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Can soil properties of Fluvisols be influenced by river flow gradient?

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The occurrence of Fluvisols is associated with the rivers, which means that their properties can be greatly influenced by the fluvial activity of the rivers. Therefore, the aim of this work were to (1.) find out whether the flow gradient along the river influenced the soil properties of Fluvisols (2.) evaluate the soil properties of Fluvisols. Soil samples were taken from Nitra River Catchment between villages Výčapy-Opatovce and Jelšovce near Nitra city. There were excavated five soil pits and soils were classified according to the World Reference Base for Soil Resources as follows: Profile 1 as Eutric Fluvisol (Loamic, Humic) (soil use: restored forest), Profile 2 as Eutric Fluvisol (Loamic, Humic) (soil use: arable soil), Profile 3 as Eutric Fluvisol (Loamic, Humic) (soil use: fallow soil), Profile 4 as Eutric Gleyic Fluvisol (Loamic, Humic) (soil use as: forest), Profile 5 as Eutric Fluvisol (Loamic, Humic) (soil use: raid forest). The investigated Fluvisols had different chemical and physical properties, but not as a consequence of the flow gradient along the river. Differences in chemistry and physical properties of Fluvisols developed along the Nitra River have been significantly affected mainly by its use, soil management practices and depth of the soil profile.

Keywords: physical and hydrophysical properties, soil structure, soil sorptive parameters, Fluvisols

1 Introduction

Fluvisols occupy less than 350 million ha worldwide (WRB, 2015). In Slovak Republic the area of Fluvisols is 309.7 thousand hectares, representing 12.6% of the agricultural land fund (Bielek, 2017). The original natural undergrowth for Fluvisols were forests and floodplain meadows. On deep alluvial and texturally heavy Fluvisols with groundwater 1.5 to 2.0 m beneath the surface are good conditions for planting of cereals, technical crops and root crops. Sandy Fluvisols are good soils for growing of vegetables and for forage crops (Zaujec et al., 2009). Fluvisols are genetically young soils developed in predominantly recent, fluvial deposits. There are located along the river plains and valleys, lake depressions and tidal marshes on all continents and in all climate zones; no groundwater and no high salt contents in the topsoil; many Fluvisols under natural conditions are flooded periodically. Soil horizons are weak differentiated, but a distinct topsoil horizon may be present (Zaujec et al., 2009; WRB, 2015). The A-horizon is often sorptive saturated, mostly alluvial texture, with a low humus content of inferior quality and a weak acidic soil pH. A-horizon of Fluvisols does not contain carbonates even when the soil is developed on carbonate alluviums. The production potential of Fluvisols is relatively wide, ranging from 33 to 90 points in a 100-point scale. This means that fertility is significantly limited by soil properties (Zaujec et al., 2009). The properties of Fluvisols are significantly influenced by soil management practices (Kotorová, 2007; Kotorová and Šoltýsová, 2011; Kotorová, 2013; Polláková and Šimanský, 2015). Fluvisols are among the azonal soils. As their occurrence is associated with the rivers, it is evident that their properties can be greatly influenced by the fluvial activity of the rivers (Zaujec et al., 2009, WRB, 2015, Bielek, 2017).

Based on the above context, the aim of this study was to find out whether the flow gradient along the river influenced the soil properties of Fluvisols.

2 Material and methods

The soil surveys were carried out to determine the soil properties of several soils along the Nitra River. Soil sampling sites are shown in the Figure 1. These localities are located between villages Výčapy-Opatovce and Jelšovce near Nitra city. Soil pits were dug on both sides of the Nitra River (the youngest part of investigated area). The parent material consists of fine particles loess and loess silt

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Figure 1 Soil sampling sites

from the Pleistocene epoch. Sometimes there are areas with sand and gravels from Neogene epochs and areas along the river, where loess and loess silt are formed from Holocene drains. The site has a temperate climate, with a mean annual air temperature of 9.7 °C. The mean annual precipitation at this site is 595 mm (333 mm between April and September). More information about the Nitra River Catchment is published in Tarník and Igaz (2015).

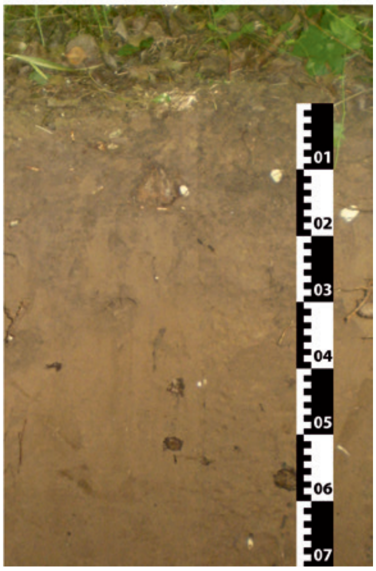
In each locality, before soil sampling a pit was excavated and the soils were classified according to the World Reference Base for Soil Resources (WRB, 2015) based on the whole-profile soil morphology. In the soil pits, the soil samples were collected (in triplicate) after 10 cm layers to a depth of 50 cm to cylinders with an inner diameter of 5 cm and height of 5 cm. Determination of physical (bulk and particle densities, pore size distributions), hydrophysical properties (soil moisture, capillary absorption, 30 minute moisture, maximum capillary water capacity, and retention water capacity) was then conducted using standard methods (Hrivňáková et al., 2011). The soil samples for determination of chemical properties, soil organic carbon and soil structure parameters (vulnerability coefficient, index of aggregate stability) were taken from described soil horizons. In laboratory, the large clods of soil were gently broken up along the natural fracture lines, and soil samples for the determination of individual size fractions of aggregates (undisturbed soil samples) were obtained. In undisturbed soil samples, individual size fractions of aggregates were determined by dry sieving. These size fractions of air-dried aggregates (>7, 7–5, 5–3.15, 3.15–1, 1–0.5, 0.5–0.25 and <0.25 mm) were used for the determination of water-stable aggregates (WSA) distribution by Baksheev method (Vadjunina and Korchagina, 1986). Following size fractions of WSA >5, 5–3, 3–2, 2–1, 1–0.5, 0.5–0.25 (macro-aggregates) and <0.25 mm (micro-aggregates) were determined. Part of the soil samples collected from the soil horizons were grinded before analysis. The soil samples were determined for: soil pH – potentiometrically in the supernatant suspension of a 1 : 2.5 soil/distilled water and 1 : 2.5 soil/1M KCl (Hrivňáková et al., 2011). Soil colloidal complex was characterized by the hydrolytic acidity (H), sum of basic exchangeable cations (SBC) and cation exchange capacity (CEC) and base saturation (Bs) which were determined by Kappen method (Hrivňáková et al., 2011). Carbonates were determined by volumetric method using a Jankov calcimeter. Soil organic carbon content (SOC) was measured using the wet combustion method (Gonet et al., 2002). The content of total iron, content of free iron oxides, the content of amorphous iron oxides by means of the microwave plasma atomic emission spectrometry (Agilent 4100MP-AES) after samples digestion in a mixture of 60% $HClO_4$ and 40%HK, after samples extraction by means of Jackson´s method (Mehra and Jackson, 1960) and after samples extraction by means of the Schwertmann method (Van Reeuwijk, 1995), respectively, were measured. In the grinded soil samples, particle-size distribution was determined by pipette method (Hrivňáková et al., 2011). Mineral composition of soil samples was determined using X-ray diffraction (XRD) method. Samples were dried at 20 °C and ground. Powders were analysed by means of Bruker AXS D5005 diffractometer equipped with the KRISTALLOFLEX® 760 X-ray generator, the vertical goniometer, 1 mm divergence slit, 2 mm anti scatter slit, 0.6 mm detector slit, and a graphite diffracted-beam monochromator. CoKα radiation was used with the applied voltage of 40 kV and 30 mA current. Random mounts of the ground materials were scanned at a counting time of 2 s per 0.01° step from 3 to 70 °2θ. XRD analyses were performed in the Department of Soil Environment Sciences, Warsaw University of Life Sciences – SGGW, Poland.

The statistical analysis was performed using the computer program Statgraphics Centurion XV.I (Statpoint Technologies, Inc., USA). The data were analyzed using one-way ANOVA, and the means (average values of soil properties) were compared with LSD test at P <0.05. The relations between chemical and physical properties in soil profiles of Fluvisols were determined through correlation matrix.

3 Results and discussion

3.1 Description of the soil profiles

Profile 1



Localization: On the left side of actual river bed Nitra (48° 23′ 48.83″ N 18° 5′ 5.99″ E).

Description: Soil pit located at the area approx. 150 m from protection wall of Nitra River. Before 2010, poplar forest (approx. 45 years' old woods) was planted. In 2015 (time of sampling) here was neglected area no cultivation, no planting – appearance of raid plants/trees.

Morphology of soil profile: Eutric Fluvisol (Loamic, Humic)

0–5 cm (Aka) slightly humid, colour: moist wet 10YR 2/3, moist-dry 10YR 6/2, loose, silty-clay-loam, crumb soil structure, aggregates of spherical shape, intensive root growth, CO_3^- 1–3%.

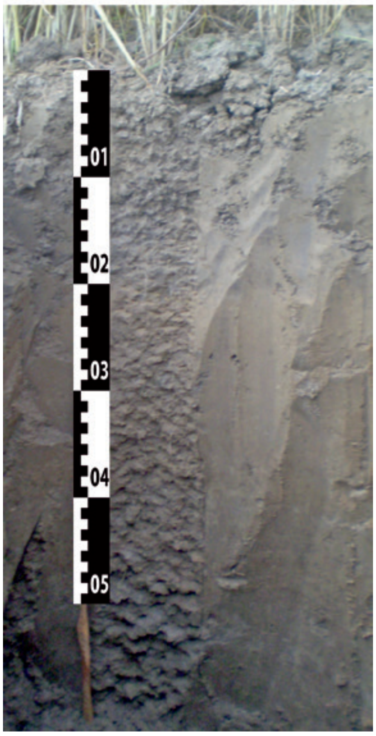
5–20 cm (Akp) slightly humid, colour: moist wet 10YR 4/3, moist-dry 10YR 7/2, oppressed, silty-loam, polyhedron, angular aggregates, intensive root growth, CO_3^- 1–3%.

20–61 cm (Ck) slightly humid, colour: moist wet 10YR 4/4, moist-dry 10YR 7/3, oppressed, silty-loam, granular soil aggregates, rust stains after Fe^{3+}, CO_3^- 1–3%.

61–72 cm (Ckgr1) moderately humid, colour: moist wet 10YR 4/4, moist-dry 10YR 7/3, oppressed, silty-loam, rust stains after Fe^{3+} on granular aggregates, CO_3^- 1–3%.

>72 cm (Ckgr2) wet, colour: moist wet 10YR 4/4, moist-dry 10YR 7/3, oppressed, silty-loam, rust stains after Fe^{3+} on granular aggregates, CO_3^- 3–5%.

Profile 2



Localization: On the right side of actual river bed Nitra (48° 23′ 47.60″ N 18° 4′ 52.86″ E).

Description: Soil pit located on right side of the artificially excavated channel connecting the two dead branches of Nitra River (Ľudovítová III. and II.). In the past this area was flooded every year. Last 10 year the area is without flood and this one is used for agriculture (planting of crops). There was planted winter wheat during sampling.

Morphology of soil profile: Eutric Fluvisol (Loamic, Humic)

0–21 cm (Akp1) slightly humid, colour: moist wet 10YR 3/3, moist-dry 10YR 6/2, oppressed, loam, crumb soil structure, aggregates of spherical shape, intensive root growth, CO_3^- 0.3–1%.

21–29 cm (Akp2) slightly humid, colour: moist wet 10YR 3/4, moist-dry 10YR 6/3, compacted, silty-loam, polyhedron, angular aggregates, weak root growth, CO_3^- 0.3–1%.

29–55 cm (Ck) slightly humid, colour: moist wet 10YR 4/3, moist-dry 10YR 6/3, oppressed, loam, granular soil aggregates, weak root growth, CO_3^- 1–3%.

55–71 cm (Ckg) moderately humid, colour: moist wet 10YR 4/3, moist-dry 10YR 6/3, loose, loam, weak root growth, granular soil aggregates, weak root growth, rust stains after Fe^{3+} on granular aggregates, CO_3^- 1–3%.

>71 cm (Ckgr) moderately humid, colour: moist wet 10YR 4/2, moist-dry 10YR 6/2, loose, loam, granular soil aggregates, rust stains after Fe^{3+} with grey coats on granular aggregates, CO_3^- 1–3%.

Profile 3

Localization: On the right side of actual river bed Nitra (48° 23′ 35.09″ N 18° 4′ 49.00″ E).

Description: The soil pit was located 20 m from the artificially excavated channel connecting the two dead branches of Nitra River (Ľudovítová II. and I.). In the past, this area has been dealt with by common agricultural practice. In 1965 the Nitra River stream was modified and this part of the area was damaged by working mechanisms. In 1986 the area (field) was again intensively used for agricultural activities and monoculture maize cultivation until 2010. From 2010 neglected area. The area is covered with raid vegetation (sallow, poplar). The dominant plant species is casuarina.

Morphology of soil profile: Eutric Fluvisol (Loamic, Humic)

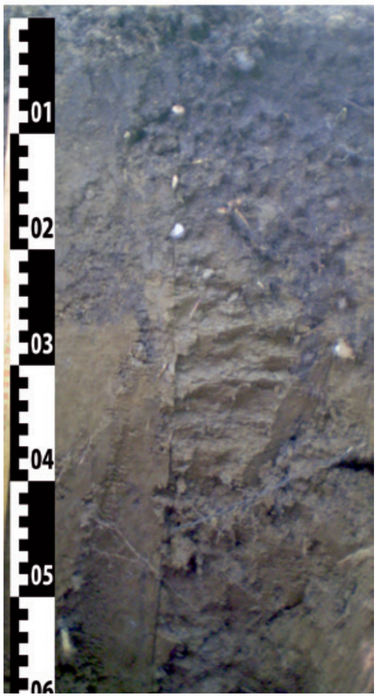
0–12 cm (Akp1) moderately humid, colour: moist wet 10YR 3/3, moist-dry 10YR 6/4, loose, loamy, crumb soil structure, intensive root growth, CO_3^- 1–3%.

12–24 cm (Akp2) moderately humid, colour: moist wet 10YR 3/3, moist-dry 10YR 6/4, oppressed, loamy, chestnuts soil structure, aggregates of spherical shape, intensive root growth, CO_3^- 1–3%.

24–37 cm (Ck) moderately humid, colour: moist wet 10YR 3/3, moist-dry 10YR 6/4, oppressed, loamy, polyhedron, angular aggregates, rust stains after Fe^{3+}, corridors after earthworms, CO_3^- 1–3%.

37–58 cm (Ckg) moderately humid, colour: moist wet 10YR 4/3, moist-dry 10YR 7/4, oppressed, silty-loam, polyhedron, angular aggregates, rust stains after Fe^{3+} with grey coats on aggregates, up to 1% of CO_3^- >58 cm (Ckgr) wet, colour: moist wet 10YR 4/3, moist-dry 10YR 7/4, oppressed, silty-clay-loam, prismatic, aggregate of columnar shape, rust stains after Fe^{3+}, corridors after earthworms, CO_3^- 1–3%, underground water at depth 70 cm.

Profile 4



Localization: On the right side of actual river bed Nitra (48° 23′ 33.55″ N 18° 4′ 46.53″ E).

Description: The soil pit was located 20 m from the artificially excavated channel connecting the two dead branches of Nitra River (Ľudovítová II. and I.). Profile 4 was located approx. 80 m by the profile 3. In the past, this area has been dealt with by common agricultural practice. In 1965 the Nitra River stream was modified and this part of the area was damaged by working mechanisms. After the mechanical regulation of the banks of the Nitra River, the area was enhanced by raid of plants/trees. The age of the oldest woods (willow and poplar) is estimated at about 55 years. The surface of the soil was not covered by any herbal communities. On the surface of the soil was a litter fall (leaves of trees in different degrees of decomposition).

Morphology of soil profile: Eutric Gleyic Fluvisol (Loamic, Humic)

0–8 cm (Aa) slightly humid, colour: moist wet 10YR 2/2, moist-dry 10YR 5/2, loose, loamy, crumb soil strucutre, aggregates of spherical shape, intensive root growth, CO_3^- <0.3%.

8–19 cm (Akp) moderately humid, colour: moist wet 10YR 2/3, moist-dry 10YR 6/2, oppressed, loamy, plate-shaped aggregates, coarse rock occurrence up to 20% in grain-size up to 1 cm, CO_3^- 1–3%.

19–27 cm (Ck) moderately humid, colour: moist wet 10YR 4/3, moist-dry 10YR 7/3, oppressed, silty-loam, plate-shaped aggregates, rust stains after Fe^{3+}, corridors after earthworms, CO_3^- 1–3%.

27–60 cm (Ckg) moderately humid, colour: moist wet 10YR 4/4, moist-dry 10YR 7/3, oppressed, loamy, rust stains after Fe^{3+} with grey coats on granular aggregates, CO_3^- 1–3%.

>60 cm (Ckgr) wet, colour: moist wet 10YR 4/4, moist-dry 10YR 7/3, oppressed, loamy, rust stains after Fe^{3+} with grey coats on granular aggregates, CO_3^- 1–3% underground water at depth 60 cm.

Profile 5

Localization: On the left side of actual river bed Nitra (48° 23′ 14.98″ N 18° 4′ 35.71″ E).

Description: Soil pit located the left side of actual river bed Nitra behind a hydropower plant. In past this area was used as arable and horticulture land originally. Upon completion of the hydroelectric power plant, this site was neglected. During sampling time, the area was covered with raid vegetation (poplar, elder, acacia). There were growing neglected apple trees as well.

Morphology of soil profile: Eutric Fluvisol (Loamic, Humic)

0–17 cm (Akp) slightly humid, colour: moist wet 10YR 3/3, moist-dry 10YR 5/2, loose, silty-loam, crumb soil structure, aggregates of spherical shape, intensive root growth, CO_3^- 1–3%.

17–24 cm (Ak/C) slightly humid, colour: moist wet 10YR 3/3, moist-dry 10YR 5/2, loose, silty-loam, crumb soil structure, aggregates of spherical shape, intensive root growth, CO_3^- 1–3%.

24–63 cm (Ck1) slightly humid, colour: moist wet 10YR 4/4, moist-dry 10YR 7/3, oppressed, silty-loam, granular aggregates, CO_3^- 3–5%.

>63 cm (Ck2) moderately humid, colour: moist wet 10YR 4/4, moist-dry 10YR 7/3, oppressed, loam, granular soil aggregates, CO_3^- 3–5%.

3.2 Particle size distribution and mineral composition

Based on visual evaluation of soil profiles there were not observed any clay coatings on aggregate surfaces which means that re-distribution of individual grain-size fractions is the consequence of the deposition of layers of different grain by fluvial activity of river. Laboratory analysis also showed that the particle-size distribution of the studied soil profiles was considerably different, so classification of the whole profile in terms of grain-size is not possible. In all Fluvisols an individual soil horizons were classified (Table 1). In A-horizons of Fluvisols, the soil texture varied among loamy (Profile 2, 3 and 4), silt loam (Profile 5 and 1) and silty-clay-loam (Profile 1), with the clay content ranging from 14.2% to 25.1%. The content of clay decreased with the depth almost in all soil profiles of Fluvisols (except Profile 3). In profile 1, clay content from Ckg and Ckgr horizons to the depth layers increased what was evident because of cohesive soil structure. In these soils, soil aggregates are not obvious but the soil is solid and plastic what is typical feature of hydromorphic soils (Zaujec et al., 2009). Overall, the fraction of silt was a predominant grain-sizes in all soil profiles of Fluvisols. There was not determined any decrease or increase along the river flow gradient for portion of particle-size distribution.

There was determined a mineral composition of Fluvisols at depth of 5–25 cm (Fig. 2). Quartz was a predominant phase in the studied soils. They also contained feldspars (albite and orthoclase) and micas (most likely muscovite). Moreover, chlorite and some other clay minerals which presence was corroborated by the occurrence of broad peak around 1.4 nm (e.g. samples 4 and 5) were found. Some samples contained trace contents of amphibole. Furthermore, carbonates (calcite and dolomite) were identified in all studied soils apart from sample 5. That sample did not contain calcite, but contains trace amounts of dolomite. In general, carbonates are not abundant constituents of the sample 5 and they can be overlooked on XRD patterns. The chemical analysis confirmed carbonates in profile 5 as well. As mentioned above the soil samples of Fluvisols contained from clay minerals mainly chlorite which is a phyllosilicates with

Table 1 Particle-size distribution of Fluvisols

Soil pit	Horizons	Depth (cm)	Sand	Silt	Clay	Texture Δ
			(%)			
Profile 1 Restored forest	Aka	0–5	19.92	54.97	25.11	silty-clayey-loamy
	Akp	5–20	16.91	60.35	22.74	silty-loam
	Ck	20–61	9.68	68.34	21.98	silty-loam
	Ckgr	61–72	32.12	53.47	14.41	silty-loam
Profile 2 Arable soil	Akp1	0–21	42.97	38.84	18.19	loamy
	Akp2	21–29	30.16	52.13	17.71	silty-loam
	Ck	29–55	43.91	41.28	14.81	loamy
	Ckg	55–71	46.67	40.49	12.84	loamy
	Ckgr	>71	41.06	48.10	10.84	loamy
Profile 3 Fallow soil	Akp1	0–12	48.05	37.26	14.69	loamy
	Akp2	12–24	40.08	39.35	20.57	loamy
	Ck	24–37	39.09	44.42	16.49	loamy
	Ckg	37–58	18.94	57.54	23.52	silty-loam
	Ckgr	>70	15.54	57.73	26.73	silty-clayey-loamy
Profile 4 Forest	Aa	0–8	43.37	37.53	19.10	loamy
	Akp	8–19	48.76	34.82	16.42	loamy
	Ck	19–27	28.47	53.05	18.48	silty-loam
	Ckg	27–60	47.98	39.11	12.91	loamy
Profile 5 Raid forest	Akp	0–17	25.16	56.55	18.29	silty-loam
	Ak/C	17–24	22.23	63.57	14.20	silty-loam
	Ck1	24–63	25.78	55.44	18.78	silty-loam
	Ck2	>63	40.12	49.31	10.57	loamy

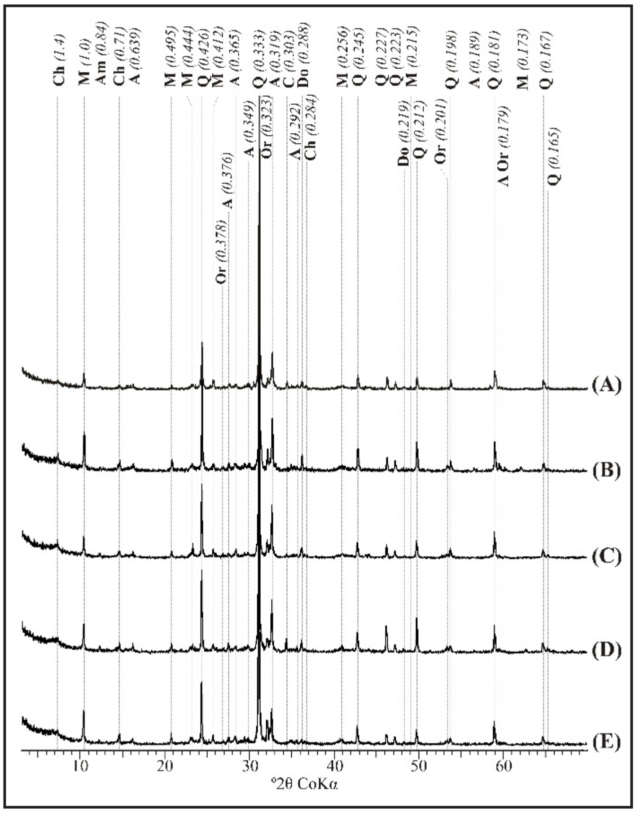


Figure 2 XRD patterns for the studied soil samples in layer 5–25 cm of studied Fluvisols
(A) sample 1, (B) sample 2, (C) sample 3, (D) sample 4, (E) sample 5. The d values (in brackets) in nm. Symbols of phases: A – albite, Am – amphibole, C – calcite, Ch – chlorite, Do – dolomite, M – muscovite, Or – orthoclase, Q – quartz

a 2 : 1 layer complex which instead of the interlayer cation contain another octahedral layer (Wiewióra and Weiss, 1990). With the increase of temperature and humidity, the 2 : 1 type clay mineral content gradually decreased and was transformed into 1 : 1 type clay mineral, and the active clay mineral was transformed into inactive clay mineral (Wu et al., 2016). In our case, nothing similar has been observed, which may be the consequence of both the fluvial activity of river, but also of the mild space on which the research was carried out. Within a small space, no significant temperature and humidity change is observed, which would have a significant effect on the intensive conversion of clay.

3.3 Physical and hydrophysical properties

The mineralogical composition is also related to the values of the particle density (ρs). The values of ρs were fairly equalized in all profiles of Fluvisols (Table 2). Smaller differences could be explained by river activity, which at different time periods created layers with different material and composition. For example, in Figure 3 it is easy to see the individual layers that were created by the fluvial activity of Nitra River (Profile 5). Lower values of the soil density were found in A-horizons in all profiles and this is due to the higher content of SOC (Table 4), since the values of this parameter depend mainly on the mineral and organic content of the soil (Zaujec et al., 2009). Based on mineral composition (Fig. 2) Fluvisols contained quartz, feldspars such as: albite and orthoclase and from micas mainly muscovite. As presented Scheffer and Schachtschabel (1970) ρs values of quartz, albite, orthoclase and muscovite are 2.65, 3.02–3.45, 2.55–2.63 and 2.77–2.88 t m^{-3}, respectively and results of soil organic carbon are mentioned in Table 4.

In soil profiles of Fluvisols, values of bulk density (ρd) ranged from 0.86 to 1.67 t m^{-3}. Lower values of ρd were identified in the upper layers and increased with the depth. Generally, the lowest values of ρd were determined in arable soil. In Fluvisols, an average values of ρd were higher by 14, 20, 28 and 37% under restored forest, fallow and raid forest, respectively compared to the arable soil. There wasn't found any decrease or increase of ρd along the river flow gradient. Significant factor which influence ρd is a particle-size distribution, soil structure and soil water content (Fulajtár, 2006; Mati et al., 2011). Generally, soils containing high percentage of clay are prone to compaction and higher values of bulk density (Polláková, 2012; Safadoust et al., 2014). The effects of human activity such as: soil tillage on changes of bulk density but other physical and hydrophysical properties use are evident also in Fluvisols (Kotorová, 2007; Kotorová and Šoltýsová, 2011; Kotorová, 2013). The highest values of total porosity (P) were determined in arable soil, while the lowest in raid forest. In A-horizons of Fluvisols under fallow, forest, restored forest, arable soil and raid forest the total porosity was slightly compacted, loose, slightly compacted, slightly compacted and compacted, respectively. In Ckg and Ckgr-horizons of all Fluvisols except profile 4 (under arable soil) the values of

Figure 3 Soil layer in C horizon of Fluvisol (soil profile FM 5)

Table 2 Physical properties of Fluvisols

Soil pit	Depth (cm)	BD	PD	Θ_{CA}	Θ_{30}	Θ_{MCWC}	Θ_{WRC}	P	Pn	Pc	Ps
		(g cm^{-3})		(%)							
Profile 1 Restored forest	0–10	0.90	2.49	38.4	37.2	36.2	35.1	64.0	26.9	35.1	2.0
	10–20	1.24	2.55	39.6	38.4	37.4	36.1	51.4	13.0	36.1	2.3
	20–30	1.37	2.60	38.9	38.2	37.5	36.4	47.2	9.1	36.4	1.8
	30–40	1.47	2.56	39.5	38.8	38.1	37.3	42.6	3.8	37.3	1.5
	40–50	1.27	2.61	39.2	37.2	35.6	33.7	51.5	14.3	33.7	3.5
Profile 2 Arable soil	0–10	0.97	2.56	42.2	40.4	38.2	35.1	62.3	21.9	35.1	11.6
	10–20	1.10	2.59	39.7	37.9	34.9	30.8	57.8	19.9	30.8	7.2
	20–30	1.04	2.61	41.7	38.5	34.4	28.8	60.4	21.9	28.8	9.8
	30–40	1.15	2.61	41.9	39.5	36.4	30.7	55.9	16.4	30.7	8.9
	40–50	1.25	2.62	42.7	41.2	39.2	33.8	52.4	11.2	33.8	7.4
Profile 3 Fallow soil	0–10	1.17	2.56	34.4	31.4	30.1	27.6	54.4	23.0	27.6	3.8
	10–20	1.41	2.60	36.8	34.7	33.6	31.5	45.9	11.2	31.5	3.2
	20–30	1.44	2.63	35.5	33.6	32.7	30.6	45.3	11.7	30.6	3.0
	30–40	1.49	2.38	36.7	35.6	34.7	33.2	37.2	1.6	33.2	2.3
	40–50	1.52	2.60	39.9	39.3	39.0	38.1	41.7	2.4	38.1	1.2
Profile 4 Forest	0–10	0.86	2.52	52.2	49.6	47.7	44.6	65.8	16.2	44.6	5.0
	10–20	1.37	2.61	38.1	35.4	33.9	31.8	47.3	12.0	31.8	3.6
	20–30	1.53	2.65	35.3	33.4	32.1	30.0	42.5	9.1	30.0	3.5
	30–40	1.52	2.64	37.0	35.1	34.1	32.3	42.6	7.4	32.3	2.9
	40–50	1.34	2.66	39.1	36.5	31.5	32.8	49.9	13.4	32.8	3.7
Profile 5 Raid forest	0–10	1.28	2.58	37.9	35.4	32.9	30.7	50.3	14.9	30.7	4.7
	10–20	1.39	2.61	38.3	36.3	34.4	32.5	46.9	10.6	32.5	3.9
	20–30	1.67	2.64	22.7	32.7	32.2	31.6	36.8	4.0	31.6	1.1
	30–40	1.62	2.64	33.9	33.3	32.8	32.2	38.7	5.4	32.2	1.1
	40–50	1.59	2.65	34.3	33.6	32.9	31.9	40.0	6.5	31.9	1.6

BD – bulk density, PD – particle density, Θ_{CA} – capillary absorption, Θ_{30} – 30 minute moisture, Θ_{MCWC} – maximum capillary water capacity, Θ_{WRC} – retention water capacity, P – total porosity, Pn – non-capillary porosity, Pc – capillary porosity, Ps – semi-capillary porosity

P signalled soil compaction mentioned layers. In profile 4 the values of P signalled slightly compaction according to criteria published by Kutílek (1966). Both the critical values of ρd and P according to Fulajtár (2006) for loamy soils (in most case our results) under fallow, forest, restored forest and raid forest were determined at the depths >30 cm, >20 cm, 30–40 cm and >20 cm, respectively. Volume of capillary, non-capillary and semi-capillary pores from total porosity represented on average 55–74.8, 19.5–31.7, and 5.84–7.94%, respectively. There wasn't found any decrease or increase along the river flow gradient for the individual categories of the soil pores. A highest values of capillary absorption (Θ_{CA}) were determined under arable soil, however, the water retention capacity (Θ_{WRC}) of this soil was the lowest. The highest ability to retain water in the soil for plants (maximum capillary water capacity – Θ_{MCWC}) was found under restored forest. Soil use of Fluvisols did not have statistically significant influence on maximum capillary water capacity and water retention capacity. Soil profiles were balanced also from the point of view of these water parameters (Θ_{WRC} and Θ_{MCWC}). As is mentioned in Kotorová (2007) in Gleyic Fluvisols these water parameters are rather affected by the water supply in the soil, heterogeneity of soil profile and content of clay particles than the soil cultivation. Opposite Polláková and Šimanský (2015) in Calcaric and Hortic Calcaric Fluvisols found the changes in soil hydrophysical properties due to different soil use and cultivation.

Significant feature of soil structure is their shape and size of soil aggregates (Shukla, 2014). For example, the

Figure 4 Shape and size of soil aggregates A) crumb structure, B) ploty structure, and C) polyedric (angular) structure

A-horizons of Chernozems have crumb structure and for Bt and Bn-horizons is typical prismatic and columnar structure, respectively. Eluvial horizons of Luvisols or Podzols have platy or laminated structure (Fulajtár, 2006). In our case, shape and size of soil aggregates were different. For example, under forest soil in A-horizon the shape of soil aggregates was spherical (Fig. 4a), while platy in Ck-horizon (Fig. 4b). Under the fallow in Ck-horizon the aggregates were angular (Fig. 4c) typical of the polyedric soil structure.

In laboratory, the contents of individual size fractions of water-stable aggregates (WSA) were determined (Table 3). Content of water-stable micro-aggregates (WSA_{mi}) ranged from 2.43 to 64.1% and covered the largest proportion whereas the size fraction water-stable macro-

Table 3 Soil structure parameters of Fluvisols

Soil pit	Horizons	Depth (cm)	Size fractions of water-stable macroaggregates in mm					WSA_{mi}	WSA_{ma}	MWDd	MWDw	Kv	Sw
			>5	5–3	3–1	1–0.5	0.5–0.25	(%)					
Profile 1 Restored forest	Aka	0–5	52.5	8.93	7.96	3.23	3.81	23.6	76.4	3.48	3.10	1.13	0.94
	Akp	5–20	24.6	11.1	4.88	4.52	6.56	48.4	51.6	3.61	1.70	2.13	0.61
	Ck	20–61	1.54	1.47	1.40	3.79	9.83	81.9	18.0	3.23	0.21	15.4	0.19
	Ckgr	61–72	0.28	1.16	0.98	1.04	8.35	88.2	11.0	2.37	0.10	25.1	0.13
Profile 2 Arable soil	Akp1	0–21	0.33	0.56	0.92	1.07	5.12	92.0	7.99	2.11	0.08	28.3	0.08
	Akp2	21–29	4.21	0.74	0.99	1.60	7.98	84.5	15.5	3.60	0.28	13.4	0.19
	Ck	29–55	0	0	0.29	0.62	3.64	95.5	4.55	3.20	0.02	156.1	0.01
	Ckg	55–71	0	0	0.46	0.93	11.2	87.4	12.6	2.61	0.05	62.8	0.16
	Ckgr	>71	2.08	6.53	6.53	7.65	11.2	70.7	29.3	2.52	0.27	10.8	0.48
Profile 3 Fallow soil	Akp1	0–12	1.01	1.15	4.29	6.36	13.1	74.1	25.9	3.81	0.17	22.7	0.38
	Akp2	12–24	0.62	0.87	3.21	4.93	11.2	79.2	20.8	3.50	0.18	20.9	0.29
	Ck	24–37	3.88	2.62	1.51	3.72	14.7	73.6	26.4	3.97	0.38	10.7	0.31
	Ckg	37–58	15.4	3.09	1.23	3.06	12.2	65.1	34.9	4.42	0.94	4.76	0.40
	Ckgr	>70	10.6	11.1	11.6	11.5	15.4	39.7	60.3	2.53	1.19	2.13	1.00
Profile 4 Forest	Aa	0–8	3.25	6.63	12.7	11.6	14.3	51.6	48.4	2.63	0.71	3.71	0.86
	Akp	8–19	2.27	2.15	3.75	4.53	9.18	78.1	21.9	2.96	0.32	9.27	0.27
	Ck	19–27	1.41	0.94	1.10	1.07	4.51	90.9	9.02	2.08	0.14	15.4	0.09
	Ckg	27–60	0.59	2.48	2.84	4.73	11.1	78.3	21.7	2.27	0.22	10.7	0.26
Profile 5 Raid forest	Akp	0–17	0.41	2.13	3.99	5.37	12.4	75.7	24.3	2.39	0.25	9.76	0.29
	Ak/C	17–24	0.60	1.07	2.14	2.61	7.24	86.4	13.7	2.52	0.14	18.5	0.15
	Ck1	24–63	0.70	0.68	1.84	1.44	1.75	93.6	6.40	0.68	0.11	7.11	0.05

WSA_{mi} – water-stable micro-aggregates, WSA_{ma} – water-stable macro-aggregates, MWDd – mean weight diameter of aggregates for dry sieving, MWDw – mean weight diameter of water stable aggregates, Kv – vulnerability coefficient, Sw – index of aggregate stability aggregates (WSA_{ma}) 5–3 mm occupied the least. There wasn't determined any decrease or increase along the river flow gradient for portion of water-stable aggregates. The aggregate size distribution was significantly affected by soil use and one-way ANOVA analysis also showed the significant differences between soil horizons for contents of WSA. Land use change has an important influence on soil properties. For example, with changes in land use, soil micro-aggregates may form macro-aggregates through the action of temporary and transient binding agents (Elliott, 1986). Forestry influences soil organic matter (SOM), which in turn influences aggregation in comparison with conventional managed systems (Atsivor et al., 2001). Forest soil dynamics improves soil aggregation while transferring organic carbon into deeper soil horizons (Podrázský et al., 2009). Arable soil had the largest content of WSA_{mi} while that soil under restored forest had the lowest. On the other hand, the highest average content of WSA_{ma} was found under restored forest and then under forest > fallow > raid forest > arable soil. In A-horizons of Fluvisols the significant higher contents of WSA_{ma} and lower contents of WSA_{mi} compared to Ck or Ckgr horizons were observed. Contents of WSA_{mi} negative correlated with MWDw (r = -0.901; P <0.001) and aggregate stability (r = -0.968; P <0.001) but on the other hand positively correlated with vulnerability of soil structure (r = 0.488; P <0.05). Values of MWDw, Sw and Kv were not affected along the river flow gradient. ANOVA showed significant effects of land use and soil depth on soil structure parameters. The highest aggregate stability resulted the lowest vulnerability under forest soil. Opposite, in arable soil the lowest aggregate stability with the highest Kv values were determined. Based on MWDw, Kv and Sw values, better soil structure was observed in A than Ck, Ckg or Ckgr-horizons of Fluvisols. Our results confirmed that the soil structure is affected except soil intrinsic properties as well as by soil use and soil management (Bronick and Lal, 2005).

3.4 Content of soil organic carbon, sorptive parameters, soil pH and content of iron and its oxides

The content of Fe in the soil is conditioned mainly by primary abundance of parent materials. Progressively released as a result of weathering, metals from complexes with the remaining components of soils, particularly with the clay minerals and the organic matter, and are included into biological turnover (Jonczak et al., 2015). Contents of Fe and its oxides could be changed due to different soil management practices (Šimanský and Jonczak, 2017). The results of the Table 4 shows that the land use as well as soil depth displayed had significant influence on the total iron content (Fet) and its amorphous (Feo) and crystalline (Fec) oxides. The values of Fet was lower by 23%, 12%, 24% and 30% under forest, restored forest, arable soil and raid forest respectively than fallow soil. The lowest content of Feo was determined under raid forest while the highest under restored forest. The highest average content of Fec was found under restored forest > under forest = raid forest > arable soil > fallow soil. In all cases higher but no significant differences in Fe and its oxides were determined in Ck, Ckg or Ckgr-horizons compared to A-horizons.

The distribution of soil organic carbon, sorptive parameters and soil pH was not effected along the river flow gradient. There are significant differences for SBC, CEC and SOC in relation to the soil use as well as significant differences in soil pH, carbonates content, hydrolytic acidity, base saturation and SOC in relation to the soil depth. The average values of CEC was lower by 51%, 51%, 41% and 35% under forest, raid forest, arable soil and fallow soil respectively than restored forest. The sorptive complex was fully saturated in soil profiles of all investigated Fluvisols. It is known that the more intensively the soil is used the more intensively its properties are changed. An unsuitable change in land use due to human activities and agricultural management practices can affect the soil properties (Papini et al., 2011). Even differences in soil management practices can negatively as well as positively influence soil properties. In addition, tillage disrupts soil aggregates, compacts soil and disturbs plant and animal communities that contribute to aggregation and lowers SOM, CEC, nutrients, microbial activity and faunal activities that contribute to aggregation (Plante and McGill, 2002). The conversion of natural forests and grasslands to agricultural land also may cause important changes in soil physical and chemical properties, especially to reduce SOM (Haghighi et al., 2010). The SOC content was almost two and a half times and one and a half times lower under forest as well as restored forest than in arable soil. When compared to arable soil, the SOC content was higher by 69% and 73% under fallow soil and raid forest, respectively. Also, the mean SOC values were more than twice as high in A than Ck, Ckg and Ckgr-horizons.

3.5 Correlations between the chemical and physical properties in the soil profiles of Fluvisols

In Fluvisols, the soil pH in H_2O negatively affected water retention capacity and volume of capillary pores. Soil pH in KCl positively affected both particle and bulk densities, while it negative effected moisture states in Fluvisols. These effects depend on the carbonate and the soil organic contents, since positive correlations were observed between $CaCO_3$ and particle and bulk densities. On the other hand, negative correlation were determined between SOC and particle and bulk densities

Table 4 Soil pH, sorptive parameters, content of soil organic carbon content of iron and its oxides in soil profiles of Fluvisols

Soil pit	Horizons	Depth (cm)	pH_{H_2O}	pH_{KCl}	$CaCO_3$	Ha	SBC	CEC	Bs	SOC	Fet	Fed	Feo	Fed/Fet	Feo/Fed
					(%)	(mmol kg^{-1})			(%)						
Profile 1 Restored forest	Aka	0–5	7.42	7.18	1.2	5.15	82.9	88	94.1	3.67	2.89	0.67	0.19	0.23	0.29
	Akp	5–20	7.52	7.36	1.2	5.49	42.5	48	88.6	1.50	2.97	0.73	0.23	0.24	0.31
	Ck	20–61	7.81	7.44	1.6	2.49	101.5	104	97.6	0.77	3.06	0.81	0.23	0.26	0.29
	Ckgr	61–72	7.83	7.59	3.0	2.66	77.3	80	96.7	0.46	2.32	0.57	0.22	0.25	0.39
Profile 2 Arable soil	Akp1	0–21	7.57	7.24	1.8	3.82	36.2	40	90.4	1.26	2.49	0.59	0.19	0.24	0.33
	Akp2	21–29	7.73	7.36	1.2	2.49	85.5	88	97.7	0.82	2.62	0.59	0.18	0.23	0.31
	Ck	29–55	7.94	7.57	1.8	2.49	45.5	48	94.8	0.50	2.52	0.59	0.19	0.24	0.32
	Ckg	55–71	7.87	7.50	1.4	2.49	25.5	28	91.1	0.41	2.53	0.52	0.17	0.21	0.32
	Ckgr	>71	7.87	7.54	1.8	2.99	29.0	32	90.7	0.32	2.09	0.51	0.17	0.24	0.33
Profile 3 Fallow soil	Akp1	0–12	7.75	7.58	1.8	4.66	35.4	40	88.4	1.36	2.40	0.48	0.16	0.20	0.33
	Akp2	12–24	7.77	7.54	2.3	2.49	13.5	16	84.4	1.09	3.06	0.56	0.17	0.18	0.31
	Ck	24–37	7.82	7.59	2.0	4.16	43.8	48	91.3	0.93	3.15	0.50	0.16	0.16	0.32
	Ckg	37–58	7.73	7.42	2.0	4.16	59.8	64	93.5	0.93	3.55	0.72	0.23	0.20	0.31
	Ckgr	>70	7.65	7.26	1.8	3.66	88.3	92	96.0	0.93	3.87	0.92	0.23	0.24	0.25
Profile 4 Forest	Aa	0–8	7.22	7.19	1.2	6.48	9.52	16	59.5	5.63	2.58	0.48	0.22	0.19	0.45
	Akp	8–19	7.43	7.34	1.7	3.99	12.0	16	75.1	1.61	2.31	0.47	0.21	0.20	0.45
	Ck	19–27	7.67	7.50	1.4	2.66	69.3	72	96.3	0.89	2.58	0.65	0.22	0.25	0.34
	Ckg	27–60	7.78	7.74	1.8	1.66	50.3	52	96.8	0.41	2.44	0.58	0.20	0.24	0.35
Profile 5 Raid forest	Akp	0–17	7.25	7.16	1.0	6.98	25.0	32	78.2	2.74	2.10	0.63	0.17	0.30	0.26
	Ak/C	17–24	7.62	7.32	1.1	3.66	52.3	56	93.5	1.12	2.42	0.65	0.17	0.27	0.26
	Ck1	24–63	7.87	7.59	2.8	3.32	24.7	28	88.1	0.42	2.34	0.61	0.14	0.26	0.23

Ha – hydrolytic acidity, SBC – sum of basic cations, CEC – cation exchange capacity, Bs – base saturation, SOC – soil organic carbon, Fet – total iron content, Fed – free iron oxides, amorphous iron oxides, Fec – crystalline iron oxides

Table 5 Correlation coefficient between the soil pH, sorptive parameters, content of the soil organic carbon, texture and parameters of soil structure in the soil profiles of Fluvisols

	BD	PD	Θ	Θ_{KN}	Θ_{30}	Θ_{MCWC}	Θ_{WRC}	P	Pn	Pc	Ps
pH_{H_2O}	ns.	ns.	ns.	ns.	ns.	ns.	-0.495*	ns.	ns.	-0.495*	ns.
pHKCl	0.465*	0.503*	ns.	-0.429*	-0.472*	-0.540	-0.500*	ns.	ns.	-0.500*	ns.
$CaCO_3$	0.507*	ns.	ns.	-0.489*	ns.	ns.	ns.	-0.486*	ns.	ns.	ns.
H	ns.	-0,508*	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
SBC	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
CEC	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
Bs	ns.	ns.	ns.	ns.	-0.433*	-0.465*	ns.	ns.	ns.	ns.	ns.
SOC	-0.580**	-0.470*	ns.	0.495*	0.537**	0.580**	0.603**	0.536**	ns.	0.603*	ns.
Sand	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	0.530*
Silt	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	-0.460*
Clay	ns.	-0.552**	0.463*	ns.	ns.	ns.	0.429*	ns.	ns.	0.429*	-0.460*

H – hydrolytic acidity, SBC – sum of basic cations, CEC – cation exchange capacity, Bs – base saturation, SOC – soil organic carbon, BD – bulk density, PD – particle density, Θ_{CA} – capillary absorption, Θ_{30} – 30 minute moisture, Θ_{MCWC} – maximum capillary water capacity, Θ_{WRC} – water retention capacity, P – total porosity, Pn – non-capillary porosity, Pc – capillary porosity, Ps – semi-capillary porosity of Fluvisols. SOC positively correlated with the moisture characteristics (capillary absorption, maximum capillary water capacity, water retention capacity) and total and capillary porosities. A decrease in SOC leads to increased bulk density and decreased porosity, thus reducing soil infiltration (Li et al., 2007). Water retention in Fluvisols depends on content of clay (Kotorová, 2007) which is in agreement with our results in Table 5. Higher clay content resulted in higher actual water content, water retention capacity and volume of capillary pores.

Soil pH effected aggregation through clay dispergation. The negative surface charge on clay particles increases with pH increase particle repulsion. Clay particles often flocculate at high pH values (Haynes and Naidu, 1998) and large aggregates form in the soils with high pH and high carbonate concentration (Boix-Fayos et al., 2001). The significant negative correlations were found between soil pH and WSA_{ma} >0.5 mm in our studied profiles of Fluvisols. In contrast, higher pH resulted in higher content of WSA. This means that with increase of soil pH is also increased the content of WSA_{mi} but on the other side content of WSA_{ma} is decreased. This could be connected with the content of carbonates in case of our Fluvisol. Carbonates were determined in the whole soil profiles of Fluvisols (except Profile 5) as it is shown in Figure 2. Carbonates positively correlated with WSA_{mi} but on the other hand negative correlation was observed between the carbonates and WSA_{ma} (Table 6). The effect of carbonates on the soil structure could be modified by soil organic carbon. Increase of SOC thereby accelerating formation of secondary carbonates. If soil contains low SOC the macroaggregate stability is enhanced by carbonates (Boix-Fayos et al., 2001), which is confirmed by negative correlation between SOC and WSA_{mi} and by positive correlation between SOC and WSA_{ma} (mainly WSA_{ma} >0.5 mm). The most important factor responsible for stabilization of WSA_{ma} in profile of Fluvisols was the SOC due to significant correlation between SOC and Sw. SOC is a key factor effected aggregate stability (Šimanský and Jonczak, 2016). A significant positive correlation was determined between SOC and MWDw (Table 6). Higher values of hydrolytic acidity resulted in higher content of WSA_{mi} and lower contents of WSA_{ma} 0.5–3 mm. Values of sum of base cations and CEC had significant effects on aggregation in profiles of Fluvisols despite the fact that CEC is one of the most important factor responsible for aggregate stability (Dimoyiannis et al., 1998). The results of Šimanský et al. (2014) also showed the fact that more intensive aggregation process in loamy soils is connected with the high content of basic exchangeable cations, and the high value of CEC and soil organic carbon content in WSA. Aggregation is stimulated by the interaction of polycationic bridging in which the repulsive forces between negatively charged clay and/or SOC are reduced. Aggregates containing polyvalent cations (Ca^{2+}, Al^{3+} and Fe^{3+}) are resistant to slaking (Tisdall, 1996). In profiles of Fluvisols, an increase of base saturation resulted in an increase of WSA_{mi} and opposite in a decrease of WSA_{ma}. Aggregation is controlled by different mechanisms in different soil types. The rate and stability of aggregation generally increases with SOC and clay surface area and CEC. In soils low in SOC or clay concentration, aggregation

Table 6 Correlation coefficient between the soil pH, sorptive parameters, content of soil organic carbon, texture and parameters of soil structure in soil profiles of Fluvisols

	Size fractions of water-stable macroaggregates					WSA_{mi}	WSA_{ma}	MWDd	MWDw	Kv	Sw
	>5	5–3	3–1	1–0.5	0.5–0.25						
pH_{H_2O}	-0.445*	-0.712***	-0.691***	-0.623**	ns.	0.721***	-0.721***	ns.	-0.569**	0.500*	-0.740***
pHKCl	-0.486*	-0.510*	-0.410	-0.366	ns.	0.620**	-0.620**	ns.	-0.551**	ns.	-0.577**
$CaCO_3$	ns.	ns.	ns.	ns.	ns.	0.451*	-0.451*	ns.	ns.	ns.	ns.
H	ns.	0.708***	0.560**	0.539**	ns.	-0.638**	0.638**	ns.	0.510*	ns.	0.633**
SBC	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
CEC	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
Bs	ns.	-0.554**	-0.728***	-0.764***	-0.484*	0.462*	-0.462*	ns.	ns.	ns.	-0.615**
SOC	0.521*	0.759***	0.728***	0.628**	ns.	-0.776***	0.776***	0.063	0.635**	ns.	0.806***
sand	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
silt	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
clay	0.602**	0.443*	ns.	ns.	ns.	-0.610**	0.610**	0.758***	0.607**	-0.440*	0.489*

H – hydrolytic acidity, SBC – sum of basic cations, CEC – cation exchange capacity, Bs – base saturation, SOC – soil organic carbon, WSA_{mi} – water-stable micro-aggregates, WSA_{ma} – water-stable macro-aggregates, MWDd – mean weight diameter of aggregates for dry sieving, MWDw – mean weight diameter of water stable aggregates, Kv – vulnerability coefficient, Sw – index of aggregate stability may be dominated by cations, while the role of cations in aggregation may be minimal in soils with high SOC or clay concentration (Boix-Fayos et al., 2001). Clay content positive correlated with content of WSA_{ma} >3 mm but on the other side it negative correlated with WSA_{mi} in profiles of Fluvisols. A significant correlation were determined between clay and MWD, K and Sw. Higher clay content resulted in lower vulnerability of soil structure in profiles of Fluvisols. Silt and sand particles did not have significant effects on the soil structure parameters. Generally, soil texture has a significant influence on aggregation. In coarse-textured soils, the SOC has a greater influence on structure; while with increasing clay content the type of clay is more important than the amount in determining aggregation (Kay, 1998).

4 Conclusions

The investigated Fluvisols had different chemical and physical properties, but not as a consequence of the flow gradient along the river. Apparently, to have the flow gradient along the river observed, more data are needed to be available from the greater river flow. Differences in chemistry and physical properties of Fluvisols developed along the Nitra River have been significantly affected mainly by the use, soil management practices and depth of the soil profile. The relationships between the soil properties were also different in Fluvisols. The bulk density and hydrophysical characteristics of Fluvisols were effected in decreasing order of significance by SOC > pHKCl > clay content > $CaCO_3$. SBC and CEC did not have any significant effects on bulk density and hydrophysical properties of Fluvisols. Soil structure of Fluvisols was effected in decreasing order of significance by clay content = soil pH_{H_2O} > SOC > Bs = Ha = pHKCl > $CaCO_3$. SBC, CEC and silt content did not have any significant effects on the soil structure of Fluvisols.

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