INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

Nr IV/4/2016, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 1745–1754
Komisja Technicznej Infrastruktury Wsi

DOI: http://dx.medra.org/10.14597/infraeco.2016.4.4.131

EFFECT OF THE FORECAST CLIMATE CHANGE ON THE APPLE TREE WATER REQUIREMENTS IN THE BYDGOSZCZ REGION

Stanisław Rolbiecki, Piotr Piszczek
UTP University of Science and Technology in Bydgoszcz

Abstract

The aim of the present research has been an attempt at evaluating the water requirements of apple trees over 2016-2050 in the Bydgoszcz region drawing on the forecast changes in temperature. The paper draws on the forecasting of mean monthly temperature for the Bydgoszcz region in 2011-2050 according to the climate change scenario for Poland SRES: A1B (Bąk, Łabędzki 2014). The water requirements of the apple tree have been determined based on the indispensable precipitation determined by Kemmer and Schulz. The water requirements were calculated for the period January through December and May through September for each year in the 35-year period (2016-2050). The reference period was made up by a 35-year period immediately preceding it (1981-2015). In the 2016-2050 period in the Bydgoszcz region, in the light of the temperature change scenarios, one could expect increased apple-tree water requirements. Determined with the Kemmer and Schulz method, the required annual (January-December) optimal precipitation will increase for the apple tree from 681 mm to 849 mm (by 168 mm, namely by 25 %). The optimal precipitation trend equations show that in the reference period (1981-2015), calculated with the Kemmer and Schulz numbers, the optimal annual precipitation for the apple tree was increasing in each pentad by 5.8-6.3 mm. In the forecast period (2016-2050) the water requirements will increase, however, in each pentad in a much greater range; from 8.5 to 9.6 mm. In the summer period (May-September) determined by Kemmer and Schulz, the optimal precipitation, expressing the water requirements, for the apple tree in 2016-2050 will increase by 84 mm.

Key words: apple tree, water requirements, optimal precipitation, forecast climate change, Bydgoszcz region

INTRODUCTION

Of all the fruit trees grown in Poland, it is the apple tree which is considered the most important species in terms of the economy (Treder, Pacholak 2006, Mika 2010, Treder 2014). According to the authors cited, the apple tree, for optimal growth and yielding, requires annually about 550-750 mm of precipitation. For the apple tree the precipitation time distribution in the vegetation period is essential. In Poland's important orchard-growing regions, located in the central, western and south-western part of the country, precipitation deficits for the apple tree, similarly as for the pear tree, are on average from 120 to 180 mm annually.

Rzekanowski (2009) reports on the greatest water deficits in the central belt of Poland (the Great Valleys Region) and for the apple tree the deficits range from 140 to 171 mm in the vegetation period, which is also due to the fact that in central Poland the mean annual precipitation most often falls within a range from 500 to 550 mm, and in the vegetation period (April-September) – around 320 mm.

Over the recent years numerous temperature and natural precipitation change scenarios for Poland have been developed (Łabędzki 2009). The scenarios, however, differ significantly mostly as compared with the summer period (June-August) since, as Łabędzki (2009) claims, all the models anticipate an increase in temperature and only few – an increase in precipitation, whereas some – even a decrease in precipitation.

Specialists estimate that the forecasted climate change can increase the water requirements of plants (Łabędzki 2009, Rzekanowski et al. 2011); hence a question about the amount of the increase, in the light of the forecast climate changes, in the water requirements of the apple tree.

The present research has been an attempt at evaluating the water requirements of the apple tree in the 2016-2050 period in the Bydgoszcz region based on the forecast temperature changes.

MATERIAL AND METHODS

The paper draws on the forecasting of mean monthly temperature for the Bydgoszcz region in 2011-2050 according to the climate change scenario for

Poland SRES: A1B (Bąk, Łabędzki 2014). The water requirements of the apple tree have been determined based on the indispensable precipitation determined by Kemmer and Schulz (Słowik 1973, Dzieżyc 1988). The authors have considered the optimal annual (January-December) precipitation for fruit trees in average soil (of average compaction) to depend on mean temperature in summer (May-September), yet assuming that at least 50% of precipitation coincides with the period from 1 May to 30 September (Treder, Pacholak 2006). With the table values for the apple tree provided by Dzieżyc (1988), the regression equation was determined (Figure 1). Then the water requirements were calculated for the period January through December and May through September for each year in the 35-year period (2016-2050). The reference period was made up by a 35-year period immediately preceding it (1981-2015). Each of the two 35-year periods was divided into seven pentads for which optimal mean total precipitation values were determined. There were also defined trends for the apple-tree-optimal precipitation time variation in successive 35 years (n=35) or 7 five-year periods (n=7). Excel spreadsheet was used.

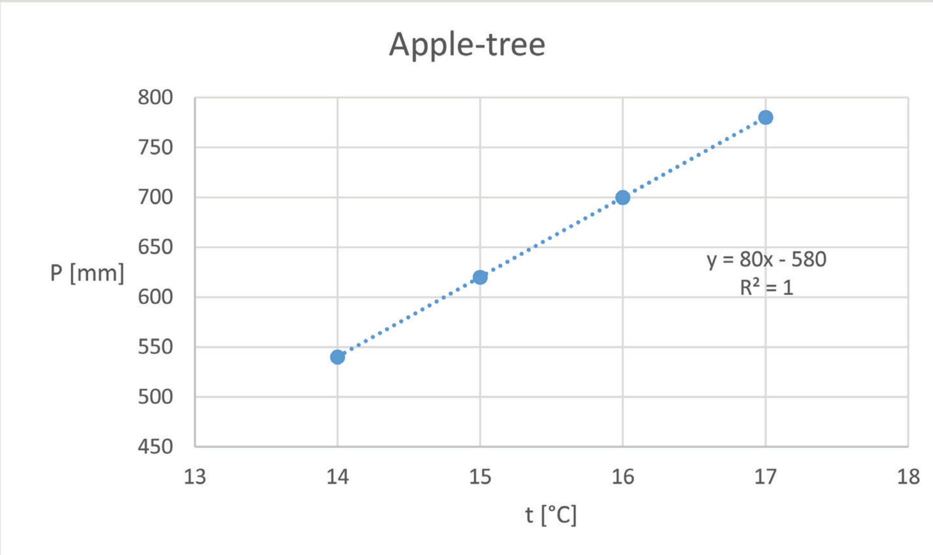

Figure 1. Relation between the mean temperature in summer (May-September) and optimal annual precipitation for apple-trees according to Kemmer and Schulz in a soil of average compaction. The own elaboration on the base of the table values for the apple tree provided by Dzieżyc (1988)

RESULTS AND DISCUSSION

The water requirements of the apple tree, expressed as the optimal annual precipitation according to Kemmer and Schulz, based on the 2016-2050 forecast temperature values, show a greater variation, as compared with the reference period (1981-2015) (Table 1). The range of precipitation variation, respectively for the 35-year periods, was 658-1066 mm and 558-874 mm, and the value of the coefficient of variation – 12.9 and 9.9 %.

Table 1. Statistical characteristics of the apple-tree-optimal annual precipitation

Specification	Period	
	1981-2015	2016-2050
Minimum (mm)	558	658
Maximum (mm)	874	1066
Median (mm)	689	850
Average (mm)	681	849
Standard deviation (mm)	67.8	110.1
Variation coefficient (%)	9.9	12.9

The trend equations for the precipitation optimal for the apple tree (Table 2, Figure 2, Figure 3) demonstrate that in the reference period (1981-2015) the optimal annual precipitation was increasing in each pentad by 5.8 mm, whereas in the forecast period (2016-2050) it will be increasing in an even greater range, by 9.6 mm, respectively.

Table 2. Equations of the trend of the apple-tree-optimal annual precipitation in consecutive years

Period	Equations of the trend	R^2	Tendency of the apple-tree-optimal annual precipitation ($mm \cdot pentad^{-1}$)
1981-2015	y = 1.1706x + 660.32	0.031	5.8
2016-2050	y = 1.9213x + 814.72	0.032	9.6

A comparison of the optimal mean (for successive pentads) annual precipitation in the 35-year periods shows that the optimal mean annual precipitation is higher in each pentad of the 2016-2050 period, as compared with the reference period (1981-2015) (Table 3). The lowest mean annual precipitation of 803 mm (the 2031-2035 pentad) of the forecast period (2016-2050) is higher than the highest mean precipitation (710 mm) reported in the 2011-2015 pentad of the reference period (1981-2015).

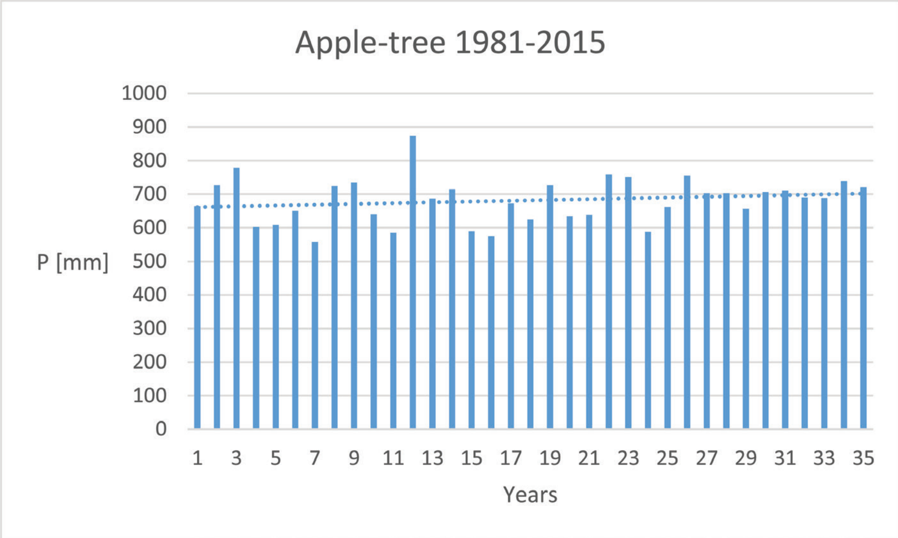

Figure 2. Temporal variability of the apple-tree-optimal annual precipitation in consecutive years of the reference period 1981-2015

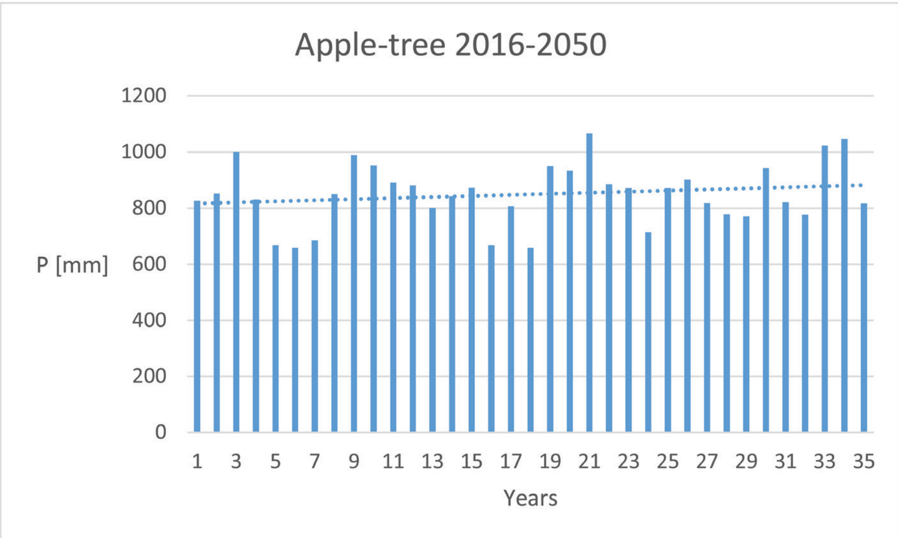

Figure 3. Temporal variability of the apple-tree-optimal annual precipitation in consecutive years of the forecasted period 2016-2050

Table 3. The apple-tree-optimal annual precipitation according to Kemmer and Schulz in consecutive pentads for the compared periods (mm)

Reference period 1981-2015		Forecasted period 2016-2050	
Pentad	P (mm)	Pentad	P (mm)
1981-1985	676	2016-2020	836
1986-1990	662	2021-2025	827
1991-1995	690	2026-2030	858
1996-2000	647	2031-2035	803
2001-2005	680	2036-2040	882
2006-2010	705	2041-2045	842
2011-2015	710	2046-2050	897
Average for 1981-2015	681	Average for 2016-2050	849

The trend equations for the precipitation optimal for the apple tree in successive pentads (Table 4, Figure 4, Figure 5) identify that in the reference period (1981-2015) the optimal annual precipitation was increasing in each pentad by 6.3 mm, whereas in the forecast period (2016-2050) the value of the water requirements of plants will be increasing in each pentad by 8.5 mm.

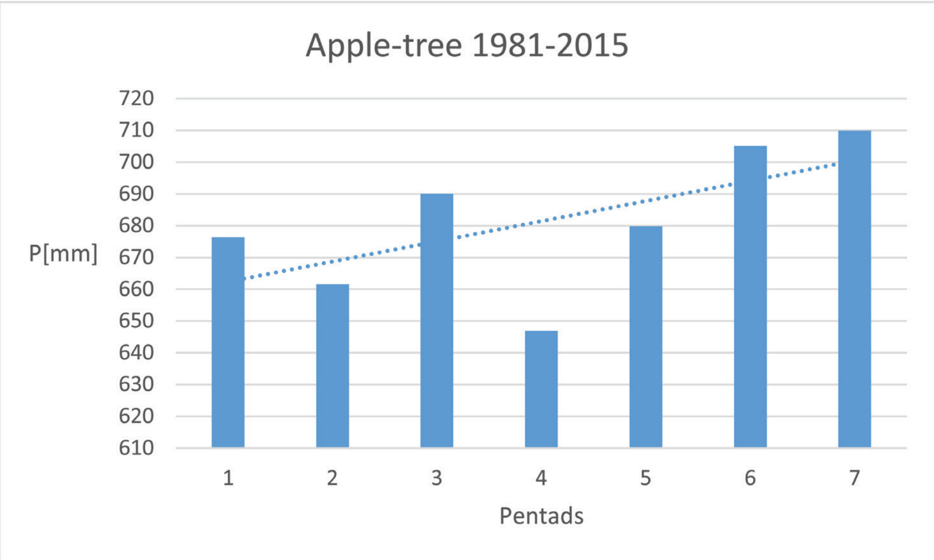

Figure 4. Temporal variability of the apple-tree-optimal annual precipitation in consecutive pentads of the reference period 1981-2015

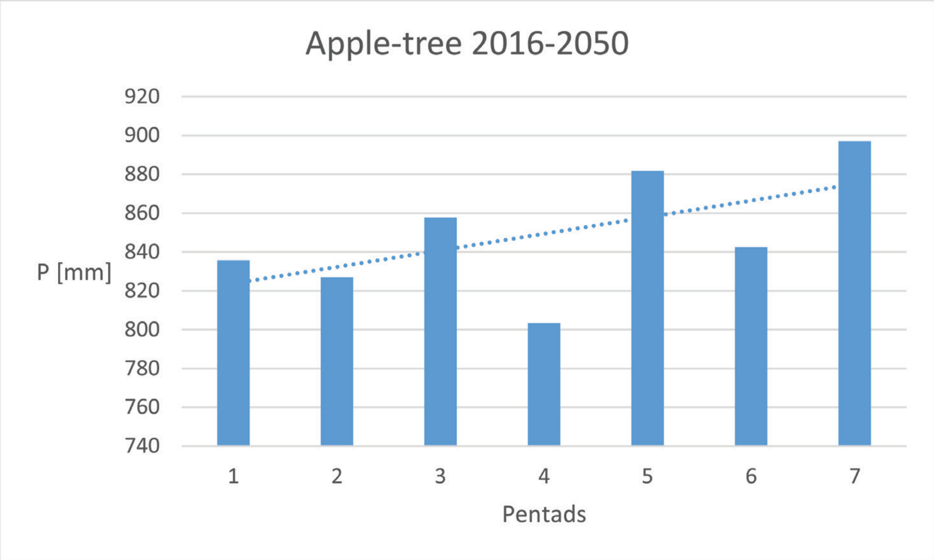

Figure 5. Temporal variability of the apple-tree-optimal annual precipitation in consecutive pentads of the forecasted period 2016-2050

Table 4. Equations of the trend of the apple-tree-optimal annual precipitation in consecutive pentads of compared periods

Period	Equations of the trend	R^2	Tendency of the apple-tree-optimal annual precipitation ($mm \cdot pentad^{-1}$)
1981-2015	y = 6.3429x + 656.02	0.3677	6.3
2016-2050	y = 8.5371x + 815.15	0.3265	8.5

In the experiment performed by Rzekanowski (1989) the water requirements of the apple tree determined as the optimal annual precipitation according to Kemmer and Schulz, mean for 5 research years, was 636 mm, ranging from 591 mm to 698 mm.

A comparison of mean (for 35 years) annual precipitation optimal for the apple tree in the periods shows that, according to the forecast temperature changes, the water requirements of the apple tree will increase from 681 mm to 849 mm (Table 5). It means that the apple-tree water requirements, expressed as the optimal annual precipitation according to Kemmer and Schulz, will increase by 168 mm, namely by 25 %. According to the assumptions by Kemmer and Schulz, the apple-tree water requirements from May through September will increase by 84 mm, respectively.

Table 5. Comparison of the optimal mean precipitation for the apple tree according to Kemmer and Schulz for the compared periods (mm)

Period	January-December	May-September
1981-2015	681	340
2016-2050	849	424
(2016-2050) – (1981-2015)	+ 168	+84
Change (%)	+ 25	

The increase in the water requirements of the apple tree can be due to the forecast increase in temperature. Bąk and Łabędzki (2014) report on the highest increase in temperature in the 2011-2050 period being anticipated in July and August. The increase, as compared with the reference period (1971-2000), respectively for those months, will be 1.5°C and 1.2°C.

The forecasted climate change (manifested by e.g. increased temperature) will definitely speed up an irrigation development in Poland, which mostly refers to modern water – and energy-saving irrigation systems; drip irrigation or under-crown mini sprinkling (under-crown irrigation) recommended for orchards (Łabędzki 2009, Rzekanowski et al. 2011, Treder, Pacholak 2006). The localized irrigation systems increase the apple-tree orchard production effects (Treder, Pacholak 2006, Rzekanowski, Rolbiecki 2000, Rzekanowski et al. 2001, Rzekanowski 2012). For example, the mean (18-year) apple yield increase on the Agricultural and Orchard-Growing Experiment Farm at Przybroda, depending on the weather conditions and experimental factors, ranged from 1.3 to 58.2% (Treder, Pacholak 2006).

RECAPITULATION AND CONCLUSIONS

With the assumptions (temperature change forecasts) and the calculations and analyses made, the following conclusions can be developed:

1. In the 2016-2050 period in the Bydgoszcz region, in the light of the temperature change scenarios, one could expect increased apple-tree water requirements. Determined with the Kemmer and Schulz method, the required annual (January-December) optimal precipitation will increase for the apple tree from 681 mm to 849 mm (by 168 mm, namely by 25 %).

2. The optimal precipitation trend equations show that in the reference period (1981-2015), calculated with the Kemmer and Schulz numbers, the optimal annual precipitation for the apple tree was increasing in each pentad by 5.8-6.3 mm. In the forecast period (2016-2050) the water requirements will increase, however, in each pentad in a much greater range; from 8.5 to 9.6 mm.
3. In the summer period (May-September) determined by Kemmer and Schulz, the optimal precipitation, expressing the water requirements, for the apple tree in 2016-2050 will increase by 84 mm.

REFERENCES

Bąk B., Łabędzki L. 2014. *Thermal conditions in Bydgoszcz region in growing seasons 2011–2050 in view of expected climate change*. Journal of Water and Land Development 23: 2014, p. 21–29.

Dzieżyc J. 1988. *Rolnictwo w warunkach nawadniania*. PWN Warszawa, 1988, p. 1-415.

Łabędzki L. 2009. *Przewidywane zmiany klimatyczne a rozwój nawodnień w Polsce*. Infrastruktura i Ekologia Terenów Wiejskich 3: 2009, p. 7-18.

Mika A. 2010. *Sad dochodowy*. Hortpress Warszawa, 2010, p. 1-307.

Rzekanowski Cz. 1989. *Wpływ nawadniania kroplowego na plonowanie najważniejszych gatunków drzew owocowych w warunkach sadu produkcyjnego*. Zeszyty Naukowe ATR w Bydgoszczy, Rozprawy 35: 1989, p. 1-79.

Rzekanowski Cz. 2009. *Kształtowanie się potrzeb nawodnieniowych roślin sadowniczych w Polsce*. Infrastruktura i Ekologia Terenów Wiejskich 3: 2009, p. 19-27.

Rzekanowski Cz. 2012. *Technologia nawadniania roślin sadowniczych w Polsce. Potrzeby, zasady i metody sterowania*. W: Inżynieria i ochrona środowiska (monogr. pod red. M. Granopsa). Wyd. UTP, Bydgoszcz, 2012, p. 130-147.

Rzekanowski Cz., Rolbiecki St. 2000. *The influence of drip irrigation on yields of some cultivars of apple trees in central Poland under different rainfall conditions during the vegetation season*. Acta Horticulturae 537, Vol. 2: 2000, p. 929-936.

Rzekanowski Cz., Rolbiecki St., Żarski J. 2001. *Potrzeby wodne i efekty produkcyjne stosowania mikronawodnień w uprawie roślin sadowniczych w rejonie Bydgoszczy*. Zeszyty Problemowe Postępów Nauk Rolniczych 478: 2001, p. 313-325.

Rzekanowski C., Żarski J., Rolbiecki St. 2011. *Potrzeby, efekty i perspektywy nawadniania roślin na obszarach szczególnie deficytowych w wodę*. Postępy Nauk Rolniczych 1: 2011, p. 51-63.

Słowik K. 1973. *Deszczowanie roślin sadowniczych*. PWRiL Warszawa, 1973, p. 1-129.

Treder W. 2014. *Nawadnianie*. W: Metodyka integrowanej produkcji jabłek (pr. zbior. pod red. J. Mocheckiego), PIORIN Warszawa, 2014, p. 15-17.

Treder W., Pacholak E. 2006. *Nawadnianie roślin sadowniczych*. W: Nawadnianie roślin (pr. zbior. pod red. S. Karczmarczyka i L. Nowaka), PWRiL Poznań, p. 333-365.

Prof. dr hab. Stanisław Rolbiecki
Department of Land Melioration and Agrometeorology
UTP University of Science and Technology in Bydgoszcz
6 Bernardyńska St., 85-029 Bydgoszcz
e-mail: rolbs@utp.edu.pl

Doc. dr Piotr Piszczek
Department of Ornamental Plants and Vegetable Crops
UTP University of Science and Technology in Bydgoszcz
Bernardyńska 6, 85-029 Bydgoszcz
e-mail: ppisz@utp.edu.pl

Received: 19.11.2016
Accepted: 02.12.2016