HYDROPHYSICAL PROPERTIES AND EVAPOTRANSPIRATION ELEMENTS OF A HEAVY CLAY GRASSLAND SOIL

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Introduction

Deforestation, increase in the agricultural activity and overgrazing are considerable global problems that cause degradation of the natural ecosystems and the soil (Celik, 2004). Land use can have a great effect on hydrophysical properties. Non-reasonable land management can cause irreversible soil structure degradation and consequently the soil cannot provide the ecological water and nutrient demand for plants. The water management properties of clay soil are unfavourable (Várallyay, 2003), the amount of water available to the plants is relatively small even at high volumetric soil water content values, they are more prone to drought so the water flux in these soils is a question of interest in soil physics and also in ecophysiological studies.

This paper focuses on the hydrophysical properties of a clay soil at a site that has come through more land use changes. The water flux was estimated between different soil depths, actual evapotranspiration was measured with eddy covariance technique and the time delay was studied between them in a non-rainy time period. The water retention and hydraulic conductivity function was used to describe water movement in the soil (Fodor and Rajkai, 2004).

Methods

The study site is situated in the Mátra Mountains near Szurdokpüspöki, Hungary (300 m asl, 47.85°N, 19.73°E). An eddy covariance station has been set up in May, 2003 to measure the CO2, momentum and latent and sensible heat fluxes within the framework of the FP5 CARBOMONT project. The measurements has been going on from that time continuously. Average half hourly latent heat fluxes have been recorded. Soil water content was measured by Water Content Reflectometers (Campbell Scientific, Inc., 1999) with a length of 30cm, in 3cm, 8cm and 20cm depths. Data was recorded in every half an hour from June 2003. Soil texture (K_A and detailed particle-size distribution) and humus content (Tyurin's method) was determined in laboratory (Búzás, 1993). For measuring water retention characteristics and saturated hydraulic conductivity Várallyay's methods (1973a,b) were used. Water-retention curve was fit on nine measured points, using the van Genuchten retention model with m=1-1/n (van Genuchten, 1984).

Soil water flux (F_s) between 3 and 8 cm and 8 and 20 cm was calculated by the following equation (Keulen&Wolf, 1986) in a non-rainy period, when soil was drying so the hysteresis effect didn't influenced the calculation:

$F_s = k_\psi \times dH/dL$, where dH is the difference in hydraulic head (cm), $H = \psi + g$.

dL is the distance of flow (cm). k_ψ is calculated by an empirical equation:

$k_\psi = a \times \psi^{-1.4}$. a is a texture-specific empirical constant ($cm^{2.4}\ d^{-1}$).

Evapotranspiration was calculated from latent heat and is given in mm. The temporal lag between the water flux in the soil and evapotranspiration was estimated by searching for the maximum correlation between the two variables at different lag intervals.

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Results and discussion

The study site has come through some land use changes. After deforestation it was functioning as a plough-land and it has been used as a cattle pasture for about 22 years.
The soil (Table 1) is characterized by significant swelling and shrinkage, under dry conditions large cracks are formed. According to the detailed particle-size distribution it is a silty clay soil, but based on K_A values, the 0-10 cm layer is silty clay, the 10-20 cm layer is clay and the two deeper layers are heavy clay. Humus content is high in all layers, but it decreases downwards.

Table 1. Soil texture characteristics, humus content and bulk density of soil layers 0-10, 10-20, 20-30, and 30-40cm.

Soil depth (cm)	K_A	Sand (%)	Silt (%)	Clay (%)	Humus content (%)
0-10	43	7.4	58.2	34.6	2.66
10-20	57	2.1	52.6	45.3	1.5
20-30	64	0.8	47.6	51.5	1.02
30-40	70	2.4	44.5	53.1	0.68

Rather high porosity and mass per volume was measured (Table 2.) comparing with the characteristic range for forest soils and for clay soils. In general the dry mass per volume of forest soils varies between 0.2 (organic layers) and 1.9 and porosity from 30 to 65 percent (Fisher & Binkley, 2000).

Table 2. Hydrophysical properties of 0-5, 5-10, 10-15 and 15-20cm soil layers.

Soil depth (cm)	Mass per volume (g cm^{-3})	Saturated water content/porosity (cm^3 cm^{-3} % at 0 MPa)	Field capacity water content (cm^3 cm^{-3} % at 0.2 MPa)	Wilting point water content (cm^3 cm^{-3} % at 1.5 MPa)	K_s (mm day)
0-5	1.19	54.6	46.1	24.3	0.018
5-10	1.36	47.4	42.7	26.4	0.020
10-15	1.42	47.4	42.4	28.4	0.018
15-20	1.46	46.3	40.4	32.1	0.007

The saturated hydraulic conductivity (K_s) is similar to that of a heavy clay soil (Table 2., van Keulen and Wolf, 1986), accordingly during the estimation of hydraulic conductivity, the texture-specific empirical constant value of heavy clay soils (4.86) was used. The van Genuchten retention model was fitted for the water retention data (Table 3.) so the hydraulic head differences could be calculated between the soil depths where soil water content was measured.

Table 3. The fitting parameters of the van Genuchten retention model (m = 1-1/n).

Soil depth (cm)	A	n	R^2	Soil depth (cm)	α	n	R^2
0-5	0.0183	1.135	0.9981	**10-15**	0.0298	1.0659	0.8631
5-10	0.0104	1.0966	0.9140	**15-20**	0.1335	1.0449	0.9818

ET and F_s show daily cycle. ET decreases near to zero at night and increases by daylight as the radiation increases (up to max. 0.3 mm/30 minutes) in a 18 day long period (04.23.-05.10.2004.). Upward water movement can be observed, F_s follows ET changes (Fig.1.). The correlation between $F_{s\ (8\text{-}3\ cm)}$ and ET and between $F_{s\ (8\text{-}20\ cm)}$ and ET was higher in the three-day period than in the 18-day period. The time lag is longer for the $F_{s\ (8\text{-}20\ cm)}$ than $F_{s\ (8\text{-}3\ cm)}$ (Table 4.).

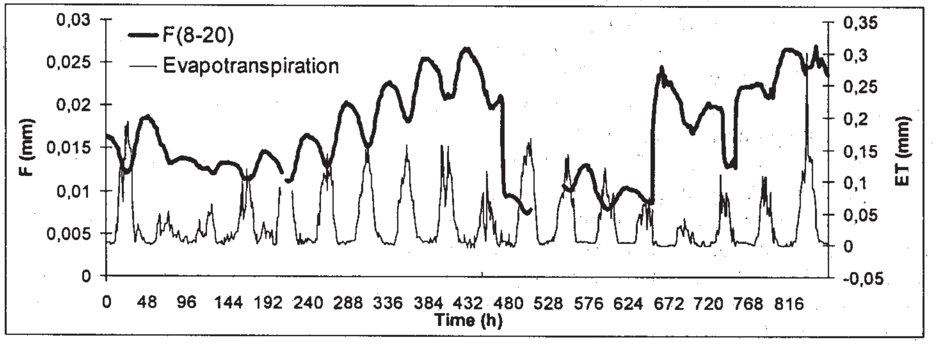

Figure 1. The ET and $F_{s\ (8\text{-}20\ cm)}$ in a non-rainy time period (04.23-05.10.2004).

Table 4. Correlations between $F_{s\ (3\text{-}8\ cm)}$ and ET and between $F_{s\ (8\text{-}20\ cm)}$ and ET.

Time period (in 2004)	Average dh (cm)	Variables	R_{max}	Time lag (h)
04.23.-05.10.	3318	ET& $F_{s\ (3\text{-}8\ cm)}$	0.170	5
	1418	ET& $F_{s\ (8\text{-}20\ cm)}$	0.250	12
04.23.-04.25.	1854	ET& $F_{s\ (3\text{-}8\ cm)}$	0.671	5
	1585	ET& $F_{s\ (8\text{-}20\ cm)}$	0.784	13

Conclusions

22 years after stopping land cultivation a semi-natural grass formed but the soil is yet mixed by the former tillage. The soil hydraulic conductivity is very low and the mass per volume is high. We considered the K_A values instead of the detailed particle-size distribution and classified the soil as heavy clay. The soil compaction can be the effect of grazing during wet conditions. The high humus content is possibly the result of the non-removed biomass production of the grass; during the land cultivation it must have been lower.

The water flux between soil depths of 3 and 8 cm follows the evapotranspiration faster than the water flux between the 8 and 20 cm layers. The sum of these fluxes ($F_{s\ (8\text{-}3\ cm)}$ and $F_{s\ (20\text{-}8\ cm)}$) is less than the amount of ET as measured by the eddy covariance system on a daily basis (with the proper time lags). Since the main rooting zone is between 0 and 18cm soil depths (containing 90% of the root mass in the 0-30cm zone), we concluded, that the soil water conductivity is modified by that of the roots. As the main resistance to water flow is presented by the soil in this system, contribution of the deeper soil layers accessed by roots are probably significant to close the balance between the measured ET and the calculated F_s values.

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