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EVALUATION OF POSSIBILITIES OF DRAINED SOILS WATER BALANCE IMPROVEMENT IN THE WIELKOPOLSKA REGION*

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ABSTRACT. The results of the research on the problem of the influence of agricultural melioration on soil water balance improvement have been presented in the paper. The research showed that in the soil conditions of the Ostrowo Szlacheckie experimental spot the retention capabilities of clay soils were increased to a large extent by lessening the volumetric density and loosening the subsoil horizon. The initial analysis of the results has also shown that by regulating the water outflow from the drainage system it is possible to limit water deficits in the area of arable lands.

Key words: drainage, soil water balance, agromelioration practices

Introduction

Formation of optimal soil air-water proportions has a vital importance for increasing the effectiveness of utilization of natural habitat potential in agriculture. According to **Marcilonek** et **al.** (1995), water excess in springtime can be more harmful for plants than its deficit in the vegetation period. It indicates the necessity of making and, first of all, keeping in technical efficiency all the existing drainage appliances. The extent of satisfying the needs of the melioration devices in the Wielkopolska region is high and exceeds 80% (**Bykowski** et **al.** 1998). Unfortunately, the devices are largely decapitalized having a low functioning capability

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and appliances from the area of 23% of arable lands need reconstruction. Moreover, the region of Wielkopolska is situated in the area of highest precipitation deficits (**Marcilonek** and **Nyc** 1990). On the basis of many years' mean climatic values of summer half year water balances, **Rojek** (1987) estimates the deficits from 120 to 140 mm in the area of Wysoczyzna Poznańska and in the dry year, with the probability of occurrence once in 10 years, as much as 250 mm. Alternative ways of soil water shortage supplementing should be favoured in the situation of absence of irrigating systems in the area of arable lands, since the equipment is expensive and economically having low effectiveness in the present situation. Agricultural melioration practices and controlling ground retention resources can be suggested.

Agricultural meliorations can, by help of improvement of soil physico-water properties, increase retention capabilities of top layers of soil profile from 10 to 60 mm as was shown in the research carried out by **Cieśliński** (1989) as well as by **Kosturkiewicz** and **Szafrański** (1993). The need of carrying into effect some agricultural melioration practices arises also from an increased extent of field mechanization proceedings and application of heavier equipment. It causes a higher density of subsoil horizons which additionally worsen the water balance of the soil profile. The results of some of the carried out surveys also indicate the existence of adjusting possibilities of ground retention by help of two-sided operation use of the drainage system (**Mioduszewski** 1994, **Nyc** et **al.** 1994, **Pływaczyk** and **Pęczkowski** 1997).

The aim and methods of the research

The aim of the research was evaluation of the influence of soil loosening over the improvement of water balance of the researched soils as well as the analysis of applying the drainage systems in the process of regulating the outflow from the arable lands of the researched area. The basis for the survey were the results of the field research and observations from the period of 1994-1997, carried out at the Ostrów Szlachecki experimental plot. Drainage watershed no. 42 was selected for the purpose of detailed field proceedings; it was further divided into four experimental plots (Fig. 1). Agromelioration measures were carried out in September 1994 on plots 1 and 2 included top soil layer loosening down to the depth of 50 cm. Areas 3 and 4 were regarded as control plots. Regular observations and measurements in the selected for the purpose watershed comprised:

– systematic (with a frequency each five days) measurements of ground water levels in 12 wells situated in characteristic points of the analysed profiles,

– measurements (with a frequency each five days) of outflows of water from the drainage system; done by help of a replaceable vessel,

– soil moisture periodical estimating by help of neutron method, with a frequency each second week,

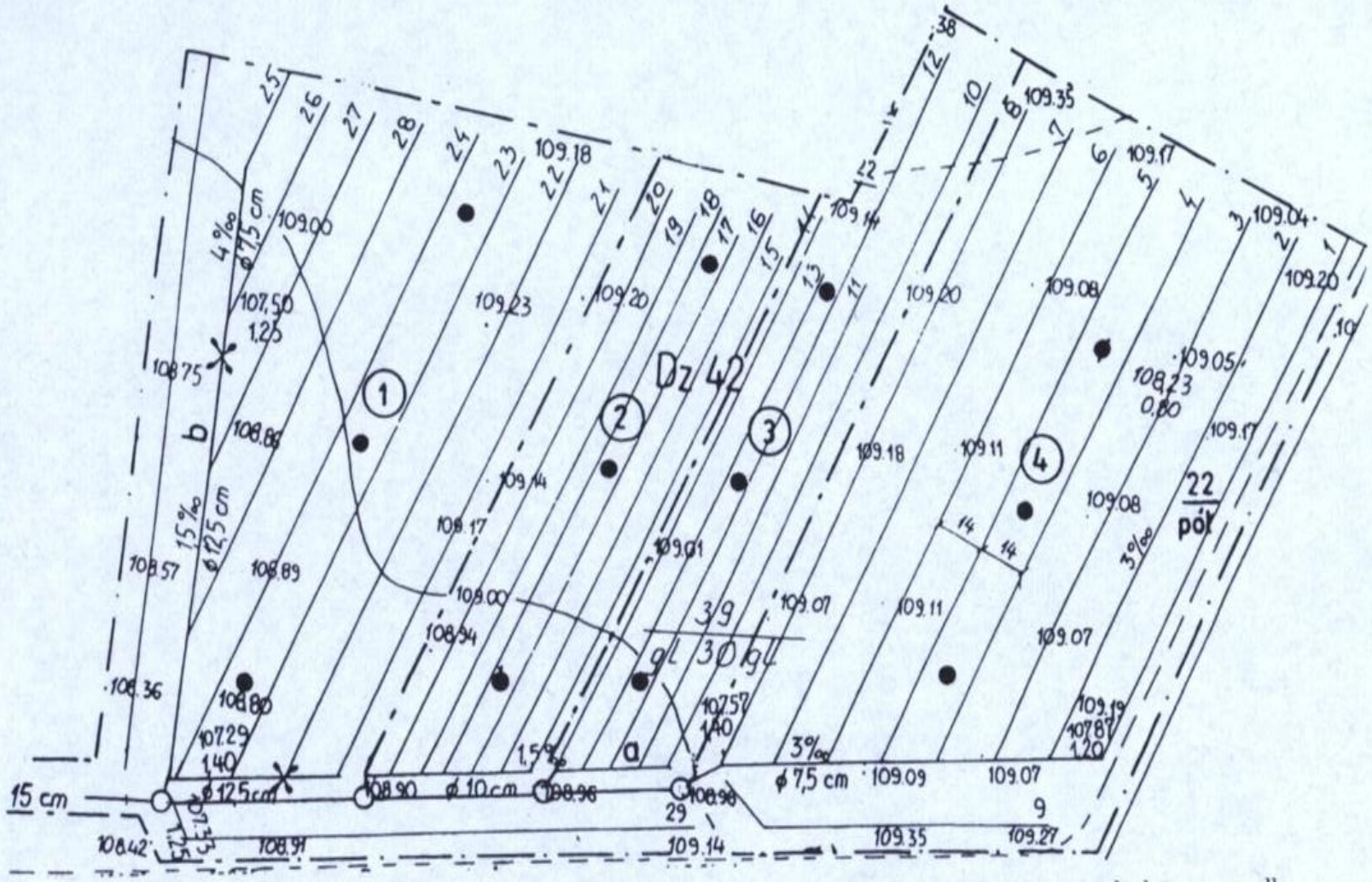

Fig. 1. Map of experimental station "Ostrowo Szlacheckie": 1, 2 – loosened plots, 3, 4 – control plots, • – wells

Ryc. 1. Mapa sytuacyjno-wysokościowa obiektu doświadczalnego „Ostrowo Szlacheckie": 1, 2 – powierzchnie spulchniane, 3, 4 – powierzchnie kontrolne, • – studzienki

– estimating of volumetric density in samples of 100 cm^3 volume, in a sequence of four repetitions for each level before the loosening procedure, directly after it and in subsequent three years since it was introduced,

– everyday precipitation observations at the research gauge station.

Physical, chemical and water properties of the researched soils were determined, by help of commonly applied methods, in the laboratory of the Department of Land Improvement and Environmental Development of Agricultural University of Poznań. A sluice gate of C-4 type, enabling damming up water and regulating its outflow from the drainage system, was set up on the SR-14 ditch being the main water collector in the ameliorated area.

The characteristics of the spot

The Ostrowo Szlacheckie drainage structure having the area of 495 ha, situated 4 km from Września, was opened in 1982. The analysis of the designed specification prepared by BPWM in Poznań, in 1978, showed that the relief of the researched area is flat (mean acclivity is 3-5‰) with poor or very poor conditions for water offtake. Periodical precipitation and thaw water excess finds its escape, to a significant extent, through sinking into the depth of the soil profile. The scheme assumed realization of systematic drainage pipes laid in trench, constructed of ceramic pipes on the area of 398 ha (76%) and trenchless drainage of polivinyl chloride pipes lying on the surface of 97 ha (24%). In the course of realization of the scheme the trenchless drainage was carried out on 90% of the area while drain pipes were laid in trench on only 10% of the discussed spot.

In the selected for detailed research drainage watershed nr 42, the depth of the drainage was 0.9 m and the spacing 14 m. The system of the drain pipes was set up by applying trenchles drainage pipes (polivinyl chloride) lying, which was inconsistent with the designed specification. After the system had been set up, some additional ceramic drain pipes were placed in the middle part of the watershed (plots 2 and 3), compacting the drainage spacing to 7 m. The improvement was introduced due to further seasonal excessive humidification of soils and the user's complaint.

The drilling and pedological research carried out in the analysed watershed 42 did not show high spatial variety of the soil cover. Typic Epiaquolls are formed from sandy clay with a mean silt and clay fractions of 22% of shallow light clay layer. The balanced "mollic" humus layer (Ap) having its thickness of about 30 cm contains 2.5 to 2.7% of organic matter. The level "calcic" (Cca) occurs from the depth of 80 cm; presence of carbonate concretions was found out in the level. The soil reaction is neutral (pH from 7.1 to 7.6 in KCl). In the humus-arable layer the amount of ferric oxide (Fe_2O_3) present is 0.7% while in the subsoil horizon amounts to 2.3% which creates no danger to the functioning drainage system.

Results

The evaluation of the influence of loosening of the top layer upon the improvement of soil water balance was carried out on the basis of the analysis of water resources changes in the layer of 0-50 cm. It was done against a background of 24 hours' precipitation sums as well as ground water levels. Three successive vegetation periods (IV-IX) of 1995, 1996 and 1997 after the procedure of loosening were selected for the analysis purposes.

The 1995 vegetation season was qualified as average humid year as far as the amount of precipitation was concerned. The precipitation sum in the period was 350 mm and was 54 mm higher than the many years' mean from 1981-1997. After the wet winter half year of 1994/95 hydrological year (aberration +44 mm) the water resources in the 0-50 cm layers were close in values in the areas researched at the beginning of the vegetation season. They ranged from 130 to 135 mm which corresponded to humidity at the water field capacity (Fig. 2). The levels of ground water occurred then at the depth of 90 cm (area 1) and down to 110 cm (area 2) from the field level. In the situation of low precipitation in April and May as well as increased field evaporation, the water resources were much lower in the analysed areas and at the end of May they came down to 50 cm, i.e. 40% of water field capacity of the soils in focus. The 1995 vegetation season was characterized by an unfavourable time precipitation distribution. A long period without precipitation, lasting from July 24 to August 23, caused a further decrease in water resources in the analysed soil layer down to the value of 30-35 mm. Ground waters, occurring at the depth of 200 cm, had a little influence over the humidification of the 0-5 cm soil layer in the season. A significant water resources increase was caused later by higher sums of 24 hours' precipitation which appeared on the turn of August. In the areas which were being loosened (1 and 2) the water resources were accordingly 108 and 103 mm and were about 20 mm higher than in the control areas.

The next analysed vegetation, 1996, season was regarded as a wet one as far as the level of atmospheric precipitation was concerned. The precipitation sum in the season was 456 mm and was 160 mm higher than the many years' mean value. At the beginning of the vegetation season, after a dry winter half year of 1995/96, water resources in the soil top layer were low; the precipitation was 70 mm lower than the many years' mean for the half year. They ranged from 63 mm (area 1) to 80 mm (area 2) on the loosened surfaces and 65 mm (Fig. 3) on the control surfaces (3 and 4). Ground water levels which occurred at the depth of 130 to 140 cm at the beginning of 1996 vegetation season were not reconstructed in the dry winter half year. With a significant precipitation deficits in April, the use of water resources in the 0-50 cm soil layer was 20 mm higher in the loosened areas in April, as compared to control plots. The situation was caused both by physico-water changes of top soil layers, which occurred after agromelioration treatment, and, connected with it, development as well as distribution of root system of the cultivated plants (**Dziamska** et **al.** 1980, **Szafrański** 1993). A favourable influence of loosening over

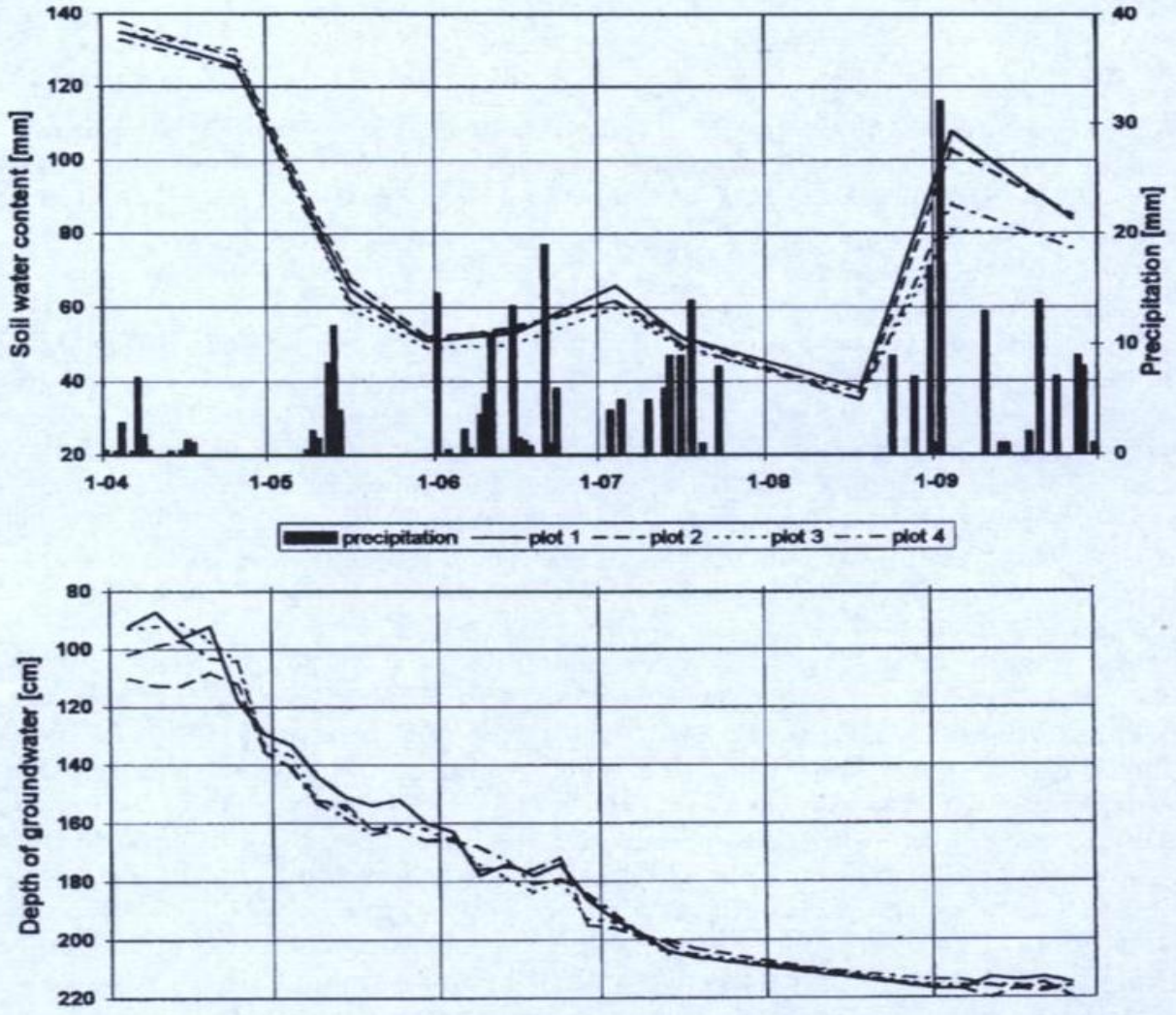

Fig. 2. Changes in soil water content in the soil layer 0-50 cm for investigated plots against the background of daily sums of precipitation and depth of groundwater during growing season of 1995 year

Ryc. 2. Dynamika zmian zapasów wody w warstwie 0-50 cm gleby na badanych powierzchniach na tle dobowych sum opadów i stanów wody gruntowej w okresie wegetacyjnym 1995 roku

the changes of soil water resources was also registered after a period of precipitation in the first half of July 1996, which sum equalled 97 mm. The water resources in the loosened soil oscillated on July 17 from 108 mm (area 2) to 115 mm (area 1) and were from 18-20 mm higher than in the control plots. The obtained research results confirmed the conclusions of the authors (**Cieśliński** 1989, **Kosturkiewicz** and **Szafrański** 1993) concerning the favourable influence of agromelioration over the increase of soil water retention in the periods of high sum precipitation.

The third, after the carried out loosening of soil in September 1994, analysed

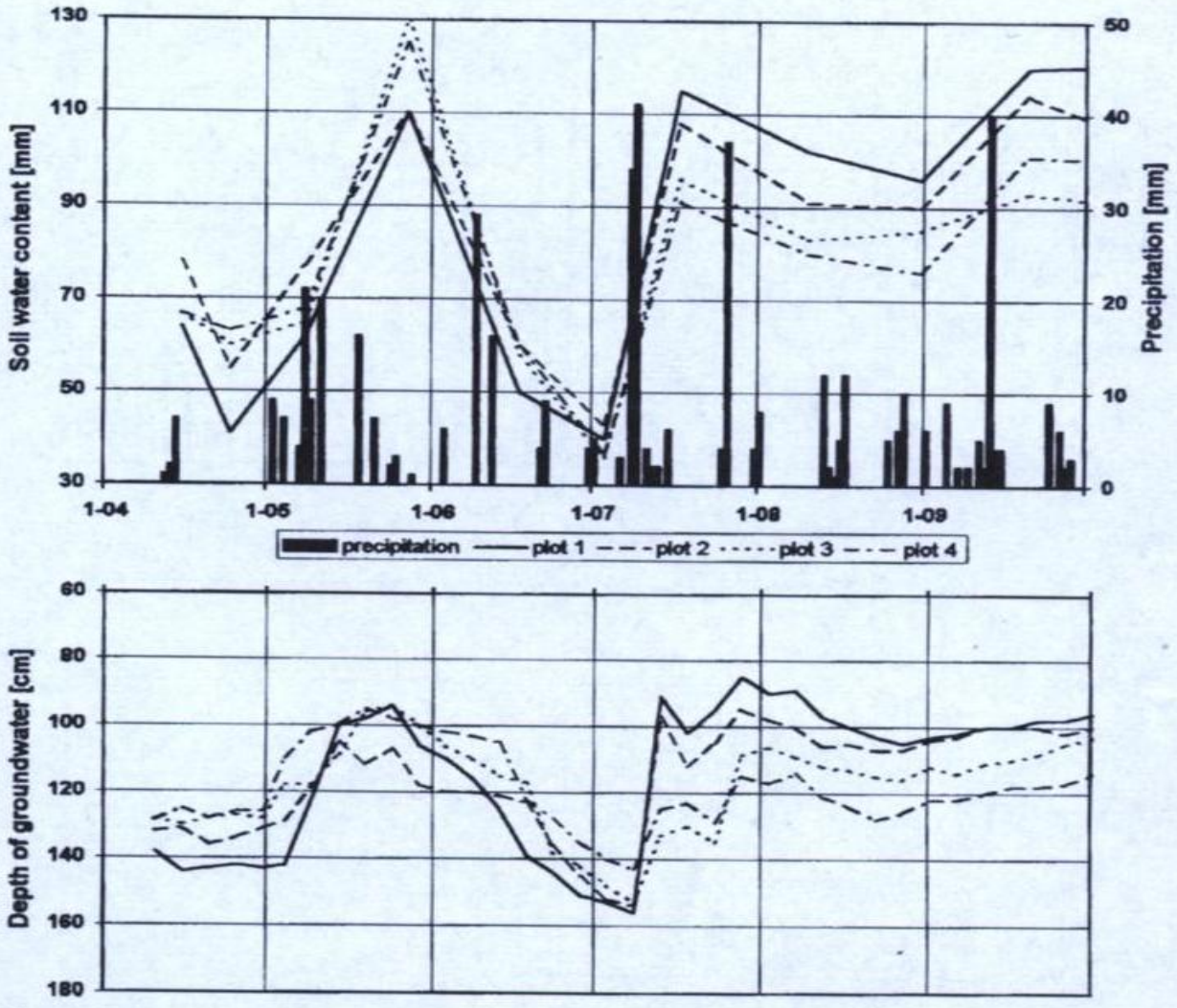

Fig. 3. Changes in soil water content in the soil layer 0-50 cm for investigated plots against the background of daily sums of precipitation and depth of groundwater during growing season of 1996 year

Ryc. 3. Dynamika zmian zapasów wody w warstwie 0-50 cm gleby na badanych powierzchniach na tle dobowych sum opadów i stanów wody gruntowej w okresie wegetacyjnym 1996 roku

vegetation period, 1997, was noted as average as far as the head of atmospheric precipitation was concerned. The precipitation sum was 269 mm and was 27 mm lower than the many years' mean. The winter 1996/97 half year was also mean (aberration +26 mm) and after the period the water resources of the top layer of the researched soils in the vegetation period, which were covered by winter wheat cultivation that year, were close to each other and equalled about 110 m (Fig 4). The ground water levels were placed at the depth of 95 cm to 105 cm. At the end of June the resources in the discussed layer decreased to the value of about 55 mm

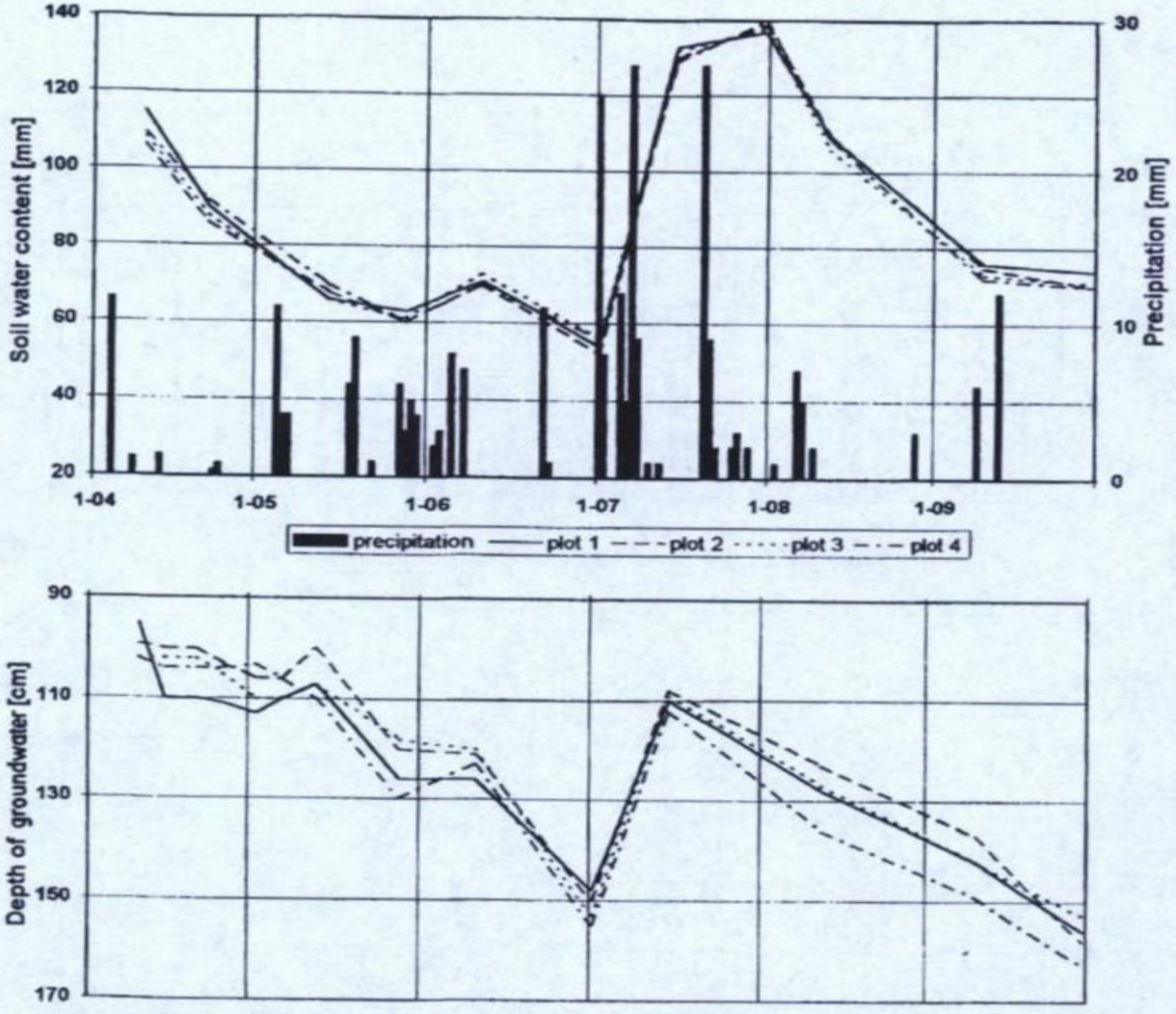

Fig. 4. Changes in soil water content in the soil layer 0-50 cm for investigated plots against the background of daily sums of precipitation and depth of groundwater during growing season of 1997 year

Ryc. 4. Dynamika zmian zapasów wody w warstwie 0-50 cm gleby na badanych powierzchniach na tle dobowych sum opadów i stanów wody gruntowej w okresie wegetacyjnym 1997 roku

in the situation of higher field evaporation, connected, first of all, with a higher demand for water by wheat. In the situation of higher 24 hours' precipitation sums in the first half of July (88 mm) there was a significant reconstruction of water resources in soil profiles of the researched areas. The resources were close to humidification corresponding to water field capacity. At the end of the discussed period, with lack of precipitation in August, the water resources in the 0-50 cm layer equalled 70 to 75 mm. The ground water levels were lower and reached the value below 150 cm from the area surface. A similar dynamics of humidification

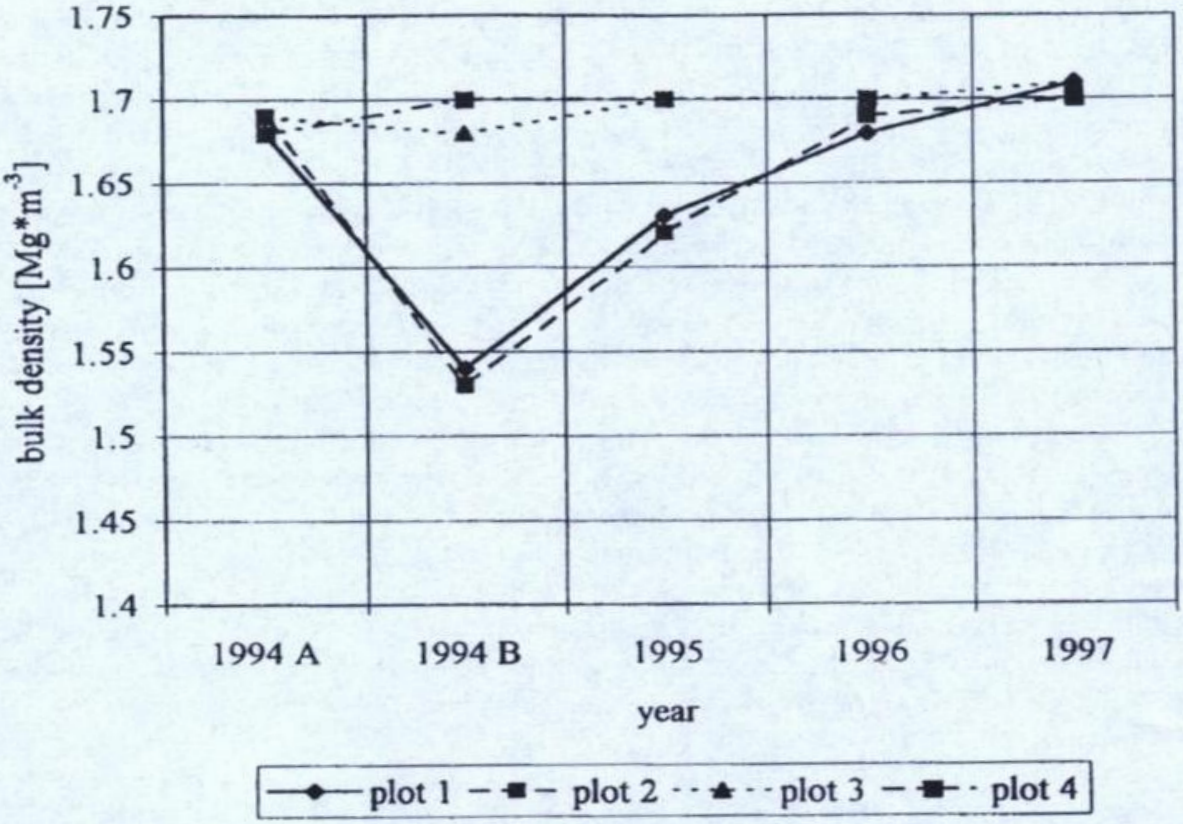

Fig. 5. Bulk densities of subsoil layer at 30-50 cm: 1994 A – before, 1994 B – immediately after and 1995, 1996, 1997 – in consecutive years after soil loosening
Ryc. 5. Wartości średniej gęstości objętościowej warstwy podornej na głębokości 30-50 cm: 1994 A – przed spulchnianiem, 1994 B – bezpośrenio po spulchnianiu, 1995, 1996, 1997 – w kolejnych latach po zabiegu

of soil top layers of the researched area was also found in the 1997 vegetation season. Thus, it can be concluded that favourable changes in water soil profile balance in the conditions of the Ostrowo Szlacheckie experimental spot are already insignificant in the third year after loosening. The observations are also confirmed by the volumetric analysis of the subsoil horizon at the depth of 30-50 cm (Fig. 5). The most meaningful changes of density of the discussed subsoil horizon were observed directly after loosening. Mean volumetric density on the loosened areas (1 and 2) equalled 1.55 Mg/m^3 and was about 0.18 Mg/m^3 smaller than in the control plots (3 and 4). Its value increased in successive years and in the third year after the treatment (1997) it reached the value close to volumetric density before the loosening. A comparatively fast inspissation of the subsoil horizon after the treatment can be connected with the occurrence of periods characterized by high soil humidification during the three of years observations. Performing cultivation treatments and harvesting which are carried out in the area by help of heavy agricultural equipment could significantly shorten the period of positive changes in the soil profile after the agromelioration. The research conducted by **Szafrański**

(1993) as well as by **Kosturkiewicz** and **Szafrański** (1993) showed, that positive changes were still observed in the fourth year after the treatment.

Limiting the water deficit in the researched soils can be achieved by regulating the drainage system outflows. The outflows in winter half years occurred only in the wet half of 1994/95. The calculated outflow ratio reached the mean value of 38 mm in the period from March to April. Having retained the amount of water, humidification of soils in May could be significantly improved. In this month, as it has been earlier discussed, water deficits connected with low precipitation in April and May and increased field evaporation occurred. The research by **Pływaczyk** and **Pęczkowski** (1997) confirmed the existence of a positive possibility of utilizing a controlled drainage system outflow to improve water retention in soil profile. An estimated value of retention growth in the layer of 1 m with a controlled outflow, in the period of July 15 till September 1, 1996 was evaluated to be 156 mm, and in the uncontrolled shed 44 mm. The research concerning the discussed problem was begun at Ostrowo Szlacheckie experimental spot in 1998. A C-4 sluice gate was constructed over the SR-14 drainage ditch which is the main collector of drainage water. The gate makes controlling the drainage water system outflow possible. The results obtained in the successive years will be the basis of evaluating the influence of controlled drainage water outflow over the formation of water balance of the researched soils.

Conclusions

1. The research proved that in mean and wet vegetation periods stages of both excessive soil humidification and high water deficits for cultivated plants occurred.

2. In the conditions of the Ostrowo Szlacheckie experimental spot, loosening carried out by help of decreasing volumetric density and loosening the subsoil horizon increased, to a high degree, retention capabilities of the researched clay soils.

3. The most significant changes in the volumetric density of the subsoil horizon were found directly after the loosening treatment. Mean volumetric density equalled 1.55 Mg/m^3 and was 0.18 Mg/m^3 lower than in the control plots. In the successive years its value was increasing to reach, in the third year after the treatment, the value approaching the density before the treatment.

4. Water resources in the 0-50 cm soil layer on the loosened areas were, after high atmospheric precipitation, about 20 mm higher as compared to the control plots. The research also showed more intensive water use over the loosened areas in the periods of precipitation deficit.

5. The initial analysis of the obtained results of the research showed that it was possible to reduce water deficits in arable areas by controlling the drainage system outflow. The thesis must be confirmed though by observing years with various meteorological conditions course.

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OCENA MOŻLIWOŚCI POPRAWY GOSPODARKI WODNEJ ZDRENOWANYCH GLEB W WIELKOPOLSCE

Streszczenie

W pracy przedstawiono wyniki badań nad wpływem aglomeracji na poprawę gospodarki wodnej gleb. Badania wykazały, że w warunkach glebowych obiektu doświadczalnego „Ostrowo Szlacheckie" wykonane spulchnianie, przez zmniejszenie gęstości objętościowej i rozluźnienie warstwy podornej gleby, w znacznym stopniu zwiększyło zdolności retencyjne gleb gliniastych. Wstępna analiza wyników badań wykazała także, że przez regulowanie odpływu wody z sieci drenarskiej jest możliwe ograniczenie niedoborów wodnych na użytkach rolnych.