Rožnovský, J., Litschmann, T., (eds): Mendel a bioklimatologie. Brno, 3. – 5. 9. 2014, ISBN 978-80-210-6983-1

# Bioclimatological characteristics of soil moisture in Hurbanovo

***Mária Tekušová; Viera Horecká; Ľubica Jančovičová***
*Slovak Hydrometeorological Institute in Bratislava, Slovak Republic*

**Abstract**
The paper deals with the analysis of the bioclimatological characteristics of soil moisture (field capacity, available water capacity of the soil, atmospheric precipitation) determined on the basis of the results of the long-term agroclimatological measurements in the vegetation periods from 1990 to 2013 in Hurbanovo. The agroclimatological characteristics of soil moisture were determined for the layers at the depths of 10 cm to 80 cm below the soil surface under standard surface (without stand). The field capacity and the available soil moisture were normally carried out by the gravimetric technique at the agroclimatological stations of the SHMI.

**Key words:** Soil water regime, available soil water capacity (available soil moisture), field capacity, soil water deficit, permanently wilting point, atmospheric precipitation.

## Introduction

Soil moisture regime is characterized by the time course of changes of moisture condition of the whole soil profile, as well as the active layer of soil. In addition to soil moisture regime is a common characteristic of soils analyzed the soil water regime, which means the sum of hydrological processes associated with the penetration of water into the soil, movement of soil moisture and water loss from the soil. Soil water regime is characterized by its water balance.

The issue of soil moisture is in detail studying in pedology, the role of agrometeorological specialist is to determine certain characteristics of soil moisture, such as field capacity, permanent wilting point and available soil water condition.

The field capacity (FC) is called amount of water that penetrates into the soil. The available soil moisture (ASM) is the difference between the amount of water in the soil at field capacity and the amount at the permanent wilting point. The wilting point represents soil moisture at which the plant will not accept soil water, to plant this water is unavailable. Permanent wilting point (PWP) is the soil moisture content at which the plant will wilt and die. While there still may water in the soil, the plant is no table to extract sufficient water from the soil to meet it´s needs.

The soil water penetrates into the lower layers in the soil gradually through gravity. Sandy soils may infiltrate through available profile within a few hours but fine textured soils such as clay or loam may take it a few days. Only a portion of the available water is easily used by the plant. The maximum soil water deficit (MSWD) is the amount of water stored in the plant´s root zone that is readily available to plant. To prevent plant water stresses (PWS) an allowable depletion factor is used to calculate the manageable allowable depletion. This factor varies but it is usually around 50%, (Nyvall et al., 2002). Saturation occurs when all the voids in the soil are completely filled with water. Although there is plenty of water available to the plant at saturation, water uptake is seriously curtailed by the lack of oxygen in the soil at soil water contents greater than field capacity. Under the total volume of water in the soil it means the amount of water in the soil, which is determined by the following limit conditions: upper limit of soil water saturation and lower limit completely dry soil.

Soil water regime interact with air and soil temperature schedule is a fundamental factor affecting the biochemistry of the processes of growth and development of vegetation and hence the yield of agricultural crops.

The reasons for creating unbalanced water regime may be: zonal - subject to weather and climatic conditions of the place, locally - the orographic, hydrological and soil conditions of interest and combined the resulting combination of zonal and local conditions.

Soil water regime can be evaluated according to the state of soil moisture, climatic elements and the condition of the plants in the stand.

Soil moisture content, it means all forms of water in the soil, expressed as a percentage of weight or volume. Available soil water is the amount of water that plants are capable of with their roots from the soil taken. Numerically, this is a positive difference between the total content of soil water (except groundwater) and permanent wilting point, expressed in mm (i.e. liters per 1 $m^2$) or in %, (Havlíček et al., 1986).

## Materials and methods

This paper analyses the results of the agroclimatological measurements (field capacity and available soil water capacity) at the climatological station Hurbanovo in the vegetation periods from 1990 to 2013.

The soil water capacity was measured by the still gravimetric method under standard surface (bare, loam black soil). The soil samplings were carried out at the individual SHMI's agrometeorological stations in the warm half-year (from March, $1^{st}$ until October, $31^{st}$) on Thursdays.

This gravimetric method consists of directly determining the amount of water according to the difference in weight of wet and dried sample of the soil. The quantity of water in the soil is determined the following way: The extracted soil samples were weighed, and then they dried in the oven at 105 °C, after drying weighed again and the weight difference before and after weighing. The tested samples were taken from layers at the depths from 10 cm to 80 cm. To the calculation of the available water capacity of the soil (available soil moisture) is important to determine the physical properties of soil and hydrolimits. The available water capacity is determined by the calculating the retention or field capacity and wilting point as their difference. Water holding capacity is a multitude of capillary bound water, which can keep the soil relatively long time. It is therefore equivalent to a field water capacity, which it is determined in the field. When the soil water content is greater than the field capacity then already is not sufficiently aerated soil. The optimum soil moisture is between wilting point and field capacity.

For the processing agroclimatological characteristics of the other long-term series of the total atmospheric precipitation, air temperature and soil temperature there are used the results of the daily measurements in Hurbanovo during the same period as measurements the soil water capacity. The processed data file absence in some years, measurements at the beginning and the end of the vegetation period (VP), because it does not allow the current status of the soil. All used data were synchronized; the missing data of field capacity and the available soil water capacity were completed by the data from Beluša station using the method of modelling causality for 3 months in 1996.

**Results**

The resulting of the agroclimatological characteristics of examined available soil moisture in layers 0 - 80 cm below the soil surface in Hurbanovo during the vegetation period (VP) in the period 1990 - 2013 are evaluated as follows: The average air temperature was 15,2 $^{0}$C, the maximum, i.e. 27,1 $^{0}$C was reached at 23$^{th}$ week of the year 2003, the minimum was in 2$^{nd}$ week of the vegetation period in the year 2005 and it reached -2,6 $^{0}$C. The maximum rainfall in the vegetation period was 94,6 mm in 12$^{th}$ week of vegetation period in the year 2010. The minimum values of rainfall, i.e. 0,0 mm, they were recorded at least one week in the year. During the reporting vegetation period, in each week (except 19$^{th}$ week) it measured the minimal rainfall. In the year 1992, there were the most weeks (9) with zero precipitation. The long-term average of rainfall was 411,5 mm. The long-term average of precipitation in the cold season (CS) of years from the season 1989/1990 to 2012/2013 was 141,8 mm, the maximum precipitation, i.e. 251,7 mm was in cold seasons 2005/2006 and the minimum, i.e. 65,8 mm was reached in season 1989/1990.

The average soil temperature layering in the soil profile in Hurbanovo during vegetation periods from 1990 to 2013 is expressed in graphical form (Fig. 1). In the layer of 0 - 30 cm, there is the mean soil temperature 16,1 $^{0}$C with the peak in July (28,1 $^{0}$C), and the minimum in March (0,1 $^{0}$C). In the layer of 0 - 80 cm, there is the mean soil temperature 15,0 $^{0}$C with the peak in July (25,2 $^{0}$C), and the minimum in March (2,3 $^{0}$C).

The typical layering (isochrones) of the field water capacity (FC) in Hurbanovo is presented in the Fig. 2. These results of soil moisture layering show that maximum of field capacity in all soil profile occurs in spring months. This phenomenon is affected by the soil water storage obtained from winter precipitation (Fig. 6 and 7). The soil moisture (FC) reached to a depth of 30 cm values about 73 mm and the maximum reached value 142,1 mm in the long-term average. The soil moisture (FC) receives in the layer of 0 - 80 cm about 207 mm and the maximum of 324,6 mm per week in the long-term average. Minimum of field capacity generally occurs in summer, usually in some week of August. The condition of field capacity relatively balanced at the depths more than of 60 cm throughout all vegetation period.

The isochrones in the Fig. 3, 4 and 5 express the course of the available soil moisture (ASM) in mm gradually in the 10 cm layers to a depth of 80 cm below bare soil surface during warm seasons. There are visualized the results of the available soil water capacity during all analyzed period and especially in the years 2003 (extra dry season) and 2010 (extra wet season), see Fig. 6 - 9. The year 2003 was characterized by particularly extreme high temperatures during the season from May to August and by very low rainfall of the season from February to August. In the year 2010 was recorded very wet, there were record of rainfall and floods in Slovakia, it fell the most rainfall, at least since year 1881. In the Fig. 4, there can see that after extra dry weeks it leads to reversing the storyline, the upper layers of soil are supplied with the moisture from the lower layers.

The following analyze of results of determining amount and course of available soil moisture is evaluated from point of view of useable for plants, separately for plants with shallow roots (layer 0 - 30 cm) and plants with deep roots (layer 0 - 80 cm),( Tužinský et al.,2002). These results are visualized in the Fig. 6 – 9.

The Fig. 6 and 7 present the weekly courses of available soil moisture during the vegetation periods from 1990 to 2013, separately in years 2003 and 2010 and their relation to weekly total precipitation in the both chosen soil layers at the depths of 0 - 30 cm and 0 - 80 cm. The calculated values of available soil moisture show, that at the beginning of the vegetation periods is the soil water capacity relatively uniform and precipitation occurs in small amounts, then with the increasing temperature and thus to the increasing of the evaporation of soil water also, the soil water capacity in the soil profile, particularly in the surface layers, gradually decreasing. The repeated process of the increasing of the available soil moisture is beginning at first in the 25$^{th}$ week in the tested vegetation periods. The available soil moisture copied the courses of the new fallen precipitation, but it effects with the lag about two weeks in the layer 30 cm bellow the surface.

The upper limit for the classification "dry soil" is < 50% for the values of available soil moisture. Analyzing the results of long-term series from 1990 to 2013 of the minimum seasonal values of available soil moisture it was found, that these values of available soil moisture were in the layer of 0 - 30 cm some weeks with the available soil moisture < 50 %, in the year 2003 were seven consecutive weeks and opposite it only one week in 2010. This limit of "dry soil" appeared also in the layer of 0 - 80 cm, it was together of ten weeks in the year 2003.

The Fig. 8 and 9 show the long-term series of available soil moisture evaluated in vegetation periods and their relation to total precipitation in the previous cold seasons and vegetation periods also. The results of the average values of available soil moisture during all vegetation periods show, that values of available soil moisture copied the time course of air precipitation.

**Discussion**

The water content in the soil is determined by climatic conditions, soil properties and its cover. For the available soil moisture in the case of soil surface with plants it is necessary to have knowledge about rainfall conditions, evapotranspiration, soil type and structure, type of vegetation cover with its characteristic root system.

Our presented results of long-term gravimetric measurements in Hurbanovo are realized in the locality with the bare surface (without vegetation). The field water capacity during vegetation periods has significantly seasonal character which is strongly dependent on precipitation conditions not only during vegetation period, but especially in the spring months and surface coverage during the previous cold season (e. g. snow cover, leafs). The course of amount of the field water capacity in the soil layer depend of amount of precipitation, their previous moisture and from their further retention in the soil, therefore it shows a time lag wear course of total precipitation (Fig. 2 – 6).

The main tested characteristic in our paper is available soil water capacity (available soil moisture). The isochrones of available soil moisture are determinate for the average condition of vegetation seasons during the period from 1990 to 2013 and for years with the maximum and the minimum rainfall in tested periods, i.e. the vegetation period 2003 a 2010, see Fig. 3 - 5.

The weekly course of available soil moisture corresponds to the theoretical assumptions, i.e. the maximum values are at the beginning of vegetation period, with the gradual decrease, the minimum is usually entering in August, the repeated course of the increasing of available soil moisture occurs usually in October (Fig. 6 and 7). The long-term course of changes of ASM from year to year has irregular nature during 1990 - 2013, but it may be observed that years with extreme values is alternated until after two consecutive peaks, resp. lows, for example this are years 1997 - 2003. In the contrast, the seasonal average values of available soil moisture are upcoming to the average available soil moisture during 1990 - 2013 when it is occurred the subsequent to six years in a row. These results agree with the analogous characteristics for determine amount of available soil water capacity, which were especially calculated to determine the drought periods, (Takáč, 2013).

**Conclusion**

The published results of the analysis of the soil moisture during the vegetation seasons in Hurbanovo (1990 – 2013) could be applied by the study of climate changes and for the practical purposes in determining the extent and occurrence of drought and also for irrigation needs of Danube lowland region with prevailing black loam soil type.

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**Summary**

V článku sa analyzujú výsledky dlhodobého radu meraní celkovej a využiteľnej vodnej kapacity pôdy v Hurbanove počas vegetačných období (od začiatku marca do konca októbra) v rokoch 1990 až 2013. Merania vodnej kapacity pôdy sa uskutočňovali gravimetrickou metódou v týždenných intervaloch (vždy vo štvrtok) pod holým povrchom pôdy (hlinitá černozem). Využiteľná vodná kapacita bola vypočítaná z poľnej kapacity a bodu vädnutia ako ich rozdiel.

Agroklimatické podmienky v Hurbanove počas hodnoteného obdobia analyzovaného dlhodobého radu využiteľnej pôdnej vlhkosti sú charakterizované výsledkami synchronizovaných dlhodobých charakteristík teploty pôdy a vzduchu s dôrazom na zhodnotenie zrážkových pomerov vo vegetačných obdobiach ako aj predchádzajúcich chladných období roka.

V práci sú vizualizované výsledky meraní poľnej kapacity a využiteľnej vodnej kapacity pôdy v 10 cm vrstvách od povrchu až do hĺbky 80 cm. Z hľadiska praktického využitia získaných výsledkov je dôležité poznanie využiteľnej pôdnej vlhkosti vo vrstvách, v ktorých majú koreňové systémy rastliny a dreviny, preto sú podrobnejšie analyzované výsledky využiteľnej vodnej kapacity vo vrstvách 0 – 30 cm a 0 – 80 cm. Výsledky určovania využiteľnej pôdnej vlhkosti sú zhodnotené ako výsledky dlhodobých meraní 1990 - 2013 a podrobnejšie v

rokoch 2003 a 2010 s extrémnymi vlahovými pomermi počas vegetačných období.

**Contact:**

RNDr. Viera Horecká

Slovak Hydrometeorological Institute

Sk - 83115 Bratislava, Jeséniova 17

Slovak Republic

+421 2 59415170, viera.horecka@shmu.sk

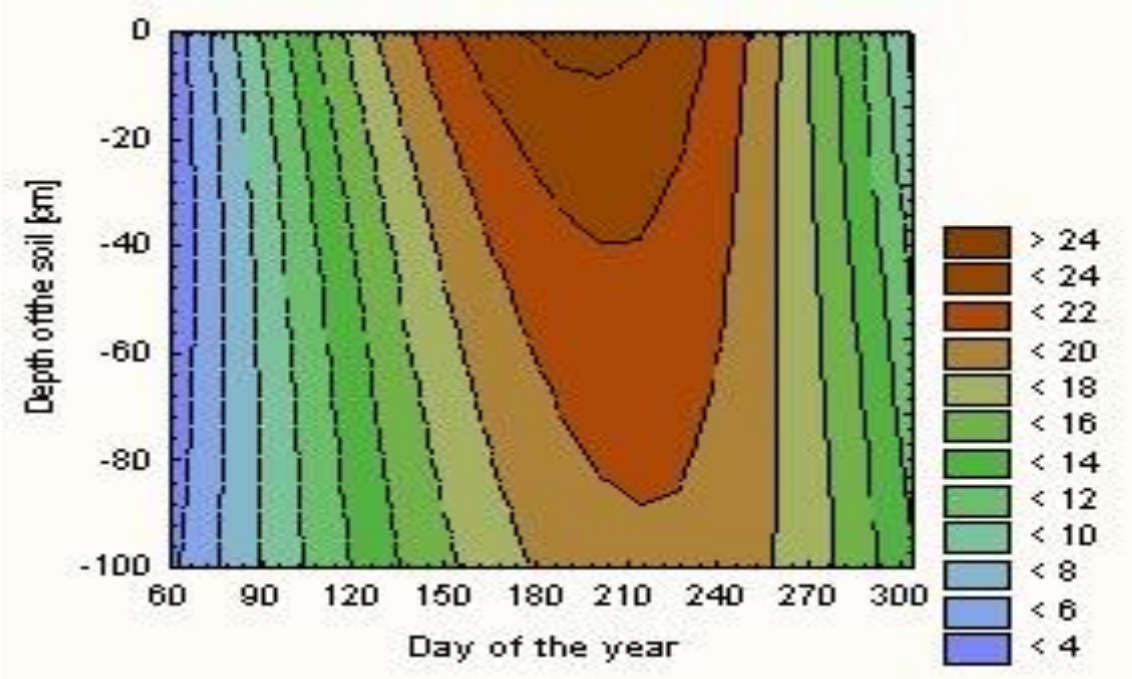


**Figure 1.** Isochrones of the soil temperatures at the depths of 0 to 100 cm in Hurbanovo during the vegetation periods 1990 – 2013.

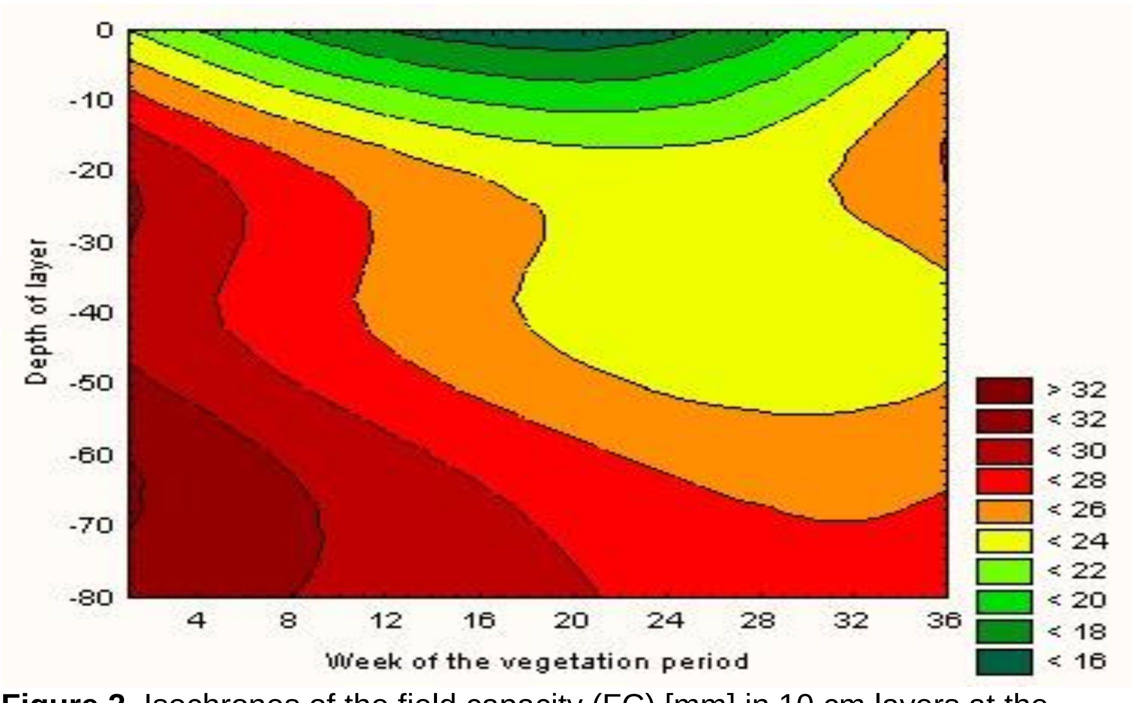


**Figure 2.** Isochrones of the field capacity (FC) [mm] in 10 cm layers at the depths from 10 to 80 cm in Hurbanovo during the vegetation periods 1990 – 2013.

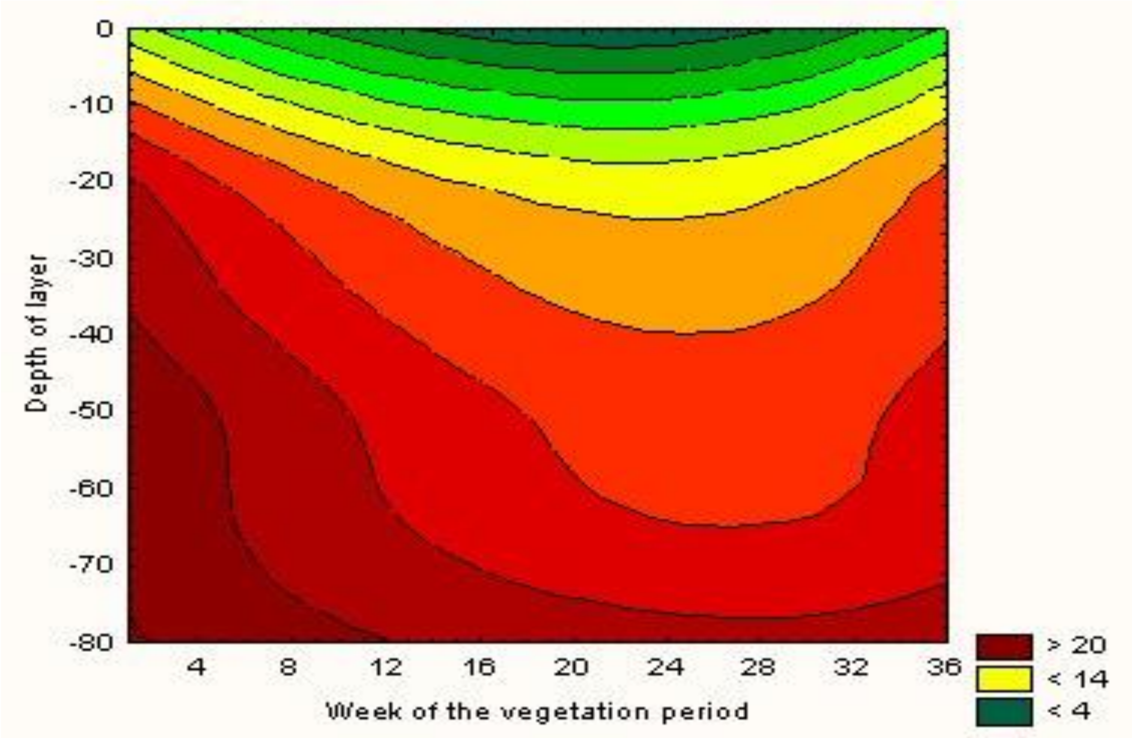


**Figure 3.** Isochrones of the available soil moisture (ASM) [mm] in 10 cm layers at the depths from 10 to 80 cm in Hurbanovo during the vegetation period 1990 – 2013.

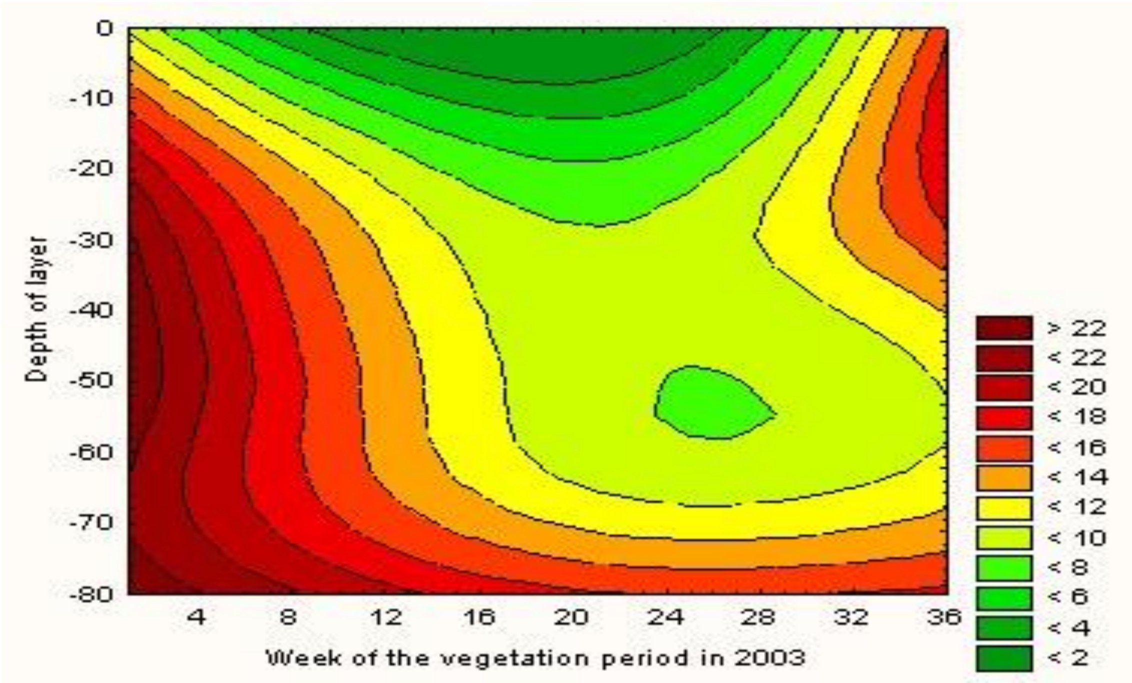


**Figure 4.** Isochrones of the available soil moisture (ASM) [mm] in 10 cm layers at the depths from 10 to 80 cm in Hurbanovo during the vegetation period in 2003.

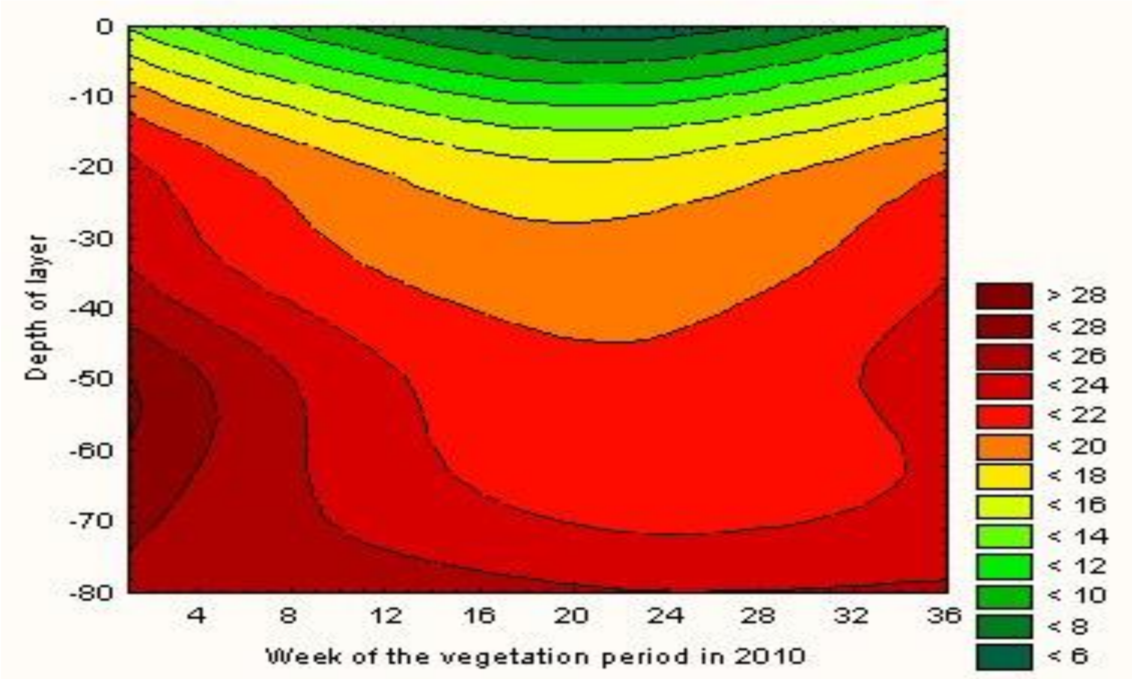


**Figure 5.** Isochrones of the available soil moisture (ASM) [mm] in 10 cm layers at the depths of 10 to 80 cm in Hurbanovo during the vegetation period 2010.

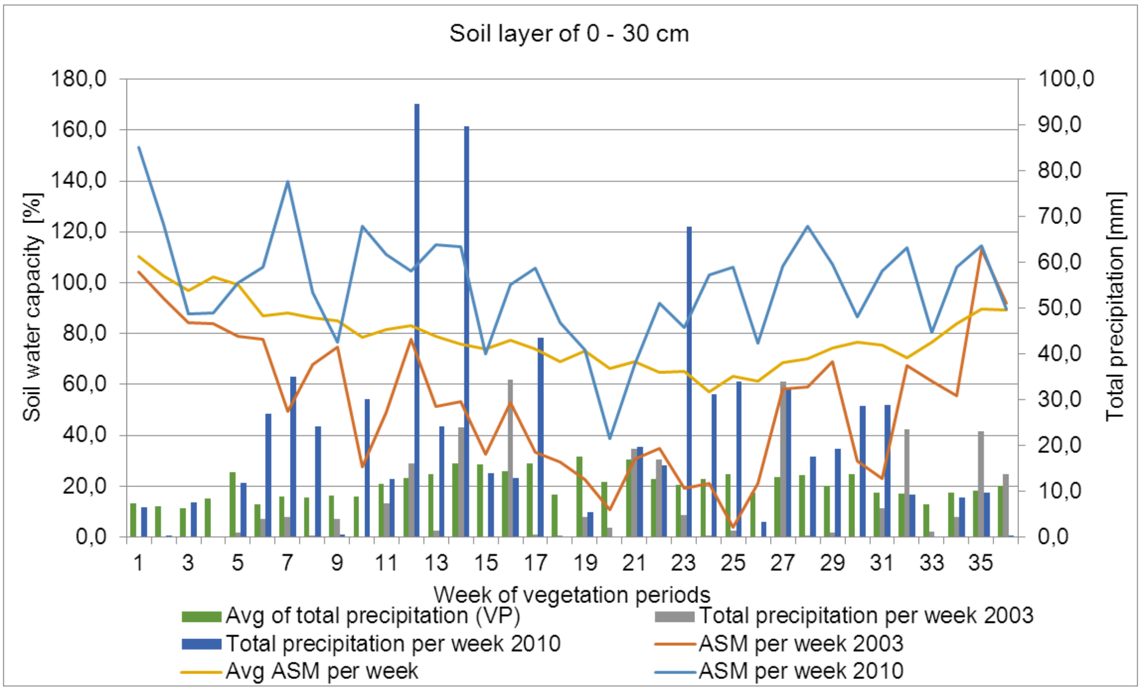


**Figure 6.** Courses of available soil moisture (Avg of ASM) [%] and average (Avg) of total precipitation per week [mm] in the soil layer 0 - 30 cm below the surface in Hurbanovo during the vegetation periods 1990 – 2013, 2003 and 2010.

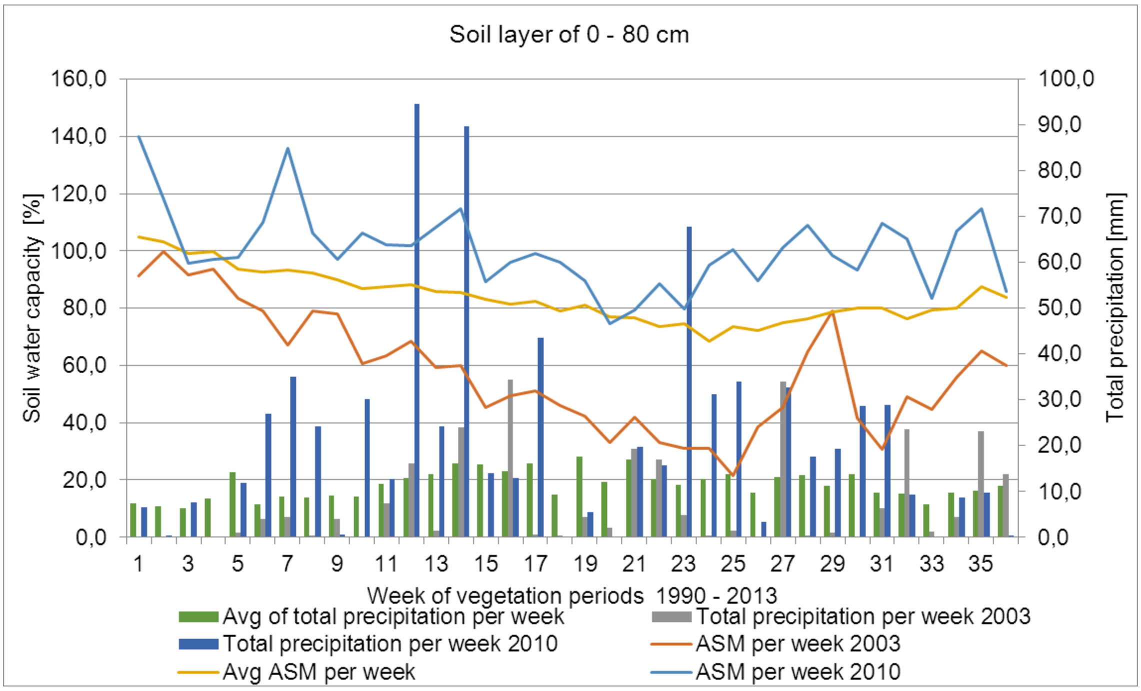


**Figure 7.** Courses of available soil moisture (Avg of ASM) [%] and average (Avg) of total precipitation per week [mm] in the soil layer 0 - 80 cm below the surface in Hurbanovo during the vegetation periods 1990 – 2013, 2003, 2010.

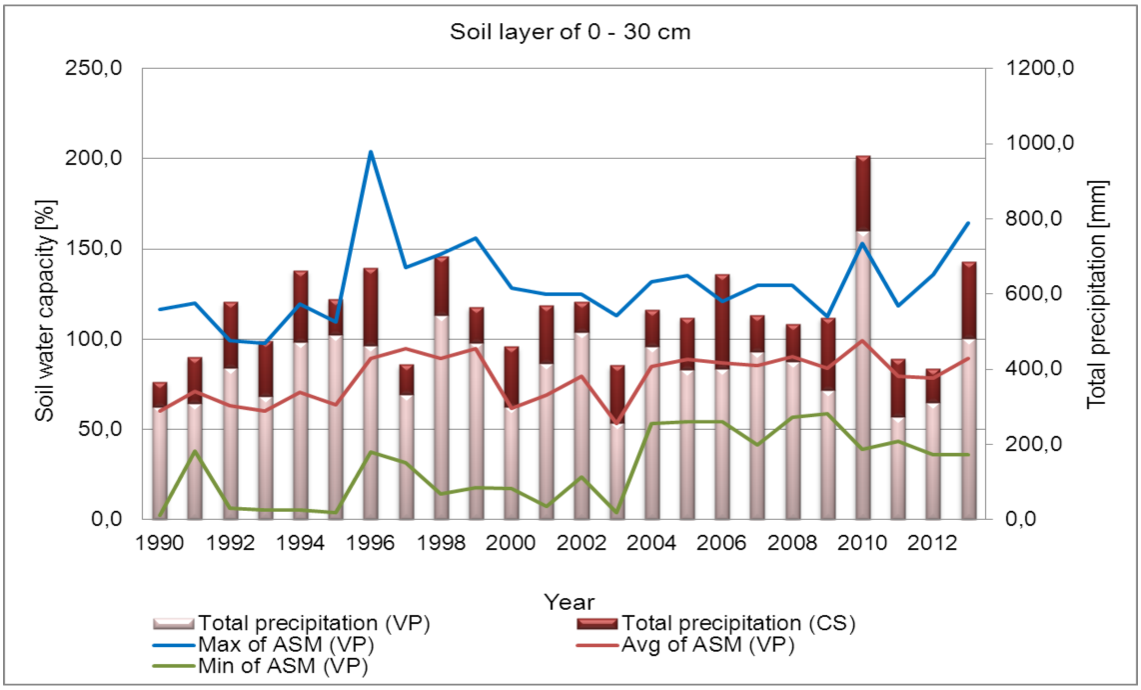


**Figure 8.** Long-term series of average available soil moisture (Avg of ASM) [%] in VP and total precipitation in VP and CS [mm] in the soil layer 0 - 30 cm below the surface in Hurbanovo during the vegetation periods 1990 - 2013.

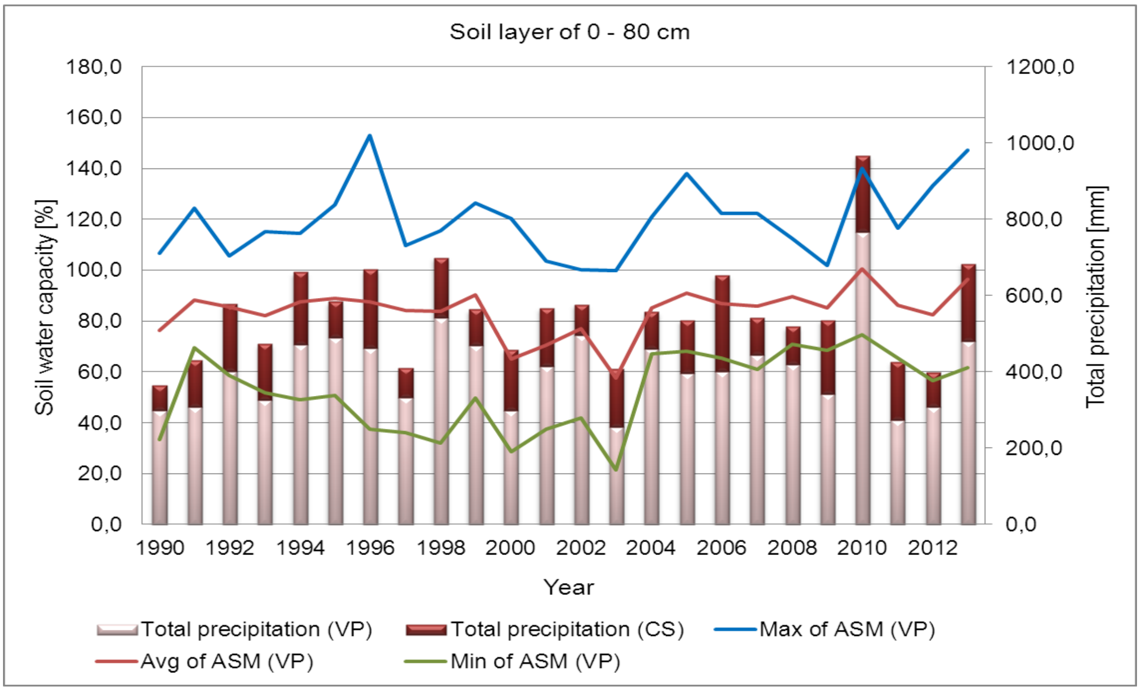


**Figure 9.** Long-term series of average available soil moisture (Avg of ASM) [%] in VP and total precipitation [mm] in the soil layer 0 - 80 cm below the surface in Hurbanovo during the vegetation period 1990 - 2013.