

Article

Sustainable Water Management of Drip-Irrigated Asparagus under Conditions of Central Poland: Evapotranspiration, Water Needs and Rainfall Deficits

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Abstract: Water is a valuable yet scarce resource in agriculture. Optimizing crop production relies on irrigation, but within the framework of sustainable agriculture, efforts should prioritize reducing irrigation water usage. Unfortunately, climate change increases plant water requirements, consequently heightening the need for irrigation. The aim of the research was to estimate the water needs of asparagus during the fern growth period (21 June–31 August) using the Blaney–Criddle method. The study also aimed to determine trends in changing water needs and estimate precipitation deficits. Calculations were carried out for the years 1981–2020 across four provinces in central Poland. The research indicated that water needs varied between 233 mm and 242 mm, depending on the province. Over the forty-year period, all provinces displayed an increasing trend in water needs, with a rise of 3.1 mm to 6.2 mm per decade. Between 21 June and 31 August, rainfall deficits occurred with varying intensity in all provinces during normal, medium dry and very dry years. The values of water needs and rainfall deficit, calculated as a result of the research, are of key importance in the design, construction, and management of drip irrigation systems for asparagus plantations in central Poland.

Keywords: *Asparagus officinalis* L.; climate change; global warming; precipitation; sustainability; water resources

1. Introduction

The basic premise and objective of sustainable agriculture is to provide solutions for producing food as well as other agricultural products at a low environmental cost that does not threaten food accessibility and availability, as well as the overall well-being of future generations [1–3]. It involves the integration of environmentally friendly practices that promote ecological balance, biodiversity, and the responsible use of natural resources [4].

Water conservation in sustainable agriculture practices is crucial to ensure the long-term viability of agriculture, efficient resource usage and addressing global water scarcity

challenges. Water conservation in agriculture is essential, as agriculture is the most water-intensive sector [5]. Water is one of the primary inputs in agriculture, playing a key role in plant growth, nutrient transport, and overall crop productivity. At the same time, water is considered as the second most limiting factor, after land, in increasing food and fibre production [6,7].

It is estimated that agricultural ecosystems use between 60% and 90% of the available water, depending on the climate and economic development of the region [8–10]—particularly irrigated agriculture, which represents over 20 percent of the total cultivated land and contributes 45 percent of the total food produced worldwide [8,11,12]. As agricultural production is highly dependent on water and increasingly subject to water risks, improving water management is essential to a sustainable and productive agro-food sector. Hence, any action to reduce water consumption in the agricultural sector while maintaining a balance between food production and sustainable water use is highly desirable. The starting point for improving agricultural water management and dealing with water security should be the estimation of the water needs of crops grown [13–15].

Such an estimation would help implement sustainable irrigation practices that minimize negative environmental and economic impacts. By accurately estimating water requirements, irrigation costs related to energy, labour and water supply can be reduced, leading to overall cost savings [16,17]. It is also key to meeting the challenges of water scarcity and ensuring the resilience of agricultural systems [18].

Taking into account the diversity of plant species, climatic conditions, soil properties, and local practices, estimating water requirements for different crops and regions is essential for sustainable and efficient agricultural water management. It helps ensure that water resources are utilized judiciously, promoting the long-term viability of agricultural systems. Therefore, the main objective of this paper is to determine the water needs of asparagus plants cultivated in Polish conditions.

The selection of suitable asparagus varieties for cultivation is a very important factor influencing yield. The result of breeding work by many centres around the world is many new asparagus cultivars [19]. Asparagus is a crop grown all over the world, with a global production of almost 8.5 million tonnes per year, with China being the production leader [20]. In Poland, there is also a systematic increase in the cultivated area and production volume of asparagus, especially green asparagus. Although asparagus production in Poland is mainly concentrated in the Greater Poland and Lubusz provinces, new plantations are also being established in other regions such as the Masovian, Łódź and Kuyavian–Pomeranian provinces [21].

The maximum production potential of asparagus can be achieved by applying organic and mineral fertilisation adapted to the nutritional needs of the species and ensuring optimum moisture content, including irrigation to make up for rainfall deficiencies. The specific nature of asparagus cultivation and care, i.e., harvesting the shoots in early spring, means that the yield (height and quality of the shoots) depends on the amount of nutrients stored during the previous year's summer growing season [22–25].

A satisfactory yield of asparagus depends on the desired diameter and quality, harvested in bunches for the fresh market or the canning industry [26]. To succeed commercially, one could introduce the concept of organic farming, i.e., growing food without the use of synthetic materials or genetically modified crops [27]. In conventional farming, farmers use chemicals during the production and processing of agricultural products. In organic farming, these substances are avoided at every stage of the production process [28]. Organic production is in line with the principles of sustainable agricultural production, which provides an adequate amount of food to meet the needs of the present generation, respecting ecological resources and the productivity of life-sustaining systems for future generations [28,29].

Asparagus production in Poland is likely to develop significantly because there are large sandy, light soil areas suitable for growing this plant. It is economically advantageous because areas previously designated for afforestation can be used for agricultural produc-

tion. In Poland, asparagus is mainly produced for export, but over the years, the popularity of this species has increased.

The largest markets in Europe are found in Germany, Belgium, Netherlands, Great Britain, and the Scandinavian countries, where they are a valuable raw material for processing due to their high flavour and nutritional quality. In achieving crop productivity, the main factor is irrigation. In the case of horticultural production carried out on light soil, the lack of capillary seepage is very often observed because the water level is often below 1.5 m (apart from the root system). Therefore, additional irrigation increases production profitability by providing water more efficiency [24,30,31]. A good solution is a drip irrigation system that delivers water directly to the plant root system and reduces water loss due to evaporation from the soil surface [23,24,32–34]. This irrigation system ensures a high-quality yield of asparagus spears as well [23–25,35,36]. Asparagus plants are relatively resistant to a water deficit during summer stem growth. However, a long-term drought may adversely affect the quality and yield of spears [32,34,37].

The primary aim of this research was to calculate the water requirements for *Asparagus officinalis* L. during the fern growth period using the Blaney–Criddle method. It was assumed that the fern growth period of asparagus coincides with the irrigation period of these plants, which in Poland lasts from 21 June to 31 August. This research spanned four decades, from 1981 to 2020. The study delved into the specific water needs of asparagus across four provinces located in central Poland. This region, due to climatic conditions, has the highest precipitation deficits, unfavourable water balances and increased frequencies of prolonged rainless periods.

The research hypotheses are formulated as follows. H1: the Blaney–Criddle climate indicator is suitable for determining the water needs of asparagus in central Poland. H2: determining the water needs of cultivated plants enables the correct design of drip irrigation system facilities, including small reservoirs as sources of irrigation water. The specific objectives of the research are: (i) estimating the water needs for asparagus plants during the fern growth period cultivated in central Poland in four different provinces, (ii) determining the temporal and spatial variability of these water needs, and (iii) calculating precipitation deficits in the region of central Poland.

2. Materials and Methods

This study applied the crop coefficient method to ascertain the water requirements of asparagus plants (*Asparagus officinalis* L.) within the Asparagus family. The crop coefficient method relies on the reference evapotranspiration (ET_o) outlined by Allen et al. [38] and Łabędzki et al. [39]. Within this method, the water requirements of asparagus plants align with the potential evapotranspiration of the species (ET_p). Calculating the ET_p of asparagus involves utilizing the Formula (1) below, where *kc* denotes the crop coefficient, defined as the ratio of measured evapotranspiration under optimal soil moisture conditions to ET_o [40].

$$ET_p = kc \times ET_o, \quad (1)$$

The determined values of the crop coefficient for specific months during the irrigation period for asparagus plants grown in central Poland have been provided in Table 1. The crop coefficient (*kc*) values were derived from the quotient of the total water usage by asparagus plants (*S*) during the irrigation period, i.e., measured evapotranspiration under adequate soil moisture conditions, as published by Rolbiecki [24], and the reference evapotranspiration (ET_o) in accordance with the Blaney–Criddle guidelines for the same time frames. The Blaney–Criddle formula used in this research was appropriately adapted to Polish climatic conditions by Żakowicz [41] by introducing modifications to the original model. The determination of the value of the plant coefficient *kc* for drip-irrigated asparagus plants was based on the results of a field experiment carried out in the years 2002–2007 in Kruszyn Krajeński located near Bydgoszcz in the Kuyavian–Pomeranian province [24]. The photos of the experimental field, which examined the water needs and results of drip irrigation of asparagus grown in a water-deficit area, are presented in Figure 1.

Table 1. The plant coefficient values for drip-irrigated asparagus (established from a field experiment conducted in Kruszyn Krajeński between 2002 and 2007 [24] and subsequently utilized in this research).

Year of Study According to Rolbiecki [24]	21–30 June	Irrigation Period 1–31 July	1–31 August
Total water used by asparagus plants during the irrigation period (S; mm)			
2002	13.8	112.0	146.3
2003	19.3	98.6	131.5
2004	13.6	91.3	100.3
2005	8.8	102.2	113.6
2006	16.6	132.8	111.5
2007	37.7	121.3	104.7
Reference evapotranspiration according to the Blaney–Criddle method (ET ₀ ; mm)			
2002	42.9	139.5	127.4
2003	44.8	137.2	118.6
2004	40.0	126.8	117.7
2005	40.2	141.0	109.3
2006	43.6	156.0	111.3
2007	45.1	131.1	115.3
The crop coefficient values (k _c = S/ET ₀)			
2002	0.321766	0.802632	1.148677
2003	0.430802	0.718484	1.109031
2004	0.339595	0.719750	0.852327
2005	0.218842	0.724698	1.039028
2006	0.380748	0.851156	1.002066
2007	0.836416	0.925001	0.908116
kc used in the present study	0.4	0.8	1.0



(a)



(b)

Figure 1. Assessment of water requirements of asparagus during the fern growth period (from 21 June to 31 August) carried out in a field experiment in 2002–2007 in Kruszyn Krajeński (central Poland); (a) experimental plantation of drip-irrigated asparagus plantations, (b) drip irrigation of asparagus plants during the fern development period [24].

In this study, the reference evapotranspiration was determined based on the Formula (2) presented below. As mentioned above, this procedure was developed by Blaney–Criddle and modified to adapt it to the climatic conditions prevailing in the region of central Poland [41].

$$ET_0 = n \times [p \times (0.437 \times t + 7.6) - 1.5], \quad (2)$$

where:

n—number of days in the month;

p—evaporation coefficients for respective months and geographic latitude [42];

t—average monthly air temperature (°C).

The Ostromęcki method, reported by Tabaszewski [43] and Żakowicz et al. [44], was employed in this study to calculate the magnitude of precipitation deficits (N). Calculations were conducted for years categorized as very dry (N_{10%}), medium dry (N_{25%}), and normally dry (N_{50%}), using the following Formula (3).

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

where:

Np%—the precipitation deficit, for which the probability of occurrence is p% (mm per period);

Ap% and Bp%—the numerical coefficients aimed at characterizing the variability of precipitation and evapotranspiration for a given meteorological station;

ETp—the multi-year average evapotranspiration during the analysed period (mm per period);

P—the average value determining the amount of precipitation, calculated based on the multi-year period for the analysed timeframe (mm per period).

The water requirements of *Asparagus officinalis* L. plants were assessed across four provinces in central Poland: Kuyavian–Pomeranian (K–P), Greater Poland (GP), Masovian (M), and Lodz (L), as shown in Table 2. The conducted analyses utilized meteorological data encompassing precipitation totals and air temperature values collected over a forty-year period, from 1981 to 2020. This meteorological data came from meteorological stations located in the cities of Bydgoszcz, Poznań, Warsaw and Łódź, which were considered representative for the studied provinces, respectively.

Table 2. Geographic position of meteorological stations in central Poland.

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

m.a.m.s.l.—meters above mean sea level.

In the study, the fern growth period for asparagus was analysed, starting on 21 June and ending on 31 August. It was assumed that the fern development period of asparagus plants coincides with the period during which irrigation of these species is carried out in Poland.

The results obtained from this research underwent an extensive and detailed statistical examination. These calculations encompassed computing various statistical parameters, such as maximum, minimum, and median values. Additionally, the analysis involved determining the standard deviation and variability coefficient. Moreover, the statistical exploration aimed to uncover potential patterns or trends in the water requirements of *Asparagus officinalis* L. plants across the four central Polish provinces under comparison. This investigation into the tendencies in asparagus plants' water requirements relied on employing robust linear regression analysis techniques. Furthermore, this study encompassed the determination of correlation and determination coefficients to gauge the relationships and predictive capabilities within the dataset. The significance of correlation coefficients, based on a sample size of $n = 40$, was rigorously assessed at various statistical thresholds: $p = 0.1$, $p = 0.05$, and $p = 0.01$ [45].

3. Results and Discussion

This study examined the water needs of asparagus plants during the fern development period in four provinces of central Poland. In Poland, the period of asparagus fern development coincides with the time when irrigation treatments for this species are conducted, lasting from 21 June to 31 August. The assessment of water needs relied on potential evapotranspiration. The calculations clearly showed both the temporal and spatial variability in the water needs of asparagus plants. The study revealed that the highest variability coefficient in the water requirements of asparagus plants (6.8%, 6.7% and 6.6%, in June, July and August, respectively) during the considered fern growth period, from 21 June to 31 August, were observed in the Greater Poland province (Table 3). Conversely, the Masovian province displayed the lowest variability coefficients (5.9%, 5.6%, and 5.1% for June, July, and August, respectively) in the water requirements of asparagus plants. The outcomes of this study corroborate and substantiate the findings of previous research conducted throughout Poland [46]. The variability in the water requirements of asparagus plants was notably pronounced in the central–northwestern region, which, based on the methodological assumptions applied at that time, also encompassed the Greater Poland province. During this earlier study, the variability coefficients reached 7.7% and 7.6% for July and August, respectively.

Table 3. Statistical analysis of asparagus water requirements in the provinces of central Poland.

Statistical Characteristics	Provinces of Central Poland	Irrigation Period = Fern Growth Period		
		21–30 June	1–31 July	1–31 August
Minimum (mm)	K–P	15	97	101
	GP	14	93	100
	M	15	95	102
	L	14	90	98
Maximum (mm)	K–P	21	125	132
	GP	20	125	134
	M	20	124	134
	L	20	120	131
Median (mm)	K–P	17	109	116
	GP	16	107	115
	M	17	108	116
	L	16	104	114
Standard Deviation (mm)	K–P	1.010	6.506	6.231
	GP	1.108	7.037	6.884
	M	0.992	6.025	6.015
	L	0.987	6.562	6.035
Variability Coefficient (%)	K–P	6.0	6.0	5.4
	GP	6.8	6.7	6.0
	M	5.9	5.6	5.1
	L	6.2	6.3	5.3

K–P—Kuyavian–Pomeranian province, GP—Greater Poland province; M—Masovian province; L—Lodz province.

The water-need values, calculated using the Blaney–Criddle formula, varied among the four studied provinces. The highest water requirements (242 mm) for asparagus plants throughout the entire irrigation season, considered from 21 June to 31 August, within four provinces of central Poland between 1981 and 2020, were observed in the Kuyavian–Pomeranian and Masovian provinces (Figure 2). Conversely, the lowest water requirements (233 mm) for the examined species were noted in the Lodz province. The values of water needs for asparagus obtained in this study using the Blaney–Criddle method are consistent with the values obtained in studies conducted under lysimetric conditions for asparagus. For context, Paschold et al. [47] reported water consumption by asparagus plants irrigated under lysimetric conditions ranging from 266 mm to 292 mm.

Similarly, according to Pardo et al. [48], seasonal water consumption by *Asparagus officinalis* L. plants under lysimetric conditions varied from 274 mm to 294 mm.

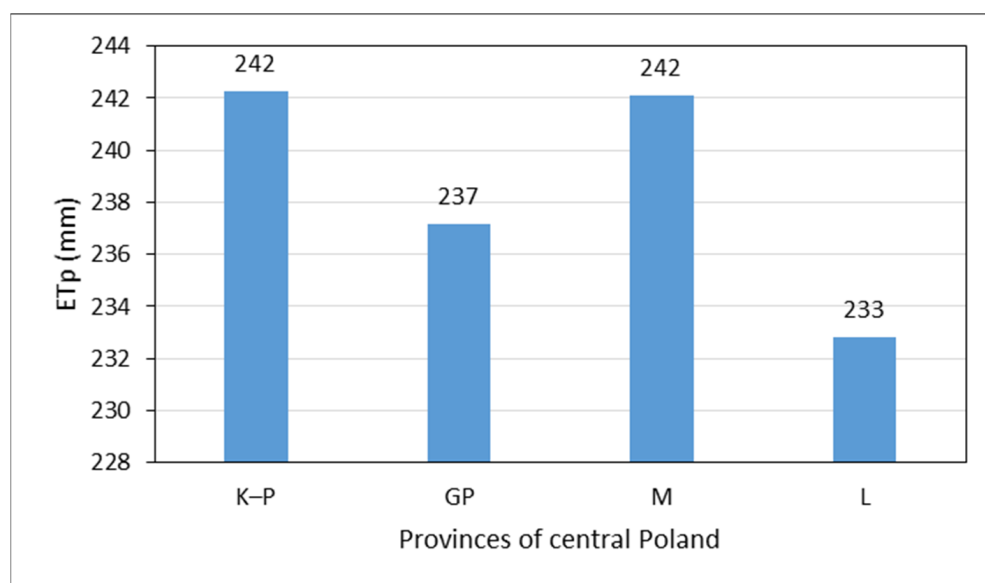


Figure 2. Water requirements of asparagus in central Poland during the irrigation period. K-P—Kuyavian–Pomeranian province; GP—Greater Poland province; M—Masovian province; L—Lodz province.

The research revealed differences in the water needs of asparagus, not only depending on the province studied but also varying by month. Across all the examined provinces in central Poland, the water requirements of asparagus were higher in August compared to July (Figure 3). During the analysed period of asparagus fern growth, depending on the province, water requirements in August ranged from 113 mm to 117 mm. For comparison, in previous studies reported by Rolbiecki et al. [46], the highest water needs for asparagus plants during two months, July and August, occurred in two regions of Poland, central–northwestern and central–eastern, and amounted to 228 mm. However, these studies concerned a different period (1981–2010) and were carried out according to a different methodology, because the reference evapotranspiration was calculated according to Grabarczyk’s formula [49] based on the sums of atmospheric precipitation. Despite this, the results currently presented, obtained using the Blaney–Criddle formula, are very similar. For example, the total water requirements in the period from 1 July to 31 August amount to 225 mm for the Kuyavian–Pomeranian province (Figure 3). Therefore, it can be assumed that the method of estimating the water needs of plants using the Blaney–Criddle formula, employed in this research, is suitable for determining the irrigation needs of asparagus in Poland. Consequently, this method may play a key role in the decision-making process concerning the placement and design of irrigation systems and the overall management of irrigation in Poland. The Blaney–Criddle method serves as a valuable tool in supporting operational irrigation planning, and its implementation can contribute to enhanced water use efficiency for irrigation and the judicious utilization of water resources.

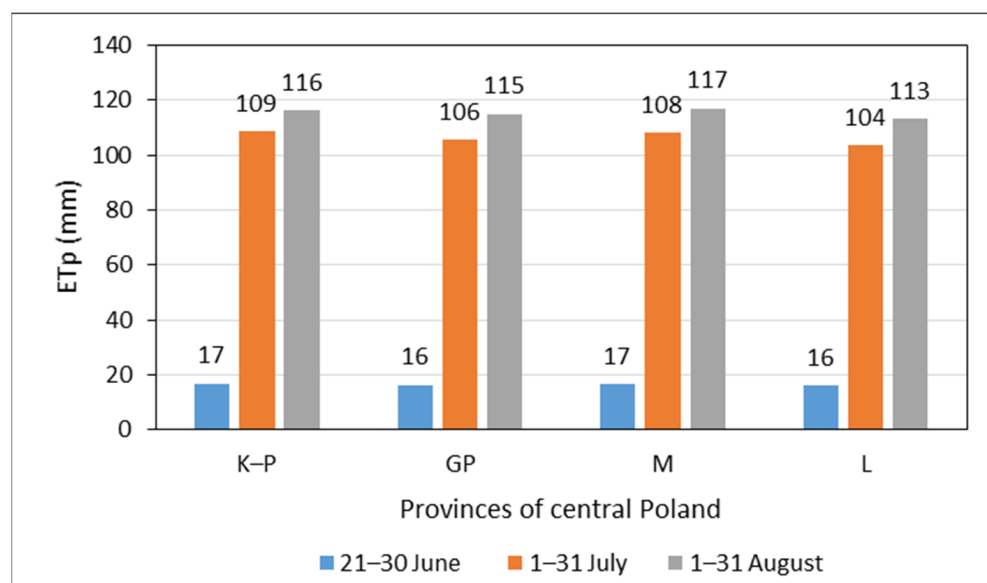


Figure 3. Monthly water requirements of asparagus in central Poland during the irrigation period. K-P—Kuyavian–Pomeranian province; GP—Greater Poland province; M—Masovian province; L—Lodz province.

During the presently examined forty-year period (1981–2020), in all four considered provinces of central Poland, there was a significant trend showing an increase in the water requirements of asparagus plants during the fern development period (between 21 June and 31 August) (Table 4, Figure 4). The generated equations for the trend in asparagus plants water requirements show that in the years 1981–2020, seasonal water requirements increased in each decade in the range from 3.1 mm in Kuyavian–Pomeranian province to 6.2 mm in Greater Poland province. In the month with the highest water needs, i.e., August, this increase was 1.7 mm and 3.2 mm per decade for both mentioned provinces, respectively (Figure 5). The regression analysis also showed that only in one month, July, and only in one province, Kuyavian–Pomeranian, the upward trend in evapotranspiration was not significant (Table 4).

Table 4. Significance and tendency for time trend of the asparagus water requirements in the provinces of central Poland.

Irrigation Period (Fern Growth Period)	Provinces of Central Poland			
	Kuyavian–Pomeranian	Greater Poland	Masovian	Lodz
Linear Correlation Coefficient (r)				
21–30 June	0.434 ***	0.597 ***	0.509 ***	0.563 ***
1–31 July	0.184 ns	0.389 **	0.357 **	0.335 **
1–31 August	0.314 **	0.544 ***	0.496 ***	0.408 ***
21 June–1 August	0.346 **	0.596 ***	0.560 ***	0.504 ***
Tendency of Water Needs (mm decade ^{−1})				
21–30 June	0.4	0.6	0.4	0.5
1–31 July	1.0	2.4	1.9	1.9
1–31 August	1.7	3.2	2.6	2.1
21 June–1 August	3.1	6.2	4.9	4.5

ns—not significant; ***—significant at $p \leq 0.01$; **—significant at $p \leq 0.05$.

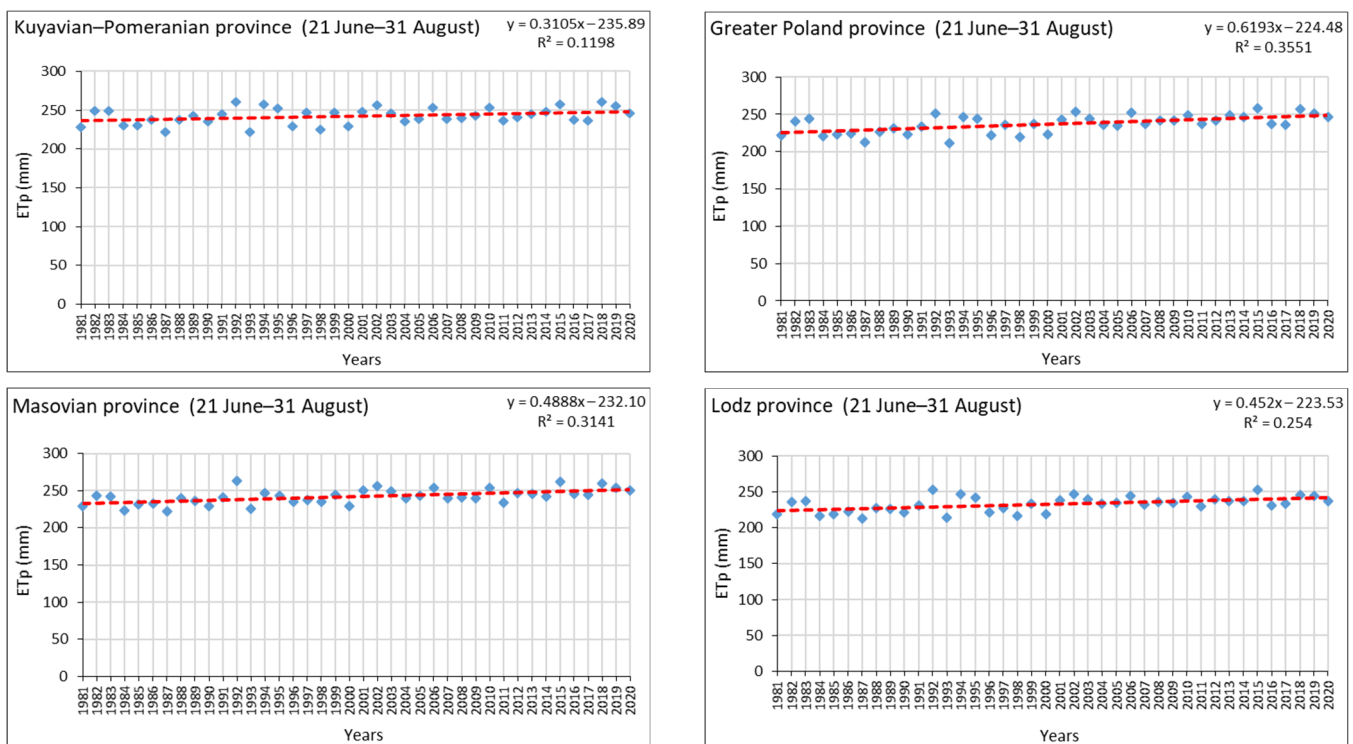


Figure 4. Time trend of water requirements for asparagus in the provinces of central Poland considered from 21 June to 31 August.

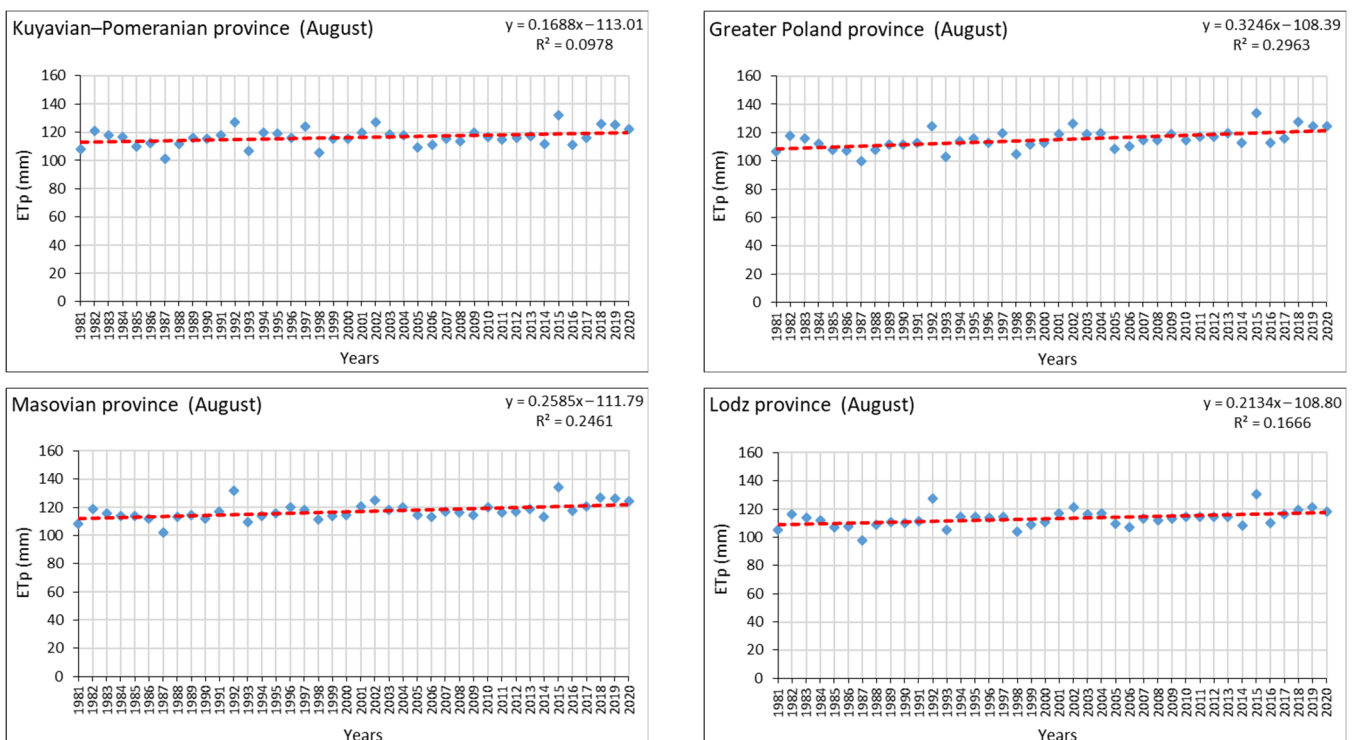


Figure 5. Time trend of water requirements for asparagus in the provinces of central Poland in August.

The increase in water requirements found in these studies across provinces of central Poland, examined in the case of *Asparagus officinalis* L. plants, is confirmed by investigations carried out for many other plant species. This has been reported by, among others, Łabędzki [50], Radzka et al. [51], Kuchar and Iwański [52,53], Kuchar et al. [54,55], and

Jagosz et al. [56–58]. It is expected that the ongoing climate changes, mainly the increase in air temperature, will result in an increase in the water requirements of all plants in the near future [50,59]. Therefore, there is a need to take adaptive actions aimed at mitigating the effects of climate warming on plants. The most desirable direction of such adaptation activities is the intensive development of irrigation systems, which is now visible all over the world. Undoubtedly, with the intensification of unfavourable climate changes, the importance of irrigation technologies, especially precise ones like drip irrigation, enabling economic management of this valuable natural resource, water, will increase significantly.

The calculations of rainfall deficit performed in this study showed considerable variation in the values of the examined parameter within the four studied provinces of the central Poland region (Table 5). It has been demonstrated that the largest deficit of atmospheric precipitation in the analysed period of asparagus fern development occurred in area of the Kuyavian–Pomeranian province. The amounts of these rainfall deficits were 183 mm, 143 mm, and 90 mm in very dry years ($N_{10\%}$), medium dry years ($N_{25\%}$), and in normal years ($N_{50\%}$), respectively. The smallest precipitation deficits, both in very dry years, medium dry years, and in normal years, were found in the Lodz province. The calculated values of these rainfall deficits were 168 mm, 129 mm and 79 mm, respectively. For comparison, in the previously mentioned studies conducted for the entire Poland by Rolbiecki et al. [46], in two regions where the highest water requirements of asparagus plants were found, precipitation deficits in normal, medium dry and very dry years were 89–91 mm, 157–166 mm and 209–245 mm, respectively. For comparison, the sum of water deficits, i.e., irrigation needs in asparagus cultivation according to Kaufmann [60], for the climatic conditions of Central Europe, ranges from 20 mm to 160 mm, depending on the location of the cultivation. In turn, Paschold et al. [61] report, based on many years of experience conducted in Germany, that the irrigation requirements of asparagus plants on a production plantation located on sandy soil, depending on the height and distribution of atmospheric precipitation, range from 48 mm to 153 mm.

Table 5. Precipitation deficit (mm) in asparagus plants cultivation in normal, medium dry and very dry years.

Years	Irrigation Period = Fern Growth Period			
	21–30 June	1–31 July	1–31 August	21 June–31 August
Kuyavian–Pomeranian province				
Normal	–	31	59	90
Medium Dry	3	57	82	143
Very Dry	7	76	100	183
Greater Poland province				
Normal	–	24	59	84
Medium Dry	2	51	82	136
Very Dry	6	70	99	175
Masovian province				
Normal	–	28	53	81
Medium Dry	–	55	77	132
Very Dry	3	74	96	173
Lodz province				
Normal	–	24	56	79
Medium Dry	1	50	78	129
Very Dry	4	69	95	168

It should be mentioned that according to research published by Żakowicz et al. [44], the value of precipitation deficits calculated for very dry years ($N_{10\%}$) ensures the water requirements of asparagus at the level of 90% and is useful in planning and designing

irrigation systems. In this research, calculations were made of water needs and rainfall deficit in asparagus cultivation in four provinces of central Poland. These data are necessary for the correct design, construction and management of drip irrigation system facilities, including small reservoirs as sources of irrigation water. Knowledge of the water needs of plants and rainfall deficits during their cultivation will allow for a significant reduction in investment costs, especially in the case of newly constructed irrigation infrastructure. It is also evident that this will also contribute to improving the efficiency of using limited water resources during irrigation. To emphasize the applied nature of this research and to indicate the possibility of practical application of the results obtained in the current research, an example of calculating the volume of a water reservoir constituting an element of a drip irrigation system is shown below. The data in Table 6 present sample calculations performed to estimate the net volume of the water reservoir (V ; m^3) supplying the drip irrigation system of an asparagus plantation with an area of 25 ha (F). These calculations used data on precipitation deficits in asparagus cultivation, which are the result of current research and are included in Table 5. It was assumed that the rainfall deficits shown there had to be covered by a drip irrigation system. The calculations of the reservoir capacity were carried out for the period from 21 June to 31 August for very dry ($N_{10\%}$) and medium dry ($N_{25\%}$) years. It should be added that rainfall deficits calculated for very dry years secure the water needs of asparagus plants at the level of 90%, and precipitation deficits calculated for medium dry years secure the water needs of asparagus plants at the level of 75%. Thus, assuming that 1 mm of water supplied to plants during drip irrigation is equivalent to 10 m^3 per ha (DI), then in the case of the Kuyavian–Pomeranian province for very dry years ($N_{10\%} = 183 \text{ mm}$, Table 5), i.e., when securing water needs is 90%, the volume of the water reservoir should be $45,750 \text{ m}^3$, i.e., $V = 183 \text{ mm} \times 10 \text{ m}^3 \times 25 \text{ ha} = 45,750 \text{ m}^3$. These calculations were made based on the following Formula (4):

$$V = N_{10\%} \times \text{DI} \times F \quad (4)$$

Table 6. Calculation of the net volume of the water reservoir supplying the drip irrigation system of an asparagus plantation with an area of 25 ha in the period 21 June–31 August in very dry ($N_{10\%}$) and medium dry ($N_{25\%}$) years. Prepared based on Table 5.

Provinces of Central Poland	Net Volume of the Water Reservoir (m^3) in the Years:	
	Medium Dry ($N_{25\%}$)	Very Dry ($N_{10\%}$)
Kuyavian–Pomeranian	35,750	45,750
Greater Poland	34,000	43,750
Masovian	33,000	43,250
Lodz	32,250	42,000

The development of the idea of sustainable management in agriculture places emphasis on optimization of production [62]. Drost [63] emphasizes that productivity in the case of asparagus results from the interaction of selecting appropriate cultivars, the production environment, and production management that maximizes yield. In the era of global climate warming, causing an increase in the water needs of plants, maximizing plant production requires the use of irrigation treatments. It is known that asparagus plants exhibit a notable resilience to soil water shortages owing to their deep and robust root systems [64–68]. However, much research conducted worldwide confirms the beneficial effect of irrigation on this species, especially during the fern development period, on its yield [69–84]. Currently, particular emphasis is placed on water-saving irrigation techniques, including drip irrigation, which, following principles, allows for rational management of this extremely valuable natural resource, water [85–89]. Efforts to reduce the amount of water used to irrigate asparagus are particularly important in water-deficient areas and on light and sandy soils [24,31,36,37,69,71,80,84]. It was found that it is possible to reduce the amount of water used to irrigate asparagus thanks to an appropriate system monitoring this process [72,76,79,80,82,83].

4. Conclusions

The goals set at the beginning of this paper have been achieved. (1) Based on calculations made using the Blaney–Criddle method, the water needs of asparagus plants during the fern development period were estimated in four different provinces of central Poland. (2) The temporal and spatial variability of these water needs was determined. Namely, it was found that, depending on the province, the water needs of asparagus plants ranged from 233 mm to 242 mm. Moreover, it was observed that in all provinces of central Poland, the highest monthly water requirements for asparagus occurred in August. Over the analysed forty years, a significant increasing trend in the water needs of asparagus plants was noted in all analysed provinces of central Poland. Water requirements increased in each subsequent decade by 3.1 mm to 6.2 mm. (3) Finally, rainfall deficits in the central Poland region were calculated. It was observed that, between 21 June and 31 August, precipitation deficits occurred with varying intensity in all provinces during normal, medium dry and very dry years. This research also successfully validated the research hypotheses established at the beginning of the study. (1) It was determined that the Blaney–Criddle climate indicator used in the calculations is suitable for assessing the water needs of asparagus in central Poland, as supported by existing literature reports. Nevertheless, it would be worthwhile to conduct future research to verify other methods for estimating the water needs of asparagus plantations in Poland. (2) The study also confirmed that determining the water needs of plants allows for the accurate design of drip irrigation system facilities, including small reservoirs as sources of irrigation water, which will reduce investment costs and optimize water consumption. This was illustrated through calculations of the volume of the water reservoir supplying the drip irrigation system for an asparagus plantation. To sum up, the analysis of asparagus water needs conducted in this research will enable precise design, construction and management of water-saving drip irrigation systems for asparagus plantations in central Poland. This will improve the efficiency of utilizing limited water resources during irrigation.

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