Selected properties of soil in Nature Reserve Alúvium Žitavy, Slovakia, Danube plain

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Abstract

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Sufficient knowledge about wetlands, which belong to the most threatened ecosystems in the world, can contribute to their maintaining or recovery. In this work selected properties of three soil profiles in Nature Reserve Alúvium Žitavy were characterized. On studied area, the soil forming substrate was represented by floodplain sediments of the rivers Žitava and Nitra on which Calcaric Fluvisol was developed. With comparison to soil profiles 1 and 2 dug on the left and right bank of river Žitava, soil profile 3 dug near confluence of the rivers Nitra and Žitava contained distinctly higher percentage of clay and had higher porosity, pH values and higher carbonates content. On the contrary, the lowest values of hydrolytic acidity, sum of bases, cation exchange capacity were found in soil profile 3, mainly in Fvc/Gl and Glp horizons. It can be assumed that in this profile the majority of base cations, mainly Ca^{2+}, were bound with CO_3^{2-} anions to solid particles or were part of shell fragments. Obtained results showed, that soil properties in NR Alúvium Žitavy were distinctly influenced by different sediments deposited by the river Nitra versus Žitava and ground water level.

Keywords

carbonates, floodplain, hydromorphic soils, hydrophysical characteristics, pH, soil texture

Introduction

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance (Kadlec and Knight, 1996).

Wetlands represent a border area between terrestrial and aquatic ecosystems. They are characteristic by three basic properties: 1) the soil is flooded or saturated with water, 2) presence of wetland plants (hydrophytes and hygrophytes), 3) presence of hydromorphic soils (Šeffer, 1996). Hydromorphic soils are characteristic by the loss or accumulation of various forms of Fe, Mn, S, or C. Iron, when reduced to Fe^{2+} form, became sufficiently soluble and can migrate away from reduced zones and precipitate as Fe^{3+} compounds in more aerobic soil zones. The zones of which where due to reduction conditions removed or depleted the iron coatings from mineral grains are termed redox depletions. They commonly exhibit the grey, low chroma colours of the bare, underlying minerals. Also iron itself turns grey to blue-green when it is reduced. The contrasting colours of redox depletions, or reduced iron zones and zones of reddish oxidized iron, result in unique mottled redoximorphic features. Other redoximorphic features are pointing on reduced Mn and the presence of hard black nodules. Under severely reduced conditions the entire soil matrix may exhibit low-chroma colours (Brady and Weil, 1999).

Ecological importance of wetlands includes the protection of biodiversity, natural filtering and water retention, slowing the flow of surface water and reducing the negative impact of flooding, preventing soil erosion, removing and storing greenhouse gases from the atmosphere. Despite important functions, many wetlands are disappearing and many unique organisms are losing with them. The result of widespread wetlands destruction is that they belong to the most threatened ecosystems in the world (Noskovič et al., 2009; Šeffer, 1996).

On the other hand, sufficient knowledge of wetland ecosystems can contribute to their maintaining or recovery. Therefore, since soils are important component of wetland environment, the aim of the work reported here was to characterize Calcaric Fluvisols in Nature Reserve Alúvium Žitavy. Obtained results can contribute to the better knowledge and understanding of soil properties of wetlands that have been preserved in Slovakia.

Material and methods

Alluvium of river Žitava was declared a Nature Reserve in 1993, on acreage of 32.53 hectares. The site is characterized by a diversity of habitats and water, marsh and wetland vegetation.

Studied area is located in the south part of Slovakia at the Danube plain, at the confluence of the rivers old Žitava and old Nitra (Lukniš et al., 1972; Lelkes et al., 2006). The climate in area is warm and dry, long term (1951–1980) average annual air temperature is 9.9 °C and long term (1901–1990) average annual rainfall is 558 mm (Lapin, 2012).

The geological substrate is composed of Quaternary Holocene alluvial sediments. Sandy layers form their substantial part. The bottom is formed by gravel or gravel with medium content of sand. The Quaternary sands and gravels are overlaid by loess on most of the area. The permeability of porous aquifers is very good. The area has high level of ground water and is rich on flowing and standing water. Predominant relief consists of planes and floodplains. Major soil types in the wider area are Mollic Fluvisol and Haplic Chernozem (Lukniš et al., 1972; Lelkes et al., 2006).

Soil properties were characterized in three soil pits dug in the autumn 2009:

- Soil profile 1 (47º51’83” N, and 18º09’25” E) was located 30 meters from the left bank of the river Žitava and in 2.3 km distance from the estuary of river Žitava, on wet meadow behind the dyke.
- Soil profile 2 (47º51’58” N, and 18º08’30” E) was located 2 meters from the right bank of the river Žitava and in 1.7 km distance from the estuary of the river Žitava.
- Soil profile 3 (47º50’81” N, and 18º07’60” E) was located 2 meters from the right bank of the river Žitava, in 30 m distance from the point, where river Žitava flows into the river Nitra.

Morphological properties were described in each soil profile and samples for analysis of soil physical and chemical characteristics were taken.

Basic physical and hydrophysical parameters (Fiala et al., 1999) were determined for each of 0.1 m layer till depth of 0.5 or 0.7 m; soil texture was determined for each horizon by pipette method (Fiala et al., 1999); total soil organic carbon content (C_T) by Tyurin method (Orlov et al., 1981); soil reaction – potentiometrically in 1 mol dm^{-3} KCl (1:2.5); content of exchangeable bases and hydrolytic acidity by Kappen’s method, carbonate contents – volumetrically (Fiala et al., 1999).

Average value of each soil parameter was calculated from three repeated analyses.

Results and discussion

The soil forming substrate was presented by floodplain sediments of the rivers Žitava and Nitra on which was developed Calcaric Fluvisol (WRB, 2006). Studied profiles differed in some morphological characters, mainly in horizons thickness, colour, texture, structure, shell fragments and gravel content, ground water level, occurrence of Fe^{3+} mottles reflecting seasonal water table fluctuations giving rise to cycles of reducing and oxidising conditions. The abundance of mottles increased with soil depth, above which the water table fluctuated.

Morphological description of soil profile 1

Calcaric Fluvisol
Ac 0.0–0.20 m, 7.5 YR brownish black (3/2), without mottles, moist, coherent, loamy, without gravel, granularly-angular structure, strongly penetrated by roots, slightly calcareous

Fvc 0.20–0.48 m, 7.5 YR brownish black (2/2), without mottles, moist, coherent, sandy-clay-loamy, without gravel, massive structure, medium penetrated by roots, slightly calcareous

Fvc/Gl > 0.48 m, 7.5 YR brownish black (2/2), Fe^{3+} mottles (30%), moist, coherent, clay-loamy, without gravel, massive structure, slightly penetrated by roots, moderately calcareous.

Morphological description of soil profile 2

Calcaric Fluvisol
Ac 0.0–0.20 m, 7.5 YR brownish black (3/2), without mottles, moist, crumbly, loamy, without gravel, granularly-angular structure, strongly penetrated by roots, slightly calcareous

Fvc 0.20–0.38 m, 7.5 YR brownish black (3/2), without mottles, moist, crumbly, loamy, without gravel, angular structure, medium penetrated by roots, slightly calcareous

Fvc/Gl > 0.38 m, 7.5 YR black (2/1), without mottles, wet, coherent, loamy, with low content of fine gravel, angular structure, Mn nodules, medium penetrated by roots, moderately calcareous, contained shell fragments.

Ground water was found at depth of 0.9 m and the ground water level was stabilised at depth of 0.7 m.

Morphological description of soil profile 3

Calcaric Fluvisol
Ac 0.0–0.20 m, 7.5 YR brownish black (3/2), without mottles, moist, crumbly, clay-loamy, without gravel, granularly-angular structure, strongly penetrated by roots, moderately calcareous

Fvc/Gl 0.20–0.40 m, 7.5 YR dull brown (6/3), with Fe^{3+} mottles, wet, crumbly, clay-loamy, without gravel, massive structure, Mn nodules, medium penetrated by roots, strongly calcareous

Glp > 0.40 m, 7.5 YR grayish brown (4/2), with Fe^{3+} mottles, wet, coherent, clay-loamy, without gravel, massive structure, Mn nodules, slightly penetrated by roots, strongly calcareous, contained shell fragments.

Ground water was found at depth of 0.9 m and the ground water level was stabilised at depth of 0.55 m.

Physical properties of wetland soils cannot be for most cases easily generalized. Texture is a fundamental index of soil physical properties. Knowledge of this property allows prediction of many other soil characteristics. Soils in flood plains show different textural patterns as a result of differences in parent material and modes of deposition of the materials (Obi, 1989). Textural composition of studied soil profiles reflects textural composition of substrate, which rivers Žitava and Nitra deposited in alluvial plain. The textural composition of individual horizons within soil profiles 2 and 3 slightly differed, but overall, texture in whole soil profile 2 was loamy, and in soil profile 3 clay-loamy. The different textural classes for each soil horizon were determined only within soil profile 1 (Table 1). Compared to other soil profiles, the most clay fraction was found in soil profile 3, dug in the locality, where the river Žitava flows into the river Nitra. This can be due to heavier alluvial sediments deposited by river Nitra which texturally differed from that of river Žitava, owing to the redoximorphic processes began already at depth of 0.2 m. Generally, by action of redoximorphic processes the clay production occurs too. Compared to our results, Kukla and Kuklová (2009) found in Fluvisol in NR Chynoriansky luh much higher content of clay fraction (32–63%), with maximum in central parts of studied profiles. They stated that influence of processes of illimerization and colmatation could be coupled (argilization caused by percolation of turbid flood water).

Particle density (ς_s) is relatively stabile soil parameter and usually increases with depth. It depends on density of soil minerals and organic matter (Zaujec et al., 2009). Considerable variation of ς_s values in soil profiles was caused by accumulation of alluvial deposits with different particle density, which influenced ς_s parameter of these soils (Table 2).

Regular increases of bulk density (ς_d) and decreases in porosity (P) with depth reflect increased compaction by the overlying sediment in soil profiles 1 and 2. On the contrary, for values of ς_d and P there is no systematic pattern of variation with depth in soil profile 3 (near confluence of rivers Nitra and Žitava). Moreover, the layer 0.2–0.3 m exceeded critical values (ς_d > 1.4 t m^{-3}; P < 47%) for clay loam (Fulajtár, 2006) and was compacted. In this layer macro-pores and air porosity were nearly completely reduced (Table 2).

Critical values of bulk density and porosity were exceeded in whole soil profile 2 beside the layer 0.0–0.1 m. Fulajtár (2006) noted, that compacted soil horizon exhibiting P values below 47% for clay loam and be-

Table 1. Particle-size composition of soils

Soil profile	Horizon	Depth [m]	Texture	Textural fractions [%] >0.25 mm	0.25–0.05 mm	0.05–0.01 mm	0.01–0.001 mm	<0.01 mm	<0.001 mm
1 Calcaric Fluvisol	Ac	0.00–0.20	sh	22.1	25.9	11.8	17.0	40.2	23.2
	Fvc	0.20–0.48	spi	33.1	17.1	10.2	14.4	39.7	25.3
	Fvc/Gl	>0.48	si	27.2	14.7	12.9	14.9	45.2	30.3
2 Calcaric Fluvisol	Ac	0.00–0.20	sh	29.8	11.5	13.3	25.5	45.3	19.8
	Fvc	0.20–0.38	sh	12.9	19.7	22.1	24.8	45.3	20.5
	Fvc/Gl	>0.38	sh	13.6	24.0	30.9	17.6	31.5	13.9
3 Calcaric Fluvisol	Ac	0.00–0.20	si	21.1	9.8	17.6	22.2	51.5	29.3
	Fvc/Gl	0.20–0.40	si	19.3	8.2	21.6	20.0	50.8	30.8
	Glp	>0.40	si	17.9	17.4	18.0	14.1	46.7	32.6

sh, loam; spi, sandy clay loam; si, clay loam.

Table 2. Soil physical and hydrophysical characteristics

Soil profile	Depth [m]	ρ_s	ρ_d	P	Pk	Ps	Pn	V_A	Θp
		[t m^{-3}]		[% vol.]					
1 Calcaric Fluvisol	0.0–0.1	2.53	1.15	54.5	42.6	3.0	8.9	9.7	25.9
	0.1–0.2	2.52	1.35	46.4	37.9	2.0	6.5	7.0	23.4
	0.2–0.3	2.58	1.37	47.8	36.4	2.0	9.4	9.8	18.3
	0.3–0.4	2.62	1.42	45.8	30.8	6.9	8.1	8.5	13.1
	0.4–0.5	2.64	1.44	45.4	31.2	4.6	9.6	10.0	14.1
	0.5–0.6	2.70	1.43	47.0	35.4	1.7	9.9	9.9	25.3
2 Calcaric Fluvisol	0.0–0.1	2.54	1.08	57.5	46.9	2.3	8.3	9.4	29.7
	0.1–0.2	2.41	1.35	44.0	40.8	0.7	2.5	2.9	24.6
	0.2–0.3	2.49	1.41	43.4	39.4	0.9	3.1	3.3	16.0
	0.3–0.4	2.54	1.44	43.3	37.7	0.8	4.8	5.1	13.9
	0.4–0.5	2.47	1.45	41.3	37.3	0.7	3.3	3.5	14.9
	0.5–0.6	2.58	1.47	42.0	37.6	–	4.4	4.1	14.2
	0.6–0.7	2.56	1.46	43.0	39.5	0.6	2.9	3.1	19.7
3 Calcaric Fluvisol	0.0–0.1	2.67	0.93	65.2	51.9	3.1	10.2	11.4	32.9
	0.1–0.2	2.41	1.20	50.2	48.6	0.6	1.0	1.3	27.6
	0.2–0.3	2.46	1.51	38.6	38.2	–	0.4	0.3	18.1
	0.3–0.4	2.54	1.23	51.6	46.5	0.5	4.6	4.8	27.6
	0.4–0.5	2.51	1.19	52.6	49.1	0.6	2.9	3.2	29.2

ρ_s, particle density; ρ_d, bulk density; P, porosity; Pk, capillary pores; Ps, semi-capillary pores; Pn, non-capillary pores; V_A, air filled porosity; Θp, available water capacity.

low 45% for loam tend to inhibit root penetration. High bulk density and low porosity may adversely affect soil biological properties and lead to decreasing of microbial biomass due to oxygen deficiency in the compacted soils (Tan et al., 2005). Obi (1989) noted that alluvial soils do not exhibit any definite pattern with regard to porosity. Where sandy deposits dominate, macro-pores would expectedly dominate. On the other hand, where the deposited material is of high clay and organic matter content, water-logging may be expected to cause pore instability with resultant tendency towards the formation of smaller pores. Nevertheless, according to Bedrna et al. (1989), values of total pore space (P) do not give any indication of pore size distribution. Optimal pore distributions are as follows: 1/3 macro-pores (Pn) where aeration and water drainage take place and 2/3 meso (Ps) and micro-pores (Pk) for water retention and capillary elevation. When considering optimal pores distribution, very low amount of macro-pores of total porosity was found in studied profiles (in soil profile 1: 14–21%, in soil profile 2: 6–14% and in soil profile 3: 1–16%). Air porosity was also very low, mainly in soil profiles 2 and 3 (Table 2). High content of capillary water and low aeration caused reduction conditions in lower horizons what resulted to the development of described redoximorphic feature.

Values of basic chemical parameters are written in Table 3. Total soil organic carbon (C_T) decreased with depth in all examined soil profiles, with values ranging from 28.4 to 40.1 g kg^{-1} for A horizons and 9.1–17.6 g kg^{-1} for subsoils. Exchangeable soil reaction (pH_{KCl}) ranged from slightly acidic to slightly alkaline. Increased content of carbonates in deeper parts of soil profiles corresponded to higher values of pH_{KCl}. Compared with soil profiles 1 and 2 dug on the left and right bank of river Žitava, soil profile 3 dug near the confluence of rivers Nitra and Žitava contained significantly higher amount of carbonates. This was possibly due to different chemical composition of alluvial sediments deposited by the river Nitra versus Žitava. According to Čurlík and Šefčík (2006) around 80% of the territory which crosses river Nitra contains 5.72% carbonates in humus horizon, whereas the river Žitava crosses territory with 5.72% carbonates only on 65% and the rest of territory contains only 0.16% carbonates. Analogously, concentration of carbonates in soil forming substrates was higher in soils of river Nitra basin compared to soil of the river Žitava basin. Moreover, Szombathová et al. (2007) reported that Eutric Fluvisol in NR Žitavský wetland (48º09' N, and 18º19' E, 40 km from NR Alúvium Žitavy) did not contain carbonates, and they were presented only in CGo horizon of Mollic

Fluvisol. On the contrary, Tobiašová (2010) found in Eutric Fluvisol in floodplain of the river Nitra 1–5% of carbonates.

Additional reason of higher amount of carbonates in studied soil profile 3 could be the content of shell fragments in lower parts of profile which contributes to the rise of carbonate concentration. Consequently, in soil profile 3 the lowest values of hydrolytic acidity (H) were found, since acidic protons were well neutralized by carbonates (Table 3).

In general, the cation exchange capacity (CEC) is related to the type of sediments of predominantly loam to clay-loam character. In the surface layers, the value is also affected by the content of humus. Sum of bases (S) ranged from 86 to 205 mmol kg^{-1} and CEC from 88 to 212 mmol kg^{-1}. Comparing the sum of bases it is evident, that the lowest values were found in soil profile 3, mainly in Fvc/Gl and in Glp horizons. Presumably, in this profile the majority of base cations, mainly Ca^{2+} (Noskovič et al., 2010), were bound with CO_3^{2-} anions to solid particles or they were part of the shell fragments. Therefore, the sum of bases and consequently also the cation exchange capacity was low, in spite the clay content was the highest just in soil profile 3 (Tables 1, 3). On the contrary, the values of CEC and also S proportionally increased with increasing of clay content in soil profile 1, where the lowest concentration of carbonates was determined and shell fragments were not occurred (Tables 1, 3). In all soil profiles, the sorption complex was saturated with base cations, mostly ranging between 97–98 %. Studied soils exhibited high buffering capacity related to carbonates content, middle CEC capacity and the high degree of base saturation.

Results obtained in this study showed that soil properties in soil profile 3 (dug in the locality, where the river Žitava flows into the river Nitra) distinctly differed from soil properties in profiles 1 and 2 dug at a greater distance (2.3 and 1.7 km) from the estuary of the river Žitava. Differences were mainly determined in soil texture, content of carbonates and pH values. Soil properties in NR Alúvium Žitavy were distinctly influenced by different sediments deposited by the river Nitra compared to Žitava and ground water level.

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Table 3. Selected ecological properties of soils

Soil profile	Horizon	C_T	H	S	CEC	BS	CO_3^{2-}	pH
		[g kg^{-1}]	[mmol kg^{-1}]			[%]		KCl
1 Calcaric Fluvisol	Ac	40.1	27.4	132.6	160	83	0.8	5.73
	Fvc	15.8	7.4	176.6	184	96	0.9	6.19
	Fvc/Gl	9.1	3.5	204.5	208	98	3.4	6.37
2 Calcaric Fluvisol	Ac	28.4	7.1	204.9	212	97	1.4	6.58
	Fvc	17.6	4.7	171.3	176	97	2.0	6.92
	Fvc/Gl	12.5	3.8	156.2	160	98	3.6	6.97
3 Calcaric Fluvisol	Ac	33.2	3.1	164.9	168	98	4.4	6.92
	Fvc/Gl	12.5	2.8	109.2	112	97	13.6	7.24
	Glp	11.4	2.4	85.6	88	97	17.6	7.43

C_T, total soil organic carbon; H, hydrolytic acidity; BS, base saturation; S, sum of bases (Na^+, K^+, Ca^{2+}, Mg^{2+}); CEC, cationic exchange capacity.

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