INFLUENCE OF SOIL TYPE ON STATISTICAL CHARACTERISTICS AND GRAPHICAL RESULTS INTERPRETATION OF THE WATER STORAGE DISTRIBUTION MONITORING ALONG THE VERTICAL OF THE SOIL PROFILE

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The results of authors of submitted article are based on knowledge that soil retention capacity and soil water availability for plants is different in various soil types. Soil types are defined by texture. It is expected that different retention capacity of soil and different availability of soil water for plants is reflected in changes of moisture regime in space and time. Moisture regime monitoring results captures these changes. Changes can be statistically and graphically analysed and interpreted. The results gained from three localities of East Slovakian Lowland (ESL) of the year 2015 extreme drought period were selected for presentation. Examined localities differs by texture compound. Localities are representing the heaviest clay soils, lighter clay-loam-silty soils and the lightest loam soils. Soil volume humidity was monitored into the depth of 1.00 m by layers of 0.10 m. All samples were taken in the same day in examined localities. Descriptive statistics method was used for data processing. Graphical representation is processed in form of chronoizophlets, line and column graphs. Different monitoring results of volume moisture and water storage in different soil types are quantified in the article. Winter water refill of soil profile, soil water storage, vertical scatter of soil profile moisture volume, temporal and spatial moisture regime changes and availability of soil water for plant cover was analysed within this quantification. The results of analysis and interpretation of moisture regime in different soil environments are necessary for water management of the country and for the design of adaptive measures for the periods of soil drought.

KEY WORDS: monitoring, moisture regime, soil types, hydrolimits

Introduction

The retention capacity and potential of water in the soil affects the water regime of the landscape (Tall and Gomboš, 2013). Retention soil capacity and soil water availability for the crops is different in various soil types (Červeňanská et al., 2016; Červeňanská et al., 2018; Šoltész and Baroková, 2011; Constantin, 2016). Soil types are defined by texture. To assess the water storage available for plant cover, is conventionally use the following characteristic points of the moisture retention curve (soil-water content), wilting point (WP) representing the value of pF = 4.18, threshold point (TP) representing the value of pF = 3.3, field water capacity (FWC) representing the value of pF = 2.0 to 2.7. Wilting point is characterized by moisture at which the crops are insufficiently supplied by water and dies. Treshold point is characterized by moisture at which soil water starts to be unavailable for the plant cover. Biological activity of plants decreases and is oriented on survival. Soil moisture on FWC represents the moisture that stays in the soil after draining of gravity water.

These facts are also reflected in the results of moisture regime monitoring (Skalová et al., 2015). They are significant in statistical and graphical interpretation of results.

The aim of the paper is to show different monitoring results of individual soil types by statistical and graphical methods. The results of monitoring in three localities at the ESL in the extremely dry year of 2015 were selected for the differences presentation.

Methodology

Three localities in the East Slovakian Lowland (ESL) were selected (Fig. 1). Monitoring was carried out into the depth of 1.0 m by 0.1 m layers. The analysed monitoring results belongs into the warm (vegetation) half-year of April to September. Soil sampling was performed on the same day in all three localities. The vegetation period of 2015 was selected for the presentation of monitoring results. This is characterized by the smallest precipitation amount of the growing period from 1970 to 2018 (Fig. 2). Lack of precipitation caused the formation of soil drought. This was manifested by the drying of the vegetation cover (Fig. 3).

From the soil point of view, clay soils predominate in

the Senné locality, clay-loam soils in Milhostov and loam soils in Somotor (Fig. 4). Soil moisture was determined by gravimetric method.

In the next step of the work, results were gained by descriptive statistics method and graphical methods in form of chronoizoplets, line and column graphs.
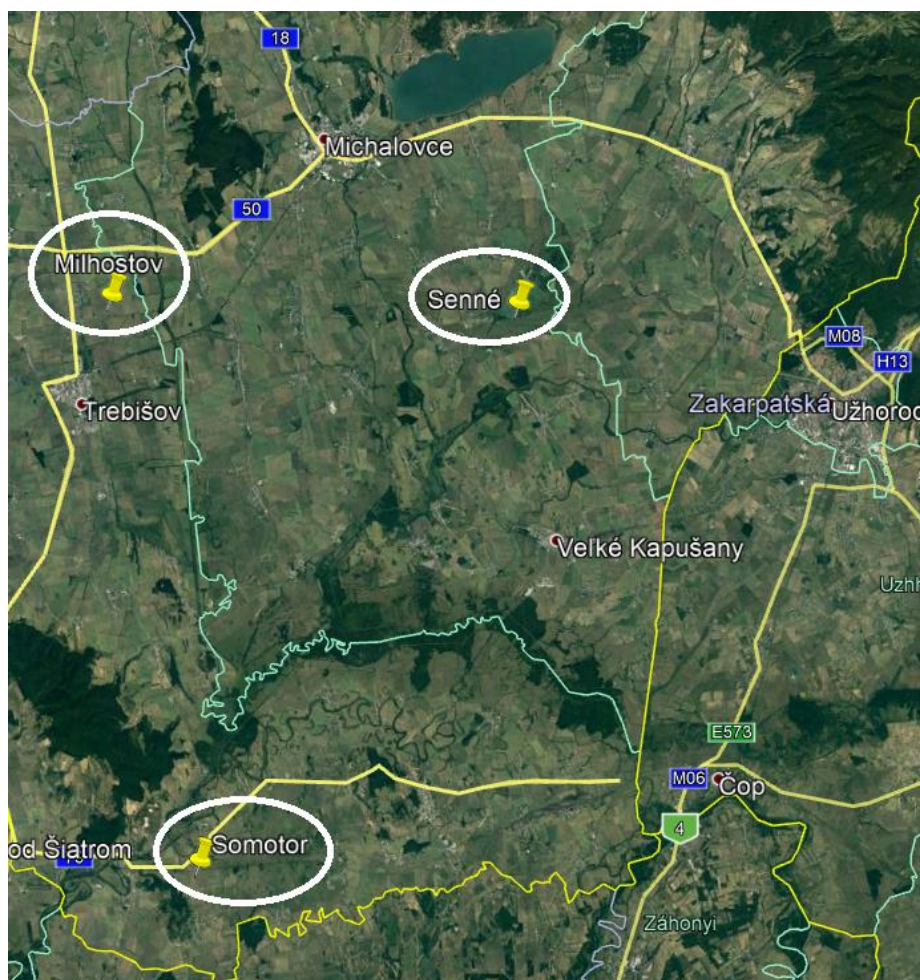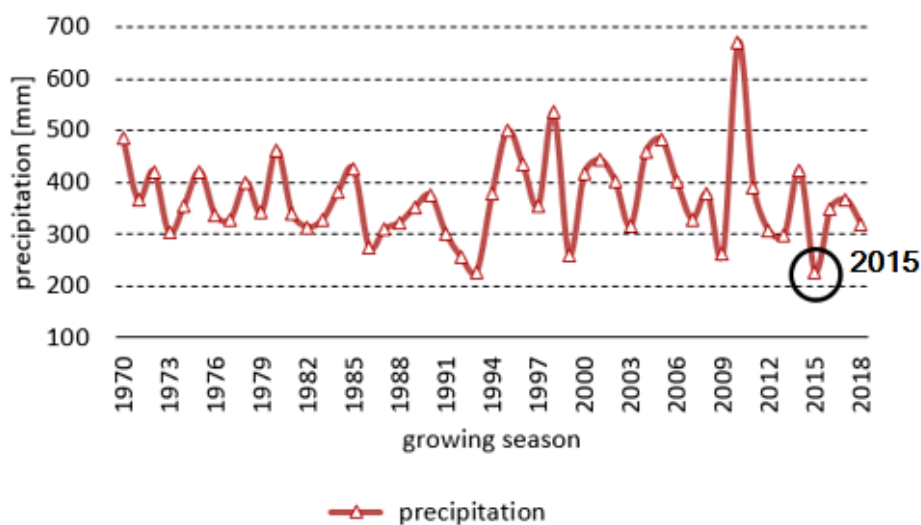

Fig. 1.   Location of sampling sites.

Fig. 2.   Total precipitation of vegetation periods 1970–2018.

Fig. 3.   Soil drought manifestations on vegetation cover on the East Slovakian Lowland. The green belt is vegetation along the stream.
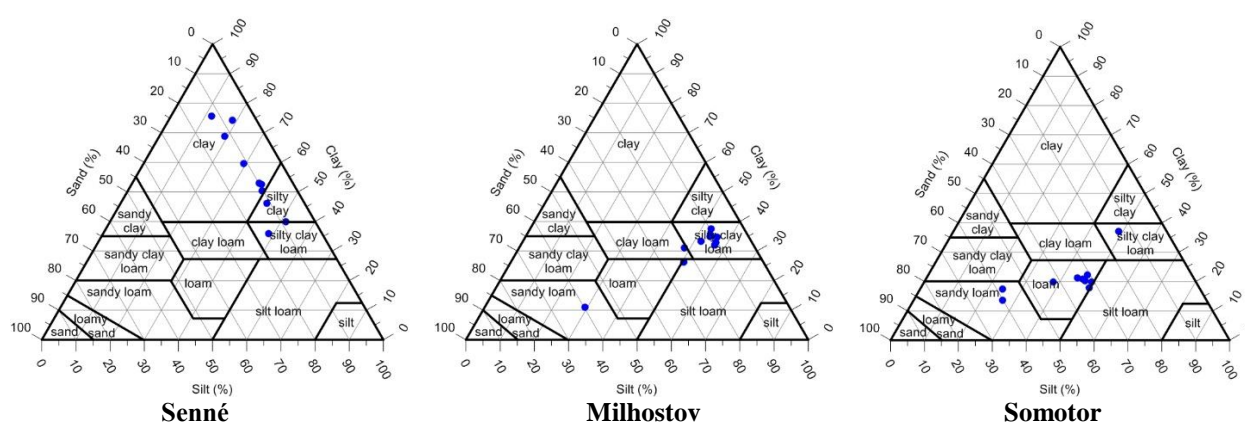

Senné   **Milhostov**   **Somotor**

Fig. 4.   Soil Identification Triangles by USDA.

Results and discussion

It is necessary to state the average retention characteristics of sampling profiles into a depth of 1.00 m at the beginning of this chapter and are indicated in Table 1. From Table 1 results that feasible (available) water capacity (FWC–WP) is within the range 150–230 mm. Clay-e soil profile of Senné has the highest retention capacity. It is also the soil profile with the lowest water availability for the plant cover. The most available water for plants is in soil profile of Somotor. This profile has the lowest retention capacity. It is the lightest soil profile with a predominance of loam soils. There are also evident differences between WP, TP, FWC in individual localities.

Characteristics of descriptive statistics of water storage in individual profiles into a depth of 1.0 m are indicated in Table 2. The average value of the water storage in the lightest soil profile in Somotor is within the interval between WP and TP. It is just above TP in other two locations. The lighter the soil profile is, the greater is the variability of water storage. The statistical distribution of water storage is flatter than the normal distribution in all cases. The distribution steepness is higher than normal. The median is not the same as the average. The stated statistical shape characteristics also have a graphic form of expression, which is not mentioned in this article due to its extent.

Soil profile volumetric moisture measurements along the vertical of individual localities are indicated in Fig. 5. All measurements were executed on the same day during the same hydrometeorological conditions. The above figure aptly shows the variability of moisture over time and space in different soil environments. Envelope curves were constructed on the borders of the individual images. These indicates the variation range of the volume moisture along the vertical of the soil profile. A thick red line passes through the centre of the representation showing the average volume moisture values. From the figure results that envelope curves approach each other in the depth at heavy, clayey soil. This means that the variability of moisture decreases but the soil water content increases. Lighter soils are vertically uniformly dried in the whole examined profile. The rate of shift of moisture courses, their envelope curves and average values on the moisture axis is given by the soil hydrophysical properties.

Another effective graphical option for displaying monitoring results is shown in Fig. 6. There are indicated results of water storage monitoring in the soil into a depth

of 1.0 m in the vegetation years around the year 2015 (range 2013–2020). There are also shown levels of hydro limits (threshold point, wilting point). This type of line display provides the information of the monitored water storage during the vegetal periods in relation to TP and WP. It is also possible to visually (also numerically) identify the replenishment of water storage during the winter using this representation. The process of soil drought formation begins in the following year in case of a low water storage refill during the previous winter half-year. From the above line courses results that the soil sensitivity to soil drought increases with the loss of clay particles in the soil profile. The moisture often drops below the wilting point in the lightest soil profile of Somotor.

Table 3 quantifies the increments of water storage in the examined profiles into a depth of 1 m. It is a numerical expression of the increments shown in Fig. 6. The results show that the largest winter soil water storage increase is in the clay soil profile of Senné. The variability of the winter increase of water storage with respect to the average ($cv = sd \, / \, avg$) is inversely

Table 1.　Parameters of retention characteristics

Locality	Hydrolimits [mm]		
	WP	TP	FWC
Senné	320	480	520
Milhostov	230	310	420
Somotor	170	230	320

Table 2.　Statistical characteristics of the water content of the soil in a depth of 1 m

Statistical characteristics	Locality		
	Senné	Milhostov	Somotor
Mean	489.9	349.7	184.7
Standard Error	9.3	12.6	15.8
Median	495.5	357.1	179.8
Standard Deviation	37.3	50.5	59.2
Sample Variance	1393.8	2547.2	3509.5
Kurtosis	-1.5	-1.2	-1.9
Skewness	-0.2	-0.3	-0.1
Range	108.4	159.8	146.6
Minimum	437.8	254.2	105.6
Maximum	546.2	414.0	252.2
Sum	7838.6	5595.2	2585.2
Count	16	16	14
Confidence Level (95.0%)	19.9	26.9	34.2

Table 3.　Statistical characteristics of the water content of the soil in a depth of 1 m

Year	Localities								
	Senné			**Milhostov**			**Somotor**		
	vegetation period			vegetation period			vegetation period		
	end	start	increment	end	start	increment	end	start	increment
	[mm]			[mm]			[mm]		
2013	440.4	-	-	-	-	-	-	-	-
2014	491.4	539.5	99	311.0	-	-	244.4	-	-
2015	449.1	546.2	55	317.5	407.0	96	122.4	252.2	8
2016	457.4	565.4	116	339.2	415.8	98	158.6	246.2	124
2017	497.1	534.4	77	340.6	413.3	74	195.3	250.1	92
2018	404.7	550.6	54	325.7	415.4	75	118.0	259.9	65
2019	416	515.8	111	276.4	345.8	20	-	-	-
2020	460.5	552.1	136	325.0	380.4	104	-	-	-
avg	452.1	543.4	92.6	319.3	396.3	77.9	167.7	252.1	71.9
sd	32.4	15.7	31.7	21.7	28.1	31.0	53.0	5.8	49.1
cv	0.07	0.03	0.34	0.07	0.07	0.4	0.32	0.02	0.68

proportional to the content of clay particles. Another possible representation of these results is the column display in Fig. 7.

A very effective display method is the representation of monitored quantities using isolines (isolines, isoplets). An isoline is physically defined as a line along which has the selected scalar of physical quantity the same value. The name of the isoline depends on which quantity it displays. Isolines along which there is the same moisture in the soil profile at different times are called chronoisoplets. A picture of the temporal moisture development in the soil profile is obtained using the chronoisoplets. Fig. 8 shows the course of volume moisture in the examined profiles during the vegetation period of 2015 using this method. The individual moisture levels are also distinguished by colour in the picture. A different humidity regime in different soil environments is evident. The soil profile was dried to
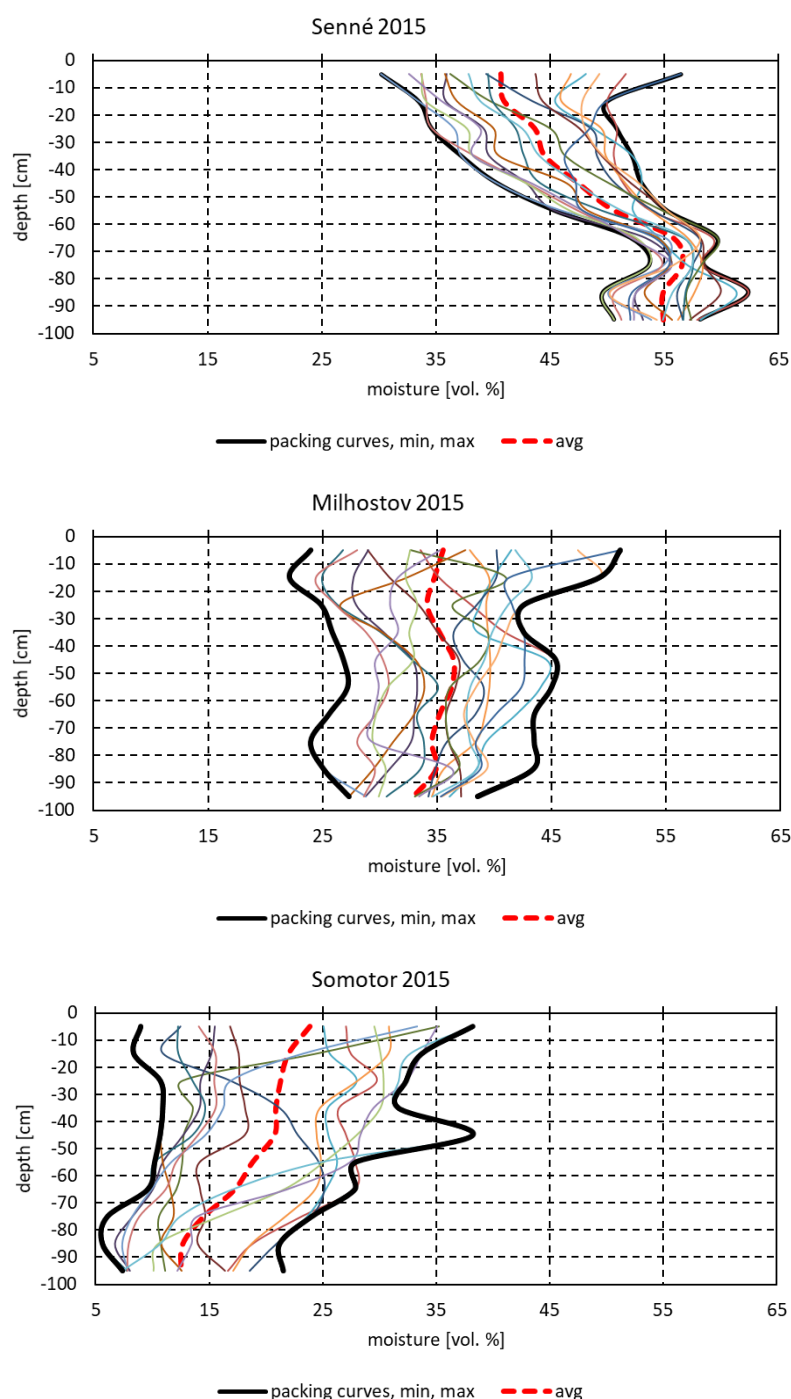

Fig. 5.   The course of volumetric moisture along the soil profile vertical up to 1.0 m in 0.1 m layers.
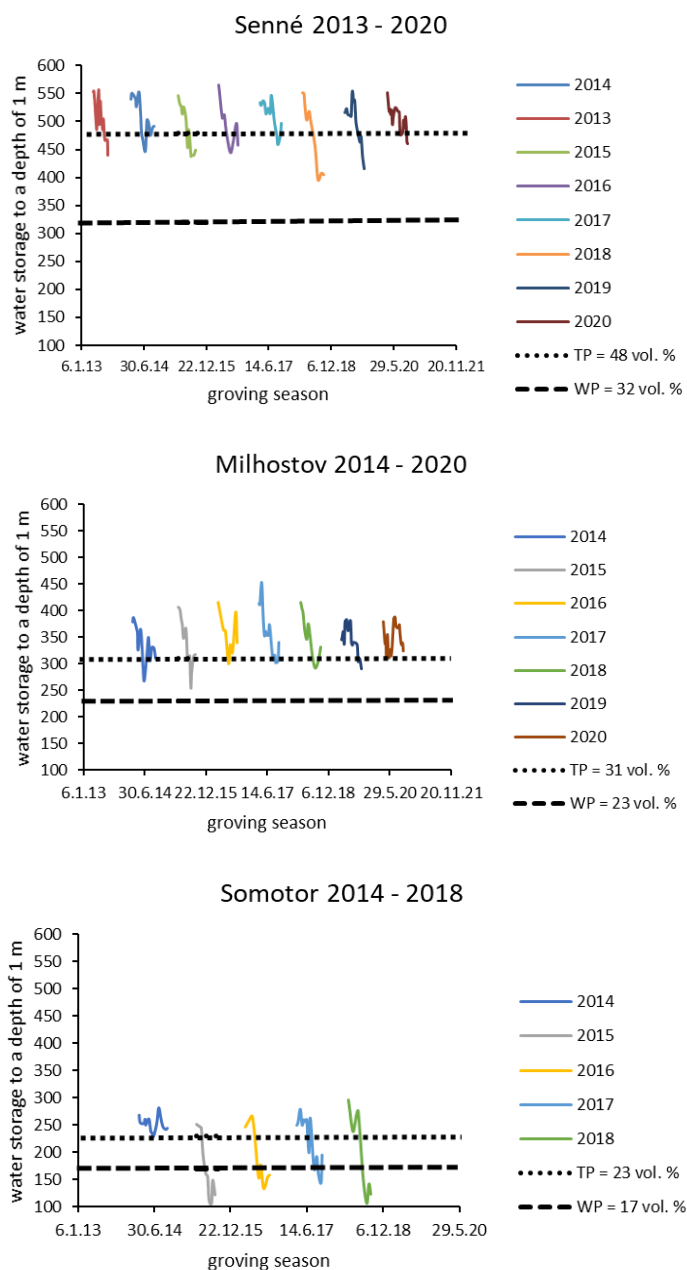
Fig. 6.   Results of water storage monitoring in the soil to a depth of up to 1.0 m during vegetal period.
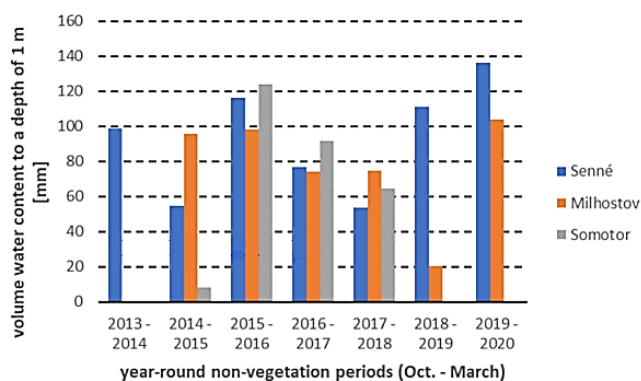

Fig. 7.   Graphical representation of water storage refill in the examined soil profiles during the winter half-year.

a depth of 0.60 m in Senné locality. Overdrying was throughout the entire profile in the other two localities. Precipitation affected only the upper soil horizons in the Somotor locality.

The information value of listed representation is increased if the limits of moisture intervals between the chronoisoplets are given by the hydrolimits. This also gives an idea of the water availability for the plant cover.

Chronoisoplets are determined by FWC, TP and WP hydrolimits in Fig. 9. It is clear from the above representations that the upper soil horizons were in the moisture state between TP and WP in the Senné locality. These soil horizons reached a depth of max. 0.60 m. The entire monitored soil profile was dried to a moisture level between TP and WP to the depth of 1.00 m in the locality of Milhostov in August. In the Somotor
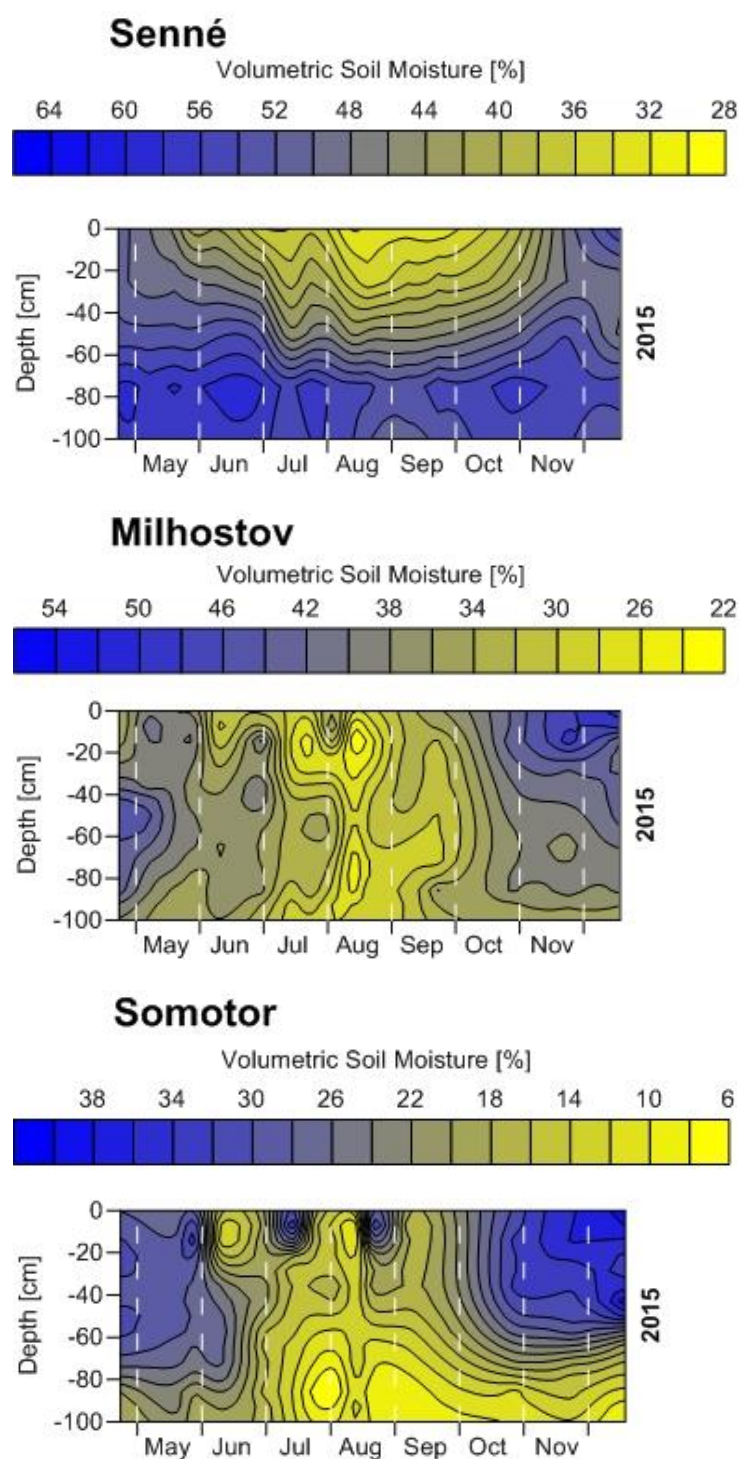

Fig. 8. *Moisture isolines course of investigated profiles (chronoisoplets).*
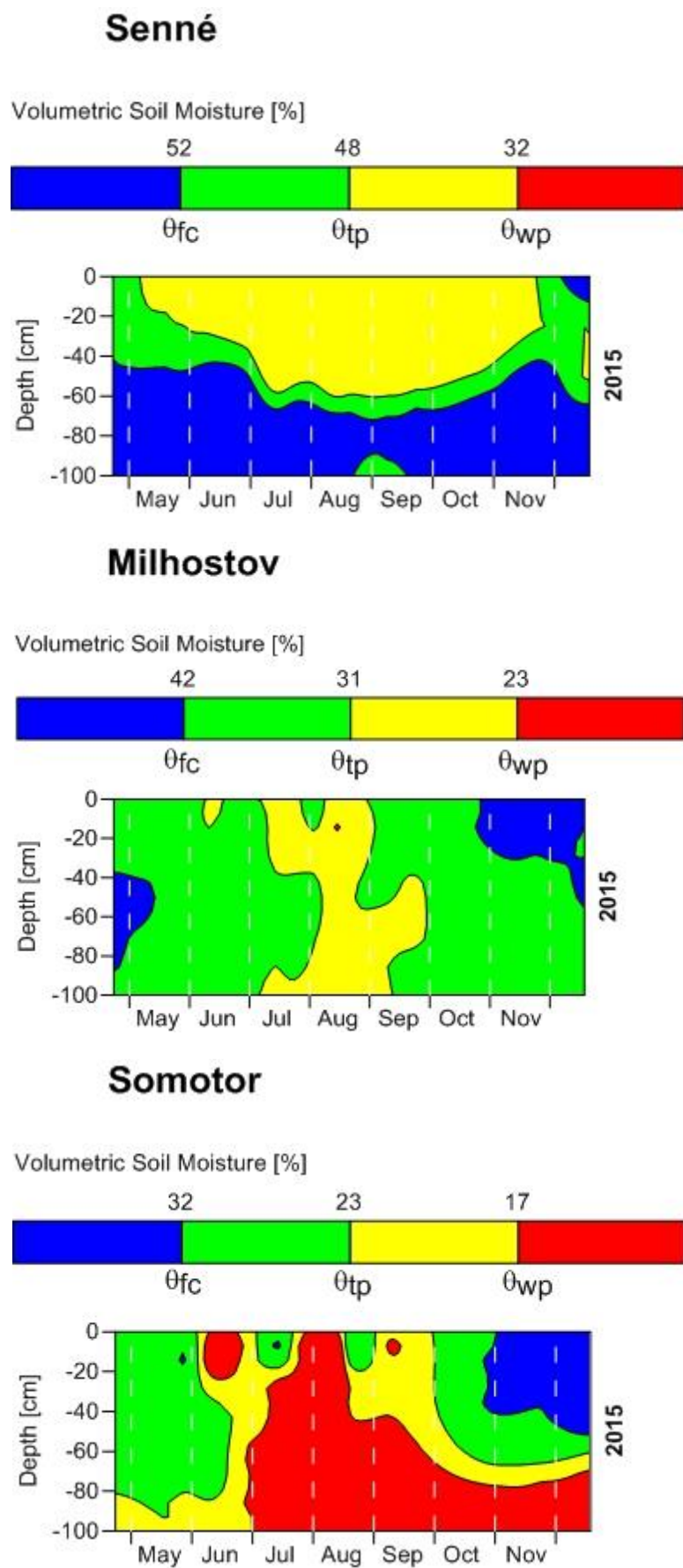
Senné

Volumetric Soil Moisture [%]

Milhostov

Volumetric Soil Moisture [%]

Somotor

Volumetric Soil Moisture [%]

Fig. 9.   *Chronoisoplets of the investigated profiles qualified by hydrolimits.*

locality at the end of July and in the middle of August, the entire soil profile was in a moisture state below the wilting point. The vegetation fall without irrigation in this locality.

Conclusion

The different results of the volumetric moisture monitoring and water supply to a depth of 1.00 m in different soil types was quantified in the article. The results of monitoring in three localities at ESL in the extremely dry year of 2015 were selected for the presentation of differences. The heaviest soils with the highest content of clay particles were in the Senné locality, lighter in the Milhostov locality and the lightest in the Somotor.

The results of monitoring confirmed that the lighter the soil profile is, the greater variability of water storage occurs. The statistical distribution of water storage in the soil was flatter than normal distribution and the steepness larger than normal distribution in all cases. Lighter soils are vertically uniformly dried along the entire examined profile. A significant shift of moisture courses, their envelope curves and average values on the moisture axis was identified numerically and graphically along the vertical of the soil profile. The increment of the clay component in the texture shifts the moisture course to higher values.

The results show that the largest winter increase of soil water storage is in the clay soil profile of Senné (92.6 mm), the smallest in the locality of Somotor (71.9 mm). The variability of winter soil water storage increase with respect to the average ($cv = sd / avg$) is inversely proportional to the content of clay particles (Senné, 34%; Somotor 68%). A graphical analysis showing the chronoisoplet was developed. Analysis proved that the drying of the soil profile manifested itself to a depth of 0.60 m in the Senné locality. In the localities of Milhostov and Somotor, it was in the entire examined profile into a depth of 1.00 m. In order to determine the availability of water for the plant cover in time and space, chronoisoplets were determined with FWC, TP and WP hydrolimits.

The results showed that the upper soil horizons were in the moisture state between TP and WP into a depth of max. 0.60 m the Senné locality. The entire monitored soil profile was dried to a moisture level between TP and WP to a depth of 1.00 m in the locality of Milhostov during August. In the Somotor locality at the end of July and in the middle of August, the entire soil profile was in a moisture state below the wilting point. In other words, the vegetation without irrigation in the said locality has dried up.

The results can be used in country water management designs and designs for adaptation measures to eliminate soil drought.

Acknowledgement

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