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Assessment of Water Needs of Grapevines in Western Poland from the Perspective of Climate Change

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Abstract: Climate changes lead to a rise in air temperature, which significantly increases the water needs of plants. Maintaining crop productivity will increasingly require the use of plant irrigation. The aim of this study was to assess the water needs of grapevines cultivated in the western provinces of Poland. The calculations were made on the basis of temperature and precipitation measurements collected at three meteorological stations in the period 1981–2010. Water needs were calculated as crop evapotranspiration, which was estimated by crop coefficients and reference evapotranspiration, determined using the Blaney–Criddle formula. The rainfall deficit was assessed by Ostromęcki's method. The tendency to increase the water needs was observed in each subsequent decade of the thirty-year period, both in the whole growing season (May–October), as well as in June–August and July. The highest values of the linear correlation coefficient for the trend of time variability in water needs occurred from June to August. An analysis of water needs and rainfall deficits indicates the need for the additional irrigation of vineyards in western Poland, especially in very dry years and in June–August. Current research results are helpful in designing vineyard irrigation systems and allow an economical and efficient planning of grapevine irrigation.

Keywords: evapotranspiration; irrigation; precipitation; vineyard; viticulture; *Vitis vinifera* L.; water deficit

1. Introduction

Currently, viticulture is conducted in regions that are limited by isotherms of a daily mean air temperature of 10 and 20 °C [1]. It is believed that the progressing global warming may contribute to changes in the regionalization of viticulture [2]. Southern Europe may become too warm to produce high-quality wines. In turn, wine production in the northern part of the Europe, i.e., in countries that are not traditionally associated with viticulture, can become profitable [2–6]. The results of Dobrowolska-Iwanek et al. [7] show that, under Polish climatic conditions, it is possible to produce wine with quality comparable to wine from established wine-producing regions. Selected wine brands showed a high antioxidant activity (ferric reducing antioxidant power—FRAP) and a high level of polyphenols. This study also provides confirmation that wines from colder climates frequently reveal unique and desirable properties. It has been observed in recent years, as a result of global warming, that grapevine fruits ripen earlier and earlier [8]. Therefore, there are currently opportunities for grapevines growing in regions where there is no tradition of wine production [9].

The possibility of commercial viticulture occurs only in places that meet basic climate requirements—mainly thermal requirements with particular regard to an average annual air temperature of around 8 °C, average air temperature during the growing season of around 14 °C, average air temperature in the hottest month of the year of around 17 °C and the sum of active temperatures (SATs) of around 2500 °C [10]. The sum of active temperatures (SATs) is calculated as the sum of daily mean temperatures above a given threshold when active crop growth takes place. In the case of grapevines it equals 10 °C. In Poland, the northern limit of occurrence of average SAT values of 2500 °C is located. Generally, the SATs in Poland ranges from 2200 °C in north-eastern Poland to 2600 °C in the middle highlands area and 2700°C in the south-west and west of the country (Figure 1). Therefore, the best conditions for growing and ripening grapes in Poland are in the western part of the country, where the highest SAT values (over 2700 °C) are recorded [11].

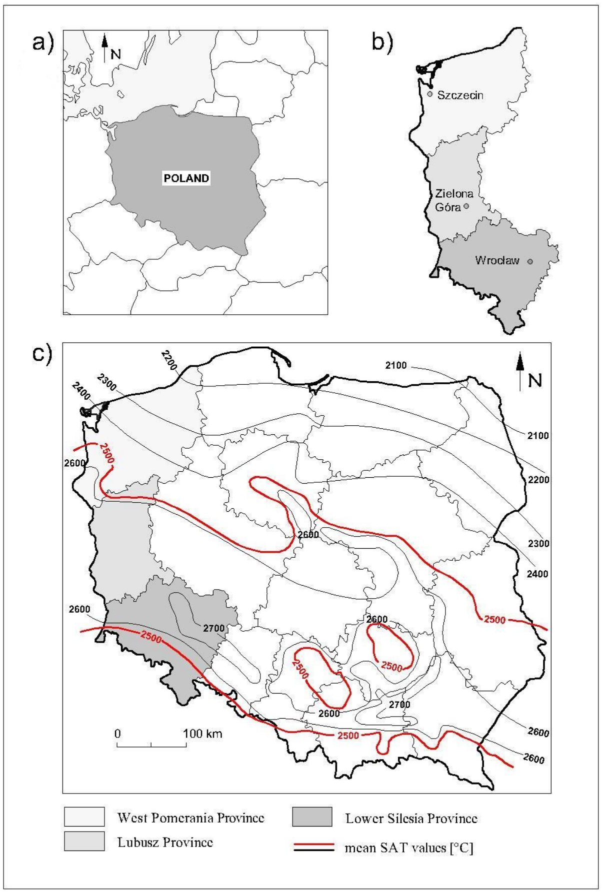

Figure 1. Provinces (NUTS-2) in Poland with examined western ones: geographical location of Poland (**a**), location of meteorological stations (**b**) and isolines of sum of active temperatures (SATs) (**c**).

Compared to 1971–2000, it is expected that the growing season in Poland (determined by the number of days with a daily air temperature higher than 5 °C) in 2021–2050 will be longer by 16 days, while in 2071–2100 by as much as 41 days and it will approach 230 and 255 days, respectively. The forecasted temperature increase during the growing season will significantly accelerate the development of plants, including grapevines [12]. Currently, in many regions of Poland viticulture is at great risk due to spring and autumn ground frosts that damage grapevine plants and fruits. Moreover, an often rainy and cold September worsens the ripening conditions and health of grapevine fruits. Despite this, the growers (farmers) take a risk and cultivate grapevines. Many vineyards have been created in recent years and the professional, commercial production of grape wines has developed [13].

In recent years, as a result of gradual, but significant global warming, interest in viticulture and wine production in Poland has increased significantly. Producers' knowledge and skills regarding viticulture and wine production have also improved significantly. The growing interest in viticulture in Poland also results from adopting Western European habits of drinking alcohol—i.e., consuming wine with meals and replacing high-percentage alcoholic beverages with wine. At the same time, consumers' awareness of the dietary and health-promoting properties of wine is also increasing. In turn, the development of vineyards is conducive to the development of breeding programs whose primary goal is to create new grapevine cultivars, which are better adapted to the Polish climate [11]. The area of vineyards in Poland is growing every year. According to the data of National Agricultural Support Center of 2 July 2020, the number of registered grapevine producers in Poland in 2020 equals 294, and the area of grapevines growing is almost 500 ha, of which over three-quarters is allocated to wine production [13]. Presently (as of 2 July 2020), there are 497 vineyards in Poland with a total area of 579.37 ha [14]. The vast majority of Polish vineyards, including almost all commercial plantations, produce wine exclusively for their own needs. Despite the growing area of vineyards in Poland, the grapevines are still not grown for the sale of fruit, as is the case in other countries, where cooperatives buy grapes from many vineyard owners and produce wine from them. This situation is the result of Polish legislation that only allows the production of wine from its own vineyards without obtaining grapevine fruits from other producers [13].

Predictable global climate changes relate to an increase in air temperature, but do not forecast an increase in precipitation in this part of Europe where Poland is located [15]. Therefore, currently one of the most important challenges of modern agriculture in the context of sustainable development is the study of the water needs of crops, which will allow for a precise replenishment of the deficit of precipitation in field crops. Although grapevine is a species that tolerates even significant water deficits, additional irrigation will be needed in many wine-growing regions in the coming years. Designing and planning a system of precise vineyard irrigation system, which would allow for crop optimization and the economical management of water resources, it is necessary to conduct research aimed at determining the water needs of the grapevines. However, no study on the assessment of water needs of grapevines has been published so far for those regions of Poland in which viticulture gives the best results. Thus, the main purpose of the present research was to estimate the water needs of grapevines grown in three provinces of western Poland. Water needs were calculated on the basis of meteorological measurements carried out in 1981–2010 for the growing season considered from May to October, with particular emphasis on summer months considered from June to August.

2. Materials and Methods

The water needs of grapevines (*Vitis vinifera* L.) for cultivation in western Poland were assessed on the basis of temperature and precipitation measurements carried out at three meteorological stations located in Szczecin, Zielona Góra and Wrocław, representative of the three provinces located in the western part of the country, including Pomeranian, Lubusz and Lower Silesian provinces, respectively (Table 1, Figure 1). The calculations were made on the basis of meteorological data collected over a period of 30 years covering the years from 1981 to 2010. The study was carried out for the growing season considered for viticulture in Poland from 1 May to 31 October. Particular attention was paid to the summer months, considered from 1 June to 31 August.

Table 1. Geographical location of considered meteorological stations in western Poland.

Province	Meteorological Station	Altitude (m a.s.l.) [1]	Latitude	Longitude
West Pomeranian	Szczecin	1	53°24′	14°37′
Lubusz	Zielona Góra	182	51°06′	17°05′
Lower Silesian	Wrocław	116	51°56′	15°30′

[1] m a.s.l. = meters above sea level.

The area of western Poland was selected for research, because the chance for profitability of viticulture is much higher there than in other parts of the country, especially in eastern Poland. In western Poland there is a low risk of adverse weather phenomena, such as late spring ground frosts, excessive summer rainfall, sudden summer cooling, rain or ground frost during grape ripening, which pose the greatest threat to the productivity of grapevine plantations in Poland. Although new grapevine cultivars such as "Rondo" or "Solaris" can be grown even in the colder areas of Poland, it is difficult to guarantee the profitability of wine production in these regions. Therefore, large, commercial vineyards should be created in the warmest regions of Poland; e.g., in western Poland, where favorable mesoclimatic conditions for viticulture are ensured. The main climatic factor determining the possibility of viticulture is the length of the growing season, which in western Poland is about 20 days longer than in eastern Poland. Another climatic parameter important for viticulture in Poland are spring and autumn frosts. On average, the last spring ground frost in western Poland occurs about 10 days earlier than in eastern Poland, and the first autumn ground frost appears about a week later. The sum of active temperatures (SATs) in the growing season, as a measure of the thermal conditions in vineyards from May to October, also supports the selection of this region for research; the SATs for eastern Poland is from 2641 to 2738 °C, and for western Poland from 2774 to 2785 °C. Finally, the sum of sunlight in western Poland, which has a direct impact on the intensity of sugar synthesis and the production of aromatic compounds and dyes in grape fruits, in the period from April to September was 65 kcal cm^{-2} [16].

The water needs of grapevine were determined by crop evapotranspiration, which was calculated using crop coefficients according to the following Equation (1):

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

where:

ETp = crop potential evapotranspiration, in sufficient soil moisture conditions (mm);
ETo = reference evapotranspiration during the month (mm);
kc = crop coefficient, expressing the effect of a set of plant factors (related to the plant development phase) on evapotranspiration in the absence of soil moisture effect on the intensity of this process (i.e., in terms of sufficient soil moisture).

Reference evapotranspiration was determined based on the Blaney–Criddle Equation (Equation (2)) modified by Żakowicz [17]:

$$\mathrm{ETo} = \mathrm{n} \times [\mathrm{p} \times (0.437 \times \mathrm{t} + 7.6) - 1.5], \quad (2)$$

where:

n = number of days per month;
p = evaporation coefficients according to Doorenbos and Pruitt [18] for months and latitude;
t = average monthly air temperature (°C).

The study uses crop coefficients (kc) determined for the subsequent months of the growing season (May–October), adapted to the reference evapotranspiration calculated by the Blaney–Criddle method [17,18] (Table 2).

Table 2. Crop coefficients (kc) for grapevine according to Doorenbos and Pruit [16].

Month	V	VI	VII	VIII	IX	X
kc	0.45	0.70	0.85	0.90	0.85	0.70

The amount of rainfall deficit (N) for grapevines with a probability of occurrence of normal years ($N_{50\%}$), medium dry years ($N_{25\%}$) and very dry years ($N_{10\%}$) was determined by the method of Ostromęcki [17] using Equation (3):

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

where:

Np% = precipitation deficit with a probability of occurrence equal to the p% (mm period^{-1});
ETp = long-term average crop evapotranspiration in the studied period (mm period^{-1});
P = average long-term precipitation in the studied period (mm period^{-1});
Ap% and Bp% = numerical coefficients characterizing the variability of evapotranspiration and precipitation for a given meteorological station.

The water needs of grapevines were determined by the mean, median, maximum and minimum values, as well as standard deviation and variability coefficient. Possible trends of changes in the water needs of grapevines were calculated by means of a linear regression analysis with a determination of correlation coefficients. The significance of correlation coefficients for the sample size n = 30 was determined for $p = 0.1$, $p = 0.05$ and $p = 0.01$.

3. Results

Among the three studied provinces of western Poland, the highest values of the standard deviation, which are a measure of the diversity of monthly sums of water needs of grapevines in the years 1981–2010, were found in Lubusz Province in May (10.0 mm) and in July (9.2 mm) (Table 3). The lowest values of standard deviation among the considered provinces were recorded in May in the Lower Silesian (2.8 mm) and West Pomeranian provinces (3.1 mm). The highest values of the variability coefficient, which is a measure of the relative differentiation of water needs of grapevines, were recorded in Lubusz Province in May (21.0%) and October (14.1%), as well as in the West Pomeranian and Lower Silesian provinces in October (13.1% and 12.8%, respectively). In all considered provinces, the lowest relative differences in water needs of grapevines occurred in August (from 4.5% to 5.5%). Generally, the highest variability of the water needs of grapevines was recorded in Lubusz Province, where the standard deviation and variability coefficient during the growing period—i.e., from May to October—were 19.8 mm and 4.6%, respectively, and during the irrigation period—i.e., from June to August—amounted to 13.9 mm and 4.7%, respectively.

The highest values of the crop evapotranspiration of grapevines, calculated for the period 1981–2010 for the western region of Poland, occurred in West Pomeranian Province, where on average in the growing season (May–October) water needs were 431 mm, in the period of increased water needs (June–August) amounted to 299 mm, and 113 mm in July, when the water needs of plants are usually the highest. In Lower Silesian Province, the lowest crop evapotranspiration values were found, which in May–October amounted to 426 mm, in June–August 293 mm, and in July 110 mm (Table 4).

Table 3. Descriptive characteristics of grapevines water needs in the years 1981–2010 in three examined provinces in western Poland.

Characteristic	Provinces	Months of Growing Season						Periods	
		May	Jun.	Jul.	Aug.	Sep.	Oct.	Jun.–Aug.	May–Oct.
Minimum (mm)	West Pomeranian	39	78	99	92	51	20	281	407
	Lubusz	37	74	88	89	48	20	271	398
	Lower Silesian	37	75	96	89	49	20	270	402
Maximum (mm)	West Pomeranian	53	95	130	111	69	33	323	466
	Lubusz	98	94	133	113	70	36	323	493
	Lower Silesian	51	92	126	113	70	36	319	452
Median (mm)	West Pomeranian	47	85	113	102	59	27	297	433
	Lubusz	46	83	109	103	59	28	294	432
	Lower Silesian	45	83	110	101	59	28	292	427
Standard deviation (mm)	West Pomeranian	3.1	4.1	7.3	4.6	4.1	3.5	11.8	13.5
	Lubusz	10.0	5.0	9.2	5.6	5.4	3.9	13.9	19.8
	Lower Silesian	2.8	4.4	6.7	4.6	4.5	3.6	11.9	12.5
Variability coefficient (%)	West Pomeranian	6.8	4.9	6.5	4.5	7.0	13.1	4.0	3.1
	Lubusz	21.0	6.0	8.4	5.5	9.2	14.1	4.7	4.6
	Lower Silesian	6.2	5.3	6.1	4.6	7.7	12.8	4.1	2.9

Table 4. Water needs (mm) of grapevines in the years 1981–2010 in the provinces of western Poland.

Periods	Provinces		
	West Pomeranian	Lubusz	Lower Silesian
May–October	431	430	426
June–August	299	296	293
July	113	110	110

In all the regions studied, the highest daily water needs of grapevines, above 3.5 mm, were recorded in July (Figure 2). Lower daily water needs of grapevines, between 3.2 and 3.3 mm, occurred in August. The lowest daily water needs were noted in May (about 1.5 mm) and October (about 0.9 m).

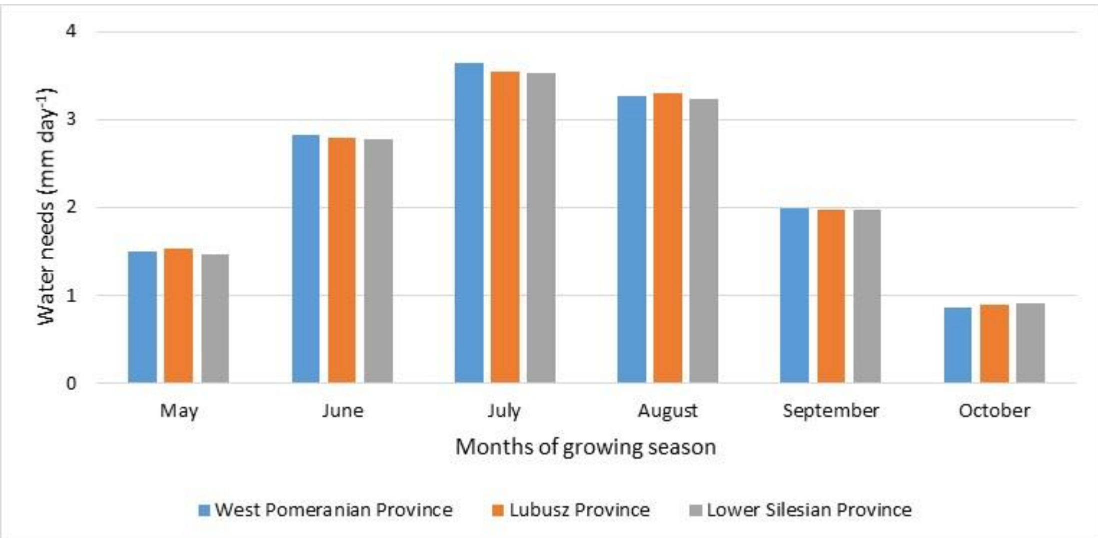

Figure 2. Daily water needs of grapevines in western Poland during the growing season (May–October).

The calculations carried out for the 30-year period (1981–2010) showed that in all the considered provinces of western Poland, there was a clear tendency to increase the water needs of the grapevines in the growing season considered in the period from May to October (Figure 3). The tendency to increase the water needs of the grapevines was also visible in the period from June to August, when the water needs of plants mostly increase (Figure 4) and in July, when the water needs of plants are usually the highest (Figure 5).

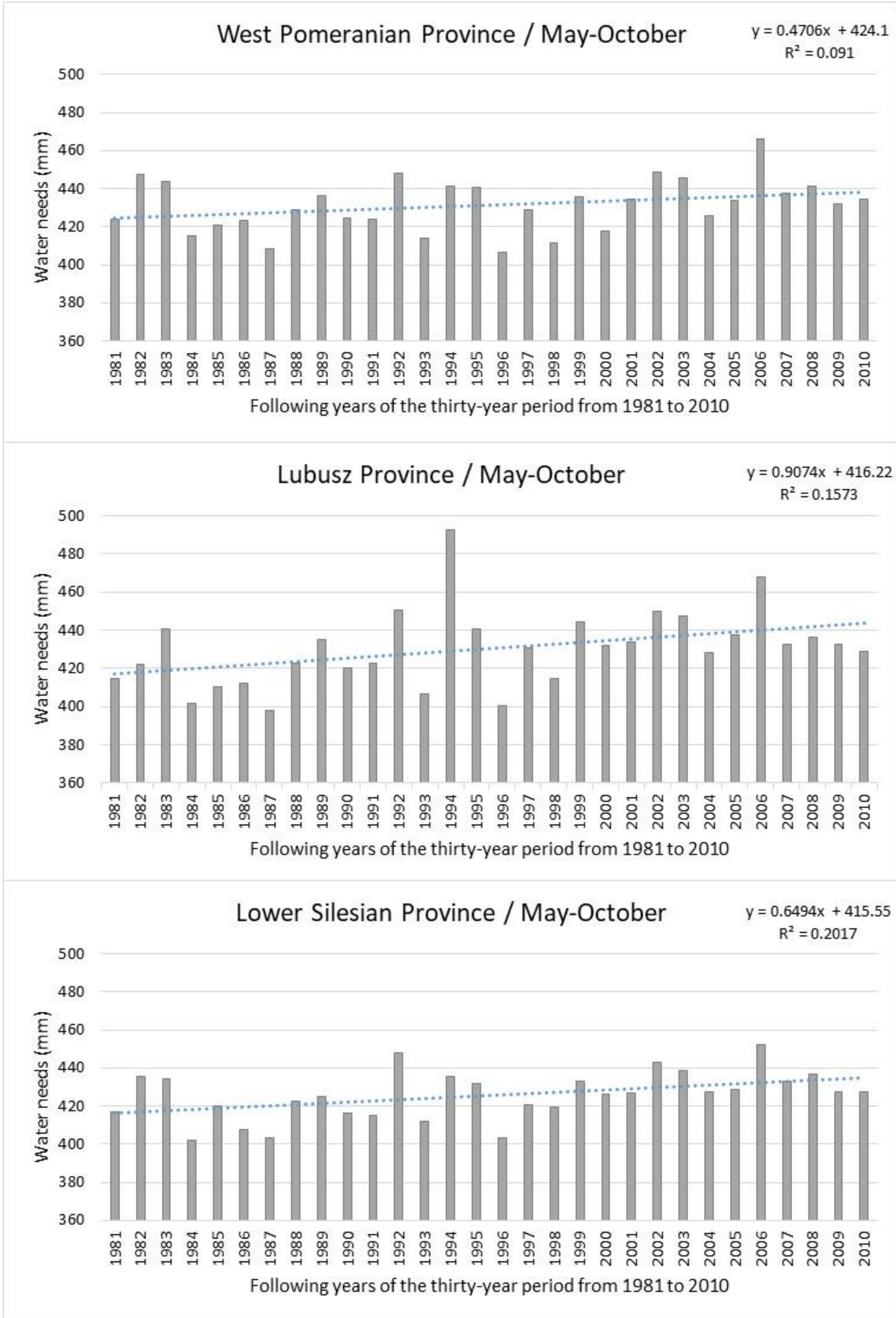

Figure 3. Time trend of water needs of grapevines during the growing season (May–October) in 1981–2010 in the western provinces of Poland.

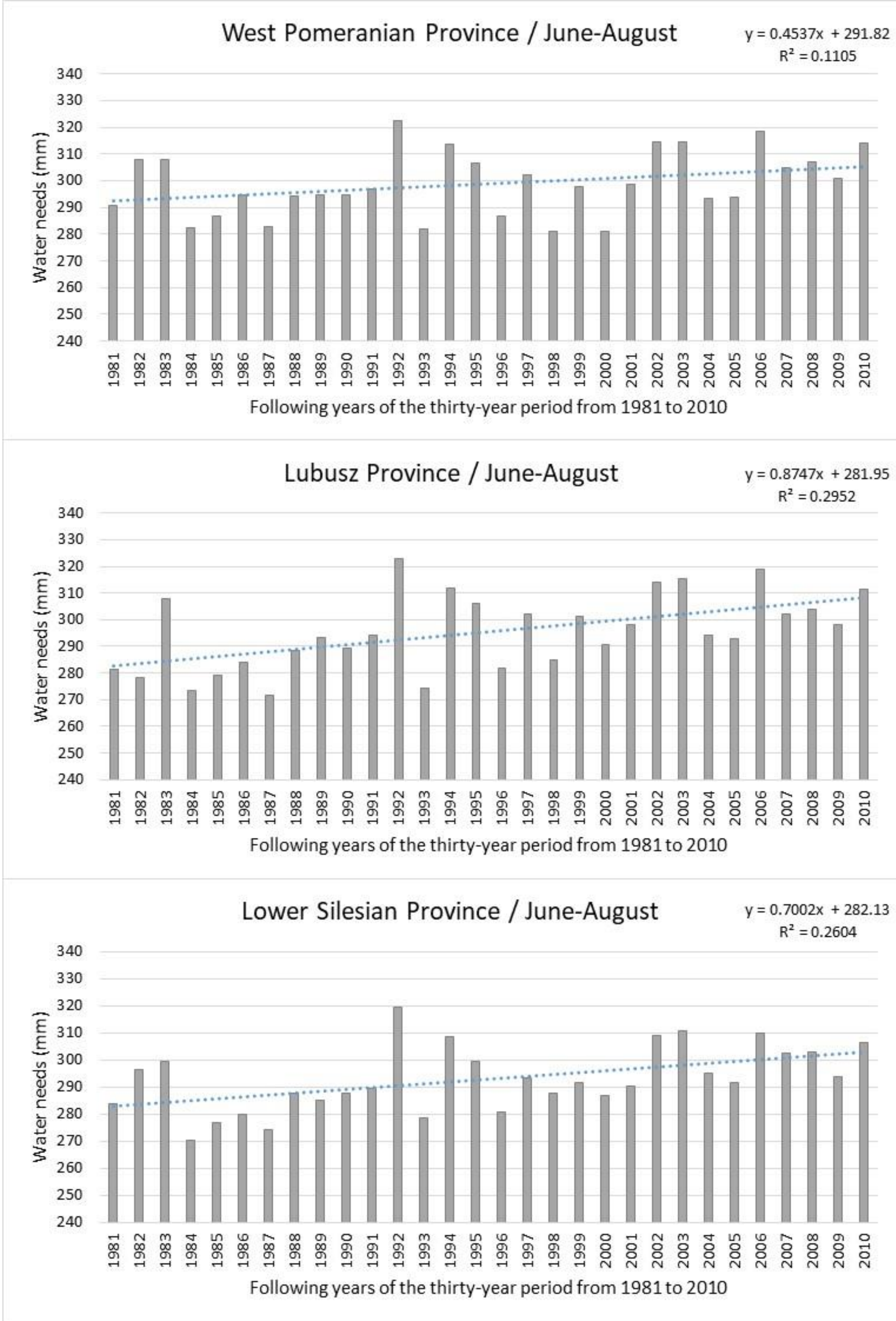

Figure 4. Time trend of water needs of grapevines in the period of increased water needs (June–August) in 1981–2010 in the western provinces of Poland.

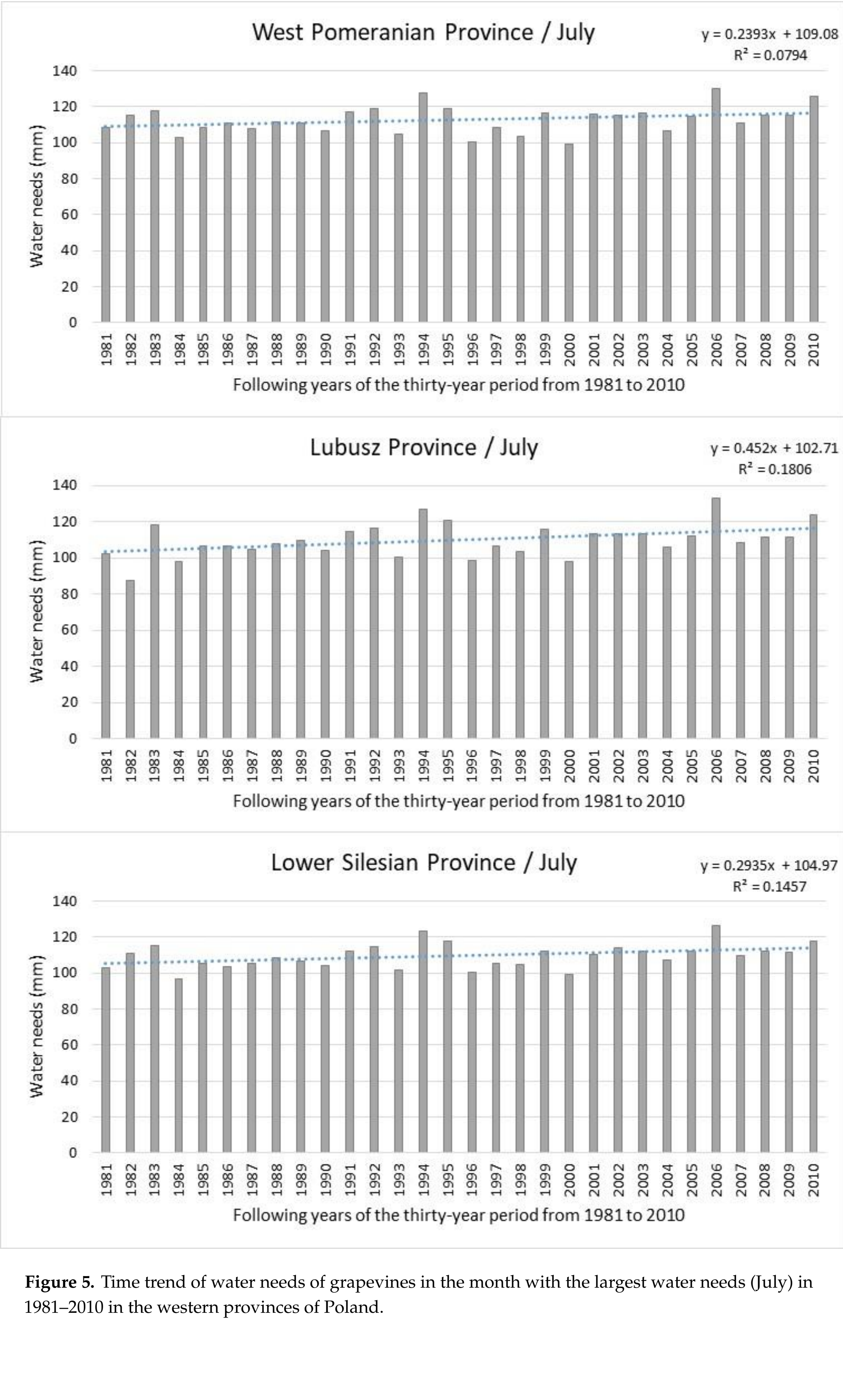

Figure 5. Time trend of water needs of grapevines in the month with the largest water needs (July) in 1981–2010 in the western provinces of Poland.

In general, the highest values of the linear correlation coefficient (*r*) for the trend of time variability of grapevine water needs occurred in the period from June to August (Table 5). The average correlation coefficient during this period was significant in each province, while in Lubusz Province (r = 0.543) and Lower Silesian Province (r = 0.510) significantly higher values were obtained than in West Pomeranian Province (r = 0.332).

Table 5. Water needs (mm) of grapevines in the years 1981–2010 in the provinces of western Poland.

Periods	Provinces		
	West Pomeranian	**Lubusz**	**Lower Silesian**
	Linear correlation coefficient		
May–October	0.302 *ns* [1]	0.397 **	0.449 **
June–August	0.332 *	0.543 ***	0.510 ***
July	0.282 *ns*	0.425 **	0.382 **
	Tendency of water needs (mm·decade^{-1})		
May–October	4.7	9.1	6.5
June–August	4.5	8.7	7.0
July	2.4	4.5	2.9

[1] *ns* = not significant; * = significant at p = 0.1; ** = significant at p = 0.05; *** = significant at p = 0.01.

Based on the analysis of equations for water need trends, it was shown that in each decade of the 30-year period studied, the water needs of grapevines increased most in Lubusz Province, where it amounted to 9.1 mm per decade in the period from May to October, 8.7 mm per decade in the period from June to August and 4.5 mm per decade in July (Table 5). The lowest increase in water needs of grapevines in subsequent decades in the period 1981–2010 was found in West Pomeranian Province, where it was 4.7 mm per decade in May–October, 4.5 mm per decade in June–August and 2.4 mm per decade in July.

The values of rainfall deficits in viticulture in the period of increased water needs—i.e. June–August—and in the month with the highest water needs—i.e., July—were correspondingly lower than in the growing season—i.e., May–October. The largest rainfall deficits during the growing season of the studied thirty-year period occurred in West Pomeranian Province, where in normal years ($N_{50\%}$), medium dry years ($N_{25\%}$) and very dry years ($N_{10\%}$) amounted to: 102, 211 and 287 mm, respectively (Table 6). The lowest rainfall deficits in viticulture, both in the growing season and in the period from June to August occurred in Lower Silesian Province, while in July this occurred in the Lubusz Province.

Table 6. Rainfall deficit (N) of grapevines (mm) in the provinces of western Poland.

Probability of Rainfall Deficit Occurrence	Provinces		
	West Pomeranian	**Lubusz**	**Lower Silesian**
	May–October		
Normal years ($N_{50\%}$)	102	85	74
Medium dry years ($N_{25\%}$)	211	197	187
Very dry years ($N_{10\%}$)	287	275	265
	June–August		
Normal years ($N_{50\%}$)	105	83	76
Medium dry years ($N_{25\%}$)	174	156	148
Very dry years ($N_{10\%}$)	223	206	200
	July		
Normal years ($N_{50\%}$)	46	28	29
Medium dry years ($N_{25\%}$)	70	55	56
Very dry years ($N_{10\%}$)	88	74	75

4. Discussion

In current research, the water needs of grapevines have been determined by the method of crop coefficients (kc), which together with reference evapotranspiration lead to the calculation of potential evapotranspiration. In turn, potential evapotranspiration is widely regarded as a measure of the water needs of a given plant species [17–19]. Due to the lack of crop coefficients determined on the basis of lysimeter tests for grapevines cultivated in the Polish climate, the study used crop coefficients developed by Doorenbos and Pruitt [18]. Crop coefficients reported by Doorenbos and Pruitt [18] were determined for fully developed vineyards, in which the soil cover in the middle of the growing season is from 40% to 50%. Current research assumes that the grapevines are grown in areas with severe frost in winter, where the first leaves appear in early May and the harvest begins in mid-September. Crop coefficients calculated by Doorenbos and Pruitt [18] have been used many times in research conducted in Poland to determine the crop evapotranspiration of fruit species such as apple, cherry, peach, apricot, pear or plum [17].

According to the study of Grzywna et al. [20], the average precipitation in the years 1981–2010 from the 53 meteorological stations in Poland was estimated at 607 mm. The average precipitation in the summer half-year is 63% of the annual total. In the western part of the country it is between 300 mm at Zielona Góra and slightly above 350 mm at Wrocław station. Precipitation in Poland is characterized by high spatial and temporal variability and there is no statistically significant change in precipitation annual totals [20].

An assessment of the water needs of vineyards located in the western provinces of Poland, based on a period of thirty years (1981–2010), showed a clear tendency to increase the water needs of the grapevines, both in the growing season (May–October) and during the period of increased water needs of plants (June–August) and in July, when the water needs of plants are usually the highest. Research published by Rolbiecki et al. [21] showed that in 1981–2010 the water needs of grapevines increased also in other regions of Poland, especially in south-eastern Poland, by as much as 7.6 mm per decade. The increase in water needs of the grapevines in the provinces of western Poland is probably caused by a significant increase in air temperature, which is the result of global warming, observed particularly in the last two decades of the 20th century [22]. According to Sadowski [12], in the 20th century in Poland the air temperature increased even by 0.6–0.7°C.

In the examined western provinces of Poland in the years 1981–2010 within the growing season (May–October), the air temperature increased by 0.2–0.4°C. In July, the temperature increased by 0.6–1.1 °C. The most significant trends were observed in the summer months (June–August) in western and south-western areas (Table 7).

Table 7. Trend equations of air temperature in the growing season of the years 1981–2010 in the provinces of western Poland.

Periods	Provinces		
	West Pomeranian	**Lubusz**	**Lower Silesian**
Linear correlation coefficient			
May–October	0.261 *ns* [1]	0.306 *	0.417 **
June–August	0.335 *	0.550 ***	0.516 ***
July	0.282 *ns*	0.425 **	0.382 **
Tendency of temperature (°C·decade^{-1})			
May–October	0.2	0.4	0.3
June–August	0.4	0.8	0.6
July	0.6	1.1	0.7

[1] *ns* = not significant; * = significant at $p = 0.1$; ** = significant at $p = 0.05$; *** = significant at $p = 0.01$.

The Blaney–Criddle formula for calculating evapotranspiration is based on air temperature (Equation (2)). In the analyzed thirty years in all three regions and all three periods there was always an increase in air temperature (Table 5). Consequently, the water needs of grapevines calculated by the crop coefficient (kc) method with the use of potential evapotranspiration (ETo) according to Blaney–Criddle also increased.

In current research, the reference evapotranspiration is calculated using the Blaney–Criddle formula, in which one of the components was air temperature, which significantly influenced the results of calculations. In a study published by Ziernicka-Wojtaszek and Zawora [23], regarding the relationship between the increase in air temperature and humidity of the upper soil layer, it was shown that in Poland an increase in air temperature by 1.0 °C causes an average monthly rainfall deficit of 6.3 mm. It follows that during the growing season considered from April to October the rainfall deficit is 44 mm, which corresponds to the sum of rainfall in April or October [23]. Research by Żmudzka [24] showed that in the second half of the 20th century, periodic droughts associated with anomalously low precipitation were also caused by the extremely high temperatures recorded at the end of the 20th century. It was found that in the last 10 years of the 20th century in the southwest of Poland a large and very warm area with different humidity levels appeared with a sum of temperature ≥10.0 °C within 3000–3200 °C in a year [23]. This phenomenon indicates the threat of a decrease in agricultural productivity of atmospheric precipitation as a result of an increase in air temperature, despite the lack of clear trends in the decrease in the amount of precipitation [25]. According to a study published by Dzieżyc [26], with an average temperature increase of 1 °C in the period from May to September, the water needs of grapevines increase by an additional 50 mm per year, assuming that about 50% of annual precipitation occurs during the growing season. According to Myśliwiec [11], rainfall is the main source of water for vineyards in Poland. In areas of Poland that are useful for the production of grapevines, annual precipitation should be between 500 and 800 mm. Particularly important in viticulture is the appropriate amount of atmospheric precipitation occurring during the growing season, because the water deficit occurring during this period contributes to the weak growth of shoots and fruits, as well as the drying of shoots and yellowing of leaves. The highest water needs of grapevines occur during the intensive growth of shoots and fruit development, which usually happens in Poland from mid-May to mid-August. In the flowering phase, which falls in June, the grapevines require moderate soil moisture and minimum air humidity, and both deficit and excessive rainfall during this period reduce flowering efficiency [11].

An analysis of the water needs of the grapevines, carried out in this study shows that even in years considered to be normal years ($N_{50\%}$), in which the probability of precipitation deficit occurrence is 50%—i.e., every two years—in all the provinces of western Poland the rainfall deficit was recorded, both during the growing season, as well as in the period from June to August and in July. The presented results justify the need for additional irrigation of vineyards located in western Poland. Irrigation should take place especially in very dry years, in which the rainfall deficit in the period from June to August exceeds 200 mm. Rainfall deficits identified in this study are very helpful and even necessary when designing irrigation systems in vineyards. Taking into account the rainfall deficit calculated for very dry years ($N_{10\%}$) during irrigation programming will guarantee a 90% covering of water needs of the grapevines thanks to supplementary irrigation [17].

Irrigation is a common agrotechnical procedure used in viticulture [27]. Although, sprinkler irrigation in vineyards is sometimes practiced in Poland, the drip irrigation system or the so-called mini-under-crown sprinklers are a much more effective and economical way of irrigating the grapevines [11,28]. Drip irrigation has long been successfully used in Poland in row crops of such fruit species as, for example, strawberry [29], blackcurrant [30], raspberry [31], apple tree [32] or plum and cherry [33]. The positive impact of modern micro-irrigation methods, in particular the drip irrigation system, on grapevines growth and yielding has also been confirmed in numerous studies [27,34–43]. Undoubtedly, the best effects of supplementary irrigation are observed in vineyards located in regions of the world where the climate is drier and warmer than in Poland—for example in

Spain, where grapevines irrigation has led to an increase in yield by as much as 58% [38]. However, according to Polish scientists, the importance of irrigation in Poland in the near future will increase significantly along with the unfavorable climate changes [15,44–48]. At the present in Poland, a temperature increase in the range of 2 to 4 °C should be expected. Climate change scenarios developed for Poland, both until 2050 and 2080, predict a rise in temperature, but only some of the scenarios provide for simultaneous precipitation increase, and there are even models that forecast a decrease in precipitation [15].

Fruits of grapevines in Poland ripen mostly in September. At that time heavy rainfall often occurs, which causes cracking and rotting of the grapes. The rainless weather has a much more favorable effect on the ripening of grapes because it promotes the quality of fruits by accelerating their ripening and additionally improves the process of the wooding of shoots [11]. Therefore, in Poland, to obtain favorable quality parameters of grapevine fruits, it is recommended to finish the irrigation of vineyards 25–30 days before harvest [28]. In the studied provinces of western Poland, the sums of rainfall in September were relatively low compared to the eastern provinces studied by Rolbiecki et al. [21]. In current research, the sum of precipitation in September in the provinces of western Poland ranged from 43 to 45 mm. In the same 30-year period (1981–2010), the sum of precipitation in the eastern provinces of Poland ranged from 51 to 63 mm [21].

It is possible to characterize moisture conditions for vineyards using the dryness index proposed by Tonietto and Carbonneau [49]. This index is widely used for regional climate assessment in grape-growing areas and we plan to use it in our future studies.

5. Conclusions

The observed and forecasted climate changes relate to an increase in air temperature, without a simultaneous rise in precipitation, which leads to an increase in the water needs of plants during the growing season. Already in many countries of the world, maintaining the high productivity of vineyards is associated with the necessity of grapevine irrigation. However, the use of economical and efficient irrigation systems requires knowledge of the water needs of grapevines grown under certain mesoclimatic conditions. Based on the calculations, it was found that the water needs of the grapevines cultivated in the western provinces of Poland gradually increased in each subsequent decade of the studied thirty-year period (1981–2010). The tendency to increase water needs was recorded throughout the growing season; however, the highest values of the linear correlation coefficient for the trend of time variability of water needs occurred from June to August. The water needs and rainfall deficits, estimated in current research, justify the need for the additional irrigation of vineyards in western Poland, which should take place especially in very dry years and from June to August. The result presented in this study will help optimize the design of irrigation systems and vineyard irrigation planning.

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