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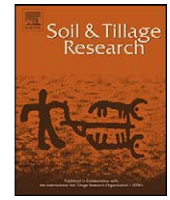

Soil structure and soil hydraulic properties of Haplic Luvisol used as arable land and grassland

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ABSTRACT

This study is focused on the comparison of soil structure and soil hydraulic properties within soil profiles of a same soil type under different land management. Study was performed on Haplic Luvisol in Hněvčeves (Czech Republic). Two soil profiles, which were in close distance from each other, were chosen: under the conventional tillage, and under the 30 years ago reestablished permanent grass cover. Soil structure was analyzed using the micromorphological method. Soil hydraulic properties were measured in the laboratory using multistep outflow experiments performed on undisturbed 100-cm^3 soil samples. Tension disk infiltrometers and Guelph permeameter were used to measure unsaturated and saturated hydraulic conductivities in the field. While soil properties studied in the deeper Bt2 and C horizons were relatively similar at both sites, properties of the A1, A2 and Bt1 horizons measured at both sites were evidently different. Lower retention ability and slightly lower unsaturated hydraulic conductivities for $h_0 = -2$ cm (from disk infiltrometers), $K(h_0 = -2$ cm), were measured at the arable land than those at grassland. This indicated that the fractions of the large capillary pores (pore radii between 20 μm and 740 μm) and also matrix pores (pore radii lower than 20 μm) in the A1, A2 and Bt1 horizons of the soil profile under the conventional tillage were smaller than those in the horizons of the soil profile under the permanent grass. Larger and more variable saturated hydraulic conductivities, K_s (from the Guelph permeameter tests) and differences between the K_s and $K(h_0 = -2$ cm) values were obtained at arable land than at grassland. This denoted that the fractions of gravitational pores (pore radii larger than 740 μm) and connectivity of large pores in the A1, A2 and Bt1 horizons of the soil profile under the conventional tillage were greater than those in the horizons of the soil profile under the permanent grass. Thus grassland soil showed well reestablished stable soil structure with favorable soil hydraulic properties not only in the A horizons, but also in the deeper Bt1 horizon.

1. Introduction

Agricultural activities frequently lead to a degradation of a soil structure and consequently to changes of porosity and soil hydraulic properties. Soil pore system is an indicator of soil quality (Pagliai and Vignozzi, 2002). Porosity influences a soil water infiltration, water retention, soil aeration, etc. Soil structural and hydraulic properties are influenced by a land use and management. All chemical, physical and hydraulic soil properties are impacted by the tillage system, fertilizers, crop rotation, etc. Vos and Kooistram (1994) showed that soil physical properties of pasture land and old minimum tillage soil were more favorable for growing crops than properties of the soil with conventional and integrated (reduced N-fertilization, reduced biocide and shallow tillage) systems. The manuring treatment improved soil aggregation and water transmission properties (Skukla et al., 2003a). Different treatments (till and no-till, with and without manure) and land use (arable land, meadow and forest) significantly affected infiltration parameters (Skukla et al., 2003b). The soil structure of permanent grassland proved to be more favorable than that of young arable land (Vanlanen et al., 1992). Noellemeyer et al. (2008) showed that organic carbon content and soil aggregation quickly decreased after 3 years of cultivation of former permanent pastures, but soil hydraulic properties were affected in the longer term. The opposite process (properties development at the reestablished grassland) was studied by Schwartz et al. (2003).

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They suggested that 10 years after conversion of cropland to grassland, grasses had not fully ameliorated changes in pore structure caused by tillage. The various land use and management systems (arable land, grassland and deciduous forest land) influenced preferential water and dye transport, and following reliability of simulation results (Bachmair et al., 2010). While flow processes in one grassland soil were satisfactorily described by applied preferential flow models, which assumed either high-continuity earthworm burrows or interaggregate macropores, very different features could not be approximated using these models in the other soils. Strong surface microtopography altering macropore flow initiation and abundance of small interaggregate tillage voids of low-continuity and slab geometry were detected in both agricultural soils. Horizontally oriented roots and surface water repellency impacted flow processes in the forest soil.

The goal of our study was to evaluate the impact of different land use and management on soil properties within the entire soil profile, to detect how deeply various land use may influence soil structure and hydraulic properties. Study focused on the assessment of a more than 30-year grass impact on soil structure amelioration at the former arable land. Soil water retention curves, hydraulic conductivities (measured using the laboratory multistep outflow test, and field tension disk infiltrometer and Guelph permeameter tests) and soil micromorphology (studied on thin soil sections) at two adjacent sites (used as arable land and grassland) were compared to examine improvement of soil properties, which in previous studies (Kodešová et al., 2008, 2009a,b) indicated an advanced degradation of arable land due to the agricultural practice. The soil hydraulic properties and pore structure were mainly assessed from a point of view of: (1) all capillary pores, which mainly control soil water retention ability; (2) macropores (large capillary—pores of radii between 20 μm and 740 μm, and gravitational pores—pores of radii larger than 740 μm, which corresponds to pressure heads between −70 and −2 cm, and larger than −2 cm, respectively) (Kodešová et al., 2008), which may cause preferential flow of various intensity and significance.

2. Materials and methods

2.1. Sites, and soil sampling and testing

The study was performed at the Hněvčeves experimental station of the Crop Research Institute in Prague, the Czech Republic (http://www.vurv.cz/). The studied soil was a Haplic Luvisol (loess parent material). Two soil profiles, which were in close distance from each other, were chosen to study the impact of different land use and management on soil properties: (1) soil profile under the conventional tillage (plowing depth of 25 cm) with the 5-yr rotation system (arable land), (2) soil profile under the grass cover (grassland). The field at the grassland was also in past the arable land, but the land use and management changed approximately 30 years ago. Since that soil has been permanently covered by grass.

Soil sampling and field experiments were carried out, simultaneously at both locations, immediately after the harvest of winter barley [*Hordeum vulgare* L.] at the arable land in 2008. Soil samples were taken in the soil pits (one at each location). Measurements were performed randomly within an area of 10 m^2, avoiding the locations impacted by either the wheels of heavy machinery or by the experimental work performed in the areas. Five soil diagnostic horizons were identified in both soil profiles (Table 1). The soil properties of the arable land were from various points of view studied before by Kodešová et al. (2006, 2008, 2009a,b, 2010b) and Leue et al. (2010). Studies (Kodešová et al., 2006, 2008, 2009a,b) showed a well developed soil aggregation but characterized by a low stability in the A1 horizon, a compact structure of the A2 horizon (plow pan), a strongly developed prismatic structure (impacted by organic and clay coating and infilling) with a very high aggregate stability in the Bt1 and Bt2 horizons, and homogeneous matrix structure of a low stability with isolated large capillary pores in the C horizon. The bi- (or multi-) modal character of pore-size distribution in all horizons initiated preferential water flow and herbicide transport, which was observed in the field (Kodešová et al., 2008) and laboratory (Kodešová et al., 2009b) and simulated using the dual-porosity or dual-permeability model in HYDRUS-1D (Šimůnek et al., 2008). It was also shown that organic and clay coatings influenced (slowed down) water and solute transport between the macropores and matrix pores. Impact of the aggregate and aggregate coating characteristics on optimized macropore hydraulic properties (mostly saturated hydraulic conductivity) from the field infiltration experiments using the HYDRUS 2D/3D code (Šimůnek et al., 2008) was in greater detail studied by Kodešová et al. (2010b). Finally, Leue et al. (2010) studied organic matter composition and distribution at the intact soil aggregate surfaces using the DRIFT device, and suggested that variably composed and distributed organic matter may cause spatially distributed hydraulic characteristics of the aggregate or vertical earthworm burrow coatings.

In our study, the multistep outflow experiment was used to characterize the soil hydraulic properties of undisturbed 100-cm^3 soil samples (which are usually used for hydraulic properties measurements in the laboratory). The single set of soil water retention and hydraulic conductivity curve was evaluated for each soil sample, despite that previous studies (Kodešová et al., 2006, 2008) showed the bi-modal character of soil water retention curves of studied soils and application of the dual-porosity or dual-permeability models to obtain two sets of soil hydraulic properties (one for the matrix pores and second one for the large capillary pores). The single set of the soil hydraulic properties characterizes all capillary pores, which are the most important for transport processes under natural conditions. Fraction of the large capillary pores may be estimated from the soil water retention curve

Table 1
The basic physical and chemical soil properties: the particle density (ρ_s), particle size distribution (clay, silt and sand), oxidable organic carbon content (C_{ox}), pH_{KCl}, pH_{H2O}, cation exchange capacity (CEC) and salinity.

Soil profile	Horizon	Depth (cm)	ρ_s (g cm^{-3})	Clay (%)	Silt (%)	Sand (%)	C_{ox} (%)	pH_{H2O}	pH_{KCl}	CEC (mmol$^+$ (100 g)$^{-1}$)	Salinity (mS cm^{-1})
Arable land	A1	0–25	2.56	18.24	66.52	15.24	1.05	6.61	6.21	26.75	18.40
	A2	25–34	2.61	21.49	39.61	38.9	0.66	6.52	6.11	28.25	11.80
	Bt1	34–57	2.59	29.43	61.40	9.17	0.48	7.09	6.34	22.75	9.90
	Bt2	57–93	2.60	23.03	63.53	13.44	0.28	7.11	6.56	29.00	10.70
	C	93–130	2.64	17.98	70.08	11.94	0.20	7.92	6.54	17.50	8.90
Grassland	A1	0–10	2.31	15.66	72.06	12.28	1.74	5.10	5.10	27.75	10.70
	A2	10–23	2.53	17.48	72.59	9.93	1.57	5.14	4.49	29.25	10.10
	Bt1	23–68	2.59	26.36	51.58	22.06	0.41	6.16	5.37	20.25	11.90
	Bt2	68–105	2.64	30.97	62.14	6.89	0.30	6.41	5.61	19.75	8.10
	C	105–130	2.63	21.27	74.07	4.66	0.14	7.77	7.68	29.50	9.60