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Research Article

CHANGES IN THE MOISTURE CONTENT OF THE MIDDLE FEN SOILS IN THE ODRA RIVER VALLEY IN THE REGION OF BRZEG DOLNY IN THE VEGETATION PERIODS 2004–2009

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ABSTRACT
In soils, where the water table is deeply located and has a minor impact on the moisture content of the surface layer, we are dealing with the precipitation-and-water type of water management. If underground water level is close to the surface, the top stratum of the soil, apart from precipitation, is additionally fed by water absorption from underground waters. Then we are dealing with ground-and-water type of management. We consider such types of water management of soil in the area of the left-bank valley of the Odra river, above and below the dam in Brzeg Dolny. The dominant soil types here are middle fen soils, based on middle clay and heavy clay as well as loam, which, in conditions of either excess or deficiency of moisture, are difficult to cultivate. The work compares water management of two soil profiles in vegetation periods between 2004 and 2009. The formation of underground waters, meteorological conditions and the course of the water reserves in the strata 0–50 cm and 0–100 cm were estimated with various supplying conditions of the active stratum of the soil. The volume of the supply with percolated water from underground water of the layer 50–100 cm on approximately 75–90 mm was also estimated. This value was mainly dependent on the depth of the retention of the water table of the soil profile above the level in Brzeg Dolny.

Keywords: moisture, soils, water, retention.

INTRODUCTION

River valley, natural between-field depressions and low peatbogs in Polish lowland account for about 11% of the total country area [25] and constitute specific habitats of characteristic water and soil proportions. They are characterized by a great production potential, their non-production role is growing including, inter alia, landscape and health qualities. Management and agricultural usage of river valleys normally require the management of water relations of the soils [4, 6, 14, 25]. The water factor, which is very changeable, determines the soil cover, plant cover and economic usage and is subject to changes according to human activities. Particularly important changes to the water factor are caused by river management, embankments, as well as exploitation of dams [18, 19, 22], retention reservoirs, fish ponds [8] and irrigation-and-drainage devices.

Rational water management is a key issue both for agriculture and other spheres of life. The dynamics of the soil moisture in the river valleys significantly depend on the process of meteorological and hydrological phenomena (river floods, infiltration from the riverbed, supply from underground waters) [17]. In many centres research is carried out regarding the evaluation of the impact of agro-meteorological factors on the formation of water resources of the soil, the impact of the depth of the underground water retention and the influence of water condition in watercourses on the volume of the water reserves in soil [5, 10, 12, 15, 16, 20, 23, 24]. The results of the works show that the fluctuations in the soil moisture mainly depend on the amount and distribution of precipitation. The meteorological conditions determine the dynamics of changes in the underground water depth as well as the volume of the water reserves in the upper soil strata [11, 13, 19]. Suitable types of cultivation or the methods of management of for example straw, do not have a significant impact on the level of moisture in soil [3].

The knowledge of management of soil and the dynamics of their moisture content mainly refers to the vegetation period, there are more and more works regarding variations in water resources in winter periods or identification of post-winter water resources in soil [1, 2, 9].

The main source of water resources in soil is precipitation. Plants absorb from the soil significant amounts of water, but only about 0.5% is used to build organic matter. Water in soil is not entirely available to, and utilized by, plants. Part of it evaporates directly from the soil, part soaks in below the root access or flows superficially. Also water contained in the roots' penetration zone is not always available for them. Plants can use only about 50% of the soil water [26]. In soils, where the water table is deeply situated and has only a slight impact on moisture content of the top stratum, we deal with a precipitation-and-water management of water. If the level of underground water is near to the ground level, the top stratum of soil, despite precipitation, is additionally supplied by wet soil from the underground waters. Then we deal with a ground-and-water type of management. We deal with such types of water management of soil in the area of the left-bank valley of the Odra river above and below the dam in Brzeg Dolny [22]. The dominant soil types here are middle fen soils, based on middle clay and heavy clay as well as loam, which, in conditions of either excess or deficiency of moisture, are difficult to cultivate. The aim of this work is the evaluation and comparison of water management in middle fen soils located in the Odra river valley below and above the dam in Brzeg Dolny against the meteorological conditions and the depth of the underground water retention as well as the course of water levels in the Odra below and above the dammed up level.

RESULTS OF THE RESEARCH

Changes in the content of moisture and the process of water reserves on selected soil profiles with various supply conditions of the active stratum of soil were subject to analysis. Two profiles were selected (marked as 2 – below water level and 5 – above the dam at Brzeg Dolny), distant from each other by about 5 km (Figure 1), wherein the content of moisture of the soil was measured on a monthly basis using a drier-and-weight method and the total of water reserves in strata

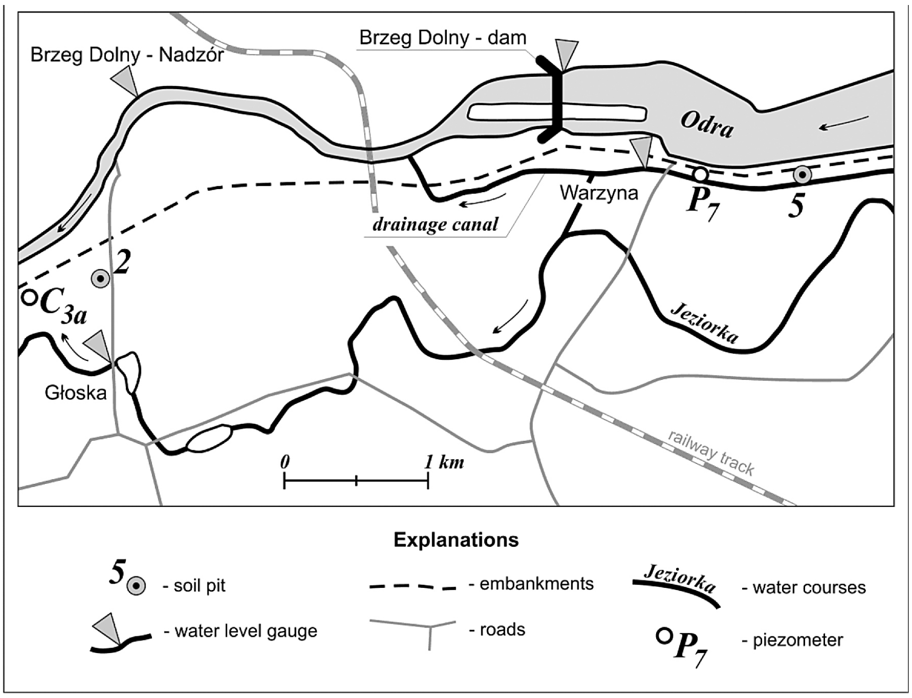

Figure 1. Localization of the selected soil profiles in the region of the Brzeg Dolny dam

0–50 and 0–100 cm were measured. Samples of soils were taken with a soil drill in three repetitions from strata 0–10, 20–30, 40–50, 65–75, 90–100 cm to the depth of the retention of the water table. Water hardly accessible for plants was determined from the difference between moisture with pF = 3.0 and pF = 4.2, whereas water that is easily accessible from the difference between pF = 3.0 and pF = 2.0 [22, 26]. The analysis was carried out for the vegetation periods between 2004 and 2009. On both research stations there were arable grounds. The selected profiles are built in the top stratum from compositions, hardly permeable to a depth of about 1.0 m (middle clay), underlain with permeable compositions (loose sand and loamy sand). The correct density of the analyzed soil adopts values between 2.51 and 2.66 $g \cdot cm^{-3}$, the porosity between 30.6 and 46.9%. In the top (one meter) stratum dominating are pores with diameter <3 μm, in deeper layers – pores with diameter of 300–30 μm [18].

Table 1 contains monthly sums of precipitation for the precipitation station in Brzeg Dolny and average monthly air temperatures for the station Wrocław-Strachowice in the periods IV–IX from 2004–2009 against corresponding average values for the period between 1954 and 2000. The precipitation station in Brzeg Dolny and the station in Wrocław are meteorological points situated nearest to the area on which the research of soil moisture were carried out. Table 1 also contains the evaluation of the periodical total of precipitation in the area, including summer half-years estimated as normal (2005 and 2006), medium dry (2004 and 2008), medium wet (2007) and wet (2009). With respect to thermal aspects, all analyzed periods, in relation to the period between 1954 and 2000, were estimated as warm.

River valleys are areas of close contact of underground and surface waters [4, 7]. Water interaction is intensified when we deal with surface water retention. In the valley above the barrage at Brzeg Dolny, the local conditions are of a pressure type, the underground water level is stable and mainly depends on the water condition in the Odra and in the drainage ditch and watercourse of Jeziorka (Figure 1). Below the dam, in the Odra bed, there are intensive processes of linear and local erosion. The erosion of the river bottom causes lowering of the water levels in the Odra which affects the water conditions in the adjacent valley [21].

Table 2 correlates monthly average depths of the retention of the water table in piezometers C_{3a} (below the dam) and P_7 (above the dam), located nearby soil pits and respectively approximately 150 and 90 m from the Odra bed (Figure 1). Whilst taking the measurements, in the periods between April and September in the years from 2004 to 2009, in piezometer P_7 the water table was in particular months on average between 0.42 and 0.92 m below the ground level. The water fluctuations were minor and depended mainly on the water levels in the Odra. However in piezometer C_{3a} the water table was significantly below 1.0 m from the ground surface, in particular months averaging between 2.21 m and 5.07 m – in the sands retaining under the top

Table 1. Monthly sums of precipitation P [mm] – including evaluation of the precipitation levels of the V–X half-year for the precipitation station in Brzeg Dolny and monthly average air temperatures t [°C] for the station Wrocław-Strachowice in the periods IV–IX from the years 2004–2009 against the values from the years 1954–2000

Specification		IV	V	VI	VII	VIII	IX	V-X	Evaluation
1954–2000	P [mm]	39	60	72	80	67	48	368	
	t [°C]	8.0	13.3	16.6	18.1	17.5	13.5	14.6	
2004	P [mm]	24.8	49.4	52.4	82.7	39.7	31.0	294.0	medium dry
	t [°C]	9.5	12.8	17	18.5	19.5	13.9	15.3	warm
2005	P [mm]	19.4	93.0	85.3	94.4	60.5	28.3	365.0	normal
	t [°C]	9.3	14.0	16.9	19.7	17.5	14.8	15.4	warm
2006	P [mm]	50.1	38.2	65.0	12.7	210.5	14.1	396.0	normal
	t [°C]	9.4	13.9	18.5	23.3	17.1	15.7	16.6	warm
2007	P [mm]	3.1	45.6	120.0	147.7	52.7	33.4	431.0	medium wet
	t [°C]	10.5	15.6	19.5	19.2	18.8	12.6	15.6	warm
2008	P [mm]	60.1	29.8	39.4	60.7	61.9	23.5	264.0	medium dry
	t [°C]	8.7	14.3	18.8	19.9	18.7	13.3	15.7	warm
2009	P [mm]	12.0	99.7	131.2	94.9	39.5	8.9	455.0	wet
	t [°C]	12.2	14.2	15.6	19.4	19.4	15.6	15.3	warm

Table 2. Monthly average depths of the retention of the water table [m] and the fluctuation amplitude [m] in piezometers C_{3a} (below the dam) and P_7 (above the dam)

Specification		IV	V	VI	VII	VIII	IX	Amplitudes
2004	C_{3a}	3.52	4.08	4.52	4.86	5.21	5.30	1.78
	P_7	0.70	0.60	0.51	0.49	0.53	0.51	0.21
2005	C_{3a}	3.76	4.14	4.43	4.69	4.86	4.78	1.10
	P_7	0.92	0.77	0.60	0.53	0.53	0.51	0.41
2006	C_{3a}	2.21	3.11	4.11	4.56	4.28	4.30	2.35
	P_7	0.77	0.74	0.67	0.71	0.68	0.58	0.19
2007	C_{3a}	4.07	4.64	4.88	4.95	5.07	4.54	1.00
	P_7	0.42	0.44	0.46	0.47	0.69	0.76	0.34
2008	C_{3a}	4.46	4.35	4.58	4.95	4.89	4.88	0.6
	P_7	0.62	0.61	0.61	0.57	0.61	0.54	0.07
2009	C_{3a}	3.64	4.42	4.43	3.48	4.15	4.71	1.07
	P_7	0.92	0.74	0.60	0.83	0.81	0.76	0.32

layer of the fen soils, having no effect on the water management of the active soil stratum.

The analysis of monthly average depths of the retention of the underground water from average monthly water levels in the Odra, made for the years 1976–2005 and for the areas distant by 120–550 m from the Odra bed, showed the following relations [21]:

- 120 m from the Odra bed
  $Hg = - 0.5042 \cdot H + 417.71$, r = 0,87;
- 220 m from the Odra bed
  $Hg = - 0.4083 \cdot H + 304.31$, r = 0,79;
- 550 m from the Odra bed
  $Hg = - 0.2565 \cdot H + 230.83$, r = 0,56;

where:

Hg– average monthly depth of retention of the water table [cm],
H – average monthly level of the water in the Odra according to the water-level gauge in Malczyce [cm],
r – correlation coefficient.

Tables 3 and 4 compile the values of the maximum and minimum water reserves measured in monthly average periods as well as their % participation in relation to the field water capacity in both analyzed pits (in strata 0–50 cm and 0–100 cm from the period IV–IX between 2004–2009). Figures 2 and 3 depict the water reserves in half a meter and a meter deep stratum of soil in the analyzed profiles and vegetation periods of the years 2004–2009 against the water reserves with the field water capacity and the capacity from a dry period.

In particular research periods of the analyzed years, the highest values of the water reserves in strata 0–50 cm and 0–100 cm in the soil profile below damming (2) were measured at the beginning of the vegetation period. Their volumes were affected by the post-winter retention values. In medium dry years the measured water reserves in the stratum 0–50 cm constituted 88–110% of the reserves equivalent to the values of the field water capacity, in normal years 83–104%, and in medium wet and wet years 108–114%. In the following months of the vegetation periods a stable reduction of the moisture content of the top stratum was observed. In a medium dry period of 2004, by the middle of April the reserves of water were below the value equivalent to the field water capacity, and in the period IV–IX 2008 in the middle of May. The lowest values of the moisture content and measured values of the water reserves were most often recorded in July and August. In medium dry periods the minimum values of the water reserves constituted only 48–50% of the value equivalent to the field water capacity, in normal periods 50–68%, in medium-wet and wet periods 63–77%. The dynamics of the moisture content and the process of water reserves in the stratum 0–50 cm were very diversified, and the changes in the reserves strictly depended on the amount and distribution of precipitation. The moisture content and the changes in the water reserves in the stratum 0–100 cm in the analyzed periods had a very similar process to the top half a meter stratum. In no measured period was a supply from the underground water recorded. The highest values of the water reserves were also recorded at the beginning of the considered periods, the lowest in July and August, particularly in the medium-dry periods of the years 2004 and 2008.

Table 3. Maximum and minimum water reserves and their percentage participation in relation to the field water capacity (PPW) in the 0–50 cm and 0–100 cm strata in the soil profile below the dam (2) in the periods IV–IX from the years 2004–2009

Period, year	Strata [cm]	Water reserves			
		Max. [mm]	%FWC	Min [mm]	%FWC
IV–IX 2004	0–50	128	88	72	50
	0–100	223	98	140	62
IV–IX 2005	0–50	151	104	98	68
	0–100	254	112	175	77
IV–IX 2006	0–50	120	83	73	50
	0–100	200	88	130	57
IV–IX 2007	0–50	157	108	112	77
	0–100	233	103	177	78
IV–IX 2008	0–50	160	110	69	48
	0–100	250	110	110	48
IV–IX 2009	0–50	166	114	91	63
	0–100	247	109	148	65

Table 4. Maximum and minimum water reserves and their percentage participation in relation to the field water capacity (PPW) in the 0–50 cm and 0–100 cm strata in the soil profile above the dam (5) in the periods IV–IX from the years 2004–2009

Period, year	Strata [cm]	Water reserves			
		Max. [mm]	%FWC	Min [mm]	%FWC
IV–IX 2004	0–50	186	101	156	85
	0–100	352	117	311	103
IV–IX 2005	0–50	179	97	158	86
	0–100	342	114	296	98
IV–IX 2006	0–50	178	97	149	81
	0–100	350	116	308	102
IV–IX 2007	0–50	182	99	160	87
	0–100	352	117	298	99
IV–IX 2008	0–50	183	99	158	86
	0–100	346	115	305	101
IV–IX 2009	0–50	186	101	128	70
	0–100	345	115	266	88

For the soil profile from the Odra valley above the dam at Brzeg Dolny (5), in the vegetation periods of the analyzed years, the calculated sums of the water reserves were characterized by a significantly lower changeability compared to the reserves in the soil profile from the areas below the dam. Regardless of the evaluation of the precipitation conditions in a given period, the water reserves in the stratum 0–50 cm were in the range of water easily accessible for plants. Maximum and minimum measured values of the water reserves were recorded in various periods in particular years and constituted respectively between 97 and 101% of the value of the field water capacity (maximum values) and between 70 and 87% of the value of the field water capacity (minimum values). Continuous supply from the underground waters had a significant effect on the volumes of the water reserves and the process of moisture content in a meter deep stratum of the soil profile. The water table was usually at the depth of 50–90 cm regardless of the precipitation level. Maximum and minimum measured values of the water reserves in a meter deep stratum of soil were respectively from 114 to 117% of the field water capacity and from 88 to 103% of the field water capacity. Low levels of precipitation and their unfavourable distribution did not have a remarkable

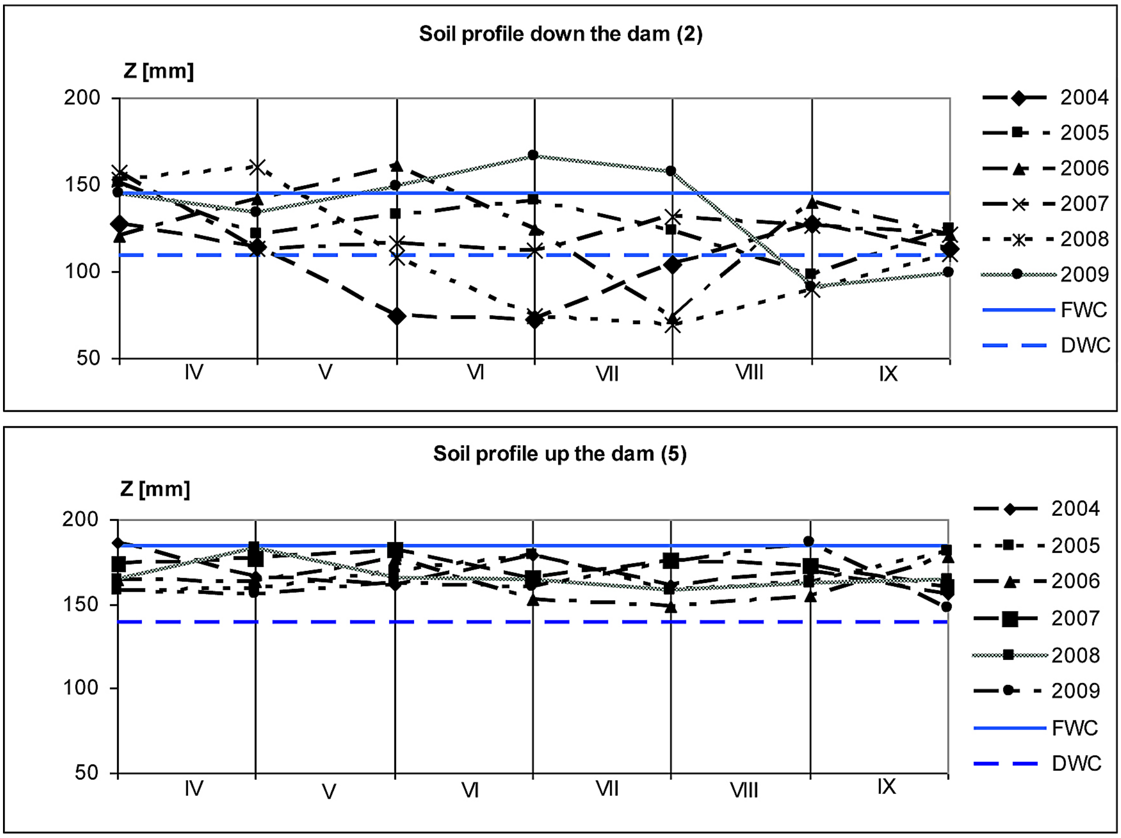

Figure 2. Water reserves in 0–50 cm soil stratum Z [mm] in soil profiles down and up the dam in vegetation periods in years 2004–2009 against the field water capacity (FWC) and drought water capacity (DWC).

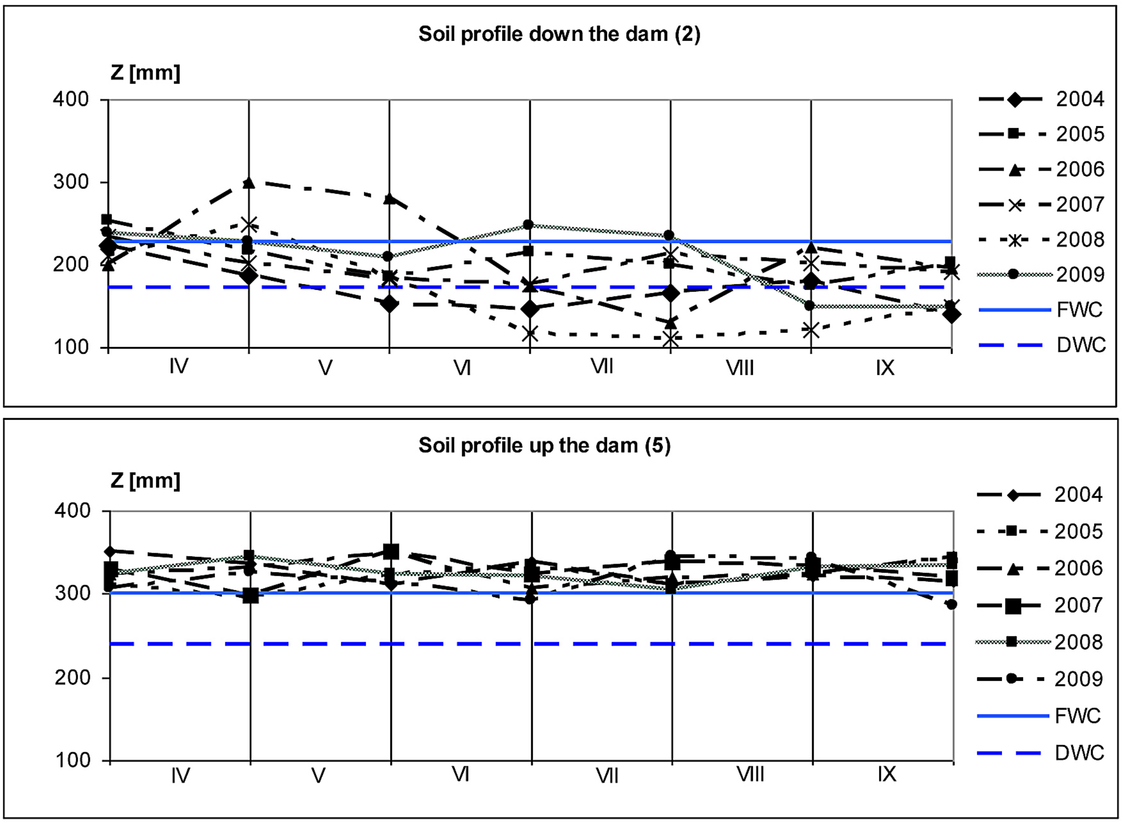

Figure 3. Water reserves in 0–100 cm soil stratum Z [mm] in soil profiles down and up the dam in vegetation period in years 2004–2009 against the field water capacity (FWC) and drought water capacity (DWC)

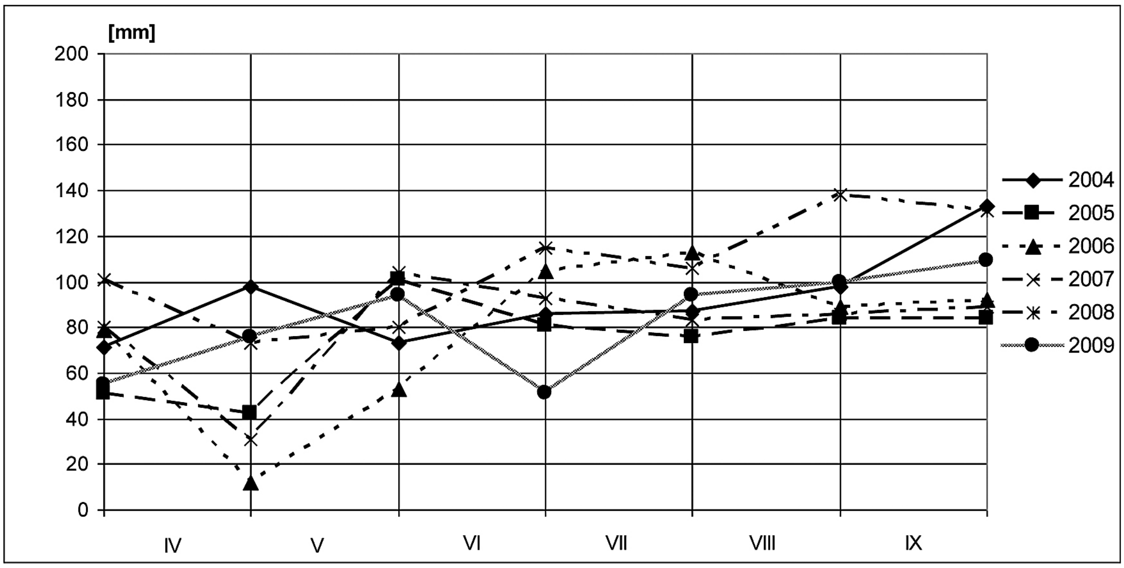

Figure 4. Differences in water reserves [mm] between soil profiles up and down the dam in 50–100 cm stratum

effect on the moisture content and changes in the water reserves in the top stratum of soil.

Differentiation in the volumes of water reserves in the analyzed middle fen soils of the Odra valley from Brzeg Dolny region, particularly in the 50-100 cm stratum, resulted from a different method of supply of the soil. Figure 4 represents the process of the differences in the soil reserves in the 50-100 cm stratum between the profiles under discussion for particular analyzed years. The smallest differences were usually recorded at the beginning of the vegetation period, in the following months the differences were getting greater, particularly in the medium-dry years. The analysis of the material gathered enabled the evaluation of the volume of the supply with wet soil from the underground waters of the 50-100 cm stratum on approximately 75-90 mm. This value mainly depended on the depth of the retention of the water table of the soil profile above the barrage at Brzeg Dolny.

CONCLUSIONS

1. The research carried out in the region of the dam at Brzeg Dolny showed that constant damming of a river has an effect on the depth of the underground water retention as well as on the water management of middle fen soils in the adjacent valley. In the analyzed vegetation periods of the years 2004–2009 the water table in the valley below the dam was retaining deeply, in particular months average from 2.21 to 5.30 m below the ground level. In the valley above the dam the present conditions were of a pressure type and the underground water level was stable, average from 0.42 to 0.92 m below the ground level.
2. The dynamics of the moisture content and the process of the water reserves in the soil of the valley below the dam in the strata 0-50 and 0–100 cm was dependent on the amount and the distribution of the rain water. In the analyzed periods and strata the water reserves were respectively from 69 to 120 mm and from 110 to 254 mm, often being below the value corresponding to the capacity of the dry period. However, an additional effect on the moisture content of the active stratum of the soil from the valley adjacent to the dammed up water of the Odra was the reaction of the water absorption from the underground water. The water reserves in the stratum 0–50 cm were from 128 to 178 mm, and in stratum 0–100 cm from 266 to 352 mm. The moisture content was usually equivalent to the values of the free water and water easily accessible for the plants.
3. The analysis and comparison of the volumes of the water reserves in both profiles enabled the evaluation of the volume of the supply with absorbed water from the underground water of stratum 50–100 cm on approximately 75–90 mm. This value mainly depended on the depth of the retention of the water table of the soil profile above the dam at Brzeg Dolny. The smallest differences were recorded at the beginning of the vegetation period (50–100 mm),

in the following months the differences were getting higher, in particular in the medium-dry years (80–135 mm).

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