Examination of water and nutrient transport in compensation lysimeters

A. KARUCZKA und J. ZSEMBELI

Abstract

Water and substance transport processes are examined in lysimeters with compensation system filled with soils salty in the deeper layers and with high clay content in the cases of different ground water levels. The investigation conditions can be characterised with 300 mm/year climatic water shortage. We established that the drying out process in the summer period is increased and the annual water balances are more negative in the soil monoliths with deeper ground water levels. Within the same climatic conditions the parameters of leaching out are significantly modified by the ground water depth beyond the soil properties. Leaching of nutrients can be detected even in the soils with high clay content. The annual leaching values are 0-0.2 kg P/ha, 0-10 kg K/ha, 1-100 kg N/ha, respectively.

Material and method

The investigations with the 42 compensation lysimeters were started in 1984. The depth of the plastic containers is 200 cm, the diameter is 95 cm. 30 lysimeters were filled with meadow solonetz soil (RSZ), 12 units with alluvial meadow soil (ÖR). The depths of the ground water level are stable in the main treatments, 90, 120 and 170 cm. To compensate the evaporated water, original ground water is added through a control system. Uniformed fertilisation (150-300 kg/ha) and surface irrigation (5-50 mm/year) are applied in the experiment. We regularly measure the basic meteorological parameters, the temperature, the salt- and moisture contents of each layer of the soil monoliths and the amount and composition of the input- and output solutions [**1, 2**]. The data processing is made by means of non-series and different other computer programmes.

Results

On the base of the measured precipitation (P) and evaporation of open water surface (E0) data the cumulative value of atmospheric water shortage is increasing step by step in the investigated period (*Figure 1*). The annual water shortage value is 265 mm, the maximum of the average values calculated for the two weeks periods was (6-8 mm/day) detected in 1994-1995. As there is no regular irrigation in the experiment, the upward movement of water is dominant in the soil monoliths.

On the base of soil moisture data, measured by neutron probe, the drying out of the soil monoliths is changing according to the depth of the ground water level (*Figure 2*).

As the measurement error of neutron probes is high in the upper 40 cm layer [**3**], the calculation of evapotranspiration (TET) from the change of the soil moisture fund (ΔTVK) is not really accurate. In early spring period the soil monoliths are saturated by water, hence the annual change of water fund (TVK) is zero. The annual evapotranspiration can be calculated by means of the following equations:

$$TET = P - \Delta TVK + SM$$

$$SM = SB + SO - (SK + SD + SE + SN)$$

where SM is the water balance of the soil monolith, SB is ground water (compensation water) input, SO is irrigation water, SK is ground water output, SD is drained water, SE is surface run-off, SN is plant uptake. If ΔTVK is zero and the precipitation (P) is the same for each treatment, the TET value is changing with the water balance of the soil monolith. The average annual values of water balances are summarised in *Table 1*.

As the data show the rising ground water level results in higher water balance value in both soil types. It is remarkable that the annual water balance data (22-25 mm) of the ÖR-soil with better hydrological properties and lower clay content are lower than values of the RSZ-soil. This can be explained partly with low water capacity value of the ÖR-soil, and partly with the fact that in wet years (1991, 1996) its water balance values are more negative.

The average values of the water balance components are shown in *Figure 3-4* in the cases of some drained treatments.

The data prove, that the ÖR-soil has more intensive hydrological features. The ground water input (SB) and the ground water output (SK, SD) values are higher as well than in the case of the

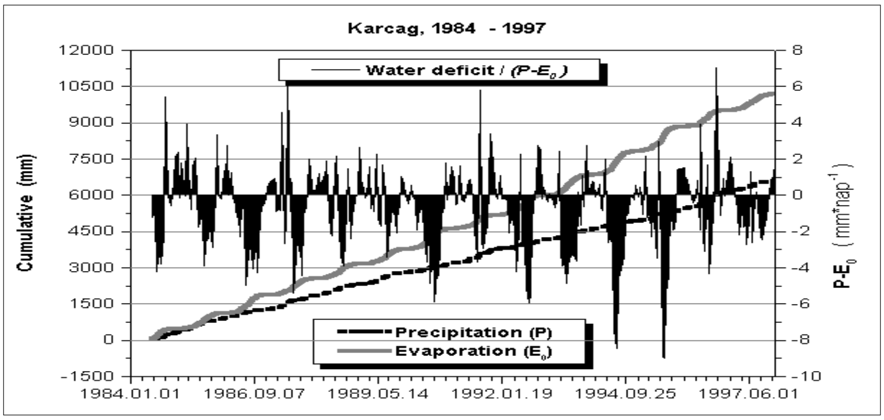

Figure 1: **Cumulative values of precipitation and evaporation**

Autoren: Dr. Antal KARUCZKA und Dr. Jozsef ZSEMBELI, Research Institute of Debrecen Agricultural University, Karcag, Postafiok 11, H-5301 KARCAG

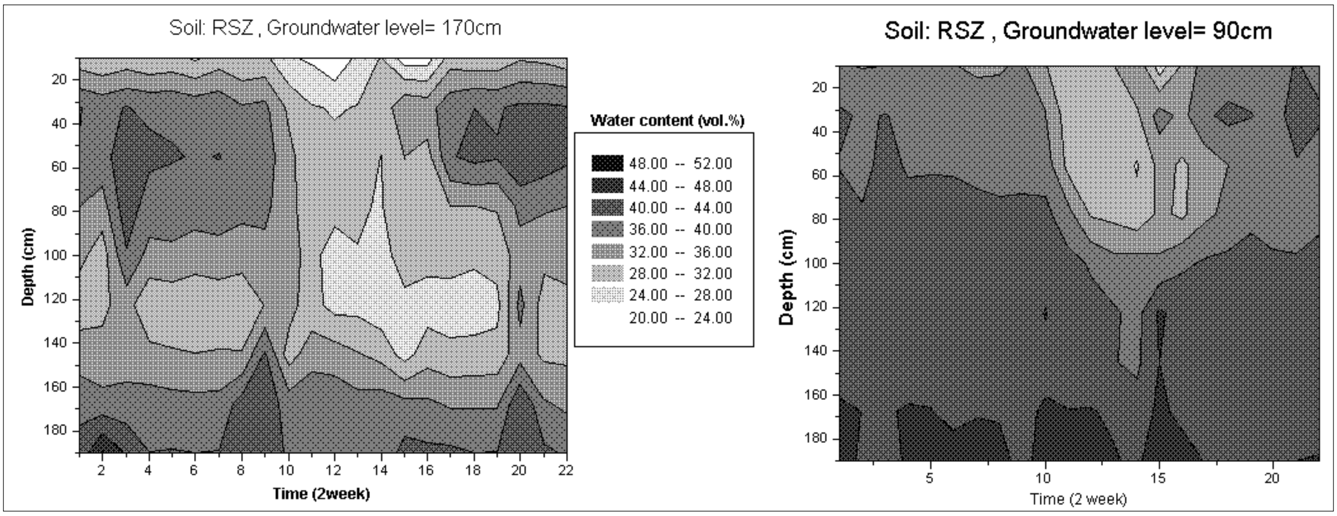

Figure 2: **Change of moisture content of the layers of the soil monoliths in 1998**

Table 1: **Average values of annual water balances**

	Precipitation	Evaporation	Average annual values of water balances (mm/year) SM-RSZ soil 170	120	90	SM-ÖR soil 170	120	90
	mm							
1985	524.6	638.9	105.0	100.4	163.0	381.9	208.4	238.8
1986	399.9	778.5	84.3	65.7	95.2	-8.8	30.9	-22.1
1987	557.5	644.6	81.7	96.0	93.7	51.6	14.8	-30.0
1988	484.5	603.3	10.9	9.6	50.9	-80.5	-34.9	59.9
1989	494.0	620.5	16.9	23.9	71.4	14.4	62.4	57.9
1990	367.1	813.1	30.2	39.0	109.5	34.4	48.7	68.2
1991	599.4	636.9	7.6	-15.0	7.0	-81.8	-106.8	-60.5
1992	381.1	837.1	29.9	34.3	48.5	19.2	54.5	77.3
1993	422.5	845.3	22.5	13.3	33.1	16.2	14.7	-36.9
1994	341.5	976.9	24.6	61.7	114.7	87.3	106.3	61.8
1995	496.8	1062.7	55.4	75.9	95.8	54.1	48.6	69.6
1996	761.6	712.3	5.6	-0.2	-10.2	-189.5	-154.7	-200.1
1997	405.1	666.4	15.7	29.2	49.5	-1.6	25.3	38.2
Average	479.7	139.8	37.7	41.1	70.9	22.8	24.5	24.8

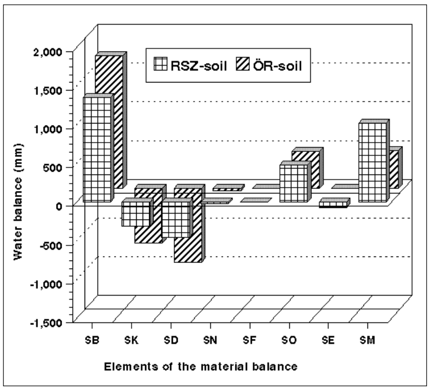

Figure 3: **Water balance components of the drained treatments**

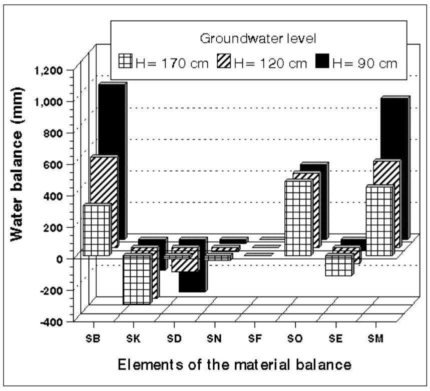

Figure 4: **Water balance components of the RSZ-soil**

RSZ-soil. Surface run-off could be measured only in the lysimeters filled with the RSZ-soil. The higher ground water levels result in higher water balance data, the ground water outputs decrease, the inputs increase. The efficiency of drainage is decreasing with the decrease of the ground water level. *Figure 5* shows the connection between the soil water balance and the crops.

Dynamics of ground water uptake of alfalfa and winter wheat

In the cases of the two indicator crops (alfalfa and winter wheat) the amount and the dynamics of the ground water input are significantly different. The maximum water uptake calculated for a two weeks time of the vegetation period is 0.2-0.4 mm/day in the case of winter wheat with shallow root zone, alfalfa, which has deeper root zone took up 0.5-1.0 mm/day water from the RSZ-soil, and 2.0-3.5 mm/day from the ÖR-soil.

Infiltration measurements were carried out in the second and the tenth years of the experiment. During this period significant changes in the infiltration rate could not figured out. The average infiltration rate, measured by gravitation method, was 0.12 ± 0.1 mm/day for the RSZ-soil, and 2.2 ± 1 mm/day for the ÖR-soil. On the base of these data we found, that water uptake of crops with deep root zone is higher than the velocity of infiltration in unsaturated conditions, hence these crops evaporate water from the ground water, or from its direct environment.

The transport of substances moving with the ground water is changing with the solubility and the amount of them. We examine the nutrient balance from the point of view of leaching, as an environment loading source. *Figure 6* shows the summarised data of nutrient balances and the rates of each balance components. The nutrient fund of the soil monoliths is decreasing if low amount of fertilisers is applied.

The order of this decrease is P<K<N. The two main components of substance balances are the input by fertilisers and the plant uptake. The effect of the ground water on the annual nutrient balance is practically negligible, in the case of P, which has low solubility, it is < 1 kg/ha, for nitrate-nitrogen 1-100 kg/ha, and for potassium 1-10 kg/ha were measured. The leaching values measured in the ly-

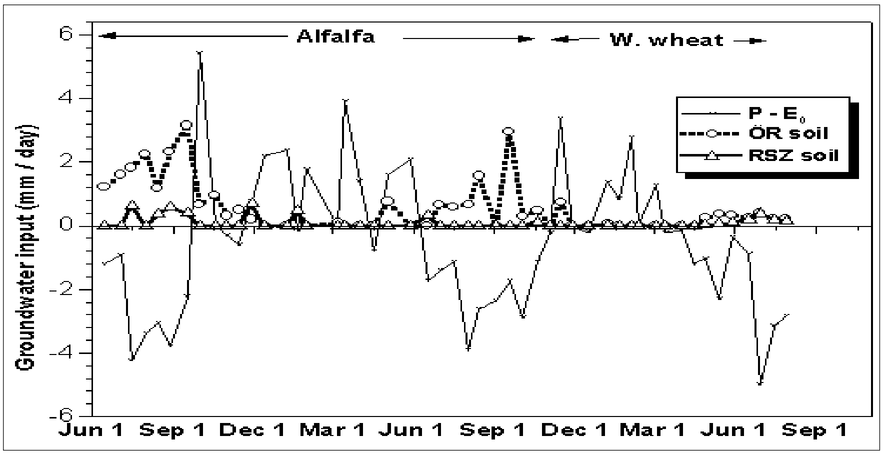

Figure 5: **Dynamics of ground water uptake of alfalfa and winter wheat**

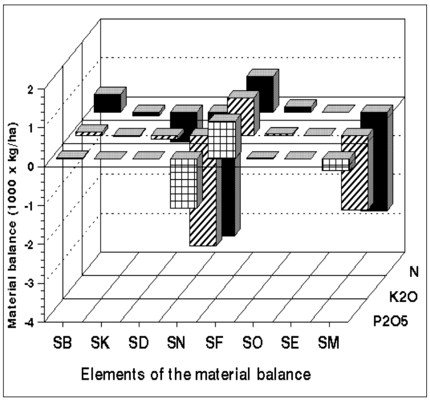

Figure 6: **Summarised nutrient balance and its components**

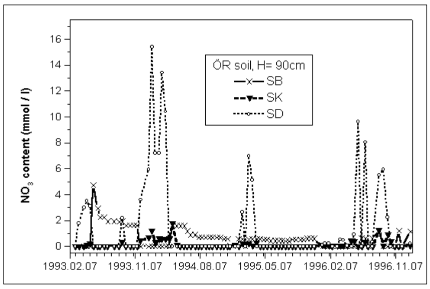

Figure 7: **Nitrate concentration of the outlet soil solution**

simeters are in good accordance with the field data [**4, 5**].

The leaching of nitrate has characteristic seasonal dynamics (*Figure 7*). The nitrate concentration of the outlet soil solution is determined by the fund of the soil and by the intensity of the ground water output. The highest nutrient loss can be figured out in the drained treatments.

On the base of our results we must take nutrient loss by leaching and the contamination of ground water into consideration even in the cases of soils with high clay content.

We found shallow drainage to have positive effect on the soil moisture content and on the leaching of harmful salts, but negative effect can be proved as well, due to the increased leaching of nutrients.

The further analysis of the above mentioned results and correlation is in progress. We intend to utilise our achievements for the verification of crop production - and soil development models.

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