

Article

Towards Water-Efficient Irrigation of Cup Plant (*Silphium perfoliatum* L.) for Energy Production: Water Requirements and Rainfall Deficit

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Abstract: The cup plant shows promise for biomass production and has significant potential for increasing biodiversity. This species primarily grows in habitats with high soil humidity. Precipitation deficits are common throughout Poland, especially in the central regions, necessitating crop irrigation. To design and manage resource-efficient irrigation for the cup plant, estimating water requirements and rainfall deficits is essential. This research aims to calculate water requirements, rainfall deficits, and irrigation demand and to assess their temporal and spatial variations for cup plants energy plantations from 1981 to 2020. The study, conducted using the Blaney–Criddle method, focused on the growing season (1 April–30 September) across four provinces in central Poland: Kuyavian–Pomeranian (18°01′ E, 53°08′ N), Greater Poland (16°50′ E, 52°25′ N), Masovian (20°59′ E, 52°09′ N), and Lodz (19°24′ E, 51°44′ N). The research revealed varying values of water requirements depending on the province, ranging from 445.9 mm in Lodz province to 465.2 mm in Kuyavian–Pomeranian province. The magnitude of water requirements also significantly depended on the month of the growing season, with the highest value occurring in July (from 103.6 mm in Lodz province to 108.9 mm in Kuyavian–Pomeranian province). Over the forty-year period, a notable upward trend in water requirements was observed across all provinces, ranging from 6.7 mm per decade to 12.5 mm per decade. On average, rainfall deficits during the growing season amounted to 125 mm in normal years, 237 mm in medium dry years, and 316 mm in very dry years. These findings are crucial for efficient irrigation management in central Poland, which, in line with sustainable agricultural development, will enable the maximization of yields of this plant while simultaneously conserving water resources.

Keywords: biodiversity; biomass; cup plant; energy crop; evapotranspiration; natural resources; precipitation deficit; sustainable agriculture; water sources conservation



Citation: Figas, A.; Rolbiecki, R.; Rolbiecki, S.; Jagosz, B.; Langowski, A.; Sadan-Ozdemir, H.A.; Pal-Fam, F.; Atilgan, A. Towards Water-Efficient Irrigation of Cup Plant (*Silphium perfoliatum* L.) for Energy Production: Water Requirements and Rainfall Deficit. *Sustainability* **2024**, *16*, 5451. <https://doi.org/10.3390/su16135451>

Academic Editor: Jan Hopmans

Received: 30 April 2024

Revised: 20 June 2024

Accepted: 24 June 2024

Published: 27 June 2024



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1. Introduction

The cup plant (*Silphium perfoliatum* L.) is a perennial plant belonging to the Asteraceae family. In the first year of growing season, this plant produces only a rosette of leaves. In the following years, generative shoots develop, the number of which increases with the age of the plant. This plant can be found in moderate latitudes—in the northeastern part of

the United States and the southeastern part of Canada [1–3]. The cup plant was brought to Europe in the 18th century. Over the last two decades, many experiments have been carried out, the main goal of which was to develop methods of growing the cup plant in various European countries, including Austria [4], Germany [5], Lithuania [6–9], Moldova [10], Belarus [11], and also in Poland [12–15]. *Silphium perfoliatum* L. easily tolerates changes in environmental conditions. However, it is sensitive to prolonged periods of drought that cause the dying of lower leaves and browning of buds. In extreme cases, plant growth is inhibited [1,3,16,17].

The plants of *Silphium perfoliatum* L. are a potentially valuable material as they can be used in multiple possible ways. One of its notable characteristics is its favorable content of minerals and products of primary metabolism, such as a protein and carbohydrates, as well as secondary metabolites, such as terpenes, essential oils, triterpene saponins, phenolic acids, tannin compounds, carotenoids, flavonoids, and ortho-dihydroxyphenols [10,18,19]. The extracts from the leaves, inflorescences, and roots of *Silphium perfoliatum* L. have antibacterial and antifungal properties [17,18,20,21]. The leaves of cup plant may also be useful in feeding farm animals [10,12,13]. The cup plant is a species also characterized by high honey and pollen yield [22,23]. Finally, the usefulness of the cup plant crop for phytostabilization and reclamation of degraded areas should be emphasized. This species could help in the process of soil stabilization and restoring soil-forming processes, initiating biological life in the substrate, and restoring plant cover appropriate for these areas [24–27].

The demand for energy produced from biomass is increasing in Europe [4–15]. Currently, the cup plant is currently drawing significant attention for its potential in biomass production, specifically for energy purposes such as the production of biofuels and the generation of thermal energy. The cup plant represents an alternative bioenergy crop that could facilitate a more eco-friendly utilization of renewable resources [28,29]. In the first year of cultivation, the cup plant produces a low yield of aboveground biomass. Only in the fourth year, with high soil moisture and an appropriate supply of nutrients, can it reach 100–120 Mg ha^{−1} [1,30]. Starting from the second growing year, data show that 11–22 Mg ha^{−1} dry matter can be obtained from a cup plant plantation [3,6,7,31,32]. In the energy context, cup plant biomass is characterized by satisfactory properties, comparable to the data on other plant species used for energy purposes [3,9,10,33–36].

In the face of the climate changes observed in recent years and the associated water crisis [37], *Silphium perfoliatum* L., due to its low water, soil, and acclimatization requirements, its ability to adapt to various climatic conditions, its potential for high dry mass yield, and its resistance to diseases and pests, can be a very valuable source of biomass for various energy production technologies [3,8–10,17,33–35,38]. Additionally, the cup plant, beyond its energy properties, plays a special role in the process of maintaining biodiversity [3,17,29,39–45]. This broad agroecological potential of the cup plant, alongside its role as an energy crop, aligns with the principles of sustainable agricultural development. In the era of climate warming, conducting sustainable crop production requires the implementation of efficient and precise irrigation practices. These practices allow for optimizing crop yields on the one hand and protecting natural water resources on the other [46–49].

Given the potential for the multifaceted use of *Silphium perfoliatum* L., it is justified to undertake research aimed at developing effective cultivation methods, including irrigation techniques, under the climatic conditions of Poland. Research results from central Poland indicate that the cup plant is well suited for cultivation under drip irrigation on light soils with low retention capacity [14,15,45]. However, to conduct precise irrigation, it is necessary to assess the water requirements of the plants and precipitation deficits. This, in turn, presents a complex scientific problem that requires the consideration of many variables and the application of advanced analysis and modeling methods. Key aspects of this problem include climatic and meteorological variables, soil properties, measurement and modeling methods, and other factors [50].

The objectives of the current research were as follows: (1) to calculate the water requirements of two-year-old cup plants and assess trends in this parameter across the four

provinces of central Poland, spanning the forty years from 1981 to 2020, as well as during the growing season; (2) to evaluate precipitation deficits and irrigation demand in normal, medium dry, and very dry years within the study region. Through this research, it will be possible to estimate the capacity of water reservoirs necessary for implementing precise irrigation practices, thereby contributing to the conservation of water resources in central Poland, where a negative water balance exists.

2. Materials and Methods

2.1. Experimental Sites

In this study, the water requirements of the two-year-old plantation of cup plant (*Silphium perfoliatum* L.) in the years 1981–2020 in four provinces of central Poland (Kuyavian–Pomeranian (K–P), Greater Poland (GP), Masovian (M), and Lodz (L)) were calculated. These assessments were conducted for the growing period of the cup plant, which lasts from 1 April to 30 September. For the calculations of the cup plant's water requirements, meteorological data on air temperature and total precipitation for a forty-year period (1981–2020) were used. Air temperature and precipitation measurements were conducted at four weather stations representative of central Poland (Bydgoszcz in K–P, Poznań in GP, Warsaw in M, and Łódź in L) (Table 1, Figure 1).

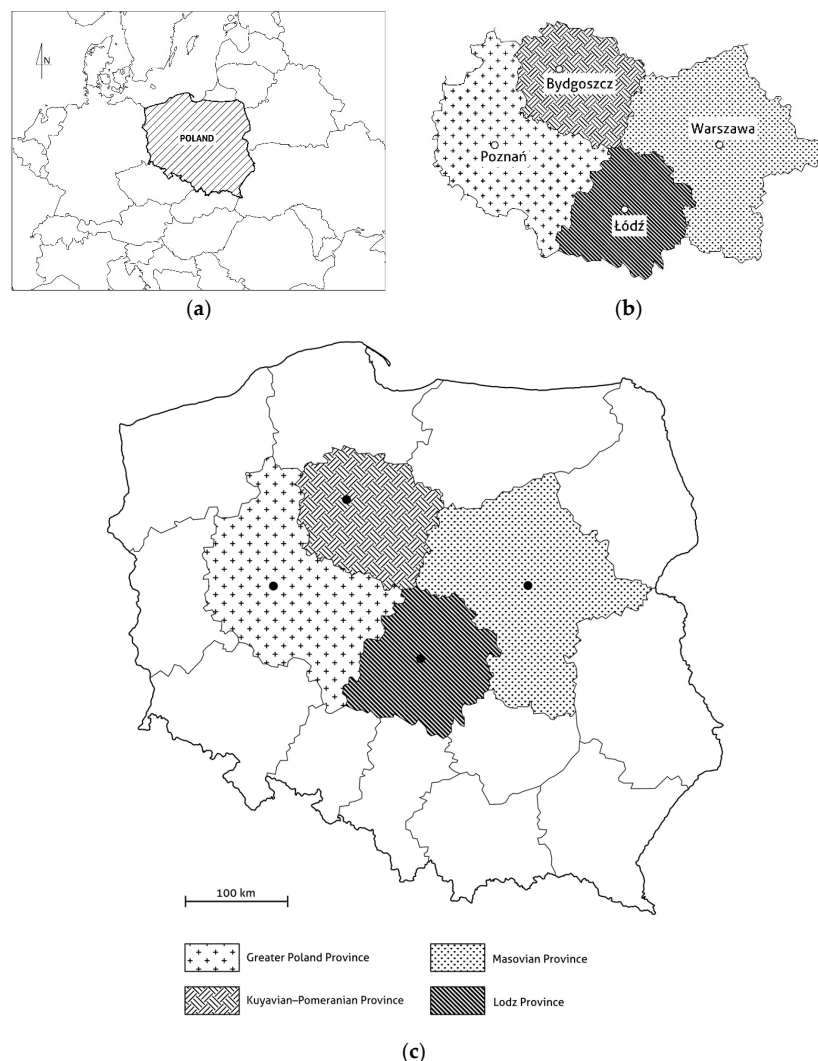


Figure 1. Location of the analyzed central region of Poland: (a) geographical location of Poland in Europe; (b) geographical location of meteorological stations in the provinces; (c) geographical location of analyzed provinces in Poland.

Table 1. Geographical position of the weather stations from which meteorological data used in this research were obtained.

Provinces of Central Poland	Station	Altitude (MASL)	Longitude	Latitude
Kuyavian–Pomeranian	Bydgoszcz	46	18°01′	53°08′
Greater Poland	Poznań	86	16°50′	52°25′
Masovian	Warszawa	106	20°59′	52°09′
Lodz	Łódź	184	19°24′	51°44′

2.2. Water Requirements and Precipitation Deficit of Cup Plants

The water requirements of cup plant were calculated using the crop coefficients method. This method relies on reference evapotranspiration [51]. In this study, the water requirements of the cup plant were determined based on the potential evapotranspiration of this species. The following Equation (1) was used for calculating potential evapotranspiration:

$$ETp = Kc \times ETo, \quad (1)$$

where

ETp = potential crop evapotranspiration (mm);

Kc = crop coefficient, defined as the ratio of evapotranspiration measured under conditions of sufficient soil moisture to reference evapotranspiration;

ETo = reference evapotranspiration (mm).

The crop coefficient values were determined for the conditions of central Poland for each month of the growing season of *Silphium perfoliatum* L. (Table 2). The crop coefficient values were derived from the ratio of total water consumption by the cup plants during the growing season (i.e., evapotranspiration measured under conditions of sufficient moisture provided by the drip system) and reference evapotranspiration using the Blaney–Criddle method [45,51–55]. These measurements were conducted during the experiment from 2016 to 2018 in Kruszyn Krajeński (53°3′39″ N, 17°52′52″ E). The cup plants were cultivated on Phaeozem soil derived from alluvial sand, which had a very low water retention capacity (Figure 2) [45].

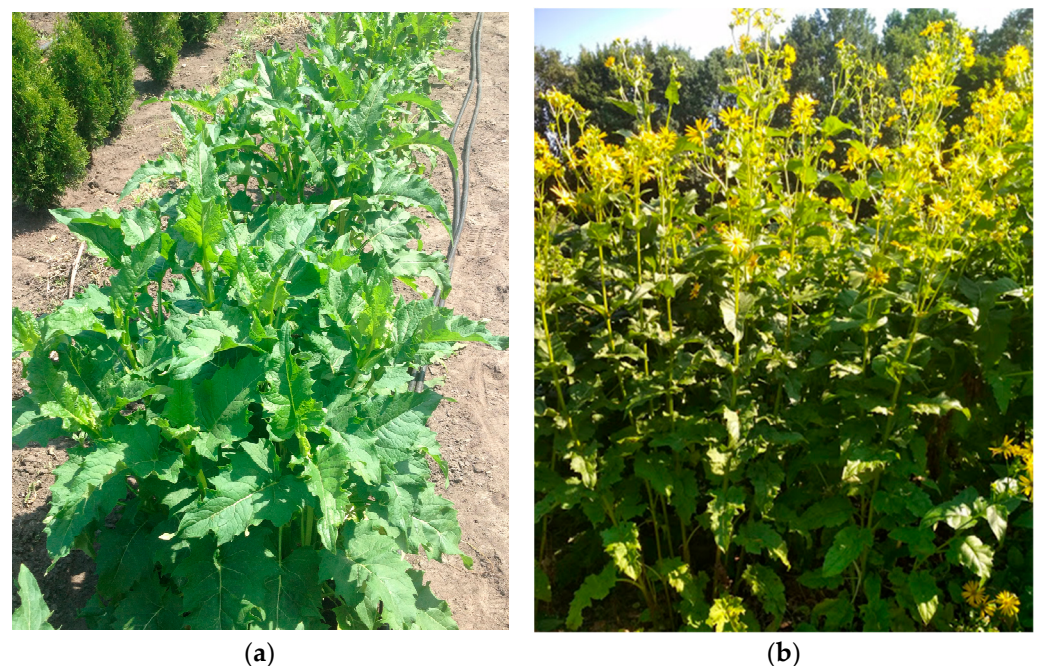
**Figure 2.** Plants of the *Silphium perfoliatum* L.: (a) drip irrigation system for cup plant plantation; (b) plants of the cup plant during flowering (photos by Anna Figas).

Table 2. Crop coefficient calculated using the Blaney–Criddle equation for two-year-old cup plants cultivated under drip irrigation conditions in central Poland [45,51–55].

	Months of the Cup Plant Growing Season					
	April	May	June	July	August	September
Crop coefficient	0.70	0.70	0.75	0.80	0.80	0.70

In this study, the Blaney–Criddle method [52–54], as modified by Żakowicz [55] for the same time intervals, was used to calculate reference evapotranspiration. This method offers the advantage of being applicable to agro-climatic analyses based solely on average air temperature and the latitude of the area, which influence the astronomical day length. In contrast, the Penman–Monteith method recommended by the FAO relies on a broader set of parameters, many of which are often difficult or impossible to measure [54]. Therefore, reference evapotranspiration was calculated using the Blaney–Criddle climate index, adjusted for Polish weather conditions [55] with Equation (2):

$$ET_o = n \times [p \times (0.437 \times t + 7.6) - 1.5], \quad (2)$$

where

ET_o = reference evapotranspiration (mm);

n = number of days in the month;

p = evaporation coefficients according to Doorenbos and Pruitt [52] for the months and latitude, modified for the geographical location of Poland (Table 3) [55];

t = monthly mean air temperature (°C).

Table 3. Average values of evaporation coefficients for selected months and latitude [55] used in Equation (2).

Latitude	Months of the Growing Season					
	April	May	June	July	August	September
50°	0.31	0.34	0.36	0.35	0.32	0.28
52°	0.31	0.35	0.37	0.36	0.33	0.28
54°	0.31	0.36	0.38	0.37	0.33	0.28

The amount of rainfall deficiency (N) for *Silphium perfoliatum* L. plants in normal years ($N_{50\%}$), medium dry years ($N_{25\%}$), and very dry years ($N_{10\%}$) was determined using the Ostromecki method [56], which has also been applied in subsequent studies [57–60]. It is assumed that the calculated rainfall deficits secure water requirements at 90% for very dry years, 75% for medium dry years, and 50% for normal years [60]. Equation (3) was employed for the calculations:

$$Np\% = Ap\% \times ETp - Bp\% \times P, \quad (3)$$

where

$Np\%$ = precipitation deficit at the occurrence probability of $p\%$ (mm period^{−1});

$Ap\%$ and $Bp\%$ = numerical factors characterizing the variability of evapotranspiration and precipitation for a given meteorological station; these factors are determined based on the analysis of the frequency distribution series (N_i), such as using the decile method [56];

ETp = average multi-year evapotranspiration during the studied period (mm period^{−1});

P = multi-year average precipitation amount in the studied period (mm period^{−1}).

The irrigation water demand (IWD) was calculated using the simplified water balance Equation (4):

$$IWD = (ETp - P) - \Delta W, \quad (4)$$

where

IWD = irrigation water demand (mm);
 ETp = potential evapotranspiration of cup plant (mm);
 P = precipitation amount (mm);
 ΔW = available soil moisture retention;
 (ETp – P) = precipitation deficit (N).

The available soil moisture retention was estimated for different soil types: light soils (40 mm), medium soils (65 mm), and heavy soils (90 mm).

2.3. Statistical Analysis

The results were statistically processed to determine the minimum, maximum, mean, and median, along with the standard deviation and coefficient of variation. An attempt was also made to determine the possible trends in changes in the analyzed index of the cup plant water requirements in the four compared provinces of central Poland using regression analysis, with the determination of correlation and determination coefficients. The significance of the correlation coefficients, with the sample size $n = 40$, was assessed at $p < 0.1$, $p < 0.05$, and $p < 0.01$ [61].

3. Results

Statistical indicators characterizing the water requirements of the cup plant were developed for four analyzed provinces of central Poland and six months of the growing season (Table 4). Based on the calculations, it was found that there was both spatial and temporal variability in the values of cup plant water requirements, which were estimated based on potential evapotranspiration. The average value of water requirements during the growing season, from the beginning of April to the end of September, ranged from 445.9 mm to 465.2 mm, depending on the province. During the months of the growing season, the highest values of cup plant water requirements, regardless of the province, were recorded in July. Slightly lower water requirements occurred in June and August. Meanwhile, the lowest water requirements of the cup plant were noted in April. Similar to the average water requirements, in the case of the variation in this parameter expressed through standard deviation, the highest values were recorded in July. The relative variation value in the water requirements of the cup plant expressed by the coefficient of variation was the highest in April and decreased gradually until August.

Table 4. Descriptive statistics of the water requirements of the cup plant in central Poland.

Statistical Indicator	Months of Cup Plant Growing Season						
	April	May	June	July	August	September	April–September
Kuyavian–Pomeranian province							
Minimum (mm)	34.7	60.7	85.9	96.6	81.1	41.6	429.5
Maximum (mm)	54.1	88.9	116.3	124.8	105.8	57.6	517.3
Mean (mm)	43.9	74.6	95.0	108.9	93.2	49.6	465.2
Median (mm)	43.3	75.3	95.0	109.1	92.8	49.7	464.5
Standard deviation	4.0	5.6	5.8	6.6	5.0	3.7	16.3
Variation coefficient (%)	9.0	7.4	6.1	6.1	5.4	7.5	3.5
Greater Poland province							
Minimum (mm)	33.9	58.3	81.5	92.7	79.7	41.2	414.6
Maximum (mm)	55.2	84.6	113.2	124.7	107.3	71.0	508.3
Mean (mm)	43.9	72.4	92.0	105.8	92.0	50.0	456.1
Median (mm)	43.3	72.6	90.8	106.9	91.9	49.5	456.2
Standard deviation	4.5	5.4	6.3	7.1	5.6	5.2	20.4
Variation coefficient (%)	10.2	7.5	6.9	6.7	6.1	10.4	4.5
Masovian province							
Minimum (mm)	32.8	64.4	85.1	94.6	81.5	42.6	429.3
Maximum (mm)	57.8	85.9	114.0	123.8	107.3	55.9	517.7

Table 4. Cont.

Statistical Indicator	Months of Cup Plant Growing Season						
	April	May	June	July	August	September	April–September
Mean (mm)	44.5	74.4	94.3	108.3	93.7	49.8	465.0
Median (mm)	44.7	74.3	94.5	108.3	93.0	49.9	464.2
Standard deviation	4.8	4.9	5.7	6.1	4.9	3.7	16.9
Variation coefficient (%)	10.7	6.6	6.0	5.6	5.2	7.4	3.6
Lodz province							
Minimum (mm)	31.1	58.1	80.1	90.4	78.3	39.9	411.3
Maximum (mm)	55.2	81.6	109.9	120.0	104.7	55.1	488.1
Mean (mm)	42.6	70.9	90.1	103.6	90.5	48.1	445.9
Median (mm)	42.7	70.7	90.3	103.6	91.0	48.1	446.8
Standard deviation	4.7	5.0	5.6	6.6	4.9	3.8	16.3
Variation coefficient (%)	11.1	7.1	6.2	6.4	5.4	7.9	3.7

As part of the research, an analysis of the time trends in the water requirements of the cup plant was conducted (Figures 3–6, Table 5). A significant increase in water requirements was observed in April, June, August, and on average throughout the growing season in all the studied provinces, with the highest increase occurring in the Greater Poland province and the lowest in the Kuyavian–Pomeranian province. In May, the increase in water requirements was not significant in any of the studied locations. In July, a significant increase in water requirements was noted in the Greater Poland, Masovian, and Lodz provinces, and in September, this was only noted in the Greater Poland and Masovian provinces.

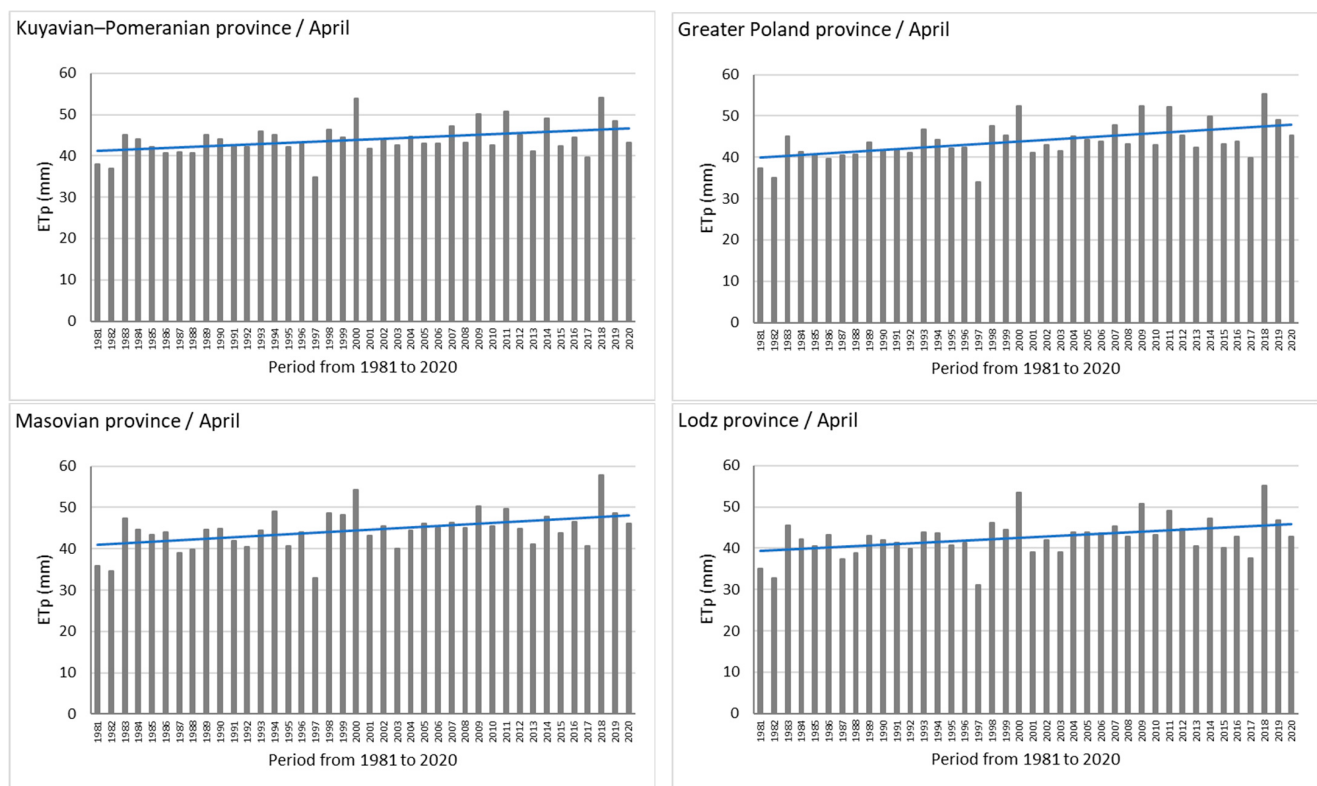


Figure 3. Time trend in cup plant water requirements in April. The trend line is marked with a blue line.

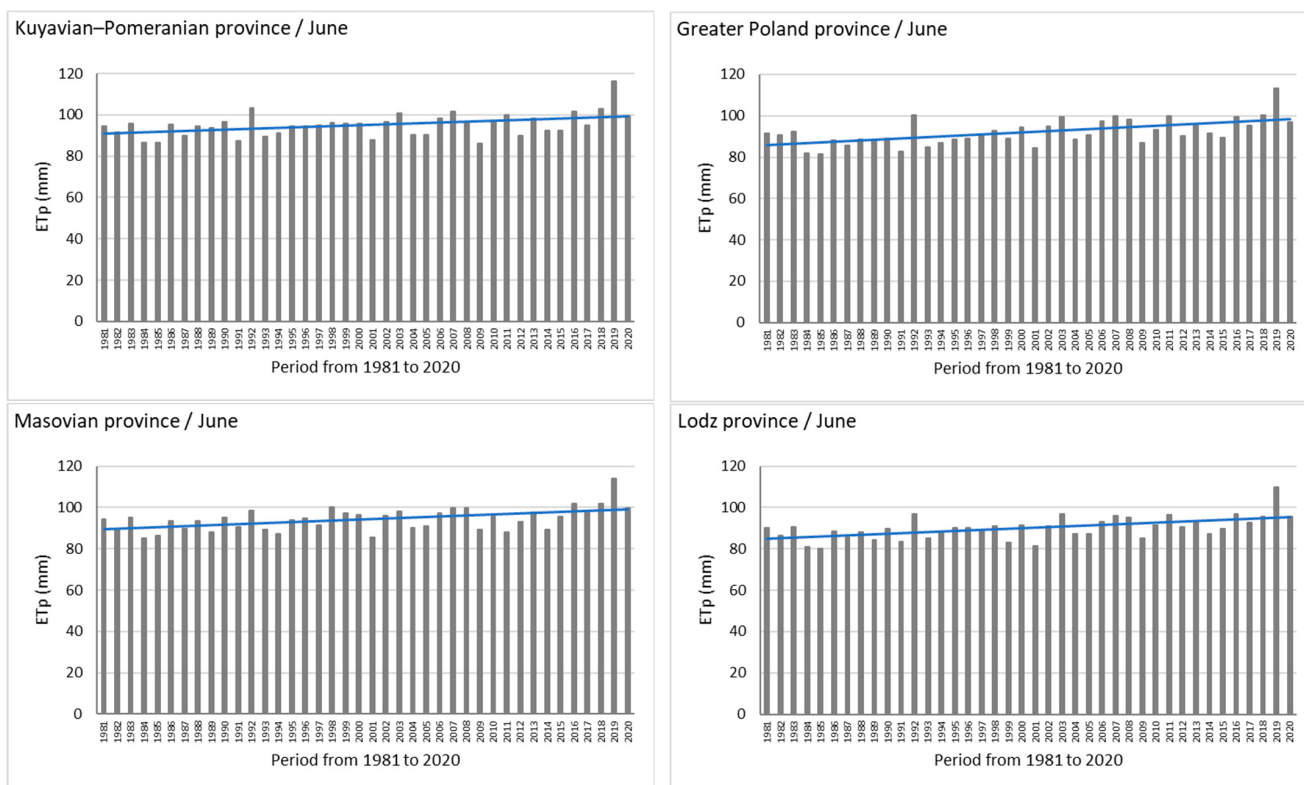


Figure 4. Time trend in cup plant water requirements in June. The trend line is marked with a blue line.

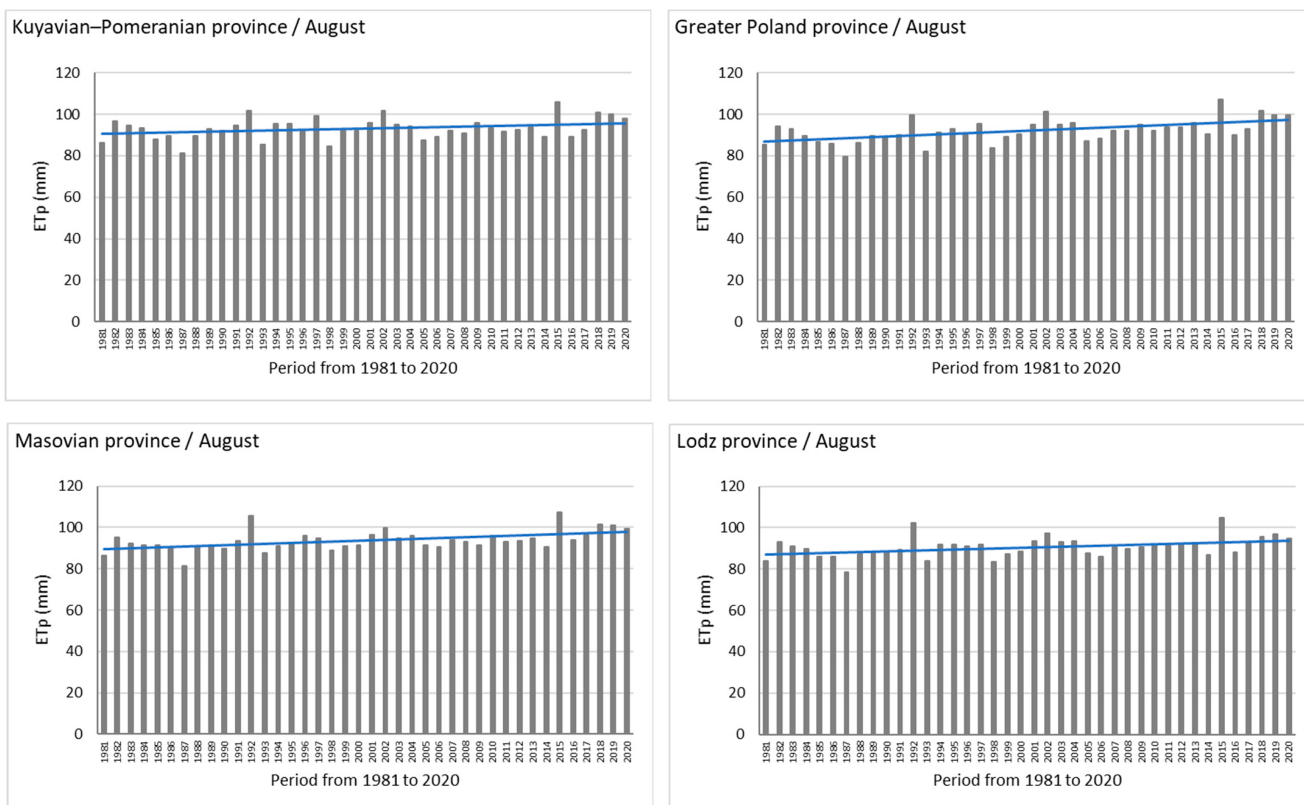


Figure 5. Time trend in cup plant water requirements in August. The trend line is marked with a blue line.

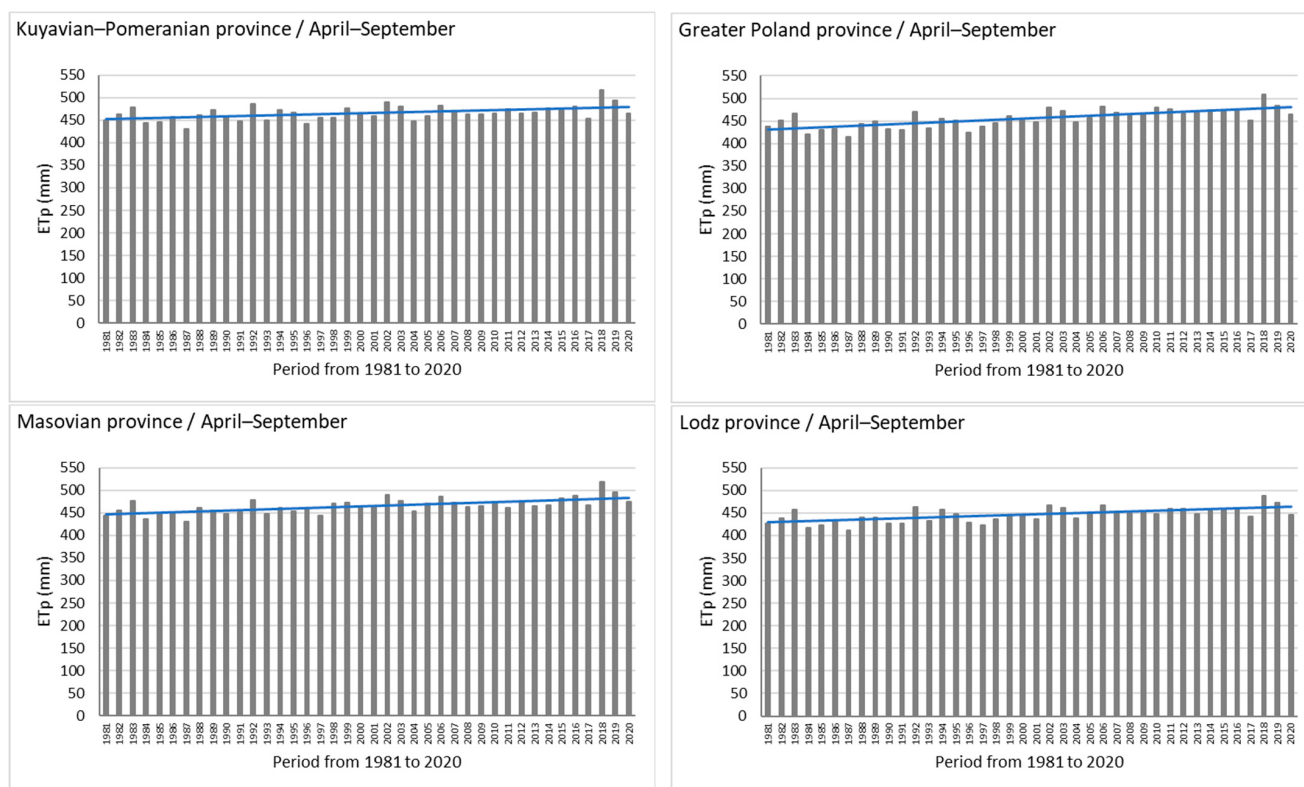


Figure 6. Time trend in cup plant water requirements during the growing season (April–September). The trend line is marked with a blue line.

Table 5. Values of correlation coefficient and tendency of the cup plant water requirements in the years 1981–2020.

Studied Period	Provinces of Central Poland			
	Kuyavian–Pomeranian	Greater Poland	Masovian	Lodz
Linear correlation coefficient (r)				
April	0.406 ***	0.534 ***	0.439 ***	0.415 ***
May	n.s.	n.s.	n.s.	n.s.
June	0.434 ***	0.597 ***	0.509 ***	0.563 ***
July	n.s.	0.389 **	0.357 **	0.335 **
August	0.313 **	0.544 ***	0.496 ***	0.408 ***
September	n.s.	0.403 ***	0.345 **	n.s.
April–September	0.477 ***	0.717 ***	0.655 ***	0.636 ***
Tendency of water requirements (mm decade ^{−1})				
April	1.4	2.0	1.8	1.7
May	0.0	0.5	0.2	0.1
June	2.1	3.2	2.5	2.7
July	1.0	2.4	1.9	1.9
August	1.4	2.6	2.1	1.7
September	0.8	1.8	1.1	0.8
April–September	6.7	12.5	9.5	8.9

n.s.—not significant; ***—significant at $p < 0.01$; **—significant at $p < 0.05$.

The assessment of the trend in the increase in water requirements for the cup plant in April, which was visible in all the studied provinces of central Poland, ranged from 1.4 mm per decade in the Kuyavian–Pomeranian province to 2.0 mm per decade in the Greater Poland province (Figure 3, Table 5).

In June, all provinces recorded the highest increase in water requirements for the cup plant, ranging from 2.1 mm per decade in the Kuyavian–Pomeranian province to 3.2 mm per decade in the Greater Poland province (Figure 4, Table 5).

In August, the increase in water requirements for the cup plant ranged from 1.4 mm per decade in the Kuyavian–Pomeranian province to 2.6 mm per decade in the Greater Poland province (Figure 5, Table 5).

On average, throughout the entire growing season, a significant upward trend in the water requirements of the cup plant was observed in all provinces. Based on the trend equations, it can be inferred that from 1981 to 2020, the water requirement during the growing season increased each decade, ranging from 6.7 mm in the Kuyavian–Pomeranian province to 12.5 mm in the Greater Poland province (Figure 6, Table 5).

Deficits in precipitation for the cultivation of cup plants, calculated for normal years ($N_{50\%}$), medium dry years ($N_{75\%}$), and very dry years ($N_{90\%}$) in this study, were observed in all provinces of central Poland and throughout the entire growing season (Table 6). In the studied provinces, the average precipitation deficits during the growing season were 125 mm in normal years, 237 mm in medium dry years, and 316 mm in very dry years. However, significant variation in precipitation deficits was noted among the provinces. The highest precipitation deficits in all categories of years were found in the Kuyavian–Pomeranian province, with 152 mm, 261 mm, and 339 mm in normal, medium dry, and very dry years, respectively. In contrast, the lowest precipitation deficit values were observed in the Lodz province in medium dry (216 mm) and very dry years (295 mm), and in the Mazovian province in normal years (103 mm). Precipitation deficits mainly occurred during the summer period, from June to August, and averaged 91 mm in normal years, 160 mm in medium dry years, and 209 mm in very dry years for the provinces. Among these summer months, August had the highest precipitation deficit, amounting to 34 mm, 55 mm, and 70 mm in normal, medium dry, and very dry years, respectively.

Table 6. Precipitation deficit (N; mm) in cup plant cultivation with a certain probability of occurrence.

Provinces of Central Poland	Studied Periods of the Growing Season				
	April–September	May–August	June–August	July	August
Normal year ($N_{50\%}$)					
Kuyavian–Pomeranian	152	129	105	31	36
Greater Poland	141	118	94	24	36
Masovian	103	94	80	28	29
Lodz	106	97	84	24	33
Mean	125	110	91	27	34
Medium dry year ($N_{25\%}$)					
Kuyavian–Pomeranian	261	215	173	57	57
Greater Poland	250	203	162	51	57
Masovian	219	186	153	55	52
Lodz	216	184	152	50	53
Mean	237	197	160	53	55
Very dry year ($N_{10\%}$)					
Kuyavian–Pomeranian	339	276	222	76	72
Greater Poland	327	263	211	70	71
Masovian	302	251	204	74	67
Lodz	295	246	201	69	68
Mean	316	259	209	72	70

The highest irrigation water demand for cup plant cultivation during the growing season occurred in very dry years and on light soil (Table 7). On average, in the central provinces of Poland in very dry years, the irrigation water demand on light soil was 276 mm, on medium soil 251 mm, and on heavy soil 226 mm. In medium dry years, these irrigation water demands were lower, amounting to 197 mm, 172 mm, and 147 mm for light, medium, and heavy soils, respectively. The lowest irrigation water demand occurred in normal years, with 85 mm, 60 mm, and 35 mm for light, medium, and heavy soils,

respectively. Among the studied provinces, the highest irrigation water demands for cup plant were observed in the Kuyavian–Pomeranian province, regardless of soil type or year category. On the other hand, the lowest irrigation water demands in medium dry and very dry years on all soil types were observed in the Lodz province.

Table 7. Irrigation water demand (mm) in cup plant cultivation during the growing period in normal, medium dry, and very dry years (mm).

Provinces of Central Poland	Type of Soils		
	Light Soil	Medium Soil	Heavy Soil
Normal year (N _{50%})			
Kuyavian–Pomeranian	112	87	62
Greater Poland	101	76	51
Masovian	63	38	13
Lodz	66	41	16
Mean	85	60	35
Medium dry year (N _{25%})			
Kuyavian–Pomeranian	221	196	171
Greater Poland	210	185	160
Masovian	179	154	129
Lodz	176	151	126
Mean	197	172	147
Very dry year (N _{10%})			
Kuyavian–Pomeranian	299	274	249
Greater Poland	287	262	237
Masovian	262	237	212
Lodz	255	230	205
Mean	276	251	226

4. Discussion

Irrigation of crops is particularly important in regions with a negative water balance and on light soils, conditions prevalent in central Poland, where the present study was conducted [62,63]. The development of irrigation infrastructure, followed by the management of precision irrigation practices for each species, requires a knowledge of the crop's water requirements and the rainfall deficit for that crop. Calculating the water requirements of cultivated plants is fundamental to rational water management and achieving optimal yields. However, water requirements depend on the plant species, i.e., its natural biological properties [64]. In this study, both the water requirements of the cup plant and rainfall deficits during their growing season were estimated. The research revealed both temporal and spatial variations in the investigated parameters, which will enable the more precise irrigation management of cup plant plantations throughout the entire growing season and across four provinces of central Poland. The increasing water requirements of crops, including in central Poland [65–69], result from global climate change, primarily associated with rising air temperatures. In the near future, the water requirements of plants will be about half higher than current precipitation levels. Therefore, the development of irrigation systems becomes necessary [70].

This study found that rainfall deficits in cup plant cultivation in central Poland occur in very dry, medium dry, and normal years. The practical application of the assessment results of water requirements and rainfall deficits is directly related to the possibility of precisely designing water reservoirs for irrigation infrastructure on energy plantations of cup plants in central Poland. In this study, sample calculations of the net volume of such a reservoir were performed for a network intended to irrigate a 30-hectare cup plant plantation in the four provinces of central Poland during medium dry and very dry years (Table 8). These calculations assume that supplying plants with 1 mm of water during

irrigation requires 10 m³ of water per hectare. Based on this assumption, the calculation is performed as follows: 10 m³ × 30 hectares × rainfall deficit (according to Table 6).

Table 8. Net capacity (m³) of the water reservoir for irrigation cup plant plantations covering an area of 30 ha located in the region of four provinces of central Poland: K–P—Kuyavian–Pomeranian province; GP—Greater Poland province; M—Masovian province; L—Lodz province.

Years	Provinces of Central Poland			
	K–P	GP	M	L
Medium dry	78,300	75,000	65,700	64,800
Very dry	101,700	98,100	90,600	88,500

Irrigation is currently one of the most important soil improvement practices, enhancing the quantity and quality of crop yields and ensuring proper plant growth and development. The irrigation technique that has recently become increasingly popular in field crops is the water-saving technique—drip irrigation. One of the many advantages of this system is the easy and precise delivery of small water doses directly to the plant’s root zone. These modern technologies, ensuring optimal soil moisture conditions, enhance plant productivity, especially in water-deficient areas with high irrigation requirements [71–74]. The importance of irrigation will continue to grow with the intensification of adverse climate changes [62,75–77]. Research results conducted in central Poland on soils with a low retention capacity indicate the beneficial impact of irrigation practices on the growth of many plants [72–74,78]. There are few studies that focus on assessing the water requirements of cup plants. However, from the limited existing research, it appears that the cup plant is suitable for cultivation under drip irrigation conditions [14,15,45]. Therefore, knowledge of the water requirements of *Silphium perfoliatum* L. is crucial as it forms the basis of rational water-saving management on the farm and ensures optimal yields of this species.

5. Conclusions

Sustainable farming of *Silphium perfoliatum* L. requires the implementation of water-saving irrigation practices. To adopt these techniques, it is necessary to understand both the water requirements of the cup plant and precipitation deficits in its cultivation. These parameters, in turn, allow for estimating the volume of water reservoirs that are part of the irrigation system for plantations. This study has shown that, depending on the province, the water requirements of the cup plant during the entire growing season ranged from 445.9 mm in the Lodz province to 465.2 mm in the Kuyavian–Pomeranian province. A distinct variation in the water requirements of the cup plant was also evident in the individual months of the growing season, with the highest monthly water requirements occurring in July (from 103.6 mm in the Lodz province to 108.9 mm in the Kuyavian–Pomeranian province). Over the course of forty years, a clear upward trend in water requirements was observed, ranging from 6.7 mm per decade to 12.5 mm per decade, depending on the province. On average, precipitation deficits during the growing season amounted to 125 mm in normal years, 237 mm in medium dry years, and 316 mm in very dry years. The results obtained in this research are of paramount importance in managing irrigation systems for cup plant energy plantations in central Poland. In line with sustainable agriculture principles, these results will allow for achieving an optimal yield of the cup plant while simultaneously conserving water resources in the provinces of central Poland.

Author Contributions: Conceptualization, A.F., R.R., S.R. and A.L.; methodology, S.R.; software, A.F. and R.R.; validation, R.R., S.R. and F.P.-F.; formal analysis, S.R.; investigation, R.R.; resources, S.R.; data curation, A.F. and A.A.; writing—original draft preparation, A.F., S.R., B.J., A.L. and H.A.S.-O.; writing—review and editing, A.F., S.R., B.J., A.L. and H.A.S.-O.; visualization, B.J.; supervision, S.R.; project administration, A.A. and F.P.-F.; funding acquisition, R.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

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