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DEFICIENCIES OF PLANT AVAILABLE WATER IN SOIL CATENA OF UNDULATING GROUND MORAINE[*]

Summary. The study presents the results of research on the deficiencies of water content in soil toposequence. The objective was to determine water deficiencies in soil in relation to the available soil water holding capacity (AWHC) and the soil location in a relief. The research results indicate a wide diversity of AWHC in the toposequence (catena), which is related to the complex movement, and distribution of precipitation water in the particular elements of the slope. The crop water deficiency and the depth of soil drying up are strongly determined by the location of the soil in the relief. During periods of vegetation the strongest and the deepest drying up is observed in the Aquic Glossudalfs of the ground moraine elevations in which the soil water dynamics is mainly determined by precipitation water. The drying up is weaker in the Typic Endoaquolls and weakest in the Cumulic Endoaquolls of the footslope, which display permanent capillary rise and lateral inflow.

Key words: water deficiencies, soil matric potential, toposequence, temporal variability

Introduction

Numerous studies carried out in the Wielkopolska Lowland concerning the temporal variations in soil moisture have shown their strong drying up during vegetation seasons and the rebuilding of their retention storage in autumn and winter (KOMISAREK 2000, KOMISAREK and KOZŁOWSKI 2005, MARCINEK and KOMISAREK 2000, 2004, MARCINEK et AL. 1994, SPYCHALSKI 1998). The deep drying up of soil and the deficiencies of readily plant available water (RPAW) result from both the amount and the distribution of rainfall throughout a year, as well as the soil pattern, location on the slope and the

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[*] The study reveals a part of the results of two-year stationary research on the soil water regime and the chemistry of ground water in the catena systems of the Poznań Lakeland within the 2 P04G 009 29 Research Project.

grown plants species. Within the toposequence (catena) the distribution of rainfall in the particular elements of the slope can modify the deficiencies or excess in the profile of plant available water (PAW). Therefore, identifying the dynamics of soil water in the toposequence may be of great relevance not only for the optimum plant production, but also for the pedogenesis and the evolution of these soils as well as the assessment of surface water pollution risks in areas that are subject to intensive farming.

Material and methods

The research was carried out in the cultivated micro-catchment area of the Przybroda Experimental Station located in the north-central part of the Poznań Lakeland within the Szamotuły Plain (coordinates: between 50°30'16" and 50°30'52" of latitude and between 16°39'35" and 16°39'53" of longitude). This area is a part of an undulating ground moraine of the Poznań Phase of the Baltic Glaciation (Fig. 1).

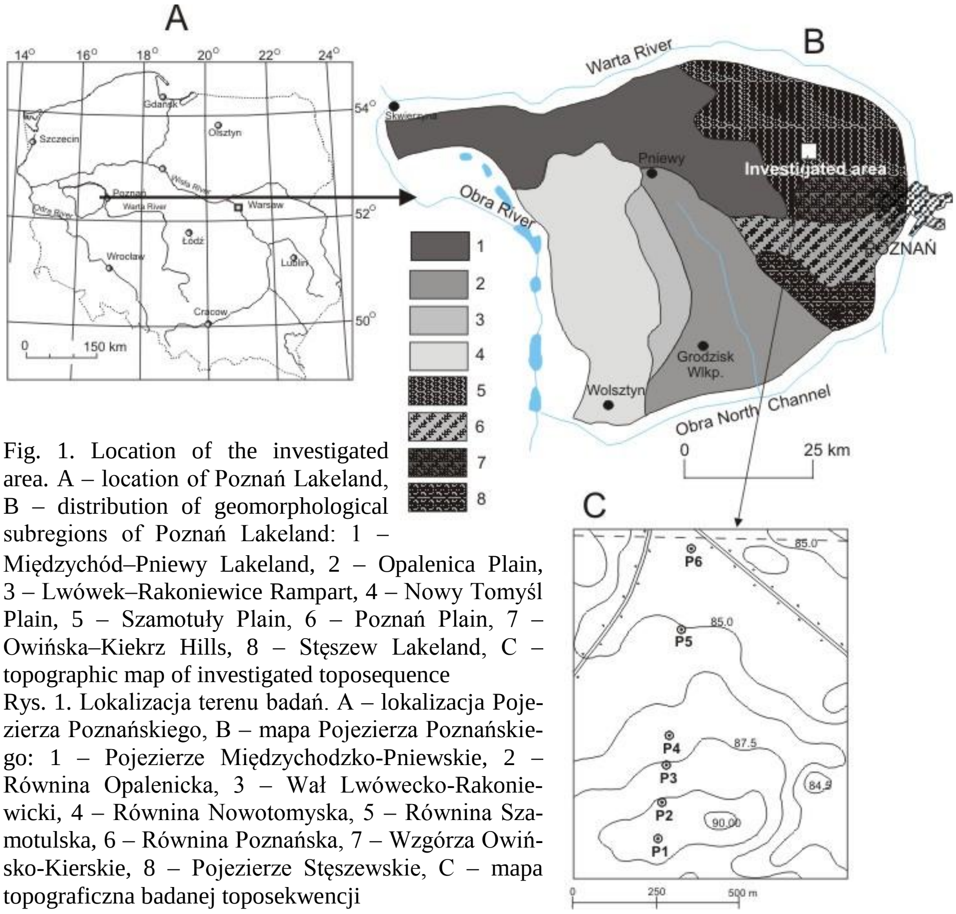

Fig. 1. Location of the investigated area. A – location of Poznań Lakeland, B – distribution of geomorphological subregions of Poznań Lakeland: 1 – Międzychód–Pniewy Lakeland, 2 – Opalenica Plain, 3 – Lwówek–Rakoniewice Rampart, 4 – Nowy Tomyśl Plain, 5 – Szamotuły Plain, 6 – Poznań Plain, 7 – Owińska–Kiekrz Hills, 8 – Stęszew Lakeland, C – topographic map of investigated toposequence

Rys. 1. Lokalizacja terenu badań. A – lokalizacja Pojezierza Poznańskiego, B – mapa Pojezierza Poznańskiego: 1 – Pojezierze Międzychodzko-Pniewskie, 2 – Równina Opalenicka, 3 – Wał Lwówecko-Rakoniewicki, 4 – Równina Nowotomyska, 5 – Równina Szamotulska, 6 – Równina Poznańska, 7 – Wzgórza Owińsko-Kierskie, 8 – Pojezierze Stęszewskie, C – mapa topograficzna badanej toposekwencji

The research covered six stationary measurement points (Fig. 1 C). In the present publication, we demonstrate only the results concerning three pedons of topsequence, i.e.: Aquic Glossudalfs (P2), Typic Endoaquolls (P4) and Cumulic Endoaquolls (P6) (Fig. 2) (SOIL TAXONOMY... 1975). The measurements of the soil moisture in the unsaturated zone were made once a week or once every two weeks from February 2004 to October 2006, using FDR and TDR moisture probes. At the same time the groundwater levels were measured.

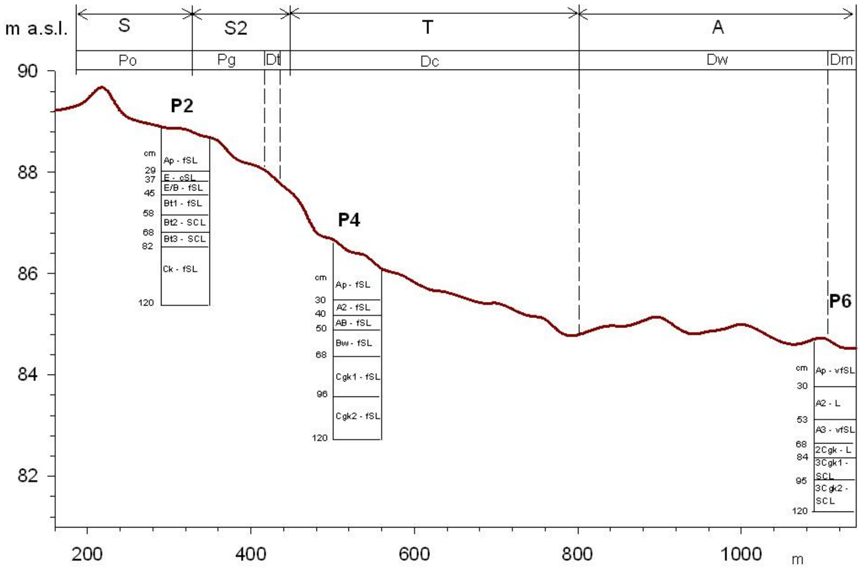

Fig. 2. Diagram of distribution of stationary measurement points; slope: S – summit, S2 – shoulder, T – pediment, A – footslope; soils: Po – Aquic Glossudalfs, Pg – Aquollic Hapludalfs, Dt – Typic Endoaquolls with argillic horizon, Dc – Typic Endoaquolls (moderately well drained), Dw – Typic Endoaquolls (somewhat poorly drained), Dm – Cumulic Endoaquolls

Rys. 2. Schemat rozmieszczenia stacjonarnych punktów badawczych; stok: S – kulminacja stoku, S2 – stok swobodny, T – stok usypiskowy, A – podnóże; gleby: Po – gleby płowe zaciekowe opadowo-glejowe, Pg – gleby płowe zaciekowe gruntowo--glejowe, Dt – czarne ziemie z poziomem argillic, Dc – czarne ziemie zbrunatniałe, Dw – czarne ziemie właściwe, Dm – czarne ziemie murszaste

Soil water retention curves of the undisturbed core samples up to 100 kPa were made using the Multistep method (VAN DAM et AL. 1994), whereas lower values of the pressure head were performed using the method of water vapour pressure over a solution of sulphuric acid (CAMPBELL and GEE 1986, KLUTE 1986). Following this, the RETC programme (VAN GENUCHTEN et AL. 1991) was used to present the soil water retention curve in the form of the parameters of the VAN GENUCHTEN (1980) equation with the MUALEM (1986) assumption ($m = 1 - 1/n$).

Because of the reported soil water pressure values measured *in situ* the field capacity (FC) are near the –10 kPa value, this value was chosen to determine the FC, i.e. the upper limit of plant available water (ULPAW) and the permanent wilting point (PWP), i.e. the lower limit of plant available water (LLPAW) was determined as the soil moisture at –1500 kPa (CASSEL and NIELSEN 1986, MARCINEK et AL. 1997). According to CASSEL and NIELSEN (1986), KABAT and FEDDES (1995) and MARCINEK et AL. (1997) it was assumed that the potentially plant available water (PAW) is between FC and PWP and the readily plant available water (RPAW) make up 2/3 of PAW. Due to RPAW = = 2/3PAW, the lower limit of readily plant available water (LLRPAW) was calculated as the PWP + 1/3(FC – PWP) and the Ψ_m at the LLRPAW was at about –155 kPa.

The temporal variability of soil moisture was determined using geostatistical methods in which the semivariance γ_k is the basic function (WARRICK et AL. 1986):

$$\gamma_k = \frac{1}{2n(k)} \cdot \sum_{i=1}^{n(k)} \left(\theta_i - \theta_{i+k}\right)^2 \tag{1}$$

where:

$n(k)$ – the number of data pairs,
θ_i – the soil moisture at time i,
θ_{i+k} – the soil moisture at time $i + k$,
k – the temporal lag.

The spherical variogram model was fitted to the experimental variogram in order to obtain the major temporal features of the temporal soil moisture variability. The spherical model is defined according to equation:

$$\gamma_k = \begin{cases} C_0 + C\left[1.5\frac{k}{a} - 0.5\left(\frac{k}{a}\right)^3\right] & k \le a \\ C_0 + C & k > a \end{cases} \tag{2}$$

where:

C_0 – random variable (nugget),
C – systematic variable,
a – correlation range.

Results

The stationary measurements of the soil moisture dynamics were made in the toposequence of Glossudalfs and Endoaquolls that is typical for the Polish Lowland. The highest location in the analysed toposequence is occupied by Aquic Glossudalfs (Fig. 2, Po). These soils have a well developed ochric (Ap), luvic (E) and glossic horizons with sandy loam texture. Despite the argillic horizon being degradated in its top part (glossic), the soils display redoximorphic features only periodically in the sandy eluvial horizons. The sandy texture and the depth of the ochric, luvic and glossic horizons have determined the PAW of the ground moraine summit soils (Table 1). Hence these horizons

Table 1. Basic properties of the investigated soils
Tabela 1. Podstawowe właściwości badanych gleb

Horizon	Depth (cm)	θ_C	θ_{FC}	θ_{WP}	θ_D	Parameters of the van Genuchten equation		Percentage of soil separates at diameter			Soil texture		Organic matter content	CaCO$_3$
		m^3/m^3				n	α	2.0-0.05 mm	0.05-0.002 mm	< 0.002 mm	PN-R-04033 (1998)	USDA (SOIL TAXONOMY... 1975)	%	
P2 – Aquic Glossudalfs														
Ap	0-29	0.341	0.218	0.066	0.153	1.2440	0.05799	73	20	7	GśP	fSL	1.34	0.0
E	29-37	0.350	0.222	0.067	0.150	1.2500	0.05500	67	22	11	GśP	cSL	0.69	0.0
E/B	37-45	0.339	0.264	0.092	0.078	1.2210	0.02510	62	20	18	GL	fSL	0.66	0.0
Bt1	45-58	–	–	–	–	–	–	61	20	19	GL	fSL	0.57	0.0
Bt2	58-68	0.342	0.293	0.110	0.065	1.2228	0.01184	53	22	25	GŚ	SCL	0.64	0.0
Bt3	68-82	0.323	0.274	0.107	0.066	1.2198	0.01520	55	23	22	GŚ	SCL	0.36	0.0
Ck	82-120	0.306	0.243	0.092	0.068	1.2025	0.02208	62	24	14	GL	fSL	0.05	10.0
P4 – Typic Endoaquolls														
Ap	0-30	0.395	0.284	0.094	0.121	1.2206	0.03840	67	21	12	GśP	fSL	3.07	0.0
A2	30-40	0.336	0.276	0.082	0.070	1.2565	0.01443	65	23	12	GśP	fSL	1.66	0.6
AB	40-50	0.342	0.264	0.071	0.098	1.2112	0.01758	67	21	12	GśP	fSL	0.91	0.7
Bw	50-68	0.333	0.219	0.052	0.136	1.3055	0.03352	66	20	14	GśP	fSL	0.76	5.1
Cgk1	68-96	0.308	0.217	0.059	0.093	1.2747	0.02670	57	29	14	GL	fSL	0.40	22.0
Cgk2	96-120	0.306	0.217	0.056	0.091	1.2577	0.03406	62	24	14	GL	fSL	0.31	21.1
P6 – Cumulic Endoaquolls														
Ap	0-30	0.441	0.318	0.111	0.140	1.2171	0.03822	55	36	9	GL	vfSL	9.48	1.0
A2	30-53	0.476	0.329	0.109	0.169	1.2179	0.04519	40	47	13	PŁP	L	5.84	1.5
A3	53-70	–	–	–	–	–	–	52	38	12	G	vfSL	2.31	0.7
2Cg	70-80	0.368	0.298	0.107	0.076	1.2211	0.02123	30	50	20	GPŁ	L	0.59	2.0
3C1gk	80-95	–	–	–	–	–	–	12	52	36	IPŁ	SCL	0.10	5.9
3C2gk	95-120	0.398	0.318	0.118	0.092	1.2115	0.02128	7	55	38	IPŁ	SCL	0.00	6.8

θ_C – saturated soil water content, θ_{FC} – soil water content at field capacity, θ_{WP} – soil water content at wilting point, θ_D – drainage capacity ($\theta_D = \theta_C - \theta_{FC}$).

have low retention at FC (0.217-0.222 m^3/m^3) as well as at the PWP (0.066-0.092 m^3/m^3) (Table 1). In the illuvial argillic horizon the water content at FC equals 0.293 m^3/m^3. This is related to the higher contents of the clay fraction and a strong subangular blocky structure.

Typic Endoaquolls have developed in the central part of the toposequence with a deep mollic horizon and a cambic horizon (Bw) underlying below (Fig. 2, Dc). This is the section of the most intensive transport and accumulation of denudation materials. Hence the depth of the mollic horizon in the upper section of the pediment is greater than in the soils that occur in its lower part. The P4 pedon, i.e. the Typic Endoaquolls, is within the influence of the groundwater level, therefore, there are gley spots and an accumulation of Fe-Mn concretions in the upper part of the cambic horizon. Furthermore, this soil displays deposit of secondary calcium carbonates and the development of a horizon with an increased calcium carbonate content (calcic) below the cambic horizon. The higher content of organic matter and the strong granular structure of the mollic horizon in pedon P4 determine the high PAW of this epipedon (Table 1). The lowest water content at FC (0.217 m^3/m^3) in this pedon is displayed by the Cgk1 and Cgk2 horizons. This could be the effect of the high calcium carbonate contents, the soil texture and the platy structure.

The lowest position on the relief within the footslope is occupied by Typic Endoaquolls which, in its final section, change into Cumulic Endoaquolls (P6) with a deep mollic horizon (Fig. 2, Dm, Table 1). The water content at FC ranges from 0.318 to 0.329 m^3/m^3 in this pedon (Table 1). The endopedons, i.e. the subsurface horizons, are featured by a high water content, both at the FC as well as at the PWP.

Figure 3 presents the profile soil moisture variation in the toposequence in comparison to the FC. The average soil moisture during the study period ($\overline{\theta}$ m^3/m^3) in the P2 profile was lower than the ULPAW, about to the depth of 150 cm. In the pedons that were located lower in the relief the depth was approximately 130 cm for Typic Endoaquolls and approximately 60 cm for Cumulic Endoaquolls. Higher moisture variations were observed in the surface horizons of the investigated soils than in the subsurface horizons, where the range clearly decreased with depth and at 150 cm was from 0.21 to 0.28 m^3/m^3 for pedon P1, from 0.18 to 0.30 m^3/m^3 for P4 and from 0.35 to 0.4 m^3/m^3 for the P6. This was confirmed by the values of the actual moisture variation coefficient for three layers, i.e.: from 0 to 50 cm, from 50 to100 cm and from 100 to 150 cm (Fig. 4). In all of the investigated pedons the highest values of this coefficient were observed in the first indicated layer, whereas in the remaining layers the variation was lower. At the same time, in the third distinguished layer the higher moisture variation was noted in the Typic Endoaquolls (P4) in comparison with the remaining pedons. On the one hand this could be affected by the water retention properties of the cambic and calcic horizons and, on the other, with a periodic lack of groundwater impact on the water dynamics in these subsurface horizons. Furthermore, below the depth of 150 cm of these soils there were sandy layers of small thickness that, during vegetation season, when the depth of the groundwater level was lower, cut off the capillary rise.

During vegetation seasons there were, however, periods when the soil water contents were clearly smaller than the moisture at the ULPAW and this was a more apparent demonstration of the matric potential (Ψ_m). The Ψ_m values presented in Figure 3 are obviously shifted in the direction of the LLPAW (Ψ_m at PWP), particularly in the epipedons.

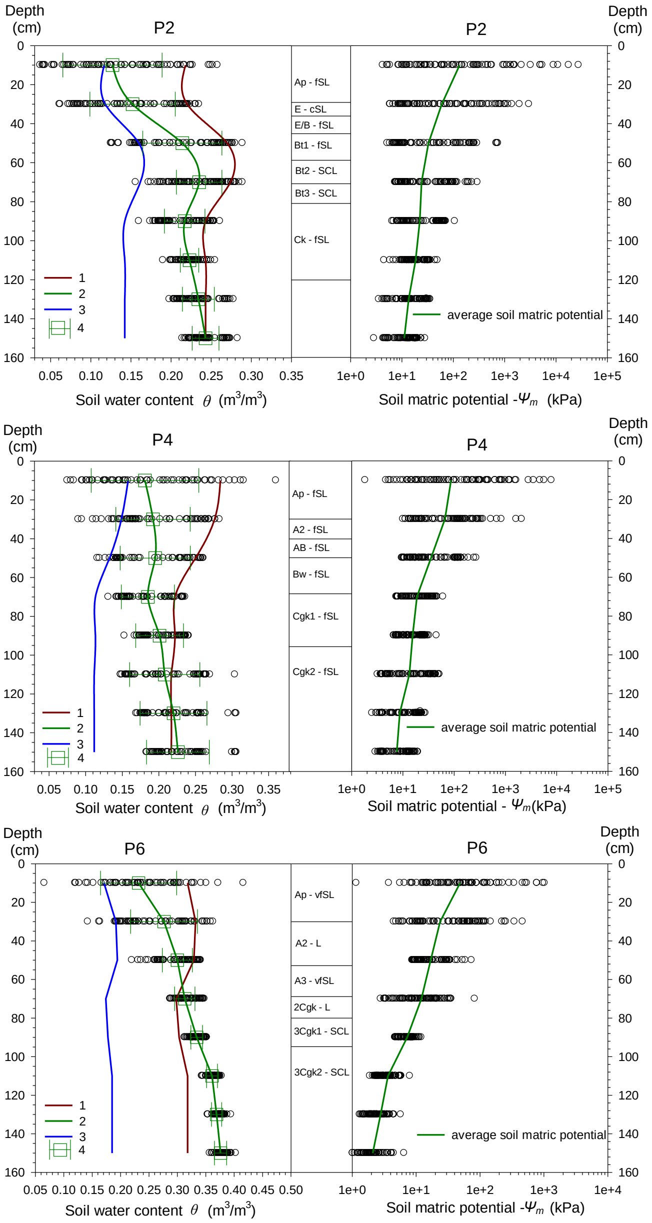

Fig. 3. Diversity of the moisture content and the matric potential in the investigated soils: 1 – the FC, 2 – the average soil water content, 3 – the soil water content at the LLRPAW, 4 – standard deviation

Rys. 3. Zróżnicowanie zawartości wody i potencjału macierzystego w badanych glebach: 1 – FC, 2 – średnia zawartość wody w glebie, 3 – zawartość wody przy LLRPAW, 4 – odchylenie standardowe

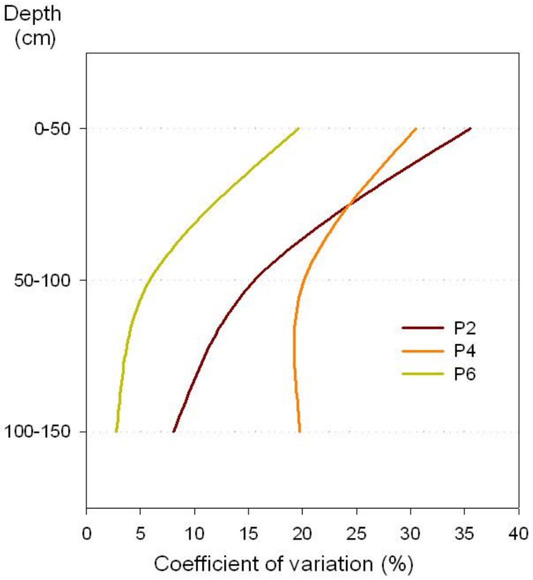

Fig. 4. Differentiation of coefficient of water content variation in the soil profile depending on depth
Rys. 4. Zróżnicowanie współczynnika zmienności zawartości wody w profilu glebowym w zależności od głębokości

The highest deficiencies of RPAW were observed in the Aquic Glossudalfs (P2). The drying up (Ψ_m < –155 kPa) of this pedon reached the depth of 70-80 cm and included the whole illuvial argillic horizon. In this pedon, down to the depth of approximately 40 cm, matric potentials below the –1500 kPa (PWP) were observed. The mean Ψ_m value from the measurement period responding to the Ψ_m at FC was observed at the depth of 150 cm (Fig. 3) and was higher than in the remaining pedons. This depth was approximately 130 cm in the Typic Endoaquolls (Fig. 3) and 60 cm in the pedon that was located in the lowest part of the relief (P6) (Fig. 3). Obvious drying up of soil was also recorded in the Typic Endoaquolls (P4) to the depth of approximately 50 cm and to approximately 35 (40) cm in the P6 pedon (Fig. 3). The decreasing depth of the presence of soil water deficiencies in pedons situated lower in the relief was related to the higher impact of the groundwater level that, for the measurement period, was on average at the depth of 327 cm in the P2 soil, 220 cm in the Typic Endoaquolls (P4) and 120 cm in the pedon that was located in the lowest part of the investigated toposequence (P6).

Figure 5 presents the temporal variability of the soil water retention in 50 cm soil layer in relation to the ULPAW and LLRPAW. The deficiencies of RPAW were express in the Aquic Glossudalfs. These may last from June to the first decade of September. In 2004, between the beginning of June and the end of August (and about to the first days of September), the soil water storages values corresponded to the plant unavailable water (PUW). During this period in 2004 there were two deficiency culminations, i.e. in

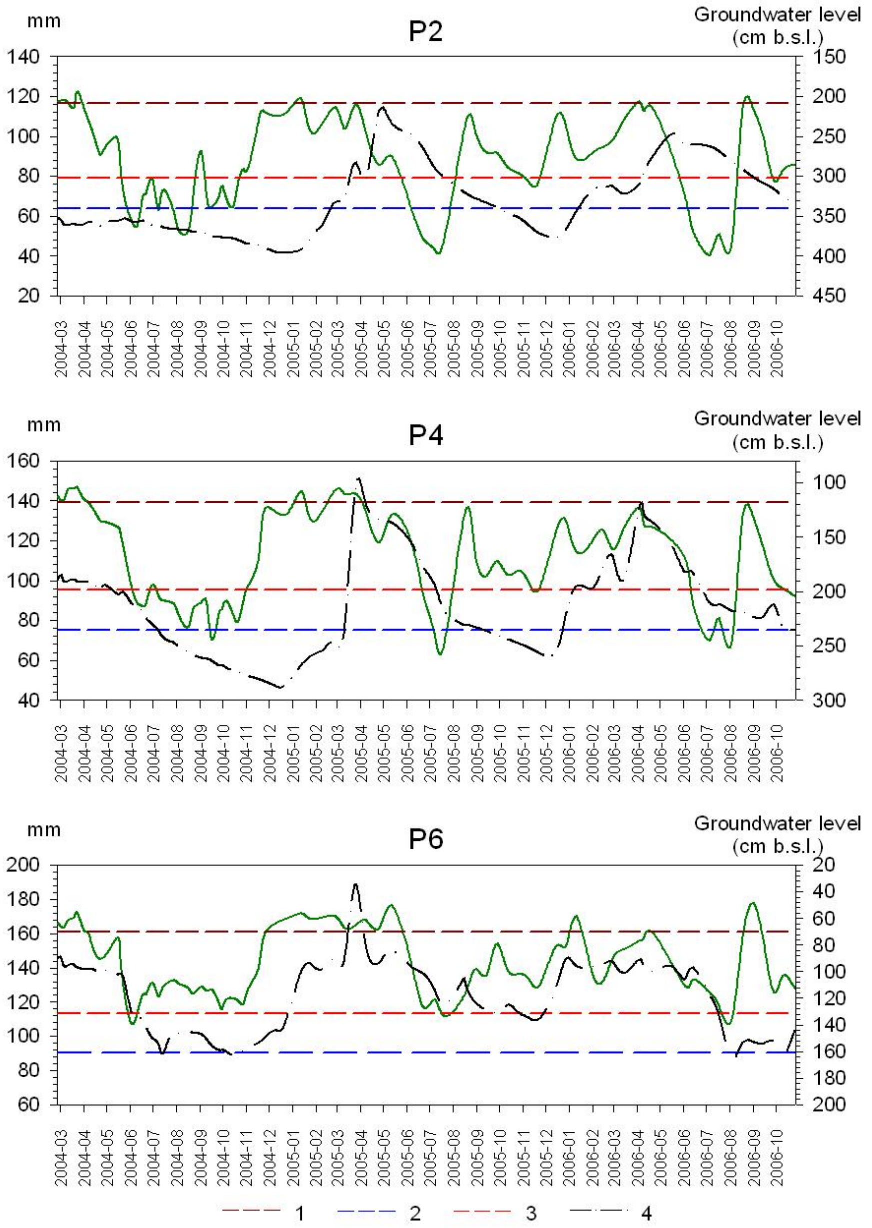

Fig. 5. Dynamics of water retention in 50 cm soil layer in relation to the ULPAW (1), to the LLEPAW (2) and to the retention at the critical pressure head of Ψ_m –58 kPa (3) and the groundwater level dynamic (4)

Rys. 5. Dynamika stanów retencji wody w 50-centymetrowej warstwie gleby przy ULPAW (1) i LLEPAW (2) na tle retencji przy potencjale krytycznym Ψ_m = –58 kPa (3) i głębokości zalegania zwierciadła wód gruntowych (4)

June and August, but up to October there were observed soil water storages, which were closed to retention at the LLRPAW. In 2005 there were deficiencies from June to July, but in 2005 from June to August. The strong drying up of the Aquic Glossudalfs (P2) to the depth of approximately 70-80 cm (Fig. 3) was related to the exhaustion of the previously retained water and the lack of capillary rise impact on the moisture dynamics of the plant rooting zone. Therefore, during the vegetation season, the highest readily plant available water deficiencies in relation to the LLRPAW in the 50 cm zone were 23 mm in 2006 (in relation to the ULPAW – 77 mm).

The distribution of the soil water retention in the Typic Endoaquolls was slightly different (Fig. 5). The depletion of PAW occurred in the same periods as in the Aquic Glossudalfs (P2) reaching their June and August culmination. In 2005 they occurred from the beginning of June to the end of July. Despite the using up of the stored water the deficiencies in this pedon were not as high as in the Aquic Glossudalfs. In the 50 cm soil layer they reached the maximum value of 73 mm in relation to the ULPAW (9 mm in relation to LLRPAW). The lower deficiencies of plant available water in the Typic Endoaquolls (P4), in comparison to the Aquic Glossudalfs, resulted mostly from the higher water retention and the shallower occurs of groundwater that could supply water to the lower horizons of this profile. In particular, this relation was expressed during the periods of the highest groundwater levels.

The impact of the ground water in the Cumulic Endoaquolls, during the measurement period, on the dynamics of the soil water storage in the distinguished layer was expressly due to the fact that the groundwater occurred shallowly (Fig. 5). The soil water storages were between the ULPAW and the LLRPAW even during the vegetation season, which proves that even during the intensive plant growth period the moisture contents corresponded to the readily plant available water. Despite the strong impact of the groundwater level on the moisture dynamic of the Cumulic Endoaquolls (P6), there were observed periods during which the soil water storages were closed to the retention at the LLRPAW (Figs. 3, 5).

In spite of distinct soil drying up and soil wetting, the changes of soil water content gradually have occurred, which are confirmed by semivariograms presented in Figure 6. These semivariograms, their models indicate that the soil water changes occurred systematically up to 32 weeks. These changes are characterized to a larger degree by the systematic variability than the random variability.

Discussion

The presented research results indicate a large variation of water deficiencies in the investigated soils of the given toposequence.

The strongest and the deepest drying up was observed in the pedons that were located in the highest part of the relief, which were out of the impact of the ground water. These soils have a sandy the A and E horizons that are featured by lower water retention. Consequently, the retained water is quickly used by the plants, which are forced to take the water from the illuvial argillic horizon. Despite the high water retention in the argillic horizon, the soil showed deficiencies of readily plant available water to the depth of 70-80 cm. These took place from June to September but up to October there

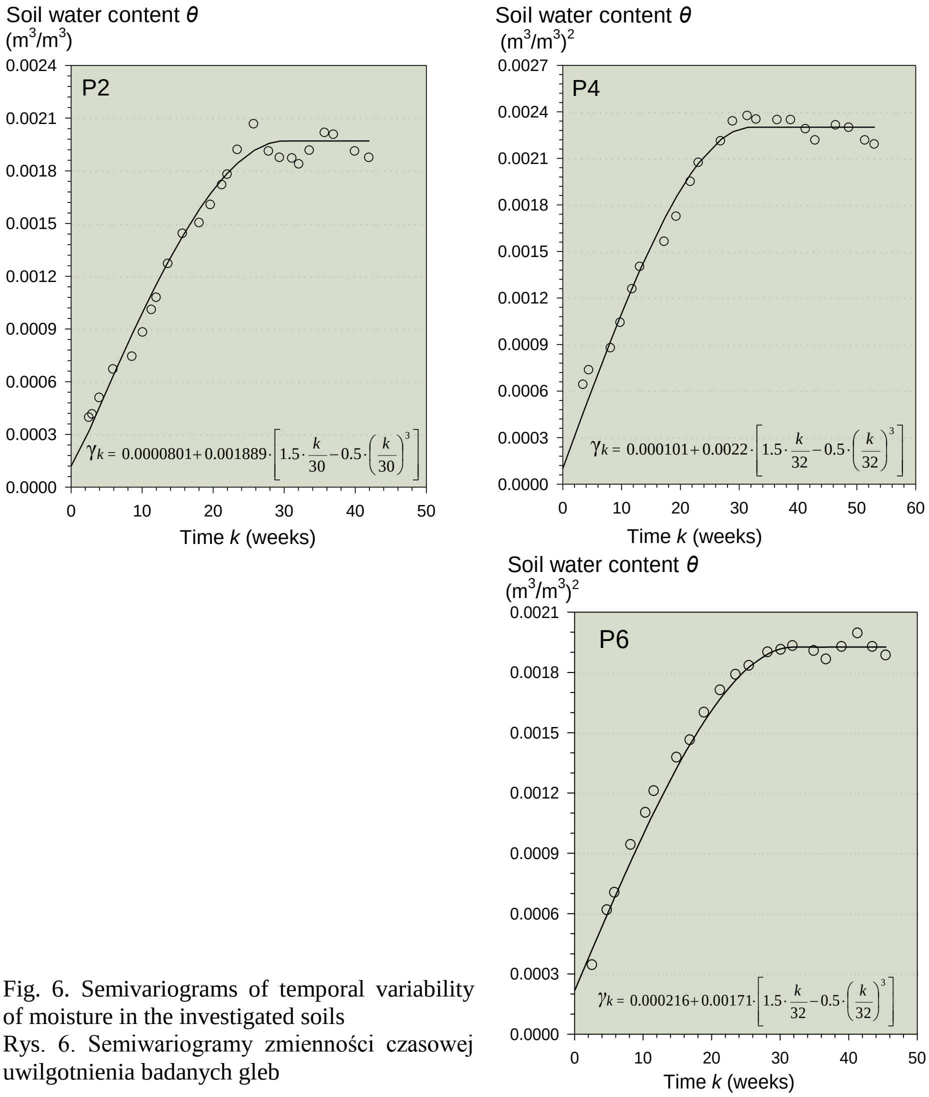

Fig. 6. Semivariograms of temporal variability of moisture in the investigated soils
Rys. 6. Semiwariogramy zmienności czasowej uwilgotnienia badanych gleb

were observed soil water storages, which were closed to retention at the LLRPAW (for 50 cm soil layer). Hence the highest deficiencies of RPAW during the vegetation season in the 50 cm soil layer were 77 mm (in relation to ULPAW). The average moisture depth equal to the FC occurred at the depth of 150 cm. This also indicates the lack of groundwater impact on the moisture dynamics of this profile. The cyclic strong drying up and wetting of the Aquic Glossudalfs in ground moraine elevations have been observed by KOMISAREK (2000), MARCINEK and KOMISAREK (2000, 2004), MARCINEK et AL. (1994) and SPYCHALSKI (1998). This is a typical feature of these soils in terms of their genesis and evolution (KOMISAREK 2000, RUST 1983, SHARMA et AL. 1998, SOIL TAXONOMY... 1999).

The Typic Endoaquolls located lower in the relief indicated weaker drying up than the Aquic Glossudalfs. The deficiencies of readily plant available water reached the depth of 50 cm. The average moisture depth equal to the FC occurred at 130 cm. This also indicates the groundwater impact on the moisture dynamics in this pedon. Lower soil water deficiencies in the Typic Endoaquolls, in comparison to the Aquic Glossudalfs, are, on the one hand, affected by the higher water retention capacity, particularly in the mollic horizon, and, on the other, by the groundwater impact on the soil water regime of this pedon. Furthermore, this soil can be additionally supplied by the runoff, which is approximately 15% in the Polish Lowland, as well as the lateral inflow. Other attributes resulting from the shallower occurrences of groundwater are the redoximorphic features in the form of apparent groundwater gley spots and the accumulation of Fe-Mn concretions in the soil profile.

The lowest soil water deficiencies were observed in the Cumulic Endoaquolls. These soils were featured by high water retention, both in the deep mollic horizon as well as in the remaining subsurface horizons. This pedon also had shallow occurrence of groundwater, which determined the fact that the soil water storages, for 50 cm soil layer were between the ULPAW and the LLRPAW even during vegetation periods. Therefore, the moisture depth equal to the FC occurred at the depth of 60 cm. Nevertheless, despite the significant impact of groundwater, there were periods when the soil water storages were closed to the retention at the LLEPAW.

The research indicates that the soil water deficiencies and the depth of drying up depend on the location of the soil in the relief. The deficits resulted from the water retention properties of the investigated soils, the groundwater level occurring, the natural drainage conditions as well as quantity and distribution of precipitation (HALL 1983, KOMISAREK 2000).

Taking into consideration that some of the crops show growth inhibition at a pressure head of –58 kPa (FEDDES et AL. 1997), the limitations of the optimum moisture conditions may occur significantly earlier and the plant available water deficiencies can last for longer periods and may concern even Cumulic Endoaquolls (Fig. 5). These deficiencies in the 50 cm layer of the soil can already occur at the half of May and last until the end of October (especially in 2004). Therefore, the quantitative assessment of plant water deficiencies for optimum plant production should take include critical pressure head that determines the best possibility of water consumption for the roots of given plants species.

Conclusions

1. The variability of the water deficiencies in the soils of the toposequences is related to the complex movement and distribution of precipitation water in the particular elements of the slope.
2. The average moisture depth equal to the field capacity, i.e. the upper limit of plant available water, is about 150 cm for the summit pedon, 130 cm for the Typic Endoaquolls and 60 cm for the Cumulic Endoaquolls of the catena footslope.

3. The strongest and the deepest drying up is observed from June to September in the Glossudalfs of the ground moraine elevations, and the weakest – in the Endoaquolls.

4. The intensity of soil water deficiencies and their depth depends on the location of the soil in the relief. The lower the location of soil in toposequence the weaker deficiencies of the easy plant available water.

5. The highest soil water deficiencies were noted in the Aquic Glossudalfs. These reached their maximum value of 77 mm in the 50 soil layer. Lower deficiencies were recorded in the Endoaquolls.

6. The changes of the soil water moisture gradually occurred up to 32 weeks and are characterized to larger degree by the systematic variability than the random variability.

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NIEDOBORY WODY DOSTĘPNEJ DLA ROŚLIN W GLEBACH UKŁADU TOPOHYDROSEKWENCYJNEGO FALISTEJ MORENY DENNEJ

Streszczenie. W pracy przedstawiono wyniki badań niedoborów wody w glebach układu toposekwencyjnego. Celem badań było określenie deficytów wody w glebach na tle ich zdolności retencyjnych oraz położenia w reliefie. Wyniki wskazują na duże zróżnicowanie deficytów wody w glebach układu toposekwencyjnego, które są związane ze skomplikowanym przemieszczaniem się i rozrządem wód opadowych w obrębie poszczególnych elementów stoku. Wielkość oraz głębokość niedoborów wody glebowej są silnie zdeterminowane położeniem gleby w reliefie, przy czym wraz z obniżaniem się rzędnej terenu maleją ilość oraz głębokość deficytów wody. W okresie wegetacyjnym najsilniej i najgłębiej przesychają gleby płowe wyniesień dennomorenowych, w których dynamika wody glebowej jest zdeterminowana głównie wodami opadowymi. Czarne ziemie zbrunatniałe przesychają płyciej, a najmniej – czarne ziemie murszaste podnóża stoku mające stały podsiąk kapilarny oraz dopływy boczne.

Słowa kluczowe: niedobory wody, potencjał macierzysty, toposekwencja, zmienność czasowa

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