SIMPLIFIED METHOD OF PORE WATER MOVEMENT ESTIMATION THROUGH THE SOIL UPPER LAYERS

ZJEDNODUŠENÁ METODA STANOVENÍ POHYBU VODY V HORNÍCH VRSTVÁCH PŮDY

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Abstract

The soil water movement was quantified on the basis of simplified presumption of mutual relationship between precipitation and soil moisture changes in time. The water movement through 5 cm depth under the soil surface and through 15 cm depth was analysed, where several times smaller amount of moving water was detected compared to 5 cm soil depth. The differences between stands depending on the vegetation cover and management as well were found out by precipitation and volumetric water content measurements analysis.

Key words: volumetric water content, water movement, time shift

Souhrn

Pohyb vody v půdě byl stanoven na základě zjednodušeného předpokladu vzájemné souvislosti srážek a změny půdní vlhkosti v čase. Byl analyzován pohyb vody v 5 a 15 cm hloubky pod půdním povrchem, kde bylo zjištěno několikanásobně menší množství pohybující se vody ve srovnání s hloubkou 5 cm. Analýzou srážek a objemové vlhkosti půdy byly zjištěny rozdíly v závislosti jednotlivých stanovišť podle vegetačního krytu a způsobu obhospodařování.

Klíčová slova: objemová vlhkost, pohyb vody, časový posun

Introduction

Modelling of water movement in the unsaturated soil matrix is usually based on the numerical solution of the Richards equation (Bardossy et al. 1995, Kutílek et al. 2000). This approach requires much computational effort; therefore practical 2- or 3-dimensional applications are extremely rare. The purpose of this paper is to describe a computationally efficient and simple method.

Material and methods

Many simplifications are presupposed in case of described method, e.g. physical properties within the 5 – 15 cm profile are similar, total sum of precipitation on the soil surface flows through the upper 5 cm soil layer without attenuation, the amounts of rain-water which will achieves 15 cm depth can be expressed by surface rain-water amounts multiply by VWC (volumetric water contents) amplitude in 5 and 15 cm ratio and so on. Suppose this, if increasing of VWC by rain has relationship - for simplification linear - with VWC decreasing after end of precipitation, than we can to do express it. The period between the beginning of precipitation and VWC increasing (Fig.1) to the reaching of VWC starting level - the same as rain before - we can split to the moisturising period (leading phase, when the soil receives water, point 1 to 2) and drying period (vanishing phase, when the soil loses water, point 2 to 3). We suppose at the same time the movement of pore water direction within the soil layer mentioned above is primarily influenced by infiltration in the moisturising period and by evaporation in the drying period (flux of infiltration and evaporational flux, Němeček et al. 1990).

VWC measurements method was based on TDR sensors CS615 (Campbell Scientific, Utah, USA) and registered by Mini-Cube VF datalogger (EMS, Brno, CZ) on the fourth sites with the different cover of vegetation in all (1 - spontaneous set aside, 2 - winter rape, 3 - target grassing set aside, and 4 - winter rape) in the different stage of development within the growing season, each one in two depths (5 and 15 cm) simultaneously within the quarter hour intervals. The simultaneous measurement of soil temperature (user manual of CS615, 2001) and at least ambulant measurement of soil bulk (better pore water) conductivity was necessary because of attainable accuracy (Pivec 2002). It was necessary to determine the dielectric properties of the soil in advance (Persson 2002). Precipitation measurement by typing bucket rain gauge SR03 (Fiedler, Ceske Budejovice, CZ) was realised. Eight rainy periods was determined in the growing season (Tab.1), within each of them the time period of drying (hrs), means from the end of the rain (point 2, Fig.1) to the attainment of VWC value before precipitation incidence (point 3, Fig.1), VWC maximum (VWC_{max}) and minimum (VWC_{min}) was further determined (Fig.1).

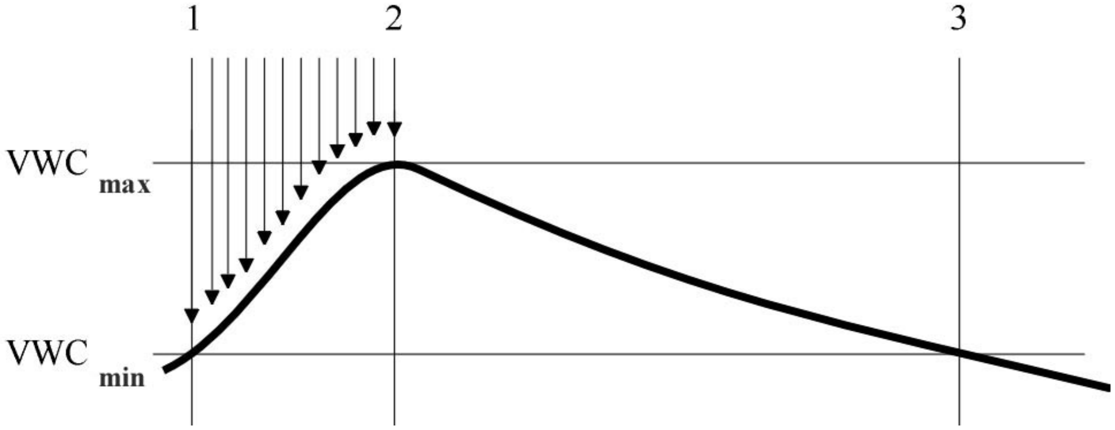

Fig.1 Course of VWC from the beginning of the rain (1) through its ending (2) upon attainment of VWC value as before precipitation incidence (3)

VWC depression intensity was calculated as the ratio of amplitudes of VWC change (VWC_{max}-VWC_{min}, %) to the time period of drying [hrs], drying intensity as the ratio of total precipitation in each period [mm] to the time period of drying. Linear approximation of dependence of drying intensity to the VWC depression intensity was than achieved for each of depth (5, 15 cm) and site separately (Fig.2 and 3).

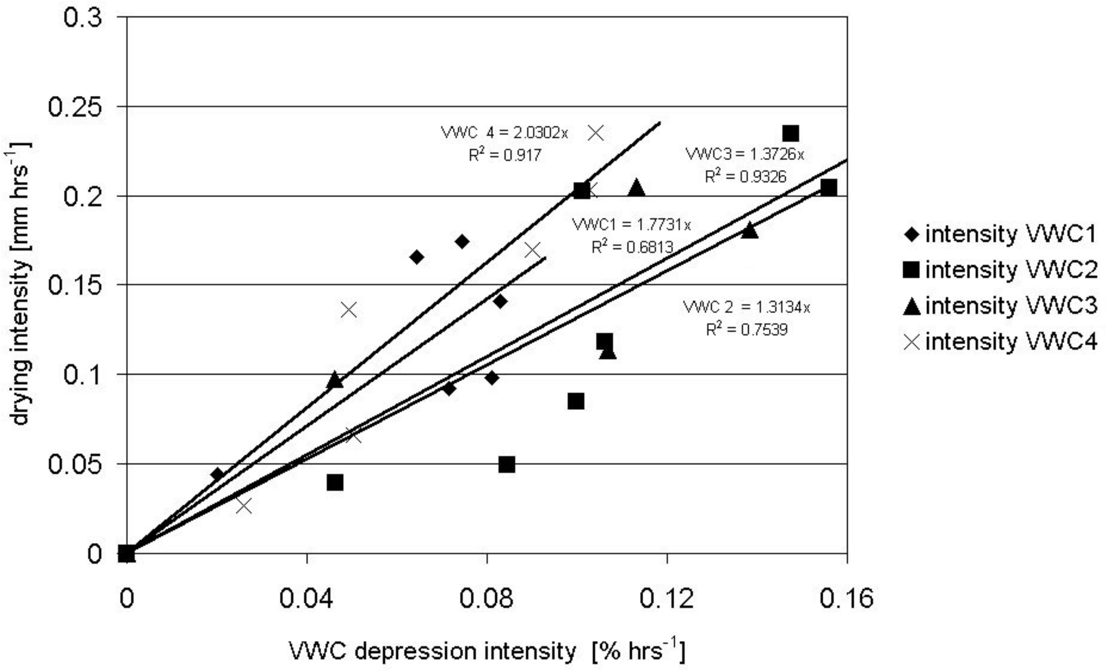

Fig.2 Dependence of VWC depression intensity in 5 cm to the drying intensity

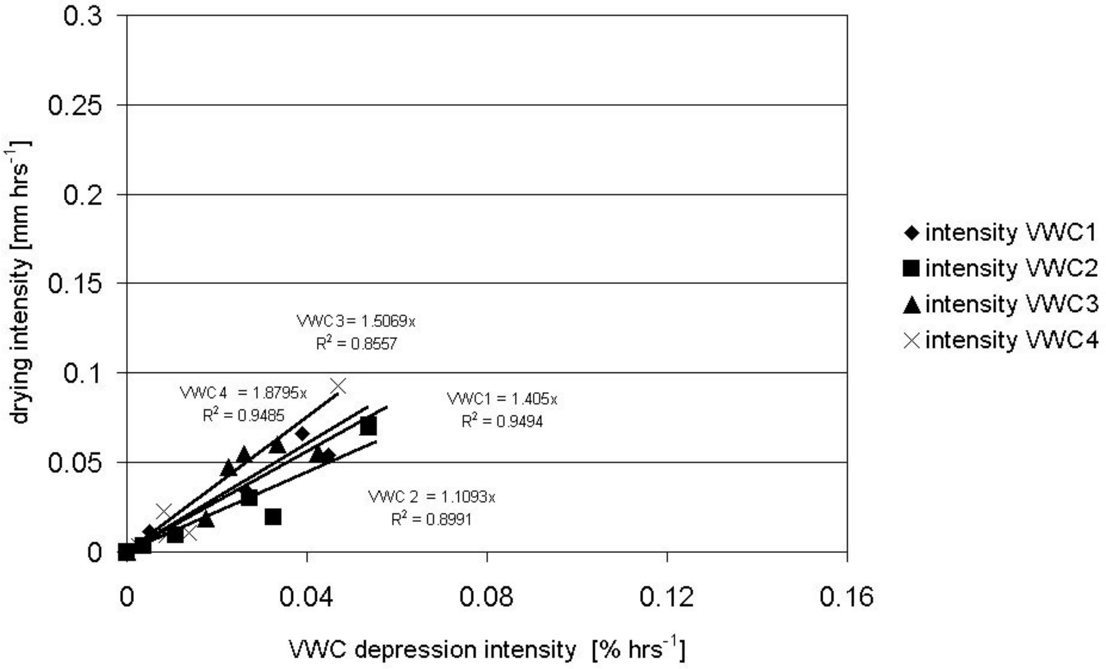

Fig.3 Dependence of VWC depression intensity in 15 cm to the drying intensity

The computation algorithms of water amount mowing in the appropriate depth and site consist in:

a) assessment of the quarter hour differences VWC_{x+1} - VWC_x and selection of positive values (means periods of VWC decrease - drying)
b) theirs multiplication by slope of linear dependency of drying intensity to the VWC decrease intensity (Fig.2 and 3)
c) hourly totals of above mentioned values

Calculation was done along with database from 9:15 hrs 09.04.2002 to 18:30 hrs 10.09.2002, 15 minutes step, eight distinguished rainy periods, each depth, and each site separately.

Results and discussion

Above-mentioned method data processing gave following results: culmination of the negative VWC values in 5 cm depth on the site No.1 – spontaneous set aside plot, was observed around 15:00 hrs, on the other sites around 13:00 hrs (Fig.4). Time shift of culmination of VWC negative values in 15 cm depth against 5 cm depth indicates time delay about 4 hours in No.3 - target grassing set aside. The shallow rooted species that are dominant in this site may be the possible reason of this phenomenon. Smaller difference of culmination of VWC negative values between the winter rapes plots No.2 and 4 was caused probably by the different soil cultivation, shallower in the plot No.2. Extremely small difference of VWC negative culmination was observed in the site 1 - spontaneous set aside (Fig.5). The deeper-rooted species may be the reason of this simultaneously achieved highest negative values of VWC. Daily mean of totals of soil water movement in 5 cm depth rarely exceeds 5 mm (5 l $m^{-2}d^{-1}$), in the 15 cm depth generally several times smaller values was achieved (Fig.6, 7). Global view of course of daily totals of soil water movement in both depths during the vegetation period brings figure 8.

Andraski (1997) indicates for vegetated soil, precipitation that accumulated in the upper 0.75 m of soil was removed by evapotranspiration. Under no vegetated waste-site conditions, data indicated the long-term accumulation and shallow, but continued, penetration of precipitation. Liu et al (1995) describes about 80% of the soil water loss through transpiration.

Conclusion

The method described above was based on the mutual relationship of precipitation and its influence on the following soil moisture changes. The results indicated the crucial influence of the depth of root system depending on the plant species of vegetation cover. Deeper-rooted species achieved highest negative values of VWC near a soil surface and in a deeper layer simultaneously. In the case of shallow rooted species the higher time delay of culmination of VWC negative values in a deeper layer against less deep layer was determined. The influence of soil cultivation appeared as a less significant in case of winter rape plots.

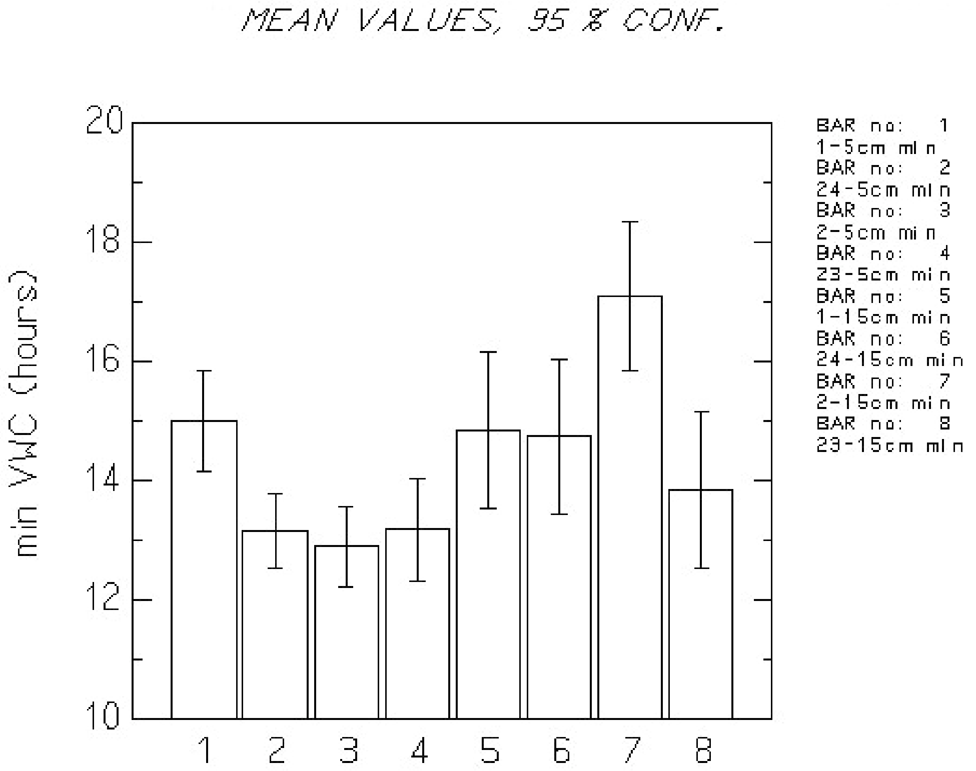

Fig.4 Time of culmination of VWC negative values in 5 cm (1-4) and 15 cm (5-8) depth

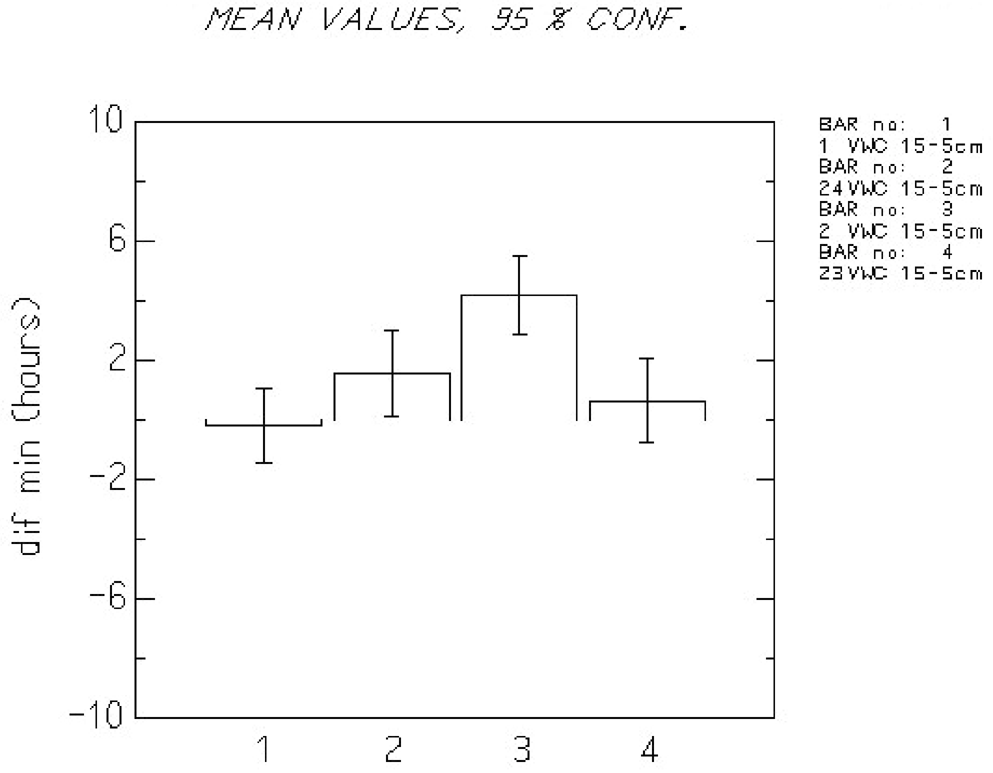

Fig.5 Time shift of culmination of VWC negative values in 15 cm depth against 5 cm depth

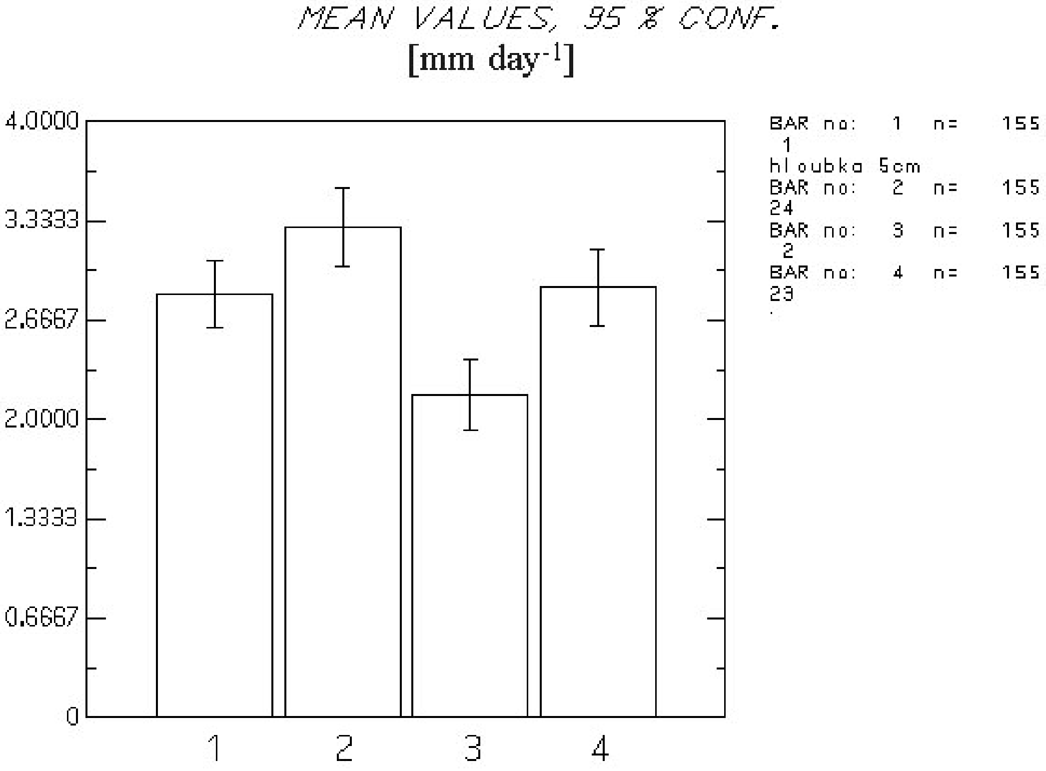

Fig.6 Daily mean of totals of soil water movement in 5 depth

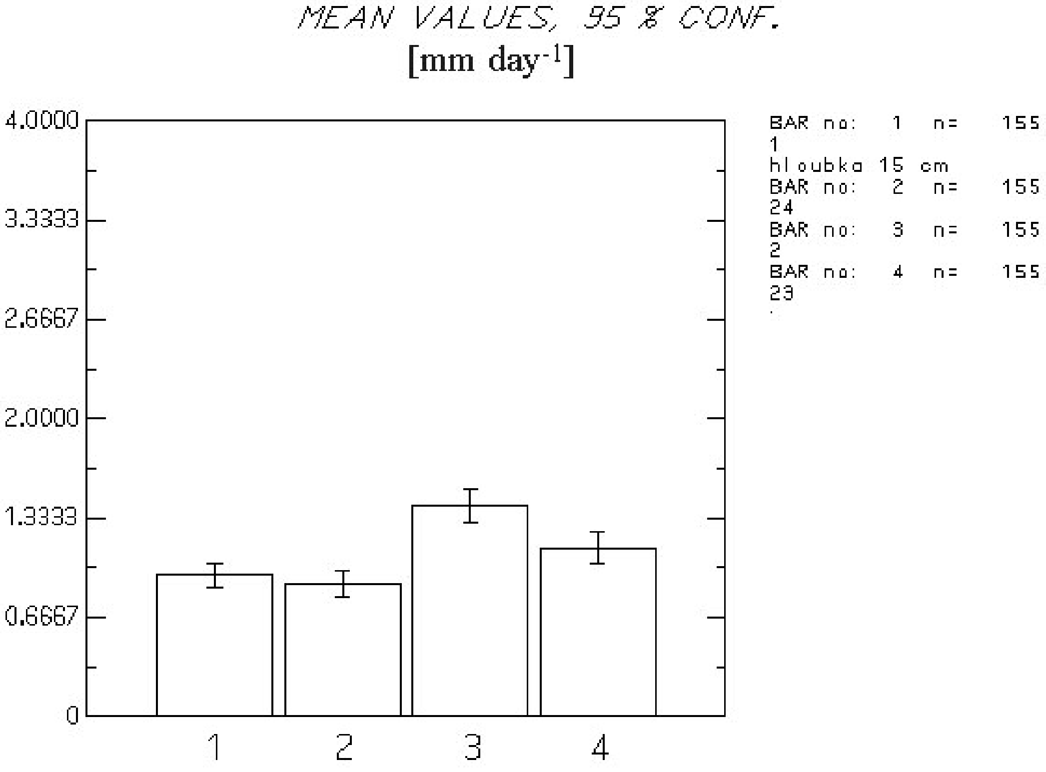

Fig.7 Daily mean of totals of soil water movement in 15 depth.

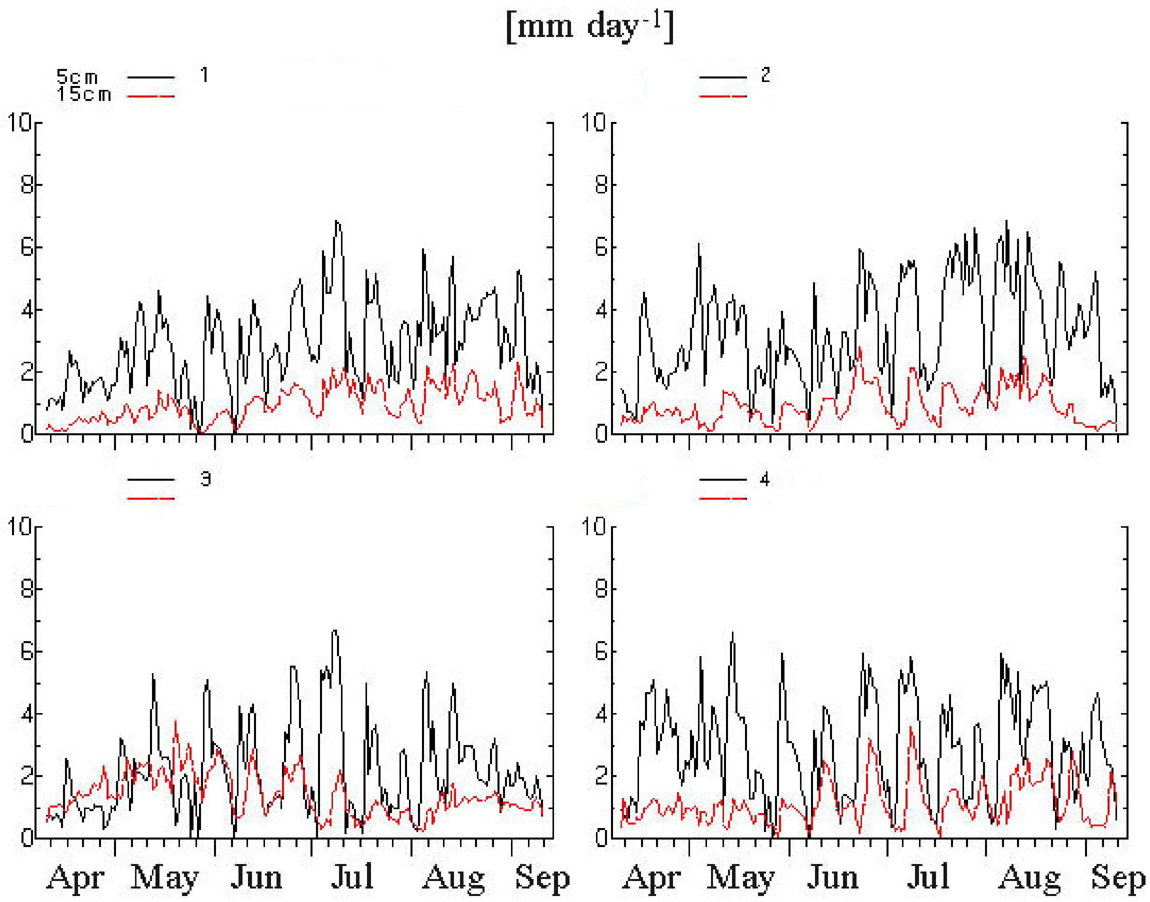

Fig.8 Course of daily totals of soil water movement in both depths during vegetation season

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