

Potential threats of agricultural drought in the Małopolska voivodeship

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ABSTRACT

Drought is a complex process occurring in the natural environment. It leads to a reduction in water resources and a slow depletion of water in the catchment area. Atmospheric drought is followed by the so-called soil drought, as soil moisture resources decrease and the soil begins to dry out. A further lack of rainfall leads to agricultural drought, which has a negative impact on crop production. For many years, IUNG PIB Puławy has been running the Agricultural Drought Monitoring System in Poland. Based on the Climatic Water Balance (KBWs), it indicates areas where there is a risk of drought in relation to crops with a specific soil structure. The aim of the study was to assess the potential risk of agricultural drought in selected areas of the Małopolska voivodeship. The districts of Olkusz, Miechów, Proszowice and Dąbrowa, where precipitation is the lowest compared to the provincial average, were analysed. The analysis shows that the risk is not significant, and where it did occur, the importance of agricultural production is relatively small. It was also shown that potential drought risks depend more on soil factors than on crop structure.

Keywords: agricultural use, soil index, climatic water balance, drought risks.

INTRODUCTION

Drought is a complex process that occurs in the water and soil environment, resulting in a reduction in the amount of water in a given ecosystem. The main cause of this phenomenon is a prolonged lack of rainfall, often combined with higher air temperatures and air circulation, which significantly increases evapotranspiration.

In such weather conditions, atmospheric drought begins first (Łabędzki et al., 2008; Łabędzki and Bąk, 2011). Its severity also depends on the time of year when it occurs. If there is still no rainfall during atmospheric drought, the process of drying out the soil profile, known as soil drought, will begin. The free water reserves in the soil profile are gradually depleted, the soil moisture reserves decrease, and the soil drying process begins (Łabędzki, 2004; Łabędzki, 2006).

In such cases, even a single instance of heavy rainfall will not always alleviate the phenomenon of drought. Heavy rainfall (so-called torrential rain) causes excess water to run off the surface of the ground instead of soaking into its profile (Kopeć, 1990). As a result, groundwater resources decrease. The springs and small watercourses begin to dry out and low levels of deep water appear in the rivers. In extreme situations, smaller watercourses cease to carry water (Twardy et al., 2001; Twardy et al., 2007; Kruk, 2017). A continued lack of rainfall during a soil drought leads to a hydrological drought and, together with a soil drought, to a so-called agricultural drought.

Soil drying, lowering of the groundwater level, and reduction of river flows pose direct economic and social threats to humans. Agriculture is particularly vulnerable, as crop yields decrease and economic losses increase (Łabędzki, 1996; Łabędzki, 2004).

The aim of this study was to assess the potential risk of agricultural drought in selected areas of the Małopolska voivodeship, taking into account soil types and the structure of popular crops. The selected areas are statistically the most vulnerable to drought. They are characterised by below-average precipitation and highly diverse soil conditions (Mioduszeński, 1996; Mioduszeński, 1999; Twardy, 2009; Kopacz, 2011).

CHARACTERISTICS OF THE RESEARCH AREA

The analysis was conducted for the northern part of the Małopolska voivodeship, covering the districts of Olkusz, Miechów, Proszowice, and Dąbrowa Tarnowska (Figure 1). This area covers 2,240 km², which accounts for 14.8% of the total area of the

Małopolska voivodeship. The largest district under consideration is Miechów (area 676.3 km²), and the smallest is Proszowice (414.9 km²). The region has a population of nearly 267,000, which accounts for 8% of the total population of the Małopolska voivodeship (data from the Central Statistical Office for 2014). The population density here is almost half the average for the entire voivodeship, at 119 inhabitants per km².

Agricultural land dominates the land use structure. Its total area is 169,907 ha, which accounts for nearly 76% of the total area of all four districts. The Olkusz district has the smallest area of agricultural land (53.1% of the total area of the district), but there are many forests (37.6%). Some municipalities in the district are heavily forested, such as Bukowno, Klucze, Bolesław, and the vicinity of Olkusz. In addition to larger towns such as Olkusz and Wolbrom, there are

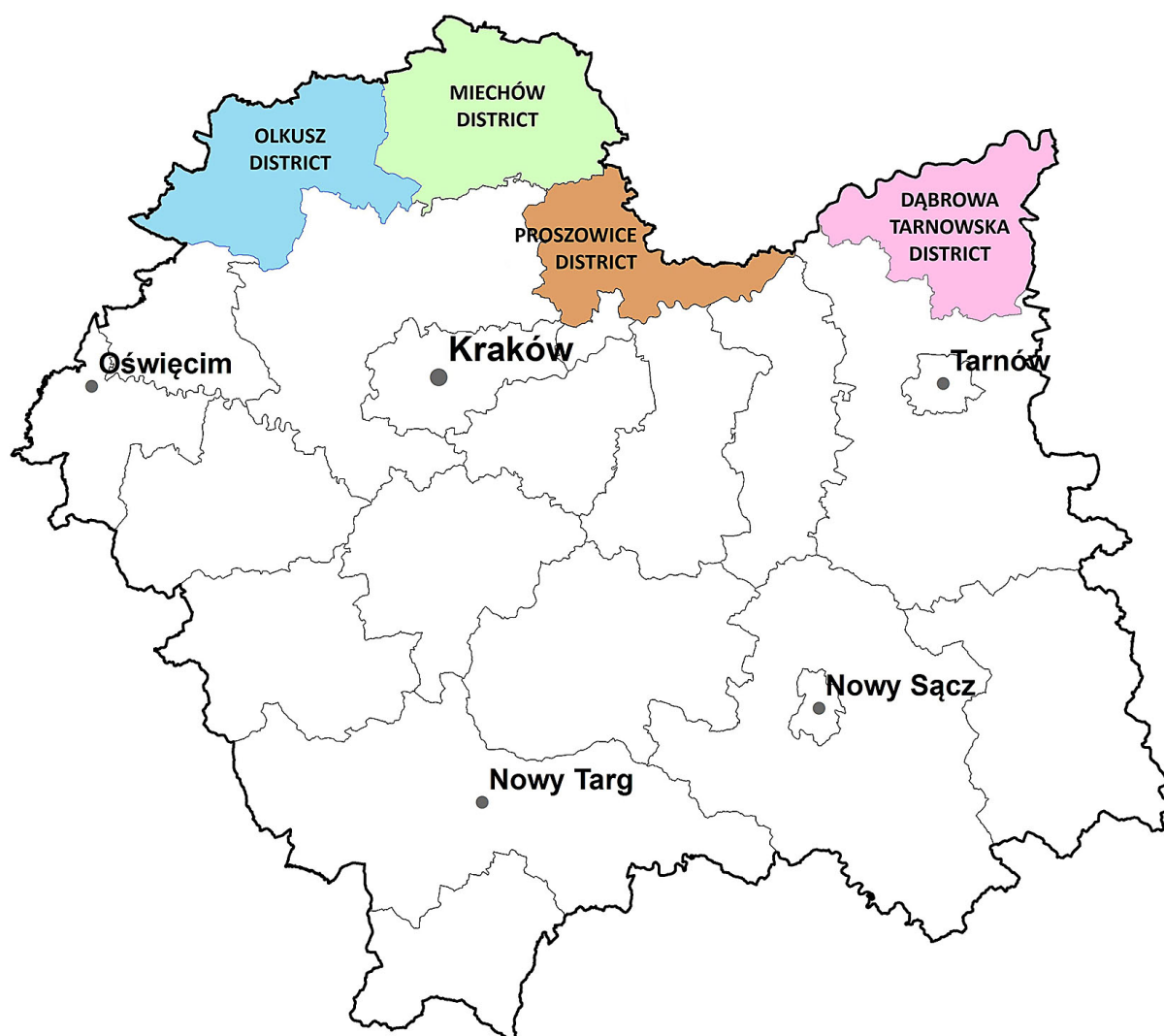


Figure 1. Research area – counties of the northern part of the Małopolska voivodeship

industrial areas here, especially in the municipalities of Bukowno and Bolesław (Table 1). The high proportion of forests in these municipalities is the result, among other things, of afforestation around industrial and mining areas as compensation for environmental changes related to mining and industrial activity in this area (Kopacz and Puszkarz, 1997).

The district with the highest share of agricultural land (93.2% of the total area) is Proszowice.

Arable land dominates the agricultural land, accounting for approx. 75% of the District's area. These areas, like the agricultural areas of the Miechów District, are the agricultural and vegetable base for the inhabitants of the Krakow agglomeration. These are areas where farmers and city dwellers are most interested in protection against drought, which potentially poses the greatest threat in terms of material losses (Smoroń et al., 2009).

Table 1. Land use structure in the analysed municipalities and districts of the Małopolska voivodeship (% of total area)

District/Comune	Agricultural land						Forests	Developing areas	Orther
	Total	including							
		Arable land	Orchards	Meadows	Pastures	Other			
Olkusz District	53.1	45.8	0.6	1.9	2.3	2.5	37.6	6.5	2.9
Bolesław	38.9	27.5	0.5	6.3	2.9	1.7	43.3	11.4	6.4
Bukowno	13.1	9.2	0.4	1.3	1.6	0.5	74.5	9.4	3.1
Klucze	36.8	28.2	0.4	2.8	3.7	1.8	48.9	5.4	8.9
Olkusz	44.0	39.1	0.2	0.6	1.9	2.2	46.8	8.5	0.8
Trzyciąż	80.8	74.1	0.9	0.8	1.4	3.6	16.9	2.0	0.4
Wolbrom	79.1	69.9	1.0	2.2	2.2	3.8	14.7	5.5	0.7
Miechów District	83.2	75.1	1.4	2.7	1.7	2.4	12.3	3.8	0.6
Charsznica	89.1	77.2	2.6	4.1	1.1	4.0	5.5	5.2	0.3
Gołcza	89.2	81.5	2.5	0.8	1.7	2.7	7.5	2.8	0.5
Kozłów	84.6	70.6	1.8	6.5	2.6	3.0	10.5	4.3	0.6
Książ Wielki	67.9	65.2	0.0	1.2	1.4	0.1	28.3	3.0	0.8
Miechów	89.6	82.2	1.3	1.6	1.7	2.8	5.0	4.9	0.5
Raclawice	78.5	72.2	1.5	1.2	1.1	2.5	18.3	2.6	0.6
Słaboszów	87.7	77.0	1.0	4.7	2.1	2.9	7.8	3.4	1.2
Proszowice District	93.2	76.3	2.1	9.6	1.5	3.8	1.9	3.5	1.4
Koniusza	94.2	79.0	2.1	8.3	1.0	3.8	1.8	3.4	0.6
Koszyce	89.4	66.9	2.3	14.0	2.4	3.8	3.3	3.3	4.1
Nowe Brzesko	92.2	70.0	2.2	11.2	3.3	5.5	2.0	3.4	2.3
Pałecznica	96.1	84.2	2.9	5.0	0.9	3.0	1.0	2.7	0.3
Proszowice	92.4	73.6	1.9	12.3	0.7	3.9	2.1	4.7	0.8
Radziemice	96.0	86.7	1.8	4.0	1.3	2.3	0.9	2.6	0.6
Dąbrowa Tarnowska District	79.5	64.1	1.3	6.1	3.6	4.3	14.6	3.8	2.2
Bolesław	84.9	76.9	0.8	1.2	0.8	5.2	6.1	3.7	5.4
Dąbrowa Tarnowska	77.1	61.6	0.8	6.6	3.6	4.5	17.3	5.3	0.4
Gręboszów	86.9	79.2	1.1	0.5	1.4	4.7	6.2	3.2	3.7
Mędrzechów	75.6	58.8	2.1	5.1	4.5	5.2	17.7	3.2	3.5
Olesno	84.6	71.4	1.4	4.1	3.4	4.2	10.6	3.3	1.5
Radgoszcz	78.6	65.9	0.6	4.8	3.4	3.9	18.4	2.5	0.5
Szczucin	75.9	52.5	2.3	12.1	5.1	4.0	16.3	4.0	3.8
Total of 4 districts	75.9	64.7	1.3	4.5	2.2	3.1	17.9	4.5	1.8

Note: Own study based on data from the Local Data Bank – Central Statistical Office.

METHODS

The analysis of the risk of drought was conducted on the basis of two selected indicators related to agricultural areas. The KBW indicator was used, as recommended in the drought risk assessment by IUNG-PIB in Puławy, and it was also related to the crop structure and soil characteristics expressed by the Wg soil indicator (Doroszewski and Marcinkowska, 1995). The Wg index was determined on the basis of the diversity of the agronomic soil categories occurring in a given municipality (District).

These categories depend on the variability of the granulometry of ploughed soil and, thus, on the field water capacity (FWC). These soils were divided into four categories, from very light (cat. I) to heavy (cat. IV). The FWC range for different soil types varies greatly. Table 2 shows the FWC values in the soil profile from 0 to 100 cm.

Agronomic soil categories determine varying susceptibility to drought. Very light soils (cat. I) are the most sensitive, and the vegetation grown on them is the most vulnerable. Light soils (cat. II) are assessed as susceptible to drought, medium soils (cat. III) as moderately susceptible, and heavy soils (cat. IV) as not very susceptible. The Wg index was therefore calculated as the weighted average of the percentage share of individual agronomic soil categories. The weights were determined empirically on the basis of long-term data obtained from the Agricultural Drought Monitoring System (SMSR) run by IUNG-PIB Puławy, through the analysis of changes in a larger research area. Higher weights corresponded to lighter soils, which are more susceptible to drought. An increasing value of the Wg index therefore meant greater soil susceptibility to drought.

The following drought risk levels were established for the Wg index:

- level 1 – no risk or insignificant risk ($Wg < 15$),
- level 2 – moderate ($15 < Wg < 25$),
- level 3 – significant ($25 < Wg < 35$),
- level 4 – very significant ($Wg > 35$).

The Wg soil index is therefore an identifier indicating the varying sensitivity of these soils to drought (Kopacz and Twardy, 2015). The second indicator used to assess the potential risk of drought is the Climatic Water Balance (KBWs).

For many years, IUNG-PIB Puławy has been operating the aforementioned Agricultural Drought Monitoring System (SMSR) in Poland. In order to determine the potential risk of drought, this study used the KBW threshold values for individual crops depending on soil types and the growing season, as applied in the SMSR (Doroszewski, 2010; Doroszewski et al., 2012). On this basis, individual KBW threshold values were determined for individual municipalities, taking into account the soil structure in each of them. They were designated with the symbol KBWg. Similarly to the soil index Wg, the KBW thresholds determined by IUNG-PIB Puławy for individual crops and growing seasons were averaged. The averaging was performed using a weighted average, where the weights were the percentage shares of individual soil types in a given municipality.

The obtained KBWg threshold values for each municipality were weighted averaged, this time taking into account the structure of field crops, based on data from the General Agricultural Census and the Regional Data Bank of the Central Statistical Office. In this case, the weights were the percentage shares of the sown area in the total arable land area for individual crops. This resulted in a quantified individual index for each municipality, taking into account the soil structure (Wg and KBWg indices) as well as field crops. It was defined as: the weighted average threshold values of the climatic water balance KBWs.

For KBWs, a division into four drought risk categories was adopted, analogously to the soil index Wg in the range of values (Kopacz and Twardy, 2015):

- level 1 – no danger or low danger ($KBWs < -230$),
- level 2 moderate danger ($-230 < KBWs < -200$),
- level 3 – significant danger ($-200 < KBWs < -170$),
- level 4 – very significant danger ($KBWs > -170$).

Using the aforementioned system and taking into account the values of the soil index Wg, an analysis of the actual drought risks that occurred in 2009–2015 was also carried out, using the results of the SMSR discussed below (Doroszewski et al., 2012).

RESULTS

In terms of granulometry, medium and heavy soils are most common in districts located in

the northern part of the Małopolska voivodeship. Together, they account for nearly 79% of all ploughed land. Light and very light soils, on the other hand, cover 21.3% of arable land.

Table 2. The range of field water capacity of soils

Field water capacity range [mm] in the soil layer 0–100 cm			
Very light soil (category I)	Light soil (category II)	Medium soil (category III)	Heavy soil (category IV)
110–145	146–210	211–270	271–460

Note: Regulation of the Minister of Environment of 23 December 2002 – Annex.

Table 3. Share (in [ha] and [%] of arable land) of agronomic soil categories.

District/Comune	Agronomic categories of soils							
	Arable land area [ha]				Share of arable land [%]			
	I	II	III	IV	I	II	III	IV
Olkusz District	8681.0	3713.9	6103.4	10878.0	29.6	12.6	20.8	37.0
Bolesław	489.8	292.3	445.7	90.1	37.2	22.2	33.8	6.8
Bukowno	612.3	129.3	11.6	0.0	81.3	17.2	1.5	0.0
Klucze	2226.1	469.8	230.4	612.6	62.9	13.3	6.5	17.3
Olkusz	3360.8	1213.0	829.9	857.6	53.7	19.4	13.3	13.7
Trzyciąż	507.7	519.0	1712.3	4446.6	7.1	7.2	23.8	61.9
Wolbrom	1484.3	1090.5	2873.6	4871.2	14.4	10.6	27.8	47.2
Miechów District	1041.2	2939.1	25015.2	22678.5	2.0	5.7	48.4	43.9
Charsznica	78.0	236.2	2745.0	2843.0	1.3	4.0	46.5	48.2
Gołcza	127.2	189.4	2727.4	4491.6	1.7	2.5	36.2	59.6
Kozłów	596.6	1527.6	1258.6	2913.7	9.5	24.3	20.0	46.3
Książ Wielki	167.8	545.5	3854.4	4383.1	1.9	6.1	43.1	49.0
Miechów	38.9	241.7	7115.1	4944.2	0.3	2.0	57.7	40.1
Raclawice	26.0	49.5	3294.9	1071.4	0.6	1.1	74.2	24.1
Słaboszów	6.7	149.2	4019.8	2031.5	0.1	2.4	64.8	32.7
Proszowice District	14.0	165.3	24883.3	7602.6	0.0	0.5	76.2	23.3
Koniusza	5.1	11.3	5086.4	1999.8	0.1	0.2	71.6	28.2
Koszyce	7.0	31.2	4054.5	652.2	0.2	0.7	85.5	13.7
Nowe Brzesko	0.0	75.8	2900.8	890.4	0.0	2.0	75.0	23.0
Palecznica	0.0	5.7	3271.6	889.5	0.0	0.1	78.5	21.4
Proszowice	0.0	24.2	6018.7	1514.9	0.0	0.3	79.6	20.0
Radziemice	2.0	17.2	3551.5	1655.8	0.0	0.3	68.0	31.7
Dąbrowa Tarnowska District	6243.3	9307.4	5695.2	15473.1	17.0	25.3	15.5	42.1
Bolesław	11.9	278.2	138.5	2438.6	0.4	9.7	4.8	85.1
Dąbrowa Tarnowska	1952.1	2571.3	1388.3	1769.9	25.4	33.5	18.1	23.0
Gręboszów	17.9	120.5	309.8	3451.8	0.5	3.1	7.9	88.5
Mędrzechów	606.3	801.7	854.7	734.8	20.2	26.8	28.5	24.5
Olesno	832.1	1692.6	1126.8	2315.6	14.0	28.4	18.9	38.8
Radgoszcz	1733.9	1912.3	905.7	1556.2	28.4	31.3	14.8	25.5
Szczucin	1089.0	1930.8	971.4	3206.3	15.1	26.8	13.5	44.6
Total of 4 districts	15979.4	16125.6	61697.1	56632.2	10.6	10.7	41.0	37.6

Note: Own study based on data from ADMS – Agricultural Drought Monitoring System (IUNG-PIB Puławy).

There are differences between individual districts and municipalities. The districts of Miechów and Proszowice have a soil structure that is slightly more resistant to possible water shortages. Very light and light soils account for only a few percent of the arable land here. The worst situation is in the municipality of Kozłów (Miechów District), where soils less resistant to drought cover 34% of the ploughland area (Table 3).

Against this background, the average soil index W_g for all four districts characterises the arable soils of this area as moderately vulnerable to

drought. In Miechów and Proszowice districts, the differences are small, with mean W_g values of 14.5 and 16.6, respectively, which is on the border between categories I and II. In all municipalities of both districts, the risk is either non-existent or moderate. The greatest variation in the index is found in the Olkusz and Dąbrowa districts. There are municipalities here where there is practically no potential risk of drought due to soil types. These include the municipalities of Bolesław and Gręboszów in the Dąbrowa district and Trzyciąż in the Olkusz district. However, there

Table 4. Soil index (W_g), weighted average threshold values of Climatic Water Balance (KBWs) and the degree of drought risk

District/Comune	W_g	Drought risk level based on W_g	KBWs	Drought risk level based on KBWs
Olkusz District	23.1	2	-233.4	1
Bolesław	30.5	3	-218.4	2
Bukowno	42.0	4	-193.0	3
Klucze	34.5	3	-209.1	2
Olkusz	33.3	3	-209.9	2
Trzyciąż	13.2	1	-255.0	1
Wolbrom	17.6	2	-246.8	1
Miechów District	14.5	1	-254.7	1
Charsznica	13.5	1	-258.7	1
Gołcza	11.7	1	-253.4	1
Kozłów	17.9	2	-244.6	1
Książ Wielki	13.7	1	-258.6	1
Miechów	14.3	1	-256.0	1
Raclawice	16.6	2	-253.4	1
Słaboszów	15.4	2	-259.7	1
Proszowice District	16.6	2	-276.7	1
Koniusza	15.8	2	-254.9	1
Koszyce	18.0	2	-250.9	1
Nowe Brzesko	16.7	2	-254.4	1
Pałecznica	16.8	2	-256.5	1
Proszowice	17.0	2	-256.4	1
Radziemice	15.3	2	-258.7	1
Dąbrowa Tarnowska District	20.5	2	-238.1	1
Bolesław	8.3	1	-262.0	1
Dąbrowa Tarnowska	26.2	3	-224.7	2
Gręboszów	7.1	1	-276.7	1
Mędrzechów	24.1	2	-235.8	1
Olesno	20.5	2	-236.5	1
Radgoszcz	26.4	3	-224.6	2
Szczucin	19.8	2	-245.7	1
Total of 4 districts	18.1	2	-248.1	1

Note: Own study based on data from ADMS – Agricultural Drought Monitoring System (IUNG-PIB Puławy).

are municipalities where the risk is very significant, for example Bukowno in the Olkusz district, or significant, for example in Klucze, Olkusz, Bolesław (Olkusz district), Dąbrowa Tarnowska or Radgoszcz (Table 4).

In the case of weighted KBWs threshold values, the situation is much better. The potential risk of drought, given the current crop structure in the municipalities and districts in question, is low. Only a significant level of risk was recorded in the municipality of Bukowno, where the highest degree of drought risk was identified due to soil types. It is a heavily forested municipality with industrial and built-up areas, and agricultural land accounts for only 13.1% of the municipality's area (Table 1). Therefore, in practice, the risk of drought in the context of agricultural production is low anyway.

Figure 2 shows the relationship between the determined Wg and KBWs indices. A significant statistical relationship was found, with a high coefficient of determination R^2 . The spread of points is not large, which means that the cultivation factor in relation to the soil factor does not cause significant changes in the level of drought risk. In other words, the crop structure in the analysed municipalities is, on the one hand, so little diversified that it does not significantly affect the level of drought risk. On the other hand, it can be concluded that even greater changes in the structure of field crops are not the most important factor

determining the risk of water shortage for plants. Therefore, the factor determining the level of drought risk (apart from other important parameters, such as climate and meteorological conditions) is the soil structure in a given area.

The above analysis of indicators based on knowledge of soil structure and information on crop structure identifies those areas which, due to the aforementioned parameters, may be potentially vulnerable to drought in terms of agricultural production. It does not take into account other non-agricultural factors or the climatic situation in individual parts of the studied area.

In order to assess the real drought risks in the selected study area, a survey was also carried out on the basis of actual measured KBW values for individual growing seasons from 2009 to 2020.

Table 5 presents selected reporting periods within the SMSR during which there was a risk of drought for the municipalities in question. The risk of drought based on the KBW value occurred in approximately 7% of cases for this area. Despite these threats, only in the case of the municipality of Bukowno (Olkusz District) was the measured KBW exceeded in relation to the weighted average threshold KBWs value. The dominant crop in this municipality is winter wheat.

The monitoring results therefore confirm earlier analyses indicating a generally low potential risk of agricultural drought in the agricultural

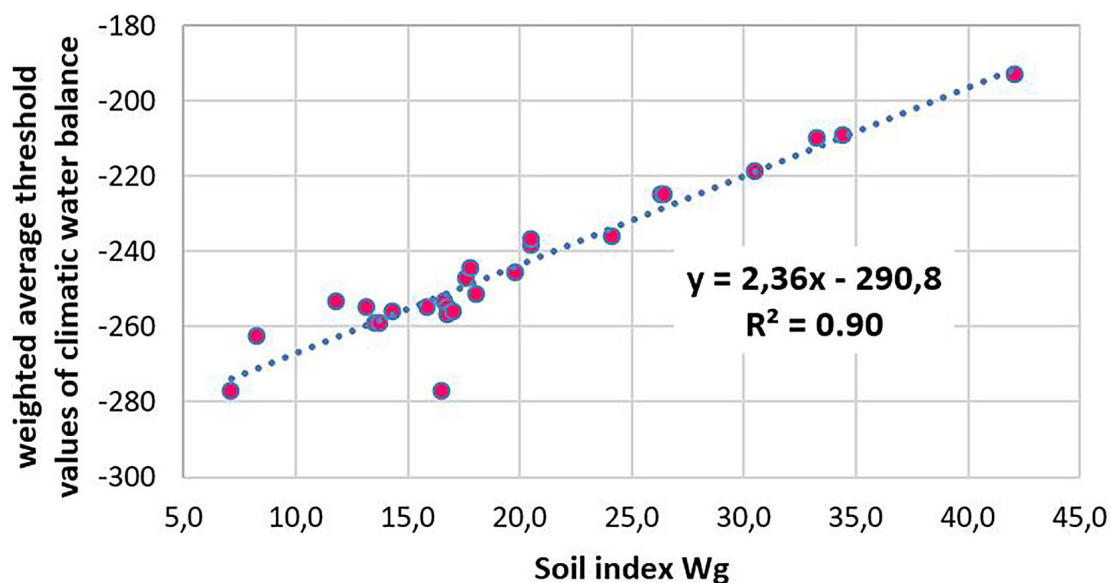


Figure 2. The relationship between the soil index (Wg) and the average threshold climatic water balance (KBWs) in the northern part of the Małopolska voivodeship

Note: Own study based on data from ADMS – Agricultural Drought Monitoring System (IUNG-PIB Puławy)

Table 5. Selected periods (from 2009–2024) in which the risk of drought occurred based on the measured KBW index (mm) against the background of the KBWs index

Comune	District	Reporting period *							The lowest values from the period 2009–2020	KBWs
		2009	2013		2015			2022		
		1.IV - 31.V	1.VII - 31.VIII	11.VII - 10.IX	21.VI - 20.VIII	1.VII - 31.VIII	11.VII - 10.IX	1.V - 20.VI		
Bolesław	Olkusz	-127.8	-148.5	-138.8	-183.9	-206.8	-156.3	-173.5	-206.8	-218.4
Bukowno		-126.4	-144.6	-135.3	-182.2	-205.5	-153.9	-175.7	-205.5	-193.0
Klucze		-121.9	-147.5	-136.2	-180.1	-201.3	-152.6	-172.3	-201.3	-209.1
Olkusz		-117.5	-143.3	-131.9	-177.7	-198.6	-148.3	-178.6	-198.6	-209.9
Trzyciąż		-114.7	-143.8	-130.3	-176.9	-194.4	-145.0	-181.4	-194.4	-255.0
Wolbrom		-122.5	-151.1	-136.3	-179.4	-197.5	-148.7	-182.0	-197.5	-246.8
Charsznica	Miechów	-132.6	-163.7	-145.9	-186.0	-203.1	-154.9	-185.0	-203.1	-258.7
Gołcza		-123.7	-157.4	-140.3	-182.5	-199.2	-150.4	-186.9	-199.2	-253.4
Kozłów		-138.3	-173.2	-152.8	-188.4	-207.1	-159.6	-187.4	-207.1	-244.6
Książ Wielki		133.7	-175.2	-153.4	-187.3	-205.8	-158.7	-193.2	-205.8	-258.6
Miechów		-124.7	-162.0	-142.8	-182.6	-199.5	-151.4	-191.8	-199.5	-256.0
Raławice		-124.8	-170.7	-147.7	-188.2	-205.0	-157.6	-189.0	-205.0	-253.4
Słaboszów		-129.4	-176.7	-153.5	-188.7	-205.9	-159.1	-187.3	-205.9	-276.7
Koniusza	Proszowice	-119.9	-160.5	-138.6	-184.4	-201.2	-154.1	-199.0	-201.2	-254.9
Koszyce		-118.6	-178.8	-151.4	-189.6	-205.1	-165.2	-197.5	-205.1	-250.9
Nowe Brzesko		-120.1	-170.4	-145.1	-187.7	-204.0	-159.6	-192.8	-204.0	-254.4
Pałecznica		-122.1	-171.6	-146.6	-187.4	-204.2	-157.0	-187.6	-204.2	-256.5
Proszowice		-120.0	-167.4	-142.9	-185.6	-202.6	-156.1	-189.4	-202.6	-256.4
Radziemice		-120.9	-165.5	-142.8	-185.8	-202.8	-155.3	-187.3	-202.8	-238.1
Bolesław	Dąbrowa Tarnowska	-119.1	-192.2	-164.1	-196.5	-211.7	-174.6	-196.5	-211.7	-262.0
Dąbrowa Tarn.		-108.7	-186.8	-159.3	-192.2	-207.2	-170.7	-193.8	-207.2	-224.7
Gręboszów		-119.8	-187.7	-159.0	-194.6	-209.6	-172.3	-198.4	-209.6	-276.7
Mędrzechów		-118.1	-194.5	-166.2	-197.7	-212.8	-175.9	-192.6	-212.8	-235.8
Olesno		-114.7	-188.0	-160.6	-195.3	-210.7	-173.2	-188.2	-210.7	-236.5
Radgoszcz		-110.8	-191.7	-163.6	-193.0	-208.0	-172.0	-189.6	-208.0	-224.6
Szczucin		-118.6	-198.7	-170.0	-198.9	-213.0	-177.7	-184.3	-213.0	-245.7

Note: Own study based on data from ADMS – Agricultural Drought Monitoring System (IUNG-PIB Puławy).

areas of the counties in question. Other studies show that the remaining areas of the Małopolska voivodeship, if only because of the higher rainfall there, are equally at low risk of this phenomenon (Kopacz and Twardy, 2015).

CONCLUSIONS

The northern part of the Małopolska voivodeship, covering four districts, is characterised by a diverse land use and agricultural production structure. The Proszowice and Miechów districts

are dominated by medium and heavy soils, which are less susceptible to drought. There are also fairly fertile soils here, characterised by high soil quality classes and agricultural production space valuation indices. These are agricultural areas, with a predominance of arable land and a long tradition of production for the food supply needs of the Kraków and Silesian agglomerations. The Dąbrowa district also has a similar agricultural character, although the granulometric composition of the soils there is less favourable in terms of drought risk. The Olkusz district, on the other hand, differs from the previous ones – it is more

industrial in nature, although it is characterised by extensive forest cover. Therefore, agriculture is of lesser importance here.

The entire area mentioned is characterised by lower rainfall than the provincial average, which makes it more vulnerable to water shortages than other parts of Małopolska.

The analysis shows that the area in question is not significantly threatened by agricultural drought. Potential threats are determined more by soil factors than precipitation, as well as by the inappropriate selection of crops for local habitat conditions. The small number of cases of agricultural drought in relation to specific plant species indicates that the crop structure in this area is well adapted to the climatic and soil conditions.

Only in one municipality, Bukowno (Olkusz District), was a minimal exceedance of the weighted average KBWs threshold recorded in relation to the worst KBW recorded in the last seven years of monitoring.

Although no significant drought threats were identified in the northern part of the Małopolska voivodeship, counteracting this negative phenomenon in agriculture is of significant economic and environmental importance. All technical and structural measures are desirable from the point of view of both agricultural production and environmental protection. The shaping of the usable space in this region plays an important role in the implementation of sustainable and lasting development.

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