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THE ANALYSIS OF CHANGES OF WATER STORES IN CLAY SOIL ON THE BACKGROUND OF WEATHER CONDITIONS IN PUCZNIEW AREA

Anna Baryła, Wiesław Ptach
Warsaw Life Sciences University-SGGW

Summary

This paper examines the changes in stocks of water in clay soils against precipitation and changes in the groundwater table. The study was conducted during the summer period (May-September) in 2001 and 2002. According to the Kaczorowska`s criteria (1962) the year 2001 was very wet, and the 2002 – average. In 2001, ground water table was at a depth of 0 to 190 cm below ground surface level, and in 2002, from 50 cm to 150 cm below the surface. Water storages in the root zone (0-35 cm) developed in 2001 at the level of 100 to 125 mm, in 2002, from 88 mm to 122 mm.

Key words: water storage, clay soil, rainfall

INTRODUCTION

Soil moisture monitoring is becoming a very important issue in the context of declining water resources. At a present time when more and more frequently numerous extreme weather events are observed and the resulting excess or long-term shortage of water, monitoring of water content in the soil profile begins to play an important issue in water management of soils in agricultural areas. From agricultural management point of view, information about rainfall is very important as rainfall increases soil moisture and allows reduction of crop irrigation. The relationship between the changes of soil moisture and precipitation are the subject of many research works [Beldring et al. 1999, Bronswijk 1991, Żyromski 2001]. The aim of this study was to analyze the water storage in the root zone of clayey soil (layer 0-35 cm) versus the precipitation and groundwater level. The research presented in this paper was conducted in the period 2001 April 30

– 2002 October 1 at the area of the Warsaw University of Life Sciences (SGGW) Agricultural Experimental Station in Puczniew.

MATERIALS AND RESEARCH METHODOLOGY

The research was conducted on the experimental plot of Department of Environmental Improvement SGGW belonging to the WULS-SGGW Agricultural Experimental Station in Puczniew (AES). Puczniew is a town in the Lodz voivodeship. Geographically, the area is located between the uplands of southern Poland and lowlands of central Poland. This zone is a denuded, high plain moraine, composed primarily of clay and sandy soils and cut by the valley of the rivers of Ner, Zalewki (tributary of Ner) and Sroczki.

Arable lands of AES Puczniew are located on Quaternary formations created as a result of action of glaciers, mostly from parts of the boulder clay of older glacial moraine and sands from glacial accumulation with boulders on the boulder clay. The terrain is slightly corrugated with strong declines in the south and north, and a slight slope in the north-west direction. The ground level ranges from about 140 to 150 m above the sea level [Wanke, 1977]. Moisture conditions for Puczniew area are conducive to the agricultural production due to rainfall, with an annual total ranges from 500 to 650 mm. Length of the growing season is dependent on climatic conditions and usually lasts 210 days. The study was conducted on plot without vegetation. Meteorological data were obtained from the Puczniew meteorological station (station is under supervision of Institute of Meteorology and Water Management). The suction pressure of the soil was measured using a tensiometer with a length of 36.5 cm. Soil moisture was read from the pF curve for each suction pressure. The values of soil moisture were the basis for the calculation of water storage values in the analyzed layer with a thickness of 0 to 35 cm. The values of water resources were calculated using the formula:

$$z = \frac{h_0 \cdot W_0}{10} \text{ [mm]}$$

where:

z – storage of water in the soil layer [mm],
h_0 – layer thickness [cm],
W_0 – soil moisture [%].

The soil water storage values presented in graphical form, with marked water and soil constant values, were determined from laboratory analyzes and tests (Table 1) [Baryła 2004] based on:

- field water capacity (FC),
- permanent wilting point (WP).

In the analyzed soil profile are clay soils. Basic physical and retention properties characteristics of the analyzed soil profile are shown in Table 1.

Table 1. Physical and water retention properties of soils in Puczniew

Soil layer (thickness) [cm]	The group of the soil	Filtration coefficient [m d^{-1}]	Moisture corresponding to pF, % vol.					
			0	1	1.8	2.0	3.0	4.2
0-15	Light clay	0.05	37.7	37.5	36.4	35.7	30.1	23.0
20-25	Sandy clay	0.5	38.7	38.2	35.6	34.3	25.8	18.1
30-35	Loamy clay	0.2	35.7	33.1	29.5	28.6	24.2	19.7
70-75	Sandy clay	0.8	31.2	31.0	29.8	29.2	24.4	19.2

Source: Results of own testing.

RESULTS AND DISSCUSION

Observation results of rainfall, position of the groundwater table and soil water retention are shown in Figure 1. Analyzing the total rainfall for individual months of 2001 against the average rainfall of long period time from 1972 to 2002 [Baryła et al. 2012] (Table 3) it can be concluded that the total rainfall for the period May-September amounted to 584.5 mm and was 66% higher than the average precipitation of years 1972-2002 for that period. Year 2001 according to the classification of Kaczorowska [1962] was defined as very wet. At the time of research particularly humid months were July and August. Year 2002 in accordance with the Kaczorowska classification [1962] belongs to the average years. Total rainfall in the months of May-September was 326.0 mm; particularly wet month during the analyzed time in 2002 was May, and a very dry August.

Seasonal droughts are important events for the growth, development and health of plants . Using the criteria defined by Schmuck and Kozminski [1967], during the analyzed period the droughts of 9-17 rainless days occurred 3 times in 2002 while moderate droughts (l8-28 days) and long-term droughts did not occur. Rainless periods occurred in the July and August 2002. Droughts occurring during growing season have very negative impact on vegetation, particularly in the early months of spring, which is the time of maximum growth and development of plants. In Puczniew in 2001 and 2002, there was no drought during vegetation period. Research conducted by Radzka et al. [2010] showed that the observed significant decrease in potato yield in the two stations (Legionowo and Włodawa) was influenced by the increasing intensity of the drought in July.

Table 2. Average total precipitation (mm) over the period 1972-2002 and the amount of rainfall in 2001 and 2002, observed on the weather station of Puczniew

Year	Months												Year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2001	15.4	25.3	43.2	76.9	55.8	78.3	227	125.9	97.5	22	34.4	37	838.7
2002	33.6	71.2	27.5	22.5	127.5	78.9	46.8	23.1	49.7	67.8	40.4	8.1	597.1
1972-2002 mean [mm]	25.7	24.7	28.5	33.1	49.5	71.3	83.1	60.1	53.2	35.5	37.6	38.3	540.7

Source: Data received from Institute of Meteorology and Water Management.

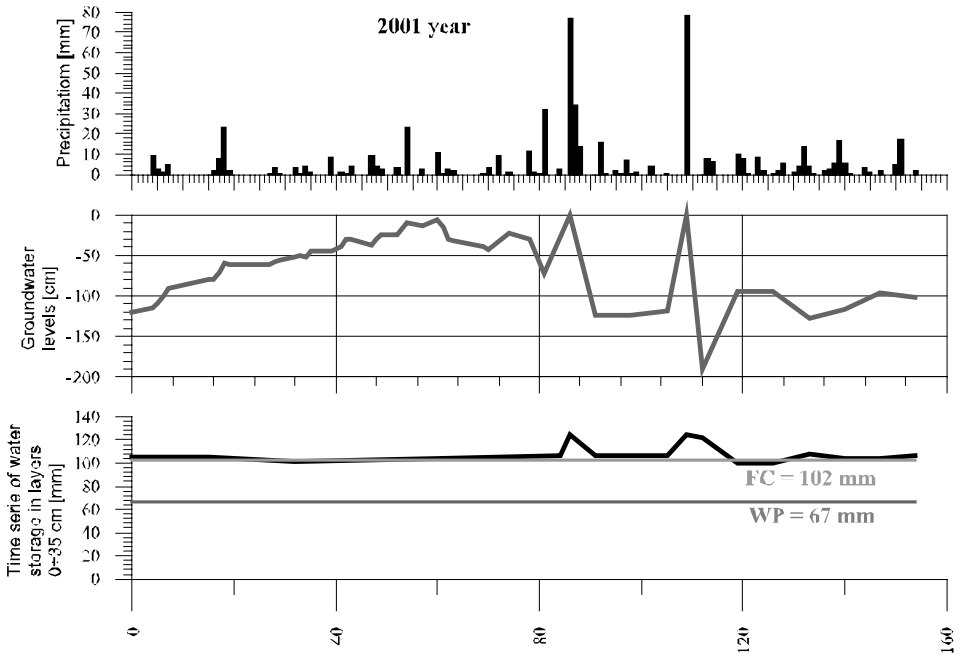
Table 3. Characteristics of rainfall conditions on the Puczniew meteorological station in years 2001– 2002 according to the Kaczorowska`s classification (1962)

Year	Months												Year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2001	d	a	vw	ew	a	a	ew	ew	vw	d	a	a	vw
2002	w	ew	a	d	ew	a	d	vd	a	vw	a	ed	a

Explanation: ed –excessively dry, vd – very dry, d – dry, a – average, w – wet, vw – very wet, ew – excessively wet.
Source: Results of own testing.

In 2001, the groundwater measurements were conducted in the period from April 30 to October 1 (Fig. 2). During this period, the groundwater level was observed at a depth of 0 to 190 cm below surface ground level. On the soil surface water was observed only two times: during the storm rainfalls on 25.07.2001 and 17.08.2001 with total equal to 77 mm d^{-1} and 78.7 mm d^{-1}, respectively. After the rains, over the next seven days water level in the wells decreased by more than 120 cm and 190 cm. The lowest value of water level was recorded on 20 of August, when the ground water level was recorded at the depth of 190 cm. In 2002, ground water level ranged from 50 cm to 150 cm below the soil surface. During the measurements performed in 2002 rainfalls were not as high as in 2001, therefore, the level of the water table had never been observed on a soil surface. In 2002, from the beginning of June groundwater dramatically decreased its level, and from 8.04.2002 it was observed below the depth of the well. In 2001, the groundwater level was observed in the range of 0 to 190 cm. In 2002, at the same time, the groundwater level ranged from 50 cm to less than 200 cm below the soil surface. A large diversity of groundwater table position observed in 2001 and 2002 was caused by the rainfall that occurred in the measuring period (2001 - 584.5 mm, 2002 -326.0 mm).

Climatic conditions such as precipitation and air temperature are the main factor influencing the depth of groundwater level and determining the volume of water stored in the soil profile [Liberacki 2011, Oleszczuk et al. 2012].

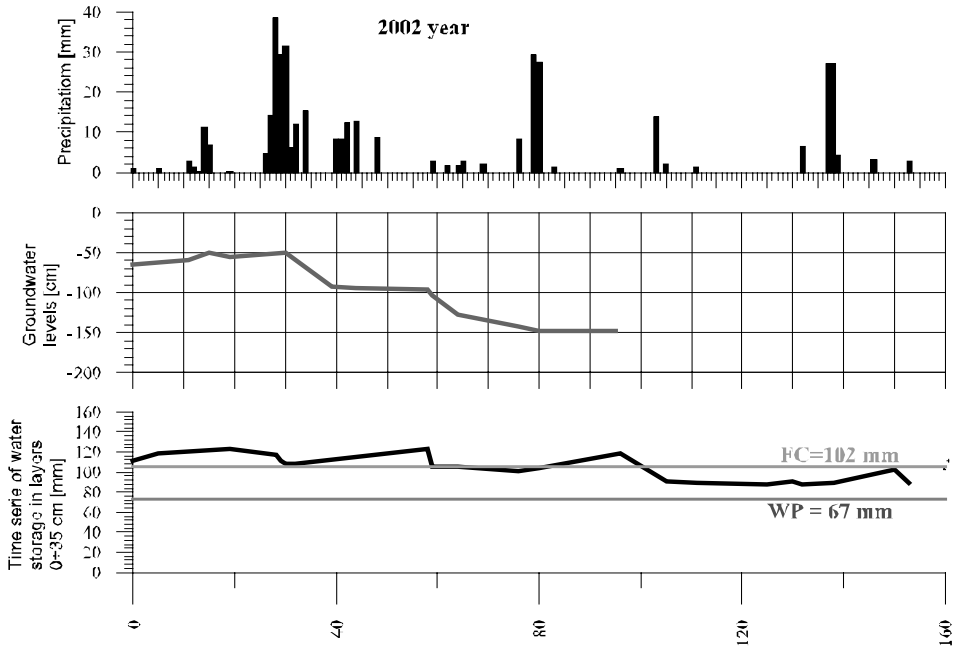


Source: Results of own testing.

Figure. 1. Time series of water storage in layers 0÷35 cm of analyzed soil profiles in Puczniew in the year 2001

The highest value of water storage (125 mm) occurred in June and August after heavy rainfalls. Soil profile was saturated. It was found that in three months (April, May and June), water storage amount was close to field water capacity and was in the range of water available to plants, which ranged from 67 to 102 mm. The greatest variability of groundwater resources was reported in July and August, when due to heavy rains ground water storage increased by about 20 mm.

During the measurement period the water storage in the root zone (0-35 cm) did not fall below the value of permanent wilting point. In the case of very wet years, the water storage remained at a level similar to that of field water capacity, while the rainfall over 30 mm was followed by a significant increase in water storage. A study done by Biniak et al. [2012] showed that the highest increase in soil retention in the not covered mineral soil of Wroclaw-Swojec occurred after rainfall exceeding 10 mm per day. For the Puczniew area there were no significant changes in soil retention with daily rainfall exceeding 10 mm. Such a fact was pointed out by Klamkowski et al. [2011] and Treder and Konopacki [1999]. This may be due to drying topsoil due to the presence of high air temperatures, contributing to topsoil incrustation, which in turn could hinder the penetration of rain water into the soil profile and increased surface runoff.

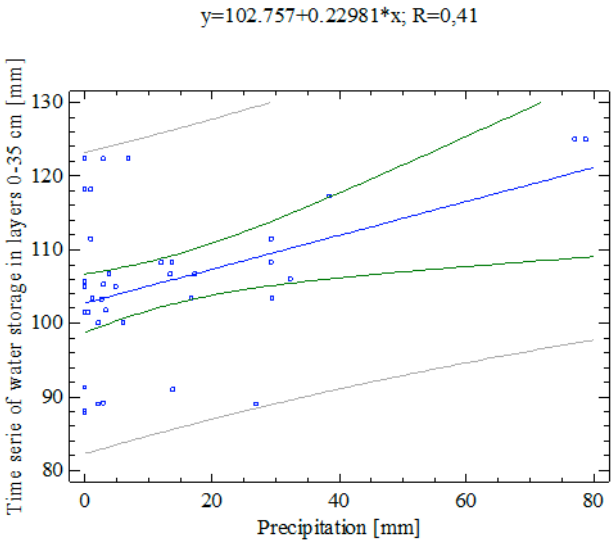


Source: Results of own testing.

Figure 2. Time series of water storage in layers 0÷35 cm of analyzed soil profiles in Puczniew in the year 2002

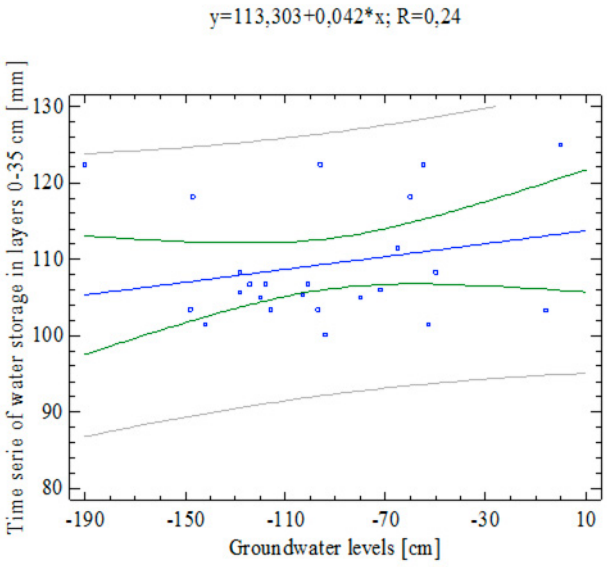
From the beginning of May 2002, water storage in the layer 0 to 35 cm of soil profile exceeded the level of Field Water Capacity, and from August 8 water stored in soil began to decrease, not exceeding the limit of permanent wilting point (67 mm for the soil layer 0 to 35 cm).

It should be noted that in period of 5-13 July 2002 nine days without precipitation occurred, in 24 July - 3 August 2002 11 days without precipitation occurred, and between 16 and 28 August 2002 - 12 days without precipitation occurred, which resulted in a significant reduction in both the groundwater table and water supplies. Analysis of the relationship between rainfall and changes in soil water storage indicates a low significance of statistical relationship between them (Fig. 3). A similar relationship can be observed between soil water storage in the 0-35 cm layer of soil profile and groundwater level (Fig. 4).



Source: Results of own testing.

Figure 3. Relationship between water storage in 35 cm soil layer and precipitation



Source: Results of own testing.

Figure 4. Relationship between water storage in the 35 cm soil layer and position of groundwater level

CONCLUSIONS

1. In the analyzed years 2001 and 2002, total precipitation amounted to 838.7 mm and 597 mm, and was higher than the average precipitation of a long period (1972-2002) amounting to 540.7 mm. This allowed including 2001 year to the very wet, and 2002 to the average category.

2. The study results showed that, for the analyzed soil, the dynamics of the depth of the groundwater table and soil water storage showed a similar periodicity and were determined by the amount and distribution of precipitation.

3. The highest values □□of soil water storage, was recorded in July and August 2001, after the storm rainfalls of 77 mm d^{-1} (July) and 78.7 mm d^{-1} (August). In those terms, the position of the groundwater table was the highest - equal to soil surface level.

4. Unfavorable distribution of precipitation caused that July 2002 was a dry month, but August 2002 was a very dry month, as the consequence of this was a significant decrease in water storage in the analyzed soil profile.

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[1]Anna Baryła
[2]Wiesław Ptach
Warsaw Life Sciences University – SGGW
Faculty of Civil and Environmental Engineering
[1)] Department of Environmental Improvement
[2)] Department of Civil Engineering
Nowoursynowska Str. 159, 02-776 Warsaw, Poland
E-mails: anna_baryla@sggw.pl
wieslaw_ptach@sggw.pl