Seasonal variability of soil structure and soil hydraulic properties

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Abstract

The study is focused on the assessment of the seasonal changes of soil structure, aggregate stability and hydraulic properties with respect to varying soil physical and chemical properties, soil management and climatic conditions. Seasonal variability of soil properties measured in surface horizons of three soil types (Haplic Cambisol, Greyic Phaeozem, Haplic Luvisol) was studied in years 2007 and 2008. Undisturbed and disturbed soil samples were taken every month to evaluate actual field soil-water content, saturated soil-water content, bulk density, porosity, pH_{H2O} and pH_{KCl}, humus content and organic matter quality expressed as A400/A600, aggregate stability using WSA index, and the soil hydraulic properties. Unsaturated hydraulic conductivity for h= -20 mm was measured directly in the field using the minidisk tension infiltrometer. In addition, micromorphological features of soil aggregates were studied in thin soil sections that were made from undisturbed large soil aggregates. Results show that the soil properties varied within the time. Aggregate stability and values of the soil properties were influenced by the climatic factors, biological activity, growth of plant roots and soil management. Values of pH slightly varied within both years at all localities. Organic matter content, organic matter quality and aggregate stability varied significantly during the first year. However, variability of those properties was considerably lower during the second year at all localities. Porosity and soil hydraulic properties were also more variable during the first year than during the second year.

Key Words

Soil structure, aggregate stability, soil hydraulic properties, micromorphological images, temporal variability

Introduction

Soil water regime is highly affected by soil structure and its stability. Various soil structure types may cause preferential flow or water immobilization (Kodešová *et al.,* 2006, 2007, 2008). Soil structure breakdown may initiate a soil particle migration, formation of less permeable or even impermeable layers and consequently decreased water fluxes within the soil profile (Kodešová *et al.,* 2009a). Soil aggregation is under control of different mechanisms in different soil types and horizons (Kodešová *et al.,* 2009b). Soil structure and consequently soil hydraulic properties of tilled soil varied in space and time (Strudley *et al.,* 2008). The temporal variability of the soil aggregate stability was shown for instance by Chan *et al.* (1994), and Yang and Wander (1998). While Chan *et al.* (1994) documented that temporal changes of aggregate stability were not positively related to living root length density, Yang and Wander (1998) suggested that the higher aggregate stability was found due to crop roots, exudates microbial by-products and wet/dry cycles. The temporal variability of the soil hydraulic properties (mainly hydraulic conductivities, *K*) were investigated for instance in following studies. Murphy *et al.* (1993) showed that *K* values at tensions of 10 and 40 mm varied temporally due to the tillage, wetting/drying, and plant growth. Messing and Jarvis (1993) presented that the *K* values decreased during the growing season due to the structural breakdown by rain and surface sealing. Somaratne and Smettem (1993) documented that while the *K* values at tension of 20 mm were reduced due to the raindrop impact, the *K* values at tension of 40 mm were not influenced. Angulo-Jaramillo *et al.* (1997) discovered that only the more homogeneous sandy soil under furrow irrigation exhibited significant decrease in sorptivity. Petersen *et al.* (1997) documented using the dye tracer experiment that cultivation reduced the number of active preferential flow paths. Azevedo *et al.* (1998) measured tension infiltration from 0 to 90 mm and showed that macropore flow decreased from 69% in July to 44% in September. Bodner *et al.* (2008) discussed the impact of the rainfall intensity, soil drying and frost on the seasonal changes of soil hydraulic properties in the structure-related range. Finally, Suwardji and Eberbach (1998) studied both, aggregate stability and hydraulic conductivities. They documented the lowest aggregate stability during the winter and increased in spring. The *K* values decreased during the growing season. The goal of this study is to assess the seasonal variability of the soil structure, aggregate stability and hydraulic properties with respect to each other and to varying soil physical and chemical properties, soil management and climatic conditions.

Methods

The study was performed in 2007 and 2008 on Haplic Luvisol (parent material loess), Greyic Phaeozem (parent material loess) and Haplic Cambisol (parent material orthogneiss). Four soil horizons (Ap 0-35 cm, Bt$_1$ 35-62 cm, Bt$_2$ 62-102 cm , Ck 102-133 cm) were identified in Haplic Luvisol, four horizons (Ap 0-21 cm, Bth 21-28 cm, BCk 29-37 cm, Ck 37-80 cm) in Greyic Phaeozem and three horizons (Ap 0-32 cm, Bw 32-62 cm, Ck 62-97 cm) in Haplic Cambisol. Soil properties were measured every month in surface horizons. Actual field soil-water content, saturated soil-water content, bulk density and porosity were measured on the 100-cm^3 soil samples (10 soil samples per each location and sampling day) using standard methods (Dane and Topp 2002). Hydraulic properties (soil water retention and hydraulic conductivity curves) were measured on the 100-cm^3 soil samples (3 samples) using Tempe cells (Kodešová *et al.* 2006). Humus quality was assessed by the ratio of absorbances of pyrophosphate soil extract at the wavelengths of 400 and 600 nm (A_{400}/A_{600}) (3 repetitions). pH_{H2O} and pH_{KCl} were determined potentiometrically (3 repetitions). Organic carbon content (C_{org}) was determined oxidimetrically by a modified Tjurin method (see Sparks 1996) (3 repetitions). Unsaturated hydraulic conductivity at tensions of 20 mm, *K* (h = -20 mm), was measured directly in the field (2 measurements) using the minidisk tension infiltrometer (Decagon Devices 2006). Micromorphology of soil structure was studied on thin soil sections (2 section) prepared from large soil aggregates. Thin sections were prepared according to the methods presented by Catt (1990). The aggregate stability was studied using the indexes of water stable aggregates (Nimno and Perkins 2002) (3 repetitions). Soil aggregate stability within the soil profiles of soil types studied here was previously discussed by Kodešová *et al.* (2009a, 2009b).

Results

Seasonal changes of soil porosity (Figure 1), actual field soil water content (Figure 2), aggregate stability determined as water stable aggregates (Figure 3) and unsaturated hydraulic conductivity measured using the minidisk tension infiltrometer (Figure 4) are shown here as examples. Results showed that studied soil properties considerably varied within both one-year periods. In addition different values and trends were observed during different years. Organic carbon content (not shown), organic matter quality (not shown) and aggregate stability (Figure 3) varied significantly during the first year. However, variability of those properties was considerably lower during the second year at all localities. Porosity (Figure 1) and soil hydraulic properties (the *K* values shown only in Figure 4) were also more variable during the first year than during the second year. Values of pH_{H2O} and pH_{KCl} (not shown)slightly varied within both years at all localities.

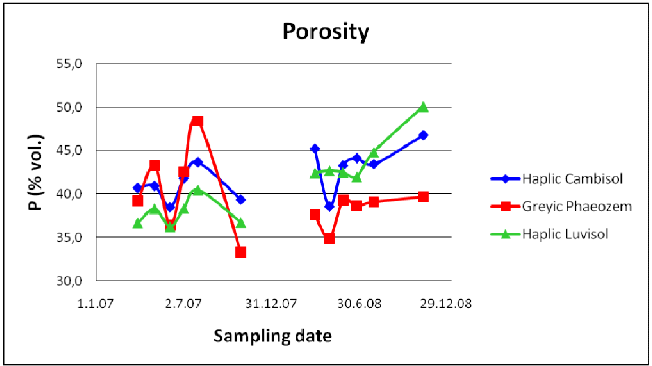

Figure 1. Seasonal variability of porosity measured on the 100-cm^3 soil samples.

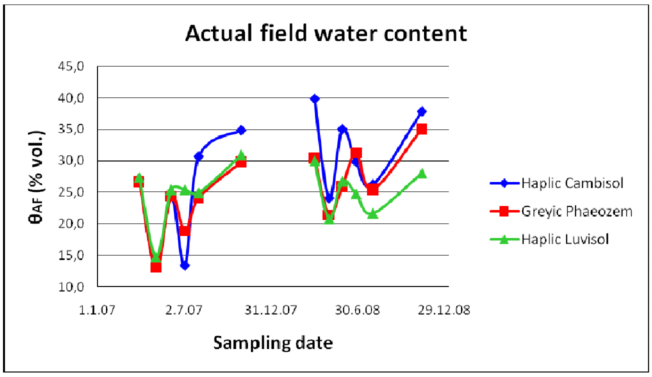

Figure 2. Seasonal variability of actual field soil water content measured on the 100-cm^3 soil samples.

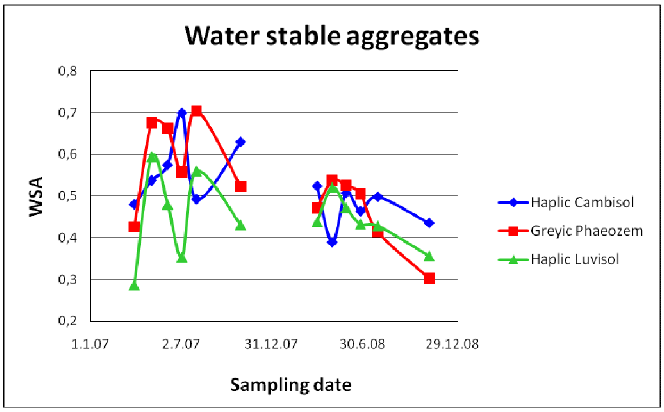

Figure 3. Seasonal variability of aggregate stability determined as water stable aggregates. Aggregate stability increases with increasing WSA value.

Soil aggregate stability depended (as also discussed by Chan *et al.,* 1994) on stage of the root zone development, soil management and climatic conditions. Larger aggregate stabilities and also larger ranges of measured values were obtained in the year 2007 than those measured in 2008. This was probably caused by lower precipitation and consequently lower soil-water contents observed at the beginning of the year 2007 than those measured during the same period in 2008. The highest aggregate stability was measured at the end of April in the years 2007 and 2008 in Haplic Luvisol and Greyic Phaeozem, and at the end of June in the year 2007 and at the beginning of June in 2008 in Haplic Cambisol. In all cases aggregate stability increased during the root growth and then decreased due to summer rainfall events. Aggregate stability reflected aggregate structure and soil-pore system development, which was also documented on micromorphological images (not shown). Hydraulic properties measured in the laboratory (not shown) reflected development of soil porous system. The fraction of larger gravitational pores increased with increasing root activity and decreased due to precipitation impact. As fractions of gravitation pores decreased fractions of capillary pores increased. Infiltration rates measured using the minidisc tension infiltrometer were impacted by the actual field soil-water content. High aggregate stability had positive influence on the infiltration rate.

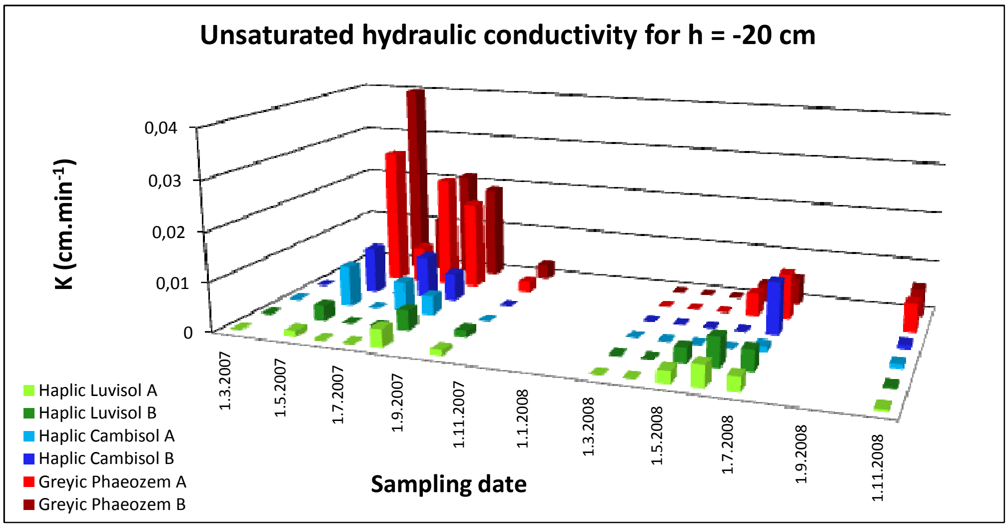

Figure 4. Unsaturated hydraulic conductivities measured for h= -20 mm using the minidisk tension infiltrometer.

Correlation coefficients (not shown) proved that the *K* (h = -20 mm) values measured using the minidisc tension infiltrometer were mostly impacted by the actual soil-water content. The *K* (h = -20 mm) values increased with the decreasing actual soil-water content. The soil aggregate stability was correlated negatively with the A_{400}/A_{600} values (e.g. incensed with the increasing humus quality) in Haplic Cambisol, and negatively with the actual field water content (e.g. increased with the decreasing actual field water content) in Greyic Phaeozem and in Haplic Luvisol. No relation between the soil aggregate stability and the organic carbon content, pH_{H2O} and pH_{KCl} values were found as expected based on previous studies carried out in these soils (Kodešová *et al.,* 2009b). Regression analysis did not show any other significant relationship between measured variables.

Conclusion

The field and laboratory tests were carried out to asses the seasonal changes of the selected soil properties in the surface horizons of three soil types. Similar seasonal trends were observed in all three soils. It was discussed that soil structure, aggregate stability and soil hydraulic properties are interrelated and depends on plant growth, rainfall compaction and tillage. However, it was also shown that climatic conditions dominantly influenced these properties. The drier conditions positively influenced the soil aggregate stability, porosity and hydraulic conductivity.

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