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CHANGES IN THE AGROCHEMICAL AND AGROPHYSICAL PROPERTIES OF DEPLETED SOILS (LUVISOLS) IN THE RADOCELO MASSIF AFTER LONG-TERM USE

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Abstract: Leached Luvisols near Bzovik (Kraljevo Municipality) were analyzed to assess the impact of land use on agrochemical and agrophysical properties. Samples from a meadow and a cultivated plot (0-20 cm, 20-40 cm) showed similar mechanical composition but differing quality. Meadow soil had better properties, while cultivated soil had lower humus, higher mobile aluminum, and poorer root conditions. Both soils were highly acidic with low phosphorus and adequate potassium. Fertilization improved phosphorus in the cultivated plot. Liming, phosphorus-rich fertilizers, and crop rotation are recommended to enhance soil fertility.

Keywords: luvisol, soil acidity, phosphorus availability, fertilization

Introduction

Leached soils are particularly common in western and north-western Serbia. Their physical properties are not uniform and depend on the original substrate on which they were formed and the areas where these soils are found. Đorđević et al. (2011) state that the superficial humus-accumulating horizon is mostly sandy-loamy, while Dugalić and Gajić (2012) state that they are light to medium loams. The Ah horizon is 1.5 times poorer in clay compared to the Bt horizon (Đorđević et al., 2011) and therefore has a heavier mechanical composition, ranging from heavy loam to clay. The chemical properties are quite inconsistent and unfavorable (Dugalić and Gajić, 2012). The active acidity (pH/H2O) ranges from 4.7 to 6.5, with the pH decreasing with depth. According to Đorđević et al. (2011), the active acidity ranges from 5.5 to 6. Đorđević et al. (2011) also find that the illuvial horizon has a slightly higher pH (around 6-6.5), which is consistent with the results of Kapović-Solomun and Eremija (2017), who also find that the acidity of the soil increases with depth. Since leached soils are poorly to moderately supplied with total nitrogen and the processes of

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nitrification and nitrogen fixation are very slow due to the pronounced acidity, the plants on such soils are insufficiently supplied with available nitrogen forms. According to Dugalić and Gajić (2012) and Kapović-Solomun and Eremija (2017), the availability of base cations in Luvisols is deficient, especially in the humus accumulation horizon. The same authors mention that the cation exchange capacity in Luvisols formed on limestone is slightly more favorable. Bošković-Rakočević et al. (2004) found that the active acidity of the leached soil was 5.70 pH units, while the substitutional acidity was 4.45 pH units, with no mobile aluminum detected. The micronutrients analyzed had the following values for available content: Zn 1.96 $mgkg^{-1}$, Cu 4.94 $mgkg^{-1}$, Mn 103.0 $mgkg^{-1}$. The total Ni content was 278.0 $mgkg^{-1}$ and the Pb content was 28.0 $mgkg^{-1}$, indicating that the Ni concentrations were above the maximum permissible values. When growing plums on leached soils formed on limestone, Janković et al. (1997) found that the soil had a light mechanical composition, with the sand content decreasing slightly with depth, while the clay content increased. Mrvić et al. (2009) pointed out in their study of the total metal content in soils in central Serbia that around 80% of the soil samples examined had element concentrations below the maximum permissible limits. The average total content of Zn in the soils of central Serbia is around 48 $mgkg^{-1}$, Cu around 27 $mgkg^{-1}$, Pb around 40 $mgkg^{-1}$ and the average total content of Ni is around 58 $mgkg^{-1}$. According to Campos (1997), Fe and Mn deficiency may not be due to an insufficient total content in the soil, but to the formation of poorly soluble compounds in soils with neutral and alkaline reactions. In acidic soils, the solubility of these elements increases, sometimes even to toxic levels. Milićević et al. (2014) state that the content of Cu and Zn directly depends on the pH of the soil, with the Cu content being significantly influenced by the organic matter content and the Zn content by the presence of clay minerals. Adamu et al. (1989) found significant negative correlation coefficients between soil pH and the Zn, Mn, Fe and Ni extracted with DTPA.

Materials and methods

The field investigations were carried out in 2022 on leached soils (Luvisol) in the Radočelo massif, in the village of Bzovik (Kraljevo municipality). Soil samples were taken from a plot with natural vegetation (meadow) and soil that has been used for agriculture for over 20 years, at two depths: 0-20 cm and 20-40 cm. The meadow is located at an altitude of 1167 m (45° 50'24" E and 48° 96'62" N). The other plot, where crop rotation and potato cultivation took place, is located at an altitude of 1161 m (45° 50'72" E and 48° 96'11" N). The soil samples from the cultivation plot were taken after the end of the growing season.

The following methods were used to analyze the agrochemical properties: active and substitutional acidity of the soil, determined potentiometrically with a pH meter; humus content, determined by the Kotzman method; total nitrogen content, determined by the Kjeldahl method; content of available phosphorus and potassium, determined by the Eghner-Riehm method (phosphorus by colorimetry, potassium by flame photometry); content of mobile aluminum, determined by the Sokolov method; content of available Ca and Mg, extracted with 1M NH_4CH_3COO; total content of Cu, Zn, Mn, Pb and Ni, extracted with aqua regia (HCl/HNO_3 in a ratio of 3:1) (McGrath and Cunliffe, 1985), followed by reading with an atomic absorption spectrophotometer; available Cu, Zn, Mn, Pb and Ni content extracted with 0.005M DTPA + 0.01M $CaCl_2$ + 0.1M TEA, pH=7.3 (Lindsay and Norvell, 1978), followed by reading with an atomic absorption spectrophotometer.

The following methods were used to analyze the agrophysical properties: Fractionation with a series of sieves for coarser fractions (%) and the pipette method (sedimentation in still water) for finer fractions (%) were used to study the mechanical composition.

Results and discussion

The content of coarse and fine sand decreased with increasing depth, while the content of silt and clay increased with increasing depth (Table 1).

Table 1.Agrophysical properties of the soil

Purpose	Depth (cm)	Coarse Sand % >0.2mm	Fine Sand% 0.2-0.02mm	Silt % 0.02-0.002mm	Clay % <0.2mm	Total Sand % >0.02mm	Silt + Clay% <0.02mm
Meadow	0-20	23.3	19.2	29.0	28.5	42.4	57.6
Meadow	20-40	16.5	16.5	31.8	35.2	33.0	67.0
Field	0-20	21.4	18.0	31.7	28.9	39.4	60.6
Field	20-40	15.3	17.9	34.7	32.1	33.2	66.8

In the meadow, the decrease was 42.4% to 33%, while in the plot where crop rotation and potato cultivation took place, it decreased from 39.4% to 33.3%.

The silt and clay content increased with depth, both in the meadow (from 57.6% to 67.0%) and in the cultivated plot (from 60.6% to 66.8%), which is consistent with the earlier studies by Janković et al. (1997).

Based on the results obtained, it can be concluded that the mechanical composition of the Ah horizon in the meadow at a depth of 0-20 cm is slightly clayey (according to the two-stage classification of Dugalić and Gajić, 2012), as the silt and clay fractions dominate, i.e. particles <0.02 mm (57.6%). According to the same classification, the meadow at greater depth belongs to the medium clay category (67.0% particles <0.02 mm). For the soil on which agrotechnical measures have been applied for many years, the soil at both depths investigated belongs to the medium clay category. These results confirm the previous studies of Gajić et al. (2001), who found that the agrophysical properties of this soil are favorable up to a depth of 40 cm and that the mechanical composition is light clay, with a bulk density between 1.0 and 1.35 mg/m^3.

The chemical properties are slightly less favorable compared to the favorable agro-physical properties, which is characteristic of Luvisols (Dugalić and Gajić, 2012). The results of agrochemical analysis (Table 2) show that the soil under the meadow has a very acidic reaction in the surface horizon, is moderately supplied with humus and total nitrogen, is well supplied with available potassium and has a very low content of available phosphorus, which is a limiting factor for plant cultivation. The content of available forms of Ca and Mg is within the optimum values. Similar values for the investigated soil fertility parameters in the surface horizon were determined for the cultivated soil.

The content of mobile aluminum is very high (9.09-12.3 mg/100g soil) and is thus well above the values that cultivated plants can tolerate (Jakovljević et al., 1991). Such a high content of mobile aluminum reduces the penetration depth of the root system and thus limits the uptake of water and nutrients from the soil, which affects the yield and quality of the crops. Bošković-Rakočević et al. (2018) determined the mobile aluminum content at 3.38 mg/100g soil by growing potatoes on Luvisol, which is located near the area where this study was conducted, suggesting that soil acidity is more influenced by the presence of H^+ ions than Al^{3+} ions.

The humus content decreases with increasing depth, and in the cultivated soil the humus content in the surface horizon (2.65%) is lower than in the meadow, which is a result of long-term cultivation and decomposition of organic matter. The content of available phosphorus in the meadow in the Ah horizon is 0.91 mg/100 g soil, while it is almost absent at a depth of 20-40 cm (<1 mg/100 g soil).

In cultivated soil, the phosphorus content is higher at a depth of 0-20 cm, namely 4.47 mg/100 g soil, while it decreases with increasing depth. A sharp decrease in available phosphorus with increasing depth was previously observed by Dugalić et al. (2021) and Kapović-Solomuni Eremija (2017), with the phosphorus content decreasing at depths of 14-45 cm. The slightly higher content of available phosphorus in the cultivated soils is due to the application of mineral and organic fertilizers, which is consistent with the results of Bošković-Rakočević et al. (2018). Leached soils are well supplied with available potassium, whereby Bošković-Rakočević et al. (2004) determined similar values.

Table 2. Basic agrochemical properties of the soil studied

Depth (cm)	pH		Humus (%)	N (%)	P_2O_5	K_2O	Ca	Mg	Al
	H_2O	KCl			mg/100 g				
Meadow 0-20	5.51	3.95	3.45	0.18	0.91	23.0	163	85.1	9.99
Meadow 20-40	5.57	3.84	1.08	0.06	<0.1	23.6	149	103	12.3
Field 0-20	5.08	3.90	2.65	0.15	4.47	56.4	137	46.6	10.6
Field 20-40	5.47	3.97	1.51	0.10	0.16	30.0	130	58.1	9.09

A limiting factor for plant cultivation on leached soils is the pronounced acidity of the soil. The values of active and substitutive acidity do not change significantly with the depth of the investigated soil profile (Table 2), as previously found in the studies by Dugalić et al. (2021). The total copper and zinc content (Table 3) was within the optimum values, while the total manganese content was above the maximum permissible concentrations, which is to be expected due to the strongly acidic chemical reaction of the soil solution. The total lead content was within the permissible values, while the total nickel content was well above the MDK (maximum permissible concentration), which is probably due to its natural origin from the initial substrate. The determined values of microelements and heavy metals were slightly lower compared to the results of Bošković-Rakočević et al. (2004) and higher compared to their average values in the soils of central Serbia (Mrvić et al., 2009).

With increasing depth, the content of nickel and lead as well as all microelements except copper decreased. The zinc content in the meadow decreased from 89.9 to 85.6 $mgkg^{-1}$ and in the cultivated plot from 105.1 to 90.6 $mgkg^{-1}$. Similar values for the total zinc content were determined by Milivojević et al. (2014), who found that the zinc content in most acidic soils in Serbia is between 55 and 119 $mgkg^{-1}$. The manganese (Mn) content also decreased significantly with increasing depth, especially in the cultivated plot, while the copper content increased slightly.

Table 3. Total content and available content of microelements and heavy metals in soil ($mgkg^{-1}$)

Depth (cm)	Total content					DTPA				
	Cu	Mn	Zn	Pb	Ni	Cu	Mn	Zn	Pb	Ni
Meadow (0-20)	52.6	1457	89.9	18.8	131	2.25	69.1	0.75	1.53	3.37
Meadow (20-40)	61.7	1294	85.6	15.3	127	2.86	32.8	0.54	1.81	1.92
Field (0-20)	56.5	2729	105.1	34.2	145	2.67	82.3	1.17	1.49	3.89
Field (20-40)	61.1	1768	90.6	24.8	75.1	2.77	54.1	0.70	1.75	2.37

Of the microelements, only the content of available zinc (0.54-1.17 $mgkg^{-1}$) was in the low availability range both in the meadow and in the cultivated soil at both depths investigated (Ankerman, 1977). The content of DTPA-extracted manganese (32.8-82.3 $mgkg^{-1}$) and DTPA-extracted copper (2.25-2.86 $mgkg^{-1}$) was very high (Ankerman, 1977). Vasin et al. (2004) mention that the increased content of DTPA-extracted manganese at certain sites in Serbia is due to the composition of the parent material on which the soil developed, the highly acidic soil reaction and the redox conditions, which are the main reasons for the increased content. The content of available lead (1.49-1.81 $mgkg^{-1}$) and nickel (1.92-3.89 $mgkg^{-1}$) was within the permissible limits.

Conclusion

The agrophysical properties of the soil under the meadow vegetation are more favorable than those of the cultivated soil. The highly acidic soil reaction, the very low content of available phosphorus and the high content of mobile aluminum are the main characteristics of this soil. The comparison of changes in the agrophysical and agrochemical properties of leached soils depending on their use allows the conclusion that the application of agronomic measures, especially fertilization, influences the changes in agrochemical properties. For successful crop production on Luvisol, it is necessary to carry out soil liming together with humification, apply NPK fertilizers with increased phosphorus content, use nitrogen fertilizers with a physiologically neutral reaction and maintain crop rotation.

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