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Assessment of observed and projected climate changes in Bačka (Serbia) using trend analysis and climate modeling

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Abstract— Climate change is one of the largest environmental issues causing hydroclimatological extremes such as floods, droughts, and aridity. The aim of this study is to assess the observed and projected climate changes in Bačka (Serbia). Detailed trend analyses and possible climate scenarios over Bačka has not been presented up to now. In this paper, four data sets were extracted and calculated: mean annual air temperature, mean air temperatures during the vegetation period, mean annual precipitation and total precipitation during the vegetation period. The presented parameters were obtained from the annual meteorological reports of the Republic Hydrometeorological Service of Serbia. Trend equation based on linear regression, trend magnitude according to the trend equation, and Mann-Kendall statistics have been used for trend analysis of climatic parameters. A GIS modeling of the possible climate scenario was created according to the Beijing Climate Center Climate System Model (BCC-CSM2-MR). Based on the trend equations, positive trends related to air temperature and precipitation variables are dominant. The trend magnitude shows the largest mean increase in all time series related to air temperature during the vegetation period. The highest mean precipitation increase occurs only in two time series. The Mann-Kendall statistics showed significantly positive trends in 11 cases and no changes in 9 cases. According to BCC-CSM2-MR, changes will be especially dominant in case of air temperatures. The expected changes in the total precipitation during the vegetation period show a tendency towards semiarid conditions. The presented results of observed and projected climate changes demand adaptation measures, especially from the aspect of sustainable agriculture.

Key-words: air temperature, precipitation, GIS modeling, trends, semiaridity, agriculture

1. Introduction

Climate change refers to a statistically significant variation in climate averages or its variability persisting for decades or a longer period of time (*Hulme*, 2017). Although climate change occurred on a global scale, its impacts often vary from region to region (*Arnell et al.,* 2019). Therefore, the analysis of changes in meteorological variables represents an important task in detection of observed and projected climate changes.

In recent years, various studies for detecting possible climate trends and changes across the world have been performed. Examining long-term trends of air temperature on annual and seasonal scales in Iran, *Ahmadi et al*. (2018) revealed that the highest increasing trends were observed in the south and southeast regions of Iran. The results showed statistically significant positive trends during autumn, spring, and especially summer. Some authors analyzed selected hydro-climatological variables (precipitation, streamflow, air temperature, and humidity) over the Middle East (*Nourani et al*., 2018, 2019). In these papers, the monthly, annual, and seasonal trends at Urmia Lake Basin from 1971 to 2013 were examined together with correlated mentioned variables. The results identified statistically significant decreasing trends in the streamflow, moderate decreasing trends in the precipitation and relative humidity, and increasing trends in the observed temperature data. *Sa΄adi et al*. (2019) analyzed trends of precipitation and precipitation extremes using a modified Mann-Kendall test in Sarawak (Malaysia). The modified Mann-Kendall test detected an annual precipitation increasing trend only at one station and no significant trend on seasonal scale at any stations. However, authors revealed the statistically significant trends of the 1-hour maximum precipitation mainly at the stations located in urban areas. This implicates the possibility of flash floods. Monthly precipitation and temperature time series from 6 meteorological stations were used to calculate meteorological drought indices over Ankara Province in Turkey (*Danandeh Mehr* and *Vaheddoost*, 2020). In the methodological sense, the well-known standardized precipitation (SPI) and precipitation-evapotranspiration (SPEI) indices were used in examining drought events. The results showed that the province suffered from 5 drought events during the period of 1971 to 2016. However, the results of examining the trends of the SPEI indicated a slight decrease trend during the observed interval; the SPI did not show the same pattern.

The patterns of projected changes of air temperature and precipitation will be intensive over many regions of the world. For example, China could be faced with an increase in temperature extremes and intensification of precipitation extremes according to CMIP5 climate model simulations (*Zhou et al*., 2014). Applied CMIP3 models (*Almazroui et al*., 2017) over the Arabian Peninsula revealed a continuous increase in projected annual air temperature and precipitation during the 21st century (2070–2099). *Bucchiagnani et al*. (2018) investigated the future climate conditions over the Middle East - North Africa region using the IPCC RCP4.5 scenario (from 1979 to 2100). Their results showed that the temperature and precipitation projections are statistically significant and generally highlight a strong warming (especially in summer) along with a reduction in precipitation. *Zittis et al*. (2019) examined the climate projections for the Mediterranean according to the CORDEX model. General warming can be expected by the end of the century (2081–2100). It is considered, that air temperature will increase by 1–5 °C with respect to the 1986–2005 reference period. A general drying (between 10% and 40%) is also inferred for the Mediterranean. *Touseef et al*. (2020) investigated the historical and future precipitation trends on water resources over the Xiajing River basin. According to the results, a decreasing trend was observed for the past 50 years over the basin with negative values of The Mann-Kendall test and Sen's slope. The future projections from CMIP5 (2020–2099) will likely be positive trends for annual precipitation. Significant positive trends were observed in monsoon and winter seasons while premonsoon and postmonsoon seasons, will likely slightly decrease.

Some authors made a contribution in detecting air temperature and precipitation trends in Vojvodina (*Tošić et al*., 2014; *Gavrilov et al*., 2015, 2016), some climate characteristics of Bačka (*Rakićević*, 1988; *Berić et al*., 1990; *Lazić et al*., 2004; *Rajić*, 2004, *Rajić* and *Rajić*, 2005; *Rajić* and *Štula*, 2007), and climate projections in Serbia (*Kržič et al*., 2011; *Vuković et al*., 2018; *Janković et al*., 2019). *Rakićević* (1988) used drought indices and classified Northeastern Bačka as one of the regions most affected by drought in Serbia. *Hrnjak et al*. (2014) identified the lowest values of the De Martonne aridity index in the northeast part of Vojvodina (including the northeastern parts of Bačka). Investigating the forestry aridity index (FAI) in Vojvodina *Gavrilov et al*. (2019) classified the northern parts of Vojvodina (parts of Bačka) as forest-steppe climate. Authors correlated the FAI values lower of the De Martonne and Pinna indices, which indicate semi-humid conditions or semi-dry Mediterranean climate, respectively. Identified lower values are caused by a lower amount of precipitation. Region of Bačka was identified as the part of the so-called R1 sub-region that includes the northern part of Serbia. The R1 is characterized by the lowest total precipitation and mostly intensive agriculture (*Gocić* and *Trajković,* 2014a; *Gocić et al*., 2020). Therefore, drought and aridity in the region of Bačka are frequent, intensive, and depending on the duration, so they could have impact on agricultural production. Also, in terms of detailed trend analysis and climate modeling, Bačka region has not been investigated yet. Thus, this paper could provide a basis to a future research of interaction between climate projections and sustainable agriculture.

The purpose of this paper is to analyze the variability of air temperature and precipitation variables at 5 meteorological stations in the region of Bačka (Serbia) during two intervals: 1949 to 2018 and 2018 to 2050. Besides, the objectives of this study are: (1) to analyze and discuss the trend characteristics of meteorological variables in detail; (2) to quantify the significance of changes by the trend equations, the trend magnitude, and the Mann-Kendall statistics; and (3) to use GIS modeling in order to detect the projected climate scenario (from 2018 to 2050) according to the Beijing Climate Center Climate System Model (BCC-CSM2-MR).

2. Research area

Bačka represents historical and geographical area in the northwest of Serbia (the western part of the Autonomous Province of Vojvodina). The borders of Bačka with the neighboring areas are of two different types: natural and artificial. The river Tisza towards Banat in the east, and the Danube towards Srem in the south are the natural borders of Bačka. Furthermore, the border with Croatia is also natural marked by the Danube (in the south and in the west). The borderline with Hungary is of an artificial type. It cuts transversely and then again merges the two biggest rivers of the Pannonian basin, rivers Danube and Tisza. In terms of climate, the northern border of Bačka does not represent a zone of separation of the neighboring climatic regions, since it belongs to the Pannonian plain, where the climatic conditions are similar. Administratively, the territory of Bačka is divided into three districts: the northern, the western, and the southern Bačka. It occupies an area of 8,671 km^2, i.e., 40.3% of the territory of Vojvodina (*Urban Institute of Vojvodina*, 2011). Spatial distribution of the selected stations is shown in *Fig. 1*, while their description is given in *Table 1*.

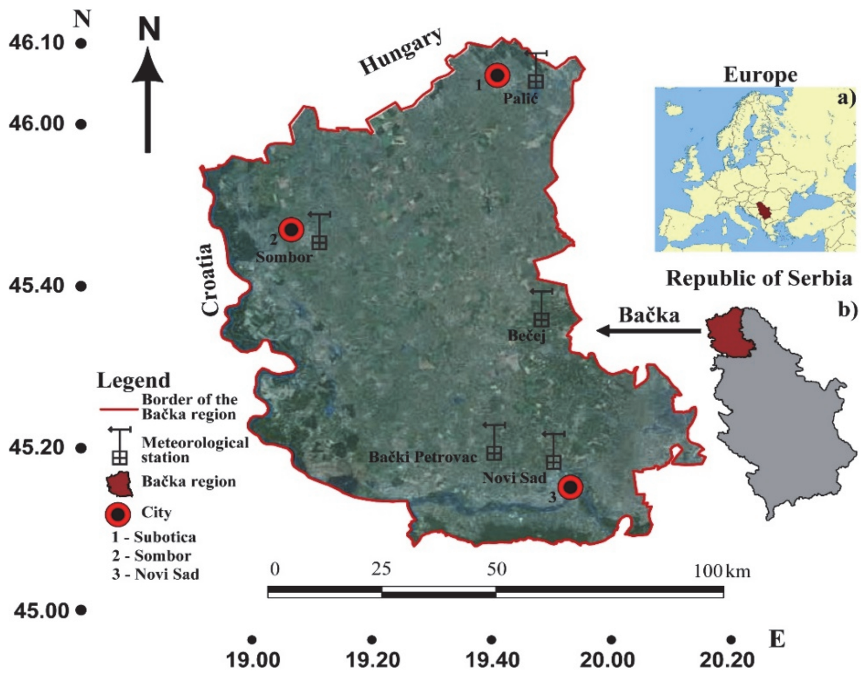

Fig. 1. Location map of Bačka with the distribution of meteorological stations.

These locations were chosen according to three parameters: (1) each of them should have good quality datasets; (2) the data should be reliable; and (3) the data should have adequate record length.

Table 1. List of used meteorological stations in Bačka with their abbreviations and geographic features, length of instrumental measurements and type (o.m.s.: ordinary meteorological station; p.m.s.: principal meteorological station)

No.	**Station name**	**Abbreviation**	**Longitude (E)**	**Latitude (N)**	**Altitude (m)**	**Length of measurements**	**Type**
1.	Bački Petrovac	BP	45º20′	19º40′	80	1948–2018	o.m.s
2.	Bečej	B	45º37′	20º04′	75	1948–2015	o.m.s
3.	Novi Sad	N	45º19′	19º50′	86	1948–2018	p.m.s.
4.	Palić	P	46º06′	19º46′	102	1945–2018	p.m.s.
5.	Sombor	S	45º46′	19º09′	87	1949–2018	p.m.s.

3. Materials and methods

3.1. Materials

Trend analysis of air temperature and annual total precipitation have been performed in the period of 70 years (from 1949 to 2018). Data from 5 meteorological stations were used, based on the Annual Meteorological Report (*Republic Hydrometeorological Service of Serbia*, 2019). Apart from the meteorological station Bečej, continuous instrumental observations were performed in all other analyzed stations. In case of Bečej, the meteorological station data have not been kept for three years (2016, 2017, and 2018). Since there was a small amount of data gaps (up to 4.3% of data), there was no significant bias of the final results. The missing data were supplemented by the method of linear interpolation. This simple statistical procedure is defined as arithmetic mean of linear interpolants between the two neighboring data sets (*Hazewinkel*, 1990). The software used for interpolation was EXCEL.

In this study, before previous calculations, statistical significance of the mean change and distribution from two different datasets was tested using the Kolmogorov–Smirnov (KS) test. The KS test is an empirical distribution function test in which the theoretical cumulative distribution function of the test distribution is compared to the empirical distribution function of the series

(*Javari*, 2016). The null hypothesis (*Ho*) is that the two dataset values are from the same continuous distribution. The alternative hypothesis (*Ha*) is that these two datasets come from different continuous distributions. The hypothesis test can be carried out at a specific statistical significance level (5%) (*Teegavarapu*, 2019). The KS test, performed using these two datasets, led to the result that the null hypothesis is not rejected suggesting that the two samples are drawn from the same continuous distribution. Therefore, it was concluded that the quality of air temperature and precipitation data was consistent and eligible for further data quality analysis, no corrections needed. For measuring the normality of the time series, the SPSS software was used.

Climate variables were categorized into 4 data sets: mean annual air temperatures (YT), mean air temperatures during the vegetation period (T_{mean}-VP), mean annual precipitation (YP), and total precipitation during the vegetation period (P_{Σ}-VP). The analysis of data, especially during the vegetation period (April-October) is very significant for agriculture.

3.2. Methods

In this paper, three statistical approaches were used, previously performed in similar researches: a) the trend equation (tendency was calculated for each time series using the method of linear regression (*Mudelsee*, 2019); b) in all cases the trend magnitude was calculated using the trend equation (*Gavrilov et al*., 2018); c) finally, all trends were assessed using the MK non-parametric test (*Zeleňáková et al*., 2018). Software EXCEL was used for the purpose of calculating the air temperature and precipitation trends. For determining the probability of confidence *p*, as well as for the purpose of hypothesis testing, the software XLSTAT was used.

3.2.1. The trend equation

The first statistical approach was to calculate the trend equation of the mentioned parameters using linear regression (*Mudelsee*, 2019). The selected approach has been long utilized in this type of research (*Feidas et al*., 2004), because it gives results which are simple to interpret; both graphically and analytically based on the shape and parameters of the trend equation. For instance, the temperature trend sign depends on the value of the slope. There are three possible scenarios: if the size of slope is greater than zero, the sign of trend is *positive* (increase); b) if it is equal to zero there *is no trend* (no changes); and c) if it is less than zero, the sign of trend is *negative* (decrease).

3.2.2. The trend magnitude

In the second statistical approach, the trend magnitude was defined as the difference in variables between the beginning and the end of the period. It was obtained from the linear trend equation (*Gavrilov et al.*, 2015). For a better understanding of the trend magnitude, in this paper the following statement was followed. First, when Δy is greater than zero, less than zero, or equal to zero, the sign of the trend is *negative* (decrease), *positive* (increase), or *no trend* (no change), respectively.

3.2.3. The Mann-Kendall (MK) non-parametric test

The Mann-Kendall (MK) test is a popular non-parametric alternative which tests the presence of a trend, or nonstationarity of the central tendency of a time series. In a parallel to the alternative parametric regression approach, the Man-Kendall test arises as a special case of the Kendall's τ, reflecting a tendency for monotone association between two variables (*Wilks*, 2011). The MK test has been widely used in hydrometeorological trend detection studies: for the magnitude and frequency of flood occurence (*Zadeh et al.*, 2020), air temperature and precipitation (*Panda* and *Sahu*, 2019), and aridity (*Nouri* and *Bannayan*, 2018). The test statisics for the Mann-Kendal trend test is (*Wilks*, 2011):

$$S = \sum_{i=1}^{n-1} sgn\ (x_{i+1} - x_i)\ , \tag{1}$$

where

$$sgn(\Delta x) = \begin{Bmatrix} +1, & \Delta x > 0 \\ 0, & \Delta x = 0 \\ -1, & \Delta x < 0 \end{Bmatrix}. \tag{2}$$

That is, the statistic in Eq.(1) counts the number of adjacent data pairs in which the first value is smaller than the second, and subtracts the number of data pairs in which the first is larger than the second. If the data x_i is serially independent and drawn from the same distribution, then the numbers of adjacent data pairs for which $sgn(\Delta x)$ is positive and negative should be nearly equal.

For moderate (n equals to about 10) or larger series length, the sampling distribution of the test statistic in Eq.(2) is approximately Gaussian, and if the null hypothesis is true, this Gaussian null distribution will have zero means. The variance of this distribution depends on whether all the x's are distinct, or if some x are repetaed values. If there is no ties, the variance of the sampling distribution of S is:

$$Var(S) = \frac{n(n-1)(2n+5)}{18}. \tag{3}$$

Otherwise the variance is:

$$Var\ (S) = \frac{n(n-1)(2n+5) - \sum_{J=1}^{J} t_j\,(t_j-1)(2t_j+5)}{18}, \tag{4}$$

where *J* represents the number of groups of repetaed values, and t_j is the number of repeated values in the *j*th group. The statistic *S* is approximately normally distributed provided that the following *Z*-transformation is employed:

$$Z = \begin{cases} \frac{S-1}{[(Var(S)]} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{[(Var(S)]} & if \quad S < 0 \end{cases} . \tag{5}$$

Finally, the measure of significance of variables, the probability *p* is computed as:

$$p = [1 - f(Z)] \times 100\ . \tag{6}$$

The probability density function for a normal distribution with a mean of 0 and a standard deviation of 1, is given by the following equation:

$$f(Z) = \frac{1}{\sqrt{2\pi}} exp\left(-\frac{Z^2}{2}\right). \tag{7}$$

By using MK test, two hypotheses were tested: the zero hypothesis (H_o) pointed to the inexistence of trend in time series; and the alternative hypothesis (H_a) pointed to the existence of a statistically significant trend in time series for the chosen level of significance (*α*). The main role in MK test belongs to the value of *p* (*Razavi et al*., 2016). The value of *p* determines the accuracy of the hypothesis. If the value *p* is lower than the chosen level of significance *α* (it is common that *α*=0.05 or 5%), the hypothesis H_o should be rejected and hypothesis H_a accepted. In case of *p* having the value larger than the level of significance, then the hypothesis H_o is accepted (*Gavrilov et al*., 2018).

3.2.4. The geographical information system (GIS) and the modeling of data

The geographical information system (GIS) is an important tool, and with the help of geostatistical and statistical methods, it may give important and valuable results. GIS may show the climate properties from the past and present and also give possibility to predict future climate. Many climate models are present today, while some of them are present with grid data. These grid data may show future climate predictions (*Li* and *Cheng*, 1999). In this research, we used GIS advanced methods and procedures to estimate climate change properties of Bačka region. GIS advanced methods present very important way of calculating and estimating annual climate properties. Climate features, which are the main reason, can not be detected without digitization and visualization for drought or hazardous weather. The relevant GIS spatial algorithms used in this research are: global kriging, semi-kriging, kriging, spatial interpolation, interpolation, and light buffer analysis. In this paper we gave priority to the global kriging algorithm, because it is useful, easy, and transparent (*Orus et al.*, 2005). Standard kriging and semi-kriging were used for climatological calculations in this research. Other techniques which may improve climatological estiamtion and performed general analysis of climate properties are interpolation technics (*Tomaszkiewicz et al.*, 2016). The semi-kriging method and nugget values between -0.5 and +1.0 on Z axis and between 0.2 and -0.5 on X axis were used. In addition, modified Gaussian regression and Kolmogorov prediction were used as well. The Beijing Climate Center Climate System Model (BCC-CSM2-MR) was used in this research. This model predicts data between 2081 and 2100. The resolution of the grid of this data is 2.5 minutes. This resolution is 5 km × 5 km in longitude and latitude. The main advancement of the BCC model from phase 5 of the Coupled Model Intercomparison Project (CMIP5) to phase 6 (CMIP6) is its precise physical parameterizations and model performance (*Wu et al.*, 2019). The 114 grid cells covering the Bačka region with an average area of 5 km^2 were used for climatological projections. This grid included analyzed climate variables for air temperature and precipitation.

With the help of a specially created computer *Tesla L3* with parallel functions of the operations, we estimated a very precise grid of 1 km^2. In that way it is possible to find all the positions and data obtained from the meteorological station at global, regional, and local scales. QGIS software was used to estimate grid for future predictions. Model projections of selected climate parameters include large uncertainties. Disagreement between individual simulations primarily arises from internal variability, whereas models agree remarkably well on the forced signal, the change in the absence of internal variability (*Fischer et al.*, 2014). For this reason, the GIS tool gave an advantage in climate projections. The error in predictions presented by GIS software is between 3% and 5%.

4. Results

4.1. Trend parameters and estimation of trends

In this paper, the results for twenty time series are presented. For each of the series, the trend equation as well as the linear trend for the interval from 1949 to 2018 were performed. The magnitude of trend (Δy), the probability of trend (p) for each time series, and Mann-Kendall statistics were used for the estimation of trends. These results summed up in *Tables 2, 3,* and *4* and *Fig. 2*.

The largest mean temperature increase Δy (*Table 2* and *3*) was recorded in the case of mean air temperature during the vegetation period (T_{mean}-VP) at stations Bački Petrovac (BP) and Bečej (B) (time series BP-T_{mean}-VP and B-T_{mean}-VP). Minor changes were identified in case of time series N-T_{mean}-VP and S-YT. In case of precipitation, the magnitude of trend is the largest in the case of time series N-YP and N-P_{Σ}-VP. The time series BP-YP is characterized by a decrease in mean precipitation.

Table 2. Trend equation (y), trend magnitude (Δy), and probability of confidences (p) for air temperature time series (from 1949 to 2018) in Bačka. Abbreviations are listed in Section 3.1. and *Table 1*.

Time series	**Trend equation**	**Δy (℃)**	**p (%)**
BP-YT	$y = 0.0237x + 10.546$	1.6	< 0.0001
BP-$\mathbf{T}_{mean}$-VP	$y = 0.0269x + 16.291$	1.9	< 0.0001
B-YT	$y = 0.0217x + 10.494$	1.5	0.0002
B-$\mathbf{T}_{mean}$-VP	$y = 0.0262x + 16.339$	1.8	< 0.0001
N-YT	$y = 0.0217x + 10.557$	1.5	< 0.0001
N-$\mathbf{T}_{mean}$-VP	$y = 0.0201x + 16.52$	1.4	0.0001
P-YT	$y = 0.0242x + 10.188$	1.7	< 0.0001
P-$\mathbf{T}_{mean}$-VP	$y = 0.026x + 16.149$	1.8	< 0.0001
S-YT	$y = 0.0211x + 10.29$	1.5	< 0.0001
S-$\mathbf{T}_{mean}$-VP	$y = 0.0215x + 16.164$	1.5	< 0.0001

Table 3. Trend equation (y), magnitude of trend *(*Δy), and probability of confidences (p) for precipitation time series (from 1949 to 2018) in Bačka. Abbreviations are listed in Section 3.1. and *Table 1*.

Time series	**Trend equation**	**Δy (mm)**	**p (%)**
BP-YP	$y = -0.0792x + 616.86$	-5.5	0.8480
BP-$\mathbf{P}_{\Sigma}$-VP	$y = 0.8409x + 365.96$	58.0	0.2438
B-YP	$y = 0.0684x + 590.86$	4.7	0.8520
B-$\mathbf{P}_{\Sigma}$-VP	$y = 0.5936x + 365.6$	40.9	0.2954
N-YP	$y = 1.4727x + 572.45$	101.6	0.1455
N-$\mathbf{P}_{\Sigma}$-VP	$y = 1.712x + 349.03$	118.1	0.0586
P-YP	$y = 1.4039x + 509.03$	96.9	0.0615
P-$\mathbf{P}_{\Sigma}$-VP	$y = 1.3171x + 318.84$	90.9	0.0963
S-YP	$y = 1.2902x + 555.14$	89.0	0.1304
S-$\mathbf{P}_{\Sigma}$-VP	$y = 1.2298x + 351.17$	84.9	0.0450

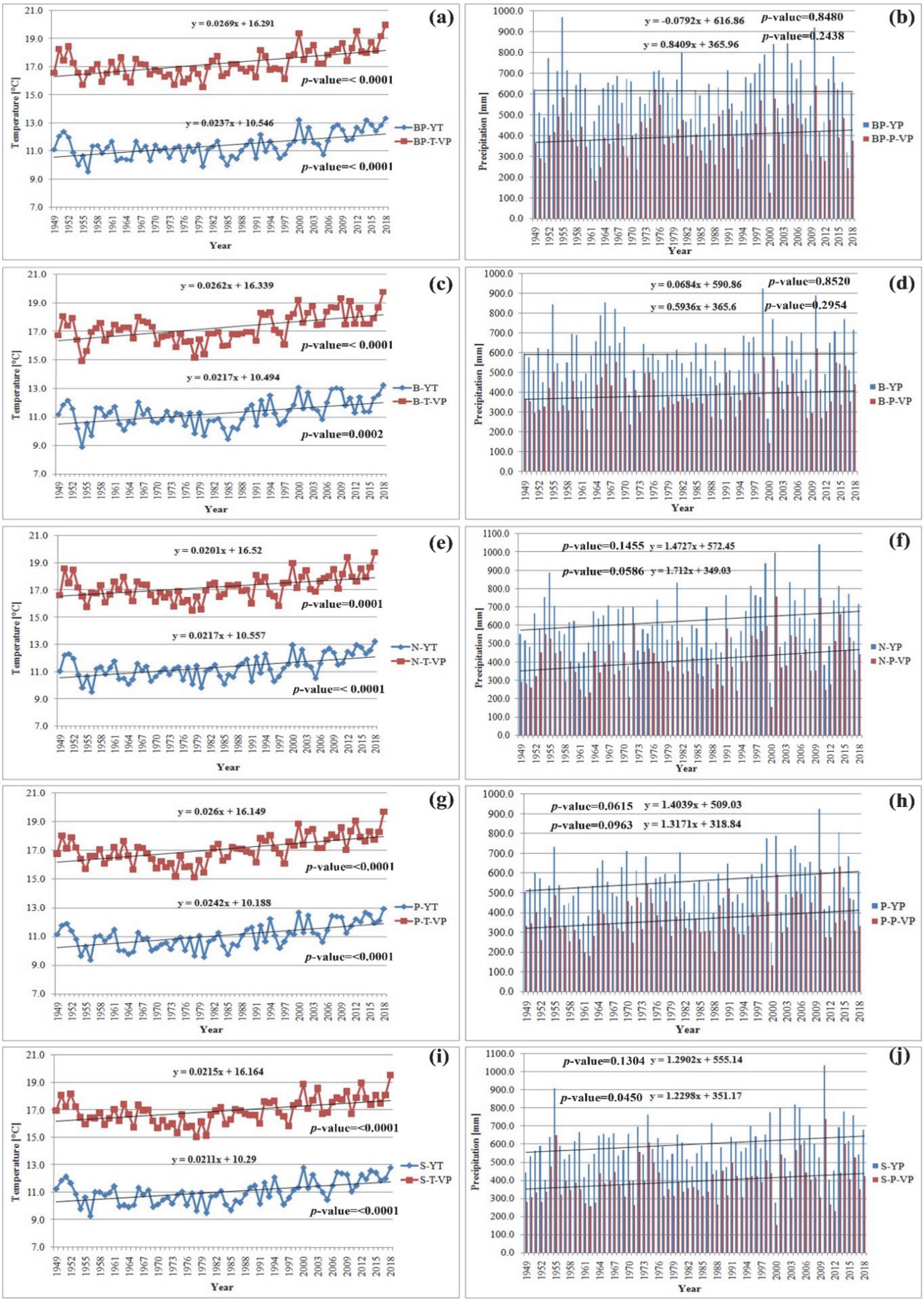

Fig. 2. Mean annual air temperature (YT), mean air temperature during the vegetation period (T_{mean}-VP), trend equation and trend lines (left column) and mean annual precipitation (YP), total precipitation during the vegetation period (P_{Σ}-VP), trend equation and trend lines (right column) from 1949 to 2018 at selected meteorological stations in Bačka.

The main results (*Table 4, Fig. 2*) for the trend equations in twenty time series are: a) in nineteen time series the trend is positive; b) in one of the time series the trend is negative (BP-YT). The analysis based on MK test has led to the following conclusions: a) in eleven out of twenty time series, there is a statistically significant positive trend, where it is necessary to apply the hypothesis *Ha*; b) in nine out of twenty time series there is no trend, therefore it is necessary to accept the hypothesis *Ho*.

Table 4. The main results of the analysis of air temperature and precipitation trends for 20 time series

Time series	Trend equation	Classical MK test
BP-YT	*Negative trend*	*significantly positive trend*
BP-$\mathbf{T}_{mean}$-VP	*Positive trend*	*significantly positive trend*
BP-YP	*Positive trend*	*no trend*
BP-$\mathbf{P}_{\Sigma}$-VP	*Positive trend*	*no trend*
B-YT	*Positive trend*	*significantly positive trend*
B-$\mathbf{T}_{mean}$-VP	*Positive trend*	*significantly positive trend*
B-YP	*Positive trend*	*no trend*
B-$\mathbf{P}_{\Sigma}$-VP	*Positive trend*	*no trend*
N-YT	*Positive trend*	*significantly positive trend*
N-$\mathbf{T}_{mean}$-VP	*Positive trend*	*significantly positive trend*
N-YP	*Positive trend*	*no trend*
N-$\mathbf{P}_{\Sigma}$-VP	*Positive trend*	*no trend*
P-YT	*Positive trend*	*significantly positive trend*
P-$\mathbf{T}_{mean}$-VP	*Positive trend*	*significantly positive trend*
P-YP	*Positive trend*	*no trend*
P-$\mathbf{P}_{\Sigma}$-VP	*Positive trend*	*no trend*
S-YT	*Positive trend*	*significantly positive trend*
S-$\mathbf{T}_{mean}$-VP	*Positive trend*	*significantly positive trend*
S-YP	*Positive trend*	*no trend*
S-$\mathbf{P}_{\Sigma}$-VP	*Positive trend*	*significantly positive trend*

According to the analyzed time series, the value of p is less than 0.0001 in eight cases. Such value was recorded in the following time series: BP-YT, BP-T_{mean}-VP, B-T_{mean}-VP, N-YT, P-YT, P-T_{mean}-VP, S-YT, and S-P_{Σ}-VP. The results obtained using MK test point to the existence of trend, according to which hypothesis *Ho* should be rejected and hypothesis *Ha* should be accepted. The risk of rejecting the hypothesis Ha in previously presented time series is less than 0.01%. For the time series N-T_{mean}-VP, the value of p is 0.0001. MK test points to the existence of trend, thus hypothesis Ho should be rejected and hypothesis Ha should be accepted. The risk of rejecting the hypothesis Ha is less than 0.01%. Furthermore, for the time series B-YT, the recorded value of p is 0.0002. The MK test points to the existence of trend, so hypothesis *Ho* should be rejected and hypothesis *Ha* should be accepted. The risk of rejecting hypothesis *Ha* is less than 0.02%. The MK test points out that there is only positive trend, when it comes to mean precipitation during the vegetation period for the time series S-P_{Σ}-VP. The recorded value of p is 0.045. In this case, we should reject the hypothesis *Ho* and accept the hypothesis Ha. The risk of rejecting the hypothesis *Ha* is 4.5%.

In the remaining time series related to mean annual precipitation and total precipitation during the vegetation period there is no trend, so the dominant hypothesis is *Ho*. The value of p for the time series N-P_{Σ}-VP is 0.0586, while the dominant hypothesis is *Ho*, and it should not be rejected. The risk of rejecting the hypothesis *Ho* is 5.87%. For the time series P-YP, the value of p is 0.0615, the dominant hypothesis is the *Ho,* and it should not be rejected. The risk of rejecting the hypothesis *Ho* is 6.15%. For the time series P-P_{Σ}-VP, the value of p is 0.0963, the dominant hypothesis is *Ho,* and it should not be rejected. The risk of rejecting the hypothesis *Ho* is 9.64%. For the time series S-YP, the value of p is 0.1304, the dominant hypothesis is *Ho,* and it should noy be rejected. The risk of rejecting the hypothesis *Ho* is 13.04%. For the time series N-YP, the value of p is 0.1455, the dominant hypothesis is *Ho,* and it should not be rejected. The risk of rejecting the hypothesis *Ho* is 14.55%. For the time series BP-P_{Σ}-VP, the value of p is 0.2438, the dominant hypothesis is *Xo,* and it should not be rejected. The risk of rejecting the hypothesis *Xo* is 24.39%. For the time series B-P_{Σ}-VP, the value of p is 0.2954, the dominant hypothesis is *Xo* and it should not be rejected. The risk of rejecting the hypothesis *Xo* is 29.54%. For the time series BP-YP, the value of p is 0.8480, the dominant hypothesis is *Xo,* and it should not be rejected. The risk of rejecting the hypothesis *Xo* is 84.80%. For the time series B-YP, the value of p is 0.8520, the dominant hypothesis is *Xo,* and it should not be rejected. The risk of rejecting the hypothesis *Xo* is 85.20%.

4.2. The geographical information system (GIS) and the modeling of data

The spatial distribution of mean annual air temperature (YT) and mean air temperature during the vegetation period (T_{mean}-VP) from 1949 to 2018, as well as the projection of the chosen variables from 2018 to 2050 are shown in *Fig. 3*.

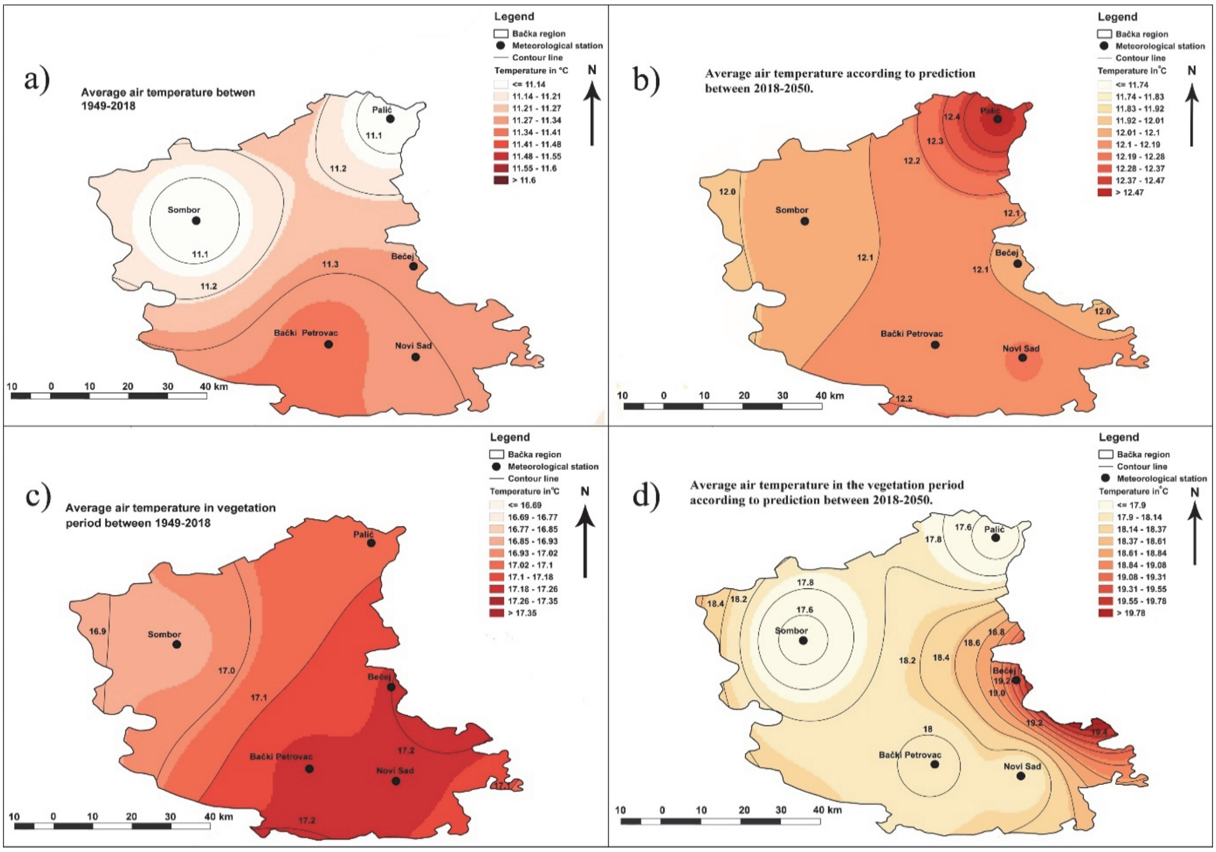

Fig. 3. Spatial distribution of air temperature values in Bačka: a) mean annual air temperature (YT) from 1949 to 2018; b) mean annual air temperature (YT) from 2018 to 2050; c) mean air temperature during the vegetation period (T_{mean}-VP) from 1949 to 2018; d) mean air temperature (T_{mean}-VP) during the vegetation period from 2018 to 2050.

During the reference period, the southern parts are characterized by prominent air temperature (above 11.3 °C). The values of temperature are the lowest in the area of Palić and Sombor (above 11.1 °C). In the projections of YT, there is a prominent increase comparing to the period 1949–2018, especially in the northern part of Bačka (above 12.4 °C). Isotherms above 12.1 °C occupie the central part of the research area. Increasing of air temperature is more prominent in the eastern and western parts of Bačka (12.0 °C).

Mean air temperatures during the vegetation period (T_{mean}-VP) in the wider area of Bački Petrovac, Novi Sad, and Bečej are limited by the 17.2 °C isotherm. Northern and central parts have similar values (17.1 °C), whereas the lowest detected values are in the west (16.9 °C). The projection of mean temperature during the vegetation period implicates dynamic changes in the air temperature. The projected values reach 19.4 °C in the eastern part of Bačka. Minor changes are expected in the northern part of Bačka (17.6 °C). The area around Bački Petrovac and Novi Sad is limited by the 18.0 °C isotherm. Air temperature changes would be more intensive in the western parts of analyzed study area (18.4 °C).

The mean annual precipitation (YP) from 1949 to 2018 (*Fig. 4*) indicates semiarid conditions in the northern part of Bačka (below 560 mm). Results in western, southern, and eastern parts of Bačka are similar (below 600 mm). The projected values of mean annual precipitation indicates moderate increase in the northern part (below 570 mm). In the western, southern and eastern parts of Bačka, pluviometric changes will be almost identical to those from 1949 to 2018 (610 mm isohyet). In case of total precipitation, during the vegetation period (P_{Σ}-VP) the values are increased in the southern parts (400 mm), and mildly decreased in the western (390 mm) and northern parts (370 mm). Projected values of total precipitation during the vegetation period are not in accordance with the values of this variable from 1949 to 2018. It implicates that aridity in the northern part of Bačka would reach even more extreme values (310 mm isohyet). These phenological conditions would have consequences on vegetation, especially in agriculture. Semiarid conditions will mildly decrease in the eastern parts (410 mm), while its values will increase on the southern part of Bačka. Decrease of precipitation will be particularly intensive in Bački Petrovac (300 mm isohyet).

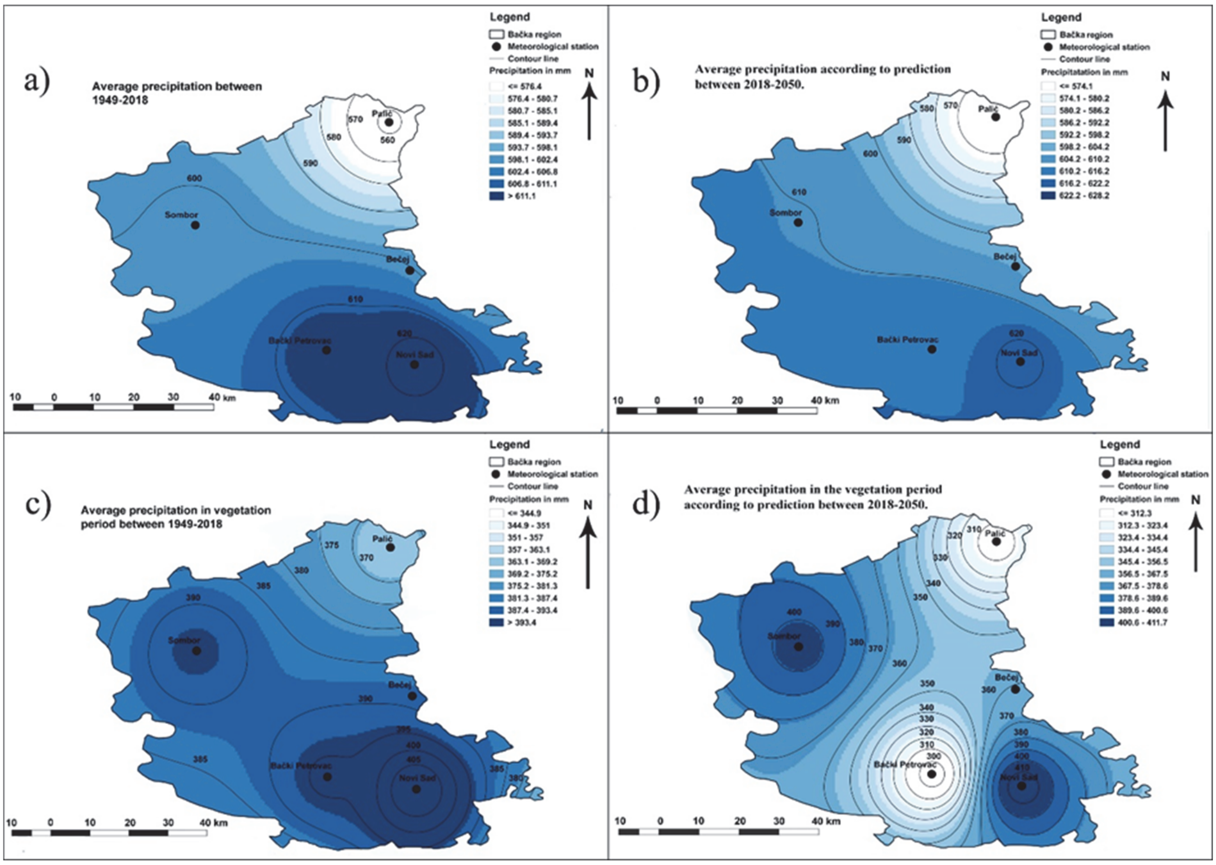

Fig. 4. Spatial distribution of precipitation values in Bačka: a) mean annual precipitation (YP) from 1949 to 2018; b) mean annual precipitation (YP) from 2018 to 2050; c) total precipitation during the vegetation period (P_{Σ}-VP) from 1949 to 2018; d) total precipitation during the vegetation period (P_{Σ}-VP) from 2018 to 2050.

5. Discussion

According to the Mann-Kendall test, all time series related to air temperature recorded a significantly increasing trend, while in nine out of ten precipitation time series did not detect any changes. It is difficult to find identical results accross the world, but certain similar patterns exist. *Wu et al*. (2016) detected significantly increasing annual air temperature and precipitation over the Dadu River basin in China. Analyzing the observed trends of precipitation and air temperature in the northeast part of Iran, *Minaei* and *Irannezhad* (2018) revealed: a) statistically increasing trend in case of annual precipitation (12.5% of the stations) and b) warming trend in case of annual air temperature (31% of the stations). *Tongal* (2019) investigated spatio-temporal changes of precipitation in the Antalya basin (Turkey). While the classical Mann-Kendall trend analysis could not reveal a significant trend for the stations, the modified Mann-Kendall test showed several significant increasing and decreasing trends in the precipitation values. Over the Mediterranean region, *Bilbao et al*. (2019) examined spatiotemporal patterns of air temperature in Spain (from 1950 to 2011) using the Mann-Kendall test. The decreasing trend of air temperature over Spain was recorded between 1950 and 1980, while significant warming was observed between 1980 and 2011. *Scorzini* and *Leopardi* (2019) detected a general, although not significant, negative trend in mean annual precipitation and significant warming in mean annual air temperature over the central part of Italy (Abruzzo region). However, this tendency has not been uniform from 1951 to 2012, but it has been characterized by a cooling phenomenon in the first 30 years (1951–1981), followed by an even stronger warming during the last three decades (1982–2012).

According to the possible climate scenario derived from the BCC Climate System Model (BCC-CSM2-MR), the increasing of air temperature will be pronounced, especially during the vegetation period. It is expected that, northern parts of Bačka become warmer compared to the reference period. The projected changes of mean precipitation will be similar in comparasion to the presented results from 1949 to 2018. Different results compared to the reference period could be expected in the total precipitation during the vegetation period. Changes will be manifested through a reduction of total precipitation. Projections of selected parameters represent the part of regional climate scenario. *Tarawneh* and *Chowdhury* (2018) examined future trends of climate changes in Saudi Arabia. For the RCP8.5 scenario, an increase of temperature occurred in the ranges from 0.8 to 1.6 ℃ (2025–2044) from 0.9 to 2.7 ℃ (2045–2064), and from 0.7 to 4.1 ℃ (2065–2084), respectively. However, precipitation showed variable patterns with respect to emission scenarios and assessment periods. In most regions, the RCP6 scenario showed a decrease in the rainfall from the reference period, while RCP8.5 and RCP2.6 showed variable patterns. For example, *Lionello* and *Scarascia* (2018) considered that air temperature will increase 20% more than the global average, while precipitation will decrease at a rate around 20 mm during the 21st century over the Mediterranean region. Climate conditions will be more severe on the territory of Iran (*Senatore et al*., 2019). According to the RCP4.5 scenario (from 2070 to 2099), the mean annual air temperature will increase by 2.4 ℃, while the mean annual precipitation will decrease by 20%. *Yin et al*. (2020) examined the long-term projections derived from a regional climate model (RCM) in the northwestern part of China. It is expected that the annual precipitation will rise by about 23.6 and 35.3 mm under the RCP 4.5 and 8.5 scenarios, respectively, while spatially averaged annual temperature will rise by about 1.95 and 1.10°C. On the territory of Serbia, *Kržič et al*. (2011) implicated: a) a projected increase in the air temperature from 2 ℃ to 4 ℃ based on regional climate models EBU-POM, b) a decrease in the precipitation from 13 mm to 6 mm (2071 to 2100). *Vuković et al*. (2018) predicted that global warming in Serbia would cause an increase in the mean annual air temperature by over 2.5 ℃ according to the stable scenario (RCP4.5) and over 5 ℃ according to the scenario of constant rise (RCP8.5). Total ammounts of precipitation do not display any significant change, apart from the reduction in the summer precipitation, along with the increase of intensity and frequency.

Analyzed results in terms of increasing trends of air temperature and no changes in precipitation trends indicate less available water resources for vegetation. For this reason, a possible aridity condition is a function of evapotranspiration rather than just a function of precipitation. These facts were confirmed in the paper of *Gocic* and *Trajkovic* (2014b). Authors noticed the statistically significant positive trends of reference evapotranspiration (ET_o) accross meteorological stations located in Bačka (Novi Sad, Sombor, and Palić). However, in order to confirm these facts in future research on the relationship between air temperature, precipitation, and evapotranspiration, it is necessary to include a larger number of meteorological stations in the territory of Bačka.

Sustainable agricultural production demands some adaptation measures in terms of drought and aridity. Possible negative effects of these phenomena can be mitigated by appropriate monitoring. From the above mentioned aspect, *Jovanović et al*. (2013) proposed the WAHASTRAT (*“Water shortage hazard and adaptive water management strategies in the Hungarian-Serbian crossborder region“*) project. The aim of this project was to find integrated water management solutions for the increasing problem of water shortage. In order to implement the project, a network of eight automatic measurement stations was set up in Southeast Bačka. Study area covers about 1,000 km² or 12% of Bačka. The presented results indicate that it would be necessary to expand the existing network of stations on the whole territory of Bačka in order to adeaqutely monitor the moisture deficit. Two important indicators make the agricultural production unsustainable nowadays: a) neglect or absence of irrigation systems, b) absence of adequate methodology of forecast of natural hazards, such drought and aridity, while such methodologies could help in prevention and reduction of damage caused by these hazards (*Armenski et al*., 2014).

Interaction between manifested climate changes and sustainability issues can also be reflected on tourism and on Ramsar wetland areas over the Bačka region. According to the observed and projected values of air temperatures, the effects of the urban heat island (UHI) can be manifested in urbas areas of Novi Sad, Subotica, and Sombor. For example, *Milošević et al*. (2020) noticed the existence of discomfort zones in urban area of Novi Sad by analyzing human thermal comfort that can affect tourism activity. On the territory of Bačka three Ramsar wetlands are located: the Special Nature Reserve "Gornje Podunavlje" (19,605 ha), the Special Nature Reserve "Koviljsko-petrovaradinski rit (5,895 ha), and the Special Nature Reserve "Ludaško jezero" (846 ha) (*Panjković* and *Stojnić*, 2014). The mentioned wetlands are climate sensitive, thus the manifested climatic patterns can lead to: a) the reduction of areas under hydrophilic vegetation and b) can cause uneven water regime. These areas are centers of heterogeneous biodiversity, so endangerment or extinction of plant and animal species is possible (*Stojanović*, 2005). Such problems must also be addressed through the preparation of planning documents in order to take adequate measures and to propose appropriate solutions. Therefore, results presented in this way could be used as a basis of policy, spatial planning, and regional development.

6. Conclusions

This paper provided the analysis of mean annual air temperature, mean air temperature during the vegetation period, mean annual precipitation, and total precipitation during the vegetation period (from 1949 to 2018). Beside statistical analysis of observed changes, in this paper a GIS modeling of a possible climate scenario over Bačka region (from 2018 to 2050) was performed. Selected trends in 20 time series were analyzed using (1) the trend equation, (2) the trend magnitude calculated from the trend equation, and (3) the MK test in the classical declaration. The main conclusions can be summarized as follows:

a) In accordance with the trend equations, positive trends were found in 18 out of 20 time series; in one of the time series there is no trend.
b) Negative trend was found only in one case.
c) Using the classical MK test, significant positive trends were found in 11 series, while in 9 cases there is no change.
d) A possible climate scenario (from 2018 to 2050) implicates that the increase in mean air temperatures would be dominant in comparison with the period from 1949 to 2018.

e) The changes of mean temperature during the vegetation period would be more intensive. The largest differences in a possible scenario would be in the eastern and western parts of Bačka.

f) Changes in the total precipitation during the vegetation period will give more certain image in comparasion with the mean annual precipitation. Semiarid conditions will be recorded in most parts of the region. Therefore, adaptation measures against potential drought and aridity problems are needed.

In this paper, the priority was given to the GIS method of climate projections rather than to the existing numerical models. In order to present the advantages and disadvantages of the GIS method, it is necessary to have more studies involving its application. Although Bačka occupies 9.8% of the territory of Serbia, it is of great importance to take into consideration smaller regions with specific features (e.g., agricultural significance of Bačka) for the purpose of future studies of climate projections on a national scale.

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References

Ahmadi, F., Nazeri Tahroudi, M., Mirabbasi, R., Khalili, K., and *Jhajharia, D.,* 2018: Spatiotemporal trend and abrupt change analysis of temperature in Iran. *Meteorol. Appl. 25*, 314–321. https://doi.org/10.1002/met.1694

Almazroui, M., Saeed, S., Islam, M.N., Khalid, M.S., Alkhalaf, A.K., and *Dambul, R.,* 2017: Assessment of uncertainties in projected temperature and precipitation over the Arabian Peninsula: a comparison between different categories of CMIP3 models. *Earth Syst. Environ. 1*, 12. https://doi.org/10.1007/s41748-017-0012-z

Armenski, T., Stankov, U., Dolinaj, D., Mesaroš, M., Jovanović, M., Pantelić, M., Pavić, D., Popov, S., Popović, L., Frank, A., and Ćosić, Đ., 2014: Social and economic impact of drought on stakeholders in agriculture. *Geographica Pannonica 18*(2), 34–42. https://doi.org/10.5937/GeoPan1402034A

Arnell, N.W., Lowe, J.A., Challinor, A.J., and *Osborn, T.J.,* 2019: Global and regional impacts of climate change at different levels of global temperature increase. *Climat. Change 155,* 377–391. https://doi.org/10.1007/s10584-019-02464-z

Berić, M., Zelenhasić, E., and *Srđević, B.,* 1990: Extreme Dry Weather Intervals of the Growing Season in Bačka, Yugoslavia. *Water Resour. Manage. 4*, 79–95. https://doi.org/10.1007/BF00429799

Bilbao, J., Román, R., and *De Miguel, A.,* 2019: Temporal and spatial variability in surface air temperature and diurnal temperature range in Spain over the period 1950 2011. *Climate 7*(1),16. https://doi.org/10.3390/cli7010016

Bucchignani, E., Mercogliano, P., Panitz, J.H., and *Montesarchio, M.,* 2018: Climate change projections for the Middle East–North Africa domain with COSMO-CLM at different spatial resolutions. *Adv. Climate Change Res. 9*, 66–80. https://doi.org/10.1016/j.accre.2018.01.004

Danandeh Mehr, A. and *Vaheddoost, B.,* 2020: Identification of the trends associated with the SPI and SPEI indices across Ankara, Turkey. *Theor. Appl. Climatol. 139*, 1531–1542. https://doi.org/10.1007/s00704-019-03071-9

Feidas, H., Makrogiannis, T., and *Bora-Senta, E.,* 2004: Trend analysis of air temperature time series in Greece and their relationship with circulation using surface and satellite data: 1955–2001. *Theor. Appl. Climatol. 79*, 185–208. https://doi.org/10.1007/s00704-004-0064-5

Fischer, E.M., Sedláček, J., Hawkins, E., and *Knutti, R.,* 2014: Models agree on forced response pattern of precipitation and temperature extremes. *Geophys. Res. Lett. 41*, 8554–8562. https://doi.org/10.1002/2014GL062018
Gavrilov, M.B., Lukić, T., Janc, N., Basarin, B., and *Marković, S.B.,* 2019: Forestry Aridity Index in Vojvodina, North Serbia. *Open Geosci. 11*(1), 367–377. https://doi.org/10.1515/geo-2019-0029
Gavrilov, M.B., Marković, S.B., Janc, N., Nikolić, M., Valjarević, A., Komac, B., Zorn, M., Punišić, M., and Bačević, N., 2018: Assessing average annual air temperature trends using the Mann–Kendall test in Kosovo. *Acta Geographica Slovenica 58*(1), 8–25. https://doi.org/10.3986/AGS.1309
Gavrilov, M.B., Marković, S.B., Jarad, A., and *Korać, V.M.,* 2015: The analysis of temperature trends in Vojvodina (Serbia) from 1949 to 2006. *Thermal Sci. 19*, 339–350. https://doi.org/10.2298/TSCI150207062G
Gavrilov, M.B., Tošić, I., Marković, S.B., Unkašević, M., and *Petrović, P.,* 2016: The analysis of annual and seasonal temperature trends using the Mann-Kendall test in Vojvodina, Serbia. *Időjárás 122*, 203–216. https://doi.org/10.28974/idojaras.2018.2.6
Gocić, M., and *Trajković, S.,* 2014a: Spatiotemporal characteristics of drought in Serbia. *J. Hydrol. 510*, 110–123. https://doi.org/10.1016/j.jhydrol.2013.12.030
Gocic, M. and *Trajkovic, S., 2014b*: Analysis of trends in reference evapotranspiration data in a humid climate. *Hydrol. Sci. J. 59*, 165–180. https://doi.org/10.1080/02626667.2013.798659
Gocic, M., Trajkovic, S., and *Milanovic, M.,* 2020: Precipitation and Drought Analysis in Serbia for the Period 1946–2017. In (eds: *Negm, A., Romanescu, G.,* and *Zelenakova, M.*) Water Resources Management in Balkan Countries. Springer Water. Springer, Cham. https://doi.org/10.1007/978-3-030-22468-4_11
Hazewinkel, M., 1990: Encyclopaedia of Mathematics. Kluwer Academic Publishers, Dordrecht. https://doi.org/10.1007/978-94-009-5991-0
Hrnjak, I., Lukić, T., Gavrilov, M.B., Marković, S.B., Unkašević, M., and *Tošić, I.,* 2014: Aridity in Vojvodina, Serbia. *Theor. Appl. Climatol. 115*, 323–332. https://doi.org/10.1007/s00704-013-0893-1
Hulme, M., 2017: Climate Change, Concept of. In (eds: *Richardson, D., Castree, N., Goodchild, M.F., Kobayashi, A., Liu, W.,* and *Marston, R.A.*) International Encyclopedia of Geography: People, the Earth, Environment and Technology. Black Wiley & Sons, Oxford. https://doi.org/10.1002/9781118786352.wbieg0343
Janković, A., Podraščanin, Z., and *Djurdjević, V.,* 2019: Future climate change impacts on residential heating and cooling degree days in Serbia. *Időjárás 123*, 351–370. https://doi.org/10.28974/idojaras.2019.3.6
Javari, M., 2016: Trend and homogeneity analysis of precipitation in Iran. *Climate 4*(3), 23. https://doi.org/10.3390/cli4030044
Jovanović, M., Pavić, D., Mesaroš, M., Stankov, U., Pantelić, M., Armenski, T., Dolinaj, D., Popov, S., Ćosić, Đ., Popović, Lj., Frank, A., and Crnojević, V., 2013: Water shortage and drought monitoring in Bačka region (Vojvodina, North Serbia) – setting-up measurement stations network. *Geographica Pannonica 17*(4), 114–124. https://doi.org/10.5937/GeoPan1304114J
Kržič, A., Tošić, I., Djurdjević, V., Veljović, K., and *Rajković, B.,* 2011: Changes in climate indices for Serbia according to the SRES-A1B and SRES-A2 scenarios. *Climate Res. 49*, 73–86. https://doi.org/10.3354/cr01008
Lazić, L., Marković, S., and *Pavić, D.,* 2004: Average and extreme precipitation heights in Bačka (1951-1990). *Geographica Pannonica 8*, 4–10. https://doi.org/10.5937/GeoPan0408004L
Li, X., and *Cheng, G.,* 1999: A GIS-aided response model of high-altitude permafrost to global change. *Sci. China Ser. D: Earth Sci. 42*, 72–79. https://doi.org/10.1007/BF02878500
Lionello, P., and *Scarascia, L.,* 2018: The relation between climate change in the Mediterranean region and global warming. *Regional Environ. Change 18*, 1481. https://doi.org/10.1007/s10113-018-1290-1
Milošević, D., Savić, S., Arsenović, D., Lužanin, Z., and *Dunjić, J.*, 2020: Analysis of human thermal comfort in Central European City during summer of 2015: A case of Novi Sad (Serbia). *Bulletin of the Serbian Geographical Society 100*(1), 31-39. https://doi.org/10.2298/GSGD2001031M

Minaei, M., and *Irannezhad, M.,* 2018: Spatio-temporal trend analysis of precipitation, temperature, and river discharge in the northeast of Iran in recent decades. *Theor. Appl. Climatol. 131*, 167–179. https://doi.org/10.1007/s00704-016-1963-y

Mudelsee, M., 2019: Trend analysis of climate time series: A review of methods. *Earth-Sci. Rev. 190*, 310–322. https://doi.org/10.1016/j.earscirev.2018.12.005

Nourani, V., Danandeh Mehr, A., and *Azad, N.,* 2018: Trend analysis of hydroclimatological variables in Urmia lake basin using hybrid wavelet Mann–Kendall and Şen tests. *Environ. Earth Sci. 77*, 207. https://doi.org/10.1007/s12665-018-7390-x

Nourani, V., Ghasemzade, M., Danande Mehr, A., and *Sharghi, E*., 2019: Investigating the effect of hydroclimatological variables on Urmia Lake water level using wavelet coherence measure. *J. Water Climate Change 10*, 13–29. https://doi.org/10.2166/wcc.2018.261

Nouri, M., and *Bannayan, M.,* 2018: Spatiotemporal changes in aridity index and reference evapotranspiration over semi-arid and humid regions of Iran: trend, cause, and sensitivity analyses. *Theor. Appl. Climatol.136*, 1073–1084. https://doi.org/10.1007/s00704-018-2543-0

Orus, R., Hernandez-Pajares, M., Juan, J.M., and *Sanz, J.,* 2005: Improvement of global ionospheric VTEC maps by using kriging interpolation technique. *J. Atmos. Solar-Terr. Phys. 67*, 1598–1609. https://doi.org/10.1016/j.jastp.2005.07.017

Panda, A., and *Sahu, N.,* 2019: Trend analysis of seasonal rainfall and temperature pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India. *Atmosp. Sci. Lett. 20*(10), e932. https://doi.org/10.1002/asl.932

Panjković, B., and *Stojnić, N.,* 2014: Biodiversity and protected areas. In (eds: *Puzović, S*., and *Radovanović-Jovin, H*.) Environment in Autonomous Province of Vojvodina: state, challenges-perspectives. Provincial Secretariat for Urbanism, Construction and Environmental Protection, Novi Sad. 168–211.

Rajić, M., 2004: Klimatske promene i potrebe za vodom u regionu Južne Bačke. *Letop. naučn. rad. Poljoprivrednog fakulteta*, *28*(1), 137–145. (In Serbian)

Rajić, M., and *Rajić, M.,* 2005: Prosečne padavine na području Bačke. *Letop. naučn. rad. Poljoprivrednog fakulteta*, *29*(1), 178-186. (In Serbian)

Rajić, M., and *Štula, S*., 2007: Klimatske promene i pojava suša na području Južne Bačke. *Letop. naučn. rad. Poljoprivrednog fakulteta*, *31*(1), 80–89. (In Serbian)

Rakićević, T., 1988: Regionalni raspored suše u SR Srbiji. *Glasnik Srpskog geografskog društva, 68*(1), 9-18. (In Serbian)

Razavi, T., Switzman, H., Arain, A., and *Coulibaly, P.,* 2016: Regional climate change trends and uncertainty analysis using extreme indices: A case study of Hamilton, Canada. *Climate Risk Manage. 13*, 43–63. https://doi.org/10.1016/j.crm.2016.06.002

Republic Hydrometeorological Service of Serbia, 2019: Meteorological Yearbook – Climatological Data. http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php Accessed 18 January 2020.

Sa'adi, Z., Shahid, S., Ismail, T., Chung, E., and *Wang, X.,* 2019: Trends analysis of rainfall and rainfall extremes in Sarawak, Malaysia using modified Mann–Kendall test. *Meteorol. Atmosph. Phys. 131*, 263–277. https://doi.org/10.1007/s00703-017-0564-3

Scorzini, A.R. and *Leopardi, M.,* 2019: Precipitation and temperature trends over central Italy (Abruzzo Region):1951–2012. *Theor. Appl. Climatol. 135*, 959–977. https://doi.org/10.1007/s00704-018-2427-3

Senatore, A., Hejabi, S., Mendicino, G., Bazrafshan, J., and *Irannejad, P.,* 2019: Climate conditions and drought assessment with the Palmer Drought Severity Index in Iran: evaluation of CORDEX South Asia climate projections (2070–2099). *Climate Dynam. 52*, 865–891. https://doi.org/10.1007/s00382-018-4171-x

Stojanović, V., 2005: Degradation and protection of wetlands in special nature reserves in Vojvodina. *Geographica Pannonica 9*, 24–28. https://doi.org/10.5937/GeoPan0509024S

Tarawneh, Q.Y., and *Chowdhury, S.,* 2018: Trends of climate change in Saudi Arabia: Implications on water resources. *Climate 6*(1), 8. https://doi.org/10.3390/cli6010008

Teegavarapu, S.V.R., 2019: Chapter 1-Methods for Analysis of Trends and Changes in Hydroclimatological Time-Series In (ed: *Teegavarapu, S.V.R.)*Trends and Changes in Hydroclimatic Variables. Elsevier. 1–89. https://doi.org/10.1016/B978-0-12-810985-4.00001-3

Tomaszkiewicz, M., Abou Najm, M., Beysens, D., Alameddine, I., Bou Zeid, E., and *El-Fadel, M.,* 2016: Projected climate change impacts upon dew yield in the Mediterranean basin. *Sci. Total Environ. 566–567*, 1339–1348. https://doi.org/10.1016/j.scitotenv.2016.05.195
Tongal, H., 2019: Spatiotemporal analysis of precipitation and extreme indices in the Antalya Basin, Turkey. *Theor. Appl. Climatol. 138*, 1735–1754. https://doi.org/10.1007/s00704-019-02927-4
Tošić, I., Hrnjak, I., Gavrilov, M.B., Unkašević, M., Marković, S.B., and Lukić, T., 2014: Annual and seasonal variability of precipitation in Vojvodina. *Theor. Appl. Climatol. 117*, 331–341. https://doi.org/10.1007/s00704-013-1007-9
Touseef, M., Chen, L., Yang, K., and *Chen, Y.,* 2020: Long-Term Rainfall Trends and Future Projections over Xijiang River Basin, China. *Adv. Meteorol. 2020* (article ID 6852148). https://doi.org/10.1155/2020/6852148
Urban Institute of Vojvodina, 2011: Regional Spatial Plan of AP Vojvodina until 2020. Novi Sad, Serbia. https://www.zavurbvo.co.rs/rppapv_cir.php. Accessed 02 March 2020.
Vuković, A.J., Vujadinović, M.P., Rendulić, S.M., Djurdjević, V.S., Ruml, M.M., Babić, V.P., and *Popović, D.P.,* 2018: Global warming impact on climate change in Serbia for the period 1961-2100. *Thermal Sci. 22*, 2267–2280. https://doi.org/10.2298/TSCI180411168V
Wilks, D., 2011: Frequentist Statistical Inference. In (ed: *Wilks, D.*) Statistical Methods in the Atmospheric Sciences (vol. 100, 3rd edition). Academic Press, United States. 133–185. https://doi.org/10.1016/B978-0-12-385022-5.00005-1
Wu, T., Lu, Y., Fang, Y., Xin, X., Li, L., Li, W., Jie, W., Zhang, J., Liu, Y., Zhang, L., Zhang, F., Zhang, Y., Wu, F., Li, J., Chu, M., Wang, Z., Shi, X., Liu, X., Wei, M., Huang, A., Zhang, Y., and Liu, X., 2019: The Beijing Climate Center Climate System Model (BCC-CSM): the main progress from CMIP5 to CMIP6. *Geosci. Model Develop*. 12, 1573–1600. https://doi.org/10.5194/gmd-12-1573-2019
Wu, Y., Wang, W., and *Wang, G.,* 2016: Detecting variation trends of temperature and precipitation for the Dadu River Basin, China. *Adv. Meteorol. 2016*, 11. https://doi.org/10.1155/2016/2564586
Yin, Z., Feng, Q., Yang, L., Deo, C.R., Adamowski, F.J., Wen, X., Jia, B., and *Si, J.,* 2020: Projected spatial patterns in precipitation and air temperature for China's northwest region derived from high-resolution regional climate models. *Int. J. Climatol. 40*, 3922–3941. https://doi.org/10.1002/joc.6435
Zadeh, M.S., Burn, H.D., and *O'Brien, N.,* 2020: Detection of trends in flood magnitude and frequency in Canada. *J. Hydrol.: Regional Studies 28*, 100673. https://doi.org/10.1016/j.ejrh.2020.100673
Zeleňáková, M., Purcz, P., Blišťan, P., Vranayová, Z., Hlavatá, H., Diaconu, D.C., and *Portela, M.M.,* 2018: Trends in precipitation and temperatures in Eastern Slovakia (1962–2014). *Water 10*, 727. https://doi.org/10.3390/w10060727
Zhou, B., Wen, H.Q., Xu, Y., Song, L., and *Zhang, X*., 2014: Projected Changes in Temperature and Precipitation Extremes in China by the CMIP5 Multimodel Ensembles. *J. Climate 27*, 6591–6611. https://doi.org/10.1175/JCLI-D-13-00761.1
Zittis, G., Hadjinicolaou, P., Klangidou, M., Proestos, Y., and *Lelieveld, J.,* 2019: A multi model, multi-scenario, and multi-domain analysis of regional climate projections for the Mediterranean. *Regional Environmental Change 19*, 2621–2635. https://doi.org/10.1007/s10113-019-01565-w