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EXTREME SOIL MOISTURE UNDER WINTER CROPS IN SPRING IN POLAND. PART I

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A b s t r a c t. This study was conducted to analyse the temporal and spatial distribution of excessive and insufficient soil moisture under winter crops (from 1 April to 30 June) published in IMGW Agrometeorological Bulletins for the years 1965-1994. The results were presented in 14 diagrams and 6 maps.

K e y w o r d s: excessive insuffcient soil moisture, winter crops, index Wug, temporal and spatial distribution

INTRODUCTION

Polish climate is characterized, among other things, by alternate occurrence of years with excessive precipitation, or precipitation deficiency, which has a pronounced impact on soil moisture [4,5]. Long periods of atmospheric droughts often brought about soil or hydrological droughts (1969, 1971, 1975, 1982, 1983, 1989 and 1992) which in turn result in a considerable decrease of plant yield [1]. Equally hazardous to plant production are wet years causing excessive soil moisture [1,7,11].

Among all the agrometorological factors soil moisture is the most complex one affecting plant growth, development and yield. However, it has rarely been used so far for estimating plant production [7], probably because of the lack of any other methods of its spatial determination, besides satellite and air photography. In recent years some attempts at spatial evaluation of top soil moisture have been made on the basis of standard meteorological data, soil texture and humus content [8,10,12].

Since 1965 the IMGW Agrometorological Department in Warsaw has prepared ten-day maps of top soil moisture on the basis of the data sent from about 300 examined areas from all over Poland [2] by local representatives. Their agricultural education and long experience, make their reports on estimated soil moisture credible. Therefore, the above mentioned reports have been used in this study to characterize temporary and spatial distribution of extreme soil moisture in Poland that has had great impact on the variation and quantity of plant yield. This paper is the first part (concerning spring) of the more detailed research covering the whole vegetation period.

MATERIALS AND METHODS

The estimates of topsoil moisture under winter crops (from 1 April to 30 June), published in IMGW Agrometeorological Bulletins for the years 1965-1994 [2] were used in this paper. The above mentioned materials were prepared by IMGW in Warsaw and presented in the form of maps on the basis of the data provided every ten days by local correspondents. Every ten days average topsoil moisture under winter crops is sent from recorded areas to Warsaw. Soil moisture is classified as excessive, sufficient and insufficient. Only extreme moisture values were analysed because

they affect the variation and quantity of plant yield. Collected data were used for making diagrams and maps [9] showing the temporary and spatial distribution of insuffcient and excessive soil moisture under winter crops in Poland. The area of the country or region with extreme soil moisture and its duration was given by means of Koźmiński's index Wug:

$$Wug = l_d \cdot p$$

where l_d - the number of subsequent ten-day periods with insufficient or excessive soil moisture in a particular stage of plant development, p - the area of the country or region with insufficient or excessive soil moisture expressed as the fraction of the total area of the country or region.

The area with extreme soil moisture (excessive and insufficient shown separately) was scaled with the help of planimeter on the maps published in Agrometeorological Bulletins. Only the insufficient soil moisture during 2 ten-day periods covering >20 % of the total area, and excessive soil moisture lasting at least ten days on the area of more than 10 % of the total area, were taken into consideration. Calculated values of the Wug index were used to estimate the area and the duration of extreme soil moisture for the years 1965-1994 in Poland, and 6 chosen regions representing different climatic regions.

The spatial distribution of the average number of periods with insufficient soil moisture lasting at least 2, 3 and 4 ten-day periods and periods with excessive soil moisture lasting at least 1, 2 and 3 in the areas recorded by IMGW are shown in 6 maps in this paper.

The average percentage of the country or region area covered by excessive or insufficient soil moisture in different ten-day spring periods is shown in the diagrams for the years 1965-1994.

RESULTS

Diagrams presented in Fig. 1 show striking differences of the Wug index in particular years and chosen areas representing different climatic conditions of the country. Periods with extreme soil moisture, recorded in spring, are often of regional character, have different duration and cover different areas. For example in 1966, intensive soil drought (Wug - 3.8) was observed in the Wrocław region whereas in the Rzeszów area there was excessive soil moisture (Wug - 2.8). In 1978 excessive moisture was noticed in the Rzeszów region (Wug - 3.3) while soil drought occurred in the Szczecin region (Wug - 2.8).

In five out of the six regions under study, more frequent soil droughts were found in the last few years, especially in the Lublin region. At the same time the frequency of periods with excessive soil moisture decreased. The calculated trends show that extreme moisture is highly significant (for excessive $r_{xy} = -0.452$, for insufficient $r_{xy} = 0.531$).

The highest variation coeffcient of the Wug index for insufficient soil moisture was found for the Białystok region (164.0 %) and the lowest for the Poznań region (118.0 %). The values of the Wug index for extreme soil moisture range from 98.2 in the Rzeszów region to 117.1 in the Poznań region. For the whole country those values are: 142.2 % and 107.6 %, respectively (Table 1).

While analysing the Wug index for excessive soil moisture in the whole country we can notice the decrease of its value in recent years (significant negative trend r = -0.424) and the increase in the case of insufficient soil moisture. In spring the Wug values for insufficient soil moisture are bigger than those for excessive ones all over the country, but in certain

Table 1. Mean values and coefficient of variation c.v. (in %) of index Wug of insufficient and excessive soil moisture in particular provinces and all over Poland. Years 1965-1994

Region	Insufficient		Excessive	
	mean	c.v.	mean	c.v
Szczecin	0.65	145.0	0.71	98.7
Białystok	0.54	164.0	0.82	111.2
Poznań	0.74	118.0	0.50	117.1
Wrocław	0.63	154.7	0.65	115.5
Lublin	0.59	144.1	0.59	107.1
Rzeszów	0.72	131.0	1.08	98.2
Poland	0.61	142.2	0.51	107.6

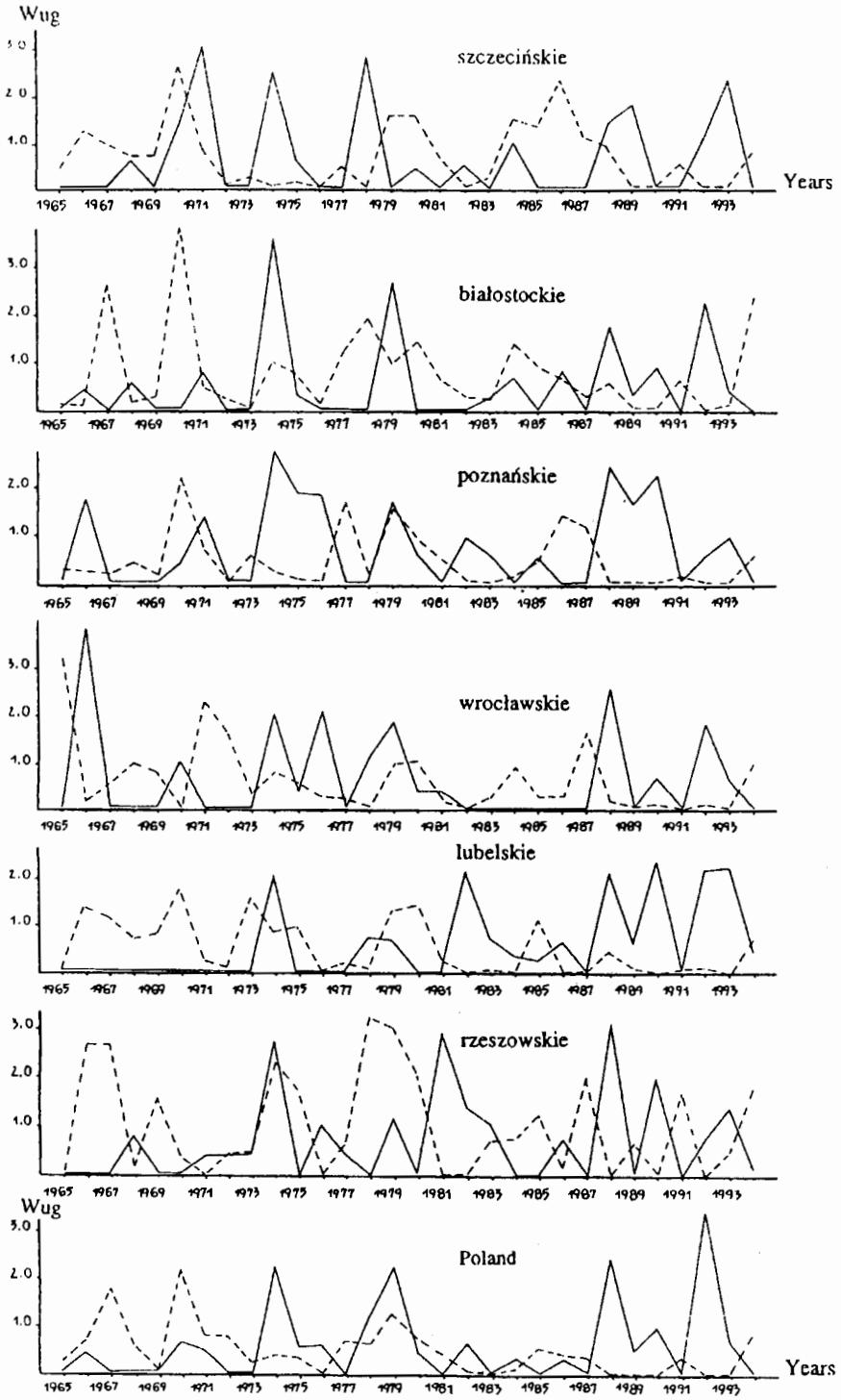

Fig. 1. Distribution of Wug index values for insufficient (___) and excessive (- - - -) soil moisture in the chosen regions and in Poland in the period from 1 April to 30 June.

regions Wug means can be contrary to them, as for example in the Rzeszów and Białystok regions (Fig. 1).

In Fig. 2 the diagrams show the frequency of years and the area with excessive and insufficient soil moisture in spring in different ten-day periods, in the six chosen regions and the whole country. From April to June the years with insufficient soil moisture are more frequent (from 5-30 %) and the areas much larger (from 5 to 15 %). The described trend is noticeable also all over Poland where the frequency of years with insufficient soil moisture amounts from 10-35 % and the occupied areas from about 5-15 % of the total country area.

In the first ten-day period of April to the second ten-day period of May, the years with excessive soil moisture are less frequent and the areas much smaller both in the studied regions (from 30 to about 5 % and from 15 to about 2 %) and the total area (from 30 to 15 % and 10 to 5 %). From the 3rd ten-day period of May to the 2nd or 3rd ten-day period of June the years with excessive soil moisture occur more often and cover larger area (Fig. 2). Excessive soil moisture in early spring mainly depends on soil temperature and precipitation in winter [6].

As seen from Fig. 3, the number of periods with insufficient topsoil moisture, lasting at least 2 ten-day periods (from April to June) is in different areas (recorded by IMGW) from below 6 to over 15. In spring, droughts lasting at least 2 ten-day periods occur in the middle-western part of Poland in the Koszalin, Słupsk, Elbląg, Bydgoszcz, Włocławek, Konin, Poznań and Gorzów regions where the number of periods is larger than 15.

In eastern and southern Poland except the Bielsk Podlaski, Krosno and Opole regions such droughts rarely occur (<9).

The spatial distribution of the periods with moisture lasting at least 3 ten-day periods (Fig. 4) ranges from below 3 to over 9. The spatial distribution of the number of periods with droughts, seen in Figs 2 and 3, is similar to the spatial distribution of atmospheric droughts, which are longer than 15 days [5].

In the studied many-year periods, extended periods (>4 ten-day periods) with insufficient soil moisture are scarce in Poland. Their number is smaller than 3 (Fig. 5). Only in 6 reported areas droughts lasting at least 4 ten-day periods occur every 5 years.

The occurrances of excessive topsoil moisture in spring are considerably different in particular, reported areas (Figs 6-8). The number of periods with excessive soil moisture lasting at least 1 ten-day period is within 9 to 27, with the highest values in south-eastern Poland (Fig. 6). Far more often excessive soil moisture can be found in the Karpaty and the Karpaty plateau than in the Sudety mountains.

Longer excessive soil moisture (>2 ten-day periods) occur less often in comparison with the above mentioned (the number of periods 1-9, Fig. 7). In southern and eastern Poland the number of periods with excessive soil moisture is higher from 3.

The periods with excessive soil moisture lasting at least 3 ten-day periods occur very rarely in spring. The number is from 1 to 3 for most part of the country and only in some areas recorded by IMGW is higher than 5 (Fig. 8).

CONCLUSIONS

1. Winter crops can be at risk every 3rd year (on average) by excessive soil moisture in early spring and insufficient soil moisture in the second half of spring.

2. More frequent soil droughts from April to June are mainly caused by the depletion of winter water reserves in the soil, the increase of water requirements and evapotranspiration.

3. In spring there are 2 periods of excessive soil moisture with more frequent occurrence - the beginning of April and the end of June.

4. The greatest threat to winter crops is caused by insufficient soil moisture in middle-western Poland and the smallest threat in the eastern and south-eastern part of the country, whereas the spatial distribution of

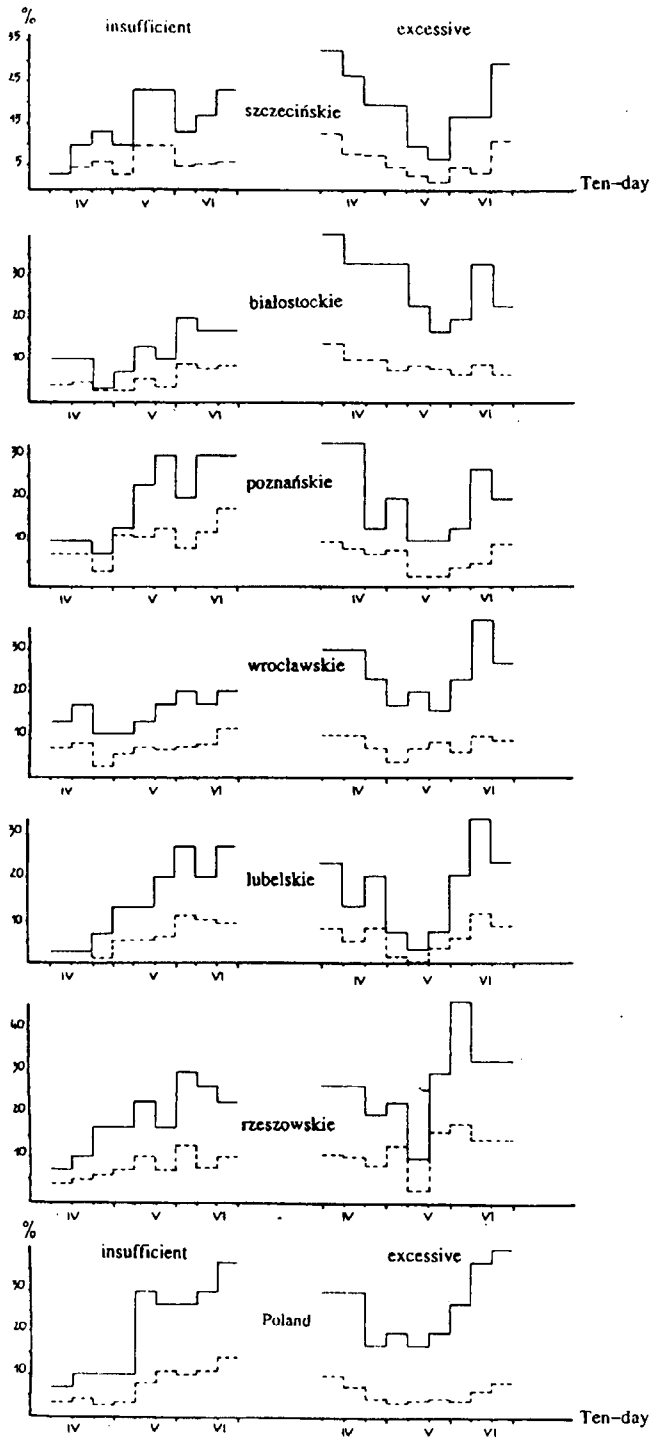

Fig. 2. Mean percentage of the area of the chosen regions and the country (- - - -) with insufficient and excessive soil moisture and the frequency of years (——) with these soil moisture.

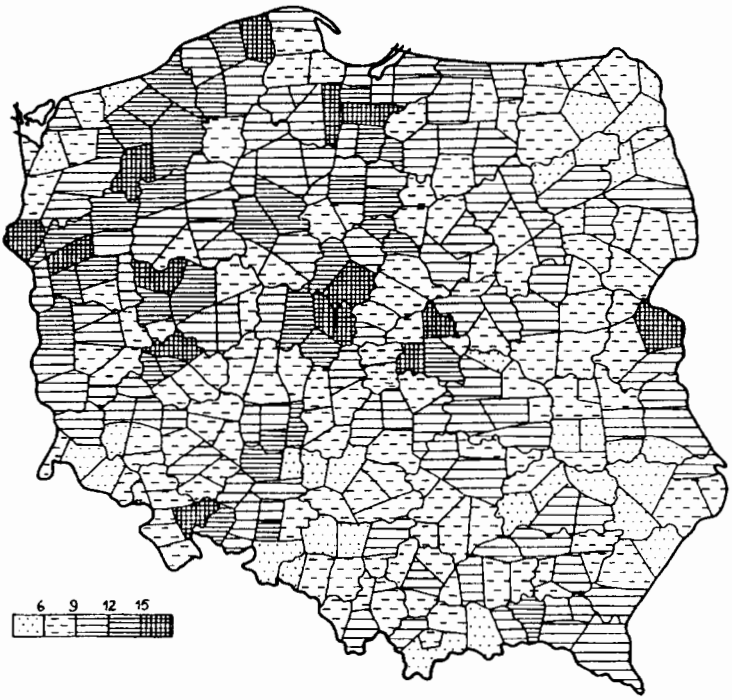

Fig. 3. Number of periods with insufficient topsoil moisture lasting at least 2 ten-day, recorded at IMGW reporting areas from 1 April to 30 June in the years 1965-1994.

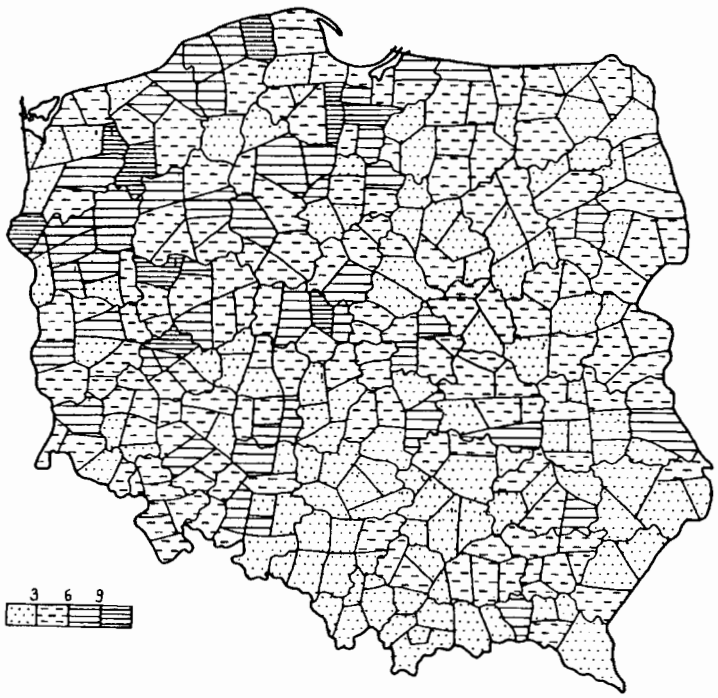

Fig. 4. Number of periods with insufficient topsoil moisture lasting at least 3 ten-day, recorded at IMGW reporting areas from 1 April to 30 June in the years 1965-1994.

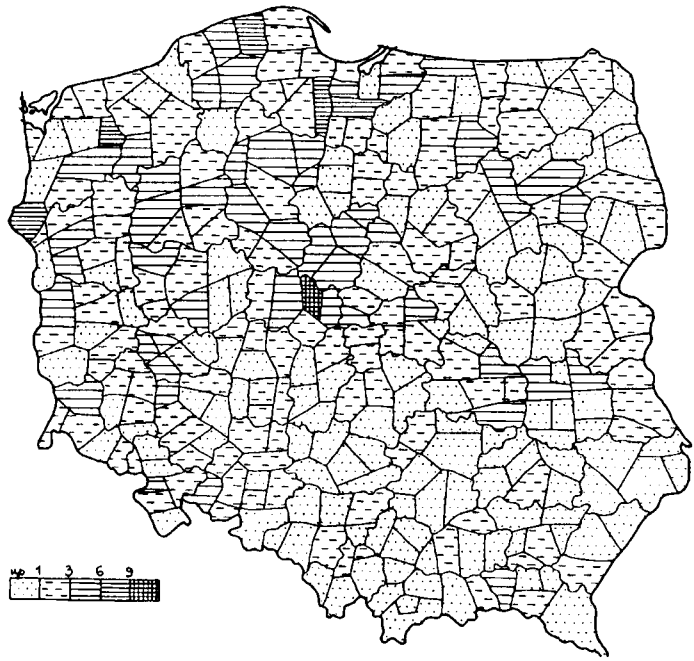

Fig. 5. Number of periods with insufficient topsoil moisture lasting at least 4 ten-day, recorded at IMGW reporting areas from 1 April to 30 June in the years 1965-1994.

Fig. 6. Number of periods with excessive topsoil moisture lasting at least 1 ten-day, recorded at IMGW reporting areas from 1 April to 30 June in the years 1965-1994.

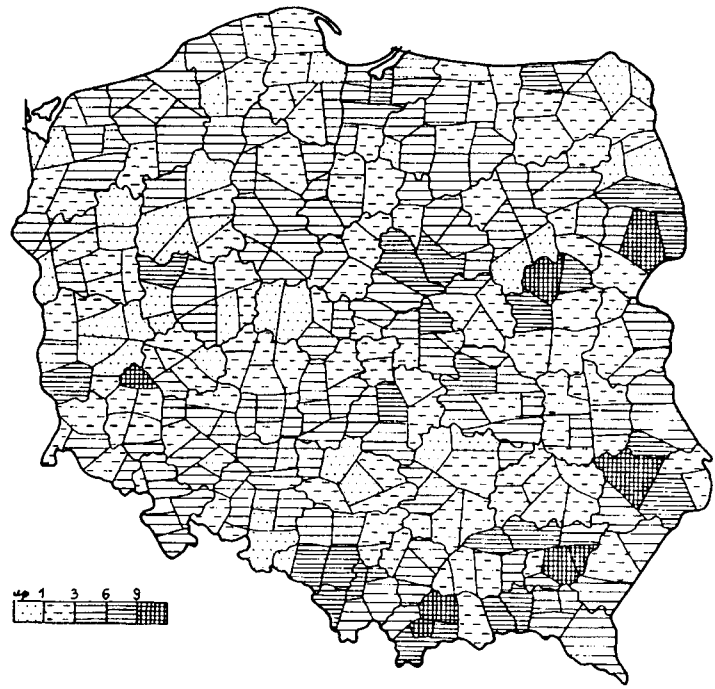

Fig. 7. Number of periods with excessive topsoil moisture lasting at least 2 ten-day, recorded at IMGW reporting areas from 1 April to 30 June in the years 1965-1994.

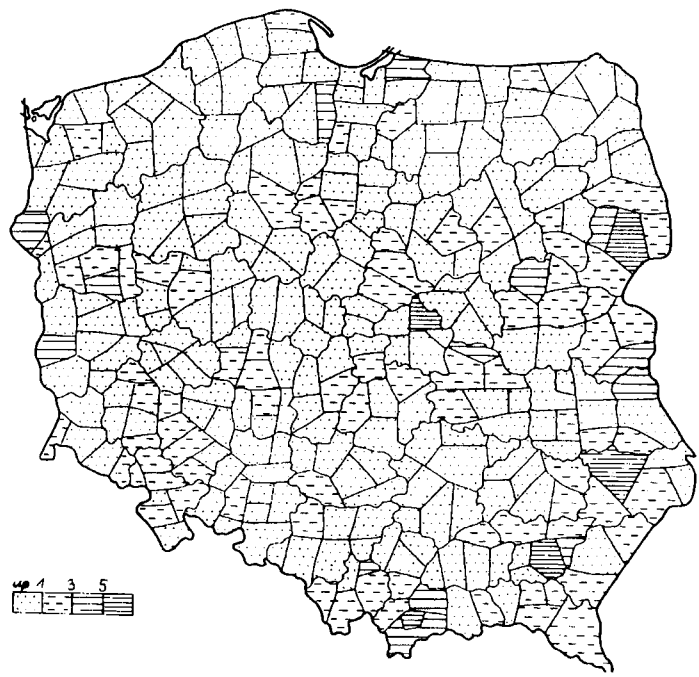

Fig. 8. Number of periods with excessive topsoil moisture lasting at least 3 ten-day, recorded at IMGW reporting areas from 1 April to 30 June in the years 1965-1994.

the thre due to excessive soil moisture is the opposite.

5. Excessive soil moisture is more frequent in the Karpaty and Karpaty plateau than in the Sudety mountains.

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EKSTREMALNE UWILGOTNIENIE GLEBY WIOSNĄ POD OZIMINAMI W POLSCE. Cz. I

W pracy wykorzystano dane o szacunkowym uwilgotnieniu wierzchniej warstwy gleby w Polsce pod oziminami (od 1 IV do 30 VI), publikowane w Biuletynach Agrometeorologicznych IMGW za lata 1965-1994. Analizowano czasowy rozklad niedostatecznego i nadmiernego uwilgotnienia gleby w poszczególnych latach (za pomocą wskaźnika Wug) oraz przestrzenny rozklad według obszarów sprawozdawczych IMGW. Wyniki przedstawiono na 14 diagramach i 6 mapach.

S ł o w a k l u c z o w e: nadmierne i niedostateczne uwilgotnienie gleby, oziminy, wskaźnik Wug, czasowy i przestrzenny rozkład.