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Influence of Forecast Climate Changes on Water Needs of Jerusalem Artichoke Grown in the Kuyavia Region in Poland

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Abstract: Most scenarios of climate change in Poland predict an increase in air temperature in the coming years. However, no significant increase in precipitation is forecast. Therefore, an increase in the water needs of plants should be expected, which requires the development of irrigation systems. To precisely determine the schedule of crop irrigation, it is necessary to investigate the water needs of plants and to estimate the prospects of changes in the future. This research aimed to estimate the water needs of Jerusalem artichoke in the period 2021–2050 in the Kuyavia region located in central Poland, where the need for supplementary irrigation is the highest. Based on the calculations, it was found that, in the growing season (21 May–30 September), an increase in the water needs of Jerusalem artichoke, of 26 mm, i.e., 9%, should be expected. The highest increase of 10 mm (i.e., by 16%) is expected in August. The results of our studies are utilitarian in character and can be used for the preparation of a strategy for the development of irrigation systems for Jerusalem artichoke cultivation in central Poland.

Keywords: crop productivity; evapotranspiration; *Helianthus tuberosus* L.; natural resources; rainfall deficit; sustainable agriculture

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1. Introduction

Plant biomass can be a raw material for the production of solid, liquid, and gaseous energy carriers. It is particularly beneficial from the point of view of environmental protection, and its greatest advantage is the almost zero carbon dioxide balance, lower emissions of sulfur and nitrogen oxides compared to fossil fuels, and lower unreliability as an energy source compared to other renewable sources, i.e., wind or solar energy [1].

The climatic conditions of Poland are favorable for the cultivation of plenty of energy plant species [1–4]. Therefore, there is a need to expand knowledge about environmental processes determining the high productivity of these plants, e.g., evapotranspiration, which is conditioned by the type of cultivated plants, access to water, and the course of weather conditions during the growing season. The most useful energy crops are those that are characterized by the efficient conversion of solar radiation energy into biomass and a high content of dry matter. At the same time, these plants should be distinguished by economical water management and high resistance to diseases and unfavorable environmental conditions.

According to the IPCC report [5], the global increase in air temperature in the years 1880–2012 amounted to 0.85 °C and this trend continues [6]. However, the rate of changes in the thermal conditions of the air in the lowest part of the troposphere differs, depending on the region of the world, because it is subject to modification by regional factors. Climate changes are also observed in Poland [7], which is located in the temperate climate zone with a transitional character between the maritime and continental climates. From west to east, the characteristics of the maritime climate disappear, letting up continental air masses from Eastern Europe [8,9]. Significant variability of weather and climatic conditions caused by variable atmospheric circulation is observed. The analysis carried out by Kejna and Rudzki [10] confirmed that in the years 1961–2018 the air temperature in central Poland increased by 0.33 °C on average per 10 years. The greatest warming in the analyzed period occurred in the summer months (in July by 0.48 °C per 10 years), but equally significant changes were characteristic for the winter months (in January by 0.46 °C per 10 years) and spring (in April by 0.41 °C per 10 years). On the other hand, forecasts of trends of changes in precipitation totals are subject to a high degree of uncertainty [11]. In the face of rising air temperature, the sums of evapotranspiration and evaporation will increase, which will translate into a change in the water needs of cultivated plants. According to Wang-Erlandsson et al. [12] on a global scale, the largest contribution to continental evaporation is transpiration (59%), followed by vegetation and substrate interception (31%), evaporation from the soil (6%) and finally evaporation from the free surface of inland water reservoirs (4%). Since changes in ground evaporation can lead to warming or cooling of the land surface [13], a better understanding of evapotranspiration changes is essential for the accurate determination of global and regional water balances and a better understanding of the hydrological interactions between land and atmosphere.

Jerusalem artichoke (*Helianthus tuberosus* L.) is known as a plant with a high ability to bind solar energy and convert it into organic matter. This is possible because, in addition to mesophyll cells, the leaves contain the cells packed around conductive bundles that bind carbon dioxide in the Calvin cycle, and thus the plant has a C3 metabolic pathway for carbon binding in photosynthesis. The photochemical efficiency of this species is higher than that of many C3 species and is comparable to some C4 species [14,15]. Leaf viability, especially the late cultivars, is longer, leading to higher photochemical products and higher dry matter yields. Jerusalem artichoke, despite the need to use additional energy in the form of ATP, is characterized by higher photosynthesis efficiency and faster biomass production [16–19]. Thus, Jerusalem artichoke plants have a high yield of dry matter per hectare. For example, Sawicka et al. [20] obtained the dry matter yield of plants (‘Albik’ and ‘Rubik’ cultivars) at the level of 22.84 t ha^{-1} in tests carried out on light soils. The total biomass yield of Jerusalem artichoke may reach as much as 110 t ha^{-1}, where the weight of the green mass is 75.6 t ha^{-1}, and the weight of tubers is 32.4 t ha^{-1} [4]. The biomass of Jerusalem artichoke plants can be used as a raw material for the combustion and production of formed fuels, subjected to alcoholic fermentation or processed into biogas [19,21–26]. For example, in the studies by Piskier [25], converted to energy value for an average of two years of research, Jerusalem artichoke generated an energy yield ranging from 84.1 GJ ha^{-1} (‘Albik’ cultivar) to 92.7 GJ ha^{-1} (‘Rubik’ cultivar). On the other hand, in the research by Sawicka et al. [20] Jerusalem artichoke, converted to the calorific value, during three years of research generated a value from about 317 GJ ha^{-1} in the case of the ‘Rubik’, and about 341 GJ ha^{-1} in the case of the ‘Albik’.

It is believed that Jerusalem artichoke is undemanding in terms of climatic conditions and resistant to low temperatures (frosts) and periods of drought (periodical lack of water) [4]. The most favorable for the growth and development of this species is warm and humid weather. It grows best on moderately compact and airy soils, rich in nutrients and moisture. However, it yields poorly on very wet and acidic soils [1].

The real possibility of setting up plantations of energy crops, e.g., species such as Jerusalem artichoke, on less fertile soils (excluding areas of natural value) exists in the Kuyavian-Pomeranian Province of Poland [4]. Such actions could effectively prevent possible fallowing and degradation of a part of arable lands. On the other hand, it can also further stimulate the economy and improve the balance of renewable energy production.

This research aimed to estimate the water needs of Jerusalem artichoke in the period 2021–2050 in the Kuyavia region in central Poland. The calculations were made taking into account the expected changes in air temperature. The Kuyavia region is located in the central part of the country, where there is the greatest need for supplementary irrigation in Poland during the growing season [27–32]. The very high need for supplementary irrigation is evidenced by, inter alia, negative values of the climatic water balance that occur in the Kuyavian-Pomeranian Province [33,34].

2. Materials and Methods

The projected values of average monthly air temperatures and precipitation totals for the Kuyavia region (Figure 1) in the years 2021–2050 (forecast period) were used in the research. The estimation was carried out according to the climate change scenario for Poland SRES (Special Report on Emissions Scenarios): A1B [35,36]. The 30-year period 1981–2010 was adopted as the reference period, using the values of average monthly air temperatures and monthly precipitation totals for the Kuyavia region according to measurements collected at the meteorological station of the Institute of Technology and Life Sciences in Falenty.

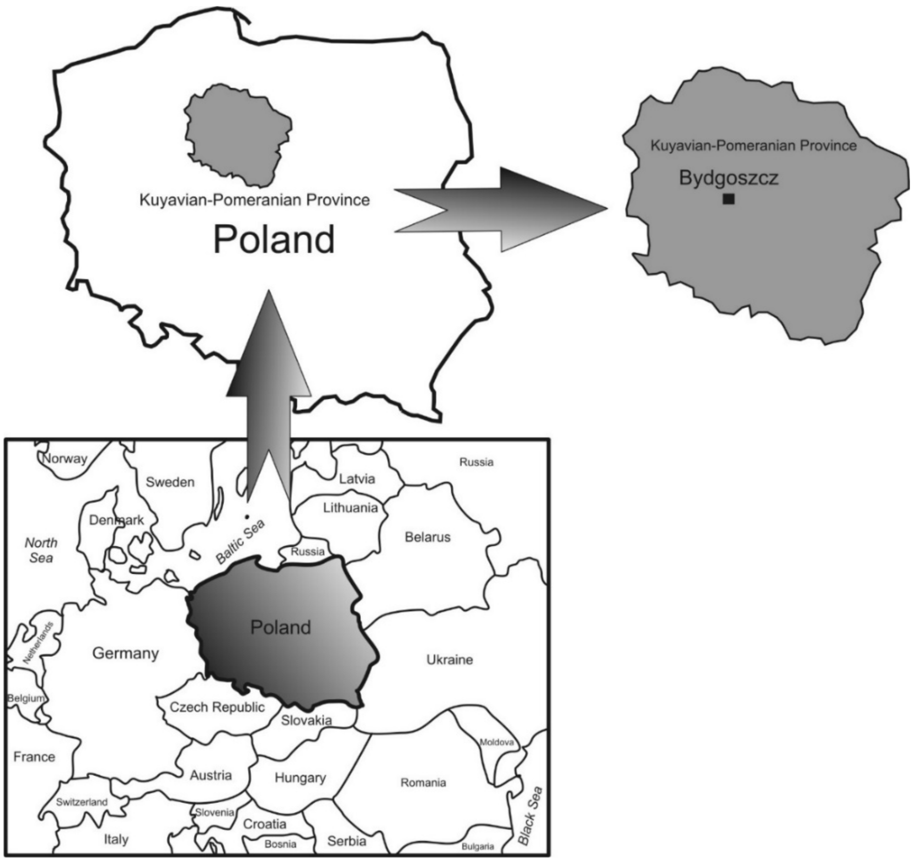

Figure 1. Geographical location of the Kuyavia region in Poland and Europe.

The water needs of Jerusalem artichoke were calculated using the crop coefficients method based on reference evapotranspiration (ETo) [37]. In this method, water needs are identified with the potential evapotranspiration (ETp) of Jerusalem artichoke. Potential evapotranspiration of Jerusalem artichoke was calculated from the following Formula (1):

$$\mathrm{ETp} = \mathrm{kc} \times \mathrm{ETo} \quad (1)$$

where:

ETp = crop (potential) evapotranspiration (mm);
kc = crop coefficient (ratio of evapotranspiration measured in conditions of sufficient soil moisture and reference evapotranspiration).
ETo = reference evapotranspiration (mm);

The values of the kc coefficient for individual months of the growing season of Jerusalem artichoke in the Kuyavia region are given in Table 1.

Table 1. Values of the crop coefficient for the Penman-Monteith formula for Jerusalem artichoke grown in the Kuyavia region [1].

Month	21–31 May	1–30 June	1–31 July	1–31 August	1–30 September
Crop Coefficient	0.46	0.83	0.77	0.69	0.67

Reference evapotranspiration in the reference period (1981–2010) was determined according to the Penman-Monteith method based on the following Formula (2) [38,39]:

$$ETo = n\,\frac{0.408\Delta R_n + \gamma \frac{900}{T+273} u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u)} \tag{2}$$

where:

ETo = reference evapotranspiration (mm d^{-1});
n = number of days;
Δ = slope vapour pressure curve (kPa °C^{-1});
R_n = net solar radiation at the crop surface (MJ m^{-2} d^{-1});
γ = psychrometric constant (kPa °C^{-1});
T = air temperature at 2 m height (°C);
u = wind speed at 2 m height (m s^{-1});
e_s = saturation vapour pressure (kPa);
e_a = actual vapour pressure (kPa).

Reference evapotranspiration in 2021–2050 was calculated using linear regression equations between Penman-Monteith reference evapotranspiration and air temperature. These equations were determined using meteorological data in the reference period. The same methodological assumption was adopted by Łabędzki et al. [40] estimating reference evapotranspiration according to Penman-Monteith for determining the water needs of late potato in the years 2021–2050 and 2071–2100 and Rolbiecki et al. [41] estimating the reference evapotranspiration according to Penman-Monteith when determining the water needs of Giant miscanthus.

The results were processed statistically by determining the following values: maximum, minimum, mean, and median, as well as standard deviation and variability coefficient. An attempt was also made to determine possible trends in changes in the water needs of Jerusalem artichoke in both compared periods using linear regression analysis, with the determination of correlation and determination coefficients. The significance of the correlation coefficients, with a sample size of $n = 30$, was determined for $p = 0.05$. Therefore, the value of the correlation coefficient was significant for $r\alpha \geq 0.362$ [42] according to the confidence interval.

Precipitation deficiencies (N) for Jerusalem artichoke in the medium ($N_{50\%}$), medium dry ($N_{25\%}$), and very dry ($N_{10\%}$) years were determined with the Ostromęcki method [43–46] using the following Formula (3):

$$Np\% = Ap\% \times ETp - Bp\% \times P \tag{3}$$

where:

Np% = precipitation deficit at the probability occurrence p% (mm $period^{-1}$);
Ap% and Bp% = numerical factors characterizing the variability of precipitation and evapotranspiration in a given meteorological station;
ETp = average multi-year amount of evapotranspiration in the analyzed period (mm $period^{-1}$);
p = multi-year average amount of precipitation in the analyzed period (mm $period^{-1}$).

3. Results

The standard deviation (SD), as a measure of the variability of the monthly totals of Jerusalem artichoke water needs, was the highest in June and July (Table 2). In the forecast period (2021–2050), the highest value of this parameter was recorded in June (13.940 mm), and slightly lower in July (10.449 mm). In the reference period (1981–2010), the highest values of the standard deviation occurred in July (13.073 mm) and June (11.107 mm).

Table 2. Statistical characteristics of the Jerusalem artichoke water needs defined as potential evapotranspiration in the growing season for the reference and forecast years.

Characteristics	Months of the Growing Season					
	21–31 May	**1–30 June**	**1–31 July**	**1–31 August**	**1–30 September**	**21 May–30 September**
Reference Period 1981–2010						
Minimum (mm)	10.5	66.7	65.7	51.0	25.0	237.7
Maximum (mm)	18.6	115.7	117.1	80.7	45.5	348.4
Mean (mm)	15.0	88.8	89.2	64.8	34.3	292.1
Median (mm)	15.4	88.0	84.1	64.3	33.0	292.5
Standard Deviation	1.816	11.107	13.073	7.596	5.137	25.444
Variability Coefficient (%)	12.1	12.5	14.7	11.7	15.0	8.7
Forecast Period 2021–2050						
Minimum (mm)	9.8	64.9	72.9	57.3	34.6	266.1
Maximum (mm)	19.5	117.0	115.2	90.7	48.9	368.7
Mean (mm)	14.0	90.6	96.6	75.1	42.2	318.4
Median (mm)	13.7	90.6	96.5	75.1	41.6	318.8
Standard Deviation	2.440	13.940	10.449	7.556	4.026	27.518
Variability Coefficient (%)	17.5	15.4	10.8	10.1	9.5	8.6

Relative differentiation of Jerusalem artichoke water needs in the analyzed growing season, which is expressed by the variability coefficient (VC), for the forecast and reference periods was 8.6% and 8.7%, respectively. The highest monthly values of the variability coefficient for the forecast and reference periods, respectively, were calculated from 21 to 31 May (17.5%) and in September (15.0%).

The variation in monthly precipitation totals in the analyzed periods, expressed by the variability coefficient, was much higher than the variation in monthly water needs and exceeded the value of 50% (except for June in the forecast period) (Table 3). The greatest relative variation of monthly precipitation totals occurred in August and September in the forecast period and amounted to 73.9% and 76.4%, respectively.

Table 4 presents linear regression equations of the trend of time variability of Jerusalem artichoke water needs, which were determined for individual months in both compared periods. Monthly totals of water needs of Jerusalem artichoke, expressed as potential evapotranspiration, showed an upward trend in the forecast period (except for September). In the reference period, an upward trend in Jerusalem artichoke evapotranspiration occurred in June and September.

Throughout the analyzed growing season of Jerusalem artichoke (i.e., from 21 May to 30 September), an upward trend in potential evapotranspiration (i.e., water needs of Jerusalem artichoke) was found (Table 5). However, the trend of time variability of water needs was insignificant in both the reference and forecast periods. The largest increase (7.2 mm decade^{-1}) in Jerusalem artichoke water needs was recorded in the forecast period.

Table 3. Statistical characteristics of the rainfall amount in the growing season for the reference and forecast years.

Characteristics	Months of the Growing Season					
	21–31 May	**1–30 June**	**1–31 July**	**1–31 August**	**1–30 September**	**21 May–30 September**
Reference Period 1981–2010						
Minimum (mm)	2.4	9.6	18.8	9.0	4.0	90.0
Maximum (mm)	36.3	106.6	194.0	210.1	103.6	463.5
Mean (mm)	16.4	51.0	78.4	59.7	44.6	250.0
Median (mm)	14.6	45.1	74.8	51.8	38.9	249.5
Standard Deviation	9.148	27.083	44.325	40.871	27.666	80.953
Variability Coefficient (%)	56.0	53.1	56.6	68.5	62.1	32.4
Forecast Period 2021–2050						
Minimum (mm)	5.0	22.0	8.0	0.0	0.0	76.3
Maximum (mm)	69.7	152.0	126.0	59.0	104.0	304.7
Mean (mm)	21.8	62.4	42.6	21.5	32.9	181.2
Median (mm)	22.2	57.5	37.6	17.0	26.0	176.5
Standard Deviation	13.692	30.736	24.922	15.897	25.141	54.408
Variability Coefficient (%)	62.8	49.2	58.5	73.9	76.4	30.0

Table 4. Time trend equations of water needs of Jerusalem artichoke in the region of Kuyavia.

Months of the Growing Season	Reference Period 1981–2010	Forecast Period 2021–2050
21–31 May	$y = -0.0295x + 15.49$	$y = 0.0418x + 13.311$
1–30 June	$y = 0.2294x + 85.206$	$y = 0.3278x + 85.531$
1–31 July	$y = -0.0493x + 89.953$	$y = 0.0558x + 95.69$
1–31 August	$y = -0.0994x + 66.378$	$y = 0.3368x + 69.855$ *
1–30 September	$y = 0.0082x + 34.138$	$y = -0.0459x + 42.927$
21 May–30 September	$y = 0.0593x + 291.17$	$y = 0.7163x + 307.31$

* Statistically significant at $p = 0.05$.

Table 5. The significance of the equations of trends water needs of Jerusalem artichoke and their tendencies in the reference and in forecast years.

Months of the Growing Season	Reference Period 1981–2010	Forecast Period 2021–2050
Linear correlation coefficient (r)		
21–31 May	ns	ns
1–30 June	ns	ns
1–31 July	ns	ns
1–31 August	ns	0.392 *
1–30 September	ns	ns
21 May–30 September	ns	ns
Tendency of water needs (mm·decade^{-1})		
21–31 May	−0.3	0.4
1–30 June	2.3	3.3
1–31 July	−0.5	0.6
1–31 August	−0.1	3.4
1–30 September	0.1	−0.5
21 May–30 September	0.6	7.2

* Statistically significant at $p = 0.05$ (P = 95%); ns = not significant.

The calculations indicate that in the forecast period, the average daily water needs of Jerusalem artichoke in July, August, and September will be higher than in the reference period (Figure 2a). In light of the expected temperature change, the greatest daily water demand for Jerusalem artichoke in the forecast period will occur in August.

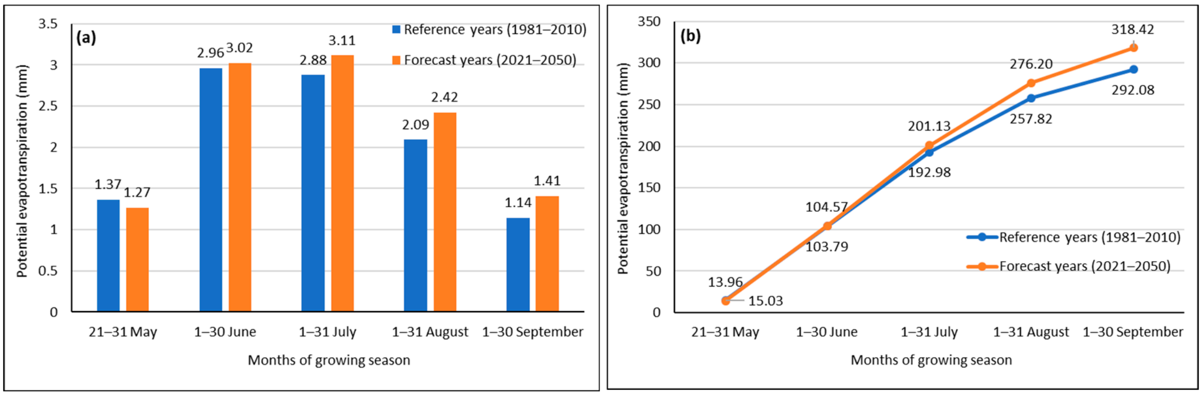

Figure 2. Jerusalem artichoke water needs, expressed as potential evapotranspiration, in the period of 21 May–30 September in the reference and forecast years presented as daily values in the particular months (**a**) and the cumulated sum curve (**b**).

Calculations of the water needs of Jerusalem artichoke, which were carried out for the forecast meteorological conditions in the period 2021–2050, indicate that during this period, the demand for water in the cultivation of Jerusalem artichoke, expressed by the increase in potential evapotranspiration, will increase in the Kuyavia region (Figure 2b, Table 6). In the thirty years 2021–2050, an increase in potential evapotranspiration by approximately 9% can be expected during the growing season (21 May–30 September). In light of the expected increase in air temperature, the largest monthly increase in potential evapotranspiration of Jerusalem artichoke (by 10 mm, i.e., 16%) may occur in August (Figure 3, Tables 4–6).

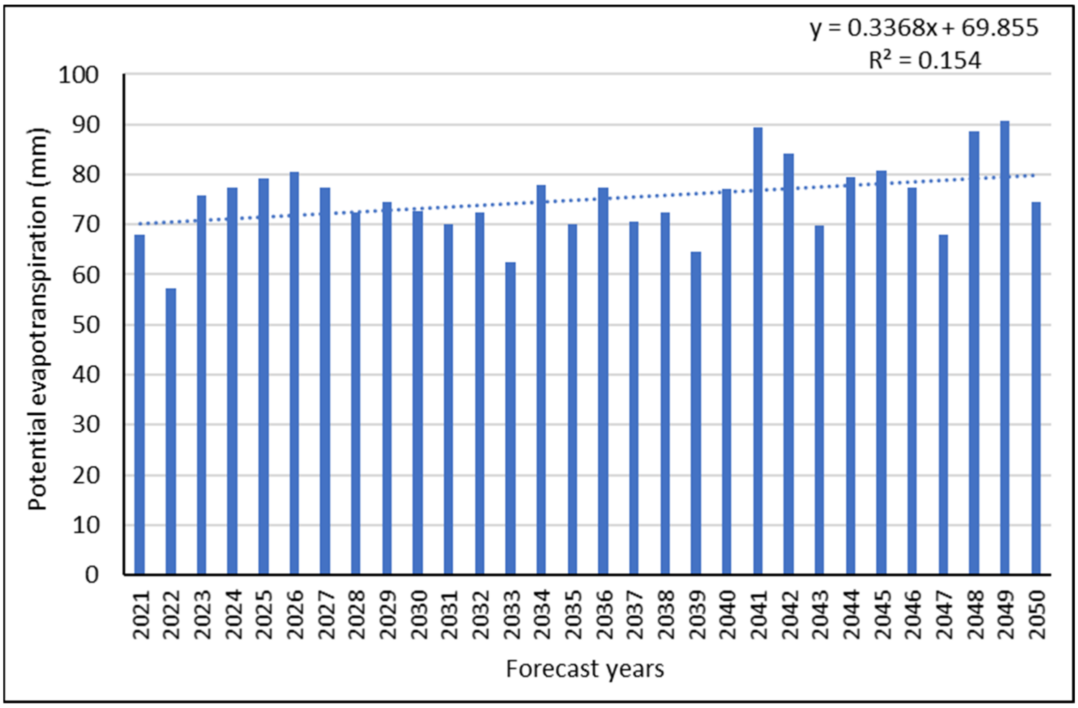

Figure 3. Time trend of Jerusalem artichoke water needs, expressed as potential evapotranspiration, in August in the forecast years 2021–2050; the dash line is the trend line.

Table 6. Comparison of the Jerusalem artichoke water needs (mm) in the reference and forecast years.

Years	Period	
	21 May–30 September	August
1981–2010	292.1	64.8
2021–2050	318.4	75.1
(2021–2050)–(1981–2010)	26.3	10.3
Change (%)	+9	+16

4. Discussion

According to Kowalik and Scalenghe [47], the water needs of crops intended for biomass production are 2–3 times lower in Poland compared to southern Europe. However, it should be expected that soon the water needs of energy crops will increase by 20–30%, and this will make these plants require supplementary irrigation [47].

The research presented in this paper aims to determine the water needs of Jerusalem artichoke in the Kuyavia region, which is located in central Poland. The water needs defined for the growing season of Jerusalem artichoke (21 May–30 September) amounted to 292.08 mm in the reference period (1981–2010) and 318.42 mm in the forecast period (2021–2050). It is believed that Jerusalem artichoke is undemanding in terms of climatic conditions and resistant to periodic water shortages [4]. According to Rossini et al. [48], the Jerusalem artichoke can be grown in regions with annual rainfall above 500 mm. In the region of Kuyavia, which was analyzed in this study, the annual rainfall is slightly higher than 500 mm and in the growing season (April–September) slightly higher than 300 mm. In the three-year field experiment conducted by Żyromski et al. [1], in the growing season covering Jerusalem artichoke vegetation, rainfall conditions were classified as wet in 2011 and 2012 (rainfall totals ranged from 454 mm to 428 mm, respectively) and very humid in 2013 (total rainfall amounted to 541 mm).

The results of our research are of great importance because, they fill the existing knowledge gap regarding the water needs of Jerusalem artichoke grown not only in the Kuyavia region, but even more broadly in the central part of Poland. In studies published up to now regarding Jerusalem artichoke, the provided information is not precise. Furthermore, the water needs of Jerusalem artichoke cultivated in the climatic conditions of Poland are little known. For example, in the research conducted by Bogucka et al. [49,50] through the absence of other reliable standards, the water needs of Jerusalem artichoke were estimated based on water needs developed for late potato. The results of our research may be useful not only in other regions of Poland, but also in other Central European countries located in the moderate transitory climate zone, oscillating between the maritime-type climate of Western Europe and the continental one of Eastern Europe. This climate is characterized by a diversity of weather types changing during the seasons of the year and showing great variability between the subsequent years.

The established assumptions and calculations made it possible to assess not only water needs, but also to determine rainfall deficiencies, which may be useful in planning irrigation in the investigated area of Poland. According to the adopted methodology [43] and forecasted changes in temperature and precipitation [35,36], in the reference period, precipitation deficiencies during the growing season of Jerusalem artichoke in the Kuyavia region were 54 mm, 121 mm, and 176 mm in the medium ($N_{50\%}$), medium dry ($N_{25\%}$), and very dry ($N_{10\%}$) years, respectively (Table 7). In the forecast period, rainfall deficits were higher and amounted to 145 mm, 207 mm, and 255 mm for $N_{50\%}$, $N_{25\%}$, and $N_{10\%}$, respectively. Deficiencies in precipitation $N_{50\%}$, $N_{25\%}$, and $N_{10\%}$ cover water needs at the level of 50%, 75%, and 90%, respectively [46]. This has its practical application, as it allows, among other things, to calculate the amount of water needed for irrigation, and thus the volume of the water reservoir intended for irrigation.

Table 7. Precipitation deficit (mm) in the cultivation of Jerusalem artichoke in the region of Kuyavia in normal ($N_{50\%}$), medium dry ($N_{25\%}$) and very dry ($N_{10\%}$) years for the reference and forecast period.

Years	21–31 May	1–30 June	1–31 July	1–31 August	1–30 September	21 May–30 September
Normal years						
1981–2010	0	38	11	5	0	54
2021–2050	0	28	54	54	9	145
Medium dry years						
1981–2010	3	57	35	24	2	121
2021–2050	0	50	72	65	20	207
Very dry years						
1981–2010	7	71	52	36	10	176
2021–2050	1	65	86	75	28	255

Jerusalem artichoke is a plant that responds well to irrigation. In a field experiment conducted in north-eastern Poland by Bogucka et al. [49,50] in response to irrigation, yields of fresh weight and dry weight of Jerusalem artichoke tubers increased by 69.3% and 65.2%, respectively. Moreover, in the case of above-ground parts of Jerusalem artichoke plants, irrigation increased fresh and dry matter yields by 42% and 43%, respectively. In these studies, Jerusalem artichoke irrigation was effective despite a large amount of precipitation during the growing season. The sum of precipitation amounted to 369 mm in the period from 1 May to 31 October, and as much as 141 mm was recorded in July. According to reports published by Baldini et al. [51] in studies conducted in different regions of Italy, irrigation increased the tuber dry matter yield of Jerusalem artichoke by 24.2%. Moreover, in the study reported by Kai et al. [52], irrigation significantly enhanced the yields of underground biomass, above-ground biomass, and tubers of Jerusalem artichoke.

The increase in the water needs of Jerusalem artichoke in the years 2021–2050 calculated in this study is the result of the projected increase in air temperature during the growing season (especially in August). Bąk and Łabędzki [35] and Łabędzki [53,54] also found that an increase in air temperature causes an increase in the water needs of plants. Łabędzki [53,54] reports that in Poland an increase in air temperature in the range of 2 °C to 4 °C can be expected. Kasperska-Wołowicz and Bolewski [55], based on over 80 years of observations conducted in the Kuyavian-Pomeranian Province, noticed a significant upward trend in the average annual air temperature, which showed an increase in temperature by 0.19 °C per 10 years, i.e., approximately 2 °C per 100 years. It is also important that the scenarios of changes in temperature and precipitation in Poland until 2050 or 2080, developed using various mathematical models, differ significantly, especially for the summer period, covering the months of June and August, i.e., the period of increased water demand for plants. All these climate change scenarios predict an increase in air temperature, but only some of them predict an increase in precipitation. Some of the climate change scenarios developed for Poland even predict a decrease in the amount of precipitation. It is expected that the average monthly value of air temperature in July and August (except for the Baltic Sea coastal regions) will exceed 25 °C [53]. Most climate change scenarios for Poland do not predict an increase in precipitation during the year. However, on their basis, an increase in winter precipitation can be expected, and a decrease in rainfall during the summer [56–62].

It is expected that the current climate changes, as shown by the results of this study, and climate changes that are forecast in the future, will or may cause an increase in the water needs of plants [35,36,63,64]. Therefore, there is a justified need to take adaptive actions to the situation of rainfall deficit, which does not fully cover the water needs of plants. Supplementary hydration can certainly be included in such activities. Many researchers agree that with the intensification of unfavorable climate changes, the importance of irrigation in Poland will increase, which will especially concern the central part of the country, including the Kuyavia region [27,40,53,54,65–70].

The results of research published by Somorowska [71] indicate that in the years 1980–2020 there was a significant increase in evaporation in most of Poland. The warm climate, together with a slight increase in precipitation, led to increased plant activity. This was manifested by an increased loss of transpiration and interception, which were not compensated by a decrease in evaporation and sublimation of the surface without vegetation cover. Increased plant activity was manifested by higher water consumption, especially in the summer months, i.e., in June, July and August. These monthly increases in plant water consumption contributed to annual changes in evaporation from the continental surface of 1.36 mm per year. Somorowska [71] found that in the period 2007–2020, annual evaporation increased by 7% compared to the reference period 1980–2006.

Nevertheless, it is expected that the irrigation area and water consumption for agricultural irrigation in Poland in the future will depend primarily on the adopted agricultural development strategy and economic conditions of agriculture. Unfortunately, the development of irrigation systems in Polish agriculture will depend to a much lesser extent on climatic conditions [54,72,73].

In our research, the water needs of Jerusalem artichoke were calculated using the crop coefficients method, based on reference evapotranspiration (ETo) [37]. ETo was determined according to the Penman-Monteith method recommended by the FAO for worldwide use [38,39]. Additionally, it was supported by the fact that the kc coefficients for Jerusalem artichoke calculated by Żyromski et al. [1] were developed to be used only with the ETo formula by Penman-Monteith. There are also other methods of estimating the water needs of plants, but we did not compare them in this study. There is, however, a need for future research to compare several methods of determining the water needs of plants for several scenarios of predicted climate change, also taking into account other regions of Poland and even neighboring countries located within Central Europe.

5. Conclusions

Jerusalem artichoke is a valued energy plant in Poland. Jerusalem artichoke tubers are a material for the production of alcohols used as fuel. Above-ground shoots after drying and grinding can be either burned directly in furnaces or used as a material for the production of briquettes and granules (pellets). It is a species that is not sensitive to water shortages in the soil, but it grows best in medium-humid and moist soils. According to most of the weather change scenarios developed for Poland, a significant increase in air temperature is expected in the coming years, which is not necessarily associated with an increase in the amount of precipitation. As a consequence of these changes, an increase in the water needs of crops should be expected, which necessitates the development of irrigation systems. To precisely determine a schedule of crop irrigation, it is necessary to investigate the water needs of plants and to estimate the prospects of those changes in the future. The purpose of the research presented in this paper was to estimate the water needs of Jerusalem artichoke in the period 2021–2050 in the Kuyavia region located in central Poland. Based on the calculations, it was found that in the years 2021–2050, during the growing season, i.e., from 21 May to 30 September, in the Kuyavia region, an increase in the water needs of Jerusalem artichoke should be expected by 26 mm, i.e., 9%. The highest increase in the water needs of Jerusalem artichoke during the growing season should be expected in August. The equation of the trend of time variability of water needs determined for August shows that the water needs of Jerusalem artichoke will increase by 3.4 mm in each subsequent decade. Therefore, it can be expected that in the forecasted thirty years, the water needs of Jerusalem artichoke in August will increase by 10 mm, i.e., by 16%. The results presented in this paper will be useful in preparing a strategy for the development of irrigation systems for Jerusalem artichoke crops in central Poland, in particular in Kuyavia, where there are the highest rainfall deficits in the country.

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