

# Physical properties of urban soil in the campus of Slovak University of Agriculture Nitra

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Soil is important ingredient of urbanized areas which are steadily increasing. Therefore, the objective of this study was to characterize selected physical properties of urban soil in the campus of Slovak University of Agriculture in town Nitra depending on different soil management practices. For studying, three soil pits were dug 100–400 meters from the left bank of the river Nitra. The soil under kept lawn in park was classified as Calcaric Fluvisol, under the herbicidal fallow and soil in main garden as Hortic Calcaric Fluvisol. Deposited material of river Nitra contained 9–47% of sand, 30–63% of silt and 23–41% of clay. Alluvial sediments close to the river bank were texturally quite homogenous, but with increased distance from river were more different. Natural compaction was strengthened with anthropogenic one due to use of agricultural machinery. The amount of available water capacity was considerably low mainly for high proportion of clay. To improve structural state, the cultivated soil in main garden requires organic fertilization and reduction of cultivation.

**Keywords:** urban soil, compaction, soil morphology, soil texture, soil structure

## 1. Introduction

Soil is one of the most fundamental components for supporting life on Earth and hence important ingredient of urban ecosystems. It is non-renewable natural resource within human time-scales, which develops slowly and changes gradually over time, showing great spatial variability.

Technological development and rapid growth of human population in the world increasingly affect the transformation of the natural environment. One of the main ecosystem components, which undergoes irreversible changes is the soil cover in urban and industrial areas. The extent and type of changes in the soil depend on many factors: duration, intensity and the use, properties of primary soil or reclamation techniques (Charzyński et al., 2013).

Urban soils represent the general term for soils occurring in urban, industrial, transportation, mining and military areas. In addition to Anthrosol in urban areas are also natural soils (for example in town parks), soils partially physically or chemically disturbed, and also cultivated soils (mostly in the home gardens). As urban are considered soils in the official borders of the town, since all areas of town are part of a consistent urban ecosystem (Sobocká, 2007). Consequently, the soil in the park and garden of Slovak University of Agriculture is regarded as soil in urbanized area. Further, also this soil can have different characteristics, depending on the

initial soil properties, the way of its use, and methods of land management.

The aim of the work reported here was to characterize selected physical properties of urban soil in the campus of Slovak University of Agriculture in town Nitra depending on different soil management practices.

## 2. Material and methods

### 2.1 Locality description

The town Nitra is situated on south-western part of the Slovak Republic (latitude 48° 18' N; longitude 18° 05' E). The most spread soil-forming substrates are loess and Quaternary Holocene loamy-clayey alluvial sediments of river Nitra. Main soil types naturally formed are Fluvisols, Mollic Fluvisols, Haplic Luvisols and rarely on limestone and dolomite Rendzic Leptosols and on loam the Cambisols (Hreško et al., 2006). In the gardens and vineyards and on anthropogenic substrates were formed Anthrosols (Szombathová et al., 2009). The climate in area is warm and dry, long term average temperature is 10.2 °C and precipitation 539 mm per year (Špánik et al., 2002). Town is located between the Danube Plain and Tribeč mountains. In the basin of the river Nitra meets lowland and mountainous part of Slovakia. The town is divided into two parts by slowly flowing river Nitra. Altitude is from 138 m (fluvial plain) to 588 m (Zobor hill) above sea level (Pálka et al., 2010). Region belongs to the Nitra river catchment. Ground water level is relatively

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stable, ranging from 1.20 to 2.50 m. Great part of the Slovak University of Agriculture (SUA) campus is located next to the left bank of the river Nitra. Hence, original soil forming substrate were Quaternary loamy-clayey alluvial sediments above gravel facies, on which were formed Calcaric Fluvisols.

## 2.2 Soil sampling and analytical methods

Soil properties were characterized in three soil pits (S1, S2, S3) dug in the spring 2012. The soils were classified according to the World Reference Base for Soil Resources (WRB, 2006) based on the whole-profile soil morphology:

- Soil profile 1 (S1) was located 400 meters from the left bank of the river Nitra under the kept lawn in park of SUA Nitra. The park and lawn in SUA campus was established in 1966. The dominant herbage in the park's lawn is *Lolium perenne* (L.).
- Soil profile 2 (S2) was located 100 meters from the left bank of the river Nitra under the herbicidal fallow in experimental lawn garden of SUA Nitra. The herbicidal fallow lasted for eight years and before was used for experimental growing the clover (*Trifolium resupinatum* L., *Trifolium alexandrinum* L.) and alfalfa (*Medicago falcata* L., *Medicago lupulina* L.) on soil cultivated to the depth of 0.3 m. During herbicidal fallow the soil was not cultivated.
- Soil profile 3 (S3) was located 380 meters from the left bank of the river Nitra on temporarily bare soil with corn (*Zea mays* L.) forecrop, in the main garden of SUA Nitra. The area of main garden was intensively cultivated to the depth of 0.3 m.

The undisturbed soil samples were collected (in triplicate) for each of 0.1 m layer to the depth of 0.8 m in S2 and S3, and in the case of S1 to the depth of 0.5 m. Soil samples were taken to cylinders with an inner volume of 200 cm<sup>3</sup> for determination of physical (particle and bulk density, total porosity) and hydrophysical (maximum capillary water capacity, water capacity, wilting point, retention water capacity, available water capacity) properties (Fiala et al., 1999). Soil samples for determination of soil structure state, we collected from A horizons of each profiles. Before determination of water stable aggregates, all soil samples were sieved to provide a range of aggregate sizes: >7, 7–5, 5–3, 3–1, 1–0.5, 0.5–0.25, <0.25 mm. These size fractions of air-dried aggregates were used for the determination of size fractions of water stable aggregates by Baksheev method (Vadjunina and Korchagina, 1986). Then was calculated mean weight diameters of aggregates for dry and wet sieving as well as vulnerability coefficient and index of aggregate stability as is described in Zaujec and Šimanský (2006). Soil samples for determination the particle-size distribution were taken from each horizons of soil profiles. Silt, sand and clay fractions were

determined using the pipette method as is described in Fiala et al. (1999).

## 3. Results and discussion

The soil forming substrate on studied area was floodplain sediments of the river Nitra on which was developed Calcaric Fluvisol. This soil type, despite slightly anthropically disturbed, was classified under kept lawn in park of SUA Nitra. In the experimental lawn garden and main garden of SUA Nitra the soil was intensively cultivated (in the past or currently) to the depth of 0.3 m, therefore was classified as Horti Calcaric Fluvisol (WRB, 2006). Studied profiles differed in some morphological characters, mainly in horizons thickness, colour, texture, soil structure, occurrence of Fe<sup>3+</sup> 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 (S1)

#### Calcaric Fluvisol

- Ac 0.02–0.25 m, 10 YR brown (4/4), without mottles, moist, crumbly, silty loamy, without gravel, granularly-angular structure, strongly penetrated by roots, slightly calcareous.
- Fvc 0.25–0.55 m, 10 YR brown (4/6), without mottles, moist, coherent, silty-clayey-loamy, without gravel, angular structure, slightly penetrated by roots, slightly calcareous.
- Fvc/Gl >0.55 m, 10 YR dark brown (3/3), Fe<sup>3+</sup> mottles (20%), moist, coherent, clayey-loamy, without gravel, angular structure, Mn nodules, slightly penetrated by roots, slightly calcareous.

### Morphological description of soil profile 2 (S2)

#### Horti Calcaric Fluvisol

- Ahtc 0.0–0.30 m, 10 YR dull yellowish brown (4/3), without mottles, moist, crumbly, silty-clayey, without gravel, granularly-angular structure, slightly penetrated by roots, slightly calcareous.
- Fvc 0.30–0.40 m, 10 YR grayish yellow brown (4/2), without mottles, moist, coherent, silty-clayey-loamy, without gravel, angular structure, no roots, slightly calcareous.
- Fvc/Gl >0.40 m, 10 YR dull yellowish brown (5/3), Fe<sup>3+</sup> mottles (20%), moist, coherent, silty-clayey-loamy, angular structure, Mn nodules, no roots, slightly calcareous.

### Morphological description of soil profile 3 (S3)

#### Horti Calcaric Fluvisol

- Ahtc 0.0–0.30 m, 10 YR grayish yellow brown (4/2), without mottles, moist, crumbly, silty-clayey-

loamy, without gravel, angular structure, medium penetrated by roots, slightly calcareous.

- Fvc/Gl 0.30–0.60 m, 10 YR dull yellowish brown (4/3), Fe<sup>3+</sup> mottles (20%), moist, coherent, clayey, without gravel, angular to massive structure, Mn nodules, no roots, slightly calcareous.
- Fvc/Gl >0.60 m, 10 YR dull yellowish brown (5/3), Fe<sup>3+</sup> mottles (30%), moist, coherent, loamy, without gravel, massive structure, Mn nodules, no roots, slightly calcareous.

Soil physical properties significantly influence the course and speed of various chemical, physico-chemical and biological processes, and also growth of soil organisms. They have significant impact on soil depth inhabited by plant roots, the proportions of water and air as well as the physical structure of soil horizons. On the basis of relationship between solid, liquid and gaseous phase of soil, it can be intended many chemical and biological aspects of soil fertility, especially availability of nutrients, water and air to plants (Dexter, 2004; Kobza, 2013).

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 reflected textural composition of substrate, which river Nitra deposited in alluvial plain. Overall, deposited material contained 9–47% of sand, 30–63% of silt and 23–41% of clay (Table 1).

Profiles 1 and 3 were in cca 400 m distance from the left bank of the river Nitra. Their textural composition had similar distribution of sand, which increased, and silt, which decreased with soil depth. However, the amount of clay in soil profile 1 increased with depth, whereas in soil profile 3 the greatest proportion of clay (41%) was found in Fvc/Gl horizon (depth 0.3–0.6m), and in depth >0.6 m it sharply decreased to 23%. It is known, that during dry period, after water evaporate from the soil, high content of clay use to cause soil cracking due to spatially unbalanced shrinkage of clay minerals (Bedrna et al., 1989; Liu et al., 2003; Fulajtár, 2006; Bielek, 2014). The phenomena of soil cracking have been found mainly in the area of main garden and the width of cracks was 3–4 cm. Otherwise, during long dry summer period, the cracks were found in the soil of whole SUA campus. Textural composition of profile 2, which was the closest (cca 100m) from the left bank of the river Nitra, almost did not change with depth. It means that alluvial sediments close to the river bank were quite homogenous, but with increased distance, the river accumulated texturally more different material (Table 1).

Particle density ( $\rho_s$ ) is relatively stabile soil parameter and depends on the density of soil minerals and organic mater, which makes the soil lightweight. In studied soil profiles, moderate variation of  $\rho_s$  values was caused by accumulation of alluvial sediments with slightly different particle density (Table 2).

Increased bulk density ( $\rho_d$ ) and decreased porosity (P) with depth highlighted increased natural compaction by the overlying sediments. Natural compaction was

**Table 1** Particle-size composition

Locality	Horizon	Soil texture $\Delta$	Textural fractions in %						Soil texture Novák
			>0.25 mm	0.25–0.05 mm	0.05–0.01 mm	0.01–0.001 mm	<0.001 mm	<0.01 mm	
1 kept lawn	Ac	ssh	7.3	9.5	30.9	27.3	25.1	52.4	IH
	Fvc	ssi	1.8	12.0	31.7	29.7	24.7	54.4	IH
	Fvc/Gl	si	7.6	15.7	19.1	18.9	38.8	57.6	IH
2 herbicidal fallow	Ahtc	ts	16.8	1.5	25.6	25.5	33.5	59.0	IH
	Fvc	ssi	9.0	6.5	21.4	30.7	32.4	63.1	IV
	Fvc/Gl	ssi	13.2	2.5	23.1	30.1	31.1	61.2	IV
3 main garden	Ahtc	ssi	2.0	6.8	28.7	34.6	27.9	62.5	IV
	Fvc/Gl	ti	7.6	11.5	13.3	26.5	41.2	67.7	IV
	Fvc/Gl	sh	24.5	22.7	17.9	12.0	22.9	34.9	H

ssh – silty-loamy, ssi – silty-clayey-loamy, si – clayey-loamy, ts – silty-clayey, ti – clayey, sh – loamy, IH – clayey-loamy, IV – clayey, H – loamy

Table 2 Soil physical and hydrophysical characteristics

Profile	in t m <sup>-3</sup>		in vol. %														
	Depth in m	$\rho_s$	$\rho_d$	P	P <sub>N</sub>	P <sub>K</sub>	P <sub>S</sub>	V <sub>AM</sub>	V <sub>A</sub>	$\Theta$	$\Theta_{KN}$	$\Theta_{KMK}$	$\Theta_{RK}$	W <sub>v</sub>	$\Theta_{ZD}$	$\Theta_V$	$\Theta_P$
1 kept lawn	0.0–0.1	2.53	1.22	51.5	6.9	41.5	3.0	12.1	8.2	39.4	46.3	43.3	41.5	19.6	33.9	19.7	21.8
	0.1–0.2	2.53	1.38	45.4	4.0	38.5	2.9	9.1	5.3	36.2	43.4	40.1	38.5	16.5	32.0	19.7	18.8
	0.2–0.3	2.58	1.44	44.5	5.4	35.6	3.5	18.3	7.0	26.2	41.9	37.5	35.6	5.9	30.7	20.3	15.3
	0.3–0.4	2.59	1.42	45.4	5.8	35.4	4.2	21.1	7.5	24.4	42.2	37.9	35.4	4.0	30.9	20.3	15.1
	0.4–0.5	2.57	1.34	46.2	6.3	35.9	4.0	21.2	8.0	25.0	43.1	38.2	35.9	4.7	31.0	20.3	15.6
2 herbicidal fallow	0.0–0.1	2.54	1.05	58.8	20.0	33.1	5.8	33.6	22.1	25.2	43.7	36.8	33.0	3.5	30.7	21.7	11.3
	0.1–0.2	2.54	1.26	50.5	8.8	39.7	2.1	14.4	9.4	36.2	43.7	41.2	39.7	14.5	33.4	21.7	18.0
	0.2–0.3	2.55	1.42	44.5	2.8	40.8	1.0	6.3	3.1	38.3	42.3	41.5	40.8	16.6	33.6	21.7	19.1
	0.3–0.4	2.54	1.36	46.5	2.9	42.9	0.7	6.8	3.2	39.7	44.1	43.3	42.9	16.7	35.2	22.9	20.0
	0.4–0.5	2.56	1.44	43.6	0.6	42.4	0.7	3.2	0.1	40.4	44.2	43.5	42.9	18.0	35.1	22.4	20.5
3 main garden	0.5–0.6	2.55	1.44	43.8	1.2	41.8	0.9	4.6	0.1	39.2	45.7	43.7	43.5	16.8	35.2	22.4	21.1
	0.6–0.7	2.58	1.48	42.6	1.4	40.6	0.6	5.7	1.7	36.9	41.7	40.9	40.6	14.5	33.5	22.4	18.2
	0.7–0.8	2.58	1.53	40.6	1.2	38.2	1.2	6.5	1.4	34.1	40.0	39.2	38.2	11.7	32.5	22.4	15.8
	0.0–0.1	2.53	1.05	56.8	12.7	38.1	6.1	23.5	15.4	33.3	45.6	41.5	38.1	10.6	34.0	22.8	15.3
	0.1–0.2	2.50	1.20	54.8	9.0	41.3	4.6	10.0	10.9	44.8	48.9	44.0	41.3	22.0	35.5	22.8	18.5
0.2–0.3	2.53	1.30	48.5	0.2	47.7	0.6	0.4	0.3	48.0	49.2	48.2	47.7	25.3	38.0	22.8	24.9	
0.3–0.4	2.52	1.29	48.6	3.3	44.9	0.5	3.1	3.7	45.5	45.9	44.9	44.9	21.2	36.7	24.3	20.6	
0.4–0.5	2.48	1.21	49.3	2.2	46.4	0.7	2.3	2.6	46.9	47.6	46.6	46.4	22.6	37.7	24.3	22.1	
0.5–0.6	2.52	1.37	45.4	2.8	41.1	1.5	4.8	3.4	40.6	43.4	42.0	41.1	16.3	34.9	24.3	16.8	
0.6–0.7	2.55	1.53	39.9	2.5	35.3	2.2	6.2	3.2	33.8	38.3	36.7	35.3	19.3	27.8	14.5	20.8	
0.7–0.8	2.55	1.54	39.8	3.1	33.9	2.9	6.6	4.0	33.3	37.6	35.8	33.9	18.8	27.3	14.5	19.4	

$\rho_s$  – particle density in t m<sup>3</sup>,  $\rho_d$  – bulk density in t m<sup>3</sup>, P – porosity in vol. %, P<sub>N</sub> – non-capillary pores in vol. %, P<sub>K</sub> – capillary pores in vol. %, P<sub>S</sub> – semi-capillary pores in vol. %, V<sub>AM</sub> – soil aeration in vol. %, V<sub>A</sub> – air porosity in vol. %,  $\Theta$  – soil moisture in vol. %,  $\Theta_{KN}$  – capillary saturation in vol. %,  $\Theta_{KMK}$  – maximal capillary water capacity in vol. %,  $\Theta_{RK}$  – retention water capacity in vol. %, W<sub>v</sub> – available water in vol. %,  $\Theta_{ZD}$  – less accessible water in vol. %,  $\Theta_V$  – wilting point in vol. %,  $\Theta_P$  – available water capacity in vol. %

**Table 3** Water-stable aggregates in A horizons

Locality	Wet sieved aggregates in %							MWD	Kv	Sw
	>5 mm	5–3 mm	3–2 mm	2–1 mm	1–0.5 mm	0.5–0.25 mm	<0.25 mm			
<b>1 kept lawn</b>	58.1	21.6	9.0	4.6	3.6	2.0	1.1	4.8	0.8	1.17
<b>2 herbicidal fallow</b>	46.6	22.3	14.6	8.1	2.5	1.0	4.8	5.3	0.7	1.14
<b>3 main garden</b>	4.6	19.4	21.9	22.7	17.2	8.1	6.1	4.4	1.0	1.02

MWD – mean weight diameter wet, Kv – coefficient of macroaggregates vulnerability, Sw – stability index

strengthened with anthropogenic one due to use of lawn tractor, what was reflected in soil profile 1 and due to use of agricultural machinery (soil profiles 2 and 3). Critical values of porosity ( $P < 47\%$ ) for clayey and clayey loamy, and  $P < 45\%$  for loamy soil (Fulajtár, 2006) were exceeded in all studied profiles. Thus, soil profile 1 was compacted from the depth of 0.1 m, soil profile 2 from the depth of 0.2 m and soil profile 3 from the depth of 0.5 m (Table 2). According to Kulli et al. (2003), compacted soils show lower rates of water infiltration and drainage from the compacted layer, availability of nutrient and exchange of gases slows down causing aeration-related problems, inhibit root penetration and ultimately affect plant growth and the crop yields.

However, porosity or total pore space does not give any indication of pore size distribution. Optimal pore distribution is 1/3 macro-pores ( $P_n$ ) where takes place aeration and water drainage and 2/3 meso-pores ( $P_s$ ) and micro-pores ( $P_k$ ) for water retention and capillary elevation (Bedrna et al., 1989).

When consider optimal pores distribution, very low amount of macro-pores of total porosity (9–14%) was found in whole soil profile 1 under kept lawn in park. On the other hand, in soil profiles 2 and 3 was found higher proportion of macro-pores (17–34% and 16–22%) but only in depth of 0.0–0.2 m. As is above-mentioned, soil in the main garden was plowed in the autumn. However, ploughed layer has still not been subsided, which was reflected as higher macro-porosity. Nevertheless, macro-porosity was extremely reduced from the depth of 0.2 m in soil profiles 2 (1–6%) and 3 (0.4–8%). The same pattern was found for air porosity, and the critical value ( $< 10\%$ ) was exceeded in the whole soil profile 1, in soil profile 2 from the depth of 0.1 m and soil profile 3 from the depth of 0.2 m (Table 2). High amount of capillary water and low aeration caused reduction conditions in lower horizons what resulted to the formation of described redoximorphic feature and Mn nodules.

Although the values of retention water capacity ( $\Theta_{RK}$ ) were high in all studied profiles, the amount of available water capacity ( $\Theta_p$ ) was considerably low. The reason was high proportion of clay, which binds the water and so reduces water availability to plants (Bedrna et al., 1989; Liu et al., 2014). Critical values ( $> 35\%$ ) of maximal

capillary water capacity (Fulajtár, 2006) were exceeded in all studied profiles (Table 2).

Characteristics of soil structure, which was analysed in A-horizons, are shown in Table 3. Content of water-stable aggregates in size fraction  $> 5$  mm decreased and in size fractions of 3–1 mm as well as  $< 0.25$  mm increased in following order: kept lawn  $>$  herbicidal fallow  $>$  main garden. The results indicated that the worst soil structural state was in the main garden compared to remaining ones. A-horizon in the main garden had the lowest values of mean weight diameter wet (MWD = 4.4), stability index (Sw = 1.02) and the highest value of coefficient of macroaggregates vulnerability (Kv = 1.0). Low aggregate stability in the main garden soil was caused by intensive cultivation. We concluded that intensive human activity damages structural state of soils. These results suggest that the ploughed soil in the main garden requires bigger care, such as sufficient fertilization with organic manures and tillage reduction. Proposed measures can help to improve the structural state of cultivated soils (Šimanský et al., 2008; Šimanský, 2011).

#### 4. Conclusions

The soil under kept lawn was classified as Calcaric Fluvisol, soil under herbicidal fallow and soil in main garden as Hortic Calcaric Fluvisol. Studied profiles differed in horizons thickness, colour, texture, soil structure, occurrence of  $Fe^{3+}$  mottles.

Alluvial sediments close to the river bank were texturally quite homogenous, but with increased distance, the river accumulated more different material.

Natural compaction was strengthened with anthropogenic one due to use of lawn tractor and agricultural machinery. Very low amount of macro-pores of total porosity (9–14%) was found in whole soil profile under kept lawn in park, while in cultivated soil the macro-porosity was extremely reduced from the depth of 0.2 m.

The amount of available water capacity was considerably low mainly for high proportion of clay, which binds the water. To improve structural state, the cultivated soil in main garden requires fertilization with organic manures and reduction of cultivation.

Overall, soil physical properties require increased attention and proper soil management.



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