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Water Needs of the Ash-Leaved Maple (*Acer negundo* L.) at the Period over Three Years after Reclamation in Different Regions of Poland

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ABSTRACT

The ash-leaved maple (*Acer negundo* L.) has low habitat requirements, which is why this species is often used in the reclamation of industrial areas. The development of the reclamation plantings depends on the optimal water soil conditions that can be controlled by watering treatments. However, the use of irrigation requires determining the water needs of the cultivated species. The objective of the study was to evaluate the water needs of the ash-leaved maple in the reclamation plantings, in the period of over three years after planting. The water needs of the ash-leaved maple were determined using the crop coefficients method. Potential evapotranspiration was calculated using the Blaney-Criddle's formula that was modified for the Polish conditions by Żakowicz. The water needs of the ash-leaved maple were assessed for five agro-climatic regions of Poland, in the years 1981-2010. The water needs of the ash-leaved maple in the growing period (April-October) were the highest in the C-E (638 mm) and C-N-W (637 mm) regions, and the lowest in the N-E (598 mm) and S-E (601 mm) regions. In July, the highest water needs were noted in the C-N-W region (149 mm) and the lowest in the S-W region (129 mm). In the studied thirty-years period, there was a significant upward trend in the water needs of the ash-leaved maple both during the growing season (except for the C-N-W region) and in July, in all the considered regions.

Keywords: irrigation, potential evapotranspiration, rainfall deficiencies, water requirements

INTRODUCTION

One of the basic reclamation treatments is the introduction of many different plant species, including trees and shrubs, which create a suitable landscape and microclimate on the reclaimed areas. The ash-leaved maple (*Acer negundo* L.) is the most popular alien species of maple in Poland

[Danielewicz and Wiatrowska 2014]. Easy reproduction and cultivation of the ash-leaved maple make it is common for use in the tree plantings, especially along the roads, in the neighborhood of water, in villages, cities and parks as well in the reclamation of industrial areas as the screen plants. The plant development on the reclaimed areas depends on the optimal water soil conditions, which in turn can be controlled by properly operated watering treatments [Żakowicz 2010]. However, the designing of irrigation system requires firstly the determination of the water needs of the cultivated species.

The aim of the presented research was to calculate the water needs of the ash-leaved maple in the reclamation plantings, over the period of three years after planting.

MATERIAL AND METHODS

The water needs of the ash-leaved maple (*Acer negundo* L.) in the period of over three years after reclamation were determined using the crop coefficients method. Potential evapotranspiration was calculated using the Blaney-Criddle's formula that was modified for the Polish conditions by Żakowicz [2010]. The water needs of the ash-leaved maple in the years 1981-2010 were assessed for five agro-climatic regions of Poland [Łabędzki et al. 2013] with the representative meteorological stations located in Olsztyn, Bydgoszcz, Warszawa, Wrocław and Kraków (Fig. 1). The rainfall deficiencies with the probability of occurrence ($N_{50\%}$, $N_{25\%}$ and $N_{10\%}$) were determined by the Ostromęcki's method [Żakowicz et al. 2009].

RESULTS

The variability related to the water needs of the ash-leaved maple in the period of April-October, expressed by the variability coefficient, ranged from 2.7% (C-N-W region) to 2.9% (S-W and S-E regions) (Tab. 1). In the month with the greatest water needs – July – the variability coefficient value ranged from 5.5% (S-E region) to 6.4% (C-N-W region).

In all the studied regions, a tendency to increase the water needs of the ash-leaved maple during the growing season (IV-X) in the

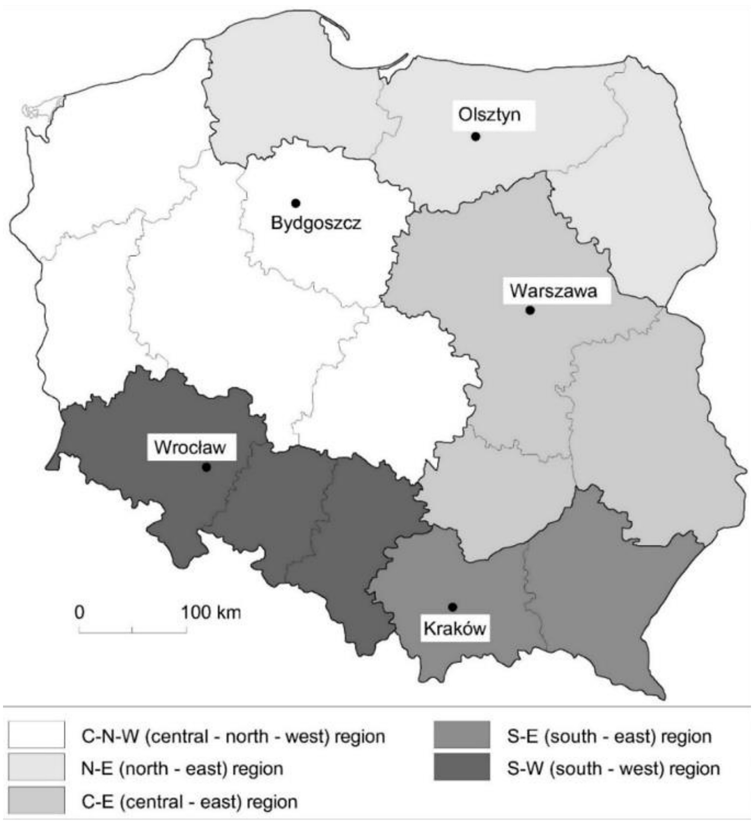

Figure 1. Agro-climatic regions of Poland with the representative meteorological stations [according to Łabędzki et al. 2013]

considered thirty-years period (1981-2010) was observed (Fig. 2). It should be noted that the trend of temporal variability of the ash-leaved maple water needs was significant for each studied region. The weakest relation (for α = 0.1 or p = 90%) occurred in the C-N-W region. In other considered regions, the significance was much stronger (for α = 0.01 or p = 99%).

In each ten-year period of the studied thirty-years, the water needs of the ash-leaved maple increased in the time from April 1 to October 31, in the range from 6.7 mm (C-N-W region) to 11.4 mm (S-E region). On average, in the years 1981-2010, considered for the five studied regions, covering all of Poland, the water needs of the ash-leaved maple during the growing season (April-October) increased by 10 mm in each ten-years period.

The highest water needs of the ash-leaved maple in the growing season, on average in the years 1981-2010, occurred in the C-E (638 mm) and C-N-W (637 mm) regions, and the smallest in the N-E (598 mm) and S-E (601 mm) regions. (Fig. 3). A similar relationship was noted in July – the month with the largest water needs during the growing season – then the highest monthly water needs of the ash-leaved maple were observed in the C-N-W region (149 mm), and the lowest in the S-W region (129 mm).

In all studied regions of Poland, a tendency to increase the water needs of the ash-leaved maple in July was observed (Fig. 4). In all considered regions, with the exception of the C-N-W region, a significant the trend of temporal variability of ash-leaved maple water needs was noted.

In each ten-year period of the considered thirty-years, in July, the water needs of the ash-leaved maple significantly increased, in the range from 3.4 mm (S-W region) to 4.4 mm (C-E region). A non-significant trend of temporal variability of the ash-leaved maple water needs in the C-N-W region was 2.6 mm. On average, in the years 1981-2010 considered for the five studied regions, covering all of Poland, in July, the water needs of the ash-leaved maple increased by 3.8 mm in each ten-year period.

Rainfall deficiencies in the summer half-year (from April 1 to September 30) as well in July,

Table 1. Water needs of the ash-leaved maple during the vegetation period

Specification	Region of Poland	April-October	July
Minimum (mm)	north-east (N-E)	557.2	127.6
	central-north-west (C-N-W)	597.5	132.8
	central-east (C-E)	596.8	130.1
	south-west (S-W)	595.6	113.5
	south-east (S-E)	571.1	120.9
Maximum (mm)	north-east (N-E)	636.9	160.1
	central-north-west (C-N-W)	673.3	171.6
	central-east (C-E)	679.0	170.3
	south-west (S-W)	667.1	148.7
	south-east (S-E)	631.2	152.2
Median (mm)	north-east (N-E)	602.0	143.3
	central-north-west (C-N-W)	636.9	150.1
	central-east (C-E)	636.4	148.0
	south-west (S-W)	631.0	129.4
	south-east (S-E)	603.1	138.7
SD (mm)	north-east (N-E)	17.0	8.7
	central-north-west (C-N-W)	17.5	9.6
	central-east (C-E)	17.9	9.0
	south-west (S-W)	18.2	7.8
	south-east (S-E)	17.6	7.6
VC (%)	north-east (N-E)	2.8	6.1
	central-north-west (C-N-W)	2.7	6.4
	central-east (C-E)	2.8	6.1
	south-west (S-W)	2.9	6.1
	south-east (S-E)	2.9	5.5

Explanations: SD – standard deviation, VC – variability coefficient

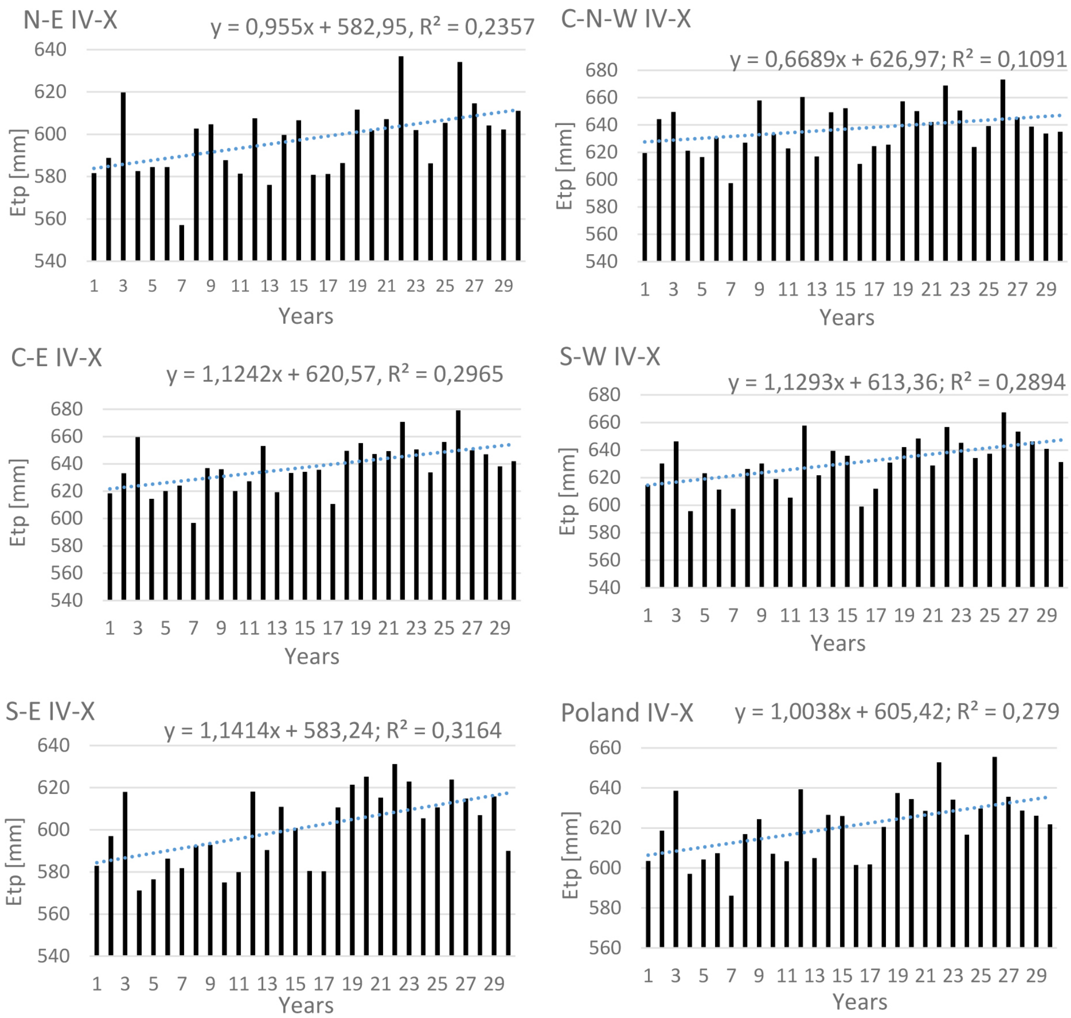

Figure 2. Temporal variability of the ash-leaved maple water needs in the period of April-October at the stage over three years after reclamation in the different regions of Poland

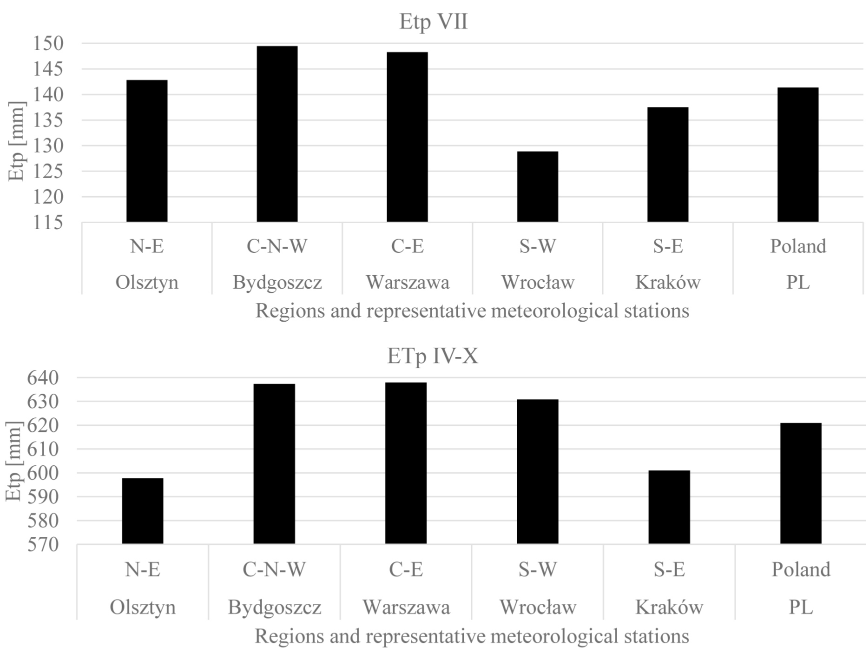

Figure 3. Water needs (ETp) of the ash-leaved maple in the growing period (April-October) and in July observed in the different regions of Poland

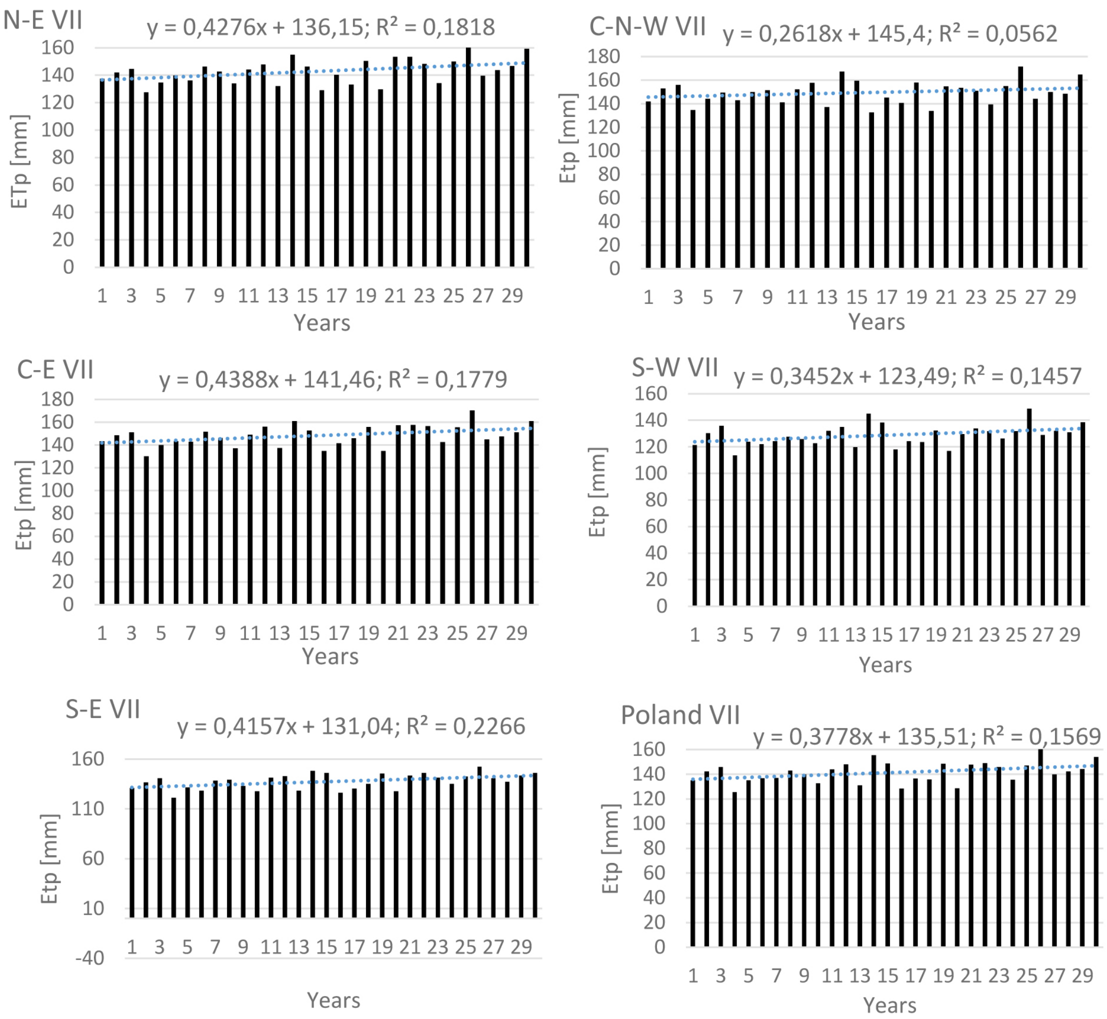

Figure 4. Temporal variability of ash-leaved maple water needs in July at the period over three years after reclamation observed in the different regions of Poland

are presented (Table 2). October was omitted, because of excess rainfall (from 5 to 16 mm) noted in this month in the N-E and S-E regions. In the other studied regions, rainfall deficiencies were observed ($N_{50\%}$ in the 5-8 mm range).

In the period of April-September, the highest precipitation deficiencies ($N_{50\%}$ and $N_{25\%}$) were detected in the C-N-W region, where they amounted to 289 mm and 439 mm, respectively. The highest precipitation deficiencies ($N_{10\%}$), in the period of April-September, were noted in the C-E region (576 mm) that according to Żakowicz et al. [2009] covers 90% of the ash-leaved maple water needs. The smallest precipitation deficiencies in the period of April-September occurred in the S-E region, where they amounted to 121 mm, 284 mm and 360 mm for $N_{50\%}$, $N_{25\%}$ and $N_{10\%}$, respectively.

In July, the highest rainfall deficiencies, ranged from 71 mm ($N_{50\%}$) to 168 and 175 mm ($N_{10\%}$), in the C-E and C-N-W regions, respectively, were observed, whereas the lowest – in the range from 49 mm ($N_{50\%}$) to 130 and 136 mm ($N_{10\%}$) were noted in the S-E and S-W regions, respectively,.

DISCUSSION

In all regions of Poland considered in the presented study, during the thirty-year period of 1981-2010, a tendency to increase the water needs of the ash-leaved maple during the growing season was observed. This trend was previously reported by Łabędzki [2009]. It is anticipated that in the near future the observed climate changes will cause an increase in the water needs of plants, including also the reclamation plantings. Therefore, it is necessary to undertake adaptation activities, among which the most effective are irrigation treatments, the importance of which will increase with the forthcoming climate changes [Rolbiecki et al. 2000, Łabędzki 2009, Stachowski 2009, Stachowski and Markiewicz 2011,

Table 2. Rainfall deficiency (N) of the ash-leaved maple in the period over three years after reclamation in the different regions of Poland

Rainfall deficiency (mm)	Region of Poland				
	N-E	C-N-W	C-E	S-W	S-E
April-September					
$N_{50\%}$	200	289	244	238	121
$N_{25\%}$	402	439	426	371	284
$N_{10\%}$	531	534	576	495	360
July					
$N_{50\%}$	69	71	71	49	49
$N_{25\%}$	124	134	127	87	103
$N_{10\%}$	148	175	168	136	130

Żarski et al. 2013, Kuchar et al. 2015, Kuchar et al. 2017, Rolbiecki et al. 2017].

Irrigation is one of the most important melioration techniques that ensure the proper development of the tree and shrub seedlings in plantings and cultivations, among others in forest nurseries and other plantings [Rzekanowski and Pierzgalski 2006, Ptach et al. 2017]. The results obtained in the presented research may be helpful in planning and programming the irrigation treatments of the ash-leaved maple. The results of many experiments carried out in the region of Bydgoszcz indicate a positive effect of irrigation – often observed in the interaction with other melioration (revitalization) methods – on the growth of seedlings of many species of trees, including: the European larch [Klimek et al. 2011], littleleaf linden [Klimek et al. 2013] and paulownia [Ptach et al. 2017].

The usefulness of a micro-irrigation system applied for watering of the ash-leaved maple grown in reclamation plantings was confirmed in field studies reported by Żakowicz [2010] as well Żakowicz and Hewelke [2012]. A positive response of the ash-leaved maple to the irrigation techniques was also presented in the experiments published by Roberts and Schnipke [1987], and Ranney et al. [1990]. High survival rate of the plants introduced into the reclaimed area depends on both the proper selection of the tree or shrub species and the provision of appropriate amounts of water, for example using the irrigation system [Żakowicz 2010, Biniak-Pieróg et al. 2016]. The ash-leaved maple has low habitat requirements, among others; it is resistant to drought [Cerny et al. 2002, Pacewicz et al. 2006, Frączek et al. 2009, Sjöman et al. 2015]. A positive reaction to irrigation may be related to the fact that *Acer negundo* uses shallow soil water (fed by rainfall) throughout the year in differing amounts [White and Smith 2015]. One of water source utilization studies suggested that *Acer negundo* and *Betula nigra* rely significantly on deep ground water sources, supplemented with shallower soil water uptake during the period of June-September [White and Smith 2013].

CONCLUSIONS

1. In the years 1981-2010, during the growing period (April-October), the water needs of the ash-leaved maple in the second stage of reclamation (i.e. in the period of over three years after reclamation) were the highest in the C-E (638 mm) and C-N-W (637 mm) regions, and the lowest in the N-E (598 mm) and S-E (601 mm) regions.
2. In July, the month with the largest water needs during the growing season, the highest monthly water needs of the ash-leaved maple were noted in the C-N-W region (149 mm) and the lowest in the S-W region (129 mm).
3. In the studied thirty-year period, there was observed a significant upward trend in the water needs of the ash-leaved maple both during the growing season (except for the C-N-W region) and in July, in all the considered regions.
4. The highest rainfall deficiencies ($N_{50\%}$ and $N_{25\%}$) during the period of April-September were noted in the C-N-W region, where amounted to 289 and 439 mm, respectively. In the period of April-September, the highest precipitation deficit ($N_{10\%}$) (576 mm) was observed in the C-E region.
5. In July, the rainfall deficiencies were the highest and ranged from 71 mm ($N_{50\%}$) to 168 and 175 mm ($N_{10\%}$) in the C-E and C-N-W regions, respectively, and the lowest in S-E and S-W regions, where they ranged from 49 mm ($N_{50\%}$) to 130 and 136 mm ($N_{10\%}$), respectively.

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