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The predicted impact of climate change on maize production in Northern Serbia

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Abstract

The projected climate change is expected to have detrimental impact on agricultural production in Northern Serbia, which imposes the need to develop mitigation strategies that will provide a stable yield and income of growing plants in the coming years. Maize is the most important crop in Serbia which occupies the largest sown area. In the present study, the aim was to determine how the average yield of rainfed maize will change in near future (2001-2030) relative to the present and if the currently or higher irrigation rate can be used as a strategy to mitigate the effect of predicted weather scenario on maize yield. AquaCrop model was calibrated with the data derived from the field experiment with rainfed and irrigated maize (2015-2018) (relative standard error ≤ 5% in rainfed and ≤ 7.3% in the irrigated trial), which was used for the simulation of maize yield. The results of the validation showed very good performance of the model (root mean square error of 0.22 and 0.16 was obtained for rainfed and irrigated maize, respectively). The model predicts the loss of maize yield of 15% with respect to maize yield from the experiment. In the predicted scenario, irrigation with average irrigation rate of 200 mm applied in the region of Northern Serbia is expected to increase the yield of maize by approximately 28%. Increased irrigation rate (250 and 300 mm) will reduce the yield of maize in comparison to the current one, thus the creation of stable maize hybrids with the increased water use efficiency should be considered as a strategy for alleviating climate change effect on maize production in the near future.

Introduction

Agricultural production is one of the most vulnerable components of a climate-changing world. The variability of climate and extreme weather events are expected to have a more deep effect on agriculture in less developed and developing countries as compared with developed states (Stigter, 2010). The impact of climate change on agriculture varies in different parts of the world but also among regions. Even though several researches have been done to assess the impact of future climate changes on crops in various parts of the world (Ahmadi *et al.*, 2015; Raja *et al.*, 2018), the smaller-scale investigations are scarce.Therefore, there is a need for an investigation of the consequences of climate change on a regional scale with particular emphasis on the vulnerability of specific locations. The projection of the climate is of high importance because it enables the development of local and regional strategies for mitigation and adaptation to future climatic threats (Eitzinger *et al.*, 2013).

Northern Serbia (Vojvodina) lies in the Pannonian zone of Southeastern Europe. It is the region of the highest importance for agricultural production of Serbia, where climate and soil characteristics are mostly favorable for rainfed cropping (Stričević *et al.*, 2011). Maize is the most important crop in Serbia, which provides the highest economical revenue. Furthermore, it is the representative of the most cropped coarse grains. During the period 1995-2016, 41% of the arable land of North Serbia was under maize production (650.000 ha). According to the Statistical Office of the Republic of Serbia, maize occupied approximately 68.4% of the whole plant production with the largest sown area (906.753 ha) and an average yield of 7.7 t ha^{-1} during 2018. Most maize crop cultivations in Vojvodina are produced under rainfed conditions. However, in some areas, maize is irrigated to stabilize the production from year to year. Based on long-term experiments carried out under the conditions of Vojvodina, Bošnjak *et al.* (2005) pointed out that, on average, the irrigation of maize increased its yield by 28.7%. The effect of irrigation on maize yield in the region depends on weather conditions of the year, primarily on the sum and distribution of precipitation. In dry years, the irrigation can be abundantly used as farming practice (Bošnjak and Pejić, 1994), while in wet years it can be very modest or it can even be omitted (Pejić *et al.*, 2011). These results suggest that irrigation in Vojvodina is supplementary in character and that precipitation can affect the soil water regime and irrigation schedule of maize (Pejić *et al.*, 2011; Pejić *et al.*, 2018). According to Dragović *et al.* (2008), most of the spring crops experience the lack of soil water in July and August. Furthermore, this is the most sensitive period for maize production, which can affect its yield (Pejić *et al.*, 2009; Pejić *et al.*, 2011).

Long-term weather analyses indicate that the Pannonian region (areas of Serbia, Hungary, Croatia, Bulgaria, and Romania) will be considerably exposed to extreme weather events expected in the future. Drought events and periods of excessive precipitation can directly affect maize farming, which can lead to changes in agricultural production. According to Stričević *et al.* (2011) and Bezdan *et al.* (2019), the pattern of extreme drought events is difficult to be accurately predicted. Eventually, this pattern can affect the demands in the market place and prices of maize and other crops. Lalić *et al.* (2011) reported on higher vulnerability of spring crops to drying days, relative to winter crops. Thus, it is worthy to find out how the future climate will affect the yield of maize and other spring crops (soybean and sugar beet) in order to adjust mitigation strategies in the region to uneven conditions in the future.

Nowadays, a lot of effort has been done regarding the application of advanced techniques and methods to foresee the future climate and to predict its impact on crop growth and yields. The impact of expected climate changes on the overall crop growth and yield can be assessed using crop–weather models. Many studies explained the expected effects of climate change in Europe on crop yield using such models (Downing *et al.*, 2000; Dubrovsky *et al.*, 2000; Lalić *et al.*, 2013). So far, the impact of potential climate changes on the territory of Serbia included the use of different models to assess the yield of maize (DSSAT and AquaCrop) (Vučetić, 2011; Stričević *et al.*, 2011; Jančić *et al.*, 2019), spring barley (AquaCrop) (Daničić *et al.*, 2019), winter wheat (SIRIUS) (Lalić *et al.*, 2013) with an emphasis on the analysis of expected weather changes. These studies included mostly long-term analysis of weather and the efficiency of crop models in simulating yields and climatic indices, which are indicators of extreme weather events.

In the present study, the aim was to determine how the average yield of rainfed maize will change in near future (2001-2030) relative to the present, and if the currently applied or higher irrigation rate can be used as a strategy to mitigate the effect of predicted weather scenario on maize yield. For this purpose, FAO AquaCrop model, version 6.0 (Raes *et al.*, 2009; Steduto *et al.*, 2009) was selected for the simulation of maize yield, since it is a water-driven model with less requirements for experimental, soil and crop data as an input, as compared with other models (DSSAT, CERES, WOFOST), which is convenient considering that the technology of maize production has already been well-elaborated. In addition, better performance of AquaCrop in simulating grain yield relative to DSSAT was reported by Babel *et al.* (2019).

Abbreviations

ETo, reference evapotranspiration; ETd, daily water used on plants evapotranspiration; kc, crop coefficient; IWUE, irrigation water use efficiency; IWUEm, irrigation water use efficiency of measured irrigated maize; IWUEs, irrigation water use efficiency of simulated maize; IRR, irrigated; RF, rainfed; RAW, readily available water; WFS, Weather forecast service.

Material and methods

Experimental site and recorded data

Field experiments with maize were conducted in Northern Serbia (45°20'N; 19°50' E; 82 m a.s.l.). The experiment took place from 2015 to 2018 under rainfed and irrigated conditions.It was set up using a random block system. The size of the experimental unit was 50.0 m^2 (2.1 × 24.0 m). The maize experiment was organized in three replicates.

The soil from the experimental field was classified as calcareous, gleyic chernozem (Loamic, Pachic-CH-cc. gl-Ip.ph; IUSS Working Group WRB, 2015). The soil belongs to a clay loam textural class. The average pH of the soil layer 0-30 cm is 7.3 and 8.1 in H_2O and KCl, respectively, humus 2.9%, $CaCO_3$ 6%, total N 0.190%, soluble P and K 29.7 and 30.4 mg 100 $g^{-1}$of soil, respectively. Water-physical properties of the soil are described by Hadžić *et al.* (1996).

Meteorological data for the reference period were compared with the predicted scenario (2001-2030) to assess the shifts in mean air temperature in the period April-September (A-S) (°C), the average number of days with minimum air temperature below 0 °C (frost days), the average number of days with maximum air temperature below 0 °C (ice days), the average date of the onset of last spring and first autumn frost, the average number of days with maximum temperature above 30 °C in the period A-S (tropical days) and the amount of precipitation in the period A-S (mm). The climate at the experiment site is characterized as moderate continental with mean annual precipitation of 557 mm (reference period 1985-2005). The mean annual precipitation during the four years of the experiment (2015-2018) was 585.7 mm. The mean annual temperature of the site is 11.5 °C. Drought is a regular phenomenon in the region. It appears almost every year, lasts over longer or shorter period influencing the yield of growing plants. In some years, drought reaches catastrophic proportions in agricultural production. In dry years, yields can be reduced by 52-76% relative to the average yields recorded in the region.

Maize hybrid NS6030 (*Zea mays* L.) was chosen for the simulation in AquaCrop. It represents a middle-late hybrid, which can reach the grain yield of 17 t ha^{-1} in optimal conditions. The optimal sowing rate is approximately 65.000 plants per ha. The length of its vegetation period is 125-130 days. Sowing of the maize was conducted according to the common practice in the region (from the middle to the end of April) along with all required technical measures. The maize was grown under two scenarios: rainfed and irrigated. Irrigation was scheduled on the basis of the water balance method using ETo and kc. ETo was calculated by the Hargreaves equation (Hargreaves and Samani, 1985).The data were downloaded from the Weather forecast service of Serbia. ETd was calculated by multiplying ETo by kc values (FAO, 2015) for initial stage 0.3-0.55, crop development stage 0.7-0.85, mid-season stage 1.05-1.2 and late-season stage 0.8-0.9. Irrigation was performed when readily available water (RAW) in the soil layer of 0.4 m was completely absorbed by plants.

$$ETd = ETo\ kc$$

The plants were irrigated by a drip irrigation system, with a lateral placed per plant row and drippers spaced at every 0.1 m. The drippers had an average flow of 1.4 L h^{-1} under a pressure of 70 kPa.The irrigation in the present experiment was scheduled mostly in June, July, and August that coincided with the periods of severe drought in the region (especially in 2015 and 2017) "Fig. 2".

Model input data

AquaCrop version 6.0 was chosen for the simulation of rainfed and irrigated maize yield during the projected scenario (2001-2030). It is a water-driven model, which includes climate, crop, and field parameters and enables the simulation of maize yield. Nevertheless, some parameters needed to be adjusted to local conditions.

During the field experiment, meteorological data of the site were obtained from a meteorological station set up in the field. During four years of the experiment, the meteorological data included minimum daily temperature (T_{min}; °C), maximum daily temperature (T_{max}; °C), average daily temperature (T_{ave}; °C) and precipitation (mm). The data were downloaded from the WFS. The climate data from 2015 to 2018 were used as input data for the model calibration and validation.

Table 1 - Input parameters for the maize yield prediction model

Parameter, unit	Calibrated value
Base temperature, °C	8
Upper temperature, °C	30
Initial canopy cover, %	0.39
Maximum canopy cover, %	96
Crop coefficient	1.05
Water productivity, kg m^{-3}	33.7
Harvest index (HIo), %	51

Crop development data were derived from the 4-year long field experiment (2015-2018) (Table 1). The input parameters were locally calibrated for rainfed maize yield in 2016 and 2018 because these years were considered stable in the sense of weather conditions (relative to 2015 and 2017during which severe lack of precipitation was recorded, which resulted in a yield lower than average). The crop yield is directly proportional to actual evapotranspiration, which is why the calibration of crop models using crop yields is reliable in partitioning water between soil storage and actual evapotranspiration (Faramarzi *et al.*, 2009). The model was validated for all scenarios (rainfed in 2015 and 2017 and irrigated maize in 2015, 2016, 2017 and 2018). The effect of soil fertility was not considered during calibration and validation since a sufficient amount of fertilizers for maize was ensured during the experiment (total of 130 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1} and 75 kg K_2O ha^{-1} fertilizer was applied according to recommendations based on the results of the soil analysis). The initial status of RAW, in the soil layer of 0.4 m was determined by soil sampling applying the thermo-gravimetrical method. The adjustment of harvest index to 51% instead of default value for maize (33%) can be attributed to the characteristics of the hybrid (Stričević *et al.*, 2011). Djaman *et al.* (2013) determined that HI in full irrigation and rainfed treatment of maize can be 57% and 49%, respectively.

Predicted scenario

Climate data for 2001-2030 were obtained by dynamic downscaling of climate simulations with the ECHAM5/MPI-OM climate model (Jungclaus *et al.*, 2006). The downscaling of the global circulation models (GCM) simulations was conducted with the coupled regional climate model EBU-POM (Djurdjević *et al.*, 2012). The set of meteorological input data consists of daily solar radiation (J m^{-2}), daily maximum (T_{max}), daily minimum (T_{min}) and average temperature (T_{ave}), daily precipitation (mm), vapor pressure (mbar) and wind speed (m s^{-1}). The projected concentration of CO_2 was defined in

AquaCrop (Mauna Loa- default atmospheric CO_2 concentration from 1902-2099).

Statistical data analysis

Three statistical methods were used to compare yield data from the experiment and AquaCrop simulations: the determination coefficient for the model (R2), the root mean square error (RMSE) and the index of agreement (d) for the validation years. In addition, the IWUEm and IWUEs (kg m^{-3}) was calculated according to Stričević *et al.* (2011) for four years (2015, 2016, 2017, and 2018) according to the following equitation:

$$IWUEm = (Yim - Yrm) / I$$
$$IWUEs = (Yis - Yrs) / I$$

Y_{im}–measured yield of the irrigated crop, Y_{rm}–measured yield of the rainfed crop and I–the amount of irrigation water applied, Y_{is}–simulated yield of the irrigated crop, Y_{rs}–simulated yield of the rainfed crop

Relative standard deviation (RSD, %) was calculated between measured and simulated yield. Analysis of variance and LSD test were performed in Statistica 13.5 (StatSoft, University Licence, University of Novi Sad, 2020). The significance of the obtained differences was established at $p \leq 0.05$.

Results and discussion

The results of the model calibration and validation (by the use of maize yield and IWUE from the field experiment) under rainfed and irrigated conditions are presented in Fig. 1 and Table 2.

The results of the calibration showed a very good performance of the model (RSD lower than 3%). Calibrated parameters were later used for model validation. Nevertheless, a small number of parameters in the default file from AquaCrop needed to be adjusted to the local conditions (HIo, soil type), which indicates that the default maize file in the model can be applied under current temperate conditions with minor modifications. The use of slightly changed default maize file in AquaCrop was reported also by Stričević *et al.* (2011).The low RMSE, R2 close to 1 and d value relatively close to 1 (in the rainfed trial), in the validation years, indicate a very good match between the observed and simulated yield of maize. The most pronounced difference between the measured and simulated yield of rainfed maize was observed in 2017 (RSD of 15%) when the model simulated more than a tone higher yield of maize. During 2017, severe periods of drought were recorded during summer months in the investigated region (maize is the most sensitive in these months). The overestimation of the maize yield by the model could be attributed to the fact that crop models cannot simulate the extreme event effects to the full extent. The other deviations among years were smaller (less than 5% in rainfed and less than 7% in irrigated years), although the model better simulated the yield of rainfed maize (with the exclusion of 2017) in general. The model mostly overestimated the yield of irrigated maize (in 2015, 2017 and 2018). To support this, some authors reported a slight overestimation of soil water content after scheduling irrigation in AquaCrop such as Farahani *et al.* (2009) in cotton and Hsiao *et al.* (2009) in maize. Similar was reported by Stričević *et al.* (2011) and Heng *et al.* (2009) in maize yield simulation, but with different hybrids.

The model simulated IWUE satisfactory for all four years

Table 2 - The results of the calibration and validation of the model

Year	Measured yield (t ha^{-1})	Simulated yield (t ha^{-1})	RSD (%)	RMSE	d	R2
Rainfed maize						
2015	8.395	8.996	4.9			
2016	13.073	12.555	2.9			
2017	6.193	7.667	15.0			
2018	12.846	12.538	1.7	0.22	0.97	0.99
Irrigated maize						
2015	12.012	13.402	7.3			
2016	13.927	13.742	0.9			
2017	13.269	13.829	2.9			
2018	13.310	13.797	2.5	0.16	0.44	0.90

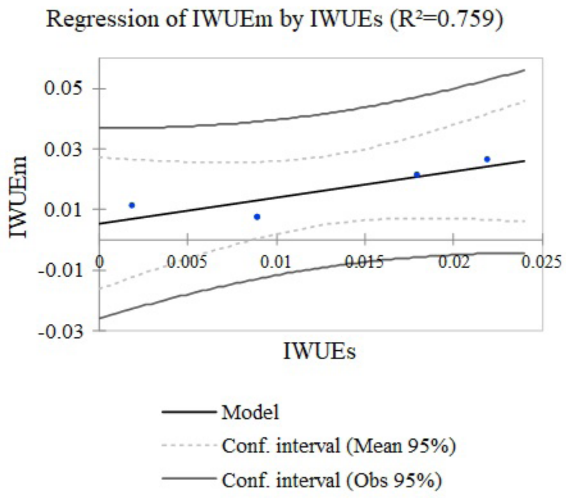

Fig. 1 - Irrigation water use efficiency of measured irrigated (IWUEm) and simulated irrigated maize (IWUEs)

of investigation (Fig. 1). The highest difference between measured and simulated maize water use efficiency was determined in 2015, when the model overestimated the irrigation water use efficiency of the maize.

Predicted climate shifts and changes in rainfed and irrigated maize yield

To better understand and perceive the changes in maize yield caused by predicted climate shifts, the most important weather indicators that affect spring crops vegetation were analyzed. To describe the current climate in Northern Serbia the daily values of meteorological variables, which were reported earlier in the study of Lalić *et al.* (2011) for the reference period 1985-2005 were used (Table 3). According to Mihajlović *et al.* (2015), the compared selected variables may have a profound effect on human activity, particularly agricultural production. As obvious from Table 3, significant differences in weather are mainly reflected in the number of tropical days and precipitation during A-S. It seems that 15% lower yield of rainfed maize in the predicted scenario, relative to the current state (2015-2018), could be the result of less precipitation during the growing season of maize (Fig. 2). To support these results, some studies indicated the loss of maize yield of 17% as a consequence of global temperature increase followed by a lack of rainfall (Thomson *et al.*, 2005). In addition, Vučetić (2011) reported a maize yield loss as a consequence of climate change in Croatia. According to the meteorological data obtained from WFS the average annual amount of precipitation during the experiment (2015-2018) was 585.7 mm. However, according to the predicted climate scenario (2001-2030), the average annual amount of precipitation is expected to decrease significantly relative to the 2015-2018 and reference period (1985-2005). In agroclimatic conditions of Northern Serbia, the maize water requirement during the growing season usually ranges between 450 and 540 mm, depending on the weather conditions and the length of the hybrid growing season (Bošnjak, 1982; Pejić, 2000).This water requirement of maize is provided by rainfall only in 4-5% of years, which cannot ensure the full potential for the yield of certain maize hybrids without irrigation (Vučić, 1976). As visible from Table 4 and Fig. 2), 2015 and 2017 were dry years for maize production, while 2016 and 2018 can be considered normal in a sense of weather conditions required for maize production. It can be assumed that the precipitation will stay prevalent variable in the determination of the yield of rainfed maize in the near future (2001-2030) since the increase in average mean air temperature in A-S period is negligible (at least in the near future). Extreme temperature increase (the number of tropical days) can be particularly dangerous for maize and other spring crops (soybeans, sunflower, and sugar beet). This usually occurs during summer months (June, July, and August), which coincides with the generative phase of crops and their highest demand for water (Kovačević and Sostarić, 2016). Based on predicted data analysis, the average number of tropical days during the growing season of maize is likely to significantly increase in the near future (by 5 days). Tropical days are mostly expected in June, July, and August (sometimes in May and September). Temperatures above 30° C usually produce disorders in spring crops through the impact on the basic metabolic processes in plants (the intensity of the respiration and

Table 3 - Mean air temperature, number of frost and tropical days, the precipitation amount in the period from April to September (A-S) and the onset of spring and autumn frost in the reference period (1985-2005) and predicted scenario (2001-2030)

Period	Mean air C ° (A-S)	Number of frost days (A-S)	Spring/autumn frost date	Number of tropical days (A-S)	Precipitation (mm) (A-S)
1985-2005	18.3[a]	2[a]	5th April/29th October	29[b]	376.5[a]
2001-2030	18.4[a]	0[a]	28th March/4th November	34[a]	369.6[b]

*Different letters between the sets of the years denote statistically significant difference according to LSD test at p≤0.05

Table 4 - Sowing, emergence, flowering, maturity/harvest dates, amount of precipitation during the growing season and irrigation water applied

Year	Sowing	Emergence	Flowering	Maturity/Harvest	Amount of precipitation during the growing season (mm)	Irrigation water applied (mm)
2015	16th April	24th April	2nd July	25th August	221.8^{d}	300^{b}
2016	19th April	27th April	5th July	4th September	367.2^{a}	120^{c}
2017	26th April	3rd May	29th June	28th August	228.0^{c}	330^{a}
2018	18th April	27th April	4th July	8th September	311.6^{b}	55^{d}

*Different letters between the years denote statistically significant difference according to LSD test at p≤0.05

transpiration, and grain filling), which often results in the loss of yield (Otorepec, 1980). Combination of the lack of precipitation and increased number of tropical days may be the reason for the rainfed maize yield decrease in the predicted scenario relative to the yield in the field experiment. Besides extremely high temperatures (above 30° C), the temperatures below 0° C can be detrimental for crops. For spring crops, late spring and early autumn frost are of the highest importance. Based on the available weather data, the period between two frosts will extend in the future relative to the reference period (1985-2005). Such a distribution of frost days could extend the growing cycle of spring crops, which may affect field operations (Lalić *et al.*, 2011). Nevertheless, the length of the growing cycle of the maize in the predicted scenario (2001-2030) does not significantly deviate from the field experiments (in average 130 days). It seems that a negligible increase in mean air temperature over the near future, relative to the reference period, will not affect the length of the growing cycle of the maize, regardless of the lack of precipitation.

Successful maize production in the Pannonian Basin depends mostly on meteorological variables and adequate irrigation (Dragović *et al.*, 2012). Maize is mostly grown under rainfed conditions under temperate climate in the region, but increasing periods of drought and temperature in the last few decades impose the need for irrigation of maize and most spring crops (su-

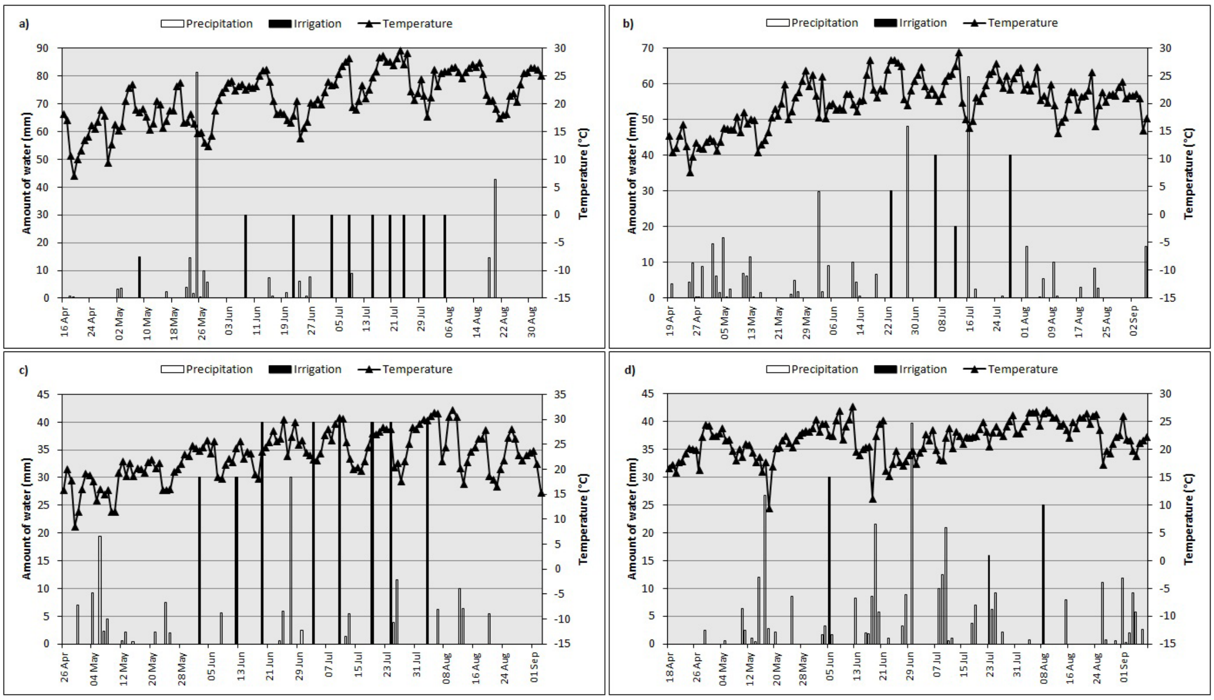

Fig. 2 - Daily weather data and water application rates for vegetation period for the following years: a) 2015, b) 2016, c) 2017 and d) 2018.

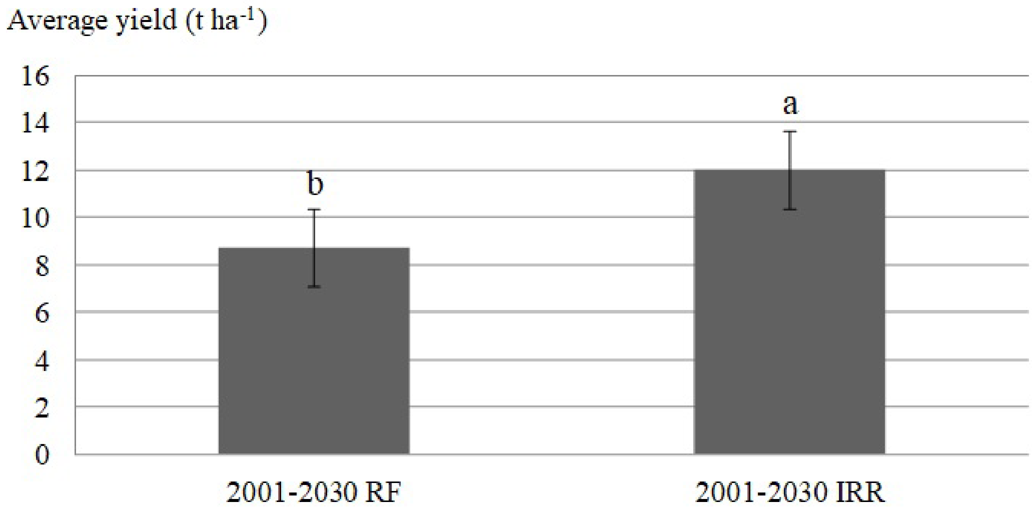

Fig. 3 - The yield of rainfed and irrigated maize in the predicted scenario (2001-2030). Different letters between the sets of the years denote statistically significant difference according to LSD test at p≤0.05

gar beet, soybean). Stričević *et al.* (2011) reported that AquaCrop is reliable in simulating the yield of irrigated maize and sugar beet.The experimental results (2015-2018) revealed that the average yield of maize was increased by approximately 25% when it was irrigated with 200 mm on average (Table 4). The irrigation was conducted in June, July, and August during the field experiment, which coincides with the periods of severe stress during crop growth in the AquaCrop simulation.

In the later part of the simulation (predicted scenario), the maize was irrigated with 200 mm to observe whether the currently applied irrigation rate could increase the maize yield in the predicted conditions as well. The simulation results showed up to 28% higher yield as a result of irrigation of maize in the projected scenario (Fig.3). According to these findings, supplying maize with the average irrigation rate in the field experiment (200 mm) could alleviate the adverse effect of predicted climate change and increase the yield of maize to some extent. The irrigation rate of 200 mm is expected not to provide the yield of the maize as high as the one obtained from the experimental results (13.3 t ha^{-1}). Hence, the irrigation rate in the predicted scenario was increased by 50 and 100 mm. The results of the simulation showed that irrigation of maize with 250 mm increased the yield only by 1% as compared to irrigation with 200 mm. Furthermore, increasing the irrigation rate for maize in the future (300 mm) could result in yield loss. However, the limitation of AquaCrop in simulating soil water content after irrigation of maize reported by Hsiao *et al.* (2009) should be considered before planning agricultural strategies, since the soil is a very heterogeneous environment, which affects the efficiency of the crop models in simulations. Contrary to that, many studies indicated the acceptable performance of AquaCrop in simulated irrigation treatments (Farahani *et al.*, 2009; Heng *et al.*, 2009; Katerji *et al.*, 2013). In addition, spring crops could be responsive to the reported amounts of additional water since their growing cycle as well as sensitive phases overlap with the one of maize in the study. The exception is sugar-beet, which is sown earlier in general (the end of March and the beginning of April), so the projected onset of early spring frost should be taken into account in planning an agricultural strategy for this spring crop.

Conclusions

The climate in Northern Serbia, as well as in the region of Southeastern Europe, has changed significantly in the last decades. The periods of extreme drought and precipitation are apparent and affect agricultural production which eventually impacts the production of most important crops in the Pannonian Basin (parts of Serbia, Hungary, Croatia, Bulgaria, and Romania). According to the present study, maize, as the most important spring crop in Northern Serbia, is expected to be vulnerable in the near future (2001-2030). The decrease in the yield of rainfed maize simulated by the AquaCrop is expected to be predominantly the result of the lack of precipitation during the growing season, as well as of an increase in extreme temperature events (tropical days) expected in summer months. Furthermore, even though field cropping in Serbia is mostly rainfed, it appears that irrigation of maize and most likely other spring crops (soybean and sugar beet) will become a necessary practice in the region. At least in the case of maize, currently used irrigation rates are expected to remain a useful mitigation strategy, but their lower effect on yield is expected in the near future, relative to current practice. Therefore, agricultural strategy for maize production in the Pannonian region should probably be directed towards the breed of maize hybrids which have advanced water use efficiency in projected uneven conditions provoked by climate change.

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References

Ahmadi SH, Elnaz M, Ali AK, Ali RS, 2015. Modeling maize yield and soil water content with AquaCrop under full and deficit irrigation management. Water Resour Manag 29: 2837–2853

Babel MS, Deb P, Sony P, 2019. Performance evaluation of AquaCrop and DSSAT-CERES for maize under different irrigation and manure application rates in the Himalayan region of India. Agric Res 8(2): 207–217https://link.springer.com/article/10.1007%2Fs40003-018-0366-y

Bezdan J, Bezdan A, Blagojević B, Mesaroš M, Pejić B, Vranešević M, Pavić D, Nikolić-Djorić E, 2019. SPEI-Based Approach to Agricultural Drought Monitoring in Vojvodina Region. Water, 11 (7): 1-32, doi:10.3390/w11071481

Bošnjak DJ, 1982. Evaporation from the free water surface as a base for irrigation scheduling and its relationship to ETP of maize and soybean. Ph. D thesis, Faculty of Agriculture, University of Novi Sad, 1-132 (In Serbian)

Bošnjak DJ, Pejić B, 1994. Rational irrigation scheduling of maize. Proceedings of the IX Conference of Yugoslav Society for Soil Investigation, Novi Sad, pp. 624–631 (In Serbian)

Bošnjak DJ, Pejić B, Maksimović L, 2005. Irrigation, a condition for high and stable corn production in the Vojvodina Province. Contemp Agric 3–4: 82–87

Daničić M, Zekić V, Mirosavljević M, Lalić B, Putnik-Delić M, Maksimović I, Dalla Marta A, 2019. The response of spring barley (Hordeum Vulgare L.) to climate change in Northern Serbia. Atmosphere 10, 14 https://doi.org/10.3390/atmos10010014

Djaman K, Irmak S, Rathje WR, Nartin DL, Eisenhauer DE, 2013. Maize evapotranspiration, yield production functions, biomass, grain yield, harvest index and yield response factors under full and limited irrigation. T Am Soc Agric Biol Eng 56: 273–293 https://digitalcommons.unl.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1409&context=biosysengfacpub

Downing TE, Harrison PA, Butterfield RE, Lonsdale KG, 2000. Climate change, Climatic variability and Agriculture in Europe. An Integrated Assessment, Research Report No. 21, Oxford: Environmental Change Unit, University of Oxford

Dragović S, 2012. Effect of irrigation on field crops yield under the variable agro-climatic conditions of Serbia. AgrForest 54: 25–40 http://89.188.43.75/agricultforest/20120514-02%20Dragovic.pdf

Dragovic S., Cicmil M., Radonjic L., Radojevic V. The intensity and impact of drought on crop production and possibilities of mitigation in Serbia. In : López-Francos A. (ed.). Drought management: scientific and technological innovations. Zaragoza : CIHEAM, 2008. p. 101-106. (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 80). 1. International Conference Drought Management: Scientific and Technological Innovations, 2008/06/12-14, Zaragoza (Spain). http://om.ciheam.org/om/pdf/a80/00800427.pdf

Dubrovský M, Žalud Z, Štastná M, Trnka M, 2000. Effect of climate change and climate variability on crop yields. Falchi MA and Omodei Zorini A eds. Proceedings of 3rd European Conference on Applied Climatology, October 16–20, Pisa, Italy

Djurdjević V, Rajković B, 2012. Development of the EBU-POM coupled regional climate model and results from climate change experiments. "Advances in Environmental Modeling and Measurements", pp 23–32. Mihajlović DT, Lalić B, eds. Nova Science Publishers Inc.: New York, USA

Hargreaves GH, Samani ZA, 1985. Reference crop evapotranspiration from temperature. Appl EngAgric 1: 96–99 http://dx.doi.org/10.13031/2013.26773

Eitzinger J, Trnka M, Semerádová D, Thaler S, Svobodová E, Hlavinka P, Šiška B, Takác J, Malatinská L, Nováková M, Dubrovský M, Žalud Z, 2013. Regional climate change impacts on agricultural crop production in Central and Eastern Europe-hotspots, regional differences and common trends. J Agric Sci 151: 787–812https://doi.org/10.1017/S0021859612000767

FAO, 2013. FAO STAT Production statistics. Food and Agriculture Organization of United Nations. http://faostat.fao.org/site/567/DesktopDefault.aspx. Accessed on 3rd July 2019

FAO Statistical Yearbook, 2015. http://www.fao.org/documents/card/en/c/383d384a-28e6-47b3-a1a22496a9e017b2/. Accessed on 3rd July 2019

Farahani HJ, Izzi G, Oweis TY, 2009. Parameterization and evaluation of the AquaCrop model for full and deficit irrigated cotton. Agron J 101: 469–476 https://pdfs.semanticscholar.org/43f7/d65fabbc43c01a056c4bbc7171884704b919.pdf

Faramarzi M, Abbaspour KC, Schulin R, Yang H, 2009. Modeling blue and green water resource availability in Iran. Hydrol Process 23: 486–501 DOI: 10.1002/hyp.7160

Hadžić V, Ćirović M, Dragović S, Kišgeci J, Ubavić M, Bogdanović D, et al, 1996. Basis of protection, use and management of agricultural land in the municipality of Bački Petrovac ("pilot"). Institute of Field and Vegetable Crops, Novi Sad (In Serbian)

Heng LK, Hsiao TC, Evett S, Howell T, Steduto P, 2009. Validating the FAO AquaCrop model for irrigated and water deficient field maize. Agron J 101: 488–498 https://pubag.nal.usda.gov/download/31424/PDF

Hsiao TC, Heng LK, Steduto P, Rojas-Lara B, Raes D, Fereres E. 2009. AquaCrop-The FAO crop model to simulate yield response to water: III. Parametrization and testing for maize. Agron J 101: 448–459

IUSS Working Group WRB 2015. World Reference Base for Soil Resources 2014, update 2015, International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106, FAO, Rome, Italy

Jancic-Tovjanin M, Djurdjevic V, Pejic B, Novkovic N, Mutavdzic B, Markovic M, Mackic K, 2019. Modeling the impact of climate change on yield, water requirements, and water use efficiency of maize and soybean grown under moderate continental climate in the Pannonian lowland. IDÖJÁRÁS 123(4): 469-486 DOI:10.28974/idojaras.2019.4.4

Jungclaus JH, Botzet M, Haak H, Keenlyside N, Luo JJ, Latif M, Marotzke J, Mikolajevicz U, Roeckner E, 2006. Ocean circulation and tropical variability in the coupled model ECHAM5/MPI-OM. J Clim19: 3952–3972https://doi.org/10.1175/JCLI3827.1

Katerji N, Campi P, Mastrorilli M, 2013. Productivity, evapotranspiration and water use efficiency of corn and tomato crops simulated by AquaCrop under contrasting water stress conditions in the Mediterranean region. Agric Water Manage 130: 14–26 DOI: 10.1016/j.agwat.2013.08.005

Kovačević V, Sostarić J, 2016. Impact of weather on the spring crops yield in Croatia with emphasis on climatic change and the 2014 growing season. J Agr Sci 70: 41–46 http://www.agr.unideb.hu/acta/archive/

Lalić B, Eitzinger J, Mihajlović DT, Thaler S, Jančić M, 2013. Climate change impacts on winter wheat yield change-which climatic parameters are crucial in Pannonian lowland. J Agric Sci151: 757–774https://doi.org/10.1017/S0021859612000640

Lalić B, Mihajlović DT, Podraščanin Z, 2011. Future state of climate in Vojvodina and expected effects on crop production. Field Veg Crop Res 48: 403–418

Lalić B, Eitzinger J, Thaler S, Vučetić V, Nejedlik P, EckerstenH, JaćimovićG, Nikolić-Djorić E, 2014. Can agrometeorological indices of adverse weather conditions help to improve yield prediction by crop models? Atmosphere 5:1020–1041https://doi.org/10.3390/atmos5041020

Mihajlović DT, Lalić B, Drešković N, Mimić G, Đurđević V, Jančić M, 2015. Climate change effects on crop yields in Serbia and related shifts of Köppen climate zones under the SRES-A1B and SRES-A2. Int J Clim 35: 3320–3334https://doi.org/10.1002/joc.4209

Otorepec S, 1980. Agrometeorology. Nolit, Belgrade (In Serbian)

Pejić B, 2000. Evapotranspiration and morphological characteristics of corn depending on the depth of soil wetting and their relationships with yield. Ph. D thesis, Faculty of Agriculture, University of Novi Sad, 1-109 (In Serbian)

Pejić B, Bošnjak Dj, Mačkić K, Stričević Z, Simić D, Drvar A, 2009. Sensitivity of maize (*Zea mays* L.) to soil moisture deficit during certain vegetation subperiods, vol 1, Chronicles of scientific works, University of Novi Sad, Faculty of agriculture, 155–166 (In Serbian)

Pejić B, Maheshwari BL, Šeremešić S, Stričević R, Pacureanu–Joita M, Rajić M, Ćupina B, 2011. Water-yield relations of maize (*Zea mays* L.) in temperate climatic conditions. Maydica 56 (4): 315–323

Pejić B, Mačkić K, Milić S, Maksimović L, Bajić I, Jancic Tovjanin M, 2018. Effect of surface and subsurface drip irrigation on yield and evapotranspiration of maize. Annals of Agronomy, 42 (1):1-8. (In Serbian)

Raes D, Steduto P, Hsiao TC, Fereres E, 2009. AquaCrop- The FAO crop model to simulate yield response to water: II. Main algorithms and software description. Agron J 101: 438–447

Raja W, Habib Kanth R, Singh P, 2018. Validating the AquaCrop model for maize under different sowing dates. Water Policy 1–16

Steduto P, Hsiao TC, Raes D, Fereres E. 2009. AquaCrop-The FAO crop model to simulate yield response to water: I. Concepts and underlying principles. Agron J 101: 426–437doi:10.2134/agronj2008.0139s

StigterK, 2010. Applied Agrometeorology. Springer, Berlin

Stričević Z, Ćosić M, Đurović N, Pejić B, Maksimović L, 2011. Assessment of FAO AquaCrop model in the simulation of rainfed and supplementally irrigated maize, sugar beet and sunflower. Agric Water Manage 98: 1615–1621 DOI: 10.1016/j.agwat.2011.05.011

Thomson AMRA, Brown NJ, Roseberg R, Lazuralde C, Benson V, 2005. Climate change impacts for the conterminous USA: An integrated assessment Part 3. Dry land production of grain and forage crops. Climate Change 69: 43–65

Vučetić V, 2011. Modeling of maize production in Croatia: present and future climate. J Agric Sci 149: 145–157doi: 10.1017/S0021859610000808

Vucic N,1976. Irrigation of Agricultural Crops. Novi Sad, Serbia: Faculty of Agriculture, University of Novi Sad (In Serbian).

http://www.stat.gov.rs/en-US (last accessed: 27th June 2019)