the Republic of Serbia", financed by the Serbian Ministry of Agriculture and Environmental Protection, the research was done in the Zlatibor region, in the municipality of Priboj.

The aim of the research was to examine soil fertility in the municipality of Priboj, as well as the potential pollution of the soil. Pollution of the agricultural soils reflects negatively on plant production and animal world, and consequently on human health and nutrition. The results of this research provide the possibility for proper and timely measurements undertaken with the aim of high harmful elements concentrations reduction, in the regions where they were previously detected.

MATERIAL and METHOD

The municipality of Priboj is situated in the southwest part of Serbia, at the boundary of three states Serbia, Montenegro and Bosnia and Herzegovina (that is, the Republic of Srpska). The town of Priboj is situated on the River Lim, on both sides of the river, in the valley with 395m altitude and it is the biggest town of the Polimlje region.

Soil samples were taken from the depth of 0-25 cm. In total, 50 soil samples were sampled from 50 locations using grid network, with 3.3 km distance between the plots (from agricultural land, pastures and forests).

The prepared soil samples were determined by the planned chemical analyses: pH in 1M KCl – electrometrically, $CaCO_3$ %– volumetrically, humus content %– calculation from organic C, organic C-% by CNS Analyser (Vario model EL III (Hanau, Germany), N% using CNS analyser, available P_2O_5 and K_2O – AL method by Egner-Riehm. For soil fertility evaluation standard classifications were used (Džamić and Stevanović, 2000). Contents of total forms of heavy metals, i.e. harmful elements: As, Cd, Cr, Cu, Ni, Pb and Zn were determined by digestion with HNO_3 and H_2O_2 and by inductively coupled plasma atomic emission spectrometer (iCAP 6300 ICP-OES, Cambridge, UK). The criteria for the assessment of soil contamination with these elements were maximally admissible concentrations (MAC) in agricultural soils, according to the Regulation (SG RS 11/19).

The data were processed by basic descriptive statistics and the correlation method. Cartographic data were processed using mapping software GIS Arc View 8.3.

RESULTS and DISCUSSION

The relief and representation of soil types

The relief of the municipality of Priboj is hilly-mountainous and very diverse. There are three basic macro shapes: the valleys of Lim and Uvac rivers, fluvio-denudation landforms and mountain masses. Among the mountains Pobijenik (1423 m), Javorje (1486 m), Bić (1386 m), Banjsko brdo (1282 m) and Crni vrh (1186 m) stand out. The highest point of the municipality of Priboj is the top of the Javorje mountain, Ober, 1486 m. Valley altitudes range from 400 to 500 m, the flats were between 900 and 1300 m and the mountains rise up to 1500 m. The lowest elevation is 392 m.

The largest part of the territory is made of mountainous soils, ranker, sirozem and litosol types on various substrates. West of the river Lim the following substrates are dominant: sandstones, marl and cherts, while in the northwest, in the region of the mountain Javorje, schist and gneiss. In the northeast part of the municipality, rankers developed on basic rocks (gabro, serpentine and harzburgits), while in the southeast part, rankers on dijabaz are dominant. Calcomelanosoles and litosoles on lime basis are less present: west of the river Lim – in the biggest part of the mountain Bić and Ožalj, in Krnjača, and east of the River Lim – in the Pribojske Čelice and Banjsko brdo.

The municipality of Priboj has few natural resources, primarily due to the natural environment, and to a lesser extent due to human negligence and carelessness. Namely, very steep slopes prevent long-term retention of weathering products, but boost soil erosion and make soil development very difficult. In the municipality of Priboj, high quality soils are under the water accumulation of Hydroelectric power plant Potpeć, or under built settlements, roads and industrial buildings.

Basic parameters of soil fertility

The largest part of the territory is occupied by acid soils (around 53% of samples had pH value 4.5-5.5), followed by extremely acid soils (25.5% of samples had pH value <4.5) and weakly acid soils (21.5% of samples had pH values 5.5-6.5). In the northern part of the municipality, soils developed on serpentine rocks of weakly acid reaction are dominant. The samples with neutral or alkaline reaction (pH 6.5-7.2 and >7.2 respectively) were not found.

The soils investigated are carbonate free, mainly with high (3-5%) and very high (>5%) humus content (86% of samples). In 14% of samples medium (1.5-4%) humus content was detected. Nitrogen content was somewhat higher than common (0.30%), due to high humus content, with maximum value of 0.51%. C/N ratio ranged from 11.12 to 11.54 and was quite favourable, which is characteristic of hilly-mountainous region, and it is slightly above favourable C/N ratio of 9-11. This C/N ratio indicates favourable concentrations of mineral N forms available to plants. In numerous researches (Kabata-Pendias and Pendias, 1989; Kadović and Knežević, 2002) state that the concentrations of some heavy metals are in linear correlations with organic C content and soil acidity.

Table 1
Chemical characteristics of soils in the municipality of Priboj

Parameter	$CaCO_2$ %	pH	Humus %	N %	C/N	P_2O_5 mg/100g soil	K_2O mg/100g soil
Mean	0.00	5.00	5.73	0.30	11.08	6.63	34.53
St. dev.	0.00	0.72	1.60	0.083	11.20	8.06	8.67
Minimum	0.00	3.30	2.58	0.13	11.54	0.05	14.40
Maximum	0.00	6.30	9.78	0.51	11.12	45.28	42.00

In the soils of investigated territory, very low (<6.0 mg/100g) and low (6.0-10.0 mg/100g) easily available P content (P_2O_5) is abundant, in the wide range from 0.05 to 45.28 mg/100g soil. Around 78% of samples contain very low and low easily available P content, while medium (10.0-16.0 mg/100g) to high (16.0-30.0 mg/100g) content is present in 22% of samples. In 2% of soil samples very high content was detected (>30 mg/100g). Medium to high P content was detected in the alluvium of Poblaćnica brook (between Hecegovačka and Pribojska Goleša), as well as in the vicinity of Priboj and Pribojska Banja. Due to the low concentrations and solubility of phosphates, many soils of this region are poor in available P content. Soil acidity influences phosphates solubility and their availability to plants, but P content is also determined by Al, Fe, Mn and Ca contents in soils, due to heavy soluble P compounds formed with these elements.

The soils of municipality of Priboj are well supplied with easily available K (K_2O) (96% of samples contain high (20.0-35.0 mg/100g) or very high (>35 mg/100g) K content) and its content is mostly of natural origin, except in the case of some fields where it can be also the result of fertilisation. Only 4% of samples have medium (12.0-20.0 mg/100g) easily available K content.

According to the results obtained for soils of Priboj municipality, soil acidity and phosphorous deficiency are the main limiting factors in agricultural production and the achievement of quality and high crop yield. To overcome these limitations amelioration measures such as calcification and phosphatisation should be applied, and the exact rates of lime and fertilisers determined.

Total content of heavy metals and potentially harmful elements in soils

Analysis of (0-25 cm) total content of heavy metals and potentially harmful elements in soils (Table 2), points out to well preserved and unpolluted soils on the territory of Priboj municipality. Among 9 harmful elements evaluated, in low number of samples, that is on small area of the municipality, elevated concentrations of 4 elements were detected (above maximum allowed concentrations - MAC); Ni in 3 samples (6% of samples), Cr in 4 samples (8% of samples), Cd in one sample and Pb in one sample as well (2% of samples). Concentrations of As, Cu, Zn and Hg in samples investigated did not exceed MAC (25, 100, 300 and 3 mg/kg). Elevated concentrations of Ni and Cr were detected in northeast part of the municipality, where serpentines and ultramafic rocks are more dominant. Cr concentrations were over 200 mg/kg in 2 samples, and over 100 mg/kg (MAC) in two other samples, while Ni concentrations were above MAC in 3 samples. The origin of these elements is of geochemical nature, confirmed by strong and extremely significant correlation between elements (0.814).

Table 2
Total content of heavy metals and harmful elements in soils of the municipality of Priboj

Element	As	Cd	Cr	Cu mg/kg	Ni	Pb	Zn	Hg
Mean	8.5	1.5	43.5	21.7	18.4	45.4	35.3	0.0999
St. dev.	4.6	0.7	39.3	11.3	13.1	26.3	21.1	0.04
Minimum	1.1	0.15	0.50	7.7	5.9	2.8	101	0.039
Maximum	17.0	3.15	207	74.6	66.8	139	6.3	0.207
% of samples with values >MAC	0	2	8	0	6	2	0	0

The danger of harmful effect of high concentrations of these elements depends on their solubility which is caused by soil properties (texture, acidity, humus content, calcium, phosphates), as well as plant cover Anthropogenically deposited Ni is more soluble and more easily accessible by plants (Grupe and Kuntze, 1988), while toxic effects of Ni in natural conditions, depending on the plant species (40-246 ppm DW) mostly visible in serpentines (Gough et al., 1979). Ni solubility increases with pH decrease, and also depends on organic matter content, which mobilises Ni from other compounds (Kabata Pendians, 2001). Cr availability in soil mainly depends on redox potential and soil pH (El-Bassam et al, 1977). In acid environment especially if pH<5, completely insoluble compounds of Cr^{+3} in mineral form (chromates) dominate, while if pH>7 Cr^{+6} is present, which is very mobile and unstable in acid and alkaline environment (James et al, 1997).

Concentrations of Pb and Cd were above MAC in one sample (2% of samples), and cannot be explained here. In further researches, it would be desirable to analyse new soil samples in the hot spots, in short distances with spatial attention on the nature of vegetation and soil types. According to Huges et al. (1980), only 0.003-0.005% of total Pb content in soil is available to plants (Wilson and Cline, 1966). Solubility of Pb and Cd increases with soil pH decrease. Cd is very soluble and mobile at pH 4.5-5.5, while when pH is above 7.5, its adsorption becomes very strong, due to its carbonate and phosphate insoluble compound formation.

CONCLUSIONS

In the municipality of Priboj, ranker, sirozem and litosol soil types dominate on different sediments: sediment rocks (sandstones, marl and cherts), basic and ultrabasic rocks (gabro, dijabaz, serpentine and harzburgits), metamorphic rocks (schist and gneiss), while calcomelanosol and lithosol on lime are less present.

The largest part of the territory is occupied by acid soils, followed by extremely acid soils and weakly acid soils. The soils investigated are carbonate free, mainly with high and very high humus content, and also with very low and low P available content and high K available content.

The soil acidity detected indicates its low productivity, which requires ameliorative measures for fertility improvement, mostly calcification and phosphatisation. Regular fertility control, should determine the lime material rates and mineral P fertilisers for particular parcels.

Total content of heavy metals and potentially harmful elements in soils: agrochemical analysis points out to well preserved and unpolluted soils on the territory of Priboj municipality, with somewhat elevated concentrations of Cr and Ni of geochemical origin that do not represent real danger to the environment. Occasionally high Cd and Pb concentrations (in 2% of samples) were found. It is considered that elevated concentrations of these elements are of geochemical origin.

In the further research, it is recommended to investigate the area of interest with increased heavy metal concentrations in the denser network of samples, with the aim to determine their territorial distribution, maximum concentrations and origin. In locations with detected Cr, Ni, Cd and Pb concentration above MDC, plant species tolerant to these high metal concentrations shoud be grown, as well as plants not used in animal and human hutrition.

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CONTENT AND MOBILITY OF ALUMINIUM IN ACID SOILS OF CENTRAL SERBIA

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ABSTRACT
Aluminum (Al) toxicity is the primary limiting factor of crop production on acid soils, which affect much of the earth's arable lands. High content of soluble Al^{3+} in soils with a pH below 5 is very phytotoxic and becomes a major limiting factor of plant productivity in acidic soils. This paper presents a review of the quality of acid soils depending on the content of mobile aluminium. Acid soils in Central Serbia (over 60% of total arable land) are marginal with respect to the cultivation of most plants due to their unfavourable physical, chemical and microbiological properties. Seventy one percent of extremely acid soils in the Republic of Serbia are under forest and grass vegetation. Forests in Serbia cover 2.7 million hectares i.e. just above 30 percent. Strongly acid soils account for 27% of the total land under acid agricultural soils, with about 23% of strongly acid soils being under fields, gardens and permanent orchards. Special attention is devoted to the presence of larger quantities of mobile Al in acid soils issue taking into consideration its harmful effects on cultivated plants, especially sensitive plants genotypes. Excess of mobile Al is especially adverse in plowing layer because it reduces the root penetration depth, accompanied by reduced nutrient uptake from deeper soil layers. The cosequences of it are reduced growth of the above ground plants part and significantly reducing of dry matter yield of plants finally. High content of mobile Al is main cause of decay of young winter wheat plants in spring on acid soils. The low productivity of acid soils in Central Serbia, resulting from low fertility and, in particular, from the very low content of available phosphorus and high levels of mobile aluminium in the humus and, at times, in the subhumus horizon, requires the use of lime, phosphorus and organic fertilizers for soil amending purposes. In order to improve crop yields and fertility of crop land a combination of improved genetics, sustainable management practices, and amending of acid soils should be used.
KEY WORDS: aluminium, acid soil, Central Serbia, content, toxicity.

INTRODUCTION
Serbia covers a total area of 8,840,000 hectares. The total agricultural area is 5,718,599 hectares (0.56 ha per capita), with arable land amounting to 4.867,000 hectares (0.46 ha per capita). Agricultural land and forests account for about 70 and 30 percent of the total land area in Serbia, respectively.

Acid soils are widespread throughout Serbia. Seventy one percent of extremely acid soils in the Republicof Serbia are under forest and grass vegetation. Forests in Serbia cover 2.7 million hectares i. E. Just above 30 percent. Strongly acid soils account for 27% of the total land under acid agricultural soils, with about 23% of strongly acid soils being under fields, gardens and permanent orchards (Čakmak et al., 2009). Occurring on acid substrates or in regions where other agro environmental factors have led to the leaching of bases and soil degradation. Long-term research has shown that acid soils cover over 60% of Serbia's land area and are becoming a constraint to plant production due to their low productivity (Stevanovic et al., 1955). The constant increase in acreage under these soils in the result of intensive agricultural practices, uncontrolled use of mineral fertilizers, effect of acid rains and absence of organic fertilizers. In consequence, the physical, chemical and biological properties of these soils have become disturbed (Jelic, 1996).

Poor physical, chemical and biological properties of acid soils pose a complex problem for plant production on these soils. Regarding chemical properties, a low ph of soil increases the levels of mobile aluminium and manganese while decreasing those of available phosphorus (Dugalić, 1998; Radanović and Predić, 1997; Jelić et al., 2003; Milivojević, 2003).

Aluminium is not a biogenic element, but it is one of the most abundant elements in the Earth's crust, with a content of 7.5% (Gautheir, 2002). In neutral and weakly acidic soils, aluminium is in the form of insoluble alumosilicate and oxides. Therefore, aluminium is the most non-partly bonded to alumosilicate minerals (about 40%), and only small quantities (submicrololar) are found in a soluble form that is capable of affecting biological systems (May and Nordstrom, 1991). Aluminium is the main or secondary component of about 250 land minerals, especially all filosylics or the so-called. "Minerals of clay" (minerals of groups kaolinite, smektit, ilit), amorphous minerals of alofan, a large number of hydroxides (bemite, gibits) and aluminium oxides.

Avdonin (1976) states that plant nutrition phosphorus is conditioned by aluminium content, since aluminium with phosphorus in highly acidic soil builds insoluble compounds from which the plant is unable to use phosphorus, and it begins to collapse due to the strong deficiency of this element in the soil solution. All plants are not equally sensitive to mobile aluminium, so the author puts them in four groups. Thus, winter wheat and barley belong to a group of very sensitive, while the corn belongs to a group of medium sensitive. In this classification scheme, the presence of mobile aluminium in the soil in the amount of 5 to 6 mg of 100g-1 of the soil conditioned the poor development of the plants, while at the amount of 10-11 mg 100g-1, the plants die.

Aluminium toxicity is considered the most important growth limiting factor in acid soils (Carver and Ownby, 1995; Jayasundara et al., 1998; Arsenijević-Maksimović et al., 2001). Also, Narro et al. (2001) and Sumner (2004) state that the poor fertility of acid soils is due to the reduced solubility of some biogens (P, Mo, B), as well as the increased presence of certain toxic elements and compounds, primarily Al. Also, numerous authors point out that the main cause of reduced production capacity of these soils is the increased content of mobile aluminium that is toxic to most cultivated plants (Jelić, 1996; Jelić et al., 2004; Jelić and Đalović, 2008).

Aluminium is characterized by complex chemicals in the soil and often shows a very different influence on the dynamics and mobility of biogenic elements, the nutrition of fertilizers, their production and quality. Considering the specificity of its behaviour in acidic soils, the aim of this paper was to present numerous studies of the content and mobility of aluminium in the most important acidic lands of Central Serbia, from the aspect of its toxicity for certain genotypes of granular plants that show very different sensitivity to its active presence in land.

CONTENT OF MOBILE ALUMINUM IN SILICON LAND

The first studies of the content of mobile aluminium in acid pseudoglems of Serbia are cited in the work of Nikodijevic (1964). He noticed significant differences in the content of interchangeable aluminium in this type of soil, depending on the pedological background. Based on the pH and content of the interchangeable aluminium, he divided the parapodsols of Western Serbia into three groups: 1. pH (KCl) ≤ 4.0 with a content of Al of 45 to 13 mg 100 g^{-1}, 2. pH (KCl) 4.0-4.5 sa with a content of Al 13.0-3.0 mg 100 g^{-1}, 3. pH (KCl) ≥ 4.5 with the content of Al exchangeable ≤ 3.0 mg of 100 g^{-1} soil. Also, the high content of mobile aluminium in acid soil was also noted by Okiljevic (1982), where there were up to 36 mg of $100g^{-1}$ of soil on individual microlaths. In these locations, plants showed signs of physiological illness, and after the analysis of the soil, it was determined that the content of mobile aluminium in these soils increased from 2 to 27 times in relation to the soil where the plants developed normally (without the symptoms of the disease).

The content of mobile aluminium in acidic soils in Central Serbia varies depending on the type and the reaction of the soil, the mother wall, the depth of the profile, the place and the applied production technology, and partly the application of mineral fertilizers (Jelic, 1996). The content of mobile aluminium in the soil of the pseudogley type of the Čačansko-kraljevačka basin, depending on the pH level of soil, was the subject of a study of a number of authors (Dugalić, 1998; Dugalic et al., 2002; Dugalić et al., 2002; Dugalić and Gajić, 2002).

Extensive research into the vertical dynamics of the exchangeable acidity and the content of movable aluminium in forest, meadow and field pseudogleys has been carried out. Thus, the distribution of the mobile Al and pH values show a strong dependence on the characteristics of the soil profile. A low average pH value in KCl was observed in the studied soil profiles (3.80-4.28). Also, the pH value of the pseudogley soil of the forest profiles was significantly reduced in relation to the land of meadow and arable varieties. The acidity of the soil is particularly pronounced in deeper horizons, as 27% for the Ah profile, 77% for the Eg profile and 87% for the B1tg soil profile have a pH value of less than 4.0.

Table 1
Content of mobile Al ions different horizons of field, meadow and forest profiles of pseudogley (Zivkovic and Dugalic, 2001)

Horizons	Profiles tested	Content of mobile Al, in mg 100 g^{-1} of soil (in % of No of tested profiles)					
		up to 3.0	3.1-6.0	6.1-10.0	more than10	more than 20	Variation
Ah (fi)	54	63.0	18.5	11.1	7.4	0.0	0.2-16.1
Ah (m)	28	64.3	17.8	7.1	10.7	0.0	1.0-15.2
Ah (fo)	20	40.0	10.0	15.0	35.0	20.0	0.4-33.2
Ah (fi-fo)	102	58.8	16.3	10.8	13.5	3.9	0.2-33.2
Eg (fi)	54	20.4	13.0	12.9	53.7	13.0	0.5-30.3
Eg (m)	28	10.7	7.1	21.4	60.7	14.3	0.3-29.4
Eg (fo)	20	0.0	15.0	0.0	85.0	45.0	3.5-53.5
Eg (fi-fo)	102	13.7	11.8	12.8	61.8	19.6	0.3-53.5
B_1tg (fi)	39	12.8	12.8	7.7	66.5	48.7	1.0-53.0
B_1tg (m)	24	0.0	8.3	12.5	79.2	54.2	3.2-46.9
B_1tg(fi-fo)	15	0.0	0.0	6.7	93.7	66.7	7.9-58.0
B_1tg(fi-fo)	78	6.4	9.0	8.9	75.6	53.8	1.0-58.0
B_2tg(fi-fo)	29	0.0	13.8	13.0	72.4	34.5	3.6-37.4

(fi) – field, (m) – meadow, (fo) – forest

The application of mineral fertilizers, especially nitrogen, leads to an increase in the acidity of the soil and the content of mobile aluminium in it (Jelic et al., 2006; 2010). Thus, on the acidic soil of the type vertisol, the largest content of mobile aluminium was registered on a nitrogen fertilized variant, as well as on all variants where a higher dose of nitrogen fertilizers of 120 kgha^{-1} was applied (Jelic et al., 2006).

Table 2
Fertilization (A_1=control, A_2=N, A_3=NP_1K, A_4=NP_2K, A_5=NP_1, A_6=NP_2, A_7=NK) and cultivar effect on the aluminium content in soil (B_1=Takovcanka, B_2=Studenica, B_3=KG-100, B_4=Matica, B_5=Lazarica, B_6=Toplica, B_7=KG-56) (Jelic et al., 2010)

	Aluminium (Al) content (mg kg^{-1})															
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	xA	B_1	B_2	B_3	B_4	B_5	B_6	B_7	xA
	Nitrogen dose: N_1 - 80 kg N ha^{-1}								Nitrogen dose: N_2 -120 kg N ha^{-1}							
A_1	15.0	14.0	8.0	16.0	14.0	6.7	4.0	11.1	15.0	14.0	8.0	16.0	14.0	6.7	4.0	11.1
A_2	24.0	20.0	25.0	15.0	30.0	5.3	6.0	17.9	23.9	25.0	30.0	20.0	30.0	17.0	10	22.3
A_3	5.2	9.0	9.0	5.0	13.1	8.0	6.0	7.9	12.0	7.9	18.0	17.0	18.0	13.8	9.9	13.8
A_4	17.0	25.0	26.0	37.0	40.0	22.0	12.2	25.6	29.0	30.0	30.0	43.8	42.0	31.0	14	31.4
A_5	19.0	24.0	30.0	30.0	34.0	4.8	8.0	21.4	20.0	20.0	25.6	25.0	18.0	20.0	3.0	18.8
A_6	12.0	12.3	17.7	29.7	21.0	10.0	24.7	18.2	14.0	14.0	16.0	25.0	26.0	12.2	32	19.6
A_7	10.0	14.0	18.0	22.0	18.0	8.3	9.8	14.3	13.0	13.0	18.0	31.0	30.0	10.9	24	21.1
xB	14.6	16.9	19.1	22.1	24.3	9.3	10.1	16.6	17.7	17.7	20.8	25.4	25.4	15.9	13	19.7
LSD- test (5% and 1%)									LSD- test (5% and 1%)							
5%	A: 0.374			B: 0.374			AB: 0.988		A: 0.557			B: 0.557			AB: 1.473	
1%	0.495			0.495			1.309		0.737			0.737			1.950	

On the same type of land Jelic et al. (2010) examined the impact of various fertilization and winter wheat genotypes on the content of the most important biogenic elements and mobile aluminium in the soil. It was found that the mobility of aluminium in this soil was changed under the influence of different fertilization systems and cultivated genotypes. Thus, the mobile aluminium content in the soil ranged between 3.0 and 44.0 mgkg^{-1}, while its highest content was found on NPK and N variants using multiple doses N.

According to the study, Đalovic et al. (2011), the average content of mobile aluminium in the soil profile type pseudogley ranged between 11.02 (Ah), 19.58 (Eg) and 28.33 mg Al 100g^{-1} (B_1tg horizon). Also, due to differences in pH values, the mobility of Al in forest lands was significantly above average (26.08 mg Al 100g^{-1} soil compared to arable fields and meadows (16.85 and 16.00mg Al 100g^{-1}).

Authors Mrvic et al. (2012) showed the results of the test content of individual forms of aluminium in pseudogley soil in Serbia. The authors conclude that the total Al in the solution of these soils has a continuous gradual increase from pH 6.0 to about pH 4.0. The concentration of Al tot in the pH interval above 4.0 was varied and ranged from 0-22 AlMmol l^{-1} in the Jabucca site to 35-50 μmol l^{-1} in the Arile locality, which was just in proportion to the reactive Al reserves, and the inverse with values of CEC and% of base cations. Under pH 4.0, Altot increased rapidly in the soil of all investigated sites. Also, the same authors conclude that the concentration of monomeric Aluminium (Almono) in pseudogley soil appeared at pH 5.5 and less, while lower toxicity polymeric Al forms appeared above these pH values.

Table 3
The effect of acidification on pH, Al mono and Altot in soil solution (Mrvic et al., 2012)

Location	ml 0.1 M HCl	pH	Al_{mono} μM l^{-1}	Al_{tot} μM l^{-1}	Al_{mono} in Al_{tot} (%)
Arilje	0	4.90	33.19	38.40	86
	0.25	4.72	34.53	40.39	85
	0.5	4.60	34.81	41.48	84
	1	4.38	37.39	43.41	86
	1.5	4.15	40.13	40.86	98
	2	3.93	61.04	61.04	100
	2.5	3.80	74.77	74.77	100
	5	3.30	219.10	219.10	100

MOBILITY AND TOXICITY OF ALUMINUM IN SOIL LANDS

The mobility of aluminium in the soil increases with increasing acidification, which is caused by rinsing the alkali metal ions (Na^+, K^+, Ca^{2+}, Mg^{2+}) and decreasing the pH of the soil (Matsumoto, 2000). Therefore, under conditions of acidic soil reaction, aluminum mobility grows by the fact that aluminum and hydrogen occupy swap sites on earth colloids. This process leads to the prevention of the binding of base cations to the surface of colloidal particles and the maintenance of high CEC values in the soil profile. By further intensification of this process, the high concentration of H+ ions on the surface of clay minerals attacks its structure, resulting in the release of Si^{4+}, Fe^{3+} and Al^{3+}as well as other ions that are part of these minerals. Further intensification of acidification leads to an ever-increasing release of Al from the structure of minerals and aluminium becomes the dominant exchangeable cation. The greatest influence on the mobility of Al in the soil has a pH value. A large dependence of the aluminium dynamics on the pH value on acidic soils is emphasized by many authors in their work (Radanović and Predić, 1997; Dugalić et al., 2002; Dugalić and Gajić, 2002; Jelić et al., 2010). On highly acidic soil reactions (pH in KCl below 4.0), the content of mobile aluminium varied depending on the pH of the soil. Thus, at pH (KCl) about 4.5 the content of the mobile Al was from 1 to 2 mgkg^{-1}, whereas at the pH (KCl) of 3.8 the content of mobile Al increased up to as much as 35-40 mgkg^{-1} (Radanović and Predić, 1997). Also, the same authors came to the conclusion that the toxic level of Al for certain genotypes and the specific agroecological environment is very different, and for our commercial varieties of winter wheat and barley, on the lands of distric pseudogle and degraded cambisol are potentially dangerous quantities above 10 mg 100g^{-1} .

The content of mobile aluminium in acidic soils in Central Serbia varies depending on the mother wall, the depth of the profile, the site and the applied production technology, especially the improper application of fertilizers. Jelic (1996) on the soil type vertisol noted a significant variation in the content of mobile aluminium depending on the weather conditions and the use of certain types of nitrogen fertilizers. The low pH value increases the mobility of aluminium in the soil solution of acidic vertisol and pseudogley (Jelić, 1996; Dugalić, 1998).

Jelić (1996) and Đokić et al. (1997) found that the high content of mobile aluminium is the main cause of the decay of young wheat seedlings in the spring on acidic acid soils. The increase in the mobility of aluminium in these soils can be the result of continuous unilateral application of high doses of nitrogen fertilizers, as well as other physiologically acidic fertilizers without Ca-component (Jelic, 1966).

In addition to pH, the content of organic matter, the composition of soil minerals and other soil properties (Drabek et al., 2003, Naramabuye and Haynes, 2007) has a major influence on the mobility of aluminium in the soil. Organic compounds in soil, both large and small molecular weights (humic acid, citric acid) reduce acidity, and therefore the content of free Al's. Mobile aluminium, which is bound in organic complexes and polymer forms in the soil, is considered to be less toxic or non-toxic for cultivated plants (Parker et al., 1988). However, some studies have shown that the presence of polymer Al_{13} in soil solution is toxic to cultivated plants (Shann and Bertsch, 1993; Hiradate et al., 1998). Recent studies of the toxicity of these polymers of aluminium by some authors suggest that these forms of Al are less common in arable land, hence the polymer Al_{13} is strongly bound to phosphates, sulphates and silicates, which is why its release from negatively charged colloids of the soil is difficult (Mossor-Pietrasyewska, 2001; Rengel, 2005).

Table 4
Influence of nitrogen doses on the content of mobile aluminium in the soil at different sampling times (mg $100g^{-1}$) (Jelić, 1996).

Sampling time	Nitrogen dose (kg ha^{-1})		Average
	60	250	
02. april	5.8	13.3	9.5
09. april	4.2	12.9	8.5
15. april	11.7	22.5	17.1
21. april	6.6	14.1	10.3
Average	7.1	15.7	11.4

The degree of toxicity of Al for growing plants depends primarily on the content and shape of Al in the soil, then the pH, the organic and inorganic ligands in the solution, the ionic strengths, and the genotype of plants (Ramaškevičiene et al., 2002; Shamshuddin et al., 2009). A very different form of aluminium is present in the soil solution in the pH dependence: Al^{3+} at pH 4-5, $Al(OH_2)^{2+}$ and $Al(OH)^{2+}$ at pH 5.5-7.0 and $Al(OH)^{4-}$ at pH 7-8. The other complex forms of Al ions in soil such as $AlO_4Al_{12}(OH)_{24}(H_2O)^{127+}$, (Al_{13}) and Al^{3+} have been proven to be toxic to plants, while for $AlSO_4^+$, $Al(SO_4)^{2-}$ and Al-F forms have not been established toxicity. $Al(H_2O)^{63+}$, which is known as Al^{3+}, is the dominant ion in acidic soils with a pH below 5.0 and is considered to be the most toxic form of this element. The status of $Al(OH)^{2+}$ and $Al(OH)_2^+$ is unclear although experimental results indicate their toxicity (Kinraide, 1997). The toxicity of certain types of Al for the roots of wheat plants increases in the following sequence: $AlF_2 + \leq AlF_2 + \leq Al_3 + \leq Al_{13}$. According to Kochian (1995), Al's toxicity for plants was confirmed only with Al_{13} and Al^{3+}.

Existing knowledge of Al's toxicity in plants is insufficient and research on this problem is continually being carried out, indicating its great significance (Matsumoto, 2000). It is believed that the difficulties in determining the Al's toxicity mechanism are related to its complex chemistry (Martin, 1988; Kinraide, 1991). Namely, in acidic soils (pH ≤ 5.0), Al^{3+} is the most toxic form of Al in the soil solution, while with the increase in soil pH the dominant forms are $Al(OH)^{2+}$ and $Al(OH)_2^+$. The first visible symptoms of Al's toxicity in plants are to stop the growth of the roots and branches. Symptoms at the root of the plants are immediately apparent, while the edges are significantly less affected (Chang et al., 1999). Root tightness is due to the inhibition of its elongation due to the negative impact of mobile aluminium. The root becomes sturdy and brittle, and the roots of the top and side cornice thicken and get a dark-brown colour. Such a root is the limited ability to adsorate significant biogenic elements (phosphorus, calcium, magnesium, and molybdenum) and water (Mossor-Pietrasyewska et al., 1997).

CONCLUSIONS

Acid soils in Central Serbia (accounting for over 60% of the total arable land area) are extremely unfavourable in term of chemical, microbiological and, in most cases, physical properties, which makes them insufficiently suitable or unsuitable for the cultivation of most small grains.

Acidic soils of the central part of Serbia show a great variation in the total exchangeable acidity, as well as the share of H^+ and Al ion in it. Also, there are significant variations of the exchangeable acidity and mobile aluminium in various profiles and horizons of acidic soils. The largest total exchangeable acidity was in the forest, and the smallest on field pseudogleys.

The mobility of aluminium varies greatly and increases considerably in the subhuman horizon, as opposed to H^+ ions whose content decreases with increasing depth. The highest content of mobile Al Ion (above 10 mg $100g^{-1}$) was found in forest profiles, much smaller in meadows, and the smallest in field varieties of acidic soils.

Soil acidity and aluminium toxicity is certain one of the most damaging soil conditions affecting the growth of most crops. The low productivity of acid soils in Central Serbia, resulting from low fertility and, in particular, from the very low content of available phosphorus and high levels of mobile aluminium in the humus and, at times, in the sub humus horizon, requires the use of lime, phosphorus and organic fertilizers for soil amending purposes.

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Assessment of agrochemical and physico-chemical properties of soils in forest plantations of the steppe zone of northern Kazakhstan

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ABSTRACT

Data on the evaluation of agrochemical, physical and physico-chemical properties of soils in various forest plantations of Northern Kazakhstan are given. For the first time, indicators of the effective fertility of ordinary black earth under artificial forest plantations and in forest belts in comparison with the virgin land and the reservoir were studied. Analysis of data on the content of mobile forms of nitrogen and phosphorus showed a low level of security. The content of exchangeable potassium is within the limits of increased security. In soils of the forest belts, the density of soil increases in comparison with artificial plantations. As a result of prolonged agricultural use in soils, under the sowing of spring spruce at different distances from the forest belt, a decrease in the proportion of calcium in the upper horizons is noted, with a simultaneous increase in the proportion of cations of magnesium and sodium. While under artificial plantations an increase in the proportion of calcium cations in comparison with virgin analogs is noted. The study of the fertility of forest soils makes it possible to use these data to develop measures for the maintenance and sustainable functioning of forests.

KEY WORDS: soil density, porosity, alkaline hydrolyzable nitrogen, mobile phosphorus, degree of soil saturation with bases, chernozem, forest plantations, fertility

INTRODUCTION

The leading factors that determine the variegation of the soil cover and the development of soils are natural and anthropogenic disturbances. They cause the development of processes that can lead the soil out of the equilibrium state and exert a corresponding influence on the level of their fertility. For the stable development of agriculture, it is necessary to maintain that optimum level of soil fertility, which can ensure the receipt of given crop yields and high productivity of forests. If in agriculture this issue is covered at different levels and by many scientists, then this problem is practically not applied to forestry.

In Kazakhstan, the area of soils under forest stands is only 4.5% of the country's territory (the total area of the forest fund of Kazakhstan is 26,446 thousand hectares, of which 12,284 thousand hectares are covered by forests). But, taking into account the anthropogenic impact on forest ecosystems, which inevitably leads to the need for artificial renewal, the withdrawal from the circulation of the well-to-do lands allocated to burdensome rewind and deposits and subsequently intensively overgrown with forest, especially in the forest-steppe zone, there arises the problem of assessing the influence of forest on the soil, deposits in the agricultural sector, or leaving them as part of a natural agrolandscape.

In the literature, there is a lot of data on the study of forest soils in various natural and climatic zones, their transformation, the influence of forest plantations on the morphological, physicochemical properties of soils and other issues [1-10]. In the Republic of Kazakhstan systematic research on the study of the main soil fertility indicators under forest plantations in the steppe zone has not been carried out. There are some works by Muenov A.Zh. [11], Sarsekova D.N. [12,13], Kahn V.M. [14], Obizinskaya E.V. [15].

In this regard, we set a goal - to study the physical, physicochemical and agrochemical properties of soils under forest plantations in the steppe zone of Kazakhstan. The objects of research were chernozems of the Akmola region (Shchuchye-Borovoe region). To monitor the dynamics of agrochemical properties of soils, key areas were selected:

1. Artificial forest plantations - birch, common pine, mixed plantings of birch and pine, virgin chernozems.
2. Birch forest belts - "zero-mark", the field of spring cereals at a distance of 25 m, 100 m, 200 m from the forest belt, 45 years old deposit.

From each site a mixed soil sample was selected for genetic horizons (at least 5 samples by the envelope method). They determined: Nitrogen hydrolyzable by Cornfield, mobile phosphorus and potassium exchange from one extract according to Chirikov, calcium, magnesium by the method with trilon B.

RESULTS and DISCUSSION

All the properties and regimes of the soil, in the first place, are determined by the content of organic matter. As shown by the analysis of the distribution of organic matter along the profile of the studied soils, the maximum humus content in the area with forest protection stands is 7.4% (Table 1).

Table 1

The content of humus in chernozem ordinary under forest stands (average of three determinations for 2015-2016.)

Plantings	Depth of selection, cm	Humus, %	Plantings	Depth of selection, cm	Humus, %
Woodland (birch)	A 4-31см	7,4	Birch dangling	A 4-35см	6,7
	B_1 31-53см	3,5		B_1 35-62см	3,0
	B_2 53-91см	1,4		B_2 62-97см	1,4
	C 91см	0,9		C 97см	0,7
25 m from the forest belt	A 0-27см	5,7	Pinus sylvestris	A 6-30см	6,3
	B_1 27-45см	3,0		B_1 30-56см	2,5
	B_2 45-68см	1,5		B_2 56-90см	1,4
	$B_к$ 68-96см	1,0		C 90см	0,9
	C 96 см	0,4		-	
100 m from the forest belt	0-25см	4,6	Birtch dangling + Pinus sylvestris	A 3-27см	6,4
	25-50см	2,2		B_1 27-60см	2,0
	50-75см	1,0		B_2 60-100см	1,1
	75-100см	0,9		C 100см	0,4
200 m from the forest belt	0-25см	4,4	Virgin land	A 2-23см	6,6
	25-50см	1,9		B_1 23-46см	1,8
	50-75см	0,8		$B_{2к}$ 46-65см	1,0
	75-100см	0,2		$BC_к$ 65-90см	0,6
Deposit	A 3-30см	5,7		C 90 см	0,4
	B_1 30-51см	2,3			
	B_2 51-75см	1,5			
	$B_к$75-115см	1,55			
	C 115 см	0,35			

With the distance from the forest belt to the plowland by 25 m and on the deposit, the humus content is reduced to 5.7%. In the horizon B1, the humus content is reduced to 1.9-3.5%. In the soil of the deposit, up to 2.3%. From the horizon B2 the humus content decreases gradually. This can be explained by the vegetation cover of the deposit area, where the processes of accumulation of organic matter are more developed in the upper horizons, in contrast to the forest belt soil and at 25 m distance from it.

If we talk about the content of humus in soils under different types of forest plantations in comparison with the virgin land, its quantity here was 6.6%. Depending on the type of plantation, the humus content does not change much - 6.3-6.7%. The humus content in the horizon B1 is 1.8-3.0% with a further decrease to 0.4-0.7%. The maximum values of this indicator were revealed in the soil under the birch plantations. That is, under the birch plantation, more favorable conditions are created for the processes of humus formation.

The nitrogen soil fund is mainly represented by organic compounds that make up the humus. It becomes available to plants only after its mobilization and transition into the mineral form.

The degree of mobilization depends to a large extent on the meteorological conditions of the warm period and agrotechnical measures. Nitrogen regime of the soil is characterized by an indicator - the content of alkaline hydrolyzable nitrogen, which has a close correlation with the content of humus.

Nitrogen starvation may be one of the reasons for the shrinking of forest cultures [16]. To establish the supply of plants with nitrogen, State Agency «RSMC Agrokhimsluzhba» of the RK recommends the determination of alkaline-hydrolyzable nitrogen in the soil according to the method of Cornfield. For lands occupied by forest plantations, the gradation of soils in terms of the content of this form of nitrogen in the republic has not been developed and therefore we take as a basis the adopted regional graduation for agricultural land. The highest dynamicity of readily hydrolyzable and ammonia nitrogen is found in the horizon of forest litter, and as a rule, their higher content is found in spring and autumn. As noted, in the mineral horizons the amount of nitrogen is much less and slightly changes during the growing season [17].

According to our observations, the average seasonal content of the determined form of nitrogen was higher in the upper horizons, where the bulk of the organic matter accumulates.

The soils of the studied plots belong to the category of very low availability, its content does not exceed 6 mg/100 g of soil (Table 2).

Table 2

Dynamics of agrochemical indicators in chernozems ordinary forest belts

Trial sites	Horizon, depth, cm	N utg, mg / 100 g of soil		P_2O_5, mg / 100 g of soil		K_2O, mg / 100 g of soil	
		2015	2016	2015	2016	2015	2016
Woodland belt	A_o 4-31см	3,7	4,6	1,9	1,8	41,7	41,7
	B_1 31-53см	4,2	3,6	1,0	1,5	35,7	32,7
	B_2 53-91см	4,0	3,6	1,3	1,0	37,3	40,6
	C 91см	4,4	3,1	0,8	0,5	21,8	26,5
25 m from the forest belt	$A_{жыр}$0-27см	4,1	3,2	2,3	1,6	46,3	33,2
	B_1 27-45см	4,0	3,1	1,7	2,3	43,0	44,2
	B_2 45-68см	4,0	3,5	1,2	1,0	49,9	38,3
	$B_к$ 68-96см	4,0	2,9	0,8	0,9	37,7	38,2
	C 96см	4,0	3,7	1,5	0,8	25,1	33,3
100 m from the forest belt (grain)	0-25 см	3,3	3,5	1,5	2,5	34,5	36,3
	25-50 см	4,2	2,7	1,2	1,6	37,0	41,3
	50-75 см	4,3	3,7	1,1	0,9	27,8	32,3
	75-100 см	4,3	4,4	0,9	0,9	15,9	35,6
200 m from the forest belt (grain)	0-25 см	4,6	4,5	1,5	1,6	39,1	42,3
	25-50 см	3,6	4,1	1,4	1,5	34,7	37,0
	50-75 см	3,9	4,0	1,5	0,7	35,1	32,7
	75-100 см	4,4	4,3	1,0	0,5	20,3	28,5
deposit	$A_ш$3-30см	4,2	3,6	1,4	2,2	30,4	35,9
	B_1 30-51см	5,1	4,1	1,9	1,2	44,3	32,2
	B_2 51-75см	4,3	4,5	1,2	0,9	37,9	30,2
	$B_к$75-115см	4,2	4,4	1,0	0,7	30,6	21,6
	C 115см	4,4	3,8	0,6	0,4	23,6	22,1

We found that the dynamics of nitrogen depended on the type of plantations and the hydrothermal conditions that formed under them. In 2015, when the amount of precipitation was less, the content of readily hydrolyzable nitrogen in the soils of the forest belt was higher.

An analysis of the annual dynamics of alkaline-hydrolysed nitrogen in the forest belt area showed that in 2015 the nitrogen content was higher for all sampling points and for all horizons. The nitrogen content increased with depth or was at the same level with the upper horizon, with the exception of the soil selection point at a distance of 100 m from the forest belt.

The temperature background and more precipitation in 2016 contributed to the reduction of nitrogen.

At the same time, the best nitrogen conditions are created at the point of selection at a distance of 200 m from the forest belt in crops of grain crops, regardless of the year of research, in the upper horizon it is not lower than the value of the fallow area.

In artificial forest plantations, the content of alkaline hydrolyzable nitrogen decreases with depth. Inside the forest belt, the nitrogen content in the horizons is in the range of 4.1-3.9 mg / 100 g soil.

In the soils of virgin land and under birch plantations, the maximum nitrogen content in the upper horizon is noted and it sharply decreases in horizon B1 (Table 3).

In the planting of pine and mixed plantations, this difference is less severe.

It was noted that in a more arid year the nitrogen content is lower than in humid years, which indicates the formation of a specific nitrogen regime under crops.

In 2016, the average seasonal pattern in the distribution of alkaline hydrolyzable nitrogen horizons was similar to 2015, on the whole, the excess was insignificant and amounted to 0.1-0.8 mg / 100 g of soil. The total content of phosphorus in the soil is quite high, but in soils it is mainly in sedentary forms.

The degree of its use by plants from the soil is only 3-5%. Therefore, the availability of plants with affordable forms of phosphorus is an important condition for optimal nutrition of the growing plants [18].

The availability of black chernozems studied by ordinary mobile phosphorus is characterized by a low level - in the range of 1.75-3.7 mg / 100 g soil (Table 2.3).

Table 3
Dynamics of agrochemical indicators in chernozems common under plantations

Trial sites	Horizon, depth, cm	N utg, mg / 100 g of soil		P_2O_5, mg / 100 g of soil		K_2O, mg / 100 g of soil	
		2015	2016	2015	2016	2015	2016
Virgin land	A 2-23см	5,3	5,8	1,6	1,9	38,9	42,9
	B_1 23-46см	3,9	4,6	2,0	1,0	50,2	33,2
	$B_{2к}$ 46-65см	4,2	4,5	1,3	0,8	40,4	33,7
	$BC_к$65-90см	3,9	4,4	0,8	0,7	21,3	26,9
	C 90 см	4,0	4,3	0,7	0,6	17,1	25,3
Birch dangling	A 4-35см	4,5	5,7	2,0	3,7	43,6	42,6
	B_1 35-62см	3,9	4,0	2,1	2,8	55,1	48,5
	B_2 62-97см	4,1	4,1	1,0	1,2	30,4	31,8
	C 97см	4,1	4,6	0,7	0,7	23,1	31,3
Pinus sylvestris	A 6-30см	5,0	4,9	1,6	2,3	50,3	47,4
	B_1 30-56см	4,1	4,7	2,1	1,0	41,7	42,7
	B_2 56-90см	4,0	4,5	1,3	0,9	39,7	32,9
	C 90см	4,4	4,6	0,8	0,8	25,2	32,1
Mixed Landings	A 3-27см	4,5	4,0	1,5	2,3	30,5	82,6
	B_1 27-60см	4,2	4,5	1,4	1,4	34,4	46,8
	$B_2$60-100см	4,5	3,9	0,9	1,1	26,5	48,8
	C 100см	4,2	4,4	0,5	0,6	16,6	39,7

With depth, the content of phosphorus is reduced, and strong variation in horizons, depending on the yearly dynamics, is not observed. This can be explained by the fact that the phosphorus compounds in the soil are chemically absorbed and less mobile than the mineral forms of nitrogen. In forest belt soils and at different distances from it, the level of mobile phosphorus content is somewhat lower than in the soil under forest plantations. But on this site the difference between the indicators at the points of selection is not as pronounced as in the forest belt, in the adjacent field and in the deposit.

In the soil of two sites in 2016, the phosphorus content in the upper horizon A and A0 rises, with the exception of forest belt points and 25 m from it. This can be explained by the peculiarity of the developing hydrothermal and forest-growing conditions under specific microrelief conditions.

The content of exchangeable potassium in the soil is determined by its granulometric composition. The soils of the studied areas according to the granulometric composition refer to medium-large sandy or coarse-silty, silty-loamy soil. According to the degree of availability of exchangeable potassium, the soils studied belong to the group of average security. The dynamics of exchangeable potassium is less subject to change depending on climatic conditions. Therefore, we gave an average of two years.

In soils, depletion of the upper horizon by exchangeable potassium is observed by washing it out into the underlying horizon (Table 2.3). The potassium content in the upper horizons is 31.7-49.2 mg / 100 g soil. The lowest content of potassium 31.7 mg / kg is observed in soil under mixed plantations. Under pine plantations, the content of exchangeable potassium is higher than in the lower horizons and generally higher in the plot - 49.2 mg / 100 g of soil. In the soils of the forest belt section and at a distance from it, a special pattern in the dynamics of exchange potassium was not revealed. The total content of the plot in the upper horizons does not exceed 45 mg / 100 g of soil.

If we talk about the optimum values of the content of mobile forms of nitrogen, phosphorus and potassium, then the ratio of nitrogen, phosphorus, potassium is 1: 2.11: 1.12 and for coniferous - 1: 0.85: 1.12, physiologically balanced for hardwoods [18]. In our case, this ratio does not correspond to the established one.

The physical and chemical properties of the soil characterize the absorptive capacity of soils. It is important for characterizing meliorative and agrochemical properties. Absorbed bases determine the reaction of the medium and the nutrient regime of the soil as a whole. This indicator is also important for revealing the peculiarities of the processes of interaction between the soil and the root system of plants.

When studying the physicochemical properties of ordinary chernozems, it was found that the value of the index of the total amount of absorbed bases in two sites is in the range of 21-30 meq / 100 g of soil (Table 4).

Table 4
The sum of absorbed bases and the degree of saturation of soils in bases in chernozems of common (average. 2015-2016)

Species of plantations	Soil horizon	Σ by field, mg-equiv / 100 g	Degree of saturation of soils with bases,%		
			Ca	Mg	Na
1	2	3	4	5	6
Birch forest belts					
forest belt	A 4-31см	27,0	68,8	29,2	2,0
	$B_1$31-53см	26,6	68,3	29,9	1,8
	B_2 53-91см	25,7	66,6	31,4	2,0
	C 91см	25,9	66,1	31,9	1,9
25 m from the forest belt (grain)	$A_{жыр}$0-27см	26,3	66,7	31,5	1,8
	B_1 27-45см	26,6	67,4	30,9	1,7
	B_2 45-68см	25,1	71,2	26,7	2,1
	$B_к$ 68-96 см	23,5	72,0	24,3	3,8
	C 96 см	24,6	61,0	33,6	5,4
100 m from the forest belt (grain)	0-25 см	25,9	70,9	27,2	1,8
	25-50 см	24,9	70,9	27,5	1,6
	50-75 см	23,6	68,0	30,3	1,7
	75-100 см	22,1	62,1	35,3	2,6
200 m from the forest belt (grain)	0-25 см	25,6	67,6	30,3	2,1
	25-50 см	26,6	66,6	31,0	2,4
	50-75 см	24,2	65,7	32,4	1,9
	75-100 см	22,6	66,2	31,1	2,7

continuation of table 6

1	2	3	4	5	6
Deposit	A 3-31 см	27,3	70,2	28,3	2,2
	B_1 30-51см	24,4	73,4	25,0	1,9
	B_2 51-75 см	27,3	59,9	29,4	2,1
	$B_к$ 75-115см	24,7	62,5	33,5	2,3
	C 115 см	23,7	58,1	37,1	3,8
Artificial forest plantations					
Virgin Land	A 3-23 см	26,2	61,5	36,1	2,4
	B_1 23-46 см	26,8	58,0	39,1	2,9
	$B_{2к}$ 46-65 см	26,8	56,9	39,7	3,4
	$B_{ск}$ 65-90 см	21,5	62,6	30,6	6,8
	C 90 см	24,2	59,1	35,8	5,1
birch dangling	A 4-35 см	28,6	67,2	31,1	1,6
	B_1 35-62 см	25,7	68,1	30,2	1,7
	B_2 62-97 см	25,7	69,6	28,7	1,7
	C 97 см	25,0	67,7	30,1	2,2
Pinus sylvestris	A 6-30 см	28,0	69,9	28,1	2,0
	B_1 30-56 см	27,3	70,5	28,1	1,4
	B_2 56-90 см	27,7	66,6	31,6	1,9
	C 90 см	29,6	66,5	31,5	2,0
mixed plantings	A 3-27 см	27,0	68,2	30,4	1,4
	B_1 27-60 см	26,0	68,7	29,3	2,0
	B_2 60-100 см	27,5	71,1	26,5	2,5
	C 100 см	25,0	68,2	30,0	1,7

This is lower than the values typical for virgin analogues (45-55 meq / 100 g soil) in 1,8-2,1 times [19]. The upper horizons are most enriched in bases.

With depth, the amount of exchange bases is gradually decreasing. In the horizons A and B this value is insignificant, but 1.1-1.2 times higher than in the parent rock, which indicates a biogenic accumulation of exchangeable calcium.

The degree of saturation of chernozems with bases is high - more than 90% is accounted for by the proportion of calcium and magnesium cations. It should be noted that the capacity of exchange absorption as a result of long-term agricultural use has decreased noticeably, and in the upper horizons it amounted to 25.6-28.6 meq. per 100 g of soil. But, according to K.Sh. Faizov in ordinary chernozems, the cation exchange capacity during development was 30-40 meq. per 100 g of soil, with the proportion of absorbed calcium accounting for 85-90%, magnesium 10-15% and sodium 1-2% [20]. As a result of prolonged agricultural use, a change in the ratio of these cations was noted. Thus, under artificial plantations, the share of magnesium decreased from 36.1 in virgin soils to 28.1-36.1%. In forest belt soils this indicator is within the range of 28-31% and slightly differs from the soil of the deposit. The change in the ratio of absorbed cations can adversely affect the properties of soils, which ultimately will affect the elements of fertility of arable land.

Thus, preliminary data on the properties of chernozems common under forest plantations have shown that one of the factors limiting the growth and development of forest plantations in the steppe zone of Northern Kazakhstan is the low level of effective soil fertility. Given the very low availability of nitrogen, phosphorus and high demands of forest crops to the level of mineral nutrition, it should be possible to use fertilizers under plantings to prevent drying up of crops, increasing their resistance to negative biotic and abiotic factors.

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Effect of glyphosate application on the number and activity of microorganisms in the soil under apple plantation

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ABSTRACT
The number and activity of soil microorganisms are affected by soil characteristics and different physico-chemical factors. Agricultural practices such as fertilization and cultivation may also have big effects on the microbial population, diversity, abundance and activity of microorganisms in soil. Therefore, the objective of this study was to investigate the effect of glyphosate application on the number of different groups of microorganisms and dehydrogenase activity in the soil of apple orchard. Experiment was set up in the area of Jablanica, Republic of Srpska. The field experiment was divided into two treatments: control - no glyphosate and treatment with recomended dosage of glyphosate. During the investigated period, two regular treatments with glyphosate were made, using dose of 1l per ha, via hand sprayer. Soil samplings were performed at 10th and 20th day after first treatment, and at 10th and 20th day after second treatment. Laboratory measurements were performed in microbiological laboratories of Faculty of Agriculture, Novi Sad. The study included the determination of total number of bacteria, actinobacteria, fungi, aminoheterotrophs and azotobacter, using the dillution method. Dehydrogenase activity of soil was determined spectrophotometrically. The results of this study suggest that the presence of glyphosate in soil may cause changes to the microbial population and activity of a soil. In this study, glyphosate treatments had negative impact on total bacterial number, number of aminoheterotrophs, fungi and actinomycetes. The negative impact of glyphosate application on number of microorganisms decreased with time. Reliable relationship between glyphosate treatments and number of *Azotobacter* sp. was not found. Dehydrogenase activity was different for investegated soil samples suggesting on potentional influence of glyphosate on soil oxidative processes.
KEY WORDS: microorganisms, glyphosate, soil

INTRODUCTION
In recent years, the potential negative effect of chemical fertilizers on the global environment has increasingly become a matter of environmental concern. Increased and incorrect application of herbicides affects negatively the health of humans, plants and animals.

Herbicides become incorporated in soil directly, during plant treatment, and indirectly, via water or residues of plant and animal origin. After application, herbicides may evaporate (volatilize), may be washed away through surface run-off, may leach into deep soil strata and ground water, may be inactivated by plants, or may be adsorbed in soil in which case they become subject to chemical or microbiological degradation. Soil microbes are responsible for litter degradation (Schneider et al., 2010), the promotion of plant growth as reviewed in Hayat et al. (2010), nutrient cycling (Van Der Heijden et al., 2008) and the degradation of pollutants and pesticides (Pino and Penuela, 2011; Zhao et al., 2009). According to Milosevic and Govedarica (2002), rate of herbicide decomposition in soil depends on the properties of the preparation applied, herbicide dose, physical and chemical soil properties, humidity, temperature, plant cover, soil cultivation technique and the types of the soil microorganisms present. Microbial degradation is considered to be the most important of the transformation processes that determine the persistence of herbicides in soil (Souza et al., 1999).

On the other hand, agricultural practices such as fertilization, using of pesticides and cultivation have big effects on diversity, abundance and activity of microorganisms in soil. The effect of pesticides on microbial diversity is mainly affected by the type of pesticide used. In general, the strongest effects are seen from the soil fumigants (Ibekwe et al., 2001).

One of the most widely used pesticide in the world is glyphosate. Glyphosate [*N*-(phosphomonomethyl)glycine] is a water-soluble non-selective herbicide applied to foliage resulting in death of most herbaceous plants. The effects of glyphosate on soil microbial communities and microbial processes have been intensively studied and contrasting results have been observed by various researchers. Some experiments did not confirm significant effects of glyphosate on soil

microbial community when applied at recommended rates (Baelum et al., 2008; Lancaster et al., 2010). In contrast, some study showed that glyphosate affected the structure of the rhizobacterial community of glyphosate-tolerant maize and decreased the bacterial diversity (Lupwayi et al., 2009). Haney et al. (2002) reported an increase of soil microbial biomass, respiration as well as carbon and nitrogen mineralization after glyphosate application. According to Mijangos et al. (2009) microbial activity may increase in rhizospheres of glyphosate-treated plants through translocation and release from roots, where it is immediately metabolized resulting in stimulation of activity and changes in functional diversity of the heterotrophic microbial community. Microbial activity appeared to be enhanced by glyphosate in the surface millimetres of soil (Strickland et al., 2009).
Since now, there have been numerous studies conducted to evaluate the environmental impacts of single applications of the glyphosate. However, there is much less studies about impacts of repeated glyphosate application. Therefore, the objective of the work presented in this paper was to investigate the effect of two glyphosate applications on the number of different groups of microorganisms and dehydrogenase activity in the soil of apple orchard.

MATERIAL and METHOD

Experiment was set up in area of Jablanica, Republic of Srpska. According to WRB classification, the experiment was conducted in cambisol soil.

The experiment was conducted in the two different plots (plot 1 and 2) having the following characteristics (Table 1):

Table 1
Soil chemical properties

plots	pH		$CaCO_3$	Humus %	Total N	Al-P_2O_5	AL-K_2O
	KCl	H_2O	%		%	mg/100g	mg/100g
1	3,51	4,82	2,47	1,90	0,09	29,19	22,53
2	3,58	4,83	2,88	2,65	0,13	3,21	14,73

Plot 1. is characterized by long-term glyphosate application. The level of applied agricultural technology and mineral fertilizers is generally low (Table 2).

Table 2
Applied agricultural practices in the last 5 years (2010-2015.)

Agricultural practices	Plot 1.	Plot 2.
Average dosage of applied glyphosate per year	6,0 l/ha	3,0 l/ha
Average amount of applied manure per year	0	100,0 t/ha
Average amount of applied mineral fertilizers per year	NPK 8:26:26 225 kg/ha KAN 27% 125 kg/ha	NPK 15:15:15 275 kg/ha KAN 27% 275 kg/ha
Average dosage of applied lime materials per year	7,0 t/ha	10 t/ha

Plot 2. is characterized by long-term glyphosate application. The level of agricultural practices is relatively high. Application of manure and mineral fertilizers was done every year.

The experiment was set up in March-June 2016. The field experiment was divided into two treatments: control - no glyphosate and treatment with recomended dosage of glyphosate.

During the period of investigation, two regular treatments with glyphosate were made (05.04. and 25.05. 2016.), using dose of 1l per ha, via hand sprayer. Soil samplings were performed at 10th and 20th day after first treatment, and at 10th and 20th day after second treatment.

Laboratory measurements were performed in microbiological laboratories of Faculty of Agriculture, Novi Sad. Microbiological analyses included the determination of total number of bacteria, actinobacteria, fungi, aminoheterotrophs and the number of azotobacters. The number of microorganisms was determined, using the dilution method (Trolldenier, 1996). Appropriate nutrient media were used (Hi Media Laboratories Pvt. Limited, Mumbai, India): nutrient agar for the total number of bacteria, synthetic agar for the number of actinomycetes, potato dextrose agar for the number of fungi, meat peptone agar for the number of aminoheterotrophs, and azotobacter medium with manitol for the number of azotobacters. The number of microorganisms was calculated to one gram absolutely dry soil and presented as $CFUg^{-1}$ soil. Dehydrogenase activity of soil was determined spectrophotometrically (Lenhard, 1956; Thalmann, 1968).

The data were statistically processed by means of Statistics StatSoft 13.2 programme. The significance of the difference between the applied treatments was determined using Fisher's LSD test.

RESULTS and DISCUSSION

The number of the investigated groups of microorganisms and enzymatic activity of soils were influenced by treatment of glyphosate and soil sampling time. The results of this study are shown in Table 3.

Table 3
The effect of glyphosate application on the number of microorganisms (CFU/1g soil)

Group of microorganisms	treatments	sampling	Plot 1	Plot 1Ø**	Plot 2	Plot 2Ø**
	I treatment	1*	9,93 h	35,3 d	19,92 h	27,36 e
Total number of		2	45,58 b	51,08 a	40,43 d	53,95 c
bacteria	II treatment	3	23,34 f	30,24 e	20,53 g	84,34 a
(10^6)		4	37,36 c	29,88 e	78,73 b	24,8 f
	I treatment	1	2,48 c	2,52 c	7,42 a	2,49 f
Actinomycetes		2	5,06 b	10,21 a	5,06 e	10,11 c
(10^5)	II treatment	3	2,33 c	11,63 a	4,71 e	20,52 a
		4	4,98 b	4,98 b	14,77 b	9,84 c
	I treatment	1	4,97 c	7,56 b	2,47 b	2,49 b
Fungi		2	5,06 c	10,21 a	5,06 b	5,05 b
(10^4)	II treatment	3	7 b	6,98 b	6,84 b	9,42 ab
		4	7,47 b	4,98 c	12,31 ab	9,84 a
	I treatment	1	7,45 d	7,56 d	14.94 e	32.34 c
Aminoheterotrophs		2	20,25 b	28,09 a	32.85 c	10.28 g
(10^6)	II treatment	3	9,34 c	2,33 f	22.81 d	58.57 a
		4	4,98 e	9,96 c	46.75 b	12.4 f
	I treatment	1	4,96 d	13,23 b	3.71 f	8.71 d
Azotobacter		2	6,33 d	1,27 e	36.07 a	22.11 b
(10^2)	II treatment	3	36,18 a	2,91 e	7.06 e	2.85 f
		4	6,22 d	8,71 c	5.53 e	20.29 c

* 1- first sampling after the first treatment; 2- second sampling after the first treatment; 3- first sampling after the second treatment; 4- second sampling after the second treatment
** Control variant, the untreated plot

In this study, after the first, second and third sampling, glyphosate application negatively affected the total number of bacteria, as well as number of actinomycetes, fungi and aminoheterotrophs. Results analysis showed that the total number of bacteria in control plot was by 75%, number of actinomycetes by 77%, fungi by 50 % and aminoheterotrophs by 61% higher than in plot where glyphosate was applied. After fourth sampling, the number of investigated groups of microorganisms was higher in plots where glyphosate was added. The statistical analysis showed that these differences were statistically significant at the level $p<0, 05$. These results indicate that repeated glyphosate applications lead to increase in number of these groups of microorganisms due the mineralization and utilization of glyphosate as an available substrate. The rate of glyphosate mineralization is related to the number of microorganisms as well as microbiological activity in the soil (Wiren-Lehr et al., 1997). Heinonen- Tanski (1989) observed that soils with high microbial activity favour the fast biodegradation of glyphosate. According to a European Commission study, based on an analysis of 13 sites, it was found that the mean half-life of glyphosate in soil is 33 days, with a range of 1-120 days.

In the Araujo (2003) research, glyphosat application had a positive impact on the number of fungi and actinomycetes, while negative on the total number of bacteria. According to Wardle and Parkinson (1990), the presence of glyphosate in soil is related to a temporary increase in the both number of bacteria in a soil and microbial activity of the soil, although the number of actinomycetes and fungi was not affected. However, Krzysko-Lupicka and Sudol (2008) verified that long-term exposure of soil microorganisms to glyphosate led to a fungal community dominated by *Fusarium* spp. Similarly, Means (2004) detected a significant increase in soil *Fusarium* within 2 weeks after glyphosate was applied at recommended rates in the field. On the other hand, most authors consider that the influence of glyphosate on the number and activity of microorganisms in soil is minimal (Busse et al., 2001; Ratcliff et al., 2006; Weaver et al., 2007). According to some authors, only long-term and repeated glyphosate applications can have an effect on the microbiological soil structure (Johal and Huber, 2009; Kremer and Means, 2009).

Influence of glyphosate application on the number of azotobacters was largely unclear. The highest number of *Azotobacter* sp. was determined after third sampling in plot with added glyphosate, while the smallest number after the same sampling but in plot without glyphosate. After first and fourth sampling, it was determined negative effect, while after second and third sampling, it was noticed the positive effect of glyphosate application. According to Milošević et al (2000), *Azotobacter* sp. is most sensitive to herbicide application. In their study, herbicide application reduced the number of azotobacters, and the largest reduction was found 14 days after treatment.

The dehydrogenase activity in soil is an indicator of biological activity of the microbial population in the soil, because soil dehydrogenase mainly microbial origin. Larger dehydrogenase activity indicates a higher intensity of respiration, or more intensive mineralization of fresh organic matter. In this study, dehidrogenase activity was influenced by glyphosate treatment, soil sampling time and soil chemical properties (Table 4).

Table 4
The effect of glyphosate application on the dehydrogenase activity (μg TPF/10g dry soil)

	treatments	sampling	Plot 1	Plot 1Ø**	Plot 2	Plot 2Ø**
	I treatment	1*	48.52 c	62.79 a	131.29 c	99.89 f
Dehidrogenase		2	57.08 b	45.67 d	94.19 g	102.75 e
activity	II treatment	3	57.08 b	42.81 e	114.17 d	148.42 a
		4	37.1 f	42.81 e	142.71 b	94.19 g

* 1- first sampling after the first treatment; 2- second sampling after the first treatment; 3- first sampling after the second treatment; 4- second sampling after the second treatment
** Control variant, the untreated plot

The highest dehydrogenase activity was measured in control variant, after third sampling, in plot 2 (148, 42 μg TPF/10g dry soil). The smallest value of dehydrogenase activity was measured in plot 1, in treated variant, after fourth soil sampling (37, 1 μg TPF/10g dry soil).

Reports about the impact of glyphosate application on dehydrogenase activity are very different. Most literature data support the stimulating effect of glyphosate on enzyme activity (Sannino and Gianfred, 2001). According to Accinelli et al., (2002) glyphosate and glyphosinate ammonium have positive effects on microbiological activity. Similarly, Araujo et al. (2003), a month after the glyphosate application, detected a slight increase in dehydrogenase activity. Haney et al. (2000) and Busse et al. (2001) observed that microbial activity was stimulated in the presence of this herbicide. According to Benslama and Boulahrouf (2013), negative effect of glyphosate application on the number of microorganisms and the increase in dehydrogenase activity on the other side, indicates the dominance of those groups of microorganisms that are able to use glyphosate as a substratum for respiration rather than for assimilation. Studies Haney et al. (2000) and Wardle and Parkinson (1990) show that glyphosate is available to microbial communities as a substrate leading to increased microbial activity.

CONCLUSIONS

The results of this study suggest that the presence of glyphosate in soil may cause changes to the microbial population and activity of a soil. In this study, glyphosate treatments had negative impact on total bacterial number, number of aminoheterotrophs, fungi and actinomycetes. The negative impact of glyphosate application on number of microorganisms decreased with time. Repeated glyphosate applications lead to increase in number of investigated groups of microorganisms, apart from Azotobacter. Reliable relationship between glyphosate treatments and number of *Azotobacter* sp. was not found. Dehydrogenase activity was different for investegated soil samples suggesting on potentional influence of glyphosate on soil oxidative processes.

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Biodiversity of Soil Samples in Vojvodina Province

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ABSTRACT

The biochemical activity of microorganisms affects the pedogenetic process and thus participates in the creation and maintenance of soil fertility. It is likely that we currently know at least 30% of the total diversity of soil fungi. This research contributes to a better knowledge of the biodiversity and the mycobiota present in soil samples of different types in Vojvodina Province (Serbia).

Soil samples of different soil types and different soil management were collected in 2012 and 2013, at totally 104 locations in Vojvodina Province. The representative soil samples were taken from the surface layer (0–20 cm depth) using soil probe. The particle-plating method on selective water agar (WA) media amended with streptomycin was used for fungal isolation. A total of 20 soil pieces (0.0020 g of soil dry weight) per sample were analysed after seven days of incubation at room temperature (25–28°C). The emerging fungal colonies were observed microscopically and transferred to suitable media for further analysis and identification according to the keys of Leslie and Summerell (2006) and Watanabe (2010). Fungal incidence (%) in samples was calculated as number of one species fungal colonies registered in the sample divided with number of total fungal colonies registered in the sample, and multiplied with 100. Frequency (%) of fungi identified was calculated as number of soil pieces in which species occurred divided with total number of soil pieces analysed, and multiplied with 100. Totally, 49 different species was registered and grouped in 29 genera. The most common soil fungi identified were organic matter decomposers, but there were many phytopathogenic fungal species such as *Alternaria* sp., *Acremonium* sp., *Bipolaris* sp., *Dreschlera* sp., *Fusarium* spp. (11 different species), *Macrophomina phaseolina*, *Pythium echinulatum*, etc. A few species were isolated that are known to be good antagonists to phytopathogenic species and usable for biological control - *Trichoderma* spp., *Gliocladium* sp. and *Penicillium* spp. Species with the highest frequencies were: *Fusarium oxysporum* – registered in 95.2% samples, *F. solani* – 89.4%, *Aspergillus* sp. – 53.9% and *Alternaria* sp. – 47.1% . The lowest frequency (0.96%) was registered in 12 species: *Aspergillus fumigatus*, *Curvularia* sp., *Epicoccum* sp., *Geotrichum* sp., *Gliocladium roseum*, *Myrothecium* sp., *M. verrucaria*, *Pythium echinulatum*, *Sporotrichum* sp., *Trichoderma* sp., *Trichothecium* sp., *Ulocladium* sp., and *Dematophora* sp. Species incidences varied depending on sample, but the lowest incidence (2.08%) were registered for species *Fusarium oxysporum*, *F. tricinctum*, *F. verticillioides*, *Mucor* sp., *Paecilomyces* sp. and *Trichoderma* sp. 2 at location Susek, while the highest incidences were registered for *F. oxysporum* at location Karlovčić – 76.47% and for *F. solani* at location Sremska Mitrovica - 59.09%.

Fungal characterization of different soil types provides important information relating to soil fertility and plant growth, especially in agricultural regions as Vojvodina Province is.

KEY WORDS: soil biodiversity; fungal incidence; fungal frequency

INTRODUCTION

The biochemical activity of microorganisms affects the pedogenetic process and thus participates in the creation and maintenance of soil fertility. Fungi play a key role in ecosystem function, primarily due to the decomposition of plant residues (Bridge & Spooner 2001). Quantitative and qualitative improvement of organic matter in the soil is mainly found in agroecosystems that contain many fungal communities (Six et al. 2006). Biodiversity in the soil is several times greater than on the surface, and it is likely that we currently know at least 30% of the total diversity of soil fungi (Heywood et al., 1995; Gams, 2007). Since the biodiversity of the soil in Serbia mainly remained unexplored, this research contributes to a better knowledge of the mycobiota present in soil samples of different types in Vojvodina Province (Serbia).

MATERIAL and METHOD

Soil samples of different soil types and different soil management were collected in 2012 and 2013, at total 104 locations in Vojvodina Province. The representative soil samples were taken from the surface layer (0–20 cm depth) using soil probe.

Fungal isolation was done according to the particle-plating method on selective water agar medium amended with streptomycin. A total of 20 soil pieces (0.0020 g of soil dry weight) per sample were incubated under laboratory conditions at 25°C and a day/night regime. After seven days of incubation, the emerging fungal colonies were observed microscopically and transferred to suitable medium for further reliable identification. Fungal identification was based on microscopic and macroscopic morphological characters of fungal colonies observed under a light microscope according to the keys of Leslie and Summerell (2006) and Watanabe (2010).

Fungal incidence (%) in samples was calculated as number of one species fungal colonies registered in the sample divided with number of total fungal colonies registered in the sample, and multiplied with 100.

Average Incidence (%) was calculated as total number of one species colonies registered in all samples analysed, divided with number of total fungal colonies registered in all samples analysed, and multiplied with 100.

Frequency (%) of fungi identified was calculated as number of soil samples in which species occurred divided with total number of soil samples analysed, and multiplied with 100.

RESULTS and DISCUSSION

Totally, 48 different species was registered and grouped in 29 genera. The most common soil fungi identified were organic matter decomposers, but there were many phytopathogenic fungal species such as *Alternaria* sp., *Acremonium* sp., *Bipolaris* sp., *Dreschlera* sp., *Fusarium* spp. (11 different species), *Macrophomina phaseolina*, *Pythium echinulatum*, etc. A few species were isolated that are known to be good antagonists to phytopathogenic species and usable for biological control - *Trichoderma* spp., *Gliocladium* sp. and *Penicillium* spp.

Species incidences varied depending on sample, but the lowest incidence (2.08%) were registered for species *Fusarium oxysporum*, *F. tricinctum*, *F. verticillioides*, *Mucor* sp., *Paecilomyces* sp. and *Trichoderma* sp. 2 at location Susek, while the highest incidences were registered for *F. oxysporum* at location Karlovčić – 76.47% and for *F. solani* at location Sremska Mitrovica - 59.09% (Table 1). Species can be with low incidence in one while it is common in other soil sample - for example incidence of *F. oxysporum* varied from 2.08% - 76.47%, *F. solani* from 3.13% - 59.09%, *Trichoderma* sp. from 2.50 – 27.91% and *Gliocladium* sp. from 2.44 – 26.83% (Table 1). Average incidences of registered species in total 104 samples varied from 0.03% to 21.76% (Table 1).

Fungal species that were present almost in all samples analysed (species with the highest frequencies) were: *Fusarium oxysporum* – registered in 95.2% samples, *F. solani* – 89.4%, and *Penicillium* sp. – 96.2% (Table 1). On the other hand, some species appeared only in one out of 104 samples analysed, and due to that the lowest frequency (0.96%) was registered in 12 species (Table 1): *Aspergillus fumigatus*, *Curvularia* sp., *Epicoccum* sp., *Geotrichum* sp., *Gliocladium roseum*, *Myrothecium* sp., *M. verrucaria*, *Pythium echinulatum*, *Sporotrichum* sp., *Trichoderma* sp., *Trichothecium* sp., *Ulocladium* sp., and *Dematophora* sp. According to Table 1 it can be noticed that species varied in frequencies and according to it, the species distribution can be categorized as: very narrow distribution (up to 12.50%), narrow (12.50-25%), moderate (25-50%), broad (50-75%) and very broad distribution (75-100%). The number of species registered with different distributions was shown in Figure 1.

Table 1
The incidence and frequency of soil fungi identified in soil samples from Vojvodina Province

	Genus/species identified	Minimal Incidence		Maximal Incidence		Average Incidence	Frequency
		(%)	Location	(%)	Location	(%)	(%)
1	*Acremonium* sp.	2.33	Crveni Čot	31.58	R. Krstur	1.27	21.15
2	*Alternaria* sp.	2.50	Hrtkovci	31.25	Susek	4.23	47.12
3	*Aspergillus fumigatus*	10.71	Novi Sad	10.71	Novi Sad	0.10	0.96
4	*Aspergillus* niger	2.44	Belegiš	5.26	R. Krstur	0.10	2.88
5	*Aspergillus* sp.	2.50	Hrtkovci	30.77	Kuzmin	4.70	53.85
6	*Bipolaris* sp.	2.50	Hrtkovci	13.79	Šimanovci	0.98	18.27
7	*Chaetomium* sp.	2.44	Belegiš	19.35	St. Banovci	0.32	4.81
8	*Cladosporium* sp.	3.23	St. Banovci	10.00	Belegiš	0.13	2.88
9	*Cunninghamella* sp.	2.22	Sr.Mitrovica	7.32	Ravnje	0.22	4.81
10	*Curvularia* sp.	4.44	Sr.Mitrovica	4.44	Sr.Mitrovica	0.03	0.96
11	*Cylindrocarpon* sp.	2.63	Futog	2.78	Kovilj	0.06	1.92
12	*Dreschlera* sp.	2.13	Iriški Venac	6.06	Sr.Mitrovica	0.10	2.88
13	*Eppicoccum* sp.	3.85	Belegiš	3.85	Belegiš	0.03	0.96
14	*Fusarium culmorum*	3.57	Jarak	5.13	Neradin	0.13	2.88
15	*F. graminearum*	2.78	Šašinci	4.76	Ašanja	0.25	7.69
16	*F. oxysporum*	2.08	Susek	76.47	Karlovčić	19.06	95.19
17	*F. proliferatum*	2.50	Laćarak	10.34	Kuzmin	0.54	11.54
18	*F. semitectum*	2.78	Kovilj	7.14	Pavlovci	0.13	2.88
19	*F. solani*	3.13	Radinci	59.09	Krčedin	21.76	89.42
20	*Fusarium* sp.	2.50	Radinci	17.50	Rivica	0.48	6.73
21	*F. sporotrichioides*	2.94	Surduk	6.45	Šašinci	0.10	1.92
22	*F. subglutinans*	2.94	Laćarak	4.00	R. Krstur	0.06	1.92
23	*F. tricinctum*	2.08	Susek	2.50	Hrtkovci	0.06	1.92
24	*F. verticillioides*	2.08	Susek	7.41	Maradik	0.41	9.62
25	*Geotrichum* sp.	4.76	Nova Kula	4.76	Nova Kula	0.03	0.96
26	*Gliocladium roseum*	3.57	Novi Sad	3.57	Novi Sad	0.03	0.96
27	*Gliocladium* sp.	2.44	Šašinci	26.83	Radenković	3.39	34.62
28	*Hyalodendron* sp.	2.17	Jazak	29.17	Susek	2.03	32.69
29	*Macrophomina phaseoilna*	2.50	Kuzmin	16.00	Laćarak	1.52	30.77
30	*Mortierella* sp.	2.70	Martinci	25.81	Jarak	7.31	70.19

Table 1 (continued)

	Genus/species identified	Minimal Incidence		Maximal Incidence		Average Incidence	Frequency
		(%)	Location	(%)	Location	(%)	(%)
31	*Mortierella verticillata*	5.71	St. Banovci	17.86	Belegiš	1.49	11.54
32	*Mucor* sp.	2.08	Susek	5.56	Kovilj	0.38	9.62
33	*Myrothecium* sp.	3.03	Kuzmin	3.03	Kuzmin	0.03	0.96
34	*Myrothecium verrucaria*	3.70	Mali Stapar	3.70	Mali Stapar	0.03	0.96
35	*Paecilomyces* sp.	2.08	Susek	13.64	Krčedin	1.78	28.85
36	*Penicillium* sp.	2.56	Neradin	46.43	Vojka	16.11	96.15
37	*Pythium echinulatum*	30.00	Begeč	30.00	Begeč	0.29	0.96
38	*Ramichloridium* sp.	2.13	Iriški Venac	10.81	Martinci	0.95	16.35
39	*Rhizopus* sp.	2.44	Šašinci	23.26	Crveni Čot	1.72	15.38
40	*Micelia sterilia*	3.33	Beška	35.29	R. Krstur	1.87	30.77
41	*Sporotrichum* sp.	4.35	Mali Stapar	4.35	Mali Stapar	0.03	0.96
42	*Stachybotrys* sp.	2.33	Crveni Čot	4.35	Sivac	0.10	2.88
43	*Staphylotrichum* sp.	2.56	Neradin	5.88	Karlovčić	0.19	5.77
44	*Trichoderma* sp.	2.50	Radinci	27.91	Iriški Venac	2.86	23.08
45	*Trichoderma* sp. 2	2.08	Susek	26.92	Kuzmin	0.54	4.81
46	*Trichotecium* sp.	3.85	Vojka	3.85	Vojka	0.03	0.96
47	*Ulocladium* sp.	2.22	Sr.Mitrovica	2.22	Sr.Mitrovica	0.03	0.96
48	*Dematophora* sp.	2.78	N. Pazova	2.78	N. Pazova	0.03	0.96

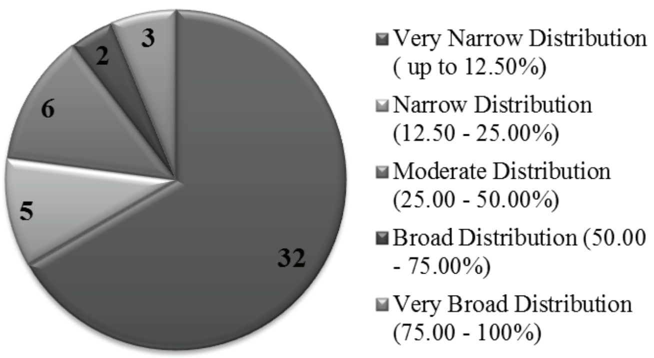

Figure 1. Number of fungal species with different distributions registered in soil samples from Vojvodina Province

According to number of soil samples in which species was registered, only five species had very broad or broad distribution, while 32 had very narrow distribution. In this study, broad distribution was registered among fungi of the genera *Aspergillus*, *Alternaria*, *Fusarium*, and *Penicillium*. Kiković et al. (1997) found *Penicillium*, *Aspergillus* and *Cladosporium* spp. as common species in alluvium soil samples from Malo Rudare (Serbia). This result can also be compared to results obtained by authors from all over the world where those species were also reported as common species in soybean soil rhizosphere in India (Maisuria & Patel 2009), soil and litter samples of Forest Reserve in Trat Province in Thailand (Paungsombat et al. 2010) and litter samples from different forest types in China (Song et al. 2004). It is known that even in tropical forests, many taxa are similar to taxa found in temperate latitudes, and the numbers of species for a particular tropical soil are normally the same or even lower than those observed for soils in temperate regions (Gams 2007). Fungi from the genera *Penicillium*, *Aspergillus*, *Cladosporium*, *Fusarium*, *Rhizopus*, *Mucor*, *Phoma* and *Verticillium* were even found in reservoirs of lakes and rivers in Serbia (Ranković 2005; 1994). Similar fungal communities were found in Bosnian river as well (Ristanović 1973), and even in Estonian lakes (Voronin 1989). This was expected because soil fungi spread easily and most of them are thermophilic and heat-resistant species which have a cosmopolitan distribution (Gams 2007).

CONCLUSIONS

Among all 48 identified soil fungi, the most common were organic matter decomposers. Generally, predominant species were *Aspergillus* spp., *Alternaria* sp., *Fusarium* spp., and *Penicillium* spp. Fungal characterization of different soil types provides important information relating to soil fertility and plant growth, especially in agricultural regions as Vojvodina Province is.

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Control of soil fertility of Sarajevo-Romanija region

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ABSTRACT
Soil fertility, as one of the soil qualities, represents less or greater ability of providing necessary nutrients for plants, water, oxygen, heat and necessary space for normal growth and development hers overhead and underground organs. Control of soil fertility and the manner of its implementation are defined by the members of Law on agriculture land in Republic of Srpska and Federation of Bosnia and Herzegovina.
For the laboratory analysis, average soil samples were taken, with 0-30 cm depth. 56 soil samples were tested. Research was carried out in the laboratory for the land of the Faculty of Agriculture in East Sarajevo. Analyzes of chemical properties of the soil were made: pH value of soil: (i) in water (H_2O) or an active reaction of soil, (ii) in a solution of 1 M KCl or substitution reaction of soil, electrometrically (inoLab pH 720, 2004); Determination of the content of humus, by bichromate method of Tyurin; Determination of available P_2O_5 by Al method spectrophotometrically (Spectrophotometers, Series 7000, 2004) and K_2O, photometrically (Sherwood`s Flame photometers, 420/425, 2004); Determination of carbonate content in the soil by the method of Scheibler; Determination of the soil adsorption complex by Kappen; Determination of total nitrogen (Kjeldahl).
Based on the study of laboratory, soil analysis results were as follows: pH H_2O 6,50, M KCl 5.20, $CaCO_3$ 2,56%, humus content 3,94%, N 0,26%, average content avilable P_2O_5 5,54 mg/100g soil, available K_2O 23,98 mg/100g soil. By controlling soil fertility of Sarajevo-Romanija region, we came to the conclusion that enable a clear understanding of the current parameters of soil fertility of the region, contributing to a clear definition of agricultural measures to be taken with the aim of repairing and improving the productive capacity of agricultural land.
KEY WORDS: control of soil fertility, Sarajevo-Romanija region, legislation

INTRODUCTION
In order to use the soil for agricultural production, it is necessary to know the properties of the types of soil, in order to on the basis obtained information to make eventual repairs soil through appropriate measures. Fertility, as one of the characteristics of the soil, represents a lesser or greater ability to provide the necessary nutrients for herbs (Kovačević, 2003). Under the basic elements of fertility of the soil and plant life factors, we mean take nutrients who easy to adopt , water in an accessible form, air and heat necessary for the development of the root system, and the life activity of microorganisms (Dugalić and Gajić, 2012).

By acting biotic and abiotic factors on the soil, there are changes in soil, presented in the form of different concentrations of humus, nutrients, carbonates, and the value of the reaction of the environment. Current values of soil fertility in a specific area are obtained by soil fertility control, and the reason for this is the fact that fertility, as a qualitative soil characteristic, determines the method of its use in agricultural production (Dugalić and Gajić, 2012). The soil fertility control and the method of it is implementation are defined by the members of the Law on Agricultural Soil of the Serbian Republic and the Federation of Bosnia and Herzegovina. Establishing a soil fertility control system, as one of the land policy measures, affects the regulation, rational use and protection of agricultural land, as a good of general interest for the Republic, in accordance with regulations (Law on Agriculture of Serbian Republic, Article 23, paragraphs 1 and 2). According to the Law on Agricultural Soil of Serbian Republic, Article 20, Paragraph 1, in order to protect and preserve of the chemical and biological properties of agricultural soil, ensure the proper use of mineral and organic fertilizers and pesticides, the owner or user of arable agricultural soil from the first to the fifth cadastral class, determines the condition and controls the fertility of agricultural soil and the quantity of the used mineral fertilizers and pesticides.

The Law on Agricultural Soil of the Federation Bosnia and Herzegovina, Article 31, defines a system of soil fertility control which is performed aiming to preserve and improve the physical, chemical and biological properties and ensure proper use of mineral and organic fertilizers. Physical and legal persons, owners or users entered in the register of agricultural farmsteads, who are the users of agricultural soil, are obliged to implement systematic control of the fertility of the soil classified by cadastral classification ranging from 1st to 4th cadastral class of arable agricultural land of more than 0,2 ha. It also defines the place of performance, the equipment and the way of displaying the results, that the systematic control of soil fertility is performed by an organization that, in terms of personnel and equipment, meets the prescribed conditions.

In Bosnia and Herzegovina, and also neighbouring countries, fertility controls are legal regulations. In Montenegro, systematic soil fertility control is obligatory, which is carried out every five years, in order to protect, preserve and improve the properties of arable agricultural soil, and is defined in Article 69 of the Law on Agricultural Soil. A company, who controls the fertility of the soil, is obliged to submit a report to a legal or physical person whose soil is controlled with instructions on the manner of use of unnatural fertilizers. In the Republic of Serbia, the control of fertility of arable agricultural soil and the amount of applied mineral fertilizers and pesticides is done appropriately at least every five years. The testing of the fertility of arable agricultural soil and the determination of the amount of mineral fertilizers and pesticides may be carried out by a business company, or a company or other legal entity registered to carry out the relevant activity, management of the appropriate technical and professional capacities and which is authorized by the Ministry of Agricultural (Law on Agricultural Land of the Republic Serbia, Article 21, paragraphs 2 and 3). Physical or legal persons are obliged to monitor the state of agricultural land owned by the state, which they use based on the rent pact. Monitoring the condition of agricultural soil in terms of soil fertility testing is done on the basis of the soil analysis of the first year after it is introduced and the last year before the expiration of the rent, rent of common pasture and rent for fishponds, and periodically at rent every five years. The testing of soil fertility for agricultural land, except for fishponds, is done in the period from June 1st to October 31st in the arable land after crop harvest, in multi-year plantations after harvest, and before the application of a fertilizer. For all the cultures that are to be harvested after October 31st, soil fertility testing is done after harvest with an obligatory reference to the harvest date. The soil fertility testing for fishponds is done after drying up the fishpond in the period from 1st of October to 1st of June (Rulebook on the methodology for monitoring the condition of agricultural land of the Republic of Croatia, Article 28, paragraphs 1, 2, 3).

As an example of evidence of the importance of soil fertility control, we give an example of the project "For the richer Vojvodina - with a little will, fertile field" from Novi Sad, which has been performed since 2002 and within which, in the first year of realization, 9 300 samples were analyzed within 9 parcels. Experts from regional agricultural services have sampled privately owned soil. This action is still in progress and so far over 100 000 soil samples have been analyzed on 87 000 different parcels (Vasin, 2008; Nešić et al., 2008).

According to the provisions of the Law on Agricultural Soil of the Serbian Republic, the fertility control of the territory of the Sarajevo-Romanija region was done. The goal of the research was to obtain correct values of soil fertility parameters in the region in order to gain a clear insight into the possibilities of soil being used for agricultural purposes and define the measures to be taken in order to increase the production capacity of the soil.

MATERIAL AND METHOD

For the laboratory analysis, the average soil samples were taken from 0-30 cm of depth, 56 soil samples were tested. Research was done in the laboratory for the soil of the Faculty of Agriculture in East Sarajevo. Analysis of the chemical properties of the soil was made:

- pH value of the soil: (I) in water (H2O) or active soil reaction, (II) in solution of 1M KCl or substituent soil reaction, electrometric (ino Lab pH 720, 2004) (JDPZ, 1966).
- Determination of the humus content, method of the Tyurin (JDPZ, 1966).
- Determination of the available phosphorus (P2O5), spectrophotometric (Spectrophotometers, Series 7000, 2004) and potassium (K2O), photometric (Sherwood's Flame Photometers, 420/425, 2004) (JDPZ, 1966).
- Determination of carbonate content in soil using the Scheibler method (JDPZ, 1966).
- Determination of the available nitrogen content (N) by Kjeldahl (JDPZ, 1966).

RESULTS AND DISCUSSION

The dominant climate on this territory is from the moderate-continental to sub mountain with fresh summers and cold winters. The average air temperature is 9.5°C, with an important rainfall of about 1125 mm/m^2. Most of this area is located at an height above 600 m. Based on the review of the

Bosnia and Herzegovina vegetation chart, based on the topographic map of section Sarajevo 1, and field work, it can be concluded that in this area still dominant vegetations are forest vegetation, vegetation of meadows, and vegetation of pastures, and on other smaller areas oranic cultures appear. The soil types of this area are mostly eutrically brown soils and brown degraded soils on clay and sand, as well as meadow without carbonate soils, and also alluvial- deluvial soils in the valleys of the rivers. The soils of this area are inhabited or located in the vicinity of the settlement, and they are processed, although a significant part is also situated under forest vegetation and vegetation of grassland of natural meadows. Mountain hilly areas are ecologically preserved and are used for the production of apples, pears, plums and other fruit trees. When it comes to vegetable and fruit production, the most are potatoes, wheat and barley. Areas planted with strawberries, raspberries and blackberries are increasing every year, while livestock production has been developed in the direction of keeping sheep, fowl, leather and beekeeping. Based on the above, we can conclude that the land is the basis for all aspects of agricultural production in the Sarajevo-Romanija region, and demand constant control and adequate exploitation.
Using the methods of work in the laboratory for testing the soil of the Faculty of Agriculture at the University of East Sarajevo, the average, maximum and minimum values of the tested parameters were obtained, which are presented in the table (Table 1).

Table 1.
Results of laboratory analyzes of soil from the area of the Sarajevo-Romanija region

	pH		$CaCO_3$	Humus	Nitrogen	mg/100g of soil	
	H_2O	MKCl	%	%	%	P_2O_5	K_2O
Average	6.50	5.20	2.56	3.94	0.26	5.54	23.98
Max.	8.03	7.33	47.86	11.27	0.74	34.45	42.15
Min.	4.92	3.82	0.66	0.84	0.05	0.16	4.42

The reaction of the soil solution is the result of the relationship between the free acid and the quantity of adsorbed cations, carbonates and easily soluble salts that can neutralize the acids (Ćirić, 1991). The value of the reaction of the environment is of particular importance for the cultivation of different cultures and the general exploitation of land for agricultural purposes, that is, it affects the growth, yield, overall successful cultivation and productivity of plant production. On the basis of the obtained laboratory analyzes of the soil of the examined region (Table 1.), we can conclude that the pH of the soil in the aqueous extract is slightly acidic (pH 6.50), with a minimum pH of 4.92 and a maximum pH of 8.03. By analyzing the soil sample in the sonic extract, an average pH of 5.20 was obtained, placing the soil in acid soils with a minimum pH of 3.82, to a maximum pH of 7.33. With average carbon content, the soils medium carbonate ($CaCO_3$ is 2.56%), while the minimum value is 0.66%, and the maximum is 47.86%.

According to the humus content, the analysis showed that the soil of this region is classified as humus soil with an average percent of 3.94%, a minimum of 0.84% and a maximum of 11.27%. Humus improves soil consistency, because it moves the boundaries of plasticity upward, so humus soil can be processed without problems in a much wider humidity interval than mineral soil (Ćiric, 1991).

The supply of the soil in nutrients is different. The results of the average nitrogen content, N 0.26%, show that the soil is rich in the mentioned element, with a minimum value of 0.05% and a maximum of 0.74%. In contrast to nitrogen richness, the soil is poor in phosphorus, with the average content of available phosphorus 5.54 mg/100 g of soil, with a minimum value of 0.16 and a maximum of 34.45. Poorness of the phosphorus is the result of acidic soil reactions, where phosphorus cannot be converted into an available form (P_2O_5), but hardly soluble Al and Fe phosphates are formed (Ćirić, 1991). According to the average value of available potassium in soil, which is 23.98 mg /100g of soil, we conclude that the soil is optimally secured with potassium. The minimum quantities of K_2O are 4.42 and the maximum is 42.15 mg/ 100g of soil.

Because of the acidity of the soil, which also caused the phosphorus poorness, it is necessary to do a soil calcification process that will lead to an appropriate value of the reaction of the environment and enable the transformation of phosphorus into an available form and the formation of soluble calcium phosphate. The norm of entered carbonate depends on the parameters of individual parcels obtained by analyzing the soil and the type of agricultural production planned on it.

CONCLUSIONS

In order to increase the productivity of the land, it is necessary to protect it from negative ecological and anthropogenic impacts. A man is the important factor responsible for the genesis and evolution of the soil. He is planning, using the results of science and the wide possibilities offered by modern technology, to try to adapt not more the selection of cultivated crops to the properties of the soil, but to change the composition and properties of the soil according to the requirements of the plants will be grown on it (Djordjevic, Radmanovic, 2016). From the above, we conclude that soil fertility control is actually one of the results of science that gives the man clear parameters of the current condition of the soil of a given area.

By controlling the fertility of the soil of the Sarajevo-Romanija region, we have reached the result that gives clear definition of the agro-technical measures that need to be undertaken with the goal of repairing and improving the production capacity of agricultural soil. As a result, we clearly see the need to correct soil acidity. By taking determined agro-technical measures, presented in the form of calcification, we contribute to reducing the acidity of the soil, which will result in the formation of a more favourable environment for the development of plants and enrichment of soil with phosphorus, which will be transformed from inaccessible form into an accessible, forming soluble calcium-phosphate.

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Effect of long-term irrigation with increased mineralization water on the quality of steppe soils

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ABSTRACT

Research deals with the problem of improving the quality of irrigation water and environmental agromeliorative land condition of Ingulets irrigation system (IIS) in the current economic, environmental, agricultural and water conditions. Due to changes of conditions of modern irrigation system and the actual mixing Dnieper and Ingulets water in the Ingulets main canal does not comply the design requirements. Scientific recommendations for solving the issue of improving the quality of water that have been developed in previous studies on water quality class II, is now on the objective economic reasons can not be realized.

For researching were usedsynthesis,field, laboratory, statistic and calculation-comparative methods. For creating of water quality model were used retrospective analysis of data base and mathematics madeling.

All possible options for the formation of water quality IIS were researched in dependence on water management conditions. The fundamentals of water quality formation technology under different water use options for IIS have been developed and their comparative analysis has been carried out.The research resulted in developed scientific and methodological principles and practical recommendations for adjustments to the rules washing riverIngulets by changing the conditions of water quality at the IIS, which are fundamentally different from the project and from the recommendations of previous research (giving up version of "antiriver"), which provides a stable water quality class II in Ingulets main canal, regardless of mode of the Main pump station, which helps to improve environmental and agromeliorative of land, conservation and improvement of soil fertility and crop yields.

KEY WORDS: irrigation, soil, irrigation water quality, environmental and agromeliorative land conditions, harvest.

INTRODUCTION

The main problem of Inhulets irrigation system (IIS) is unsatisfactory quality of irrigation water (high mineralization and chemical composition). In period 1957-2009 years Inhulets main canal irrigation water was formed by mixing of water from rivers Inhulets and Dnipro. Inhulets water was polluted by Kruvbas industrial. Longer watering that irrigation water caused to secondary mineralization and alkalinisation, which decries of IIS soils eco-reclamation status.

Improved scientific recommendation, which solved the irrigation water quality problem can’t be realized because of economic factors. It is necessary to improve new ways, methods and technologies to remove the problem of irrigation water quality on IIS.

MATERIAL and METHOD

The main task of the research carried out at the Ingulets irrigation system in the period 2000-2016 was to provide an objective generalized assessment of the effectiveness of the eco-reclamation regime of the Ingulets irrigation system in different, characteristic periods of the system's operation.

For an objective evaluation of eco-reclamation regime efficiency, an index method, developed by professor V.V. Morozov, was used. The essence of the method consists in a comprehensive assessment of all indicators of eco-reclamation regime during the study periods of the work of the Ingulets irrigation system. Therefore, the studies presented in this article have both theoretical-methodological and practical value for the management of the soil-forming process.

The key element in managing the soil-forming process is the formation of an ecological-reclamation regime of irrigated soils and landscapes.

Under the eco-reclamation regime is understood the set of requirements for regulated indicators of the soil-forming process, the formation of which is ensured by the appropriate ecological and land reclamation state of the agro-landscape, the increase of fertility and productivity of soils, and the production of environmentally friendly agricultural products. Principles and methods of forming eco-reclamation regime of irrigated land are a necessary component of monitoring irrigation lands.

In assessing the efficiency and effectiveness of the eco-reclamation regime eco-reclamation regime of irrigated land, it is expedient to use the index method, which is based on an analysis of the ecological and land reclamation indicators of the eco-reclamation regime.

The index is a generalizing indicator that characterizes the dynamics of the level of the studied process in time, in comparison with the normative (maximum-permissible) values, the plan, the project or their relationships in space and time.

In the methodology of studying the soil-forming and landscape-process processes, the indices are considered as relative values of the dynamics of each of the studied ecological-land reclamation, economic, environmental indicators and the study process in general (general, integrated indices).

In land reclamation soil science, irrigated agriculture, ameliorative hydrogeology, hydromelioration, ecology, landscape, economics, environmental economics, the index method for assessing the effectiveness and efficiency of eco-reclamation regime is also an important interdisciplinary analytical tool, including study of the relationships between the studied indicators. In this case it is expedient to apply not only individual indices, but also systems (blocks) of indices.

In the study of soil-forming and landscape-process processes, the index method should be used in analyzing the changes in soil condition as a studied system and its elements at all stages of their development.

Algorithm of the index method for evaluating the effectiveness and efficiency of forming the eco-reclamation regime eco-reclamation regime of irrigated soils:

1. Indices are determined for all regulated indicators of eco-reclamation regime. Indicators can be as physically determined values (for example, yield, groundwater level, water mineralization, soil filtration coefficient, drainage runoff, etc.), and calculated values, using simulation and forecasting methods (for example, irrigation quality indicators for irrigation water - SAR, SAR *, ion exchange rate).

2. For all analyzed parameters of eco-reclamation regime required presence of maximum permissible concentrations, or their normative values, having the appropriate scientific and methodological substantiation.

3. Indices are defined for both individual indicators and for a group (block) of indicators that characterize the study of the process (for example, it is processes of flooding, secondary salinization, soil salinization, etc.), as well as for the general determination of the effectiveness and efficiency of the formation of eco-reclamation regime.

4. When determining the indices, the eco-reclamation regime indicators are conditionally divided into quantitative and qualitative. Regulatory quantitative indicators include those that can be characterized by the phrase "the more, the better" (for example: groundwater level, crop yield, profitability, etc.). The regulated qualitative indicators include those which are characterized as "the smaller, the better" (for example: the degree of salinization and salinization of the soil, mineralization and indicators of the chemical composition of irrigation water, the content of soils and water of toxic and radioactive elements, heavy metals, a number of economic indicators - cost, payback period of reclamation measures, etc.).

5. Indices are conventionally divided into those that characterize the efficiency of eco-reclamation regime (they include technical and economic indicators: yield, cost, payback period, etc.) and those that characterize the effectiveness of eco-reclamation regime, they are mainly environmental and land reclamation indicators (groundwater level, degree of salinity of soil salinization, mineralization and chemical composition of irrigation, drainage, waste water, etc.).

6. Indices of effectiveness and efficiency of eco-reclamation regime (I) is determined by the formula:

$$I = \frac{I_1}{I_2}, \qquad (1)$$

where: - I_1- for quantitative indicators, the actual value of the indicator in the analyzed time period, and - the design (plan, normative) value of this indicator; - - for qualitative indicators, the normative (planned) value of the indicator, or its maximum permissible concentration, and I_2 - the actual value of the indicator.

7. For all studied indicators at I ≥1 eco-reclamation regime is characterized as effective (effective) for this indicator, and at I <1 - as not effective (not effective) for the corresponding indicator.

For example, determining the effectiveness of eco-reclamation regime in soybean cultivation on irrigated soils in the Ingulets massif, the actual yield of 3.5 t/he was obtained at the planned (planned) yield - 3.0 t/he. In determining the index of the effectiveness of eco-reclamation regime in quantitative index - yield (y) by the formula 1, we get the value $I_{ó} = \frac{3,5}{3,0} = 1,16$ > 1 (“+” - eco-reclamation regime effective).

The general index of effectiveness (efficiency) of eco-reclamation regime ($I_{ç}$) is calculated according to the formula 2:

$$I_{ç} = I_1 \cdot I_2 \cdot ... \cdot I_n, \qquad (2)$$

where, I_1, I_2, I_n - the indices of the effectiveness (efficiency) of eco-reclamation regime for all the studied indicators of eco-reclamation regime (quantitative and qualitative).

At $I_{ç}$ ≥1 - eco-reclamation regime is effective (effective), and at $I_{ç}$ <1 - eco-reclamation regime - not effective (not effective).

8. If necessary, a more detailed description of the degree of effectiveness (efficiency) of eco-reclamation regime irrigated soils (Table 1.).

Table 1

Classification of the degree of effectiveness (efficiency) of the eco-reclamation regime of irrigated soils

Index value	Efficacy rate (efficacy) eco-reclamation regime
<0,8	Low effectiveness (efficiency)
0,80-0,99	Not effective (not effective)
≥1,0-1,2	Effectiveness (efficiency)
>1,2	High degree of effectiveness (efficiency)

9. Indices of performance (effectiveness) of eco-reclamation regime is determined in time and space. It is possible to compare them on different experimental sites, as well as in different periods of the irrigation system.

It is important that the base of comparison (maximum permissible or normative indicators) remained unchanged. At the same time, this method involves comparing not the actual values of the studied indicators, but only the corresponding indices.

10. The index method for evaluating the effectiveness and efficiency of the eco-reclamation regime, regime of irrigated soils (lands) should be used in the implementation of ecological-agromeliorative monitoring of irrigated soils (land), in the implementation of land reclamation projects and their environmental expertise, in scientific research and in developing recommendations for optimization of all indicators and parameters of the ecological and reclamation regime of irrigated soils.

RESULTS and DISCUSSION

In this article we give an example of the use of the index method in assessing the effectiveness of technologies for improving the quality of irrigation water in the Ingulets massif.

Characteristic periods of formation of quality of irrigation water of gas stations are distinguished:

The I period 2000-2003 years - the period when the transition to paid water use was carried out, a measure that offset the share of state's underfunding for the operation of the system at the expense of water users. During this period, due to the imperfect implementation of the land reform, irrigated lands (which constitute a single reclamation complex) were dismantled, which led to a decrease in irrigated areas, water supply volumes and, correspondingly, a deterioration in the quality of irrigation water (mineralization and ecological and land reclamation indicators).

The II period - 2004-2007 years - the time when a scientifically substantiated system of management of the quality of irrigation water on the Ingulets irrigation system was introduced, according to which quality in the main channel was regulated by the number of constantly operating pump-power aggregates of the Main pumping station. These research Morozov V.V. and Volochnyuk E.G. (2003), point to the inadmissibility of even short-term breaks in the work of the main pumping station.

III period - 2008-2010 years - the time when applied scientific recommendations to improve the quality of irrigation water in modern economic conditions was not possible due to significant changes: the reduction of water collection due to the transfer of a significant number of water users to drip irrigation and the refusal of the main channel "Mykolayivvodokanal" from replenishing the Zhovtnevy Reservoir from the main channel. This greatly influenced the work of the Main pumping station and caused the inability to timely pull up and hold near the Main pumping station of the Dnieper water, which led to a sharp increase in the concentration of chlorides in irrigation water, and the quality of other irrigation indicators also improved.

IV period - 2011-2016 years - at that time, the option "Rinse from above Karachunivsky Reservoir" was introduced, when, according to the "Regulation on the environmental improvement of the Ingulets River, improvement of the water quality in the Karachun reservoir and the injector in the Ingulets irrigation system, water discharge from the Karachuniv reservoir was carried out from April to August the cost of 10-20 m^3/s in the volume of 120-130 million m^3. This ensures a stable, satisfactory water quality in the main channel throughout the irrigation period. The scientific substantiation of the new variant was developed by Kherson State Agricultural University (Professor Morozov VV) and the Department of Channels of the Ingulets Irrigation System - (Ph.D. Sciences, Kozlenko E.V.) in 2011.

Table 2 shows the average values of the main indicators of the quality of irrigation water (main channel Ingulets irrigation system) in the above defined characteristic periods of work of the Ingulets irrigation system.

Table 2
Average values of indicators of quality of irrigation water in main channel Ingulets irrigation system

Indicators of quality of irrigation water	Units of measurement	Average values of water quality indicators in characteristic periods of work of the Ingulets irrigation system				
		2000-2003	2004-2007	2008-2010	2011-2015	2016
1	2	3	4	5	6	7
Mineralization	g/dm^3	1,95	1,43	1,83	1,47	1,66
pH	-	8,03	7,58	7,61	7,41	8,15
HCO_3^-	m- eq/dm^3	2,95	4,45	3,79	3,19	3,49
Cl^-	m- eq/dm^3	14,83	7,86	10,55	9,51	9,41
SO_4^{2-}	m- eq/dm^3	13,50	10,56	14,26	10,47	10,40
Amount of anions		31,28	22,87	28,59	23,17	23,29
Ca^{2+}	m- eq/dm^3	8,38	6,40	7,00	5,80	5,40
Mg^{2+}	m- eq/dm^3	8,80	8,15	8,61	6,49	7,30
$Na^+ + K^+$	m- eq/dm^3	14,60	8,31	12,97	10,82	12,14
Amount of cations		31,78	22,86	28,58	23,12	24,84

The average mineralization of irrigation water and chloride content in the 1st period was 1.95 g/dm3 and 14.83 m-eq/dm3, which did not correspond to the design value. Due to the introduction of the new operating rules of the main pumping station (Morozov V.V., Volohniuk E.G.), the mean mineralization and chloride content were established in the 2nd period at the values of 1,43 g/dm3 and 7.86 m-eq/dm3. Analyzing the third period, it should be noted a significant deterioration of these indicators, respectively, 1,83 g/dm3 and 10,55 m-eq/dm3. Due to the introduction of a new regulation, "Rinse from the top of Karachuniv reservoir" in the IV period - the average mineralization and chlorides improved and amounted to 1,47 g/dm3 and 9.51 m- eq/dm3. In 2016, the introduction of a new method for the formation of water quality IIS took place. The effectiveness of forming the quality of irrigation water for the characteristic periods of the work of the IIS is presented in Table 3.

Table 3					
Changes in the effectiveness of forming the quality of irrigation water in the characteristic periods of work of the Ingulets irrigation system					
Water Quality Indicators	Average indexes of efficiency of forming water quality during periods of work of the Ingulets irrigation system				
	2000-2003	2004-2007	2008-2010	2011-2015	2016
1	2	3	4	5	6
Mineralization	0,89	1,21	0,88	1,15	1,02
pH	0,95	1,00	1,00	1,02	0,93
HCO_3^-	1,40	0,91	1,15	1,00	1,15
Cl^-	0,69	1,28	0,96	1,07	1,06
SO_4^{2-}	0,90	1,18	0,79	1,13	1,15
Ca^{2+}	0,73	0,96	0,89	0,83	1,11
Mg^{2+}	0,77	0,83	0,77	1,00	0,9
$Na^+ + K^+$	0,84	1,69	0,85	1,13	0,91
General index	0,35	2,24	0,45	1,35	1,33

The analysis of the data obtained from the research showed that in the I and III periods the operation of the Ingulets irrigation system for the formation of the quality of irrigation water was ineffective, as indicated by the average index values for the mineralization of the irrigation water 0.89 and 0.88. Due to the introduction of recommendations for scientifically grounded water quality in the II and IV periods, the Ingulets irrigation system operation regime was effective, as indicated by the index values: 1.21 and 1.15. Hydrogen pH indicates that the system is ineffective only in the I period - 0.95. Accordingly, effective II, III and VI periods, the indices of which correspond to 1.00; 1.00 and 1.02. Analyzing the index of HCO^{3-} it can be argued that the second period is ineffective - 0.91, while the periods I, III and IV are effective and characterized by indices: 1.4; 1.15 and 1.00. An analysis of the chloride content showed that water quality formation was effective in the 2nd and 4th periods, the index of which is 1.28 and 1.07, respectively, the I and III periods were characterized as ineffective - 0.69 and 0.96. The index of calcium content indicates the ineffectiveness of water quality formation in all periods: 0.73; 096; 0.89; 0.83. The index of quality index on the content of magnesium confirms that the work of the Ingulets irrigation system was effective only in IV period – 1.00, and ineffective in others: 0,77; 0.83; 0.77. Analyzing the content of sodium and potassium shows that the quality of water formation was ineffective in the I and III periods - 0.84; 0.85, and effective - in the II and IV periods - 1.69; 1.13.

CONCLUSIONS

The new way of forming irrigation water quality of IIS includes water discharge from the Karachuniv reservoir was carried out from April to August the cost of 10-20 m^3/s in the volume of 120-130 million m^3.

The main assessment of the efficiency of forming the quality of irrigation water in the Ingulets irrigation system is characterized by general indices which indicate that in general the Ingulets irrigation system worked effectively in the 2nd and 4th periods: 2.24 and 1.35 and ineffective in the 1st and 3rd periods 0.35 and 0.45.

In the conditions of the Ingulets irrigation system showed that the proposed index method for assessing the effectiveness of the ecological and land reclamation regime of irrigated lands is objective and complex and can be used in assessing the operation of the irrigation system and its individual elements.

Literature

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Influence of applied irrigation water on yield and yield components of peas (*Pisum sativum* L.)

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ABSTRACT

Characteristics of contemporary farming are vast negative changes which consequently lead to uncontrolled natural resources exploitation. It is big demand regarding water usage on economic efficiency and efficacies way have tremendous relevance. This scientific work will show results based on three year of research (2010-2012) influence of irrigation norms on yield and yield components of green peas. Two-factorial split-plot method was performed on the soil type called Chernozem with slightly sightof clay and sandy traceon the location of trail fields of the extension farmer's service Sombor. On the major examined plots were four versions in terms of irrigation (version without irrigation and versions with 10 mm, 20 mm, 30 mm water per irrigation portion) this research embraced four varieties of pea: Avola, Linkoln, Mastin and Polar. Average grain yield was 5.86 t/ha, however on the variants with irrigation succeeded grain yield was higher (17-37%) in comparison to non-irrigated variants. The highest grain yield has variety named Polar (6.61 t/ha). Average weight of 1000 grains for all examined varieties was 300.26 g, while number of grains per husk was 7.15. Exanimated plots with irrigation on have recorded highest average height of plants, they were longer and husk was wider, total weight of 1000 grains as well as number grains per husk in comparison to variant without irrigation. Through this research significant positive correlation between yield and plant hight ($r=0.91^{**}$) has been succeeded, also correlation in number of grains per husk and husk width ($r=0.85^{**}$), and husk length ($r=0.59^{*}$). In addition, number of grains per husk was in significant positive correlation with plant height ($r=0.58^{*}$), yield and number of grains per husk ($r=0.51^{*}$), and plant height and husk width ($r=0.51^{*}$). All final results from this research show that even with smallest portions of water for irrigation can come up to satisfy results of yield chosen varieties of green pea in way of normal usage of systems for irrigation and their rational explanation in practice in ours agro-ecological conditions.

KEY WORDS: *Pisum sativum* L., irrigation, yield, yield components, correlation.

INTRODUCTION

One of the limiting factors in the production of peas is definitely a precipitation deficit during the vegetation period, which demands the application of irrigation in order to achieve high and stable yield. That is why one of the required measures for the treatment of peas is irrigation, especially in the case of peas produced for industrial processing (Bošnjak, 2003). Irrigation stabilizes its yield on a high level and achieves the better quality of peas regarding the uniformity of ripening, hardness and colour. The yield of peas is in direct correlation with the amount of precipitation and proper watering in the stage of intensive growth of plants (Marković, 2012). Martin et al. (2006) which claim that by different irrigation standards, overall yield was increasing from 3.3 t ha^{-1} (treatment without irrigation) up to 5.3 t ha^{-1} (in case of full irrigation norm). Irrigation in the flowering stage is especially important, where beside the increase of yield, it also prolongs the vegetation so the harvest can be timely done (Ashraf, 2010). According to Baigorri et al. (1999), critical periods in the production of peas in regard to water are germination, flowering and pod formation. When there is a lack of precipitation, the irrigation during the period of flowering increases the number of pods for market and the number of seeds per pod, and in the period of yield formation it increases the weight of both pod and seed (Silim et al., 1992). High temperatures and water deficit during the reproductive stages of pea growth, resulted in a reduced number of seeds (Guilioni et al., 2003). According to Efetha (2011), the reduction of moisture content in soil to less than 60% FWK, reduces the yield and quality of peas. Also, Singh et al. (1990) emphasize that the optimal size of a pod, optimal number of pods per plant and maximum yield of consumption peas are achieved with one watering in the stage either before or after the flowering. In agro-ecological conditions of Vojvodina, one watering in the period of flowering has always given a positive effect on the increase of number of pods and seeds in them (Vučić, 1981). However, if the irrigation schedule is not in compliance with the requirements of crops and physical properties of soil, the irrigation may not have any effect on the yield of peas or that effect can be negligible.

Considering the fact that the reserves of water available for irrigation are lower and lower every year, in the world and in our country as well, and the requirements for food are increasing, it is necessary to be more rational in water resources and food management. In that regard, the goal of this research is to establish in the agro-ecological conditions of Vojvodina, through experimental researches, the effect of irrigation on the yield and the yield components of consumption peas in order to determine rational water regime. By applying the correlation coefficient, the influence of certain yield components on the yield of technologically ripe peas of selected varieties and their interdependence will also be described.

MATERIAL and METHOD

Experimental design

Three-year long (2010-2012) field experiments performed on the experimental fields of Agricultural extension service in Sombor, Vojvodina, The Republic of Serbia (45.750831'N; 19.136127'E; altitude of 87 m). Two-factorial experiment was set according to a split-plot method in threefold repetition, where on the main plots there were four variants of irrigation (factor A) in which four varieties of green peas were analyzed (factor B), which were harvested in their technological ripeness intended for industrial processing. The surface of a basic plot was 5 m², and the total experimental surface was 600 m². The irrigation variants were: control – without irrigation; 1st variant – with 10 mm of water per irrigation shift; 2nd variant – with 20 mm of water per irrigation shift; 3rd variant – with 30 mm of water per irrigation shift. The duration of shift was 10 days with modifications depending on the amount and schedule of rainfall on experimental area, and the irrigation was applied with by sprinklers. The research used: early Avola variety, medium-late Lincoln and late varieties Mastin and Polar.

The experiment used common technology for the production of peas. In all three years of research, sowing was done in early spring (in the period 20. 02. – 01. 04.) with 95 plants/m², with spacing between rows of 15 cm, that is 7 cm in a row. Minimum quantities of mineral fertilizers were used for fertilizing peas, and that would be YARA MILA 13:13:21 formulation in the amount of 200 kg ha^{-1}, that is 26:26:42 kg ha^{-1} of active matter. The seed was treated with Nitragin. The seed inoculation was performed immediately before the sowing.

Soil analysis

The experiment was done on chernozem soil with the signs of gleization in wattle. The anaysis of the soil (Table 1) showed that it was neutral to weakly alkaline (Thun, 1965), that is alkaline (Ubavić, 2003), which is the basic property of the most quality land in Vojvodina. In regard to the content of $CaCO_3$ (Škorić et al., 1985), it was classified in the group of weakly carbonated soil, and in regard to the content of humus it was a soil with medium humus content. In regard to the total N in the soil (Ubavić and Bogdanović, 1995), it was characterized as a medium supplied with this element. Regarding the phosphorus and potassium content, the soil was classified in the group with optimal content of these two elements (Manojlović, 1988).

Table 1.
Chemical properties of soil.

Years	pH		C_aCO_3 %	Humus %	Total N %	P_2O_5 mg/100g	K_2O mg/100g
	H_2O	KCl					
2010	8,26	7,67	3,60	2,34	0,143	19,2	22,8
2011	8,75	7,82	3,50	1,74	0,136	22,8	19,9
2012	8,34	7,74	3,81	2,35	0,157	32,1	32,1

This paper shows the results of obtained yields of peas and yield components (height of a plant, weight of 1000 grains, number of grains per pod, length and width of a pod).

The obtained results were statistically processed by variance analysis method (statistical software GenStat 12th Edition), where the significant difference between treatments was tested by LSD test, on the threshold of significances of 1% and 5%.

Determining dependencies between the observed characteristic is performed by calculating the correlation coefficient (r) of the n-2 degrees of freedom (Hadživuković, 1989).

Climate conditions

The data in the Table 2 show differences in medium monthly temperatures of air and quantity of rainfall by month between research years. The meteorological data show that average annual temperatures of air in all three research years were on the level of a multi-year average (11.7°C). Also, the air temperatures in growing season during all three research years were rather equal and on the level of a multi-year average, so it can be said that they were favourable for growth and development of crops of peas.

Table 2.
Medium monthly temperatures of air (°C) and total precipitations (mm) for the period 2010-2012 and multi-year average (2003-2013), Sombor, Vojvodina, Serbia

Month	Temperatures				Precipitations			
	2009/10	2010/11	2011/12	Multiyear averages	2009/10	2010/11	2011/12	Multiyear averages
VII	23.0	22.8	21.8	22.8	30	41	84	64
VIII	22.8	21.1	22.5	22.0	45	52	32	61
IX	18.8	15.3	19.8	16.8	15	111	32	53
X	11.4	8.6	10.2	11.3	47	46	23	53
XI	7.7	8.5	2.2	6.6	60	72	3	52
XII	3.0	-0.1	3.5	1.8	62	72	68	49
I	-1.1	0.9	2.0	0.5	84	21	37	42
II	1.2	0.2	-4.3	0.8	55	22	57	38
III	7.0	5.9	8.2	6.4	13	24	3	38
IV	12.1	13.3	12.7	12.6	55	11	40	43
V	16.8	16.7	17.5	17.5	195	42	57	75
VI	20.3	20.9	22.6	21.1	240	42	24	80
Hydrological year	11.9	11.2	11.6	11.7	901	556	460	648

Vojvodina climate zone is characterized by variable precipitations in quantity and distribution during growing season, so during the research, total precipitation quantity varied from 460 mm-901 mm (Table 2). Based on the total precipitation quantity and in comparison with multi-year average values, we may conclude that the year of 2010 was especially wet, while 2011 and 2012 had a little lower precipitation quantity than average multi-year values. During growing season in 2010, there were 558 mm of rainfall which was twice more than a multi-year average. Especially large quantity of precipitations was recorded in the period May-June (435 mm) compared to other two research years. During 2011 in pre-growing season there were 415 mm or 75% of total annual precipitation quantity, and in growing season 141 mm, which is 133 mm less than multi-year average. During 2012, in pre-growing season the total precipitation quantity was 279 mm or 61%, and during growing season 181 mm or 39% of the total precipitation quantity.

Due to unbalanced precipitation schedule and the fact that for normal growth and development of peas it is necessary to provide optimum moisture in soil surface layer (0-30 cm), during growing season 2011 and 2012 all irrigated plots were watered more often than in 2010.

RESULTS and DISCUSSION

Yield and yield components

Yield is a basic indicator of productivity of a variety and applied agro-technical measures. After the analysis of obtained results (Table 3), we was noticed that irrigation standards and varieties with their genetic potential had effect on the formation of yield and yield components of peas during three-year long researches.

On average for all varieties, the highest yield was obtained with the application of the 3rd irrigation variant (6.66 t ha^{-1}), which was for 37% more, compared to the variant without irrigation. On average, for the whole experiment, the highest grain yield was obtained with Polar variety (6.61 t ha^{-1}), and the lowest with Avola variety (5.46 t ha^{-1}), and the differences between the varieties are also the result of varietal specificity. The obtained results are in accordance with other authors' results which point out the increase in the yield of peas depending on irrigation standards (Martin and Tabley, 1981; Sorensen et al., 2003, Martin et al., 2006). Also, Salem et al. (1990) claim that on the variants without irrigation, the yield of peas varied from 3687 to 4550 kg ha^{-1}, and on the irrigated variants from 3850 to 6187.5 kg ha^{-1}.

Table 3.
Yield, yield components and morphological characteristics of peas depending on irrigation variant and variety (2010-2012)

Variants (A)	Variety (B)	Yield of grain ($t\ ha^{-1}$)	Height of plants (cm)	Weight of 1000 grains (g)	No of grains /pods	Width of a pod (mm)	Length of a pod (mm)
Control	Avola	4.27	486.7	326.20	5.13	11.11	69.18
	Linkoln	4.55	712.7	308.30	7.24	12.20	75.13
	Mastin	4.70	838.9	272.30	7.44	12.80	97.13
	Polar	5.94	691.8	236.30	6.67	11.60	64.44
	Average (A)	4.87	682.5	285.78	6.62	11.93	76.47
1st variant	Avola	5.46	526.7	340.40	5.49	11.67	70.89
	Linkoln	5.42	742.9	319.40	7.51	12.84	75.42
	Mastin	5.50	884.7	273.50	7.62	12.64	100.71
	Polar	6.41	738.0	236.80	6.91	12.15	68.49
	Average (A)	5.70	723.1	292.53	6.88	12.33	78.88
2nd variant	Avola	5.84	558.7	348.70	5.69	11.47	74.62
	Linkoln	5.97	792.7	338.30	7.60	13.14	79.09
	Mastin	6.21	948.0	282.20	8.15	12.16	100.71
	Polar	6.80	792.4	241.90	7.47	13.05	72.71
	Average (A)	6.21	772.9	302.78	7.23	12.46	81.78
3rd variant	Avola	6.28	565.3	358.80	6.29	11.76	77.16
	Linkoln	6.43	839.3	361.20	8.47	13.31	83.76
	Mastin	6.65	1054.9	290.00	8.42	12.56	106.04
	Polar	7.28	841.6	269.80	8.29	13.22	76.51
	Average (A)	6.66	825.3	319.95	7.87	12.71	85.87
Average according to variant (B)	Avola	5.46	534.4	343.53	5.65	11.50	72.96
	Linkoln	5.59	771.9	331.80	7.71	12.87	78.35
	Mastin	5.77	931.6	279.50	7.91	12.54	101.15
	Polar	6.61	765.9	246.20	7.34	12.51	70.54
Average		5.86	751.0	300.26	7.15	12.36	80.75

LSD	Variant with irrigation		Variety		AXB		BXA	
	5%	1%	5%	1%	5%	1%	5%	1%
Yield of grain	0.30	0.46	0.29	0.39	0.55	0.75	0.57	0.78
Height of plants	25.00	37.87	22.22	30.12	43.44	58.50	44.55	60.23
Weight of 1000 grains	16.93	25.66	13.46	18.25	27.10	36.52	26.93	36.49
Number of grains per pod	0.61	0.93	0.37	0.50	0.82	1.11	0.73	0.99
Width of a pod	0.66	1.00	0.51	0.69	1.03	1.39	1.01	1.37
Length of a pod	2.15	3.26	2.90	3.93	5.26	7.14	5.80	7.86

Ratio between mentioned variants in the quantity of peas yield is shown graphically where a statistical significance is a difference between variants shown with black coloured bars (Figure 1).

Growth and development of peas depend in the first place on a variety, environmental conditions and applied agro-technical measures. On all irrigation variants, we noticed larger average height of plants compared to the variant without irrigation (Table 3). On average for the whole experiment, Mastin variety had the largest average height of a plant (931.6 cm), and Avola variety had the smallest (534.3 cm). The obtained results confirm the statements of Martin (1996) who points out that water stress before flowering reduces the growth of peas.

The results of three-year long research show that the obtained average weight of 1000 grains is 300.26 g. On average for all varieties, the largest weight of 1000 grains was recorded on 3rd variant which is 12% higher compared to the controlled one. The weight of 1000 grains is a varietal characteristic and thus between different varieties this research recorded a bigger difference than between irrigation variants. The largest weight of 1000 grains was achieved by Avola variety (343.53 g), and the difference was significant compared to Mastin and Polar varieties (Table 3). The obtained results are in accordance with the statements of Sadowska et al. (1994), which point out that the weight of 1000 grains with Polar variety was between 211.4-428.7 g. Opposed to that, Martin and Tabley (1981) and Martin et al. (2006) claim that irrigation influenced the increase of peas yield, but the weight of the seed was mainly unchanged.

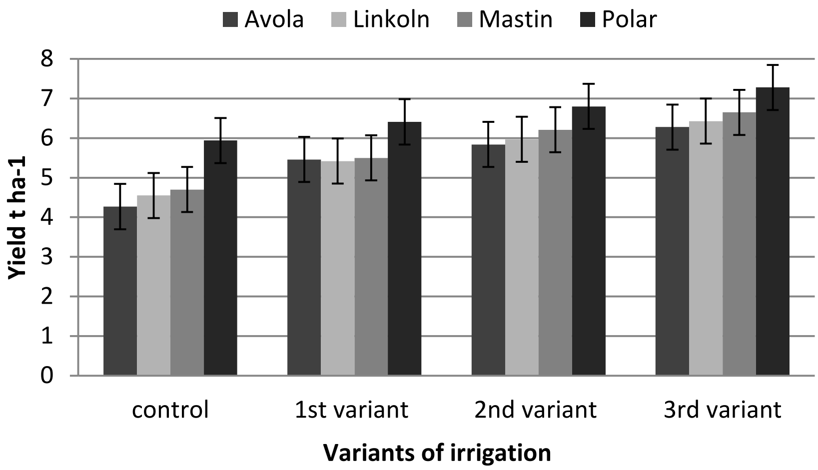

Figure 1. Average yield of peas (t ha^{-1}) depending on irrigation variant and variety (2010-2012)

The results show that on all irrigation variants, there was on average larger number of grains per pod compared to the control variant (Table 3). Comparing the varieties, we established that Mastin variety had the largest average number of grains per pod (7.91), and Polar variety had the smallest (5.65). The obtained results are in accordance with the results of Silim et al. (1992) and Martin et al. (2006) which claim that by increasing irrigation standards, the number of grains per pod increases. Opposite to that, a little smaller number of grains per pod was obtained by Bennett and Webb (1987) and Bhujel and Lepcha (2015), which confirms that this variable characteristic mainly depends on a genotype, although climate conditions during formation and watering of grains also have great influence on its value.

Length and width of a pod depend on the position on a certain nodule. The average width of a pod in three-year average was 12.36 mm, and the length of a pod was 80.75 mm. On all variants with irrigation, with both characteristics, there were better results compared to the variant without irrigation, which confirms that apart from a variety, agro-environmental conditions and applied agro-technical measures also have effect on these parameters. The obtained results in this research are in accordance with the results of Khan et al. (2013) which claim that depending on the quantity of precipitation, that is the tolerance of genotype to drought, the length of a pod was 4.38 – 9.33 cm, while Sadowska et al. (1994) point out that the largest width of a pod with Polar variety (9.6 mm) was recorded on 26th day from flowering.

Correlation between examined parameters

To perceive the interrelations between examined quantitative features, we calculated the correlation coefficients (r) of yield and yield components of technologically ripe peas (Table 4).

Table 4.
Correlation coefficients of the yield components and the yield of peas (2010-2012)

	Weight of 1000 grains	No of grains /pods	Width of a pod	Length of a pod	Yield of grain
Height of plants	0.06	0.58*	0.51*	0.30	0.91**
Weight of 1000 grains	-	-0.29	-0.14	-0.05	-0.23
No of grains /pods	-	-	0.85**	0.59*	0.51*
Width of a pod	-	-	-	0.36	0.44
Length of a pod	-	-	-	-	0.06

α (0.05)=0,497; α (0.01)=0,623

The results of the research show that the established very significant positive correlation between the yield and the height of plants (r=0.91**), as well as between the number of seeds per pod and the width of a pod (r=0.85**). There is also established a significant positive correlation between the number of seeds per pod and the length of a pod (r=0.59**), number of seeds per pod and the height of a pod (r=0.58*), the yield and the number of seeds per pod (r=0.51*), and between the height of a plant and the width of a pod (r=0.51*).

At the same time, there are no significant differences established between other components.

The obtained results are in compliance with the statements of Kuchinda and Lawal (2003), which point out that the yield of technologically ripe peas is in the positive correlation with the height of plants, index of leaf surface, number of pods per plant, weight of seed and number of seeds. Also, Đorđević et al. (2004) claim that there is a high correlation between the yield and the yield components r=0.82-0.95. Ramzan et al. (2014) state that the yield of technologically ripe peas is in the significant correlation with the number of seeds per pod (0.603**), pods per plant (0.534**) and weight of plant (0.464**).

The applied agro-technical measures, the environmental factors and their interaction also had, apart from the varieties, large influence on the high interdependence of certain yield components.

CONCLUSIONS

Based on the obtained results, the conclusion is that irrigation standards as well as varieties have positive effect on yield and yield components of peas. The average yield of peas was 5.86 t ha^{-1}, and the highest yield was obtained with 3rd irrigation variant, which was 37% more, compared to the variant without irrigation. The highest grain yield has variety named Polar (6.61 t/ha). On all irrigation variants, it was recorded larger average height of plants, length and width of a pod, total weight of 1000 grains and number grains per husk compared to the variant without irrigation.

Calculating the correlation coefficient (r), it has been established that there are significant correlations between the yield and the yield components of peas.

According to the obtained results, we can conclude that with selecting the adequate peas varieties and perceiving the possibilities of their production with the application of rational watering standards, there can be expected the satisfying yield results, and at the same time the preservation of water resources with long-term consequences.

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Water infiltration affected by different land use types and soil texture in temperate climate

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ABSTRACT

Surface soil hydrological properties like water infiltration and hydraulic conductivity have important consequences for hydrological properties of soils in river basins and their knowledge is needed for sound land management, as well as flood risk prevention. They are very dynamic properties due to varying land use management practices. The objective of this study was to evaluate the effects of two land uses (native meadow and arable) on surface (0–30 cm) infiltration characteristics of a silty clay loam and sandy loam soils at three sites in the Kolubara river valley and the Nišava river valley, respectivelly, with temperate climate, Serbia.

A site consisted of two adjacent but different land uses on the same soil types. For each land use, water infiltration rates were measured in triplicate using double ring infiltrometer. Particle size distribution, bulk density and soil organic matter content of the surface soil were determined.

Experimental measurements in the field indicated that treatments significantly influenced water infiltration characteristics on both locations. At both site the infiltration rates showed a decrease as a function of elapsed time. Steady state infiltration rate and cumulative infiltration of sandy loam-textured soils under the meadows were much lower than that for the arable soils. By contrast, the infiltration capacity and cumulative infiltration of silty clay loam soils under the meadows was significantly (P < 0.05) higher compared to arable soils. Increase in infiltration capacity of arable soils were related to decrease in bulk density. In addition, in tilled sandy loam soil infiltration was much higher than in silty clay loam soil. However, infiltration in a silty clay loam under meadow was lower compared with sandy loam soil. According to the results of our study it could be concluded that the land use change infiltration properties of surface soil and consequently may alter the water balance of the area by changing the amount of surface runoff and soil water retention. Knowledge of how management practices affect infiltration capacity can aid growers in reducing soil quality and degradation.

KEY WORDS: vegetation change; meadow; arable land; Fluvisols, surface soil

INTRODUCTION

Numerous human activities can significantly alter land cover properties and subsequently hydrological and watershed processes. Land use change affect physical, chemical and biological properties of soils (Shukla et al., 2003; Yimer et al., 2008). Also, soil management or land use affects soil hydraulic properties, and thus the water balance and hydrology of the land (Bodhinayake and Si, 2004). After tillage a soil results in quick changes in the physical condition of a soil until a new equilibrium is reached. Native meadows represent specific ecosystems that have significant importance for water regime in landscape (Halabuk, 2006). Their character, especially expressed through soil physical properties and vegetation have influence on hydrological processes, e.g. infiltration, water retention and evapotranspiration (Bullock and Acreman, 2003). However, native meadows were extensively destroyed and transformed to arable lands in the past. Recently, there has been a higher interest for studying these ecosystems to get the knowledge of their multiple importance. Land use change from natural vegetation to arable lands has a marked effect on infiltration, water transport characteristics and surface runoff (Tollner et al., 1990; Broersma et al., 1995; Gajić et al., 2008; Yimer et al., 2008). Grain size distribution strongly influences hydraulic properties of soil, and therefore texture has often been related to hydraulic conductivity (Saxton et al., 1986).

The measurement of water infiltration into the soil is an important indication in the regards of the efficiency of drainage and irrigation, improving the yield of crops, optimizing the availability of water for plants, minimizing water erosion and describing the soil permeability (Selim, 2011). Also, knowledge of the land use impacts on soil quality is necessary for sustainable agricultural production.

Effects of land use on infiltration characteristics, particularly in the river valleys, have not been documented in the Serbian Fluvisols to the best of our knowledge. This information is needed for improving our understanding of the effects of land uses on infiltration and runoff, and thus on soil hydrology in temperate climate. Therefore, the purpose of this research was to determine the effects of land use change on infiltration capacity in the topsoil (0–30 cm) on a long term basis. For this purpose, two different kinds of land use were selected. Our hypothesis was that before the change in land cover the initial soil structure of the two subsites was similar and the observed differences in soil infiltration properties were caused by conversion in land cover.

MATERIAL and METHOD

To carry out the research, two experimental sites characterized by contrasting texture. The study sites were located in two physiographic regions of the Republic of Serbia. Site 1 is located in the Kolubara river valley near Obrenovac (latitude 44^{o}33'02''N, longitude 20^{o}08'18''E, 82 m a.s.l.) and site 2 is located in the Nišava river valley near Pirot (latitude 43^{o}09'04''N, longitude 22^{o}35'06''E, 361 m a.s.l.).
The research regions have a temperate climate. The experimental plot in the Obrenovac has a long term average annual total precipitation of 687 mm. The average annual temperature is ~11^{o}C. The long term annual average precipitation and annual average temperature in the study site of Pirot were 587 mm and 10.7^{o}C, respectively.

Soils at site 1 are located on the first dry terrace of the Kolubara river, are formed over poorly carbonated fluvial sediments, and classified as a non-carbonated, eutric, silty claye loam, Fluvisols. Soils at site 2 are located on the inundation area of the Nišava river, are formed from fluvial sediments, and classified as a non-carbonated, dystric, sandy loamy, Fluvisols. Each of these two sites is in an owned by private farmers. Within a site, one subsite was always a meadow with the other subsite in adjacent cropland on the same soil types. The major plant species of native meadows included *Medicago lupulina* and *Lathyrus sp*. (first site) and *Poa palustris* L, *Festuca rubra* and *Agrostis stolonifera* L. (second site). The field at the cropland was also in past the native meadow, but the land use and management changed approximately 50 years ago. The arable sites have been in cultivation of corn (*Zea mays* L.) and wheat (*Triticum aestivum* L.) in rotation.

Within each subsite, three randomly selected spots were chosen for the measurement of water infiltration into the soil and for sampling pits. A soil pit was also excavated immediately adjacent to the infiltrometer test locations. Pits were excavated, soil profiles described, and bulk soil samples taken at depth of 0–30 cm for particle size distribution and soil organic carbon (SOC) content. Particle size fractions were determined by the pipet method after dispersion with tetrasodium pyrophosphate solution (Rowell, 1997). Soil organic carbon concentration was determined using the dichromate method (Rowell, 1997). The percent soil organic matter (SOM) was calculated by multiplying % SOC by a factor of 1.724. Bulk density was determined with the undisturbed soil samples of a 100-cm^3. At site 2, due to coarse texture of soil, about 82% sand, were difficult to obtain undisturbed soil samples (cores) for determination bulk density. Table 1 summarizes the main characteristics of these soils.

The infiltration rates were measured in triplicate (duplicate) on each subsite by using a double ring infiltrometer until steady state was achieved (Bertrannd, 1965). A constant head of water 2 cm deep was maintained in both the 30 cm diameter inner ring and the 60 cm diameter outer (buffer) ring. The rings were driven concentrically into the soil surface to a depth of approximately 15 cm without remove natural plant cover with minimum soil disturbance. Plant cover will not affect the infiltration rate because it is the soil properties and bio- and structural pores that control infiltration rate. The volume of infiltrated water in the infiltration ring were recorded at time increments of 0, 5, 10, 15, 30, 60, 90, 120, 150, 180, 210 and 240 min for calculation of infiltration rate and cumulative infiltration. When the amount of water entered into the soil did not significantly change with time for two consecutive measurements taken at 30-min intervals, steady state flow was assumed and steady state infiltration rate was calculated based on the last two measurements. Generally, steady state was achieved within 210–240 min. Water level in the outer ring was maintained at a level about the same as the water level in the inner ring.

Conventional statistics (ANOVA) were used to assess treatment differences. Treatments were compared using LSD differences at the $P < 0.05$ callbacks.

RESULTS and DISCUSSION

The soils of the two sites show contrasting characteristics in terms of particle size distribution and texture in the top layer (0–30 cm) (Table 1). However, there was no significant effect of the land use systems on particle size distribution for the 0–30 cm layers. The soil at site 1 has a silty clay loam texture in a topsoil layer. As seen in table 1, the soil at site 2 has a sandy loam texture in a topsoil layer.

Table 1
Certain physical and chemical soil properties in the depth of 0–30 cm of the treatment plots

Site	Land use	SOM† (%)	Bulk density (g cm^{-3})	Particle size distribution (%)‡			
				Sand	Silt	Clay	Texture
Obrenovac (Site 1)	Meadow	3.59	1.49	7.5	55.0	37.5	Silty clay loam
	Arable	3.18	1.35	9.5	51.1	39.4	Silty clay loam
Pirot (Site 2)	Meadow	0.94	–	66.6	23.6	9.8	Sandy loam
	Arable	0.81	–	66.0	25.9	8.1	Sandy loam

†SOM – soil organic matter,
‡ sand (2.00–0.05 mm), silt (0.05–0.02 mm), clay (< 0.002 mm).

The arable land had a significantly lower SOM compared to meadow at the first site (~ 11% for 0–30 cm, at P < 0.05). At the second site, significant differences in SOM were observed between meadow and arable at a depth of 0–30 cm (16 % higher in meadow soils than in arable). These differences can be attributed to tillage practices. These results agree with the findings of Celik (2005). Mean bulk density of the meadow was significantly higher than that of the arable soil (at site 1). The lower bulk density in the arable soil may be attributed to tillage. Higher bulk density causes lower total porosity.

The infiltration curves for both sites as well as cumulative infiltration curves over a certain period are presented in figures 1 and 2, respectively. In this study changes in land use significantly (P < 0.05) affect infiltration characteristics of investigated soils. Water infiltration into all treatment plots declined with time. In the first site, the initial infiltration rate or sorptivity at 5 min was lower on arable soil by 13% and higher by 84% in the second site (Fig. 1) compared to meadow. The values of initial infiltration rate in meadow and arable were 491 mm h^{-1}and 426 mm h^{-1} in silty clay loam (site 1) and 690 mm h^{-1}and 1269 mm h^{-1} in sandy loam soils (site 2), respectively. The initial infiltration rates in meadow and arable of the sandy loam soil (site 2) were 40% and 199% greater than that of the silty clay loam soil (site 1), respectively.

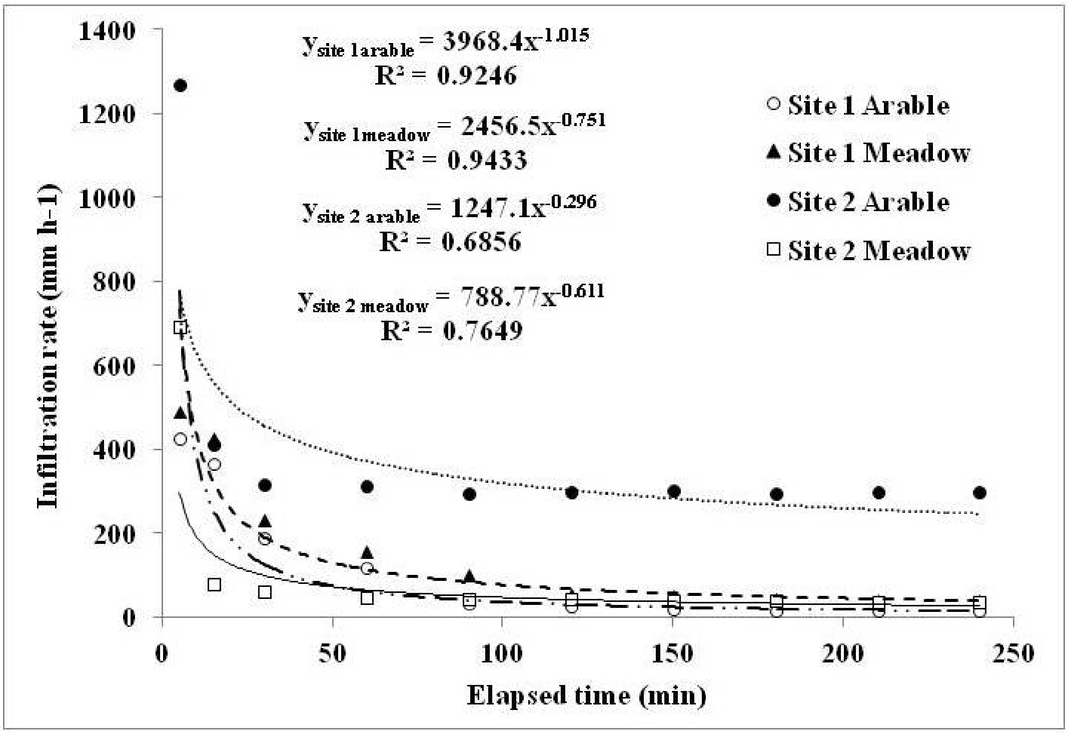

Figure 1. The infiltration rate values under different land uses.

Long term tillage of silty clay loam soils also resulted in reduction of infiltration rates, but not in sandy loam soils. As a consequence, the potential runoff of precipitation varies among land uses, which in turn may alter the water level of researched soils. In silty clay loam soil under meadow (site 1), mean final steady state infiltration rate or hydraulic conductivity near saturation (39 mm h^{-1}) was a significantly (P < 0.05) higher than in arable (15 mm h^{-1}), implying that there was a larger number of pores and greater pore continuity under grassland. Both land uses had similar clay, silt and sand content (Table 1). Thus, the large differences in infiltration rate between meadow and arable silty clay loam soil suggest that meadows have a well-developed macropore structure and connectivity. Tillage may have destroyed macropores and continuity of the macropore network and/or prevented the formation of larger pores in the tilled layer that could conduct water at low tensions, as reported by Maulé and Reed (1993). These results show that the meadows are capable of transmitting more water into soil than arable soils at near saturated conditions at site 1. Our observation is similar to that of Bodhinayake and Si (2004) who reported that macroporosity and total porosity under grass were significantly larger than under cultivated land. These differences in porosity led to differences in hydraulic conductivity: the saturated conductivity under grass was up to three times larger than under cropland (Bodhinayake and Si, 2004). According to Maulé and Reed (1993), cultivation may have destroyed macropores and continuity of the macropore network and/or prevented the formation of larger pores in the tilled layer that could conduct water at low tensions. Haghighi et al. (2010) have also observed similar results and reported that the final infiltration rate of pasture was higher than cultivated sandy soils in watershed of Iran. Decline the infiltration rate in the cultivated soils could be a result of break-up of the soil aggregates by tillage and compaction from farm implements (Bharati et al., 2002). The higher final infiltration rate observed in grass soils can be ascribed to dense root systems (Baumhardt and Lascano, 1996), high soil organic matter and total porosity (Celik, 2005). Less organic matter in cultivated land may have reduced aggregate stability and percentage of stable aggregates (Elliott and Efetha, 1999). Consequently the soils become less porous (Mapa and Gunasena, 1995). The results of our study are also comparable with that of Van der Kamp et al. (2003), who found greater infiltration rates in brome grasslands than in cultivated fields.

In this study steady state infiltration rate in the sandy loam soils (site 2) under meadow (37 mm h^{-1}) was up to eight times smaller compared to arable soil (298 mm h^{-1}) (fig. 1). Our findings suggest that infiltration of precipitation and snowmelt is likely to be greater and runoff is smaller in arable sandy loam soils than that in meadows. This result is very striking, but not so infrequent. According to Hsiao et al. (2007), cultivation of soil increases infiltration rate by creating more voids in the soil for water to infiltrate, but its effects are temporary. These results are in accordance with previous studies (Paoletti, 1999; Bens et al., 2007) showing that sandy soils support smaller earthworm populations than clayey soils resulting in lower hydraulic conductivity in sandy soils. Infiltration capacity was strongly affected by the presence of certain plant functional groups, such as grasses and legumes (Fischer et al., 2014). Archer et al. (2002) reported that grasses decreased and legumes increased hydraulic conductivity. The fibrous and rhizomatous roots of grass species tend to reduce infiltration by clogging soil pore space and blocking water flow (Archer et al., 2002). Thus, our results can be partial explained by the promotion of earthworm abundance by legumes and finer soil texture, but further research is necessary to support these findings. Results of this study confirmed the importance of soil structure as influenced by biotic processes and corroborate the findings of Bonsu (1992) who suggested that the texture based calculation underestimates the hydraulic conductivity, particular in fine textured soils. In addition, partial residue cover and tillage operations that lodge crop residues may increase infiltration (Baumhardt and Lascano, 1996). Additionally, infiltration capacity decreased over the growing season presumably by the growing roots clogging macropores (Barley, 1954; Gish and Jury, 1983).

As expected, significantly higher steady state infiltration rate was observed in the arable sandy loam soils (298.2 mm h^{-1}) when compared to silty clay loam soils (15 mm h^{-1}). Surprisingly, in this study steady state infiltration rate in silty clay loam soils under meadow (39 mm h^{-1}) was slightly higher compared to sandy loam soil (37 mm h^{-1}). Greater steady state infiltration rate can be expected in sandy loam soils when compared to silty clay loam soils as a consequence of a higher sand content and lower swelling. However, this results agree with Jarvis and Messing (1995), Lin et al. (1999) and Fischer et al. (2014), who found higher hydraulic conductivity in finer as compared to coarser textured soils due to well-developed soil structure (root channels, earthworm burrows) and a high degree of macroporosity. Biotic effects, especially the presence of certain plant functional groups affecting earthworm biomass, shape hydraulic conductivity and may even reverse effects of texture (Fischer et al., 2014). Furthermore, the presence of surface plant residues can be counteracted as a negative effect of no-tillage on infiltration properties (Lampurlanés and Cantero-Martínez, 2006). According to Kördel et al. (2008), pore size distribution, and hence water movement in undisturbed soils, strongly depends on soil type and composition. They reported that clayey soils contain many fine pores, whereas large pores dominate in sandy soils, leading to a pronounced differentiation in saturated hydraulic conductivity. Accordingly, water movement in sandy soils is much faster than in silty and clayey soils. This explains the large difference between conductivity in sandy loam and silty clayey loam soils at the first site. However, the values may significantly differ for native soils depending on soil type, soil formation, and compaction (Kördel et al., 2008).

According to our measurements, land uses change the cumulative infiltration. The mean cumulative infiltration into meadow or arable land is plotted in Fig. 2. Results showed that cumulative infiltration is dependent on the management systems. The cumulative water infiltration integrates the soil response to treatment effects on infiltration rate (Baumhardt and Lascano, 1996). At the first site, cumulative infiltration after 240 min into soil with natural grass cover taken was 62% greater than into arable due to herbs interception of raindrop impact. Reduction of large pores and increased soil bulk density due to soil consolidation may have caused a decline in water infiltration on arable land. Infiltration efficiency would be enhanced if there is a plant canopy, of either trees or herbs, covering the soil so that momentum of the falling rain is dissipated by the foliage first, thus reducing break up of the soil aggregates at the surface and minimizing soil surface sealing (Thurow, 1991). The curves in Figure 2 clearly show that the cumulative infiltration after 240 min was significantly lower in meadow (229 mm) compared to arable (1302 mm) at the second site in sandy loam soils. The results showed that the cumulative infiltration of the sandy loam soil under meadow was ~21% lower than that of the silty clay loam soil. Explanation for lower infiltration capacity in sandy soils under meadow at the

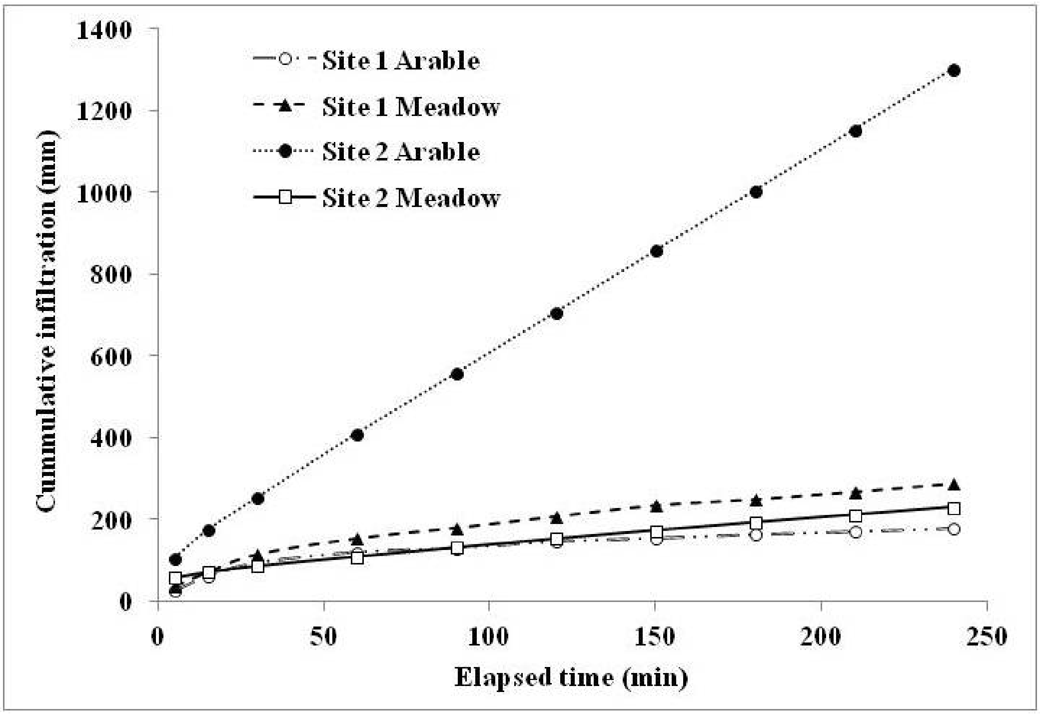

Figure 2. Cumulative infiltration curves for different land use types.

second site compared to meadow at the first site could be that the formed macropores are less stable over time in sandy than in clayey soils (Kördel et al., 2008). However, the cumulative infiltration after 240 min for arable sandy loam soils was 7.3 times greater than that of the silty clay loam soil. A higher cumulative infiltration in meadow can be ascribed to high soil porosity. According Yimer et al. (2008), soil texture, organic matter and bulk density are critical factors in influencing soil structure and thus infiltration. The differences in texture found in this study are fairly great and are assumed to have severe effect on infiltration. The higher clay concentration of the silty clay loam may be responsible for the significantly lower infiltration values observed. The dispersion and swelling of clay particles may have caused the sealing of the soil pores leading to low infiltration rate. This is in agreement with the results of Liu et al. (2003).

CONCLUSIONS

Change in land use from natural meadow to arable led to significant changes in key hydrological characteristics of the soils including cumulative and steady-state infiltration. The silty clay loam soils under natural meadows can be considered hydrologically superior in terms of water intake. They accept water faster than long term tilled soils and have higher cumulative infiltration. Cultivation of soil, in addition to reducing water infiltration, increases the hazards of erosion. Cumulative and steady state infiltration of sandy loam soils under the meadows was significantly lower than that for the arable soils. For explaining variations in hydrological processes, such as infiltration capacity, the structure of soil fauna and plant communities need to be considered.The results of this research may offer a temperate agricultural land management strategy for soil and water conservation and land degradation mitigation

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Spatial and temporal estimation of flooding and erosion susceptible areas by application of a physically based distributed model

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ABSTRACT

Floods and especially flash floods can have devastating consequences on the economy, environment and people. A physically based distributed model of runoff, erosion and sediment transport was established by the joint application of the SHETRAN river basin modelling system and Geographic Information Systems (GIS). This model was used for the recognition of the flooding and erosion/deposition susceptible areas as well as soil water content in a 114.31 km^2 mountainous torrential catchment of the Lukovska River in Serbia.
Given that in small water courses flash floods account for over 80 % of the total annual sediment transport the model was calibrated using the example of a storm event from 1986 and validated for three other storm events in 1974, 1976 and 1979. The model calibration and validation for the hydrological section of the model was performed by comparing the measured and the simulated values of discharges, while the model calibration and validation for the sedimentation section of the model was performed by comparing the measured and the simulated values of sediment concentrations at the outlet point of the basin. The ArcGIS software ArcView 10 was used both for preparing model parameters related to the physical characteristics of the catchment for each grid cell and for displaying and visualising the results of the model.
The obtained results of runoff and sediment concentrations in a flow at the catchment outlet show good agreement with their measured values. The spatial and temporal distribution of water depths, soil water content and erosion intensities were identified for the calibration storm event, during which 67.5 mm of rain fell in only two hours. The peak of the produced torrential wave was 69.2 m^3/s. The estimated maximum water depth in streams was 3.7 m. The simulated erosion rates were within the range of 1 to 11 t/ha and they corresponded to the observed rates of erosion in Europe during extreme rain events. The areas that are flood prone and susceptible to intensified erosion were identified. The presented methodology is useful in identifying the flooding and erosion vulnerable regions in a catchment on the basis of which relevant decisions regarding water and sediment management can be taken.
KEY WORDS: Flooding; Land degradation; Sediment transport; Soil water content; Torrential catchment; GIS application.

INTRODUCTION

Floods and especially flash floods can have devastating consequences on the economy, environment and people. Hilly and mountainous areas in Serbia, which occupy 3/4 of its territory, are extremely vulnerable to flooding and land degradation. Torrential streams have a specific hydraulic and hydrological regime which is manifested in occurences of torrential waves, that can be intense but short in duration, and they can transport large amounts of solids. The torrential Lukovska river catchment is very exposed to flooding and land degradation. Based on Petkovic and Kostadinov's (1989) research it was noticed that in small watercourses flash floods account for over 80 % of the total annual sediment transport.

In this study, a physically based distributed and rain event model of runoff, erosion and sediment transport was established for the 114.31 km^2 Lukovska River catchment in Serbia. The model was obtained by the joint application of the SHETRAN modelling system and the ArcGIS software. SHETRAN is a hydrological, integrated surface and subsurface modelling system for water flow, solute and sediment transport in river catchments, developed at the Water Resource Systems

Research Unit (WRSRU), University of Newcastle upon Tyne (Bathurst et al., 2007, Ewen et al., 2000).

The obtained model was used to simulate water and sediment discharge, water depths and erosion/deposition rates in soil surface over the catchment during extreme rain events. In that way, the affected flooding and erosion prone areas under large rainfall events could be identified. The obtained results are very important when planning protective measures against flooding and erosion.

It is worth mentioned that SHETRAN (Ewen et al., 2000; Birkinshaw & Webb, 2010), similarly to other physically based distributed models of erosion and sediment transport, such as: WEPP (Nearing et al., 1995), SWAT (Neitsch et al., 2002), AGNPS (Young et al., 1989), GUESS (Rose et al., 1983), was often used to simulate only the runoff and sediment discharge at the catchment outlet (Singh et al., 2011; Dechmi et al., 2012;). On the other hand, simplified methods and/or models are used for assessment of flooding and erosion prone areas in catchments whereas these processes are often treated separately in the models. For example, potential flood risk areas were identified by analysing digital elevation models in (Alho et al., 2008; Manfreda et al., 2011) while a simplified numerical models were used in (Leopardi et al., 2002; Chang et al., 2010). Spatial and quantitative assessment of soil erosion on a catchment scale has often been performed by linking the empirical Universal Soil Loss Equation (USLE) (Wischmeier et al., 1978) with GIS (Perovic et el., 2012; Mishra & Deng, 2009; Manoj & Debjyoti, 2010;).

MATERIAL and METHOD

Method

The model was established by the calibration and the validation of the SHETRAN modelling system. The ArcGIS software ArcView 9.3 was used both for preparing the model parameters related to the physical characteristics of the catchment for each grid cell and for displaying and visualising the results of the model.

SHETRAN (version V4.4.1) water flow and sediment transport component were used in this study. The water flow component consists of 4 modules: evapotranspiration/interception; overland/channel; variably saturated subsurface and snowmelt (Ewen et al., 2000). Interception is calculated using a modified Rutter model (Rutter et al., 1972). Potential evapotranspiration is calculated using the Penman equation (Penman, 1948). Actual evapotranspiration is calculated using the Penman – Monteith equation (Monteith, 1965). The variably saturated subsurface (VSS) module simulates fully three – dimensional flow in saturated and unsaturated porous media. The SHETRAN sediment transport component simulates soil erosion by raindrop and leaf drip impact, soil erosion by overland flow, two dimensional convection of eroded sediment by overland flow and one dimensional movement of sediments by channel flow (Bathurst et al., 2007;). The transport capacity of overland flow can be determined by using the Yalin (1963) and Engelund - Hansen (1967) equations, while the transport capacity of channel flow can be determined by using the Engelund-Hansen and the Ackers and White (1973) equation.

Examples of recent applications of the SHETRAN model include (Birkinshaw & Webb, 2010; Wilkinson et al., 2010, Birkinshaw et al., 2011).

The model calibration and validation were performed in particular for hydrological and for sedimentation section of the model on the basis of the measured streamflow hydrographs and the measured maximim daily concentrations in a flow at the catchment outlet respectively. The evaluation of the model performance is based on simulations of runoff hydrographs and the graphs of sediment concentrations at the basin outlet and comparisons between the simulated and the observed values visually and using the two statistical parameters: the relative mean square error (RMSE) and the coefficient of determination (CD) (Gupta et al., 1998):

$$RMSE = \frac{100}{\bar{O}}\sqrt{\frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n}} \quad (1)$$

$$CD = \frac{\sum_{i=1}^{n}(O_i - \bar{O})^2}{\sum_{i=1}^{n}(P_i - \bar{O})^2} \quad (2)$$

where *O* is observed discharge (m^3 s^{-1}), *P* is simulated discharge (m^3 s^{-1}), $\bar{O}$ is the average value of the observations and *n* is the total number of observations. The RMSE value indicates the extent to which the simulations are overestimating or underestimating observed values, expressed as a percentage of the average value of the observations. The CD statistics describes the ratio of the scatter of the simulated to that of the observed values. A CD value of one indicates that the simulated and observed values match perfectly.

Study area

The torrential 114.31 km^2 Lukovska River catchment (Fig. 1) is situated in the south part of Serbia. The Lukovska River is a tributary of the Toplica River, which belongs to the catchment of the South Morava. Altitudes in the Lukovska River catchment vary from 515 meters above sea level in the lower parts of the catchment to 1652 meters above sea level in the source areas of the catchment. Once in every ten years floods in the Lukovska River flooding zones generate a flow of approximately 100 m^3s^{-1} whereas low flows constantly provide for 99 % flow of about 0.1 m^3s^{-1}, so that the ratio between small and large water flows is approximately 1:1000, which shows the torrential character of the streams.

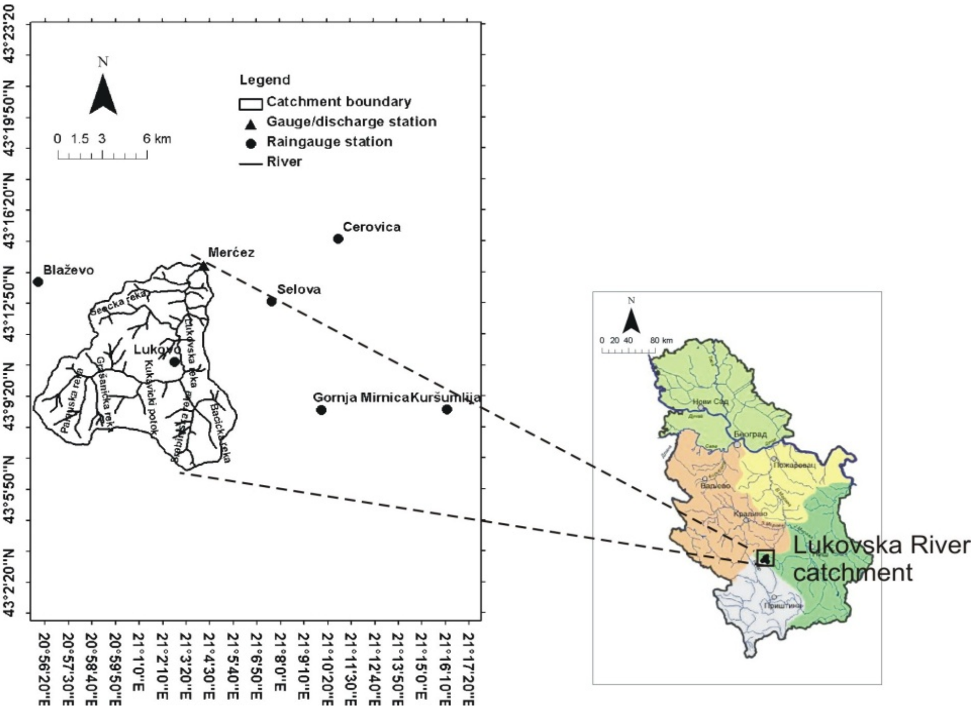

Figure 1. The Lukovska River catchment with river system and the rain gauging and hydrological stations in the catchment

From the studied catchment, the two soil types were identified: humus-siliceous soil on schists (82 %), and eutric brown soil on flysch (18 %) (Fig. 2a). Both types of soils are of clay - loamy texture. However, the eutric brown soil on flysch is morphologically more developed than the humus - siliceous soil on schists because it was developed by further pedogenesis of the humus - siliceous soil on schists. The dominant geological types in the catchment are flysch sediments (shales, marls, marly limestones, sandstones and siltstones) (84 %) (Fig. 2b). Due to cracked and tectonic damage of surface parts of the terrain, it is of low to medium water permeability to depths of 10 - 20 m below the groundwater level (Energoprojekt, 1986). There are seven different vegetation types in the Lukovska River catchment (Fig. 2c): deciduous forests (76 %), coniferous forests (2.22 %), mixed forests (0.87 %), transition area between forest and brush (9.83 %), agricultural land (6.86 %) and natural grasslands (4.21 %).

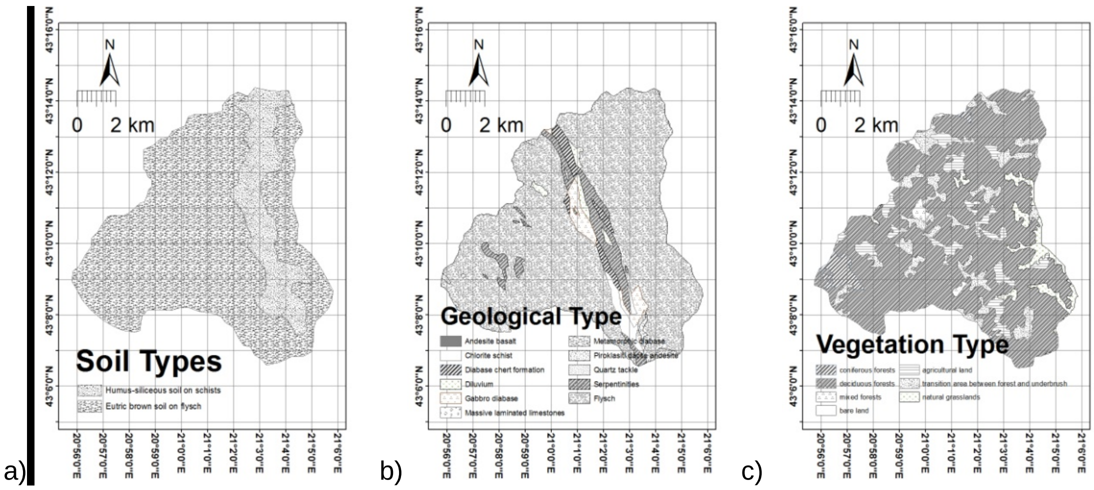

Figure 2. The digitized soil map (a), geological map (b) and vegetation map (c) of the Lukovska River catchment up to "Merćez" water level monitoring station

Material

Input data consist of meteorological data, digital elevation model, soil map, geological and vegetation maps. The basic input data for the model are the average hourly rainfall in the catchment during the analysed rain events. The Hydrometeorological Observation System consists of a single climatological station (Kuršumlia), 5 rain gauging stations (Selova, Lukovo, Stave, Blaževo and Gornja Mirnica) and a single hydrological station (Merćez) (Fig. 1). Daily values of precipitation are measured at the rain gauging stations in the catchment while hourly values of precipitation and of other meteorological data are measured only at the climatological station in Kuršumlia. The hourly values of runoff and the maximum daily values of sediment concentration are measured at the hydrological station "Mećez". It was assumed that there was an even distribution of rainfall at the same time over the whole surface of the basin, the intensity of which equals the values of average hourly heights of rainfall. Average hourly heights of rainfall were determined approximately basing on the hourly heights of precipitation measured at the climatological station in Kuršumlia and the daily rainfall for the whole catchment. The daily rainfall for the whole catchment were determined based on the daily rainfall from 5 rain gauging stations in the catchment by application of the method of Thiessen polygons (Thiessen, 1911). The model was calibrated on the example of a storm event in 1986 and validated for three other storm events in 1974, 1976 and 1979 (Table 1).

The adopted grid cell size in this study was the area of the size of 500 m * 500 m. All the remaining input data, the corresponding input parameters and the source of these data are summarised in Table 2. The preliminary values of the calibrated parameters were determined from the literature (Table 2), while their finally values were determined in the process of the model calibration and validation.

Table 1

Total amounts of precipitation (P_{tot}) fallen on the ground and the measured maximum daily values of sediment concentration (C_{max}) during the analysed rain events

The number of rain event	The simulation period	Duration of rain events	P_{tot} (mm)	C_{max} (kg/m^3)
1	7.05.1974.(8:00h)-11.05.1974.(23:00h)	8.05.1974(19:00)-9.05. 1974.(06:00)	41.51	3.0
2	6.06.1976.(7:00h)-8.06.1976(05:00h)	6.06.1976(07:00)-7.06.1976(06:00)	51.47	11.3
3	21.08.1979.(07:00h)-24.08.1979. (00:00h)	21.08.1979(20:00)-22.08.1979(06:00)	45.63	4.61
4	16.07.1986.(13:00h)-18.07.1986.(05:00h)	16.07.1986(22:00)-17.07.1986(00:00)	67.47	21.1

RESULTS and DISCUSSION

Through numerous simulations it was concluded that the size of the runoff and the sediment discharge in the catchment resulting from a given rainfall are most dependant on the following parameters of the hydrological section of the model: the Strickler coefficients for overland flow and for river flow, the vertical saturated hydraulic conductivity of the subsurface soil and the horizontal saturated hydraulic conductivity in the saturated zone. The above mentioned parameters primarily affect the value of surface runoff, except the horizontal saturated hydraulic conductivity in the saturated zone that affects the values of base flows. The most significant parameters of the sedimentation section of the model are: the erodibility coefficient due to rain and the erodibility coefficient due to overland flow. The values of these parameters were determined through the process of calibration of the model, and checked through the process of the model validation. The values of the all other model parameters were fixed and adopted from the literature (Table 2). The Strickler coefficients for overland flow and for streams, as well as the vertical saturated hydraulic conductivity of subsurface soil were adjusted to model the surface runoff. The horizontal saturated hydraulic conductivity in the saturated zone was adjusted to model the base flows.

Table 2
Input data and parameters used in the model

Component	Type of input data	Input parameters	Source of input parameters
Water flow	Meteorological	Hourly precipitation Hourly air temperature, Hourly relative air humidity Mean hourly wind speed insolation	Republic Hydrometeorological Service of Serbia (RHMZS)
	Hydrological	Registered streamflow hydrographs	
	Topographic	Digital elevation model (DEM) of the resolution: 25 m * 25 m	University in Novi Sad, Technical Faculty
	Land use / vegetation distribution	Strickler's coefficient for overland flow (S_t) and for channel flow (S_{tR})	Literature (Engman, 1986)
		Canopy drainage parameters Canopy storage Vegetation cover indices Vegetation root density distribution over depth	Literature (Lukey et al., 2000)
Sediment transport		Raindrop size distribution drop sizes Fall distance for canopy drainage Proportion of canopy drainage falling as leaf drip Ground cover fractions	Literature (Armstrong and Mitchell, 1987)
Water flow	Soil/rock types	Porosity and specific storage Residual water content Saturated conductivity in unsaturated soil (k_{vs}) Saturated conductivity in saturated soil (k_{hs}) vanGenuchten-α, vanGenuchten-n	The field research and literature (Carsel and Parrish, 1988)
Sediment transport		Erodibility coefficient due to rain (K_R) Erodibility coefficient due to overland flow (K_F)	Literature (Bathurst et al., 2007)
		Sediment porosities particle size distribution	Literature (Engman, 1986)
	Sedimentation data	Registered maximum sediment concentrations	RHMZS

During the calibration and validation of the sedimentation part of the model, the Yalin (1963) and Engelund - Hansen (1967) equations were compared in order to determine the equation for calculating the sediment transport capacity of overland flow. The Engelund - Hansen and the Ackers and White (1973) equations were compared in order to determine the equation for calculating the sediment transport capacity of channel flow. The equation of Engelund - Hansen was adopted to be an appropriate equation for calculation of the transport capacity for both the overland flow and channel flow because it produced realistically possible values of sediment concentration in the flow. The calibrated parameters are shown in Table 3.

The results of the model calibration and the validation are presented in Fig. 3, together with the correlation relations between the simulated and the registered streamflow hydrographs. Based on a visual inspection of the predicted and the registered hydrographs as well as on the obtained correlation relationships and statistics CD and RMSE it can be concluded that a satisfactory agreement between the modelled and the registered runoff hydrographs was obtained. The largest discrepancy between the modelled and the observed hydrographs was noticed on the example of the wave in 1974 because this wave of water belonged to a medium and not to high flows. The predicted values of maximum sediment concentrations in flow corresponded entirely to their observed values for the all analysed waves.

Table 3
Calibration intervals and the optimal values (in parenthesis) of calibrated parameters for the Lukovska River catcatchment

Soil/rock type	Depth (m)	Texture	soil/rock parameters k_{vs} (m day^{-1})	k_{hs} (mday^{-1})	K_R (J^{-1})	K_F mg(m^{2}s)$^{-1}$
Humus-sliceous soil on chists	0-0.30	Clay loam	0.031-0.061 (0.048)		0.1-10 (1.0)	0.5-10 (2)
Clay base	0.30-0.7	Clay	0.013-0.032 (0.019)			
Flysch	0.7-4			0.01- 5 (3.2)		
Eutric brown soil on flysch	0-0.50	Clay loam	0.031-0.061 (0.048)		0.1-10 (0.5)	0.5-10 (1)
	0.50-1.1	Loam	0.145-0.179 (0.163)			
Clay base	1.1-2	Clay	0.013-0.032 (0.019)			
Flysch	2-4			0.01-5 (3.2)		
Vegetation type	Overland flow/channel parameters S_t (m$^{1/3}$s^{-1})	S_{tR} (m$^{1/3}$s^{-1})				
Deciduous forests	4 – 8 (4.65)					
Coniferous forests	4 – 8 (4.65)					
Mixed forests	4 – 8 (4.65)	15-40 (33)				
Transition area of forests and underbrush	8 – 15 (9.0)					
Agricultural land	8 - 20 (16.0)					

The extreme storm event in the Lukovska River catchment in July 1986 produced about 67.5 mm of rain over two hours. Rise and fall of the resulting flood was very sharp with the peak flow of 69.2 m^{3}s^{-1}. occurring just 4 hours after the rain had begun (Figure 3). The temporal and spatial distribution of water depths and erosion/deposition rates were presented for the typical torrential rain event in 1986 in Figs. 4 and 5, respectively. The water depths on soil surface and in streams and the erosion/deposition intensities follow the changes of runoff values. Their values increased during the time of runoff increasing and reached its highest values at the time of occurrence of the maximum runoff in the catchment, which was 2 hours after the rain had begun. After that, the decrease of runoff caused the decrease of erosion and sediment transport capacity of flow as well as the increase of the sediment deposition on soil surface.

The water depths on soil surface and in streams were in the range of 0 to 3.7 m. The maximum water depth of 3.7 m was observed at the catchment outlet in the moment of occurring of the peak discharge at the catchment outlet. In that moment the water depths in other parts of the catchment began to decrease. It can be noticed the increase of water depths on soil surface and in channel network from higher to lower altitudes (Fig. 4). The obtained results of erosion/deposition intensities for each grid cell were classified using the nine classes listed below: extreme erosion (> -30 tha^{-1}), high erosion (-30/-10 tha^{-1}), medium erosion (-10/-3 tha^{-1}), low erosion (-1/-3 tha^{-1}), stable (-1/1 tha^{-1}), low deposition (1/3 tha^{-1}), medium deposition (3/10 tha^{-1}), high deposition (10/30 tha^{-1}) and very high deposition (>30 tha^{-1}) (Fig. 5). This classification has been derived by adopting the erosion risk classes used by INRA (The Institute National Recherche Agronomique) (Le Bissonnais et al., 2002) and by extending them to take deposition into account.

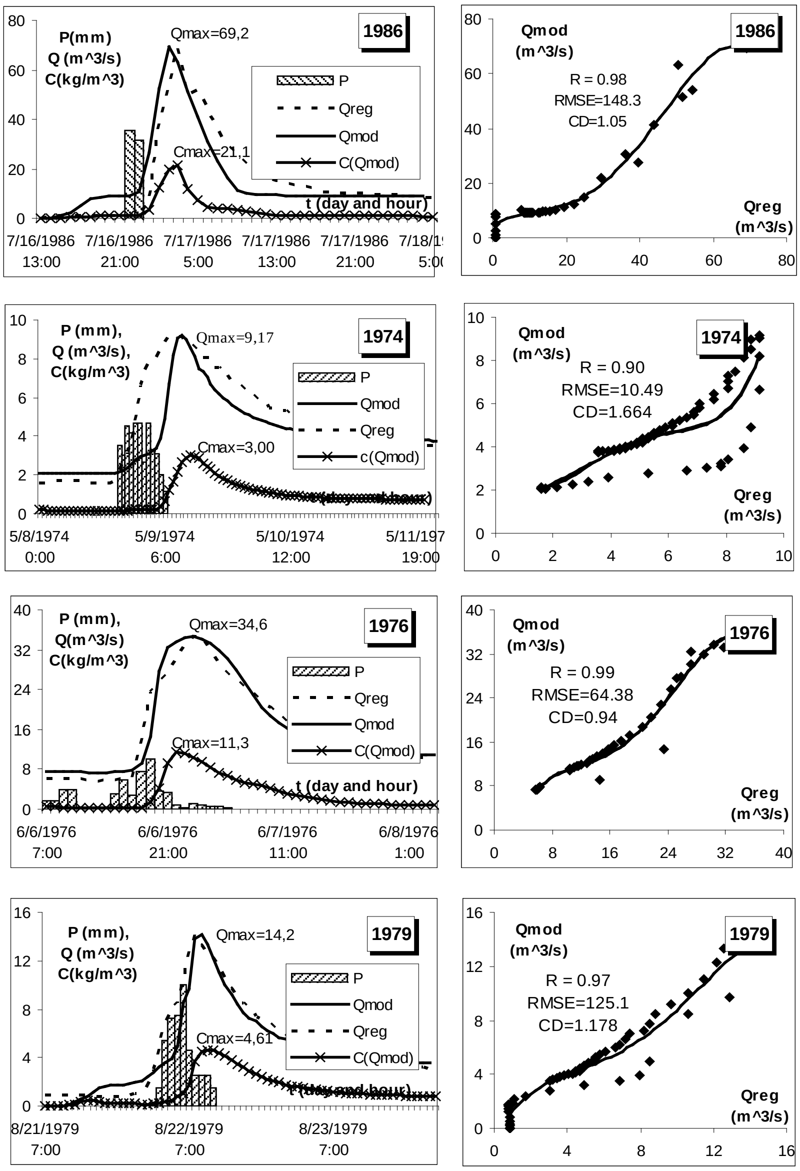

Figure 3. Predicted (Q_{mod}) and registered (Q_{reg}) hydrographs and predicted sediment concentrations c (Q_{mod}) for the calibration and the validation rain events (P) (a). Correlative relationships between the registered and the predicted hydrographs for the calibration and the validation rain events (b)

The analysis of the obtained spatially distributed maximum erosion intensities (Fig. 5c) indicate that approximately 59.7 % of the total catchment area was affected by erosion during this rain event with the average erosion intensity of 3.24 tha^{-1}. It was also estimated that nearly 67.7 % of the catchment was stable or affected by low erosion. The classes of medium erosion and medium sedimentation have been observed for 28.6 % and 3.13 % of the catchment area, respectively. The high erosion intensities were identified for only 0.58 % of the area, which were mostly located in the zones of steep slopes, in the upper parts of the catchment. The maximum erosion intensity of 11 tha^{-1} in the catchment was obtained for the area located on the humus siliceous soil and in the deciduous forest. The average erosion intensity for the humus siliceous soil on schist was 2.32 times higher than for the eutric brown soil on flysch. Beside that the forest areas were found to be more susceptible to soil losses by water than agricultural land and in the range with natural grasslands. The obtained results can be explained by the fact that degraded forests are often located on steep slopes with poorly developed humus-siliceous soil on schists. Basing on the above, it can be concluded that the influence of intensive storm event, the steep slopes of the terrain, the weak soils and the rocks of low permeability resulted in the intensive torrential wave of short duration containing lot of eroded sediments.

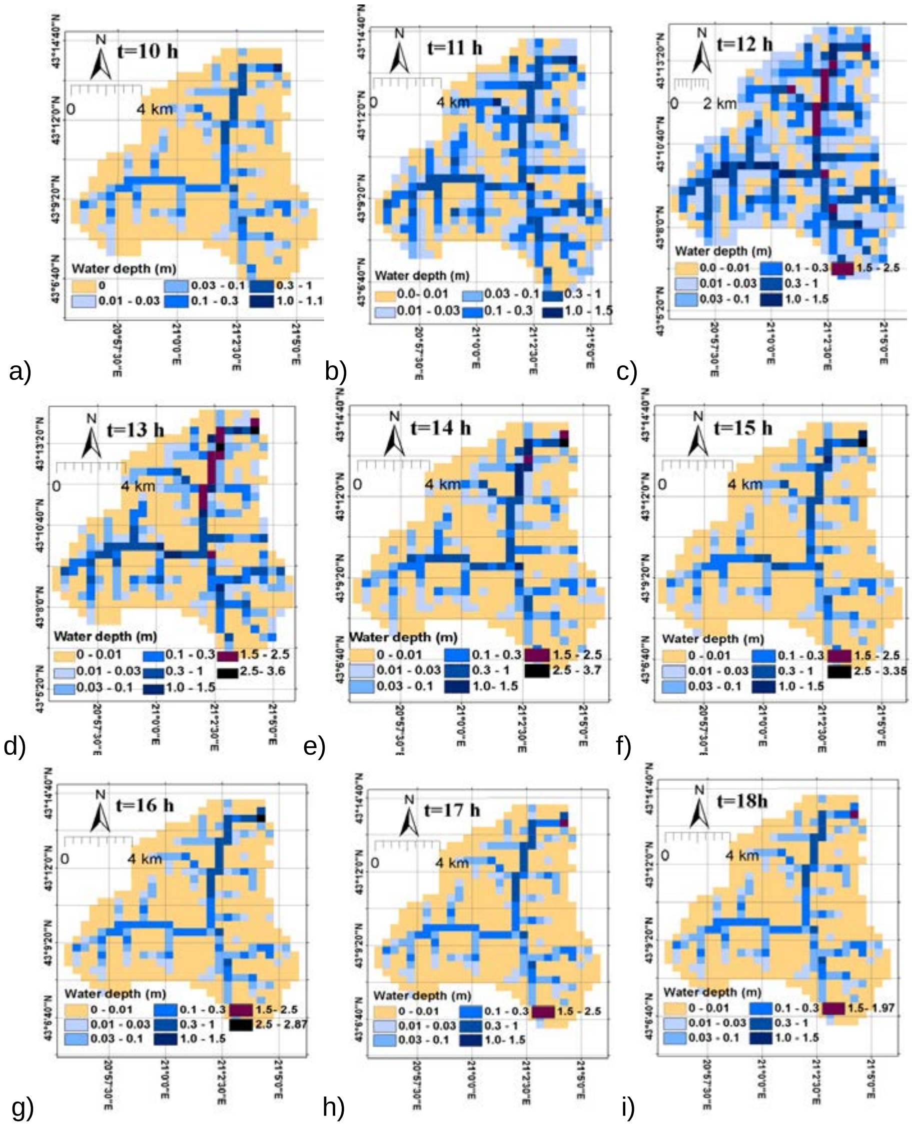

Figure 4. Water depths in streams and on soil surface in the Lukovska River catchment a) 16.07.1986. at 23.00h (t=10h); b) 17.07.1986. at 00.00h (t=11h); c) 17.07.1986. at 01.00h (t=12h); d) 17.07.1986. at 02.00h (t=13h); e) 17.07.1986. at 03.00h (t=14h); f) 17.07.1986. at 04.00h (t=15h); g) 17.07.1986. at 05.00h (t=16h); h) 17.07.1986. at 6.00h (t=17h); i) 17.07.1986. at 07.00h (t=18h);

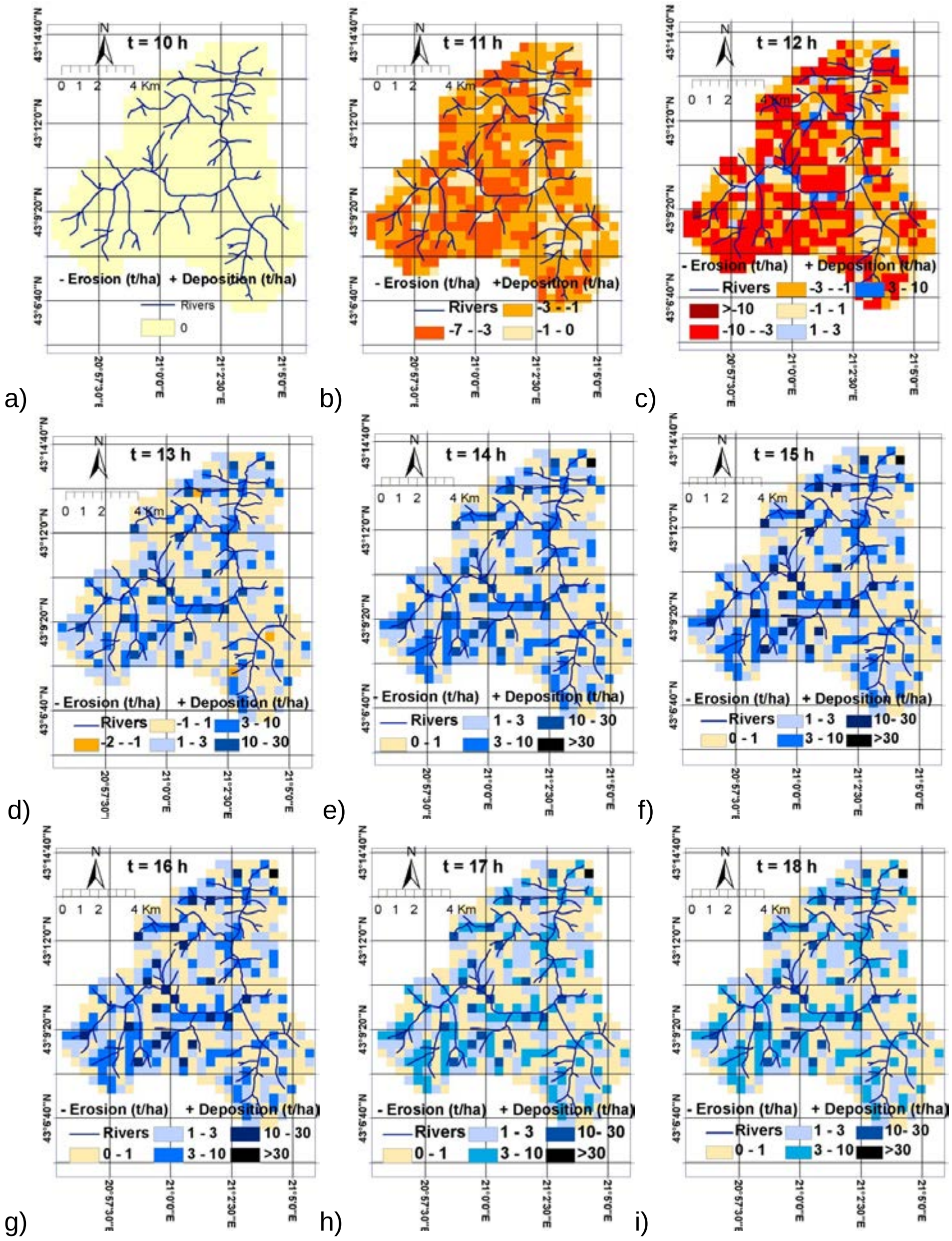

Figure 5. Spatial representation of erosion (-) and deposition (+) intensities in the Lukovska River catchment: a) 16.07.1986. at 23.00h (t=10h); b)17.07.1986. at 00.00h (t=11h); c) 17.07.1986. at 01.00h (t=12h); d)17.07.1986. at 02.00h (t=13h); e) 17.07.1986. at 03.00h (t=14h); f)17.07.1986. at 04.00h (t=15h); g) 17.07.1986. at 05.00h (t=16h); h) 17.07.1986. at 06.00h (t=17h) and i) 17.07.1986. at 06.00h (t=18h)

CONCLUSIONS

The joint application of the SHETRAN modelling system and the GIS in this study resulted in a physically based distributed rainfall-runoff and erosion and sediment transport model. Since investigations of erosional and sediment transport processes in torrential basins in Serbia show that most erosion and sediment transport take place in two or three storms each year the model was calibrated and validated to four representative intensive rain events on the example of the torrential Lukovska River catchment in Serbia.

In addition to the estimation of water and sediment discharge at the catchment outlet, the obtained model was used to estimate the spatial and temporal distributions of water depths and erosion/deposition intensities within a catchment during one rain event. In that way, the areas which could be expected to be affected by flooding and by intensified erosion can be identified. The estimated erosion rates corresponded to observed rates of erosion in Europe during extreme rain events (Morgan, 1998). The obtained results of water depths and erosion intensities over the catchment during one intensive rain event present useful general indicators on the basis of which relevant decisions in regard of water and sediment management can be brought.

Many uncertainties in the model calibration and validation concerning the evaluation of parameters will be minimized by establishing hydrological stations in some of the tributaries of the Lukovska River where the continual measurements of water and sediment discharge will be performed. In this way, it could be possible to check whether the model could represent internal hydrological, erosional and sedimentation processes properly. That would set prerequisities for a wider application of a developed model type.

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Drought occurrence and irrigation requirements in central Vojvodina

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ABSTRACT

Soil and climate conditions in Vojvodina Province, the largest granary in Serbia located at the northern part of the Republic, are very favourable for successful crop production. The most common type of soil is chernozem, with favourable chemical and water-physical properties, where field and vegetable crops can be grown in conventional and organic production without restriction, therefore achieving high yields of good quality. Generally observed, climate conditions in Vojvodina are also suitable for crop production. Limiting factors are the sum and especially the distribution of precipitation, both in years and seasons, and in shorter periods, especially if they coincide with plants' critical stages for water.

Therefore, it is necessary to monitor and analyse all the parameters in the process of crop production in order to spot the negative trends that could threaten the stability and quality of production. In that case, it is necessary to react timely with measures that will stop or slow down the negative processes in order to maintain or repair existing state of production.

This paper analyses the climate parameters that significantly affect water and nutrient regime of soil and crops. Average daily air temperatures were particularly analysed as a factor on which a potential evapotranspiration and crop needs for water depend, as well as the precipitation, which is the main source of crops' water supply. Mutual influence and connection of these climate parameters, crops and soil affect the occurrence of drought and need for irrigation as a measure for the most successful regulation of water deficit for successful crop production.

The sum and distribution of precipitation, as well as the average daily air temperatures, were analysed per years, seasons and months for the period of 30 years (1987-2016) in Bački Petrovac, which is located in central part of Vojvodina (φN 45° 20´, λE 19° 40´, 82 mnm). Based on the analyses, potential plant evapotranspiration was determined using Thornthwaite and Türc method, in order to define crops' water supply through de Martonne aridity index (IdM), as well as drought occurrence, its duration and intensity in this area.

A high percentage of dry years were found by the analysis of meteorological data for central Vojvodina. Drought occurrence due to uneven distribution during growing period is even more frequent and occurs in almost all years, as well as in those with average and above average precipitation sum.

These results were compared to the meteorological data on precipitation and mean daily air temperatures for Bački Petrovac from previous years (1948-1990), which analyses were shown in *Osnovi zaštite korišćenja i uređenja poljoprivrednog zemljišta opštine BačkiPetrovac* (Basics of protection and use of agricultural land in the municipality of Backi Petrovac) (Hadžić et al., 1996). Increase of mean daily air temperatures can be seen in all months, especially during growing period (1.0-1.4°C), and averagely 0.8°C or 7.3% per year. Thus, potential evapotranspiration (ETP) was increasedas thermic process depending on air temperature. The lack of water needed to meet the crop needs for water was increased, especially in July and August, in spite of precipitation sum that was at the same level or insignificantly higher than the sum in previous period (346.5 mm in previous period versus 371.4 mm in the last thirty years for growing period).

KEY WORDS: precipitation, air temperatures, potential evapotranspiration, crops' water supply, drought

INTRODUCTION

Soil and climate conditions in Vojvodina, the largest wheatland situated in the northern part of Serbia, are very favourable for successful plant production. The most widespread soil type is chernozem, characterized by good chemical and physical properties (Živković et al., 1972; Glamočlija et al., 2015), suitable for cultuvation of field and vegetable crops with high yields and good quality, under either conventional or organic cropping system. Generally, climate conditions in Vojvodina are suitable for plant production (Spasova et al., 1999). One of the limiting factors of plant production is the low amount, as well as unfavourable long-term (across years and growing seasons) and short-term distribution of rainfall (Maksimović et al., 2017), especially when it occurs during the critical stages of high crop water requirement. Monitoring, analysis and estimation of weather and climate conditions are essential and therefore a primary subject of interest and analysis to many authors and studies (Dragović, 1995; Popović et al., 2005; Lalić et al., 2011).

One of the most harmful weather conditions in our region - drought - is by definition caused by a low amount of rainfall, insufficient for normal growth and development of cultivated crops. According to Miljković and Škorić (2001), drought occurrence has increased in Serbia, becoming an almost continuous condition. Using the method applied by Hargreaves in 1992, Bošnjak (1995) found that Vojvodina has a semi-arid or arid climate in summer, primarily in July and August - the finding which was also confirmed by Dragovic et al. (2005).

Many meteorological models concerning Europe and especially Central Vojvodina, Serbia, predict the worsening weather conditions: high temperatures, drought and water availability decline (IPCC, 2007). For this reason, it is necessary to monitor and analyze parameters of plant production process so as to observe the negative trends which might impede stability and quality of production. Measures are required in such cases in order to terminate or slow down negative processes, and maintain or improve production. The effects on plant production, caused by unfavourable climate factors, temperature and its extreme values, as well as lack of rainfall, can be reduced by choosing tolerant cultivars, earlier planting, use of appropriate production technology (Dragovic et al., 1997; Popović et al., 2015), but most of all by irrigation.

The paper studied climate parameters which massively affect water and nutrient regime of soil and plants. Mean daily air temperatures were specifically analysed, as agents of potential evapotranspiration affecting plant water requirements, as well as rainfall as the main source of plant water and nutrient supply. Mutual influence and relationship between the climate parameters, plants and soil, affect the occurrence of drought and the need for irrigation as the most successful measure in regulating water deficit in plant production.

MATERIAL AND METHOD

The amount and distribution of rainfall and mean daily air temperatures were examined across years, growing seasons and months, during the period of the last 30 years (1987-2016). The study was carried out in Bački Petrovac, situated at the central part of Vojvodina in the vicinity of Novi Sad (φN 45° 20´, λE 19° 40´, 82 asl). Based on the obtained results, potential evapotranspiration and water balance were determined by the method of Thornthwaite, rain index by the method of Lang, and drought index by de Martonne's method, so as to determine plant water supply, drought occurrence, duration and intensity in this region, as well as the need for irrigation.

RESULTS AND DISCUSSION

The analysis of a thirty-year sequence of meteorological data (1987-2016) collected from Bački Petrovac confirmed that the mean air temperatures were at 18.7°C during vegetation periods, whereas mean annual temperatures were at 11.8°C. The results were compared to meteorological data from previous years (1948-1990) concerning mean daily temperatures and rainfall sums in Bački Petrovac, and the analyses were reported in the text book "Basics of protection and use of agricultural land in the municipality of Backi Petrovac" (Hadžić et al, 1996). Increase in mean monthly air temperatures was noticeable in all the months of study, mainly in July and August (by 1.4°C), but also during the whole vegetation period (1.0-1.4°C), while mean annual temperature increase was 0.8°C or 7.3% (Tab.1).

After completing the analysis of air temperature and rainfall data, collected at meteorological station Belgrade (100 km from the meteorological station) for the period of 107 years, Popović (2007) confirmed the trend of air temperature increase by 1.1°C. These results partly correspond to the results obtained by many other authors from the countries within the Danube region, as cited by Prohaska and Ristić (2001), who predicted the air temperature increase of 3-4°C in the next 100 years.

Table 1.
Rainfall sum (mm) and mean monthly air temperatures (°C) in central Vojvodina (Bački Petrovac), Serbia

Months	Rainfall (mm)			Mean monthly air temperatures (°C)		
	Period		Difference	Period		Difference
	1948-1990	1987-2016		1948-1990	1987-2016	
January	37.8	38.4	+0.6	-0.5	0.7	+1.2
February	41.1	34.7	-6.4	1.7	2.4	+0.7
March	38.7	37.5	-1.2	6.1	7.0	+0.9
April	47.4	46.6	-0.8	11.4	12.4	+1.0
May	58.4	69.6	+11.2	16.5	17.7	+1.2
June	84.9	81.1	-3.8	19.6	20.8	+1.2
July	55.9	66.5	+10.6	21.1	22.5	+1.4
August	58.5	50.7	-7.8	20.5	21.9	+1.4
September	41.5	56.2	+14.7	16.7	16.9	+0.2
October	39.4	54.8	+15.4	11.3	11.7	+0.4
November	51.9	45.8	-3.4	5.9	6.2	+0.3
December	56.2	43.6	-12.6	1.5	1.4	+0.2
Vegetation period	346.5	371.4	+24.9	17.6	18.7	+1.1
Annual Value	611.8	628.2	+16.4	11.0	11.8	+0.8

During the last 30 years, mean rainfall sums have been slightly higher compared to the analyzed period, i.e. 25 mm more rainfall was recorded during vegetation periods (371 mm vs 346 mm) and 12 mm more rainfall annually (628 mm vs 612 mm), which does not match the predicted values (Lalić et al, 2011). Annual and monthly oscillations are much more prominent than before (Graph. 1) ranging from 248 mm in 2000, to 973 mm in 2010, or 103 mm in 2000, to 636 mm in 2010 regarding the vegetation period (April - September).

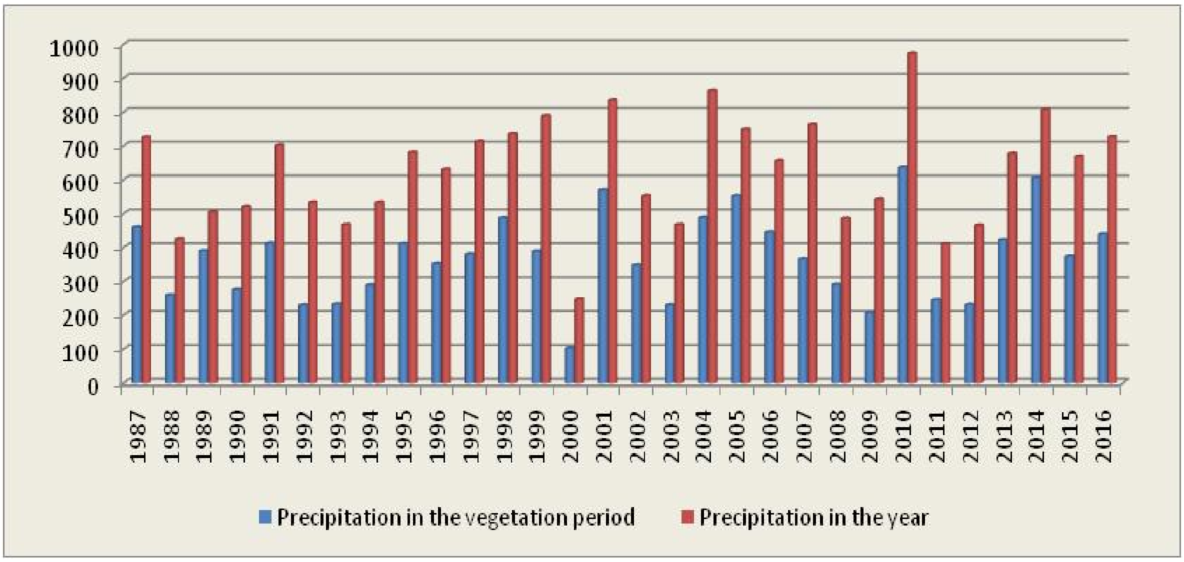

Figure 1. Rainfall sums (mm) in central Vojvodina during vegetation periods and annual rainfall (Bački Petrovac, 1987-2016)

Periods of insufficient plant water supplies are recorded even in the years with ample amounts of rainfall, as indicated by the drought index according to de Martonne. De Martonne's aridity index indicates longer or shorter drought periods during one year. The calculated indexes regarding the 30-year period (1987 – 2016) and the previously examined period (1948-1990) are presented in Table 2.

Table 2.
Monthly drought index according to de Martonne

Month	Period 1948-1990	Period 1987-2016
January	47.7	43.1
February	42.2	33.6
March	46.0	26.5
April	26.6	25.0
May	23.0	30.2
June	34.4	31.6
July	21.6	24.6
August	23.0	19.1
September	18.6	25.1
October	22.2	30.3
November	39.2	36.0
December	58.1	45.9
Annual Value	29.1	28.8

30-40 humid conditions – no irrigation
20-30 semiarid conditions – irrigation required
10-20 arid conditions – irrigation necessary
<10 very arid conditions – irrigation mandatory

The extended period of semiarid climate conditions, currently lasting from March to October, has been reported (April-October in the previously reported period), except for June as this region's peakof rainfall. According to de Martonne's analysis of hydrothermal coefficient, adjusted to irrigation requirements by Milivojević (1980), natural soil water regime conditions indicate the need for irrigation.

Lang's Rain-Factor, which represents the relationship between annual rainfall sums and mean annual air temperature, also indicates more humid climate compared to the last 30 years, as the rain index value reflects the steppe climate more closely than before. Rain factor values of 40-60 was characterized by Lang as a steppe and savannah climate, i.e. the closest form of the humid climate. Arid climate includes values below 40, whereas humid climate is indicated at values above 60. According to our data, rain factor for the periods 1987-2016 and 1948-1990 was 53.2 and 55.6, respectively.

Other authors (Popović et al., 1994) report the decreasein annual rainfall sums (1931-1960 vs 1961-1990) especially in the areas with mean rainfall sums below 650 mm, i.e. eastern Vojvodina, Šumadija, Pomoravlje, Stig and Negotinska Krajina, as the main agricultural regions of our country.

High percentage of drought years has been determined by the analysis of meteorological data for central Vojvodina. Drought occurrence due to uneven distribution of rainfall during vegetation periods has become frequent in almost all the years of study, including the years with average and above average amounts of rainfall.

The results of the 30-year period analysis (1987-2016) in Bački Petrovac indicate the lack of rainfall in central Vojvodina during summer months (in 83% cases in July and 87% cases in August), as compared to the water requirements of most cultivated plants (Tab. 3). A similar trend was detected in the same region by Maksimović and Dragović (2002) by analyzing data obtained from 1948 – 2000 at the neighbouring meteorological station Rimski Šančevi, according to which drought periods occured in July in 77.4% cases, and in August in 86.8%.

Table 3
Percentages of dry years according to rainfall sums for July and August in the central part of Vojvodina Province (Bački Petrovac, 1987-2016)

Rainfall, mm	July		August		Drought ranking
	No.	%	No.	%	
0-25	5	16.7	8	26.7	Extremely dry
26-50	11	36.6	10	33.3	Very dry
51-75	5	16.7	4	13.3	Dry
76-100	4	13.3	4	13.3	Moderately dry
	25	83.3	26	86.6	Total dry years
101-125	-	-	2	6.7	Moderately rainy
>126	5	16.7	2	6.7	Rainy
Total	30	100	30	100	

Water fluctuation and consumption affect the water content in the arable soil layer as well as its plant availability (Pejić et al., 2010), thus requiring soil water balance monitoring. Potential evapotranspiration (ETP), as a thermal process dependent on air temperatures, increases due to increased air temperatures in central Vojvodina. The deficit of water needed for plant requirements is increased in central Vojvodina, especially in July and August, regardless of the sum of rainfall, equal to or slightly higher than the sum recorded in the earlier period (346.5 mm in the previous period compared to 371.4 mm during a 30-year analysis of the vegetation periods, from 1987 to 2016). According to the water balance analysis, carried out by the method of Thornthwait for the period 1987-2016 (Tab. 4) there is a surplus of water of 65 mm in the winter period (I-III month), while the average water deficit in July and August amounts to 77 mm and 81 mm, respectively. September water balance deficit of about 24 mm is not significant since the vegetation period of most cultivated crops ends and maturity or harvesting period starts by that time. Water deficit of 181 mm should be compensated by irrigation so as to improve soil water balance and plant nutrient regime. As a cultuvation practice irrigation would help sustain and improve soil fertility and plantnutrient regime, which would ultimately stabilize and increase crop yield and good quality (Sikora et al., 2015).

Table 4
Water balance in central Vojvodina (Bački Petrovac, period 1987-2016)

	X	XI	XII	I	II	III	IV	V	VI	VII	VII	IX	Total
i	3.62	1.38	0.15	0.05	0.33	1.66	3.96	6.78	8.66	9.75	9.36	6.32	52.02
(ETP)	47.11	20.22	2.78	1.11	5.71	23.76	50.90	81.78	101.40	112.59	108.61	76.90	-
ETP	44.29	15.97	2.09	0.88	4.62	24.24	57.52	104.68	130.81	147.49	131.41	79.97	743.98
P	54.80	48.50	43.60	38.40	34.70	37.50	46.60	69.60	81.10	66.50	50.70	56.20	628.20
r	10.51	43.04	84.55	100.00	100.00	100.00	89.08	54.00	4.29	0.00	0.00	0.00	-
Δ	10.51	32.53	41.51	15.45	0.00	0.00	-10.92	-35.08	-49.71	-4.29	0.00	0.00	-
ETR	44.29	15.97	2.09	0.88	4.62	24.24	57.52	104.68	130.81	70.79	50.70	56.20	562.79
wd	-	-	-	-	-	-	-	-	-	76.70	80.71	23.77	181.19
we	-	-	-	22.07	30.08	13.26	-	-	-	-	-	-	65.40

i - monthly thermal index, (ETP) - uncorrected potential evapotranspiration, ETP - corrected potential evapotranspiration, P – rainfall, r – soil water reserve, Δ - the amount of water that fills (+) or is taken (-) from the reserve, ETR - real evapotranspiration, wd – water deficit, we – excess water

CONCLUSIONS

The amount and distribution of rainfall and mean daily air temperatures were examined across the years, growing seasons and months, during the period of the last 30 years (1987-2016.). The study was carried out in Bački Petrovac, situated in the central part of Vojvodina, in the vicinity of Novi Sad.

Summer droughts were observed throughout the years of study, namely 83.3% in July and 86.6% in August, when monthly sums of rainfall (66.5 mm or 50.7 mm, respectively) are insufficient for plant water requirements. Drought caused by uneven distribution of rainfall during the vegetation period had become more frequent and occured in almost all the years of study. According to the drought index by de Martonneand rain factor by Lang, the region of central Vojvodina requires irrigantion as it steadily becomes more arid as compared to the earlier period from 1948 to 1990.

Increased mean daily air temperatures were recorded in all studied months, especially in the vegetation period (1.0-1.4°C), and annual increase was 0.8°C or 7.3%. Potential evapotranspiration (ETP), being a thermal process dependent on air temperatures, was thus increased. According to the water balance by Thornthwaite, potential evapotranspiration (ETP) was 744 mm, while real evapotranspiration (ETR) was 562 mm. Increased lack of plant available water, insufficient to supply the necessary water requirements, occurred in July and August regardless of rainfall sums, equal to or higher than the rainfall sum recorded during the vegetation periods under previous observation (346.5 mm recorded in the previous period compared to 371.4 mm recorded in the last 30 years).

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Vertical / city farming in Serbia as an alternative to soil farming in horticulture - General overview –

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ABSTRACT
According to a new UN DESA report, “World Population Prospects: The 2015 Revision” (2015), the current world population of 7.3 billion is expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100. Growing population on the planet requests new solutions of plants growing, which would not carry out only on the soil and which would lead to producing high quality and safe food, high yields and protection of environment.
New soilless methods have been examined in protected areas: greenhouses with big multilayers fully equipped (for young plants and bulbs), greenhouses with small multilayers for propagation and young plants production, small vertical set-up in closed environment for various crops and research appliance (container, chamber), small vertical farms in closed environment for various crops and research appliance, fully automated large farms in closed and controlled environment for notable production of leafy vegetables and herbs.
Production of leafy vegetables and herbs in closed fully climate-controlled greenhouses / rooms, around the world showed a lot of good results, some of which are: keeping the environment clean, producing safe and healthy food, achieving optimal efficiency in the usage of space due to multilayer production, reducing the expenses in water and nutrients, enabling energy saving is through LED lighting. Also, in propagation areas the germination of plants is quicker and roots grow faster, while plant quality is increased and consistent. Plant productivity and yields are higher than in traditional crops production. These are only some of the virtues of vertical / city farming, and many are still left to be examined in the light of the ongoing growth of world population.
KEY WORDS: overpopulation, vertical / city farming, multilayers, LED lighting, climate control.

INTRODUCTION
According to a new UN DESA report (United Nations, Department of Economic and Social Affairs “World Population Prospects: The 2015 Revision” (2015), the current world population of 7,3 billion is expected to reach 8,5 billion by 2030, then 9,7 billion in 2050, and 11,2 billion in 2100. The growing population of the planet requires new solutions for plant / food production, which will not only refer to cultivation on the soil in open field. It implies vertical cultivation of plants in modern greenhouses and fully closed systems with completely automatic regulation of climatic and other conditions during the growing period. It means applying the newest technologies, which would result in the production of high quality and safe food in cities, on smaller areas, while achieving high yields, and contributing to environment protection. Scientific examination of plant production in closed systems with complete automatic climate control, hydroponics and automation of the production process is one of special interests in plant sciences (Sprecht et al., 2014). One of the common terms, which is referring to that type of plant cultivation is “city farming”. To meet the demand for food production and all accompanying needs of a growing and increasingly affluent population, experts predict that it would be needed to double the global crop production over the next 35 years.

MATERIAL and METHOD
City farming comprises production of various crops in urban areas, in closed objects with artificial light, in order to provide successful process of photosynthesis and crop productivity. It is one of the solutions for a growing population of the planet in the near future, as well as for the present moment.

Closed systems are equipped with all installations, software and computers which are necessary for providing optimal climate and other conditions for plants growth and their development. The most important installations are: light, CO_2, water, ventilation, electrical, heating installations and installations for hydroponics. This kind of high-tech urban farming became interesting in the recent decades, and is gradually developing.

Scientific research intended for high-tech city farming has mainly been directed towards leafy vegetables, which are hydroponically grown, using nutrient film technique (NFT) or rockwool for horticulture. Leafy vegetables most often used in experiments, and practice, are lettuce, spinach, medical and spicy plants. Nowadays, scientific examinations are being carried out with various cabbage species, tomato, and even root vegetable crops.

High-tech city farming can be conducted in various spaces, such as rooms, different chambers, buildings intended for such purpose, removable grow-trainers. Most importantly, such spaces should be equipped with proper installations, which would provide optimal conditions for plants' growth and development. It has been shown in scientific research and practice, that no pesticides are needed in optimal conditions.

Space for high-tech city farming should be equipped with light emitting diodes (LED lamps), which are constructed so as to provide optimal light recipes for every phenophase of the plant's growth, in order to assure light necessary for photosynthesis and plant productivity. Installations for CO_2 implementation, combined with optimal light and air humidity, enable the opening of stomas for necessary CO_2 consumption. In this way, it is possible to produce high quality edible plants.

Plants are grown vertically, on layers with installed hydroponics growing systems like NFT system, or combined NFT system with rock-wool cubes, and LEDs above the plants rows. Range between layers depends on the crops, types of LEDs, and space height adapted for the city farming. This enables efficient growth of various crops on a smaller area, high quality of fresh vegetables and greater yields (Heuvelink and Kierkels, 2017).

RESULTS and DISCUSSION

As leafy vegetables are major crops in high-tech city farming, light emitting diodes (LED) are on 18 hours during the day, while being off 6 hours during the night. While the lights are on, dose of CO_2 is in range of 600-800ppm (or, up to 1000ppm, depending on the species). While the lights are off, ambient CO_2 is typically 400ppm. Wave length of the light is in range of 400–700nm, which is adequate for photosynthesis. Air humidity is kept on 70-75% during the day and 80-85% during the night (when lights are off). In optimal conditions, the use of pesticides is not needed, and many scientists are likely to equalize high-tech city farming with organic farming, according to official principles of organic crop production.

According to Despommier (2010), outdoor farming is subjected to various levels of attack from a wide variety of microbes (viruses and bacteria) and plant pests often resulting in significant loss of many types of annual harvest, especially caused by significant climate changes in the last decades. Well-engineered indoor growing facilities, as high-tech city farming, can minimize or even eliminate the possibility of such losses, and without the use of pesticides. In optimal growing conditions for plants, development of various diseases is almost eliminated, and plants are strong and very resistant towards diseases and pests (Ben-Yakir and Fereres, 2015). At the same time, significant studies have shown that in a well-controlled environment, nutritive characteristics of leafy and other vegetable crops (lettuce, spinach) become more qualitative (e.g., colour, nutrients, shelf life) than in traditional way of growing (Nicole et.al, 2016). According to Elena Dănilă and Dorin D. Lucache the light's wavelength is also important, as it's correlated with the colour and light absorption (Table 1).

With the progress of light emitting diode (LED) lighting efficiency and the knowledge of light-plant interaction, better quality control can now be achieved together with improved energy efficiency (Nicole et al., 2016). It is possible to achieve high growth efficiency (in g mol-1) and at the same time fulfil the requirements on crop quality; for example: high yield, good colour (high anthocyanin index or chlorophyll index) and texture (firmness), high flavonoids content or controlled nitrate levels.

Regarding the light intensity, LED lighting with a large variety of spectral composition / recipes (from UV to far-red) and dynamic control could be used with a total radiation level dimmable per colour up to 600 µmol m^{-2} s^{-1} (Nicole et al., 2016; Ntagkas et al. 2016). According to Nicole et al. (2016) and Yong Xu (2016), light emitting diodes (LED) are an efficient source of light in horticulture needed for photosynthesis and plant productivity. Characteristics which positioning LED lighting better than other types of lightning in horticulture, are their relatively low energy consumption, lower exposure of the plants to radiation heat, long lifetime, flexibility in positioning above or inside a crop, the ability to control the light spectrum and produce high light levels. At the same time, the possibility to control the light spectrum offered to the plants has been a major reason for applying LED lighting in order to optimize photosynthesis, photomorphogenesis and nutrient content. It enables additional control to the final product quality that was never possible before. Thanks to LED lighting, it is possible to do monitoring nitrogen absorption by leafy plants in order to avoid harmful nitrate concentrations in their leaves, what is important for human health. Actually, nitrate levels in vegetables grown in plant factories (high-tech city farming) and greenhouses can be significantly reduced by the appropriate light strategy.

Table 1.
Characteristics of Common Light Sources

Wavelength	Characteristics
280-320nm (Ultraviolet-B)	In general the effects of UV-B are deleterious to plant growth and development.
320-400nm (Ultraviolet-A)	May have an additive effect with the requirement for blue.
400-500 nm (Blue)	An absolute quantity for elongation control is required for higher plants.
500-600nm (Green)	Not necessary for photosynthesis, but contributes to photosynthesis and is a significant component of most radiation sources.
600-700nm (Red)	Optimize output for maximal photosynthesis. Monochromatic red will cause abnormal development in some species.
700-750nm (Far-red)	Enhancement of flowering, stem elongation, etc. of certain species (as a function of the red/far-red ratio) with the quantity centred around 725 nm equal to or greater than the quantity centred around 660 nm.

City farming represents growing plants hydroponically in controlled environment, too. Benefits of city farming and hydroponics (Resh, 2004) as the main type of crop production in city farming are:

(1) Hydroponics systems can use up to 90% less water and 75% less fertilizer than traditional farming, offering a significantly smaller carbon footprint
(2) Hydroponic growing systems can be set up to recycle water and nutrients, greatly reducing the resources necessary to produce food
(3) Reduced reliance on fossil fuels when food is produced in urban areas due to limited transportation impact and machinery use
(4) City farming also allows for multiple crops per year, resulting in higher annual yields and fresh products for urban areas
(5) By providing constant and readily available nutrition, hydroponics allows plants to grow up to 50% faster than they do in the soil
(6) The use of hydroponics broadens the ability to garden in small spaces, producing the same yield as soil gardens in 80% less space, what is important for high-tech city farming
(7) Food produced in city farms, hydroponically, is of a high quality because fruits and vegetables have a high biological and dietary values
(8) Crops for household consumption are harvested when they are ready to be used.
(9) City farming enable production of fresh edible plants products, which ahve intact nutritional and medicinal properties (vitamins, minerals)
(10) City farming and hydroponics involves less labour, upkeep, and harvesting efforts than traditional farming methods.

According to Kozai and Ohyama (2006) in this kind of food production there is remarkable reduction in electricity cost for transplant production by using thermally insulated walls, multi-shelves, advanced lighting and air conditioning systems, etc. Annual production capacity of transplants per floor area is about 10 times higher in the closed system than that in the greenhouse, partly due to the high planting density, high percentage of salable transplants, and the use of multi-shelves in the closed system. There are many other advantages of the closed system over the greenhouse, as described later. The closed system can also be applied for production of herbal/medic, besides vegetables, like it was mentioned.

City farming enables vertical production of propagation plant material (Vaštakaitė and Viršilė, 2015), and regular crop production in controlled environment. Because of that, the area for city farms can be very different. It can be as display cases with controlled conditions that can be placed in supermarkets, or other places where people gather and want to refresh with fresh vegetables or fruits. City farms can be smaller or larger areas (e.g. of several hundred meters), and with vertical cultivation, the crop yield is achieved as in larger areas (e.g. in modern greenhouses).

CONCLUSIONS

High-tech city farming is not only a scientific research target. It's gradually coming to life in practice. Because of significant climate change and growing population on the planet, there is a need for new solutions regarding food production. One of those solutions are high/tech city farms, which bring a lot of benefits especially for the inhabitants of big cities. One of those benefits is fresh, high quality food on a smaller area. There are pros and cons in this moment, but it is good a path for future generations in the context of looming overpopulation of the planet. Controlled environment and hydroponics have already resulted in important social benefits, especially for the poorer strata of society, and can positively affect our urban areas.

In order to achieve global food security goals, it is possible to implement alternative farming methods that could increase agricultural outputs and reduce negative climate impacts on food production, and to use urban areas, too, for additional high quality food production.

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Water-yield relations of drip irrigated maize in temperate climatic conditions

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ABSTRACT

The objective of the study, conducted in Vojvodina a northern part of the Serbia Republic, was to analyse the effect of drip irrigation on yield, evapotranspiration and water productivity of maize (*Zea mays* L.) in 2015–2016 years.
Maize hybrid NS 6030 was used for the trials. Irrigation was scheduled on the basis of water balance method. Daily evapotranspiration was computed using the reference evapotranspiration (ET_o) and crop coefficient (kc). Maize sensitivity to water stress was determined using a yield response factor (K_y). To assess the irrigation effects on maize yield, irrigation water use efficiency (I_{wue}) and evapotranspiration water use efficiency (ET_{wue}) were determined.
The yield in irrigation conditions in 2015 (11698 kg ha^{-1}) was statisticaly higher as compared with control without irrigation (8395 kg ha^{-1}). In rainy 2016, there was no statistical difference in yield between irrigated (13927 kg ha^{-1}) and non-irrigated crops (13073 kg ha^{-1}). The amounts of water used on evapotranspiration under irrigated conditions (ET_m) were 489–512 mm and 234–366 mm, under non-irrigated conditions (ET_a) respectively. The values of I_{wue} and ET_{wue} were 0.66–1.16 kg m^{-3} and 0.69–1.19 kg m^{-3}, respectively. K_y values from 0.24 to 0.52 in the growing season indicate that maize is moderately sensitive to water stress under climate conditions of Vojvodina region. Results of the K_y, I_{wue} and ET_{wue} can be used as a good basis for maize growing in the region in terms of optimum water use, and also for the improvement of crop technology.
KEY WORDS: maize, irrigation, water use efficiency, yield response factor

INTRODUCTION

Maize (Zea mays L.), one of the most important field corps, is grown on approximately 24% of areas cultivated with cereals (about 155 million ha). Furthermore, the participation of maize in grain production amounted to approximately 30% (i.e. about 609 million tons), while the average yield was 4.97 t ha^{-1} in the period 2006–2015 (FAO Statistical Yearbook, 2015). In Vojvodina, a northern part of the Serbia Republic, maize is the dominant field crop, grown on average in 640,000 ha, or about 42% of the total arable land. The average yield in the period 2006-2015 was 5.0 t ha^{-1}, with a significant variation from 2.94 to 6.44 t ha^{-1} (Statistical Yearbook of Serbia, 2015), correlated, first of all, with the sum and distribution of precipitation.

It is generally considered that maize is resistant to drought and that maize plants use water economically. Nevertheless, maize consumes great amounts of water due it is large vegetative mass, high yields and a long growing season. In the case of water deficiency, maize successfully overcomes drought, but yields less, because plants consume less readily available categories and forms of water from the soil (Bošnjak et al., 2005). Based on long-term experiments carried out under the conditions of Vojvodina, Bošnjak et al. (2005) pointed out to maize yields lower by 28.7% as a result of a deficit of easily available soil water with a remark that yield can be lower by 147–159% in extremely dry years in relation to yields recorded under irrigation conditions. Cakir (2004) emphasizes the yield amount of 15 t ha^{-1} under irrigation conditions in north-western parts of Turkey, while the amount of 5 t ha^{-1} under rainfed conditions. A striking example of low yields of maize (ranging from 1.22 to 4.63 t ha^{-1}) under rainfed conditions is provided by studies carried out by Vasić et al. (1997) in the arid region of eastern Serbia. The effect of irrigation on the increase of maize yields depends on weather conditions of the year, primarily on the sum and distribution of precipitation. In dry years, it can be great (Bošnjak and Pejić, 1994), while in wet years, it can be very modest or even it can be omitted (Pejić et al., 2011).

The actual evaluation of stress related to the yield due to soil water deficit during the maize growing season can be obtained by the estimation of the yield response factor (K_y), that represents the relationship between a relative yield decrease ($1–Y_a/Y_m$) and a relative evaporation deficit ($1–ET_a/ET_m$). In fact it is the amount of yield (Y) lost per unit of evapotranspiration (ET) loss. A larger K_y value indicates larger yield losses due to water deficit. Doorenbos and Kassam (1979) estimate 1.25 of K_y for the maize growing season. Vaux and Pruitt (1983) suggest that it is highly important to know not only the K_y values from the literature but also those determined for a particular crop species under specific climatic and soil conditions. This is because K_y may be affected by other factors besides soil water deficiency, namely soil properties, climate (environmental requirements in terms of evapotranspiration), growing season length and inappropriate growing technology. In order to approach the implementation of any idea on the intensive utilization of agroecological conditions or the development of new procedures for the irrigation regimes of crops, it is necessary to know precise water needs of plants, i.e. potential evapotranspiration (ETP). Water requirements of maize under agroecological conditions of the Vojvodina region vary from 450 to 540 mm (Bošnjak, 1982, Vasić, 1984, Pejić, 2000).

The estimation of water use efficiency in relation to evapotranspiration (ET_{wue}) can show a more realistic evaluation of irrigation effects, i.e. of the irrigation regime applied in maize crops. Also, the importance of analyzing ET_{wue} is illustrated by the efforts of numerous studies that consider the total water use for evapotranspiration towards transpiration use as to the productive part of water to plants (Howell et al., 1997). The parameter ET_{wue} mostly depends on precipitation amount and distribution and establishes whether the growing period is favorable for plant production or not. Wang et al. (1996) pointed out that crop yield depends on the rate of water use and all the factors that increase yield and decrease water used for ET favorably affect the water use efficiency. Howell (2001) indicated that ET_{wue} generally is highest with less irrigation, implying full use of the applied water and perhaps a tendency to promote deeper soil water extraction to make better use of both the stored soil water and the growing-season precipitation. An even clearer estimation of irrigation effects and the applied irrigation regime can be obtained by the evaluation of irrigation water use efficiency (I_{wue}). If the irrigation regime is not synchronized with water needs of crops, water and physical properties of soil and weather conditions, the effect of irrigation can fail, that is the I_{wue} values can be bellow the optimum. The parameter, I_{wue}, generally tends to increase with a decline in irrigation if that water deficit does not occur at a single growth period (Howell, 2001).

The objective of the study was to estimate the yield response factor (K_y) and on the basis of this factor to analyze a seasonal maize response to water stress and in such a way to obtain additional information that can be useful in the improvement of maize growing practices under climate conditions of Serbia. The established values of ET_{wue} and I_{wue} will be used in analyses of the applied irrigation regime and effects of irrigation on maize yields with the aim to use water more efficiently in irrigation practice. Estimated values of water use on maize evapotranspiration will be compared with previously established water requirements by maize under agroecological conditions of Vojvodina region.

MATERIAL and METHOD

The experiment with irrigated maize was conducted at Bački Petrovac experimental field of Institute of Field and Vegetable Crops in Novi Sad (N 45° 19`, E 19° 50`) on the calcareous chernozem soil on the loess terrace in 2015-2016 years. Over the 1964 to 2014 period, the annual mean air temperature, precipitation and relative humidity were 11.20C, 598.7 mm and 76% respectively. According to the Hargreaves climate classification system, the study area is classified as arid in the summer period, from Jun to August (Bošnjak, 2001). In the growing season of 2015 (16 April to 25 August), the mean air temperature and total rainfall were 20.20C and 220 mm respectively. In rainy 2016, in the growing season (19 April to 6 September), the mean air temperature and total rainfall were 19.40C and 380 mm respectively. As expected, rainfall is not sufficient for maize production. For this reason, irrigation is needed for acceptable yields of maize grown in the region. The amount of water added by irrigation was 285 mm and 130 mm in 2015 and 2016 respectively (Figure 1, Table 2). Maize hybrid NS 6030 was used for the trials. The row spacing was 0.70 by 0.24 m. The size of the experiment unit was 50.0 m^2 (2.1 x 24.0 m) and was replicated three times.

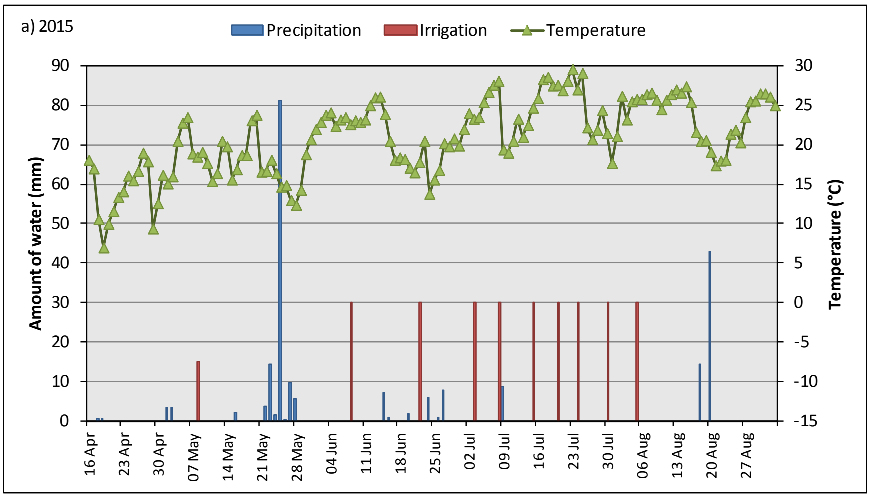

Figure 1. Irrigation schedules, irrigation water applied and meteorological data in the 2015 experimental year

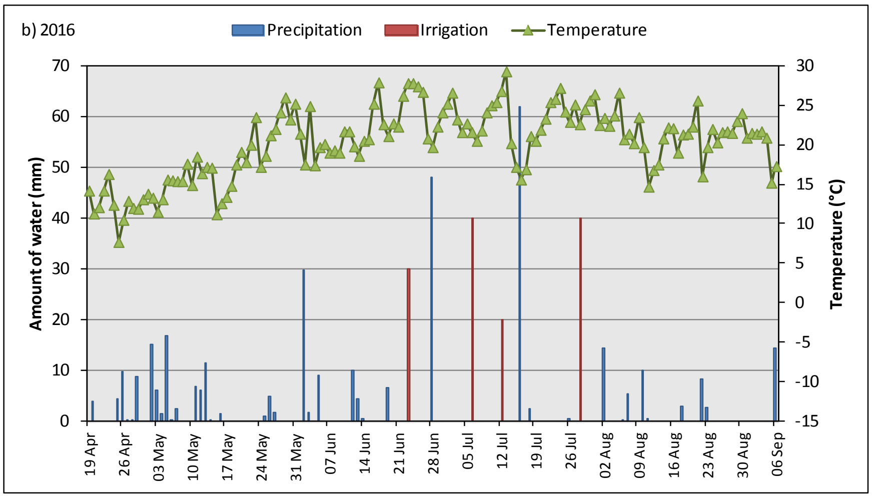

Figure 2. Irrigation schedules, irrigation water applied and meteorological data in the 2016 experimental year

The trial was established in a system of random blocks and adapted to technical specifications of drip irrigation system. The plants were irrigated with a lateral row per plant row with drippers spaced every 0.1 m. The drippers had an average flow of 1.4 l/h under a pressure of 70 kPa. The trial included irrigated and non-irrigated, control variants. Irrigation was scheduled on the basis of water balance method using reference evapotranspiration (ET_o) and crop coefficients (k_c). ET_o was calculated by Hargreaves equation (Hargreaves and Samani, 1985).

$$ET_o = 0.0023(T_m+17.8)(\sqrt{T_{max}-T_{min}})R_a$$

ET_o – reference evapotranspiration (mm day^{-1}), T_m – the average daily air temperature (^{0}C), T_{max} – the maximum daily temperature (^{0}C), T_{min} – the minimum daily temperature (^{0}C), R_a – the extraterrestrial radiation (mm d^{-1}).

Daily water used on plants evapotranspiration (ET_d) was calculated by multiplying ET_o with kc values (according to FAO, 2015) for initial stage 0.3–0.55, crop development stage 0.7–0.85, mead season stage 1.05–1.2 and late season stage 0.8–0.9 (Figure 3 and 4).

$$ET_d = ET_o\ k_c$$

Irrigation started when readily available water in the soil layer of 40 cm was completely absorbed by plants.

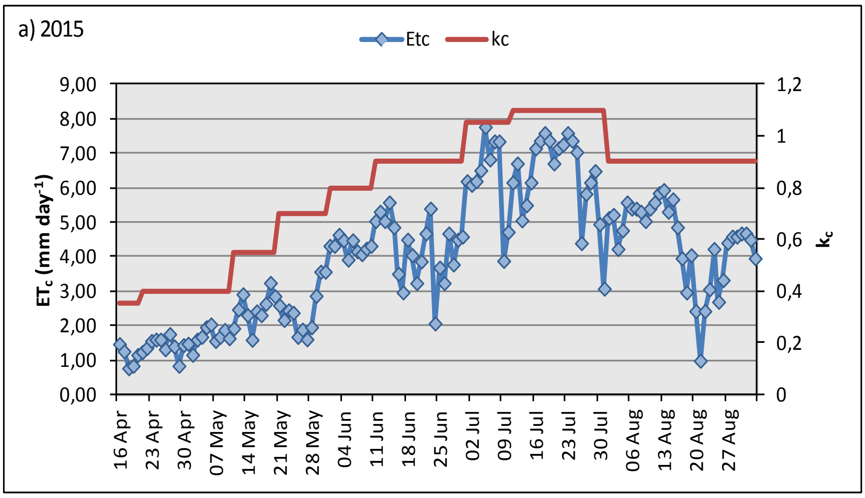

Figure 3. Daily evapotranspiration and crop coefficient of maize in the 2015 experimental year

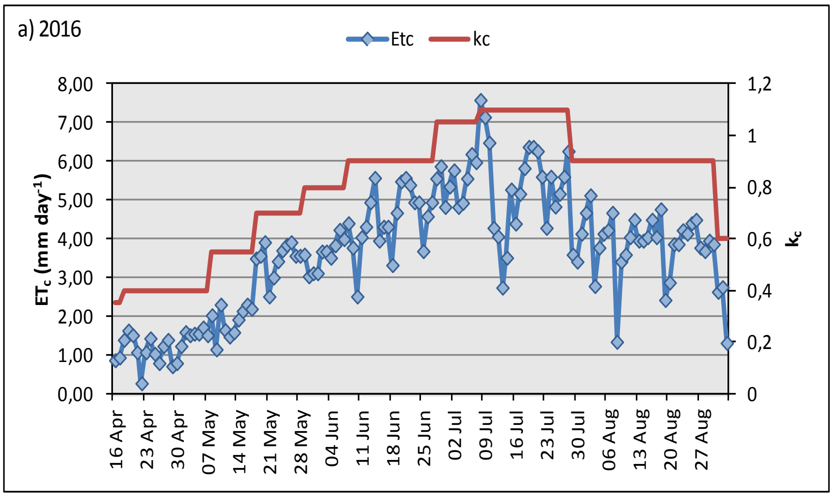

Figure 4. Daily evapotranspiration and crop coefficient of maize in the 2016 experimental year

Yield response factor: The yield response factor (K_y) for total growing season was determined using the Steward's model (Doorenbos and Kassam, 1979) as follows:

$$\left(1-\frac{Y_a}{Y_m}\right) = K_y \left(1-\frac{ET_a}{ET_m}\right)$$

Where: Y_a = the actual harvested yield (non-irrigated, kg ha^{-1}), Y_m = the maximum harvested yield (under irrigation, non limiting conditions, kg ha^{-1}), K_y = the yield response factor, ET_a = the actual evapotranspiration (mm) corresponding to Y_a, ET_m = the maximum evapotranspiration (mm) corresponding to Y_m, $(1–ET_a/ET_m)$ = the relative evapotranspiration deficit, and $(1–Y_a/Y_m)$ = the relative yield decrease.

Water productivity: Irrigation water use efficiency (I_{wue}, kg m^{-3}) and evapotranspiration water use efficiency (ET_{wue}, kg m^{-3}) were estimated as Bos (1981, 1985).

$$I_{wue} = \frac{Y_m - Y_a}{I}$$

$$ET_{wue} = \frac{Y_m - Y_a}{ET_m - ET_a}$$

Where: I = the amount of irrigation water applied (m^{-3} ha)

All recommended agronomic practices were applied for cultivation and plant protection at the experimental site. A total of 130 kg N/ha, 75 kg P_2O_5/ha and 75 kg K_2O/ha fertilizer was applied according to recommendations based on the results of the soil analysis. The technological maturity of the crop was detected on 25 August in 2015 and on 6 September in 2016, but maize was harvested by hand on 30 September and 6 October respectively. Precipitation and air temperature data were obtained from Meteorological Station located at experimental field (Figure 1 and 2). Grain yield was expressed in kg ha^{-1} adjusted to 14% moisture content. Statistical processing of data was done by the analysis of variance (ANOVA) and testing the obtained results by the Fisher's LSD test ($P< 0.05$ levels between the means).

RESULTS and DISCUSSION

The yield in irrigation conditions in the season of 2015, which experienced severe drought, was statisticaly higher (11,698 kg ha^{-1}) as compared with control without irrigation (8,395 kg ha^{-1}). In rainy, 2016 there was no statisticaly difference in yield between irrigated (13,927 kg ha^{-1}) and non-irrigated variant (13,073 kg ha^{-1}), (Figure 5 and Table 1). Results are in agreement with many studies conducted in a wide range of environments which confirm that irrigation can positively affect the yield increase of maize (Istanbulluoglu et al., 2002, Cakir, 2004, Pejic et al., 2010, 2011, 2013). As well, results are in accordance with authors who pointed out that in rainy years effect of irrigation on maize yield may be negligible, or missing (Pejić et al., 2011). Given data indicate that climatic patterns in Vojvodina are changeable and longer-term predictions of precipitation are not possible. That confirms the supplementary character of irrigation in Vojvodina, (Pejić et al, 2011a, 2011b), i.e. that precipitation can affect the soil water regime and irrigation schedule of maize. Maksimović and Dragović (2002), Pejić et al. (2006) reported that in years with limited precipitation, the effect of irrigation on sugar beet yield was higher than 45%, but in rainy years that effect was lower than 20%.

In the study period, evapotranspiration rate in irrigation conditions (ET_m) and in rainfed control variant (ET_a) were 512 mm and 234 mm in 2015 and 489 mm and 366 mm in 2016 respectively (Table 1, 2 and 3). The calculated average value of maize ET_m of 500 mm (Table 1) is in accordance with values previously recorded for the agroecological conditions of the Vojvodina region. Bošnjak (1982), Vasić (1984), Pejić (2000) determined in field plots that water requirements of maize for the conditions of Vojvodina varied from 460 to 530 mm. Škorić and Berić (1994) have determined for the same climate conditions by the calculation over reference evapotranspiration (ET_o) and crop coefficients (k_c) that water requirements for normal growth and development of maize amounted to 523 mm. Stegman (1986) reported similar values of seasonal water use of maize for North Dakota of 432–514 mm. The calculated values of readily available soil water deficit of 278 mm (Table 1) point to the fact that the genetic potential for yield of otherwise very high-yielding maize hybrids will not be fully realized, since the amount of precipitation determines the potential yield levels.

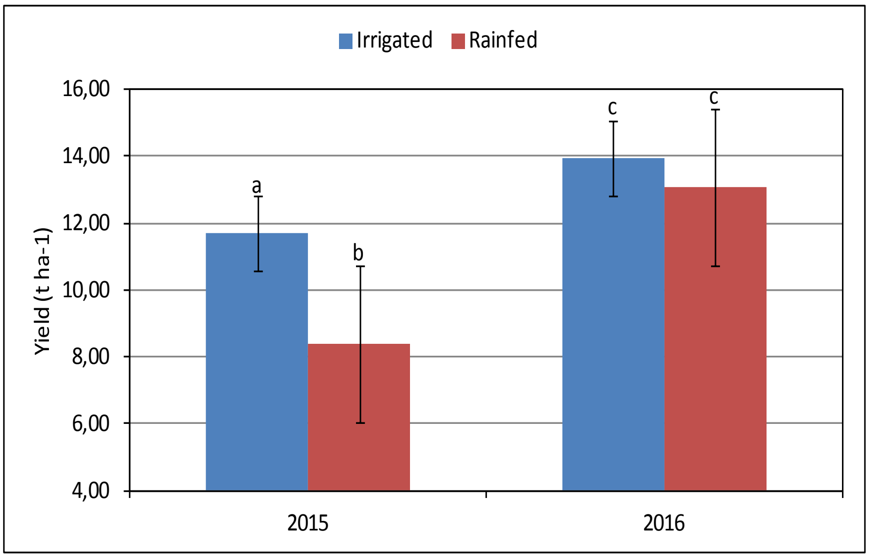

Figure 5. Yield of maize under irrigated and non-irrigated conditions

Agriculture in Vojvodina indubitably lacks water as one of the cornerstones of crop production (Vučić, 1976). The values of K_y of 0.52 and 0.24 recorded for the maize growing season (Table 1) are lower than values established by other researchers based on results obtained under arid climatic conditions (Doorenbos and Kassam, 1979, 1.25 FAO publication, Howell et al. 1997, 1.47 for Bushland in Texas, Cakir, 2004, 1.36 for arid conditions of Turkey). Obtained K_y value of 0.52 and 0.24 are in accordance with results obtained under moderate climate. Furthermore, Kanber et al. (1990) and Istanbulu et al. (2002) have established values of 0.93 and 0.76 for coastal areas of Turkey. Pejić et al. (2009) point out that the K_y value of 0.65 determined for climate conditions of Vojvodina is the result of weather conditions, first of all, of precipitation amount and their distribution. Values of 0.52 and 0.24 in the growing season indicate that maize is moderately sensitive to the soil water deficit under climatic conditions of Vojvodina. On average, relative evapotranspiration decrease were 49%, resulted with yield reduction of 17% (Table 1).

Table 1
Yield response factor and water productivity of maize

Year	ET_m	ET_a	Y_m	Y_a	$1–Y_a/Y_m$	$1–ET_a/ET_m$	K_y	I	I_{wue}	ET_{wue}
2015	512	234	11698[a]	8395[b]	0.282	0.732	0.52	285	1.16	1.19
2016	489	366	13927[n]	13073[n]	0.061	0.252	0.24	130	0.66	0.69
Av.	500	300	12812	10734	0.172	0.492	0.38	208	0.91	0.94

Table 2
Water balance of maize in 2015

Elements	Month					
	April	May	Jun	July	August	Growing season
ET_m (mm)	19	62	120	195	116	512
P (mm)	1	126	25	9	59	220
Δ	-18	+28	-60	0	0	
r (mm)	30	12	60	0	0	
ET_a (mm)	19	62	85	9	59	234
d (mm)	0	0	35	186	57	278
s (mm)	0	16	0	0	0	16

Table 3
Water balance of maize in 2016

Elements	Month						
	April	May	Jun	July	August	Sep.	Growing season
ET_m (mm)	19	80	116	138	122	14	489
P (mm)	28	76	110	65	45	14	338
Δ	+9	-4	-6	-27	0	0	
r (mm)	28	37	33	27	0	0	
ET_a (mm)	19	80	116	92	45	14	366
manjak mm)	0	0	0	46	77	0	123
višak (mm)	0	0	0	0	0	0	0

The best method to describe the role that irrigation has in water use efficiency (WUE) in irrigated agriculture is by expressions given by Bos (1981, 1985). Many researchers have evaluated water use efficiency in different ways (Bos, 1985, Howell, 2001, Payero et al., 2006). Consequently, care should be taken when comparing WUE values. Gained results under given agroecological conditions can be compared only in the approximately same temporal distance, because not only genetic potential of yielding was smaller more than 30 years ago (Pejić, 2013), but also growing practices have been significantly modified (Videnović et al., 2007). Irrigation water use efficiency (I_{wue}) and evapotranspiration water use efficiency (ET_{wue}) determined in the period of investigation ware 1.16 kg m^{-3} and 1.19 kg m^{-3} in 2015 and 0.66 kg m^{-3} and 0.69 kg m^{-3} in 2016, respectively (Table 2). Obtained values are congruent with results of Yazar et al. (2009) gained for the conditions of the Mediterranean climatic conditions in Southern Turkey, for the maize irrigated by drip system (I_{wue} 1.61 kg m^{-3}, ET_{wue} 1.54 kg m^{-3}). Pejić et al. (2010) determined for the conditions of Vojvodina region I_{wue} and ET_{wue} 1.8 kg m^{-3} to 2.8 kg m^{-3}, respectively. Robertson et al. (1980) recorded maximum values of I_{wue} (4.5 kg m^{-3}) for the conditions of Florida noting that the highest maize yields were recorded when I_{wue} ranged from 2.0 to 3.0 kg m^{-3}.

CONCLUSIONS

Based on obtained results it can be concluded that irrigation significantly influenced the yield of maize in semi-arid climatic conditions of the Vojvodina region. The average evapotranspiration rate in irrigation conditions (ET_m) and in rainfed control variant (ET_a) were 500 mm and 300 mm respectively. The average value of K_y in this study of 0.38 indicates that maize is moderately sensitive to the soil water deficit under climatic conditions of Vojvodina. The average values of I_{wue} and ET_{wue} were 0.91 kg $m^{-3}$and 0.94 kg m^{-3} respectively. These results could be used as a good platform for maize growers in the region in terms of improvement of the cropping technology, optimum utilization of irrigation water and for the planning, design and operation of irrigation projects.

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Hydrological characteristics of eugley soil in protected part of the alluvial plain of Danube river in Vojvodina

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ABSTRACT

Eugley soils are representatives of preterrace part of bottomland. They can be found in the area of relief depression, or in the lowest part of the floodplain. The main characteristic of these soils is excessive moistening with flood or groundwater. In the embankment protected part of the alluvial plain where there is no flood, the soil is moistened with groundwater. Groundwater dynamics of these areas is dependent on the level of the water level of the Danube River, which affects level of groundwater in a protected part of the alluvial plain.

This paper presents the studies of eugley soil in the area of middle flow of the Danube River in Vojvodina (Nothern Serbia). External and internal morphology were determinated in soil profiles of eugley soil on the left bank of the Danube River, in part protected by an embankment. The particle size distribution of the soil was determined according to the international B-pipet method prepared in the sodium-pyrophosphate. Depth of groundwater of eugley soil in the tested area as well as soil moisture content at 10, 30 and 70 cm depth were measured monthly during 2011.

Particle size distribution of the studied soils showed increased proportion of the total clay, the texture classes were sand, silty loam, and the most prevalent texture class was loam. Measured soil moisture content in 2011 at a depth of 10 cm was moving from 19.47 to 71.08 vol.%, At a depth of 40 cm soil moisture content ranged from 15.99 to 57.75 vol.%,while at a depth of 70 cm soil moisture was in the range of from 15.95 to 52.12 vol.% for all three studied soils. The level of ground water varied within the measured year. In the profile 1 ground water ranged from 50 to 190 cm below the soil surface, for the profile 2 these values ranged from 30 to 170 cm in depth, whereas in the profile 3 the depth of the groundwater was from 30 to 190 cm. It can be concluded that the soil moisture content at all three depths was the highest at the spring.

KEY WORDS: Eugley; Soil moisture; Ground water; Danube

INTRODUCTION

Eugley soils as a type of soil belonging to the class of gley soils are found on the surfaces around the river flows, and have a clearly separated gley horizon, divided into two subhorizons: subhorizon of the secondary oxidation Gso and subhorizon of reduction Gr (Škorić et al., 1985). They occupy the lowest parts around rivers in the pre terrace part, so-called depressions. According to Živković et al., (1972) these soils in the area of Vojvodina cover an area of 15.269 ha and they are located around the various branches of major rivers, depressions and the lowest parts of alluvial plain. Antić and Jović, (1965), considered eugley soils to be natural habitats of willows as a result of their properties and wetting, while Wilde (1962), according to Živanov and Ivanišević (1986), emphasized the classification of these soils in relation to the depth of the gley horizon, and divided them into α –gley, β – gley and γ - gley, depending is it the depth of the gley horizon up to 40 cm, from 40 to 80 cm or over 80 cm, and Antić et al. (1969) distinguished ά / β- gley and β / γ gley. Moistening of these soils can be induced by flood and groundwater, and in the case of studied soil, moistening is exclusively by groundwater, since it is a protected part of the alluvial plain. The greatest influence on the pedogenetic processes and properties of eugley soil on this area had a regime of underground water (Pekeč, 2010). Because of the specific moistening of this area, the aim of the paper is to show the mechanical composition of these soils and the dynamics of groundwater movement and soil moisture throughout the year in which the measurements were made.

MATERIAL and METHOD

The eugley soils in the area of the left bank of the middle flow of Danube in Vojvodina (northern Serbia) are studied in this paper. During research, eugley soils were examined in the area of the protected part of the alluvial plane, the part that is protected by dam from floodwaters. The pedological profiles were opened and the inner and outer morphology of the profiles were described, photo documentation was made, and the coordinates of profiles' locations were taken (P1: N $45^{0}17^{'}49.4^{''}$ E $19^{0}53^{'}16.1^{''}$; P2: N $45^{0}17^{''}14.5^{''}$ E $19^{0}53^{'}38.5^{''}$; P3: N $45^{0}17^{'}30.2^{''}$ E $19^{0}53^{'}18.9^{''}$). A certain number of soil samples in deteriorated state were taken from each profile and they were analyzed in the laboratory of the Institute of Lowland Forestry and Environment. Analyzes of the physical properties of these soils were made. Also, mechanical composition according to the international B-pipet method with preparation in sodium pyrophosphate was determined according Bošnjak et al., (1997). The classification of mechanical elements was made by Atterberg, and the texture class is determined according to the American classification of basic classes according to the texture according (Belić et al., 2014). Measurements of groundwater depth were performed throughout the year during 2011 in the area of the examined eugley soil, and also the soil moisture was measured at three depths, i.e. at depths of 10, 40 and 70 cm in the same terms.

RESULTS and DISCUSSION

Observing granulometric composition of the examined eugley soils, an increased share of total clay ranging from 50.93 to 61.30% can be noted, while the total sand content is lower and its values are from 38.70 to 49.07% (average). The textural classes of these soils are: sand, silty loam and the most dominant texture class is loam (Table 1). According to Pekec et al. (2011) eugley soil has heavier mechanical composition in the rhizosphere zone, with an increased content of total powder and clay and an increased content of capillary pore compared to non-capillary pores.

Table 1
Granulometric composition

No. of profile	Horizon	Total depth (cm)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Total sand (%)	Total clay, (%)	Textural class*
1	Aa	0-25	3.07	32.45	46.32	18.16	35.52	64.48	loam
	Gso	25-80	1.94	39.94	40.44	17.68	41.88	58.12	loam
	Average		2.51	36.19	43.38	17.92	38.70	61.30	
2	Aa,p	0-30	4.46	19.82	55.6	20.12	24.28	75.72	silty loam
	I Gso	30-60	1.90	32.94	46.76	18.4	34.84	65.16	loam
	II Gso	60-90	2.27	85.81	7.12	4.8	88.08	11.92	sand
	Average		2.88	46.19	36.49	14.44	49.07	50.93	
3	Aa	0-35	3.67	28.93	48.36	19.04	32.60	67.40	loam
	Gso	35-80	0.48	46.88	36.16	16.48	47.36	52.64	loam
	Average		2.07	37.91	42.26	17.76	39.98	60.02	

***The texture class is determined according to the American classification of basic classes according to the texture.

Analyzing the soil moisture in profile 1 (Fig. 1) it is evident that the highest soil moisture was at 70 cm depth and had a limit value from 38.81 to 52.12 vol.%. Lower moisture values were observed at a depth of 10 cm, ranging from 21.44 to 59.34 vol%, and the lowest values were at a depth of 40 cm where the limit values ranged from 21.20 to 40.65 vol .%. The high moisture content at a depth of 70 cm is associated with the level of groundwater in the observed period, which is the main source of moisture at this depth.

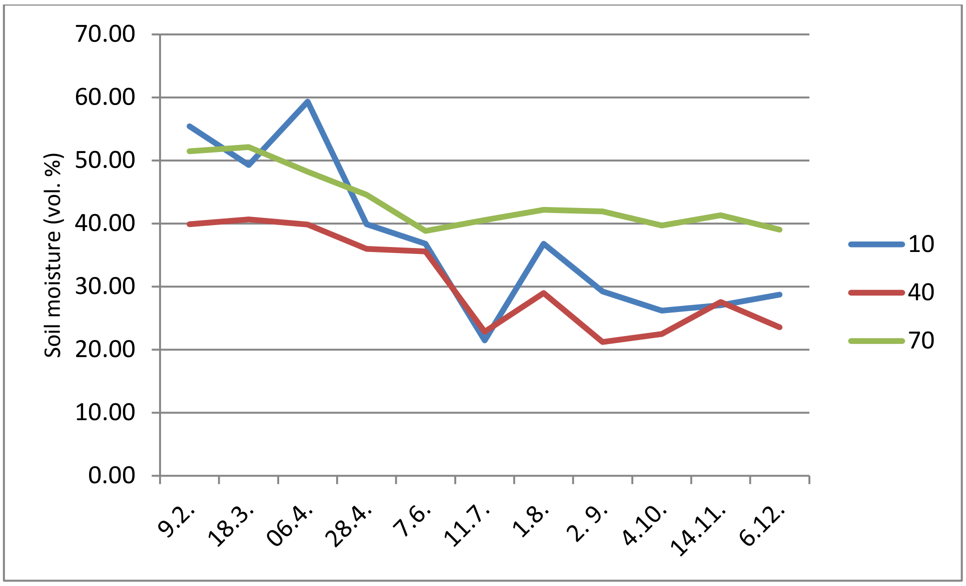

Figure 1. Soil moisture in the profile 1 during 2011

Observing the soil moisture in profile 2 (Fig. 2), it can be seen that for the largest part of the measuring period the highest soil moisture was at 10 cm and it amounts from 26.52 to 56.32 vol.%. Lower soil moisture was at a depth of 70 cm depth, and its values ranged from 17.02 to 50.17 vol.%. For this profile the lowest values of soil moisture over a longer period were recorded at 40 cm depth, where the moisture ranged from 19.73 to 57,75% vol. High moisture values of the soil at depths of 70 cm can be associated with direct groundwater influence and capillary climbing of groundwater, while for higher values of soil moisture at a depth of 10 cm is responsible atmospheric precipitation.

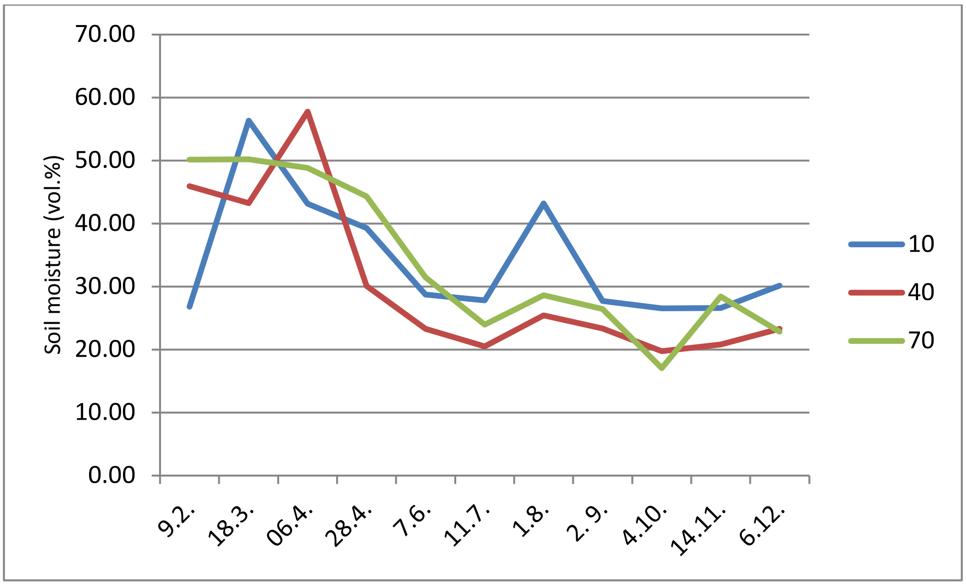

Figure 2. Soil moisture in the profile 2 during 2011

For profile 3 (Fig. 3), moisture of the year was the highest at 10 cm depth. Moisture values at a depth of 10 cm ranged from 19.47 to 71.08 vol.%. At a depth of 40 cm the soil moisture values were in the range of 15.99 to 51.64 vol.%, while at a depth of 70 cm, the moisture was from 15.95 to 50.17 vol.%.

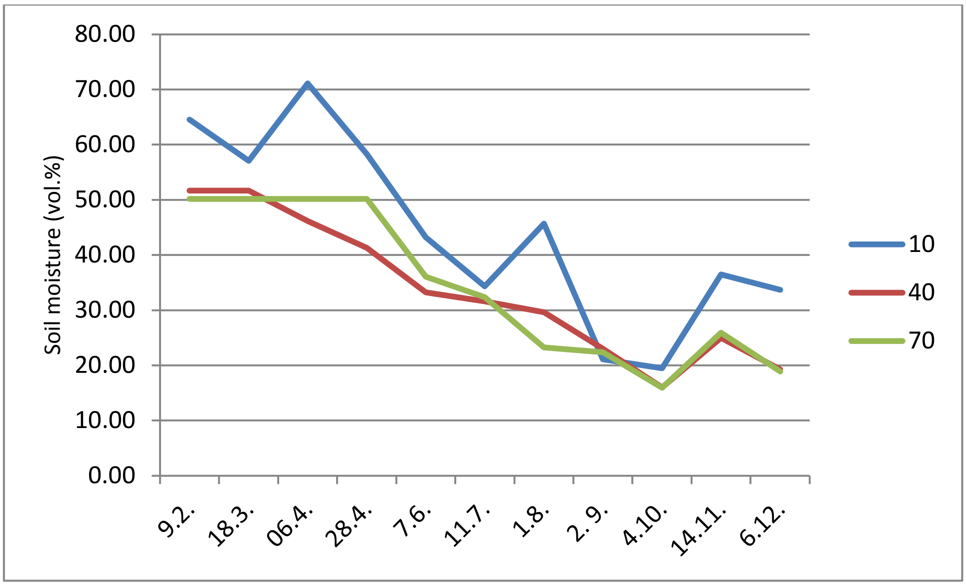

Figure 3. Soil moisture in the profile 3 during 2011

In general, observing all three pedological profiles i.e. soil moisture at all depths, it can be concluded that the highest values of moisture were in the spring, until the beginning of June or July, after which there is a constant decrease. The lowest values of soil moisture are noticeable in the middle of July, i.e. in the beginning of September and October. These observations suggest that the precipitation had an impact on soil moisture content at depth of 10 cm, and the influence of the groundwater level was evident on the soil moisture distribution, especially at depths of 70 and 40 cm. This is evident in the movement of the groundwater level (Fig.5) which had periods of constant decline. After that, the level increased again in the middle of November which fallowed the moisture content of the soil at depths of 40 and 70 cm. Pekeč and Katanić (2016) reported higher soil moisture values at higher depths, observed in dry summer months, when capillary climbing of groundwater occurs, and the surface horizon has low moisture content in this period due to the lack of precipitation. Pekeč and Katanić, (2015), examining the eugley soils in the protected part of the alluvial plane, considering their way of moistening solely by groundwater, conclude that these soils are saturated with water and over wet and contain little air, especially in the lower parts of the profile, and can be noted that these soils have poorer water-air properties compared to other hydromorphic soils.

Analyzing the Danube water level (Fig. 4), it is possible to note variation of the water level until the beginning of August, then the water level in the riverbed begins to fall. The lowest recorded value during the water level measurement for 2011 is -8 cm, while the highest value recorded at the beginning of August was +291 cm.

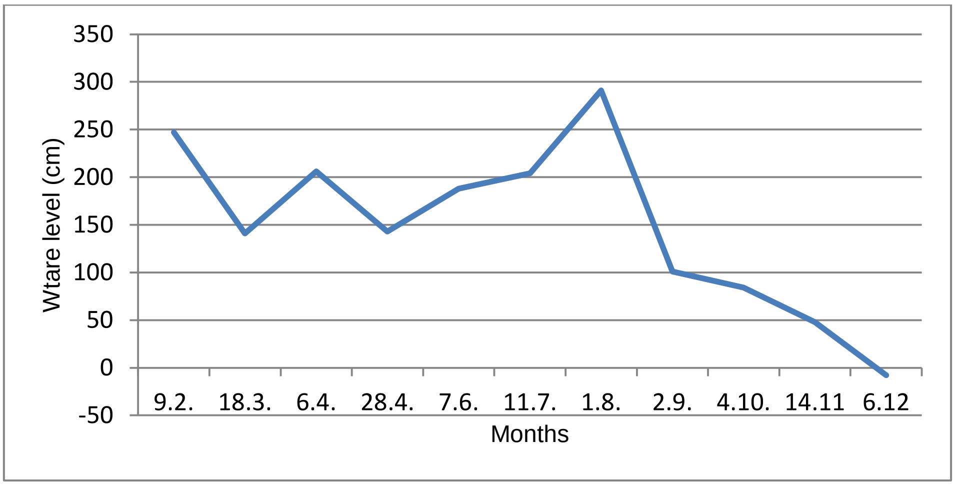

Figure 4. Water level of the Danube River during 2011 (Water station Novi Sad)

The level of groundwater in all studied profiles (Fig. 5) varied during the year. Except for a slight increase in the beginning of the measurement period, the groundwater level had a constant decline with smaller or larger variations until the beginning of October, and further it grew until mid-November after which it fell again. The lowest measured value for profile 1 was 190 cm, while the highest value was -50 cm. As it can be seen from the above figures, the annual amplitude of groundwater variation for this profile is 140 cm.

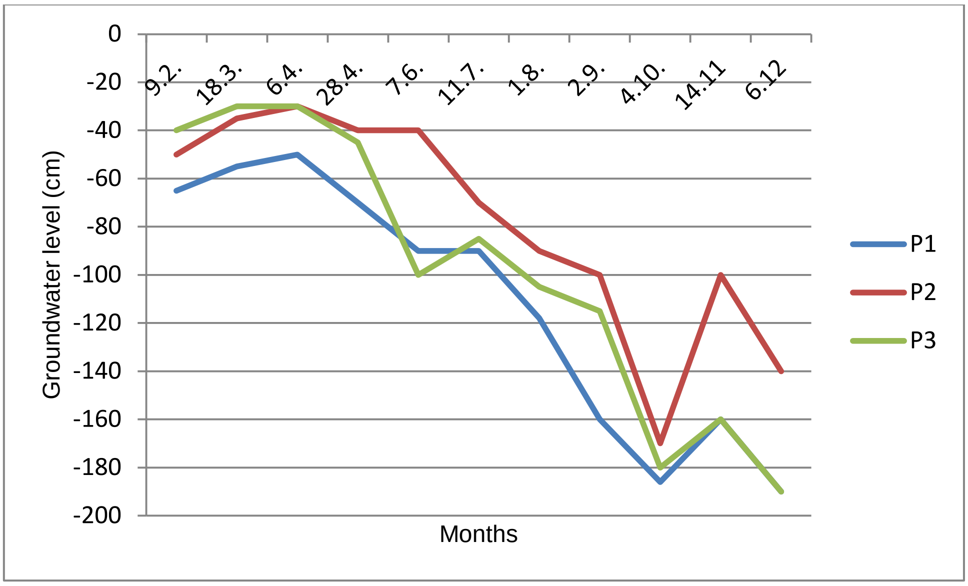

Figure 5. Groundwater level for profiles 1, 2 and 3, during 2011

Analyzing groundwater dynamics in profile 2 (Fig. 5), it can be seen a constant decrease in the level with a slight increase at the beginning of the measuring period with the highest value at -30 cm, until the beginning of October when the minimum value was -170 cm after this leads to a rise in groundwater levels by mid-November, followed by a decline in levels. The amplitude of the variation of the groundwater for this profile was 140 cm.

The dynamics of groundwater movement in profile 3 (Fig. 5) had almost the same trend as in the previous profiles. The groundwater level declined constantly from the beginning of April throughout the year, and its rise was again measured in mid-November. The lowest measured value was -190 cm, while the highest value of the groundwater was -30 cm. The amplitude of variation in this profile throughout the year was 160 cm. Considering the dynamics of groundwater movements for all three profiles, we can conclude that there is a noticeable increase in groundwater level by the beginning of April, after which there is a decrease until the beginning of October, after which the increase in the groundwater level is again evident until the half of November, and after that there is a decrease in the level by the end of the year. Pekeč et al., (2010) find that in the year when Danube water level was high and the groundwater level was high, a high degree of correlation was noted, while in the year with lower water level and groundwater was lower and a low degree of correlation was noted.

Generally, in studied soils the highest groundwater value for all three profiles was -30 cm (profile 2 and 3), while the lowest measured value was -190 cm (Profiles 1 and 3). Pekeč et al., (2014) studing eugley soils around Futog, according to Wilde's ecological classification classified these soils in α-gley. These are extremely shallow soils where the gley horizon is at a depth of only 40 cm. Groundwater was at a depth of 50-60 cm at the time of measurement in autumn, and during the spring period, groundwater is raised in several parts of the pedological profile, and the basic vegetation of the entire area is reed (*Phragmites communis*).

It can be concluded that the groundwater, especially at the beginning of the measuring period, was high, which is characteristic for eugley soil, to gradually decrease during the year, which is partly in accordance with the movement of the Danube water level. Also, in all profiles, the level of groundwater increased after a long constant decline. Amplitude of groundwater variation throughout the year for all three profiles was 140cm (profile 1 and 2) and 160 cm (profile 3).

CONCLUSIONS

This paper presents the studied eugley soils in the protected part of the alluvial plane of the Danube River in Vojvodina. In examined soils prevailed content of total clay so the texture classes of these soils were sand, silty loam and mainly loam. The soil moisture in all three pedological profiles of the eugley soil, at all depths, had the highest values in the spring to mid-April, after which the soil moisture content decreased. The lowest values of soil moisture are noticeable at the end of the summer period and in the beginning of October. At a depth of 10 cm, the greatest influence on the moisture content in the soil had precipitation, and in this layer the moisture was highest during the second part of the year, while at a depth of 70 cm and 40 cm the influence of the groundwater level on the soil moisture is evident. This is especially noticeable in the first part of the year, where the highest soil moisture level is recorded at a depth of 70 cm with high level of groundwater. The highest groundwater value for all three profiles was -30 cm, while the lowest measured value was -190 cm. It can be concluded that groundwater, especially at the beginning of the measurement period, was high (which is characteristic for eugley soils) to gradually decrease during the year. Oscillations of groundwater level in all three eugley soil profiles ranged from 140 cm to 160 cm throughout the year.

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Application of infiltration pools in reducing runoff from urban basins

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ABSTRACT

Urbanization has caused many problems for humankind and environment. The surface runoff has increased and the infiltration has decreased due to increase in impermeable and decrease in permeable surfaces. Traditional drainage systems cannot manage to carry all the atmospheric water away, so outpouring and clogging of systems often occur. It is considered that the problem of flooding in urban areas could be resolved by constructing infiltration pools which could be an effective alternative tool for traditional drainage systems. The purpose of this paper is to simulate the transformation of rainfall into runoff and to analyse the effect of infiltration pool on decrease of surface runoff in urban basins.

The transformation of rainfall into runoff and the effect of infiltration pool on decrease of surface runoff were analysed by applying the SWMM model (Storm Water Management Model). These issues were analysed on the example of the experimental urban basin located in the courtyard of the Faculty of Civil Engineering in Belgrade. Calibration of the model includes determination of coefficient of filtration, capillary potential and initial moisture deficit. Here the calibration was performed based on the measurements of changes in water level in the infiltration pool, obtained for different values of the flow. Adopted values of the coefficient of filtration, the capillary potential and the initial moisture deficit were used in simulations of runoff in the basin under the influence of real and synthetic rain events.

This analysis shows that significant amount of water is infiltrated through the bottom of the pool. Based on the obtained results it can be stated that infiltration pool is an effective solution for reducing surface runoff from urban basins. This and similar analysis, performed on the experimental basin, should contribute in resolving one of numerous problems brought by urbanization.

KEY WORDS: infiltration; runoff; infiltration pool; calibration; experimental basin

INTRODUCTION

Apart from many benefits rapid development of cities and urbanization of rural areas also bring a number of problems. One of the most significant is the increased urban runoff that greatly affects the quality of life. Population growth increases the amount of wastewater, and at the same time runoff that comes from atmospheric precipitation is increased due to urbanization The quality of wastewater is worse than before. The following illustration (Figure 1) shows the influence of urbanization on runoff increase.

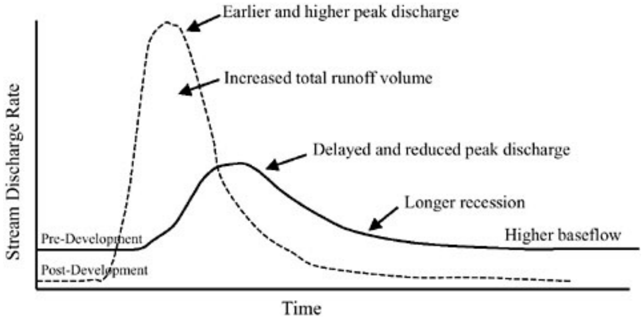

Figure 1. The impact of urbanization on the hydrograph of the outflow from the basin

The traditional approach of the rainwater drainage system design is based on collecting the flow as quickly as possible and to implement it by the rainwater collection system to the recipient. Due to the increase in the load, these systems are becoming bigger, but without improving the quality of runoff before releasing it into the recipient (Vasilić et al., 2013). Experimental basins are formed to establish sustainable systems that provide draining runoff, improve its quality and improve the environment. The urbanization and methods of solving the problems caused by urbanization have developed together. Source controls and best management practices relying on natural processes may be considered as supplemental or alternative solutions to conventional urban drainage systems. Stormwater infiltration has received increased attention during the past decade, but the existing knowledge does still not enable professionals to solve all problems faced in practical applications (Mikkelsen et al., 1996). The construction of infiltration pools is one of the ways to reduce surface runoff in urban areas through infiltration. The infiltration pools offer one solution for these two problems, for increased stormwater runoff and for decreased stream water quality. In Lyon, south-east of France, stormwater infiltration basins were built starting 30 years ago as a result of urban development. Infiltration basins have valuable technical and environmental advantages (Ferguson, 1994): decrease of stormwater flows in sewer systems, retention of stormwater pollution and recharge of groundwater. Roldin (2012a) analyzed the impact of infiltration, through soakways, on combined sewage overflows in a 3 km^2 urban catchment in Copenhagen and estimated reduction in annual overflow volume of 68 %. Lee et al. (2010) and Montalto et al.(2007) conducted a cost-effectiveness analysis on stormwater best management practices and showed that permeable pavements were most cost-effective in managing runoff, reducing peak flows and delaying peak runoff time as compared to green roofs and traditional storage basins and traditional drainage systems. The most common sub-surface infiltration structures in areas with a thick zone of medium permeability deposits are infiltration trenches.

The purpose of this study is to evaluate the effectiveness of infiltration pools as a stormwater management strategy. The model of the urban basin is established through the process of the model calibration. After that, the transformation of rainfall into the runoff is simulated and the effect of infiltration pool on the decrease of surface runoff in urban basins is analyzed on the example of the experimental urban basin developed in the yard of the Faculty of Civil Engineering in Belgrade.

MATERIAL and METHOD

Description of the basin and infiltration pool in the model

Data for purposes of this study are provided in the framework of the project of the Ministry of science, education and technological development of the Republic of Serbia TR37010 “Systems for draining rainwater as a part of urban and transport infrastructure". The project envisages the establishment of experimental basins where the formation of runoff, as well as the effects of some measures on the basin, will be studied with appropriate measurements (Vasilić, 2013). One of them was formed in the yard of the Faculty of Civil Engineering in Belgrade where there is an infiltration pool used in this paper. The great advantage of this basin is that it belongs to the real urban area and has its own meteorological station (Figure 3), which provides relevant data for research in the field of hydrological cycles. It consists of three types of surfaces. The largest part of the basin belongs to the asphalted impermeable surface of the parking in the yard of the Faculty of Civil Engineering (900 or 2000 m^2, it can be controlled), the smaller part of the basin is a grassland (1000 m^2) and the smallest part is the roof of the Institute of Physics building (100 m^2). The following figure (left) shows the shape and division of the basin into five sub-basins.

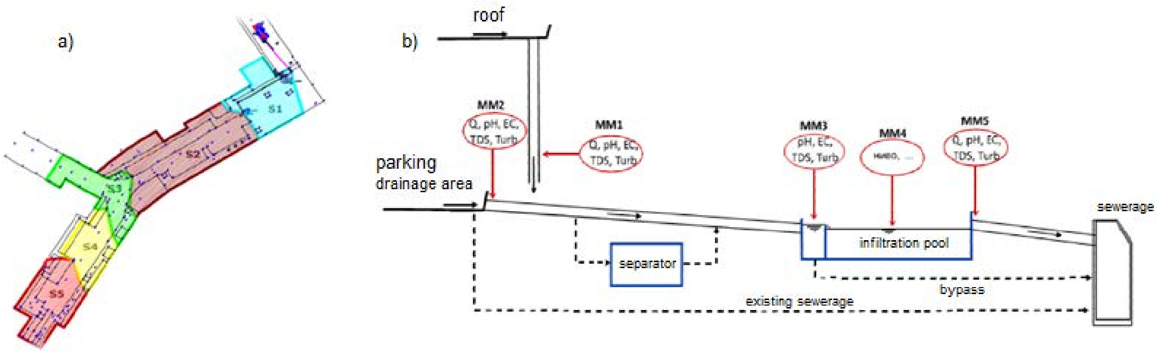

Figure 2. The shape and division of the basin, b) Flow scheme of water (Vasilić et al., 2013)

The following table gives the surfaces of the sub-basins, as well as the surfaces of permeable and impervious surfaces within each sub-basin.

Table 1
Total surface area of sub-basins and share of permeable and impervious surfaces

Designate of basin	Surface – A (m^2)				
	Total A_i (m^2)	Impervious			Permeable (greenery)
		Asphalt	Concrete, rock	Metal roof	
S1	584	0	102.9	104.1	377
S2	1229	441.1	465	0	322.9
S3	483.9	356.6	64.8	0	62.5
S4	410.2	135.3	188.8	0	86.1
S5	624.4	109.4	328.2	0	186.8
Total (m^2)	3331.5	1042.4	1149.7	104.1	1035.3
%	100	31.3	34.5	3.1	31.1
Total (%)	100	68.9			31.1

Outflow from all surfaces is accepted in one profile on the basin, then by the existing concrete channel conducted to the object for the repair of the quality of the outflow. Infiltration as the runoff control method mimics the best the natural hydrological processes in the basin. Additionally, the runoff that feeds groundwater is naturally purified by the process of infiltration through the soil. In the basin, a separator was installed directly upstream of the infiltration pool (Figure 3). It is required due to suspended matter, which can reduce the infiltration capacity of the pool by clogging the pores in the soil. The flow of water is schematically shown in Figure 2 (right).

The built infiltration pool has a surface A = 6 m^2 and overflow edge at 0.5 m from the bottom of the basin. Inlet storage is provided with bypass Ø 100 mm, which allows the surface runoff removal during more intense rainy episodes and improves the system's management. The dimensions of the inlet storage are basically 1.15 x 0.75 m. The water is poured into an additional chamber where the bypass is built. From this chamber, the water carries out through a pipe Ø 200 mm to the existing sewage. The dimensions of this chamber are basically 0.85 x 0.75 m. Also, an outlet storage located directly behind the infiltration pool is provided which accepts excess water that can not be accepted by the infiltration pool. From this chamber, the water is carried out through the PVC pipe Ø 200 mm into the existing sewage. The dimensions of the outlet storage are basically 1.5 x 1.0 m. Between the inlet storage and infiltration pool, the Thomson overflow was designed at the Z_{T1} = 0.35 m from the bottom of the inlet storage, while between the infiltration basin and the outlet storage the Thomson overflow was placed at the Z_{T2} = 0.5 m from the bottom of the infiltration basin (Vasilić, 2013).

Figure 3. The real state of objects in the experimental basin in Belgrade

The infiltration pool in the model is presented as a water storage object with a permeable bottom. The inlet and outlet storage are modeled as a water storage object with an impermeable bottom (Figure 4). The chamber with bypass will not be modeled because it is considered that for the needs of this paper, a system without bypass is sufficient.

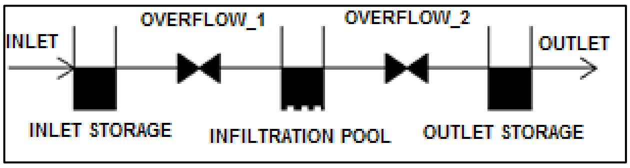

Figure 4. Model of the infiltration pool in SWMM

Calibration of the infiltration pool model

The model of the infiltration pool is calibrated based on the data obtained from the initial load test with pure water. Initial load testing involved filling the infiltration pool with the variable flow so that the overflows were not activated. At the same time, measurements of level changes in the pool were performed. The mean flow was 3.65 l/s and this value was used in the calibration of the infiltration pool model. Measurement of the level was performed during the charging of the pool and afterward (Figure 5). Based on these measurements, the filtration coefficient is 37.80 mm/h. Within the Seepage Loss attribute, the capillary potential (Suction Head), the filtration coefficient (Conductivity) and the initial deficit of moisture (Initial Deficit) were set. The initial deficit is the difference between the maximum humidity and the initial humidity of the soil. These values were changed so that the results of the model match the results of the measurement. These parameters represent soil characteristics in the basin which are important for model formation. In the calibration model, only the infiltration pool is modeled, without the inlet storage, the outlet storage, and the overflows.

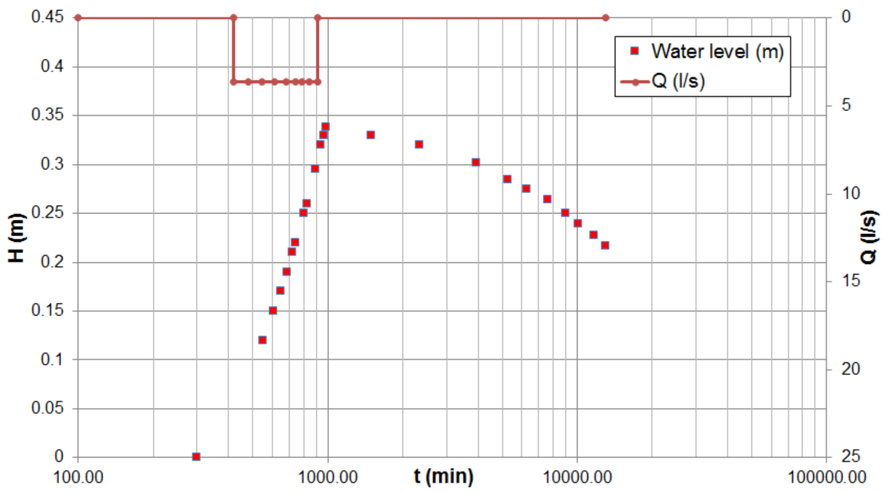

Figure 5. Inflow and change of level in the infiltration pool

Representation of the SWMM software package

The SWMM software package (Storm Water Management Model) is used to analyze the outflow and infiltration from the urban basin. In the SWMM software package, the interaction between several main components of the environment is modeled in the so-called objects. In this case, they are the atmosphere, land surface, transport system and groundwater, in which infiltration from the land surface goes.

The Green Ampt method is used to calculate infiltration within the SWMM model. The Green Ampt method is based on the calculation of the intensity of soil infiltration assuming that a steep, wet front will be formed during the process and that the process takes place in a semi-infinite environment. The following figure shows the parameters of the Green-Ampt model.

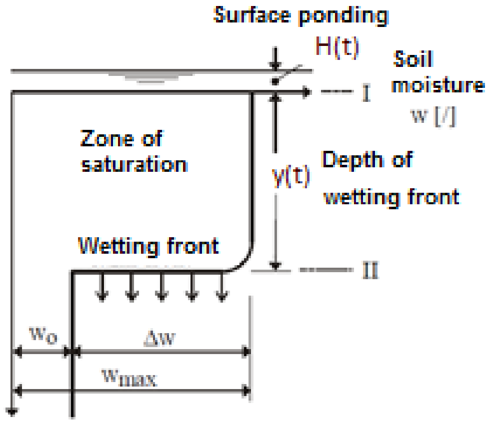

Figure 5. Modeling of infiltration using the Green-Ampt method

The wet front represents the boundary that separates the soil of the initial moisture w_0 (below the wet front) from saturated soil w_{max} (above the front). The process is described by the following equations:

- equation of continuity:

$$F(t) = y(t) \cdot (w_{max} - w_0) = y(t) \cdot \Delta w \Rightarrow y(t) = \frac{F(t)}{\Delta w} \tag{1}$$

where F(t) is cumulative amount of water infiltrated into soil until the time t, y(t) is position of the wet front after time t, w_{max} is maximum soil moisture under saturation conditions (soil porosity ϕ), w_0 is initial moisture soil and Δw is initial deficit of moisture in soil;

- dynamic equation:

$$q(t) = -K_f \cdot \left(\frac{\Psi_2 - \Psi_1}{z_2 - z_1}\right) = -K_f \cdot \left(\frac{-y(t) + h_k - H(t)}{y(t)}\right) \tag{2}$$

where is q(t) = intensity of soil absorption (infiltration), K_f is Darsi's filtration coefficient for the saturated environment, H(t) is the water level in the pool.

The Manning equation in the SWMM software package is used to establish the relationship between the flow (Q), the cross-sectional area (A), the hydraulic radius (R), and the slope (S) of open and partially filled closed collectors (Robert Manning, 1890).

$$Q = \frac{1}{n} \cdot AR^{\frac{2}{3}} \cdot \sqrt{S} \tag{3}$$

where n is Manning's Roughness Coefficient.

The mathematical basis of the model is the equations of maintaining the mass and quantity of motion for an unsteady line flow by open channels (equation of continuity and dynamic equation), i.e. Sen-Venan equations, which can be written in the form:

- equation of continuity:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0, \tag{4}$$

- dynamic equation:

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+gA\frac{\partial H}{\partial x}+gAS_f=0, \qquad (5)$$

where K is flow, k is coordinate (distance) along the flow, A is cross-sectional area, H is piezometer level (level of bottom + water depth) and S_f is slope of the energy line (Mijić, 2006).

In order to solve Sen-Venanov equations, the program implements Dynamic wave model. This model solves complete Sen-Venan equations, wherefore this method gives the most accurate results. This method is applied in systems where is a significant effect of increasing the level in the channel due to downstream boundary conditions. Because of the limited capacity of the upstream pipe in the pool, instead od Tompson's overflow (V-NOTCH), the overflow of the rectangular shape (TRANSVERSE) is set on both places in the model. The formula for the flow on the rectangular overflow is:

$$\mathrm{Q}=\mathrm{C}\cdot\mathrm{L}\cdot\sqrt{2\mathrm{g}}\cdot\sqrt{\mathrm{H}^3}=\mathrm{C_w}\cdot\mathrm{L}\cdot\sqrt{\mathrm{H}^3} \qquad (6)$$

where Q is flow; C is overflow coefficient, here C = 0.32; L is the length of the overflow edge; g is gravitational acceleration; H is spillover height.

Input data

In order to get acquainted with the basin and facilities in it, geodetic and construction maps were used. These are the georeferenced plan of the basin, the situation, basics and characteristic intersections of the infiltration pool.

Simulations of infiltration and runoff were made on the basis of hydrological maps for real and synthetic rain. Real rain data is obtained from measurements at the local meteorological station located in the basin. The series of data includes three days, from 4.4.2015 to 6.9.2015. Four episodes are selected for modeling purposes and the histogram is obtained for 2 minutes of discretization (Figure 6, right).

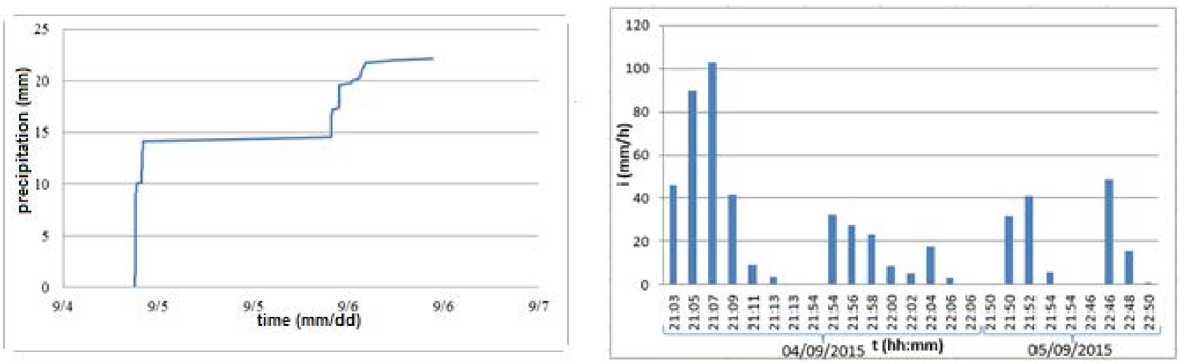

Figure 6. The summarized line and the histogram of precipitation in the basin

Within this analyze, synthetic rain common for Belgrade is used. It is a rainfall of two years return period, with 5 minutes duration, whose height of precipitation of 6 mm was read from the HTP curve (Figure 7). A rainfall of constant intensity 72 mm/h and short duration of T_k = 5 minutes is formed, based on which the effect of infiltration pool on the observed basin is analyzed.

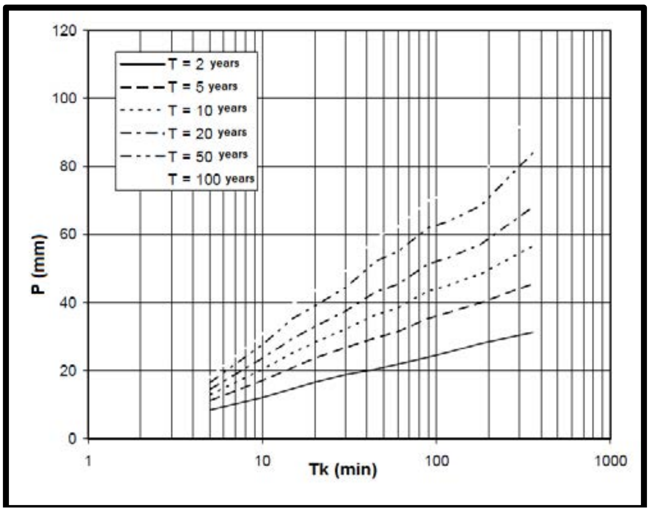

Figure 7. Dependence on the pluviographic station Beograd-Vračar (period of processing 1925-1989) (Vasilić, 2013)

RESULTS and DISCUSSION

In this chapter, the results of the calibration of the infiltration pool model and the results of simulations with the observed and synthetic rains are presented. Based on the obtained results, the importance of the infiltration pool in reducing the runoff from urban areas was evaluated

Values of the filtration coefficient (K), the capillary potential (H_k) and the initial moisture deficiency (Δw) (Table 2) are varied in the calibration, so that the simulated water levels in the infiltration pool correspond to measured values. Results obtained from the model by applying calibrated model parameters (Table 2) and the measurements coincide sufficiently. (Figure 8):

Table 2

Calibration parameters of the infiltration pool model

Filtration coefficient K (mm/h)	37.8
Capillary potential H_k (m)	450
Initial moisture deficit Δw (-)	0.025

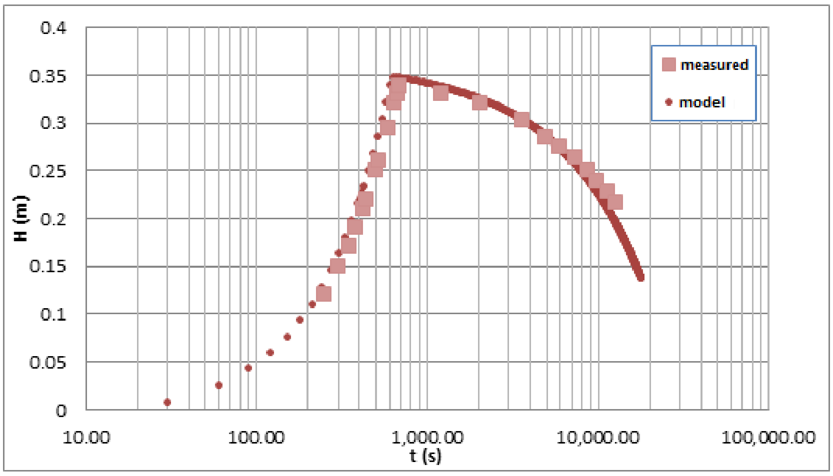

Figure 8. Results of the model and level measurement in the infiltration pool

The results of the simulation are shown through the hydrographs of flow in the pipe Ø 200 mm (INLET), on the first overflow (OVERFLOW_1), on the second overflow (OVERFLOW_2) and in the pipe Ø 200 mm (OUTLET), which is also the outlet from the outlet storage. The first two rainy episodes represent the first day, and the other two represent the second day. Hydrograps below are shown, which enable a more detailed view. Separate hydrographs for first two (Figure 10) and the other two rainy episodes (Fugure 11) are created.

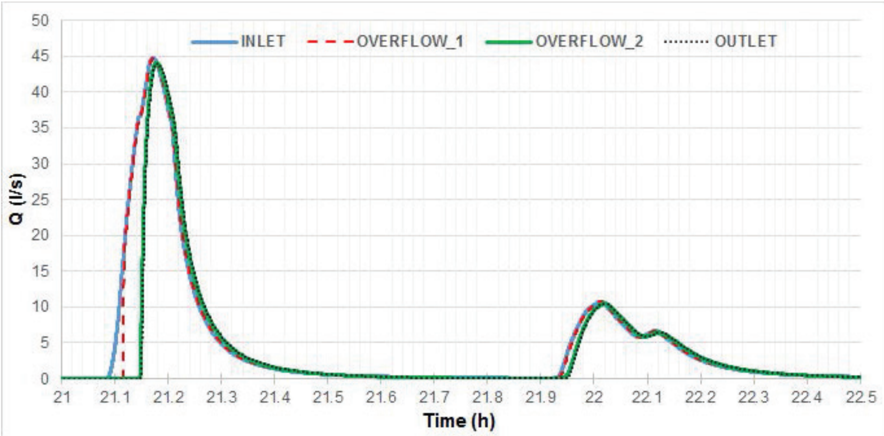

Figure 10. Hydrograph for the first and second rainy episodes

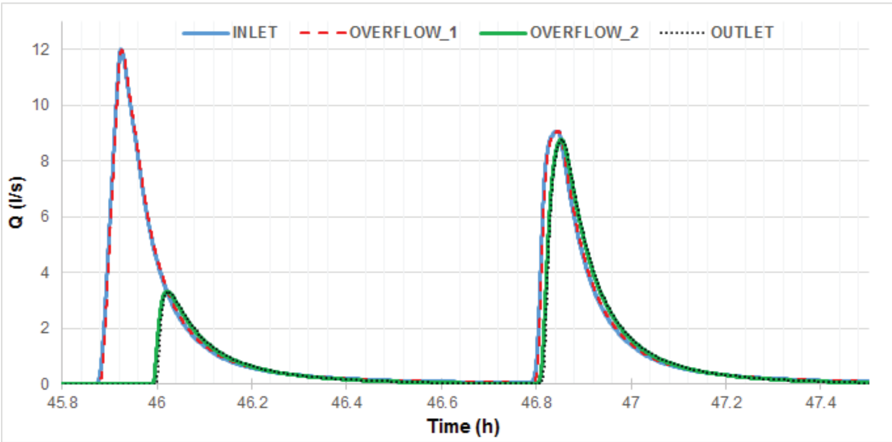

Figure 11. Hydrograph for the third and fourth rainy episodes

Based on the given hydrographs (Figures 10. and 11.), total amount of water that enters the system, volume of infiltrated water and amount of water that goes into the sewage system is determined. By comparing these volumes (Table 3.), the effectiveness of the infiltration pool is determined.

Table 3
Characteristic volumes of water in relation to the total inflow into the system

V_{INLET} (m^3)	35.31	100.00 %
$V_{OVERFLOW\_1}$(m^3)	34.75	98.40 %
$V_{OVERFLOW\_2}$(m^3)	27.48	77.80 %
V_{OUTLET} (m^3)	27.48	77.80 %
$V_{INFILTRATION}$ (m^3)	7.27	20.60 %

According to the data, it can be seen that infiltration is 20.60% of the total inflow into the pool. This means that the infiltration pool, in this case, reduces the runoff from the basin by around 20.60 %, which is very useful for urban basins and existing sewage systems. Also, this is very important from the aspect of the quality of the outflow, because the infiltrated water is also purified through a natural filter which is, in this case, the soil. The results of the simulation of runoff for the analyzed synthetic rain are shown in graph (Figure 12).

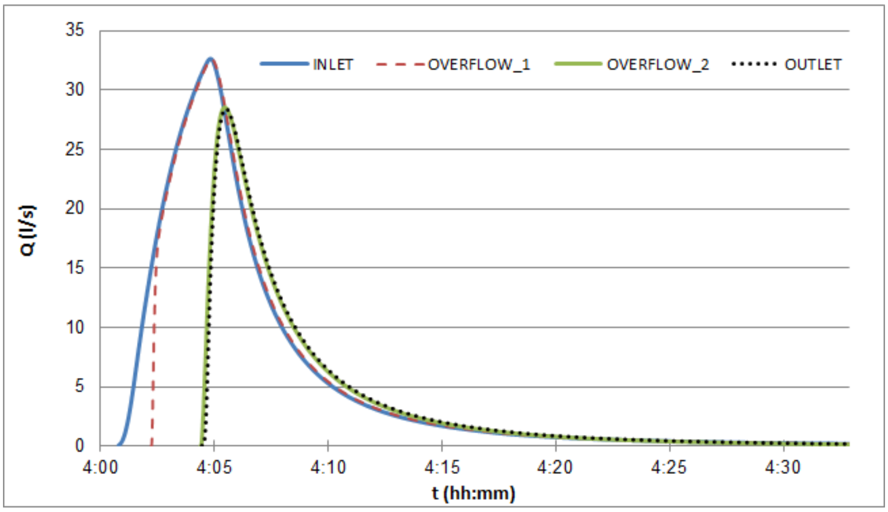

Figure 12. Hydrograph for synthetic rain

In the simulation of synthetic rainfall, the characteristic volumes of water are calculated. With these values, we estimate how much water is infiltrated through the bottom of the pool and how much that amount is significant for reducing the amount of water that goes into sewage systems. The results are shown in the following table.

Table 4
Characteristic volumes of water in relation to the total inflow into the system

V_{INLET} (m^3)	11.10	100.00 %
$V_{OVERFLOW\_1}$(m^3)	10.54	95.00 %
$V_{OVERFLOW\_2}$(m^3)	7.06	63.60 %
V_{OUTLET} (m^3)	7.06	63.60 %
$V_{INFILTRATION}$ (m^3)	3.48	31.35 %

According to the results shown in Table 4, it can be seen that 31.35 % of the total amount of water that has entered the runoff collection system is infiltrated through the bottom of the infiltration pool. This significantly reduced the outflow in the sewage system, which indicates the great importance of the infiltration pool.

CONCLUSIONS

The basic goal of this paper is to examine the effectiveness of infiltration pools in reducing the amount of surface runoff. The case study was real urban basin which includes a system for collecting outflow, a system for reduction in its quantity, as well as a part of the system that is responsible for improving the quality of the outflow.

According to the obtained results of executed simulations, more water is being infiltrated through the bottom of the infiltration pool in the synthetic rain, than in the observed rains. Synthetic rain is one episode, with humidity conditions in the soil which allow infiltration to take place with maximum intensity. On the other side, observed rains, in fact, are continual time series and in this case, it is not possible to avoid the influence of increasing soil moisture on reducing infiltration and increasing outflow during the time.

Based on the obtained results, the basin is behaving completely completely correct in observed rains, as well as in synthetic rain. In any case was not there any failure, congestion or flooding of the system. Also, it is noticed that more water is infiltrated during the synthetic than the observed rains. It can be seen that by observed rains, this is about 20 % of the total inflow into the system, while when we look at synthetic rainfall, infiltration is about 32 % of the total outflow that came into the system. It can be said that the amount of outflow, which goes away into the sewer system, is significantly reduced. These indicators confirm that the infiltration pool is an effective solution for reduction of runoff from urban basins.

In the future system analysis, it would be interesting to perform simulations with the rains of a longer return period in order to examine the behavior of the system in some stronger and more intense rain. Given that the role of the infiltration pool in the reduction of runoff volume has been examined here, in the future, it would be good to monitor the quality of water infiltrating through the bottom of the pool and to see the importance of the infiltration pools in improving the quality of the outflow.

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Regulated using of drainage-discharge water of rice irrigation system

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ABSTRACT
Regulated using of drainage-discharge water of rice irrigation systems. Katerina Dudchenko, Vladimir Kornberger, Vladimir Dudchenko, Vladimir Morozov, Alexei Morozov.
The way of using drainage and discharge waters of rice irrigation systems for irrigating rice and related crops has been worked out on the basis of the investigation results. The regulation of drainage and discharge flow interrelated with groundwater reduces rice irrigation norm by 1000–1300 m^3/ha, discharge volumes beyond the system – to 1204 m^3/ha and increases rice yields by 0.9-1.0 t/ha on average.
KEYWORDS: rice, rice irrigation system, drainage and discharge water, yield.

INTRODUCTION
The most common rice irrigation mode in the world and Ukraine is the continuously flooding and shortened flooding. Rice growing in such technologies requires significant water input, rice irrigation norm is 15-20 thousand m^3/ha. The actual problem of growing rice in the South of Ukraine lies in the fact that the technological process requires considerable amounts of irrigation water. Non-productive technological discharges may exceed 50% of water supply in rice growing systems (RGS). The outflow is discharged into the Black Sea aquatorium which worsens the ecological situation in the rice-planting region and recreation zone. The water is discharged into the Black Sea aquatorium which worsens the ecological situation in the rice-planting region and recreation zone. Thus the problems of re-using drainage and discharge waters, minimizing non-productive discharges, saving resources and protecting nature are the actual ones.

MATERIAL and METHOD
The research was conducted on the territory of rice irrigation systems of the Skadovsk district, Kherson region, which has typical reclamation landscape, climate, soil, geological, hydrological and water management conditions for rice growing area of Ukraine. The soils of the experimental plots are chestnut alkali of medium loamy content.

The major method of investigation was a field poly-factor experiment in working conditions. The research scheme was: rice irrigation by water from the irrigation canal Krasnoznamyansk (mineralization 0,25-0,35 g/dm^3); rice irrigation by drainage and discharge water (DDW), mixed with irrigation water in drainage and discharge water two-stage regulation condition. For researching were used field, laboratory, statistic and calculation-comparative methods.

In the process of research, we tested the resource-saving technology of using drainage and discharge waters of rice irrigation systems, which had been developed on the basis “Rice growing technology with meeting the requirements of the environmental protection” [1].

Rice fields are flooded immediately after sowing, the water layer being not higher than 8–10 cm. The water is gradually absorbed by the soil and evaporates. The moisture absorbed by the soil is used for saturation, deep and side filtration which gets into drainage and discharge canals.

After seedlings appear the checks are gradually filled with water, one third of the plant being over the surface of the water. During the tillering stage the water layer ranges from 5 to 7 cm. After tillering the depth of the water in the check is gradually increased to 10–12 cm and kept at this level until the stage of wax ripeness. During this period the level of ground water rises to 1m.

Possibility of outflow regulation appears in the second decade of June. The biggest outflow volume was recorded during the second decade of June to the third decade of July. In order to reduce filtration losses of water from the checks it is necessary to increase the water level in the drainage and discharge network, the vertical levels in the checks and drainage and discharge canals being minimized, in some cases the water level in the drainage and discharge network exceeding this parameter in the checks. The water level in the drainage and discharge network is regulated with automated regulators of the drainage flow patented by the authors (Pat. 87665 Ukraine, MPK A01B 79/00. The device for regulating the level of drainage and discharge waters) [2]. The given hydro-technical installation consists of a slide (1) (Figure 1,2), connected with a screw (3), lifting and lowering the shutter (7), made of sheet steel (4 mm thick) and regulating the height of a rectangular water discharge tunnel (2). The construction moves along the support-chassis (4), made of rolled steel corner section. For regulating the water level in the drainage and discharge tunnel the shutter is equipped with grooves for sandors (5), made of rolled steel corner sections (profile 50×53).

The device works in the following way: the shutter (7) (Figure 2) is lowered with the screw (3), preventing the movement, the level of water in the canal gradually rises until it reaches the mark of the rectangular weir (6) (Figure 2, 3). As the level of water continues to rise the surplus water, flowing over the threshold of the rectangular weir through the rectangular tunnel (2) (Figure 1), gets into the water discharge pipe (10) (Figure 3) and is directed beyond the system. Changing the mark of the threshold of the weir with the regulating sandors it is possible to regulate the level of water in the canal corresponding the level of water in the checks.

Taking into consideration the increase of the level of groundwater to 1 m from the surface and its relatively low mineralization (0,45–0,67 g/dm^3), it is possible to apply irrigation of the related crops (alfalfa, soybean, sorghum and others). During this period drainage and discharge waters can be used for surface irrigation and sprinkle irrigation of the related crops (alfalfa, soybean, sorghum and others), and also for moisture charging irrigation.

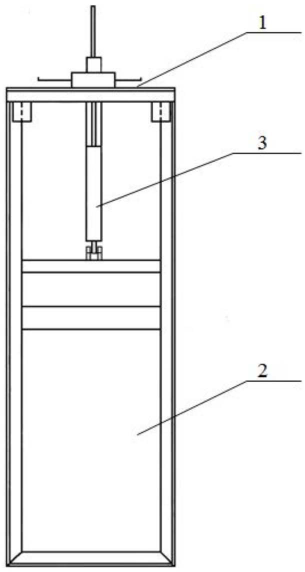

Figure 1. Front view of the regulator
1 – slide,
2 – rectangular water discharge tunnel,
3 – screw

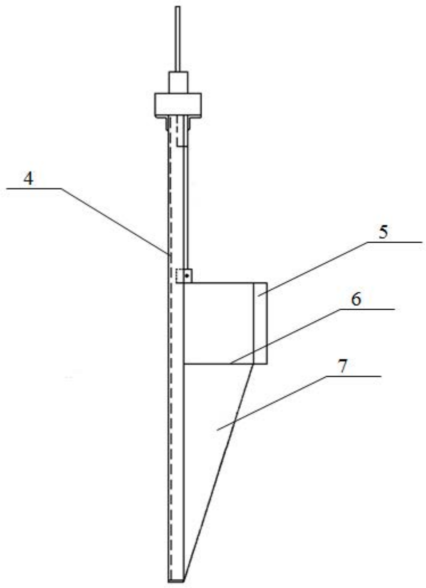

Figure 2. Regulator, side view
4 – support-chassis part,
5 – grooves for sandors,
6 – rectangular weir,
7 – shutter

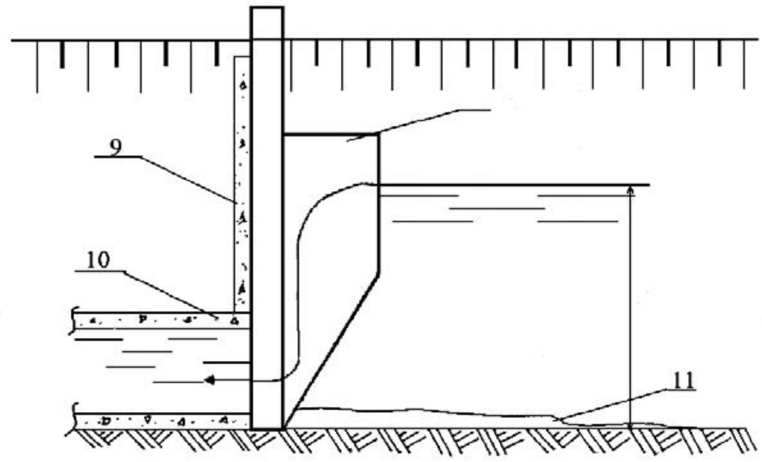

Figure 3. The scheme of water movement through the regulator of the level of drainage and discharge waters of rice irrigation systems

8 – device for regulating the level of drainage and discharge waters, 9 – concrete cap, 10 – water discharge pipe, 11 – silt, H – water depth in the drainage and discharge canal, h – water depth in the water discharge pipe, - direction of water movement.

In 25–30 days after rice panicles develop the water supply to the checks is stopped so that at the beginning of the phase of full grain ripeness the water supply in the checks be used by the plants at the final phase of vegetation – full ripeness. If the technological recommendations concerning the depth of water in the checks (10–12 cm) are followed and the water supply is stopped on time at the phase of full ripeness, the discharge of surplus water does not normally occur [1, 3].

RESULTS and DISCUSSION

Drainage and discharge water quantity is reduced to zero during the third decade of July to the second decade of September. The outflow was changing during 34,8 m3/ha to 3198,5 m^3/ha in research period, which was 2-28% water input (14275-17581 m^3/ha).

Table 1

Main indices of efficiency of the technology of using drainage and discharge water of rice irrigation systems

Indices of efficiency	Units of measurement	Year of research	Variants		Effect achieved, ±Δ
			experiment	control	
Yield	t/ha	2009	5,26	6,12	-
		2010	5,30	5,30	0
		2011	5,41	4,71	0,7
		2012	8,24	6,15	2,09
		2013	6,42	6,16	0,26
		2014	7,13	7,10	0,03
Irrigation norm	m^3/ha	2009	14275	45525	-1250
		2010	14428	15628	-1200
		2011	14403	15581	-1280
		2012	14838	16088	-1250
		2013	15337	16567	-1230
		2014	18696	17581	-1115
Outfall of drainage and discharge outflow	m^3/ha	2009	347,53	2585	-2237,5
		2010	173,19	2628	-2454,8
		2011	1685,9	2581	-895,1
		2012	2169	3020	-851,0
		2013	4322	4322	0
		2014	2703	3084	-381,0

The technology of using drainage and discharge water allows for reducing the rice irrigation norm by 1000–1300 m^3/ha (Table 1), at the expense of raising the level of groundwater and reducing filtration-related expenses within the check. Reducing the discharge volumes beyond the system is 400–2500 m^3/ha (Table 1). The considerable variation is explained by different areas of the experimental plots, technical conditions of RIS and the quantity of the installed regulators.

Analysis of rice yields for the research period showed that the yield ranged from 5,25 to 8,24 t/ha on the experimental plots and it was 4,38–6,16 t/ha on the test plots. The difference of the investigated parameter was 0,86 t/ha on average.

Irrigation water use efficiency is a ratio of the irrigation water volume to rice yield and called water using coefficient. Thought base rice growing technology the coefficient was in average 2927 m^3/t, thought regulated using of drainage and discharge water of RIS the coefficient was 2352 m^3/t.

CONCLUSIONS

1. The way of regulated using of drainage and discharge water of rice irrigation systems can reduce volume outflow by reducing seepage and percolation loses form checks and using DDW to rice and related crops irrigation in average to 1204 m^3/ha.
2. The irrigation water volume for rice growing reduces to 1000-1300 m^3/ha because of regulated using of DDW.
3.Watering of rice by drained-discharge waters with regular usage increases rice yield in average to 0,9-1,0 ton per hectare, due to the higher number of nutrients in drained-discharge water.
4. The irrigation water use efficiency increasing thought regulated using of drainage and discharge water of RIS was 575 m^3/t in average.
5. The implementing overall economic effect of the method of regulation using of drainage-discharge water for rice irrigation systems 178,82 USD. per hectare, with prices of 2009 year.

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The assessment of the soil erosion and runoff in the Sekularska Rijeka river basin, Northeast Montenegro

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ABSTRACT

Soil erosion is a growing problem within the Mountainous region of North Montenegro and Southwest Serbia being a very serious threat to soil quality of the agricultural land. We used IntErO model for the assessment of sediment yield and runoff in the Sekularska Rijeka river basin from the Northeast Montenegro. The studied area is characterized by the continental climate. The temperature coefficient of the region, T, is calculated on 1.00; the amount of torrential rain, hb, on 115 mm. The structure of the river basin, according to the rock permeability, is the following: f0, poor water permeability rocks, 45%; fpp, medium permeable rocks, 12%; very permeability rocks, 43%. The coefficient of the region's permeability, S1, is calculated on 0.71. The coefficient of the river basin planning, Xa, is calculated on 0.35. The coefficient of the vegetation cover, S2, is calculated on 0.69. Average river basin decline, Isr, is calculated 43.48 % indicating that in the river basin prevail very steep slopes. Set of geographical, climate, geology, pedology and land use inputs are included in the IntErO simulation model. The results shown that the net soil loss was calculated on 18,630 m³ per year, specific 287 m^3km^{-2} per year. The results of this study are the determination of erosion processes; new information about the state of the runoff and soil erosion intensity, illustrating the possibility of modelling of sediment yield with such approach.

KEY WORDS: Soil erosion; Runoff; IntErO model; Sekularska River basin.

INTRODUCTION

Soil erosion associated with non-point source pollution is a considerable environmental problem with respect to the off-site transport of sediment from agricultural land and nutrient-rich pollutants adsorbed to the eroded sediment into nearby waterbodies and the neighbouring environment (Junakova et al., 2017). This process is causing land degradation but also water management and hydro-technical problems (Gholami et al., 2014). Mountainous watersheds are affected by natural disasters, above all erosion problems, but also floods, overflows, inundations, landslides and pollution (Tazioli et al., 2015).

Measures for erosion control are being undertaken in all developed countries, which absorbs much resources and require reliable, scientifically based estimation in three main aspects: geographical (spatial), quantitative (erosion rate and removed substrate mass), and temporal (Litvin et al., 2017).

Quantification of soil erosion in a watershed is important and one of the basic steps of all studies to encompass lots of environmental problems and to evaluate the amount of sediment moved, transported and deposited in and out of the basin. On the other hand, direct measurements of erosion in a watershed are possible with multi-years measurement of solid transport in the closing-section (Tazioli, 2009).

Sediment load measurements are useful to calibrate soil erosion models (Sadeghi et al., 2014; Vujacic et al., 2017) that are after useful tools to evaluate the amount of discharge and erosion in a watershed, when hydrometric and discharge data are not available (Behzadfar et al., 2014).

Hydrological models are basically employed for hydrologic forecast and to get an insight of hydrologic processes (Goyal et al., 2017). Calculations of erosion rate and soil loss from slopes using logical-mathematical erosion models within different landscape zones revealed spatial-temporal regularities in the dynamics of these parameters and made it possible to assess the role of changes in the main natural and anthropogenic factors of erosion (Litvin et al., 2017).

According to the local experiences in Slovenia, Serbia, Montenegro, Macedonia Bosnia and Herzegovina, Erosion Potential Method – EPM (Gavrilovic, 1972) was successfully applied all over the regions of Balkan Peninsula, but also in the watersheds of Apennine Peninsula (Vujacic et al., 2017; Spalevic et al., 2017; Spalevic et al., 2016; Mincev, 2015; Kostadinov et al., 2014; Spalevic et al., 2014; Sekularac, 2013; Spalevic et al., 2013; Spalevic et al., 2012; Tazioli, 2009; Milevski et al., 2008; Zorn and Komac, 2008).

At the Bregalnica basin in Macedonia (Milevski et al., 2008), a very good match has been achieved between the results obtained using the EPM method and onsite measurements. It should be highlighted that the EPM/IntErO model considers the total sediment load, whereas most of the measurements conducted in the studies cited take into account suspended load only.

In Italy, using the same methodology, Tazioli (2009) found that this model corresponds well concerning annual sediment yield using nuclear probes for suspended-load measurements on Musone and Esino watersheds. Similar studies were applied earlier at the Prescudin catchment in Italy, (Bemporad et al., 1997) recording a minimum deviation between predicted and measured sediment yield values (Spalevic et al., 2017). The Gavrilovic model is an empirical EPM (erosion potential model) created for the analytical determination of erosion coefficients, quantification of gross erosion and average annual sediment yield (Auddino et al., 2015).

In this part of Montenegro the main cause of loss of topsoil is soil erosion initiated by water. During the heavy rainfalls the ground became saturated, water gathers on the ground, running across the surface, carrying topsoil with it, causing water flow on the land surface. This runoff carries the detached soil materials away and deposits them downstream. In the studied area the land is with very steep slopes (average river basin decline, Isr, is 43.48%). and there is a greater potential for soil erosion due to the fact that gravity pulls the water and soil materials down the slope.

The objective of this paper is to apply computer-graphic modelling by using the IntErO model establishing a structured data base that may be used after to predict soil erosion scenarios for the establishment of intensive agricultural–livestock production at the Sekularska Rijeka River Basin.

MATERIAL and METHOD

Study area. The river basin of the Sekularska Rijeka (65 km^2) is the right-hand tributary of the river Lim in the Northeast Montenegro, encompassing the villages of Sekular and Rijeka Marsenica. It is located 10 km east of Andrijevica; 10 km south of Berane, 15 km North of Plav in Montenegro. Satellite imagery was used to estimate standard morphometric methods (Figure 1.).

Fieldwork & laboratory analysis. The research part related to geology and soil is based on previous geological (Zivaljevic, 1989) and pedological studies (Fustic and Djuretic, 2000) of Montenegro. Furthermore, we collected some soil samples for chemical and physical analysis. The grain size composition of the soil was determined by the pipette method. The soil samples were air-dried at 105°C sifted through 2 mm sieve and dispersed using sodium pyrophosphate. Total carbonates were determined by the volumetric Scheibler method; the soil reaction (pH in H2O and nKCl) was determined with a potentiometer; the content of the total organic matter was determined by the Kotzman method; easily accessible phosphorous and potassium were determined by the Al-method and the adsorptive complex (y1, S, T, V) was determined by the Kappen method (Spalevic et al., 2017).

Climatological data were received from the Institute of Hydrometeorology of Montenegro (1948-2015). We analysed torrential rains, annual air temperatures, and average annual precipitations. We used IntErO model (Spalevic, 2011), for calculation of sediment yield and runoff, based on Erosion Potential Method (Gavrilovic, 1972) and designed to assess annual erosion rates.

During the field work, using a morphometric methods, various data on intensity and forms of soil erosion, land use, and the measures taken to reduce or mitigate erosion were recorded. Different forms including the shape of the slope, the depth of the erosion base and the density of erosion rills were determined.

The natural length of the main watercourse we calculated to be 15.18 km. The shortest distance between the fountainhead and the mouth, is 13.02 km. The total length of the main watercourse, with tributaries of I and II class, is 21.71 km. The average slope gradient in the river basin, Isr, is calculated on 43.48%, indicating that in the river basin prevail very steep slopes. The average river basin altitude (Hsr), the average elevation difference of the river basin (D) are 1397.52 m, 687.52 m, respectively.

IntErO model application. The IntErO (www.agricultforest.ac.me/Spalevic/IntErO) program package (Spalevic, 2011) was used to estimate maximum runoff discharge from the basin and the intensity of soil erosion, with the Erosion Potential Method – EPM (Gavrilovic, 1972) embedded in the algorithm of this computer-graphic method.

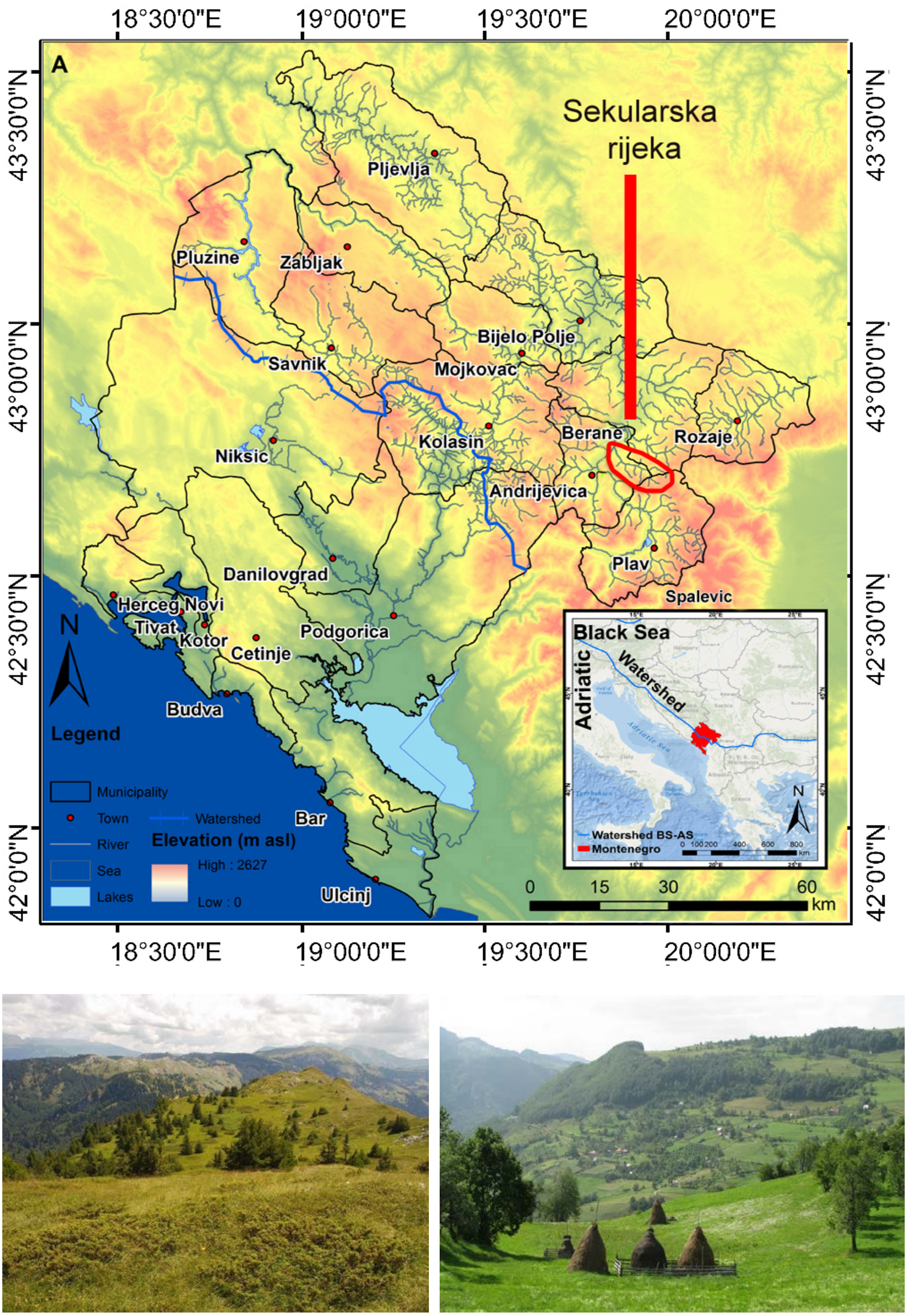

Figure 1. Location and view on the studied Sekularska Rijeka river basin

Model verification. Sediment yields were calculated for all the tributaries of the Lim river basins, which include the Sekularska Rijeka river basin. The model results were then compared with the measurements (Bathymetry) obtained at the Potpec reservoir. Using the Model the sediment yield was calculated to be 347 273 m^3year^{-1}; while actual geodetically performed measurements were 350 000 m^3year^{-1}. This validates calculations of the results for sediment yield obtained by model. This leads to a conclusion that the model is applicable for the observed area (Spalevic et al., 2017).

Figure 2. Bathymetry at the Potpec reservoir

RESULTS and DISCUSSION

Model Parameters Calculation

Climatic characteristics. Data used in research were provided by the Institute of Hydrometeorology of Montenegro. The studied region has a continental climate, with rainy autumns and springs and cold winters. The absolute air temperatures recorded range from a minimum of -29.8°C up to 35 °C. On the basis of the available data, the average annual air temperature, t0, is 9°C; average annual precipitation is 944.3 mm. Calculated temperature coefficient for this area, T, is 1.0; the torrential rain, hb, is calculated to be 115 mm.

The geological structure, soils and land use. This part of Montenegro consists mainly of Paleozoic clastic, carbonate and silicate volcanic rocks and sediments of the Triassic, Jurassic, Cretaceous-Paleogene and Neogene sediments and Quaternary. The most common soil type is Dystric Cambisols (90%). In some smaller areas in the river basin there are also soils such as Fluvisols and Colluvial Fluvisols. Structure of the land use is the following: Plough-lands: 3.7 %; Orchards: 3.02 %; Mountain pastures: 19.94 %; Meadows: 28.24 %; Degraded forests: 7.06 %; Well-constituted forests: 38.04 %. The coefficient of the vegetation cover, S2, is 0.69.

Soil erosion and runoff. The relief of the hilly-mountainous terrain is characterized by steep slopes from which the water runs off and flows quickly, which is favourable for triggering the soil erosion process. The dominant erosion form in this area is surface runoff; more severe forms of erosion, such as rills, gullies and ravines, are rare, according to the analysis of our filed visit.

The erosion causes some places to lose fertile land, and results in sterile alluvial deposits on the fertile soils of the small alluvial terraces close to the main watercourse. Surface erosion has taken place in all the soils on the slopes, with the effect that this erosion is most pronounced on the steep slopes with scarce or denuded vegetation cover.

The assessment of the soil erosion and runoff in the Sekularska Rijeka river basin using IntErO model is presented at the Table 1.

Table 1
Part of the IntErO report (inputs and outputs) for the studied watershed

River basin area	F	64.94	km²
The length of the watershed	O	40.61	km
Natural length of the main watercourse	Lv	15.18	km
The shortest distance between the fountainhead and mouth	Lm	13.02	km
The total length of the main watercourse and tributaries	ΣL	21.71	km
River basin length measured by a series of parallel lines	Lb	17.43	km
The area of the bigger river basin part	Fv	44.52	km²
The area of the smaller river basin part	Fm	20.41	km²
Altitude of the first contour line	h0	800	m
Equidistance	Δh	100	m
The lowest river basin elevation	Hmin	710	m
The highest river basin elevation	Hmax	2003	m
A part of the basin with very permeable products from rocks	fp	0.43	
A part of the river basin area consisted of medium permeable rocks	fpp	0.12	
A part of the river basin consisted of poor water permeability rocks	fo	0.45	
A part of the river basin under forests	fš	0.55	
A part under grass, meadows, pastures and orchards	ft	0.42	
A part under bare land, plough-land and without grass vegetation	fg	0.02	
The volume of the torrent rain	hb	115	mm
Incidence	Up	100	years
Average annual air temperature	t0	9	°C
Average annual precipitation	Hyear	944.3	mm

Results:			
Coefficient of the river basin form	A	0.52	
Coefficient of the watershed development	m	0.53	
Average river basin width	B	3.73	km
(A)symmetry of the river basin	a	0.74	
Density of the river network of the basin	G	0.33	
Coefficient of the river basin tortuousness	K	1.17	
Average river basin altitude	Hsr	1397.52	m
Average elevation difference of the river basin	D	687.52	m
Average river basin decline	Isr	43.48	%
The height of the local erosion base of the river basin	Hleb	1293	m
Coefficient of the erosion energy of the river basin's relief	Er	144.99	
Coefficient of the region's permeability	S1	0.71	
Coefficient of the vegetation cover	S2	0.69	
Analytical presentation of the water retention in inflow	W	1.2996	m
Energetic potential of water flow during torrent rains	2gDF^½	935.91	m km s
Maximal outflow from the river basin	Qmax	311.14	$m^3 s^{-1}$
Temperature coefficient of the region	T	1	
Coefficient of the river basin erosion	Z	0.376	
Production of erosion material in the river basin	Wyear	44388.8202	$m^3 year^{-1}$
Coefficient of the deposit retention	Ru	0.42	
Real soil losses	Gyear	18630.35	$m^3 year^{-1}$
Real soil losses per km^2	Gyear km^{-2}	286.9	$m^3 year^{-1}$

CONCLUSIONS

The model has taken into account all of the above parameters (22 input data and 22 results) and it was calculated that the real soil loss under current conditions is 18,630 m^3 $year^{-1}$, and specific is 287 m^3 $year^{-1}$ per square kilometre. The river basin belongs to 5th category a region of very weak erosion (1 - strong erosion, 5 – very weak). According to the value calculated for the (a)symmetry coefficient there is a possibility for large flood waves to appear in the studied river basin.

The presented approach using the Intensity of Erosion and Outflow (IntErO) model is an initial step for our team for further Ecological modelling. The model, according to our experiences has a potential to become a vital tool to reduce uncertainty for environmental policy decision-making in this Region. The team of authors is continuing the further research of this modelling using / changing different types of agriculture production in the basin and taking into consideration various climate change scenarios.

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