ROCZNIKI AKADEMII ROLNICZEJ W POZNANIU CCCX

MELIORACJE I INŻYNIERIA ŚRODOWISKA

20

Część I

POZNAŃ 1999

CZESŁAW SZAFRAŃSKI

EVALUATION OF WATER RESOURCES OF THE GNIEZNO LAKELAND AGRICULTURAL MICROCATCHMENT

From Department of Land Improvement and Environmental Development
The August Cieszkowski Agricultural University of Poznań

ABSTRACT. The results of a many years research carried out at the Experimental Research Station of Mokronosy situated in the area of the Gniezno Lakeland have been presented in the paper. The research has shown that in water management of richly reliefed area soils, apart from a sequence of meteorological conditions, a vital role is played by land relief. It was found that while using the land agriculturally both a high seasonal changeability of water resources of soils and changeability occurring in sequences of dry and wet years had to be taken into consideration. The resources condition possibilities of plant production development and its worthwhileness.

Key words: meteorological conditions, land relief, water resources of soils

Introduction

The area of arable lands in Poland covers approximately 18.7 mln ha, which amounts to 60% of the total country's surface. The quality of agricultural space though, because of unfavourable climatic conditions and dominant poor soils, significantly differs from the European standards. Application of mineral fertilisers, pesticides, as well as modern machines and agricultural tools has caused a very fast increase in crops in a relatively short time (**Nawrocki** 1996). On the other hand highly productive plants are characterised by high demands and sensitivity to all kinds of climatic anomaly (**Dzieżyc** 1993). Negative results of the anomaly can

Rocz. AR Pozn. CCCX, Melior. Inż. Środ. 20, cz. I: 511-520

PL ISSN 1230-7394

be counteracted, apart from available water resources use intensification, by increase of natural water resources in productive areas (**Somorowski** 1993). Water resources used in agriculture are first of all soil humidity dependent upon meteorological conditions course and disposable surface and ground waters. Water economy of these resources must take into consideration their high changeability appearing in sequences of dry and wet years. That is why further reclamation proceeding aiming at adapting environmental conditions to the needs of intensive plant production will be indispensable (**Kostrzewa et al.** 1994, **Marcilonek et al.** 1995, **Somorowski** 1993, **Szafrański** 1993). Reclamation undertakings though must be based on a proper recognition and parametrization of the soil environment, as well as a good knowledge of water cycle in an agricultural catchment. It especially applies to richly reliefed young postglacial areas, characterized by a high variability of soil cover and changeability of humidity connected with varied supply by surface and subsurface run-offs as well as ground waters (**Kosturkiewicz** and **Szafrański** 1983, 1984, **Szafrański** 1988).

The areas enclosed within the early glacial relief amount to about 30% of the country's surface. According to "The instructions to arable lands draining" (1988) nonsystematic draining combined with agricultural melioration treatments should be applied on these areas (**Kosturkiewicz** and **Szafrański** 1988). It ensures levelling of soil humidity in from-the-peak-to-foot of the slope-profile, increasing water storing capability both in springtime and after high yield precipitation and also influences limiting water erosion of soils (**Kosturkiewicz** and **Szafrański** 1993, **Mioduszewski** 1991, **Szafrański** 1992, 1995).

Recognition and proper shaping of water resources in agricultural microcatchments by help of complex reclamation and field practices is in agreement with expectations and demands of the contemporary agriculture as well as the needs of natural environment protection.

Methodology

The results of the research and field observations carried out in the period of 1978-1996 at the Experimental Research Station of Mokronosy, situated within the area of the Gniezno Lakeland (latitude 52°53' N, longitude 17°28' E) have been presented in the paper. In the hydrological years of 1984/85 and 1985/86 the field research was not carried out due to lack of financial means to support it. The area in discussion is used as arable lands. Research and field observation were carried out on experimental surfaces, located in the upper, middle and lower parts of the slopes as well as field gullies.

Stationary observations and measurements included:

– limnigraphic registration of surface and subsurface run-offs from 11 experimental plots, with longitudinal slopes from 1.4 to 11.6%. The length of the plots

was 30 m, and the width 10 m. The metodology of measurements of the run-offs was presented in the work by **Szafrański** (1987),

– measurements of ground water levels in wells with a frequency of each five days and in the periods of high everyday humidity,

– daily precipitation measurements by help of Hellman's pluviometer and in vegetation period by help of a pluviograph. Also the thickness of snow cover and depth of soil freeze-up were observed in wintertime,

– systematic soil humidity measurements in typical soil profile by help of dryer-weight method and neutron probe (sounder).

The research and field observation enclosed also pedological proceedings, consisting in pits making and soil drillings, from which sampler for laboratory analysis were taken. The field measurements of soil water properties included determination of field water capacity and infiltration of top layers of the researched soil profiles. Physical and chemical properties of soils were determined in the laboratory of the Department of Land Improvement and Environmental Development of Agricultural University of Poznań. It was done applying commonly known methods. The course of meteorological conditions in the researched period was analysed and characteristic hydrological years were selected on the basis of the results of daily precipitation measurements at the Department's own gauge station and also mean daily air temperature, from the meteorological station of the Institute of Meteorology and Water Management of Gniezno. In the paper the course of water resources of agricultural microcatchment located in the area of the Gniezno Lakeland has been presented for a dry year, a wet one and a mean one.

Results

The ground and soil configuration

The area covered by the research is characterized by a strongly varied ground relief, typical for the early glacial relief. Numerous ponds and pits having no run-off and elevations reaching up to 7 m of true height and maximum longitudinal slope up to 12% characteristic for the early glacial period occur there. The Experimental Research Station of Mokronosy is situated on an undulated ground moraine of the Baltic glaciation of the Poznań stage. The moraine is composed of boulder clay, sanded in top layers. In the soil cover of the researched object, similarly to the Gniezno Lakeland, the dominant soils are of lessive type and constitute 83% of the area. Only about 17% of the researched soils are of Typic Endoaquolls soils type, occurring in the lower parts of the slopes and in ground gullies. Lessive soils, occurring on the slopes and elevation peaks, are regarded as belonging to valuation class IIIb and IVa, of the 4th complex of agricultural usability, while Typic Endoaquolls soils belong to class IIIa of the 2nd complex of agricultural usability. They have a significantly higher, as compared to lessive soils, water

and sorptive capacity and are less sensitive to drought periods. A detailed soil characteristics of the discussed object and their properties were presented in the work of **Szafrański** (1993).

The course of meteorological conditions

The climate of the Gniezno Lakeland is characterized by transitory features from oceanic to continental. Various masses of the air abrasing over the area form a changeable weather and evoke the occurrence of significant differences in quantities of precipitation and air temperatures, both in subsequent years and months of a given year. The vegetation period and field works start in the third decade of March and the period of active vegetation ends in the first decade of October. In the period of many years' research in the Experimental Research Station of Mokronosy there were years which could be regarded as wet, mean and dry (Fig. 1). While evaluating humidification of a hydrological year, apart from the amount of precipitation and air temperature as well as their aberration from mean values of many years' periods, sequence of half years and wet and dry years are very important. Taking into consideration the above factors the hydrological year 1987/88 was assumed a wet one, the 1991/92 a dry one and 1994/95 a mean one.

In the wet year of 1987/88 the total sum of precipitation was 133 mm higher than the many years' mean, with a probability of occurrence together with higher values once in a period of about nine years. Especially the winter half year was extremely wet having precipitation 93 mm higher than the mean value. In the half year high soil moisture and high ground water levels were observed as well as surface and subsurface run-off and drainage network outflow were spotted. High proportion run-off appeared in the researched area, although there was moisture deficit in lessive soils situated on the slopes of considerable acclivity, with the occurrence of unfavourable distribution of precipitation and its high density in the wet summer half year of 1988.

The 1991/92 hydrological year was dry (335 mm), with a probability of the occurrence of the same precipitation total together with lower values once in five years' period. The summer half year of 1992 was especially dry, and the precipitation total was 149 mm lower than the many years' mean for the period, with a probability of occurrence together with lower values once in 11 years' period. In the half year and 1.4°C higher air temperature as compared to many years' mean values, considerable decrease of soil water reserves and further lowering of ground water levels occurred. It must be also stressed that the year in discussion was the fourth hydrological one in the course with a total precipitation lower than the many years' mean (Fig. 1). The year was characterized by the occurrence of hydrological drought culmination, which had started in the researched area in the dry summer half year of 1989 when all the field ponds dried up. The hydrological year of 1994/95 can be rated as belonging to the group of mean years though. The sum of atmospheric precipitation equalled 498 mm and was only 21 mm higher than the many years' mean.

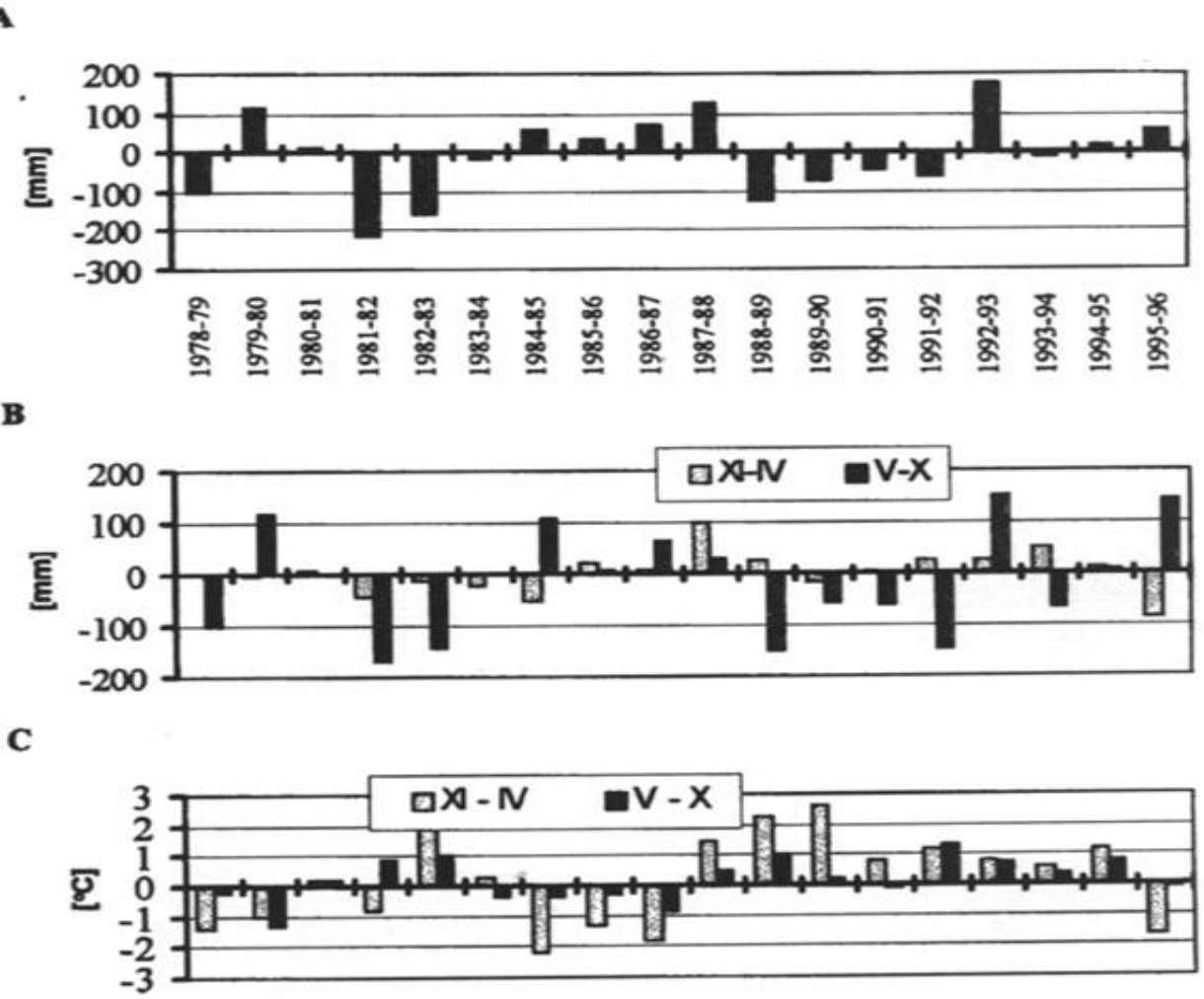

Fig. 1. Deviations of year (A) and half-year (B) sums of precipitation according to Mokronosy Station and mean half-year air temperatures (C) IMGW Gniezno Station from means of multiyear period 1978/79 to 1995/96

Ryc. 1. Odchylenia sum opadów rocznych (A) i półrocznych (B) z posterunku opadowego Mokronosy oraz półrocznych średnich temperatur powietrza (C) Stacji IMGW Gniezno od średnich z wielolecia dla lat hydrologicznych 1978/79-1995/96

Soil water resources of the researched area

The level of ground water table is a crucial factor influencing soil water resources in the richly reliefed post glacial areas. A few forms of soil profiles in the area microrelief were distinguished while analysing the ground water levels' measurement results at the Mokronosy Reasearch Station. The pointed to profiles can influence the occurrence and dynamics of ground water levels in the selected, for the analytical purposes, wet, mean and dry years occurred in the area where Typic Endoaquolls soils exist, situated close to the foot of the slope (P) and the lowest ones were observed in typical lessive soils situated at the tops of the elevations

(W). The influence of the area microrelief on the formation of ground waters can be also observed in the slope-situated lessive soils' profiles. The highest ground water levels occur on a concave slope (Zwk), having hindered conditions for both surface and ground water outflow, while on a plain slope (Zp), as well as on a convex one (Zw), both having good water outflow conditions, ground waters are situated much lower.

The course of meteorological conditions showed its influence upon different reactions of ground waters in the analysed years depending upon the position of soils in the area's relief. The maximum levels in the springtime of the wet hydrological year 1987/88 oscillated from 25 to 44 cm below the area's surface in the soils situated at the foot of the slope and on the concave slope. It proves the necessity of the area drainage to provide optimum water-air relations for the growth of cultivated plants and proper conditions for carrying out techniques of field-crop production. In the remaining soil profiles, the maximum states were much lower and could not cause excessive soil humidification.

The fact that in lessive soils situated on the plain and convex slopes, as well as at the top of the elevation the minimum ground water levels in the wet year are placed low and reach the value of 308 to 396 cm is worth mentioning. Thus they cannot significantly influence humidification of surface soil profile layers. A similar course of characteristic ground water levels and the amplitude of their fluctuations occurred in the mean year of 1994/95 (Tab. 1), whereas in the dry hydrological year of 1991/92, considering a high shortage of precipitation as compared to the many years' mean values, the levels of ground water were placed low. The mean ground water levels in the year, in lessive soils on the plain and concave slopes, as well as at the top, fluctuated from 338 to 455 cm below the area surface. Thus they could not swell the top soil layers by help of capillary rise.

Table 2 presents maximum and minimum water resources as well as the number of water shortage days in the vegetation seasons of the discussed years. As can be observed from the table, the highest water resources in the 0-100 cm layer, similarly to ground water levels, occurred in the soil profiles situated at the foot of the slope and on the concave slope, whereas the lowest water resources were observed in lessive soils situated on the convex slope and at the top of the elevation. Apart from a vital influence of the area relief, the dynamics of soil humidity changes in the researched vegetation periods was mainly dependent upon the meteorological conditions course. The lowest water resources, in the analysed soil profiles, occurred in the wet vegetation period of 1988. The maximum water resources were observed on the turn of July and they exceeded water field capacity (PPW) in the profiles situated at the foot of the slope and on the concave slope. In the months discussed, the precipitation was characterized by high intensity and efficiency. About 30 mm of water, which constituted almost 10% of the summer half year precipitation, ran out in the form of surface run-off from the slopes having a considerable acclivity. The additional amount of water swelled the concave slopes and their foot bringing about their excessive humidification. Lack of drainage network in the area would make crop harvesting impossible and would cause high losses in potato harvest.

Table 1

Maximum, mean and minimum depth of ground-water levels and amplitudes of their variation in analysed hydrological years for various location of soil profiles in the area relief
Maksymalne, średnie i minimalne stany wody gruntowej oraz amplitudy ich wahań w analizowanych latach hydrologicznych przy różnym położeniu profili w rzeźbie terenu

Year Rok	Location of profile Położenie profilu	Depth of ground-water level (cm) Stany wody gruntowej (cm)			Amplitudes Amplitudy (cm)
		max. maks.	mean śr.	min.	
1987/88	P	25	114	183	158
Wet	Zwk	44	134	184	140
Mokry	Zp	72	198	308	236
	Zw	84	205	317	233
	W	103	251	396	293
1994/95	P	40	167	216	176
Mean	Zwk	55	182	263	208
Średni	Zp	92	245	335	243
	Zw	129	271	357	228
	W	140	308	448	308
1991/92	P	95	246	305	210
Dry	Zwk	91	240	326	235
Suchy	Zp	115	338	431	316
	Zw	167	418	538	371
	W	183	455	587	404

P – foot of slope, Zwk – concave slope, Zp – straight slope, Zw – convex slope, W – top of slope.

P – podnóże zbocza, Zwk – zbocze wklęsłe, Zp – zbocze proste, Zw – zbocze wypukłe, W – wierzchołek.

In the remaining soil profiles maximum water resources were much lower. It must also be stressed that even in the wet vegetation period of 1988 minimum water resources occurred in the values lower than those of water available to plants in soil situated on both the convex slope and at the elevation's top. The periods of humidity shortage were respectively from 11 to 16 days for the soils.

In the dry vegetation season of 1992 optimum humidification occurred in the 0-100 cm layer of the analysed soil profiles only at the beginning of the period. Minimum water resources dropped below the level of the water easily available to plants in all the profiles, in the situation of high shortages of precipitation as compared to the many years' mean value. Minimum resources in lessive soils' profiles situated on the plain and convex slopes as well as the top of the slope

Table 2

Maximum and minimum water contents in the soil layer 0-100 cm and number of days with water deficiency during growing seasons of analysed years for various location of soil profiles in the area relief
Maksymalne i minimalne zapasy wody w warstwie 0-100 cm oraz liczba dni z niedoborem wilgoci w okresach wegetacyjnych analizowanych lat przy różnym położeniu profili w rzeźbie terenu

Year Rok	Location of profile Położenie profilu	Soil water content – Zapasy wody				Number of days with water Liczba dni z niedoborem wilgoci
		maximum maksymalne		minimum minimalne		
		mm	%PPW	mm	%PPW	
1987/88	P	284	104	211	77	0
Wet	Zwk	278	106	203	77	0
Mokry	Zp	250	95	180	68	0
	Zw	235	90	154	59	11
	W	206	77	151	57	16
1994/95	P	268	98	192	70	0
Mean	Zwk	262	100	184	70	0
Średni	Zp	249	95	166	63	0
	Zw	227	87	163	62	0
	W	202	75	150	56	27
1991/92	P	230	84	128	47	64
Dry	Zwk	226	86	119	45	72
Suchy	Zp	185	70	96	37	85
	Zw	190	73	93	36	89
	W	184	69	87	33	93

P – foot of slope, Zwk – concave slope, Zp – straight slope, Zw – convex slope, W – top of slope, PPW – field water capacity.

P – podnóże zbocza, Zwk – zbocze wklęsłe, Zp – zbocze proste, Zw – zbocze wypukłe, W – wierzchołek, PPW – polowa pojemność wodna.

reached the values from 87 to 96 mm in the period and approached the values of resources occurring with the humidification of permanent withering, whereas the water resources were higher and the duration of water shortages in the profiles was significantly shorter than in the remaining profiles (Tab. 2) in lessive soils on the concave slope and Typic Endoaquolls at the foot of the elevation. It must be also stated that such high water deficits in 1992 occurred in the period of the highest water demands of plants. It influenced their growth in an unfavourable way causing especially significant decrease in harvest of spring and root crops. Rape crops in the year were 35% lower, and potato as well as sugar beets crops were as much as 60% lower as compared to the crops obtained in the region in the period of optimum soil humidification in the vegetation season.

Conclusions

1. In the richly reliefed early glacial areas, a significant role is played both by the area relief and meteorological conditions course in the process of water resources formation. The relief is a decisive factor determining the depth of ground waters occurrence which influence humidification of top soil profile layers.

2. It was stated that significant seasonal changeability of soil water resources and wet and dry years series variability had to be taken into consideration while using the areas agriculturally. The resources condition the possibilities of plant production development and its worthwhileness.

3. In the physiographical conditions of the Gniezno Lakeland the highest ground water levels and humidification of top soil layers occur in Typic Endoaquolls situated at the foot of the slopes and in lessive soils on the concave slopes. In wet and mean years, the places are fed by additional amount of water coming from surface or subsurface run-off from the areas situated above them. That is why the soils often present excessive humidification and call for air-water ratio regulations.

4. In dry years high humidification deficit occurs in lessive soils on the plain and convex slopes as well as the top of the slope. The carried out researched proves that water deficit in the soils frequently occurs in the periods of highest water demands from plants. It unfavourably influences both the growth and harvesting of the plants cultivated in the areas.

Literature

Dzieżyc J. (1993): Czynniki plonotwórcze – plonowanie roślin. PWN, Warszawa.

Kostrzewa S., Pływaczyk A., Nowacki J. (1994): Wpływ drenowania i rzeźby terenu na osuszenie gleb sudeckich w okresie wiosennych prac polowych. Rocz. AR Pozn. 268, Melior. Inż. Środ. 15, cz. 1: 177-183.

Kosturkiewicz A., Szafrański Cz. (1983): Spływy powierzchniowe i podpowierzchniowe w bilansie wodnym gleb. Pr. Kom. Nauk Roln. Kom. Nauk. Leśn. PTPN 45: 127-144.

Kosturkiewicz A., Szafrański Cz. (1984): The role of surface and subsurface flow in the natural drainage of soil profile. In: International Committee of Irrigation and Drainage. 12th Congress. 827-834.

Kosturkiewicz A., Szafrański Cz. (1988): Stosowanie drenowań niesystematycznych. Załącznik do „Wytycznych drenowania gruntów ornych". Mat. Instr. IMUZ 65: 1-10.

Kosturkiewicz A., Szafrański Cz. (1993): Agromelioracje w gospodarce wodnej gleb terenów bogato rzeźbionych. Rocz. AR Pozn. 244, Melior. Inż. Środ. 12: 65-77.

Marcilonek S., Kostrzewa S., Nyc K., Drabiński A. (1995): Cele i zadania współczesnych melioracji wodnych. In: Ekologiczne aspekty melioracji wodnych. Instytut Ochrony Przyrody PAN, Kraków: 71-84.

Mioduszewski W. (1991): Wpływ melioracji na środowisko przyrodnicze. Biul. Inf. Melior. Roln. 2: 1-5.

Nawrocki S. (1996): Rolnictwo a ochrona środowiska. Zesz. Eduk. IMUZ 1: 35-45.
Somorowski C. (1993): Melioracje jako dyscyplina naukowa i działalność praktyczna. In: Współczesne problemy melioracji. Wyd. SGGW, Warszawa: 9-28.
Szafrański Cz. (1987): Spływy powierzchniowe i podpowierzchniowe w gospodarce wodnej meliorowanego terenu. Rocz. AR Pozn. 182, Melior. 7: 99-139.
Szafrański Cz. (1988): Stany wody gruntowej na tle ukształtowania meliorowanego terenu. Zesz. Probl. Post. Nauk Roln. 359: 27-42.
Szafrański Cz. (1992): Spływy powierzchniowe i erozja wodna gleb na bogato rzeźbionych terenach polodowcowych. Zesz. Nauk. AR Krak. Konf. 35: 101-109.
Szafrański Cz. (1993): Gospodarka wodna gleb terenów bogato rzeźbionych i potrzeby ich melioracji. Rocz. AR Pozn. Rozpr. Nauk. 244.
Szafrański Cz. (1995): Agromelioracje w eksploatacji systemów drenarskich. Zesz. Nauk. AR Wroc. 266, Konf. 8: 221-228.
Wytyczne drenowania gruntów ornych. (1988) IMUZ, Falenty.

OCENA ZASOBÓW WODNYCH W MIKROZLEWNI ROLNICZEJ NA POJEZIERZU GNIEŹNIEŃSKIM

Streszczenie

W pracy przedstawiono wyniki wieloletnich badań prowadzonych w Doświadczalnej Stacji Badawczej Mokronosy, położonej na Pojezierzu Gnieźnieńskim. Badania wykazały, że w gospodarce wodnej gleb terenów bogato urzeźbionych, obok przebiegu warunków meteorologicznych, istotną rolę odgrywa rzeźba terenu. Stwierdzono, że przy rolniczym użytkowaniu tych terenów należy uwzględnić dużą zmienność sezonową zasobów wodnych gleb oraz zmienność występującą w seriach lat mokrych i suchych. Zasoby te warunkują możliwości rozwoju produkcji roślinnej i jej opłacalność.