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WATER AND IRRIGATION REQUIREMENTS OF FIELD CROPS GROWN IN CENTRAL VOJVODINA, SERBIA

ABSTRACT

Amount and distribution of precipitation and mean daily air temperatures were analyzed in the period of 30 years (1987-2016) in Bački Petrovac, situated in the vicinity of Novi Sad, central Vojvodina. Increase in mean daily air temperatures was recorded during the whole vegetation period, 5.7% on average compared to the previous period (1948-1990). According to the water balance used as the basis for drought estimation, regular and increased deficit in plant-available water was observed mainly in July and August, despite the recorded sum of precipitation equal to or slightly higher than the previously obtained average. High oscillations of field crop yields, mainly due to different weather conditions in specific growing seasons, had been observed across the growing years. Average yields recorded in the period 2006-2014 for most significant field crops - maize, sugar beet, sunflower and soybean, were higher compared to the previous period by 2.16%, 17.81%, 19.39% and 38.71%, respectively. Average yields in Republic of Serbia were as follows: maize 5.19 t ha^{-1}, sugar beet 46.42t ha^{-1}, sunflower 2.34t ha^{-1}, and soybean 2.58t ha^{-1}. The yields varied between 12.09% and 24.49%. Analyzed meteorological data indicate the need for irrigation, which would maintain and improve soil fertility, regulate soil water and nutrient regime, and thus provide the basis for a more successful plant production.

Keywords: air temperatures, drought, plant water requirements, precipitation, water deficit, yield.

INTRODUCTION

Climate, soil and yield are inextricably intertwined in natural environments and should therefore be adjusted in order to produce profitable, high-quality food.

The success of plant production is affected by many factors which vary from one to the other production season. Some of them can be altered using genetics, breeding, selection, cultivar classification (Pavićević, 1976; Dragović, 1997; Popović et al., 2015a, 2015b, 2016a, 2016b; Živanović et al., 2017) or by applying various cultivation practices in production technology. Soil quality can

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also be improved by applying soil management practices, such as fertilization, organic matter introduction, soil tillage, a melioration, drainage, irrigation, and so on. Weather conditions, which is the most important factor of successful plant production, can be least altered.

It is necessary to monitor and analyze all the parameters in the process of plant production so as to observe the negative trends which could adversely affect the stability and quality of production. In such case, cultivation practices should be applied in order to halt or slow the negative processes and thereby maintain or improve plant production.

Agro-meteorological research are mainly related to: studies and estimations of changes in agro-climatic potential based on climate change and oscillations; studies of meteorological occurrences causing significant damage in agriculture in order to decrease their negative effects; improvement of operative agro-meteorology, especially the introduction of crop/time and time/plant disease models into practice in order to increase the quality of agro-meteorological analyses and forecasts; trial performance at lysimeter stations, etc (http://www.hidmet.gov.rs/latin/meteorologija/agro.php).

Great damage caused by drought in different industrial sectors (agriculture, water treatment and energy industry, etc) causes the need to take suitable precautions in order to reduce drought risks and related negative effects. Each plan to combat drought has three main components: monitoring and early announcement, estimating risks and reducing the negative effects. Permanent monitoring of all relevant parameters (temperatures, precipitation, insulation, wind, evapotranspiration, soil moisture, groundwater level etc.) is necessary, as it enables timely overview of the first signs of drought occurrence (Spasov, 2003).

The study analyzed climate parameters which significantly affect soil and plant water and nutrient regime, primarily mean daily air temperatures (largely influencing potential evapotranspiration and plant water requirements) and precipitation sum as the main plant water and nutrient source. Serious disturbance in hydrological balance negatively affects soil production capabilities. Mutual effects and relationships between climate parameters, plants and soil, make irrigation necessary as it is a cultivation practice which most successfully regulates plant-available water deficit in plant production.

MATERIAL AND METHODS

The amount and distribution of precipitation and mean daily air temperatures in the 30 year period (1987-2016) were analyzed in Bački Petrovac, near Novi Sad in central Vojvodina (φN 45° 20′, λE 19° 40′, 82 m a.s.l.). Potential evapotranspiration (ETP) i.e. plant water requirements were determined according to the results. Water requirements of the main field crops were calculated according to the biological method by Dragović (Maksimovic and Dragovic, 2002), using changed crop coefficients (i_c) depending on the development stage of the cultivated crop and temperatures (t °C) in a given month, by the equation:

$$ETP = \sum t\ °C \cdot i_c$$

Water balance, the relationship between water gain and water loss, was used in order to analyze the outbreak and intensity of drought. Differences between precipitation (P) and potential evapotranspiration (ETP) were calculated so as to obtain the level of climatic precipitation deficit required for undisturbed plant water supply (P-ETP). Deficit of available water in soil, needed to satisfy water requirements of the most frequently grown crops, also expresses irrigation needs which is the most efficient hydro-ameliorative measure for combat against drought.

RESULTS AND DISCUSSION

Mean daily air temperatures affecting potential evapotranspiration and plant water requirements were analysed for the region of central Vojvodina, as well as precipitation as the main plant water source containing dissolved nutrients. Sum and distribution of precipitation across short periods, years and growing seasons, is of particular importance, especially during the critical phases of plant development.

Analysis of temperature conditions in the air at ground level and moisture conditions (relationships between the amount of precipitation, evapotranspiration, and soil moisture) results in the obtained values of agro-climatic parameters and indexes determining climate conditions in plant production. Values of parameters used for agroclimatic resource estimation are obtained from processing multiannual data sets usually for a vegetation period and its parts. Mean air temperatures of 18.6°C were observed in this area during the vegetation period according to the 30-year data (1987-2016) collected in Bački Petrovac (Tab. 1).

Tab. 1. Mean monthly air temperatures (°C) at weather station Bački Petrovac across the tested periods

Months	Average 1948-1990	1987-1996	1997-2006	2007-2016	Average 1987-2016
April	11.4	11.5	11.9	12.7	12.0
May	16.5	16.6	18.2	18.3	17.7
June	19.6	19.8	21.1	21.4	20.8
July	21.1	22.1	22.3	23.2	22.5
August	20.5	21.5	21.8	22.4	21.9
September	16.7	16.8	16.7	17.3	16.9
Vegetation period	**17.6**	**18.0**	**18.7**	**19.2**	**18.6**

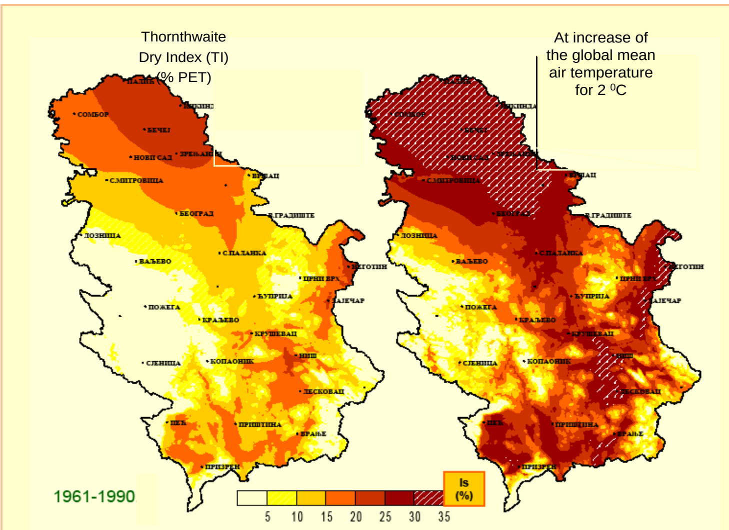
Compared to data from the previous period (1948-1990) obtained in the studies of numerous researchers (Hadžić et al., 1996), increase in mean daily air temperatures is observed in all the months, especially July and August (1.4°C) as well as throughout the whole vegetation period (1.0°C) (Tab. 1).

Evident increase in mean daily air temperatures has been observed in the last few decades, with the warmest period in 2007- 2016 when the recorded air temperature means were 19.2°C (Tab. 1).

Monthly temperature increase, as compared to the previous period 1948-1990, was: April-1.3; May-1.8; June-1.8; July- 2.1; August-1.9 and September 0.6°C. Experts of the Republic Hydrometeorological Institute of Serbia predicted the increase in Thornthwaite drought index (Is=TI) during moisture/drought monitoring in Serbia, due to global increase in mean daily air temperatures by 2°C (http://www.hidmet.gov.rs/podaci/agro/ciril/klipro_agrorhmzs.pdf).

The changes indicate significantly higher deficit of available water in soil (Graph. 1). Plant potential evapotranspiration is also increased by about 20%.

Studying the Thornthwaite precipitation-efficiency index, used to identify the characteristics of arid and humid climate, Selek et al. (2017) found that semi-arid zones in Turkey had significantly expanded (about 14% increase) between the two 30-year periods (1950-1980 and 1981-2010). By using the Thornthwaite precipitiation efficiency index, Li et al. (2016) recorded lower drought intensity in the last 53 years, which indicates certain benefits in the crisis of water use at the territory of Xinjiang in China. Kalaiarasi and Vipulanandan (2010) determined seasonal drought intensity and drought severity through Thornthwaite precipitation-efficiency index with a better correlation with annual precipitation sum than the suction pressure measured in the active zone.



Graph. 1. Thorntwaite dry index increase based on mean daily air temperatures increase by 2°C, 1987-2016

Thornthwait water balance is used to determine the level of precipitation required for evaporation and transpiration. According to Maksimović et al. (2017) potential evapotranspiration (ETP) for central Vojvodina is 744 mm, while real evapotranspiration (ETR) is 562 mm. Water deficit for plant requirements is increased, especially in July and August, despite precipitation sum equal to or slightly higher than the sum in the vegetation period during the previous period of observation (346.5 mm in the previoud compared to 371.4 mm in the last 30 years). Water deficit of 181 mm should be added by irrigation, so as to improve soil water balance and plant nutrient regime. Moreover, it would preserve and improve fertility of arable land, provide better plant nutrient regime as well as stabilize and increase crop yields and their quality (Sikora et al., 2015).

Mean sums of potential evapotranspiration (mm) in Vojvodina according to Penman Monttheith for the period 1971-2000 are connected to temperature conditions (http://www.hidmet.gov.rs/latin/meteorologija/pros_pet.php) and they vary slightly compared to the Novi Sad data, so that the data collected in Bački Petrovac can be considered as the average for Vojvodina due to its close proximity to Novi Sad and less variation of the fundamental climatic condition.

Agronomic sources define drought as insufficient plant water supply from precipitation and other sources i.e. potential evapotranspiration (ETP). Drought can occur as soil, air, and physiological drought, which are interconnected and mutually dependent. Soil drought is highly significant for agriculture as it causes temporary or permanent water deficit, visibly limiting and reducing plant growth and development, decreasing organic matter production and crop yield (Dragović, 1997). Special attention is therefore given to soil water balance in the study, used for determination of water deficit by comparison of plant water requirements and precipitation-derived water gain. The deficit can be mitigated to some extent by the multidisciplinary approach to this issue, although irrigation is the most reliable method of drought combat.

Precipitation sums in the vegetation period are very variable across growing seasons, with much more pronounced fluctuations in the last six years compared to the previous study period. The percentage of precipitation recorded in relation to the multiannual average varies and ranges from 7% in August 2012 to 268% in May 2014 (Graph. 2).

Precipitation means during the vegetation period are higher by an average of 24.2 mm when comparing the periods 1987-2016 and 1948-1990 in central Vojvodina (Tab. 2, Graph. 3).

In the analysis of precipitation periods in 1971-2000, Spasov (2003) observed that precipitation decrease is less expressed in the growing seasons, while decrease in precipitation was not observed on an annual basis. This is a more favourable situation for plant production (Graph. 3) compared to forecasts provided by different hydro-meteorological models, according to which increased air temperatures and decreased precipitation is to be expected in this area, especially during vegetation periods (IPCC, 2007; Lalić et al., 2011).

The main crop water requirements are calculated using the biological method elaborated by Maksimović and Dragović (2002), through changing the plant coefficient (i_c) depending on the development stage of the cultivated crop and temperature conditions (t°C) in a given month, by the equation

$$ETP = \Sigma t°C \cdot i_c.$$

Research by Cipris and Evtushenko (1980), cit. Maksimović and Dragović, 2001) confirm that the changes in biological coefficients, as well as the amount of water during the growth period, is highly correlated with weather conditions. Calculations using the mean values are shown for the central Vojvodina across periods of research (Tab. 3), and in ten year intervals (Tab. 4). The month of April is excluded from calculation since it is the time when plants are sown, sprout or go through initial stages of development, when transpiration is very low.

The highest mean water requirements (ETP) are observed in sugar beet, followed by maize and sunflower, and the lowest in soybeans. Water deficit follows this trend and it is highest in sugar beet (with approximately 50% of sugar beet water requirements during the growing season). All major crops have had increased water requirements during the last thirty years (1987-2016) compared to the previous period of research (1948-1990).

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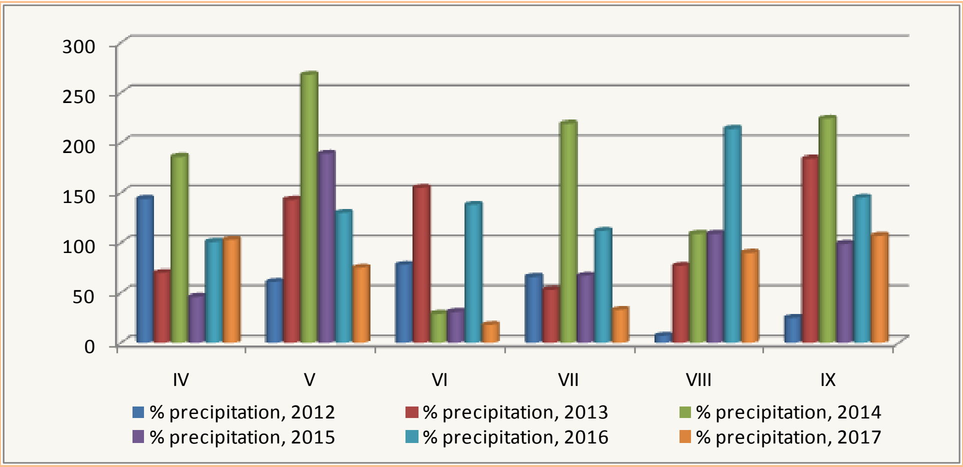
Plant water requirements were constantly increasing during the observed decades (Tab. 4), reaching the amount of 600 mm for sugar beet, 526 mm for maize and sunflower, and 503 mm for soybeans. The values were determined in earlier periods with extremely dry and hot production seasons.

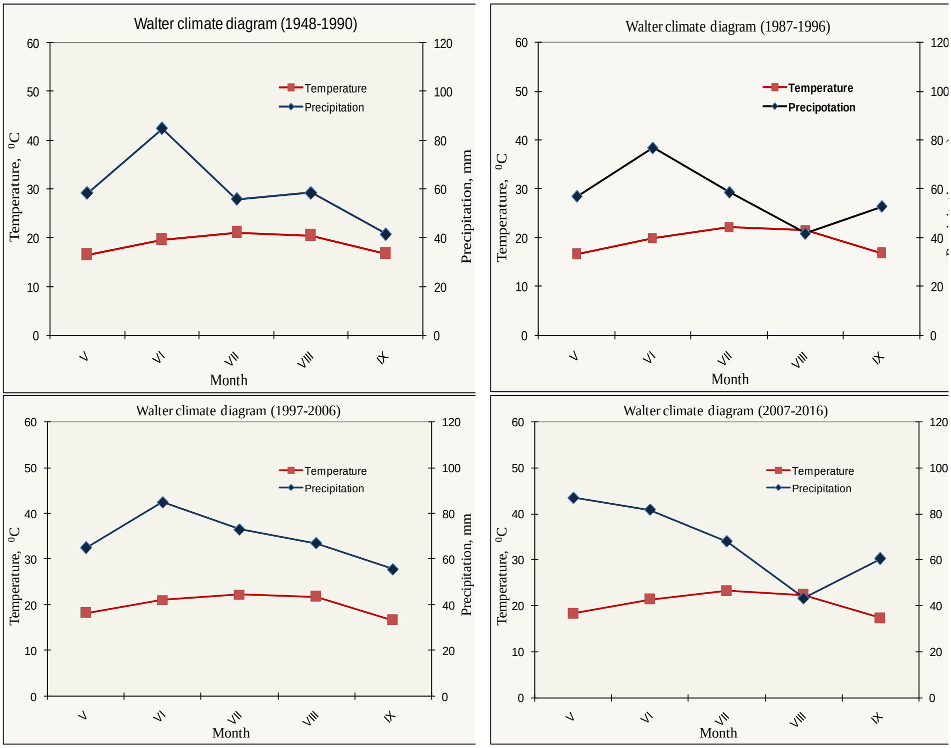
During the summer season (June, July and August), water requirements of most cultivated crops were approximately 100 – 150 mm per month (Tab. 3-4).



Graph. 2. Percentage (%) of precipitation related to the multiannual average (mm) at weather station Bački Petrovac, 2012-2017

Table 2. Total precipitation (mm), Bački Petrovac, Serbia

Months	**Average 1948-1990**	**1987-1996**	**1997-2006**	**2007-2016**	**Average 1987-2016**
April	47.4	44.8	53.7	41.1	46.5
May	58.4	56.8	64.9	87.0	69.6
June	84.9	76.7	84.9	81.8	81.1
July	55.9	58.6	73.0	68.0	66.5
August	58.5	41.7	67.0	43.4	50.7
September	41.5	52.6	55.7	60.4	56.2
Vegetation period	**346.5**	**331.2**	**399.2**	**381.7**	**370.7**



Graph. 3. Walter climate diagram accross study periods, 1948-1990; 1987-1996; 1997-2006; 2007-2016;

Summer deficit of water required for unhindered plant growth and development is very pronounced in central Vojvodina. During the 30 years of study (1987 – 2016) conducted in Bački Petrovac, drought was observed in July and August, (Maksimović et al., 2017) in 83% and 87% of the years, respectively (Tab. 5). Moderately wet to wet conditions were observed in July in 36.6% of the studied years as it is the month with the maximum amount of rain in this area.

Table 3. Field crop water requirements ETP (mm) and water deficit according to water balance in the region of Vojvodina (Bački Petrovac), Serbia

Month	Average		Sugarbeet		Maize and Sunflower		Soybean	
	Tempe-rature	Precipi-tation	ETP	Deficit	ETP	Deficit	ETP	Deficit
1948-1990								
May	16.5	58.4	76.7	18.3	71.6	13.2	56.3	-
June	19.6	84.9	117.6	32.7	94.1	9.2	100.0	15.1
July	21.1	55.9	137.4	81.5	117.7	61.8	117.7	61.8
August	20.5	58.5	127.1	68.6	114.4	55.9	108.0	49.5
September	16.7	41.5	60.1	18.6	60.1	18.6	55.1	13.6
Average	18.9	299.2	518.9	219.7	457.9	158.7	437.1	140.0
1987-2016								
May	17.7	69.6	82.3	12.7	76.8	7.2	60.4	-
June	20.8	81.1	124.8	43.7	99.8	18.7	106.1	25.0
July	22.5	66.5	146.5	80.0	125.6	59.1	125.6	59.1
August	21.9	50.7	135.8	85.1	122.2	71.5	115.4	64.7
September	16.9	56.2	60.5	4.3	60.8	4.6	55.8	-
Average	18.6	324.1	549.9	225.8	485.2	161.1	463.3	148.8

Table 4. Field crop water requirements ETP (mm) and water deficit according to water balance in the region of Vojvodina (Bački Petrovac), Serbia

Month	Average		Sugarbeet		Maize, Sunflower		Soybean	
	Tempe-rature	Precipi-tation	ETP	Deficit	ETP	Deficit	ETP	Deficit
1987-1996								
May	16.6	56.8	77.2	20.4	72.0	15.2	56.6	-
June	19.8	76.7	118.8	42.1	95.0	18.3	101.0	24.3
July	22.1	58.6	143.9	85.3	123.3	64.7	123.3	64.7
August	21.5	41.7	133.3	91.6	120.0	78.3	113.3	71.6
September	16.8	52.6	60.5	7.9	60.5	7.9	55.4	2.8
Average	19.4	286.4	533.7	247.3	470.8	184.4	449.6	163.4
1997-2006								
May	18.2	64.9	84.6	19.7	79.0	14.1	62.1	-
June	21.1	84.9	139.3	54.4	113.9	29.0	120.3	35.4
July	22.3	73.0	145.2	72.2	124.4	51.4	124.4	51.4
August	21.8	67.0	135.2	68.2	121.6	54.6	114.9	47.9
September	16.7	55.7	60.1	4.4	60.1	4.4	55.1	-
Average	20.0	345.5	564.4	218.9	499.0	153.5	476.8	134.7
2007-2016								
May	18.3	87.0	85.1	1.9	79.4	-	62.4	-
June	21.4	81.8	141.2	59.4	115.6	33.8	122.0	40.2
July	23.2	68.0	172.6	90.8	143.8	75.8	143.8	75.8
August	22.4	43.4	138.9	95.5	125.0	81.6	118.0	74.6
September	17.3	60.4	62.3	1.9	62.3	1.9	57.1	-
Average	20.5	340.6	600.1	259.5	526.1	193.1	503.3	190.6

Table 5. Percentage of dry years according to precipitation sum in July and August 1987-2016 in Vojvodina (Bački Petrovac), Serbia

Precipitation sum, mm	July		August		Category
	No.	%	No.	%	
0-25	5	16.7	8	26.7	Extremely dry
26-50	11	36.6	10	33.3	Very dry
51-75	5	16.7	4	13.3	Dry
76-100	4	13.3	4	13.3	Moderately dry
	25	83.3	26	86.6	Dry years - total
101-125	-	-	2	6.7	Moderately humid
>126	5	16.7	2	6.7	Humid
Total	30	100	30	100	

Drought effect on crop production. Variations in precipitation during growing seasons as well as low water balance in soil are the main reasons of low and unstable yields in Vojvodina Province observed in some years of study. Even in shorter periods, precipitation deficit causes water deficit in soil, poor water and nutrient regime of cultivated crops. Previously established lower precipitation decrease in the growing season in Vojvodina still has negative effects on agriculture, considering that most of the Vojvodina surface receives less rainfall compared to other regions in Serbia (Spasov, 2003).

Analyzing the yields of field crops in Vojvodina Province in the period 1965-2003, Bošnjak (2004) reported very low yields of the analyzed crops. The reductions exceeded 50% of the yields that can be obtained by irrigation (Table 6). Dragovic (1999) found that the average yields were much below genetic yield potentials of these crops, which were realized under 50%.

Average yields of all four tested crops in the Republic of Serbia during the period 2006-2014, were higher than in the previous period by 2.16% in maize, 17.81% in sugar beet, 19.39% in sunflower and 38.71% in soybean (Tab. 6).

Table 6. Average yields, extreme yields, and variation coefficient

Crops	Average yield (t ha^{-1})		Yield extremes (t ha^{-1})		CV (%)	
	1965-2003	2006-2014	1965-2003	2006-2014	1965-2003*	2006-2014**
Maize	5.08	5.19	2.26-7.11	3.25-7.51	21.57	24.49
Sugar beet	39.40	46.42	24.71-49.16	35.94-54.71	14.36	12.09
Soybean	1.86	2.58	0.92-7.25	1.73-3.54	27.55	21.14
Sunflower	1.96	2.34	1.39-2.63	1.90-2.90	16.64	14.40
Faostat.org. 2017; *Bošnjak, 2004; **Calculated of authors						

Average maize yields were 5.19 t ha^{-1}, varying from 3.25 to 7.51 t ha^{-1}; sugar beet yields were 46.42 t ha^{-1}, varying from 35.94 to 54.71 t ha^{-1}; sunflower yields were 2.34 t ha^{-1}, varying between 1.90-2.90 t ha^{-1}, while soybean yields were 2.58 t ha^{-1}, varying between 1.73-3.54 t ha^{-1} (Tab. 6). Sugar beet and sunflower yields exhibited the lowest variation (CV=12.09% and CV=14.40%, respectively). The largest variation was recorded in maize (CV=24.49%) and soybean (CV=21.14%) (Tab. 6).

CONCLUSIONS

Amount and distribution of precipitation and mean daily air temperatures were analyzed in the period of 30 years (1987-2016) in Bački Petrovac, situated in the vicinity of Novi Sad, central Vojvodina.

Increase in mean monthly air temperatures by 5.7% was observed during the whole growing period, compared to the earlier period (1948-1990), with oscillations from 1.2% in September to 7.3% in May. As it is a thermal process which depends on the air temperature, potential evapotranspiration (ETP) i.e. water requirements of the main field crops exhibited an increase. According to the results of water balance, as the basis of drought estimation, there was a regular and increased deficit of water needed to satisfy plant water requirements, which was especially notable in July and August, regardless of precipitation sum equal to or slightly higher than precipitation sum recorded during the growing period.

Great oscillations of field crop yields in Vojvodina were observed in the study years, which mainly occurred due to variable weather conditions during the production season.

Compared to the previous study period, average yields of the four crops studied in the period 2006-2014 were higher by 16.2% in maize, 17.81% in sugar beet, 19.39% in sunflower, and 38.71% in soybeans. Average yield of maize, sugar beet, sunflower, and soybean was 19.5 t ha^{-1}, 46.42 t ha^{-1}, 2.34 t ha^{-1}, and 2.58 t ha^{-1}, respectively. Yields ranged from 12.09% to 24.49%.

Meteorological data recorded in central Vojvodina indicate the need for increased irrigation. Irrigation would preserve and improve fertility of agricultural soils and regulate soil water and nutrient regime, which would provide the conditions for a more successful plant production in a positive correlation with the yield of the grain per unit area.

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