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THE EVALUATION OF SOIL WATER STORAGE IN A SMALL CATCHMENT IN 2009 AND 2010

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The soil water storage in a soil profile was calculated from the measured values of volumetric soil water content by the Profile Probe PR2/6 (Delta-T Device Ltd.) in the Bocegaj catchment in the depth up to 1m. The monitored season in the year 2009 followed after a dry season, and in the year 2010, rainfalls were above the average values. The soil water storage was higher than the mean value of field capacity during the season with high precipitation events. With a decreased amount of rainfalls, rising air temperature and crops growing, the soil water storage was in recession. In the vertical direction, the volumetric soil moisture as well as soil water storage in every soil profile have their characteristic progresses.

Keywords: soil water storage, volumetric soil water content, soil water storage changes, direct monitoring

The environment is directly or indirectly affected by the development of society in all spheres at various stages of evolution. The landscape structure is being changed, as well as the processes connected to landscape. One of these processes is the water cycle. Knowledge of soil water content is significant, especially for farmers. They might be able to react in time to avoid the water stress of plants by additional irrigation. In practice, this information may also help water managers, ecologists etc.

As Šútor and Rehák (2009) wrote, the monitoring of the dynamics of agricultural soil water storage in Slovakia has not been established yet. Šútor (1991) wrote that the soil water storage in an unsaturated zone may be determined indirectly by the moisture retention curve. On its basis, the soil water storage is determined for the chosen characteristic points (wilting point, field capacity). The second alternative is the direct monitoring. The soil water storage obtained by direct monitoring is considered as the real level of storage (Šútor and Rehák, 2009).

Material and methods

The changes of the soil water storage were evaluated in a subcatchment of the Bocegaj stream with an area of 9.75 square kilometres. It is situated in the Southeastern Slovakia, approximately 10 kilometres northeast of Nitra. The daily average air temperature is 9.8 °C (mean value for the years 1961–1990) in the Nitra region, and the total yearly precipitation is 539 millimetres (mean value for the years 1961–1990). The soil types are mainly represented by Haplic Luvisol (52 percent of the arable soil), Cambisols (37.5 percent) and Fluvisols (10.5 percent). The soil texture groups are represented by loam top soil and clay loam subsoil (62.1 percent of the arable soil), clay loam (15.3 percent), loam (7.5 percent), and sandy loam soils (15.1 percent). A spatial distribution of soils is shown in the Figure 1. According to the information from hydrogeologists, the relatively confined aquifer is quite variable under the terrain, at a range of approximately between 2 and 12 metres. The same situation exists with the ground water level. Detailed description of the area of interest is presented in the work of Kaletová (2011).

The volumetric soil water content was monitored from the 8th of September 2009 to the 24th of November 2010 at the depth of 1 meter. The soil moisture was measured by the Profile Probe PR2/6 (Delta-T Device Ltd.) with a connection to the Moisture Meter HH2 (Delta-T Device Ltd.). The Profile Probe PR2/6 uses frequency domain reflectometry to measure the volumetric soil water content. A localization of the monitoring places in the area of interest is shown in the Figure 1. The place 1 is situated at a forest edge, the places 7 and 8 are in a meadow and other places are in arable land.

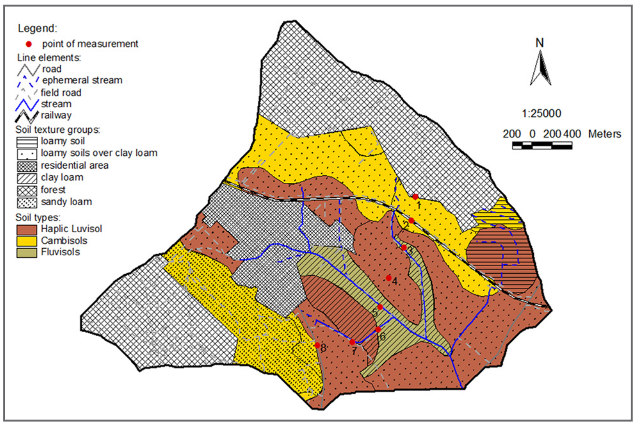

Figure 1 The map of soil types and soil texture groups according to the data from The Soil Science and Conservation Research Institute in the research area

The soil water storage was calculated by the equation:

$$W = \theta \times h / 10 \qquad (1)$$

where:
W – the soil water storage in millimetres
θ – soil moisture (volumetric soil water content) in percentage of volume
h – the soil depth in centimetres (Fulajtár, 2006).

Results and discussion

The observation places do not cover the whole subcatchment of the Bocegaj stream, which is why not all of the soil types are represented. There are two reasons for this. First, the sandy loam Cambisols are in a meadow with the depth lower than 1 m. Second, the loamy Cambisols and the Haplic Luvisols are used as vineyards or are cultivated by the individual farmers.

The soil water storage in the soil profile was calculated from the measured values of the volumetric soil water content. During the monitoring period, the access tube placed in the soil profile at place No 7 was damaged; therefore we did not put the results from this place into the article.

The field capacity (FC) 40 % (range 35 – 46 %), the wilting point (WP) 19 % (range 17 – 23 %) and porosity 51 % (range 49 – 53 %) were experimentally measured in the laboratory for the clay loam soil; for loam soils, the FC had mean value 36 % (range 31 – 41%), WP 17 % (range 15 – 20 %) and porosity 49 % (range 47 – 51%) (Agricultural Compendium, 1981).

Figure 2 shows the progress of the changes of the soil water storage at the observation places, the average value calculated from all the observation places, as well as the

Table 1 The differences of the soil water storage in the soil profile in mm between the days of the measurements

Date, Location (1)	1	2	3	4	5	6	8
08. 09. 2009	0	0	0	0	0	0	0
23. 09. 2009	-10.9	-3.3	1.6	-0.8	-11.9	17.1	*
30. 09. 2009	-1.7	-8.3	-15.0	37.6	-14.5	-5.6	-0.5
08. 10. 2009	-2.4	-6.8	-11.6	-24.8	8.1	-7.3	-34.9
14. 10. 2009	1.1	-9.1	-0.3	22.2	-12.6	-10.0	1.4
21. 10. 2009	32.7	42.7	100.5	31.5	65.7	73.4	68.7
28. 10. 2009	4.7	-0.1	-30.1	14.6	-12.2	-3.7	17.6
03. 11. 2009	1.7	25.7	*	2.1	-6.1	18.3	-16.8
20. 11. 2009	35.6	42.9	*	68.9	*	136.1	68.1
23. 03. 2010	50.1	54.5	**	-34.8	**	-11.6	53.4
08. 04. 2010	0.8	6.5	7.6	2.3	-15.9	4.3	0.3
26. 04. 2010	18.2	4.0	-6.5	21.4	12.0	18.4	-6.2
07. 05. 2010	8.1	6.3	1.7	6.0	-1.0	18.6	6.4
13. 05. 2010	-20.1	-2.4	-3.1	9.9	-17.7	-21.4	12.2
24. 06. 2010	7.2	6.0	-7.9	10.6	1.4	14.4	35.7
29. 06. 2010	3.5	3.8	-10.6	-3.1	-18.6	-24.1	-23.2
08. 07. 2010	-29.5	-26.0	-37.6	-34.8	-28.6	-29.6	-59.6
14. 07. 2010	-29.1	-32.0	-19.8	-3.5	-23.4	-32.9	-22.8
21. 07. 2010	-14.4	-13.7	-18.8	-20.5	-28.4	-35.0	-19.4
04. 08. 2010	6.1	26.3	30.3	48.7	39.0	104.0	5.3
12. 08. 2010	4.9	4.1	-8.6	10.3	-4.6	8.0	39.3
24. 08. 2010	-15.1	-5.4	-1.8	-15.8	4.2	-5.1	-13.9
03. 09. 2010	26.1	10.5	15.1	23.4	34.8	37.1	78.1
14. 09. 2010	9.9	47.5	21.1	13.7	22.6	14.5	27.3
24. 09. 2010	-13.8	-7.9	10.6	-15.8	-18.3	-34.6	-15.7
14. 10. 2010	-13.8	-11.5	1.6	-27.4	-21.4	0.5	19.1
28. 10. 2010	13.6	-6.3	3.6	*	14.6	-14.7	*
24. 11. 2010	20.6	19.9	25.4	*	52.0	-5.4	-33.3

*the measurement was not taken; **the difference was not calculated because of the missing data from the previous measurement

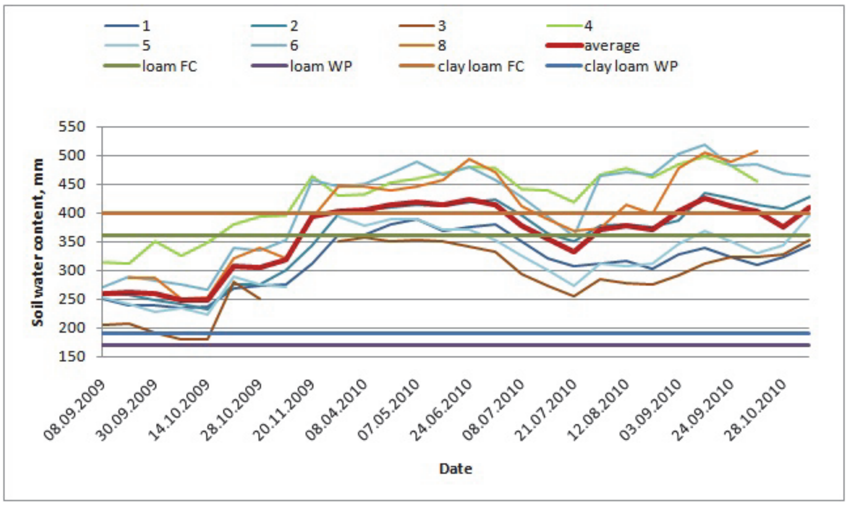

Figure 2 The progress of the soil water storage in millimetres in the observation places

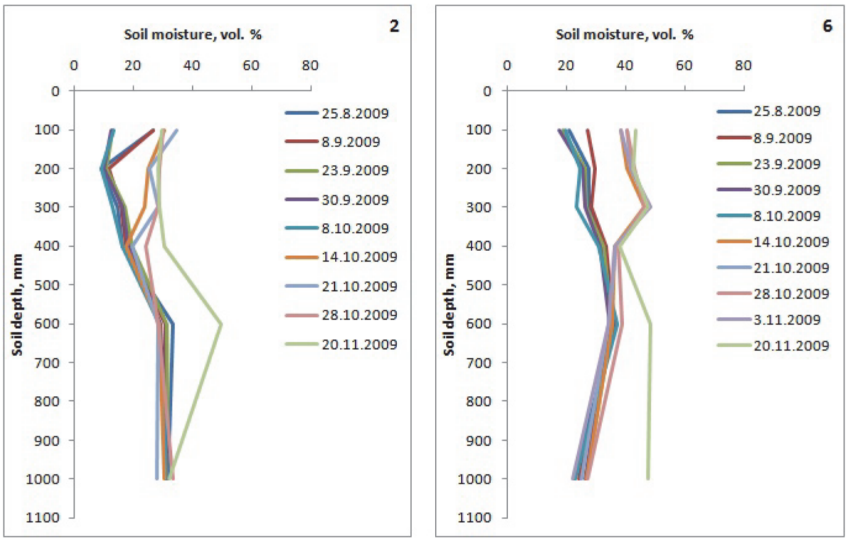

Figure 3 The progress of the volumetric soil water content in year 2009

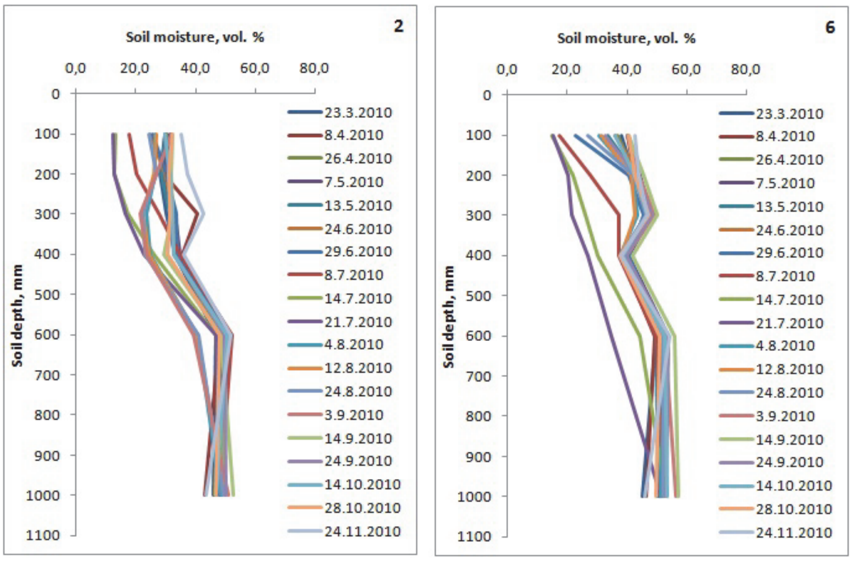

Figure 4 The progress of the volumetric soil water content in year 2010

mean values of the wilting point and the field capacity for the loam soils and the clay loam soils.

The systematic measurements started in September 2009 during a season without precipitation and after harvest. Therefore, the soil water storage was at the lowest values at that time. With the precipitation events, the soil water content rose. The first high rise was measured in mid-October, and then at the beginning of November 2009. In 2010 we started measurements at the end of March, whereby we attempted to record the soil water storage during the winter. In Figure 2 and Table 1, one can see the next rise of the soil water storage after the winter. Rainfalls recharged the soil water storage until the end of June 2010. The amount and intensity of the rainfalls during the spring season 2010 was higher than the retention water capacity. This fact caused the waterlogged soils and water erosion in the area.

The soil water storage was higher than the mean value of the field capacity during the whole spring season 2010. With a decreased amount of rainfalls, the rising air temperature and crops growing, the soil water storage was in recession.

The differences in the soil water storage of the soil profile between the days of measurements in millimetres were calculated according to the equation (1) are shown in the Table 1. The negative value means decrease and the positive one accumulation of the water in the soil profile.

We had obtained the particular soil water storage in the arable soil of the area of interest by the calculation of the average soil water storage in the soil profile for the soil type. At the area 92.84 hectares of clay loam soil, there was storage at a minimum 20,650.7 m^3, a maximum 39,345.6 m^3 (an average 31,678.38 cubic metres), and at the area 376.76 hectares of loam soils the minimum was 99,916.8 m^3 and the maximum 180,832 m^3 (average 149,211.2 m^3). The soil profile up to the depth 1 m was able to intercept (store) 18,694.9 m^3 in clay loam soil and 80,915.5 m^3 in loam soil during the monitored season.

In the vertical direction, the volumetric soil water content as well as soil water storage have their characteristic progresses in each soil profile. The Figures 3 and 4 show the chosen representative curves of loam (2) and clay loam soil (6). There is a visible variance in the progress of volumetric soil water content in the soil profile. The monitored season in the year 2009 followed after a dry season, and in the year 2010, rainfalls were above the average value (868 millimetres).

Comparing the curves in the years 2009 and 2010, one can see the distribution of volumetric soil water content at the time with higher and lower amounts of precipitation. In the season with the higher amount of precipitation, there is a recession of volumetric soil water content at the depth of 400 mm, and then an increase of soil moisture, which changed minimally during the long-time rainfalls in the clay loam soil. In these locations, the ground water level was not observed at the depth of 2 m, therefore the influence on soil moisture by capillary raised ground water is not assumed. In the second case, the range of volumetric soil moisture at the depth of 400 mm is essentially higher, and the steadiness or equilibrium of the soil water storage is at the depth of 600 mm. In the literature (e.g. Dub, 1963) it is written that by the influence of evapotranspiration, the arable soil, during the dry season, is dried up only in the upper layer up to the depth of 150 mm and slightly less in the layer from 150 to 250 mm, the deeper layers dry up very little.

Conclusions

The soil water storage in the soil profile was calculated from the measured values of volumetric soil water content. The soil water storage during a year was recharged by rainfalls and with accumulated water in the soil profile from the previous precipitations. High influence on the amount of water in the soil, besides the precipitation and storage from the previous events, had high air temperature, vegetation season, crop grown on the soil and the soil type.

We noticed the different progress of the soil water storage in arable soil with the agricultural crops, in meadows, and in a forest. The amount and intensity of rainfalls during the spring season 2010 was higher than the retention soil capacity. This fact was documented by the water-logged soils, the flooded parts of the soil surface and water erosion in the area. However, not the whole area had the same problems. In arable soil, the soil water storage differentiated by the crops and the soil type.

At the area 92.84 hectares of the clay loam soil, there was storage at the minimum 20,650.7 m^3, and the maximum 39,345.6 m^3 (an average 31,678.38 cubic metres), and at the area of 376.76 hectares of loam soils the minimum was 99,916.8 m^3 and the maximum 180,832 m^3 (average 149,211.2 m^3).

Knowing the amount and the dynamics of the soil water content, we may predict and react in time to the current, especially the climatic conditions of the environment. Farmers may determine the date and the amount of an additional irrigation, or apply other agrotechnical arrangements; water managers may forecast the floods and other climate changes.

The knowledge obtained from the direct monitoring of the volumetric soil water content, concerning the soil water storage and its dynamic, allows us to calculate the hydrological balance of an area in the complex range.

References

AGRICULTURAL COMPENDIUM. 1981. Amsterdam : Elsevier Scientific Publishing Company.

DUB, O. 1963. Hydrologia, hydrografia, hydrometria. Bratislava : Vydavateľstvo technickej literatúry, 1963.

FULAJTÁR, E. 2006. Fyzikálne vlastnosti pôdy. Bratislava : Výskumný ústav pôdoznalectva a ochrany pôdy, 2006.

ŠÚTOR, J. 1991. Pôdna voda v systéme využiteľných vodných zdrojov. In: Vodohospodársky časopis, roč. 39, 1991, č. 5 – 6, s. 435 – 447.

ŠÚTOR, J. – REHÁK, Š. 2009. Problematika vody v zóne aerácie pôdy s ohľadom na integrovaný manažment povodí, súčasnú legislatívu a smernicu EÚ. In: Acta hydrologica Slovaca, roč. 10, 2009, č. 1, s. 94 – 108.

KALETOVÁ, T. 2011. Retencia a spotreba vody v poľnohospodársky využívanej krajine. Dizertačná práca : Nitra : SPU.

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