Water Shortage in Polish Agriculture and Its Economic Consequences

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Abstract: Water is a key factor in the development of agricultural production, both for crops and animals. Poland, one of the main producers of agricultural produce and foodstuffs in the European Union, is regarded as belonging to the group of countries with poor water resources, with the country more frequently experiencing droughts in recent years. This paper presents an overview of the issue of water management in Polish agriculture and the possible consequences of changes in this area as a subsystem of the national economy – agribusiness. The principal source of data for the analyses was information from public statistics and the State Research Institute of Soil Science and Cultivation (IUNG-PIB). The analyses show that there is an urgent need for changes to the approach to water shortages in agriculture at various levels of decision making, both with regard to agricultural policy as well as in the behaviour of farmers. The connections described here can serve as a basis for more comprehensive economic research in the field of water usage in agriculture.

Keywords: climatic changes; agricultural drought; agribusiness; agriculture; Poland

JEL Classification: Q15; Q54; R11

1. Introduction

Water is the most precious natural resource and plays a leading role in the life of humankind and the natural environment. From an economic point of view, water fulfils its special role both for the individual and for households (for drinking, cooking and cleaning), as well as in many areas of production and services in the national economy. Among the sectors and branches of industry in which water is of key importance in economic processes are agriculture and heat and electricity production (hydroelectric plants, water used to cool reactors, etc.) (Piwowar & Dzikuć, 2022). On a global scale, it is agriculture that uses the most water resources (around 70-80% of global water resources) (Crovella et al., 2022; Bazilian et al., 2011). There are of course many other sectors in which water is used as a raw material for production or as an environment for production processes. The subject of consideration in this article is the use of water resources in agricultural production, a key aspect to which is the noticeable shortage of water resources in Poland, both as a whole and in agricultural processes. In recent years in particular, low total rainfall has coincided with high temperatures, which has had a negative effect on the volume and quality of crops (Żmudzka, 2004). Meanwhile, due to ever more favourable conditions, opportunities are being created in Poland for the growing of plants that require high temperatures (Koźmiński et al., 2021).

This paper relates to the territory of Poland, a country that is of significant importance in terms of agricultural production in the European Union, especially in the production of cereals, rapeseed, sugar beet, apples, poultry, pork and milk (Firlej et al., 2015; Szajner & Szczepaniak, 2020). Agricultural production requires a large amount of water, and the principal source of water for crops is atmospheric precipitation. The amount and type of precipitation varies considerably over time and geographical location. The climatic changes currently observed in Poland consist of a rise in temperatures and the more frequent occurrence of extreme phenomena. Rural areas are therefore faced with serious challenges in terms of adapting to the effects of climate change. According to data from the Institute of Meteorology and Water Management in Warsaw, in the years 1951-2020, there was a statistically significant increase in the average annual air temperature (at a significance level of 0.05), with a rising trend of 0.29 °C per 10 years. This translates into a rise in temperature in the period given (since 1951) of 2.0 °C (Klimat Polski, 2021). In addition, especially in recent years, there have been periods of very high temperatures in the summer months. In combination with relatively low rainfall (and other unfavourable changes from the point of view of agriculture, including snow-free winters), these have had an unfavourable effect on agriculture, especially the growing of crops. What is more, as indicated by Grillakis (2019), drought conditions are expected to worsen in Europe, especially in Eastern Europe and the Mediterranean Basin. Poland belongs to the group of countries with few water resources in comparison to European countries in general. It is estimated that the total amount of water flowing into the Baltic per Polish citizen per year is just under 1,600 m3, that is almost three times less than the average inhabitant of Europe (around 4,600 m3) (Florek et al., 2017).

The topic of water management in the Polish agricultural sector is being addressed ever more frequently in the subject literature, especially in the context of improving water retention and flood protection. The issue of making rural areas in Poland more resilient to climate change, amongst others by land consolidation, was the subject of an analysis by Stańczuk-Gałwiaczek et al. (2018). There are also many studies in this field concerning microbiology, plant physiology and agronomy, including the dependencies and effects of changes to soil humidity on soil biology, and changes in the quality and quantity of crops (Brzozowski & Stasiewicz, 2017; Siebielec et al., 2020). Interesting research in this field has also been conducted into the development of energy crops in Poland, e.g. a study by Liberacki et al. (2022) into the conditions for the development of willow for energy purposes in the west of Poland. This is an important issue, as development of such production and greater use of biomass for energy needs (e.g. as part of agricultural biogas plants) is one of the key elements in ensuring energy security for Poland based on renewable sources (Bielski et al., 2021; Piwowar et al., 2016). Meanwhile, Piwowar et al. (2021) and Kuczyńska et al. (2021) addressed issues related to unfavourable changes in water pollution due to agricultural activity. However, very little space is dedicated in the subject literature to the problem of scarcity of water resources and its effect on agriculture, as well as in the context of mutual linkages within agribusiness.

It is also worth underlining that not only the production of crops requires a suitable supply of water, but also animal husbandry. The water footprint for slaughter livestock (the main category in livestock production in Poland) is dependent above all on the type of fodder and the effectiveness of animal production (Florek et al., 2017). In the rearing and breeding of animals, water from precipitation and watering are used to produce fodder, in addition to water used for drinking and maintaining livestock.

The principal aim of this paper is to identify problem areas that may appear along with the deepening problems related to water shortages in agriculture in Poland. Taking into account the scarcity of such papers in the subject literature, this paper fills this gap by providing a broad view of the issue in question in the context of the development of agribusiness. As such, this article is a synthetic exploration of new tendencies in this research field.

2. Methodology

This paper uses the following research methods: monographic/descriptive methods, analyses and syntheses, induction and deduction. Data concerning current problems related to drought affecting agricultural crops in Poland was obtained from the Agricultural Drought Monitoring System (acronym SMSR in Polish). This system uses the climatic water balance (CWB) and the regional variability of soil conditions to assess the threat of drought. The CWB expresses the difference between atmospheric precipitation and potential evapotranspiration. Climatic water balance values are calculated for subsequent sixty-day periods on the basis of meteorological station readings (synoptic stations and precipitation gauges belonging to the Institute of Meteorology and Water Management – IMGW). This system was developed by the Institute of Soil Science and Cultivation for the Ministry of Agriculture and Rural Development. The system is designed to indicate areas that have suffered losses caused by drought to crops covered by the 'Act on subsidies for the insurance of agricultural crops and livestock in Poland' (SMSR System). This paper presents the results for the most important agricultural crops in Poland in terms of the largest sown areas – cereal crops, as well as rapeseed and agrimony.

3. The Scale of the Problems of Water Shortages in Polish Agriculture and its Possible Consequences for Agribusiness

Analyses of the threat of drought in Poland have shown that 55.64% of the territory of Poland is under serious threat of drought. Areas at the highest, most extreme threat level cover close to 5% of the country (State Water Holding Polish Waters, 2022). The threats to agricultural production in Poland are evidenced by water shortages for crops, which are calculated as the difference between evapotranspiration and atmospheric precipitation, taking into account soil retention (Mioduszewski, 2012). The latest information from the Agricultural Drought Monitoring System (acronym SMSR in Polish) shows that in Poland in the years 2020-2022 there was a worsening of the phenomenon of water shortages in cereal and rapeseed crops (Table 1). Cereals are the most important group of crops in Poland. The sown area in Poland in 2021 was 10.9 million hectares, with a domination of cereals (68.4% of the total sown area). Rapeseed crops covered about 1 million hectares in Poland in 2021 (Agriculture in 2021, 2022). Polish public statistics includes the joint production of rapeseed and agrimony, of which the decided majority is winter rape.

Table 1. Drought in Poland for cereal and rapeseed crops in the years 2020-2022

Details	Spring cereals			Winter cereals			Rapeseed and agrimony (spring, summer)		
	2020	2021	2022	2020	2021	2022	2020	2021	2022
Number of communes with drought	922	1,115	2,096	761	733	1,909	247	1,212	1,734
% of communes with drought	37.22	45.01	84.62	30.72	29.59	77.07	9.97	48.93	70.00
% of arable land with drought	12.34	14.30	38.17	8.93	8.32	25.19	2.52	13.12	20.97

The data presented in Table 1 shows that the problem of water shortages affects extremely large areas of cereal and rapeseed production in Poland. According to reports by the IUNG-PIB, considerable areas of rapeseed crops suffered from water shortages in the Lubelskie voivodeship (the region that has the second largest area of rapeseed crops after the Dolnośląskie voivodeship). Detailed information on crop losses in individual voivodeships and communes are available on the Agricultural Drought Monitoring System website (SMSR System).

Drought is a natural phenomenon and cannot be completely eliminated. However, action can be taken to limit its influence on the level of agricultural production, and to counteract its effects. This action, taken at the level of agriculture and rural areas, is extremely important taking into account its effects on other areas of agribusiness (Figure 1).

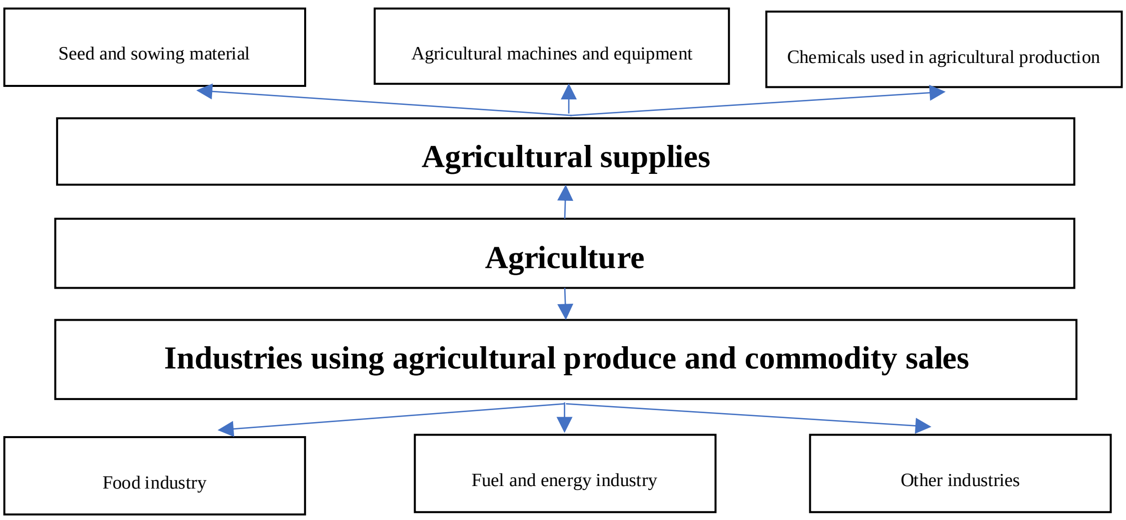

Figure 1. Selected areas experiencing problems connected to water shortages in agriculture

Water shortages in agricultural production will result in changes (both in terms of quantity and quality) for the whole agribusiness sector. Agricultural producers to an increasing degree will have to pay attention to the selection of species and varieties for which water stress will not be a key factor in limitations on the size and quality of crops. Generally, plant needs are expressed using the transpiration coefficient, which determines the amount of water used (transpired) in kilograms or in litres calculated for 1 kilogram of dry plant mass. Plant varieties that use C4 photosynthesis (including corn) use less water to form a crop, while the most popular crops in Poland (which use C3 photosynthesis) use more water. On the one hand, a rise can be expected in the production of heat-tolerant plants (e.g. sunflower, soya and corn), while on the other hand, new varieties will be developed and implemented of plants currently grown, but with better parameters regarding water stress (higher tolerance to water shortages). This will be linked to changes to other elements and agrotechnical processes (including the varieties and types of fertilizers and pesticides used, as well as the agricultural machines and equipment used). Changes in the field of agricultural supplies for production will move in the direction of the development of products that stimulate the growth and development of plant root systems. Balanced fertilising with phosphorus and potassium will be highly important (development of the root system, correct water management). There may also be an increase in the use of no-till conservation systems (including aggregates for strip-till).

Water shortages will also affect the quantity of livestock production. In this case, the effect will be the result of the linkages between crop and livestock production (production of fodder), as well as keeping livestock as a part of industrial farming. In terms of meadows and pastures, there will be a problem with several windrows. In meadow and pasture farming, optimal water levels affect the quality of meadow and pasture fodder, which translates into the productivity achieved in livestock production. What is more, these levels are the basis for development in low-cost production systems (e.g. ecological animal husbandry), and are a key factor in limiting threats and ensuring an equilibrium in the natural environment (Burczyk et al., 2018). Meanwhile, intensive animal production requires very large water resources, especially for the production of beef and pork. The water footprint for meat increases depending on the type, with the lowest being for poultry, followed by pork, mutton and then beef (Mekonnen & Hoekstra, 2012). These variabilities are explained by the difference in the fodder conversion coefficient. Ruminants (cattle, sheep and goats) have a low fodder conversion coefficient in comparison to monogastric animals (poultry and pigs) (Ibidhi & Ben Salem, 2020).

As underlined above, water shortages can have an influence on the structure of sowing (type and category of crops, changes in areas of sowing/planting for particular groups of use/varieties). This in turn may be a challenge in terms of new knowledge that is required for conducting proper agrotechniques for the development of crops e.g. soya (currently, the sown area in Poland is around 25,000 hectares). There will also be changes in the times of agrotechnical processes, e.g. adapting sowing dates to thermal and humidity conditions, and using varieties with shorter vegetation cycles that are more resistant to water shortages. These changes must take place not only in the agrotechnical sphere (in addition to those mentioned earlier, e.g. greater use of organic fertilisers, introducing catch crops) and in new investments in watering infrastructure, but also in general agricultural practices that encourage the infiltration and retention of water in the soil in rural areas.

Changes to the production of agricultural produce will be transmitted to the processing industry. The largest recipient of agricultural produce is the food industry, therefore every change to crop sowing practices (and consequently harvests) will have a direct effect on the foodstuffs available to processing plants. This raw materials barrier, which may appear due to a decrease in the supply of agricultural produce, will limit production capability and the currently high levels of food exports, and will result in a growth in imports (e.g. of cereals and oil-rich plants), and as a consequence worsen the balance of foreign trade in agricultural produce and food. The changes may affect not only the food industry, but also other industries in which agricultural produce is processed (e.g. for biofuel or biocomponents). There will also be changes to the trade in commodities in the agribusiness sector, especially in the context of adapting to the current and future needs of the agri-food industry and consumer (social) needs.

4. Summary

Changes in the climate not only have an effect on actions undertaken in the field of agriculture, but also on all other areas of agribusiness. Agriculture is connected to other sectors both on a functional and production level, and as a result, any changes to agriculture have consequences for the remaining sectors (supplies, industry and trade). The importance of water is therefore crucial not only for the agricultural sector, but also for other production and service sectors of agribusiness. The problem of water management in agriculture is complex, as both a shortage of water as well as excessive use of water (waste) lead to social, environmental and economic problems, the consequences of which reach beyond the scope of agricultural activity in a given region. These consequences are felt over a considerably larger geographical area as well as in the activity of related enterprises (the production and distribution of agricultural supplies, plant nurseries, the food industry, gastronomy, trade, etc.).

Changes in agriculture due to the warming of the climate require both the adaptation of agricultural production to the new conditions (selection of species/varieties, times of sowing, new threats related to plant diseases, pests, etc.), as well as the design of new solutions in rural areas to improve water retention and for flood protection. The current issue of the scarcity of water resources in agriculture must take into consideration the context of sustainable development, and the existence of more complicated and complex relations than previously anticipated, for example for the issue of water footprint (e.g. the issue of taking into account the import and export of fertilisers, fodder, etc.) make it difficult to make comparisons in this domain. It is also vital to better understand how water stress affects long-term growth and crops, which can be the basis for new research initiatives into plant modification, crop rotation, agrotechnical processes etc. A change is necessary in the approach of agricultural producers, and particular attention should be paid to the issue of the availability of water. Climate change will force new initiatives to be undertaken in terms of switching from growing water-absorbent species/varieties in favour of those which use water resources to a lesser degree. This can be followed up by a system of financial incentives (e.g. in terms of changes in the direction of crop production instead of the action currently taken), as well as implementing economic instruments to water and agricultural policy, including those referring to internalisation of the external effects of agricultural production on the availability of water. Changes to water management in agriculture and rural areas will generally require a variety of socio-economic and environmental compromises.

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References

Agriculture in 2021. (2022). Statistics Poland, Warsaw.

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, P., Mueller, A., Komor, P., Tol, R. S. J., & Yumkella, K. K. (2011). Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy, 39*(12), 7896-7906. https://doi.org/10.1016/j.enpol.2011.09.039

Bielski, S., Marks-Bielska, R., Zielińska-Chmielewska, A., Romaneckas, K., & Šarauskis, E. (2021). Importance of Agriculture in Creating Energy Security—A Case Study of Poland. *Energies, 14*(9), 2465. https://doi.org/10.3390/en14092465

Brzozowski, B., & Stasiewicz, K. (2017). Effects of water stress on the composition and immunoreactive properties of gliadins from two wheat cultivars: Nawra and Tonacja. *Journal of the Science of Food and Agriculture, 97*(4), 1134-1142. https://doi.org/10.1002/jsfa.7839

Burczyk, P., Gamrat, D., Gałczyńska, M., & Saran, E. (2018). Rola trwałych użytków zielonych w zapewnieniu stanu równowagi ekologicznej środowiska przyrodniczego. *Woda-Środowisko-Obszary Wiejskie, 18*, 21-37.

Crovella, T., Paiano, A., & Lagioia, G. (2022). A meso-level water use assessment in the Mediterranean agriculture. Multiple applications of water footprint for some traditional crops. *Journal of Cleaner Production, 330*, 129886. https://doi.org/10.1016/j.jclepro.2021.129886

Firlej, K., Hamulczuk, M., Kozłowski, W., Kufel, J., Piwowar, A., & Stańko, S. (2015). *Struktury rynku i kierunki ich zmian w łańcuchu marketingowym żywności w Polsce i na świecie*. Wyd. IERiGŻ-PIB.

Florek, M., Barłowska, J., & Litwińczuk, Z. (2017). Ślad wodny w produkcji zwierząt rzeźnych. *Annales Universitatis Mariae Curie-Skłodowska, Sectio EE Zootechnica, 35*(3). https://doi.org/10.24326/jasbb.2017.3.1

Grillakis, M. G. (2019). Increase in severe and extreme soil moisture droughts for Europe under climate change. *Science of the Total Environment, 660*, 1245–1255. https://doi.org/10.1016/j.scitotenv.2019.01.001

Ibidhi, R., & Ben Salem, H. (2020). Water footprint of livestock products and production systems: A review. *Animal Production Science, 60*(11), 1369-1380. https://doi.org/10.1071/AN17705

Klimat Polski 2020. (2021). Wyd. Instytut Meteorologii i Gospodarki Wodnej – PIB.

Koźmiński, C., Nidzgorska-Lencewicz, J., Mąkosza, A., & Michalska, B. (2021). Ground Frosts in Poland in the Growing Season. *Agriculture, 11*(7), 573. https://doi.org/10.3390/agriculture11070573

Kuczyńska, A., Jarnuszewski, G., Nowakowska, M., Wexler, S. K., Wiśniowski, Z., Burczyk, P., Durkowski, T., & Woźnicka, M. (2021). Identifying causes of poor water quality in a Polish agricultural catchment for designing effective and targeted mitigation measures. *Science of the Total Environment, 765*, 144125. https://doi.org/10.1016/j.scitotenv.2020.144125

Liberacki, D., Kocięcka, J., Stachowski, P., Rolbiecki, R., Rolbiecki, S., Sadan, H. A., Figas, A., Jagosz, B., Wichrowska, D., Ptach, W., Prus, P., Pal-Fam, F., Łangowski, A. (2022). Water Needs of Willow (Salix L.) in Western Poland. *Energies, 15*(2), 484. https://doi.org/10.3390/en15020484

Mekonnen, M. M., & Hoekstra, A. Y. (2012). A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems, 15*(3), 401-415. https://doi.org/10.1007/s10021-011-9517-8

Mioduszewski, W. (2012). Zjawiska ekstremalne w przyrodzie—Susze i powodzie. In A. Łachacz (Ed.). *Wybrane Problemy Ochrony Mokradeł* (pp. 57–74). Uniwersytet Warmińsko-Mazurski w Olsztynie.

Piwowar, A., & Dzikuć, M. (2022). Water Energy in Poland in the Context of Sustainable Development. *Energies, 15*(21), 7840. https://doi.org/10.3390/en15217840

Piwowar, A., Dzikuć, M., & Adamczyk, J. (2016). Agricultural biogas plants in Poland–selected technological, market and environmental aspects. *Renewable and Sustainable Energy Reviews, 58*, 69-74. https://doi.org/10.1016/j.rser.2015.12.153

Piwowar, A., Dzikuć, M., & Dzikuć, M. (2021). Water management in Poland in terms of reducing the emissions from agricultural sources–current status and challenges. *Cleaner Engineering and Technology, 2*, 100082. https://doi.org/10.1016/j.clet.2021.100082

Siebielec, S., Siebielec, G., Klimkowicz-Pawlas, A., Gałązka, A., Grządziel, J., & Stuczyński, T. (2020). Impact of Water Stress on Microbial Community and Activity in Sandy and Loamy Soils. *Agronomy, 10*(9), 1429. https://doi.org/10.3390/agronomy10091429

SMSR System. (2022, December 13). Retrieved from https://susza.iung.pulawy.pl/system/

Stańczuk-Gałwiaczek, M., Sobolewska-Mikulska, K., Ritzema, H., & van Loon-Steensma, J. M. (2018). Integration of water management and land consolidation in rural areas to adapt to climate change: Experiences from Poland and the Netherlands. *Land Use Policy, 77*, 498-511. https://doi.org/10.1016/j.landusepol.2018.06.005

State Water Holding Polish Waters. (2022, December 15). Retrieved from https://www.wody.gov.pl/aktualnosci/2763-jak-przeciwdzialac-suszy-aktualna-sytuacja-w-polsce

Szajner, P., & Szczepaniak, I. (2020). Ewolucja sektora rolno-spożywczego w warunkach transformacji gospodarczej, członkostwa w UE i globalizacji gospodarki światowej*. Zagadnienia Ekonomiki Rolnej, 4*(365), 61-85. https://doi.org/10.30858/zer/128631

Żmudzka, E. (2004). The Climatic Background of Agricultural Production in Poland (1951–2000). *Miscellanea Geographica, 11*(1), 127-137. https://doi.org/10.2478/mgrsd-2004-0015