The field water regime in a deformable sub-irrigated peat-moorsh soil profile

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Summary
The paper presents the results of analysis of the soil water regime in a deep fen peat-moorsh soil located in the Middle Biebrza Basin (Poland) within the Kuwasy drainage sub-irrigation system used as permanent grassland. The observed values for pressure head, moisture content and groundwater level show that the required water conditions were present in the root zone of grasslands even during dry periods with low sums of precipitation in June and July 2006. Changes in the soil surface level of up to 42 mm were also observed during the period considered.

Key index words: soil water conditions, sub-irrigation, soil surface level

Introduction
The study was conducted on peat soils, which had been drained for conversion into agriculturally productive meadows and pastures as well as arable land. Effective drainage of peat soils in the case of meadows and pastures requires a decrease in the water table in the range of 0.4 m to 0.8 m below the soil surface. In the case of conversion of peatland into arable land, a greater decrease in groundwater level - up to 1-1.2 m below the soil surface - is required (Okruszko, 1993; Ilnicki 2002; Joosten and Clarke, 2002). Drainage and implementation of agricultural use of peatlands are the main factors causing the 'moorshing' process, which transforms peat into its new more mineralised form called 'moorsh'. Moorshing of organic soils comprises biological, chemical and physical changes caused by increased aeration of the soil. Subsidence of the soil surface due to the drainage process is also observed (e.g. Schothorst, 1977; Ilnicki, 2002). This process can be irreversible or can have a periodic nature i.e. seasonal changes in soil water storage and shrinkage-swelling cycles of peat-moorsh layers which cause periodic movement of the ground surface (Oleszczuk *et al.*, 1999; Price, 2003; Kennedy and Price, 2004; Brandyk *et al.*, 2006, Camporese *et al.*, 2006). The concept of wise use of peat resources, which assumes both environmental protection and rational agricultural use, strongly depends on proper water management. In order to perform rational water management of peat-moorsh soils so-called drainage sub-irrigation systems are constructed. Such systems provide drainage after intensive rainfall and sub-irrigation during periods with water deficits.

The aim of this paper is to analyse the soil water regime of a deep fen peat-moorsh soil profile located in the Middle Biebrza Basin (Poland) within the Kuwasy drainage sub-irrigation system. The changes in the soil surface level of the analysed peat-moorsh soil profile due to moisture content and corresponding groundwater level changes were also analysed.

Materials and methods
The results of field measurements performed on the soil profile "Biebrza 29" located in the middle of a ditch spacing of 300 m and two drainage pipes (60 m spacing) are reported in this study. The soils in this area are mainly deep fen peat-moorsh soils with a moorshing layer (0-30 cm) at the top, overlying willow peat with a medium degree of decomposition. The soil surface is covered by meadow vegetation with hay production of about 9 t ha^{-1}. For rational management of Polish peat soils under grassland farming with sub-irrigation, prognostic soil moisture complexes have been specified (Okruszko, 1994; Okruszko and Ilnicki, 2003). According to this classification the analysed peat-moorsh soil profile was classified as complex B (moist). The following values of groundwater level: minimum available – z_{min} = 35 cm, average z_{opt} = 70 cm and maximum available z_{max} = 95 cm below the soil surface should be maintained for rational water management of the complex B under Polish conditions. The following values of pressure head in the root zone (0-30 cm): minimum available h_{min} = - 50 cm (corresponding to 6% of air cont.), optimum h_{opt} = - 100 cm (corresponding to 10% of air cont.) and maximum available h_{max} = - 500 cm (corresponding to minimum easily available volumetric moisture content) were also established as water management criteria for complex B. In order to achieve a groundwater level position in the range of the required soil moisture criteria, the water discharge in the open ditches was blocked by

means of hydraulic structures (gates). In the early spring and after intensive rainfall the system provides soil drainage, whereas during the relatively dry summer season the gates were closed and sub-irrigation took place (Brandyk *et al.*, 1989). Such sub-irrigation was planned according to actual plant water requirements, which were estimated using meteorological data measured in situ.

The data for the period from 28th of April to 23th of September 2006 are considered in this paper. The following data were measured (every 3 days) in the field: soil water pressure head, moisture content, groundwater level (below the soil surface) and the soil surface level changes (below the reference level). Measurements of soil water pressure head and moisture content were performed at the following depths: 10, 20 and 30 cm. The pressure head was measured using tensiometers (Cassel and Klute, 1986) and soil moisture content was measured using the TDR method (Cassel *et al.*, 1994; Kim *et al.*, 2000; Oleszczuk *et al.*, 2004). The TDR probes were equipped with two parallel wave-guides, 25 cm in physical length, 5 mm in diameter and 25 mm apart, and were installed horizontally. The Tektronix cable tester 1502B was used for measuring soil dielectric constant values at each depth. The dielectric constant values were converted into soil moisture content values using the calibration equation developed by Oleszczuk *et al.* (2007). The vertical movements of the soil surface level due to soil water content changes were monitoring according to Bronswijk (1991). The precipitation rates were recorded at Biebrza meteorological station located nearby.

Results

The results of the field measurements of precipitation, soil surface level, moisture content and pressure head (at 10 cm, 20 cm and 30 cm below the soil surface) and groundwater level are presented in Fig. 1. The pressure head and groundwater level criteria for soil moisture complex B are also indicated in Figures 1d and 1e. From the analysis of the presented data it can be seen that very wet conditions prevailed only during short periods at the beginning and at the end of the vegetation period in 2006. The very wet conditions at the beginning of the vegetation period were the result of the water stored in the soil profile during winter time, while the very wet conditions observed in September 2006 were the results of very high and intensive precipitation values which occurred in this period. During the rest of the vegetation period both pressure head and groundwater level were kept within the range between maximum and minimum allowable values (Figs. 1d and 1e), except for a very short period at the end of July when the groundwater level dropped slightly below its maximum allowable value. The measured data indicate wet conditions in the upper soil layers at the beginning of the observation period and then the values of soil moisture content, groundwater level and soil surface subsidence systematically decreased. The drying of the soil profile was caused by a relatively very dry period which occurred in July 2006 (the monthly precipitation sum was only 23.2 mm). This dry period caused a decrease in soil moisture content from about 60% vol. at the beginning to only 35% vol. at the end of July at a depth of 10 cm below the soil surface (Fig. 1c), a decrease in the soil surface position to the lowest point (below 99.65 m) and in the groundwater level to the lowest point (below 98.40 m, Fig. 1b). The intensive precipitation which occurred in August and at the beginning of September 2006 caused a relatively fast increase in moisture content (up to about 78% vol. at 10cm depth), soil surface level (up to 99.69 m) and groundwater level (up to 99.25 m). Analysis of the field data presented in Fig. 1b indicates that the maximum observed value of the change in the soil surface level was equal to 42 mm. The changes in the soil surface level corresponded to the changes in groundwater levels as well as to the changes in soil moisture content.

Conclusion

The studies of the field water regime at Biebrza for a deep fen peat-moorsh soil profile with a medium degree of decomposition and medium advanced moorshing belonging to the prognostic soil moisture complex B equipped with a drainage sub-irrigation system showed properly managed soil water conditions. Even properly managed soil water conditions cannot exclude deformation of the peat-moorsh soil and the maximum observed value of the soil surface elevation change was equal to 42 mm.

Acknowledgements

The study was supported by Polish Ministry of Science (research project no. 2 P06S 029 30, 2006-2008)

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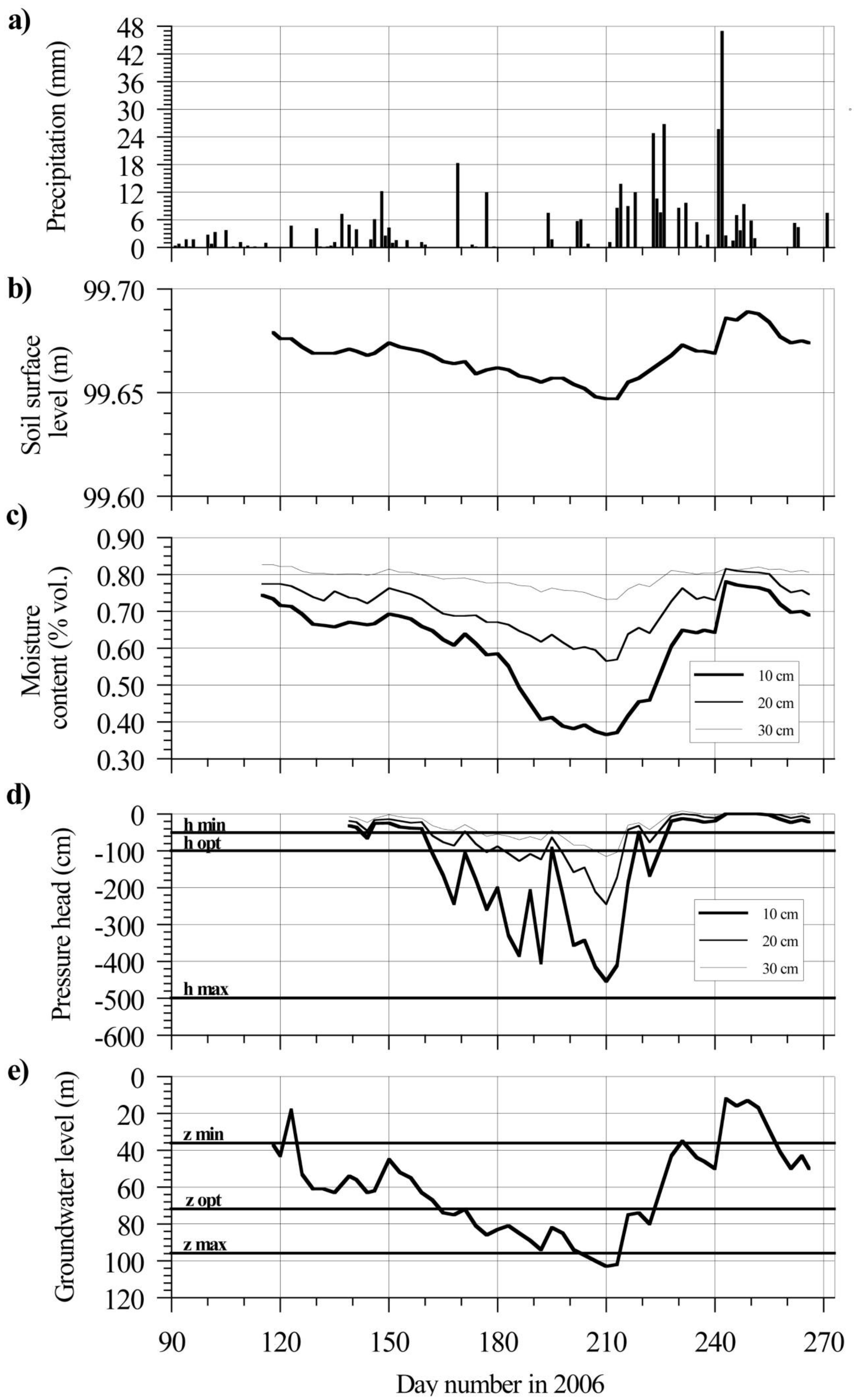

Figure 1. Results of field measurements in the peat-moors soil profile: a) precipitation; b) soil surface level, c) volumetric moisture content, d) pressure head and e) groundwater level during vegetation period in 2006. The required pressure head and groundwater level values are indicated (see text for explanation)

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