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CLIMATE TRENDS OF TEMPERATURE AND PRECIPITATION IN NIŠAVA RIVER VALLEY (SERBIA) FOR 1960–2015 PERIOD

Marija Prokić^{1*}

¹ University of Niš, Faculty of Science and Mathematics, Department of Geography, Niš, Serbia

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Abstract: Since climate plays a crucial role on our planet and is an inseparable part of all human activities, it is necessary to precisely record all parameters in order to estimate current climate conditions, climate characteristics of a certain region, as well as to try to predict and calculate further trends of climate change. Therefore, for the purpose of this paper, air temperature and precipitation of four meteorological stations in the Nišava river valley in Southeastern Serbia (municipalities of Dimitrovgrad, Pirot, Bela Palanka and Niš) have been considered for the period 1960–2015 along with statistical methods for analysis of these parameters and prediction of their trends. Results have shown that there is a positive trend in mean annual air temperatures and average seasonal air temperatures for the whole region which can influence natural processes and human activities. For precipitation, it can be concluded that no significant change in mean annual precipitation for the observed period has occurred. However, there is a great difference in the amount of precipitation between consecutive years, especially from 2000 onwards which can cause very dry years or years with floods.

Keywords: climate, temperature, precipitation, linear trend, Nišava valley

Introduction

There are many definitions of climate given by various authors with slight variations. According to the Intergovernmental Panel on Climate Change (IPCC) 2013 glossary, climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (Planton, 2013).

As climate greatly influences various aspects of planet Earth, natural processes on it and human activities, keeping climate data plays an essential role. It is necessary to precisely record all parameters in order to estimate current climate

* Correspondence to: marijaprokić91@gmail.com

conditions, climate characteristics of certain region, as well as to try to predict and calculate further trends of climate change.

According to the most commonly used Köppen climate classification, which depends on average monthly values of temperature and precipitation, the territory of Nišava valley could belong to the Cfwax type — Danube type of moderately warm and humid climate: the winter is somewhat drier than summer which is very warm, which is a characteristic of continental climate; maximum precipitation is recorded in early summer. Vojvodina, northern and eastern Serbia has this climate type (Dukić, 1998). Also there are influences from climates of neighboring basins, mostly from Wallachian Plain, then Pannonian Basin, along Morava valley, and the least from Aegean basin, through Vardar and Južna Morava valley (Marković, 1967). Rakićević (1980) has done climatic regionalization of Serbia and on the basis of that regionalization Nišava valley belongs to region II-13 and II-14. These are Niš-Leskovac climate region and Nišava valley region. The first one includes Niš-Aleksinac valley, Leskovac Dobrič and Toplica valley. This is the warmest region with the lowest precipitation in Serbia. Fogs are very rare, average cloudiness is low and the shortest duration of snow cover in Serbia is recorded. The second one is compared to the previous more severe as we go from west to the east as elevation increases.

Some research concerning Nišava River discharge variability has already been done for this area (Ducić & Luković, 2009), but analysis of temperature and precipitation was not the main focus. According to this paper, decrease in discharge was detected in the observed period (1961–2000) for all three profiles (Piro, Bela Palanka and Niš), which is consistent with the allegations and the IPCC about the dominant influence of anthropogenic greenhouse effect on reducing discharge in the rivers of Serbia. The authors concluded that in recent decades there isn't anything dramatically happening with climate, and present changes may be related to natural cycle. The aim of this paper is to focus on and analyze two main climate parameters – temperature and precipitation and discover their current trends and whether some significant change can be observed.

Data and methods

For the analysis of climate characteristics and trends of climate parameters data from meteorological stations in Dimitrovgrad, Piro and Niš were used for the period 1960–2015 and data from the station in Bela Palanka for the period 1991–2015. These data were acquired from the Republic Hydrometeorological

Service of Serbia. From east to west, the first meteorological station is in Dimitrovgrad which is principal meteorological station founded in 1926. Meteorological stations in Pirot and Bela Palanka are ordinary meteorological stations while meteorological station in Niš is principal meteorological station founded in 1889 and located in the central part of the city of Niš in Niš Fortress. Geographic coordinates of these four stations are shown in the Table 1 and their positions in the Nišava valley are represented in the Figure 1.

Table 1. Meteorological stations from which data were used

Meteorological station	Type of the station	Latitude	Longitude	Elevation (m)
Dimitrovgrad	Principal	43°01' N	22°45' E	450
Pirot	Ordinary	43°09' N	22°36' E	370
Bela Palanka	Ordinary	43°13' N	22°19' E	291
Niš	Principal	43°20' N	21°54' E	202

Data used were mean monthly air temperatures and mean annual air temperature, and monthly and yearly amounts of precipitation.

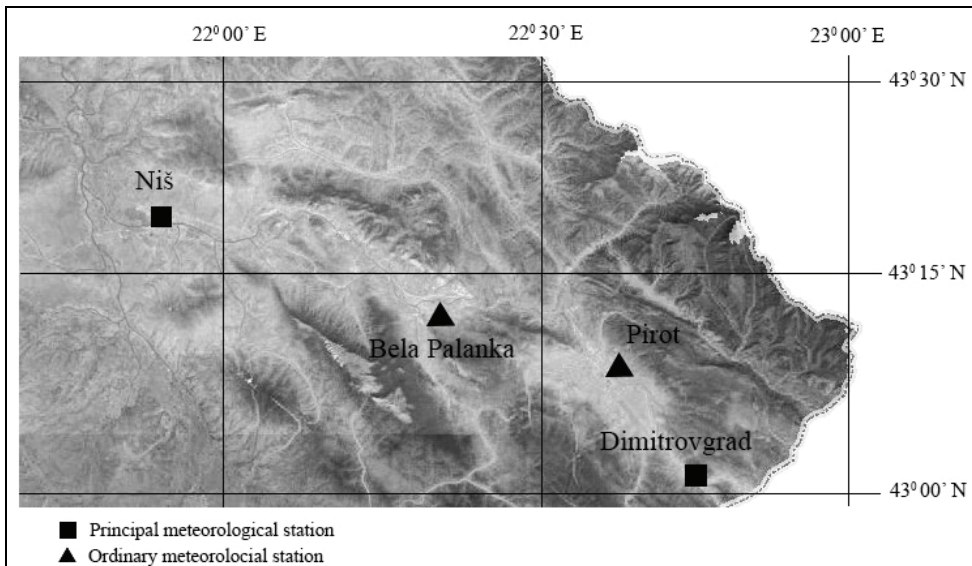


Figure 1. Position of meteorological stations in Nišava river valley

For meteorological stations in Dimitrovgrad and Pirot there were no available data for the period 1986–1989, and for the station in Pirot data from year 1962 was missing as well. Therefore, the method of linear interpolation was used to

fill in the missing data for the mean annual temperatures. In order to calculate trends of these climate parameters, statistical methods of linear trend estimation and extrapolation were used. Pearson's correlation coefficient was used to measure the linear correlation and Student's t-test was used to test linear trend significance

$$t = R \sqrt{\frac{n-2}{1-R^2}} \tag{1}$$

where R is Pearson's correlation coefficient, R_2 is determination coefficient and n series length.

Results and discussion

Analyzing the available data (Tables 2 and 3), it turned out that out of four stations in Nišava valley Dimitrovgrad has the lowest mean annual air temperature of 10.0 °C. Mean annual temperature in Pirot is 11.1 °C, in Bela Palanka 11.4 °C and in Niš 11.8 °C.

Table 2. Mean annual air temperatures (°C) on the territory of Nišava valley for the period 1960-2015

Meteorological station	Mean annual temperatures
Dimitrovgrad	10.0 °C
Pirot	11.1 °C
Bela Palanka*	11.4 °C
Niš	11.8 °C

This is not the consequence of the difference in latitude since it is quite small but is more the result of the difference in elevation between these stations.

Table 3. Mean monthly air temperatures (°C) on the territory of Nišava valley for the period 1960–2015

Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Dimitrovgrad	-0.9	0.9	5.0	10.0	14.8	18.1	19.8	19.6	15.4	10.7	5.7	0.9
Pirot	-0.2	1.9	6.2	11.2	16.0	19.3	21.2	20.9	16.6	11.6	6.4	1.7
Bela Palanka*	0.4	1.9	6.5	11.5	16.3	19.9	21.9	21.7	16.6	11.7	6.7	1.8
Niš	0.4	2.5	6.9	12.1	16.9	20.2	22.1	22.0	17.5	12.2	6.9	2.0

When average seasonal temperatures are analyzed (Figure 2) then average spring temperatures at all stations are slightly lower than average autumn temperatures. The difference between average spring and autumn temperatures in Niš is almost

insignificant (12.0 °C for springtime and 12.2 °C for autumn). The difference between average spring and autumn temperatures in Dimitrovgrad, Pirot and Bela Palanka is a little bigger, 10.0 °C and 10.6 °C for Dimitrovgrad, 11.1 °C and 11.5 °C for Pirot and 11.4 °C and 11.7 °C, which can be the result of higher elevation of these two stations and therefore longer periods with snow cover and more amount of energy needed for melting of snow after winter.

Average summer temperatures increase as we go along the Nišava valley downstream the Nišava River, from Dimitrovgrad to Niš (Dimitrovgrad 19.2 °C, Pirot 20.5 °C, Bela Palanka 21.2 °C and Niš 21.4 °C). In the same direction average winter temperatures also increase (Dimitrovgrad 0.3 °C, Pirot 1.1 °C, Bela Palanka 1.4 °C and Niš 1.6 °C), but they all have positive values. This increase of average summer temperatures and decrease of average winter temperatures is most likely due to the difference in elevation between these stations as it decreases from Dimitrovgrad to Niš.

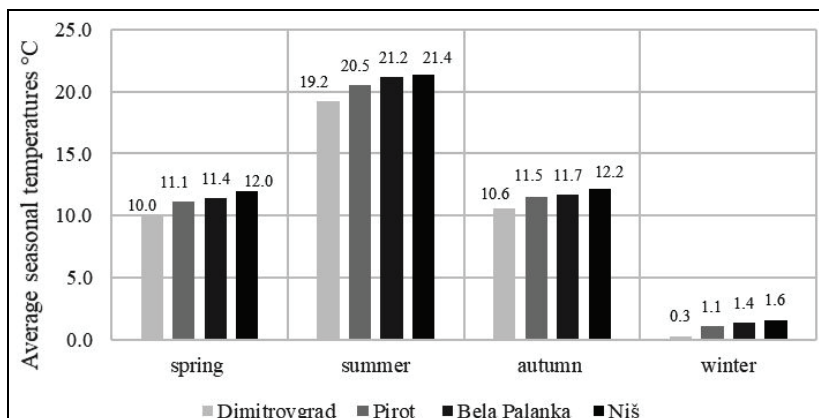


Figure 2. Average seasonal air temperatures (°C) for the period 1960–2015

When trend of air temperature during this analyzed period is considered it can be observed that there is a significantly positive trend of moderate correlation degree at three stations ($R = 0.5905$, $t = 5.3768$, $DF = 54$, $p \leq 0.05$ for Niš; $R = 0.6437$, $t = 6.1813$, $DF = 54$, $p \leq 0.05$ for Pirot; $R = 0.4223$, $t = 3.4236$, $DF = 54$, $p \leq 0.05$ for Dimitrovgrad). This means that the annual air temperatures are increasing (Figure 3). The most distinct value of increase is in Pirot and Niš while it is more moderate in Dimitrovgrad. If the trend of mean annual temperatures continues in the next period as well and stays unchanged then it is expected that in the year 2100 mean annual temperature will be 11.8 °C for Dimitrovgrad, 14.8 °C for Pirot and 14.8 °C for Niš. Similar results were presented by Ristić Vakanjac, Milovanović, Vakanjac, and Čokorilo Ilić (2014)

where it was predicted that mean annual temperature would be 11.2 °C for Dimitrovgrad. When these values are compared to the current mean annual temperatures for the observed period 1961–2015 then it is the increase of more than 3 °C, except for the station in Dimitrovgrad. For Bela Palanka, statistically significant correlation cannot be noted ($R = 0.5112$, $t = 0.8525$, $DF = 23$, $p > 0.05$), which might be due to shorter period of observation.

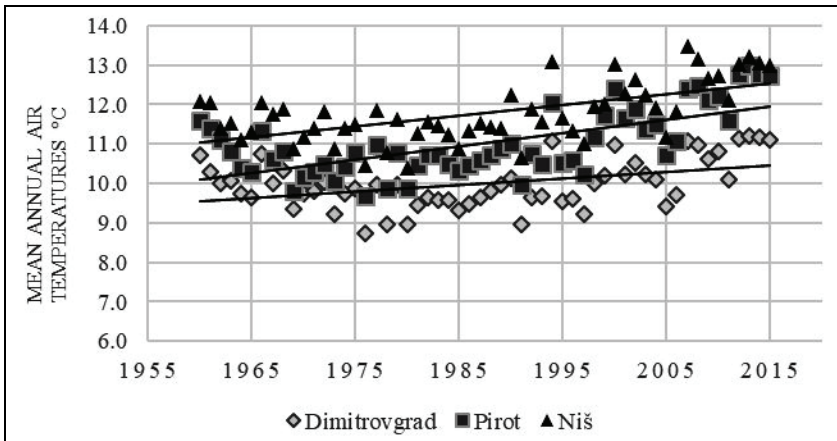


Figure 3. Linear trends of mean annual air temperatures (°C) for the period 1960–2015

Analysis of seasonal trends of air temperatures showed that at Bela Palanka meteorological station for the period 1991–2015 and all other meteorological stations for the period 1961–2015 there is a positive trend for spring, summer and winter (Figures 4a, 4b, 5, 6, 7a and 7b).

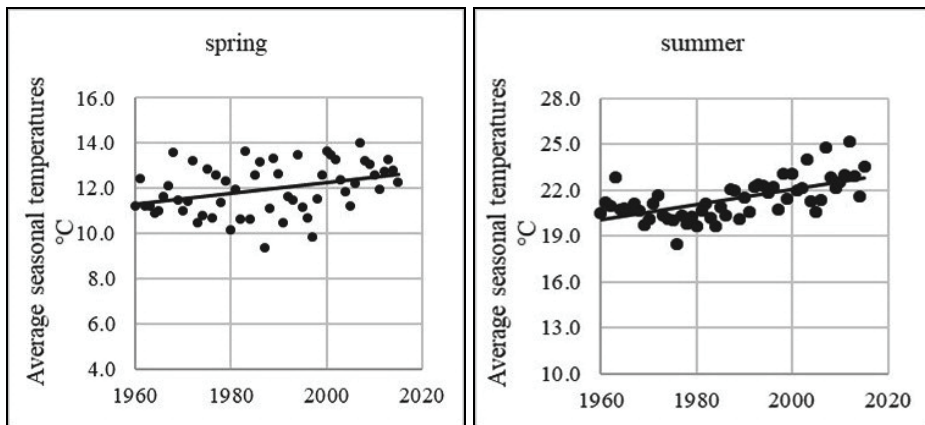


Figure 4a. Linear trends of average seasonal air temperatures (°C) for meteorological station Niš

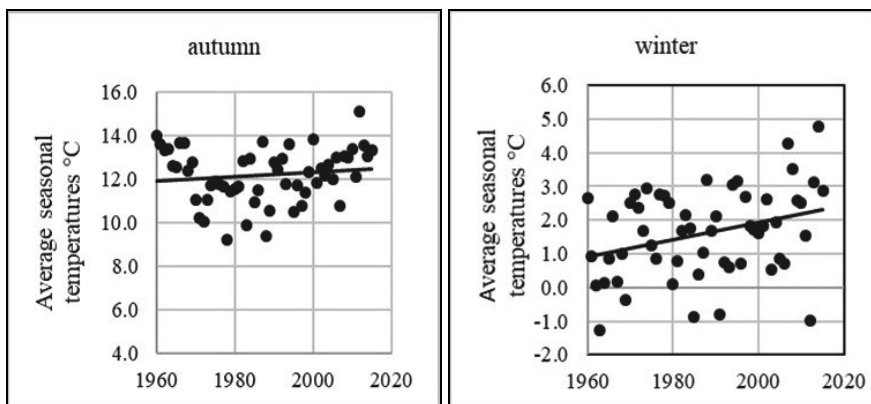


Figure 4b. Linear trends of average seasonal air temperatures (°C) for meteorological station Niš

All stations recorded the most distinct change in summer months. Autumn months show not so sharp trend of values for meteorological stations Pirot, Bela Palanka and Niš, while station in Dimitrovgrad shows a constant, neither increasing nor decreasing trend.

According to Rakićević (1980), this region is one of the driest regions in Serbia. If fluviometric gradients are compared, then places with same elevation and at similar latitudes get 1.11 mm less amount of rainfall on every kilometer from west to east per year. Even though many factors influence the amount of precipitation and its distribution during a year, and the way of its occurrence, atmospheric processes and relief have the most important and decisive role, as stated by Milovanović (2010). In the case of Nišava valley this correlation does not play a significant role since there is the difference in elevation among these four meteorological stations. Therefore, increasing elevation is the main reason why the amount of precipitation increases upstream from Niš to Dimitrovgrad. Also according to Milovanović (2014) in valleys where, with all directions of the movement of air masses, descending air flow prevails, precipitation is smaller, both in comparison with the surrounding mountains and gorges that connect the basins. In Niš, mean annual precipitation is 597.3 mm for the analyzed period 1960–2015. According to Rakićević (1976), Bela Palanka was the place with the smallest amount of mean annual precipitation (526 mm) for the period 1931–1960. In this paper analyzed period is 1991–2015 according to which mean annual precipitation is 612.9 mm. In Pirot, mean annual precipitation is 601.1 mm and 649.2 mm in Dimitrovgrad.

The difference in the amount of precipitation during this observed period can be significant. For example, minimum amount of precipitation in Niš (385 mm), Pirot (261 mm) and Dimitrovgrad (311 mm) was recorded in the year 2000, while the minimum of 320 mm of the observed period was in Bela Palanka in 2011, even though the year 2000 was also very dry here (358 mm). In Pirot and Dimitrovgrad, this is below 50% of the mean annual average precipitation of the observed period, 43.4% and 47.9% respectively. Maximum amount of precipitation for all four stations was recorded in 2014 (Niš 950 mm, Bela Palanka 831 mm, Pirot 914 mm, Dimitrovgrad 977 mm). In Niš, Pirot and Dimitrovgrad it is more than 50% higher than annual average precipitation (59.1%, 52.1% and 50.5%). Based on analyzed data it can be concluded that from the year 2000 onwards there are more occurrences of extreme dry and wet years.

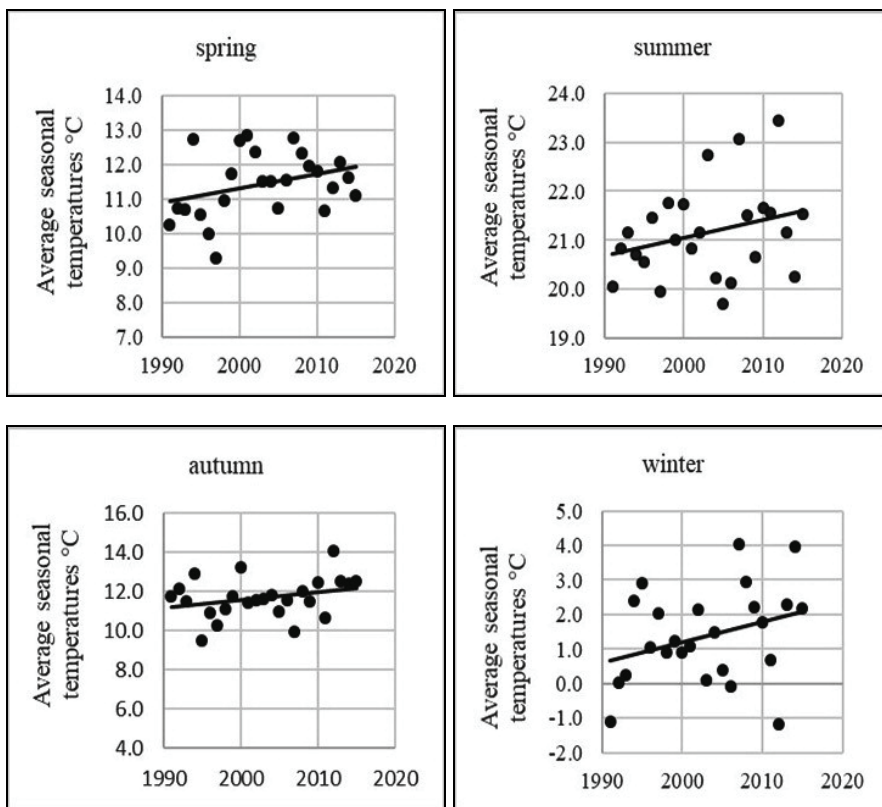


Figure 5. Linear trends of average seasonal air temperatures (°C) for meteorological station Bela Palanka

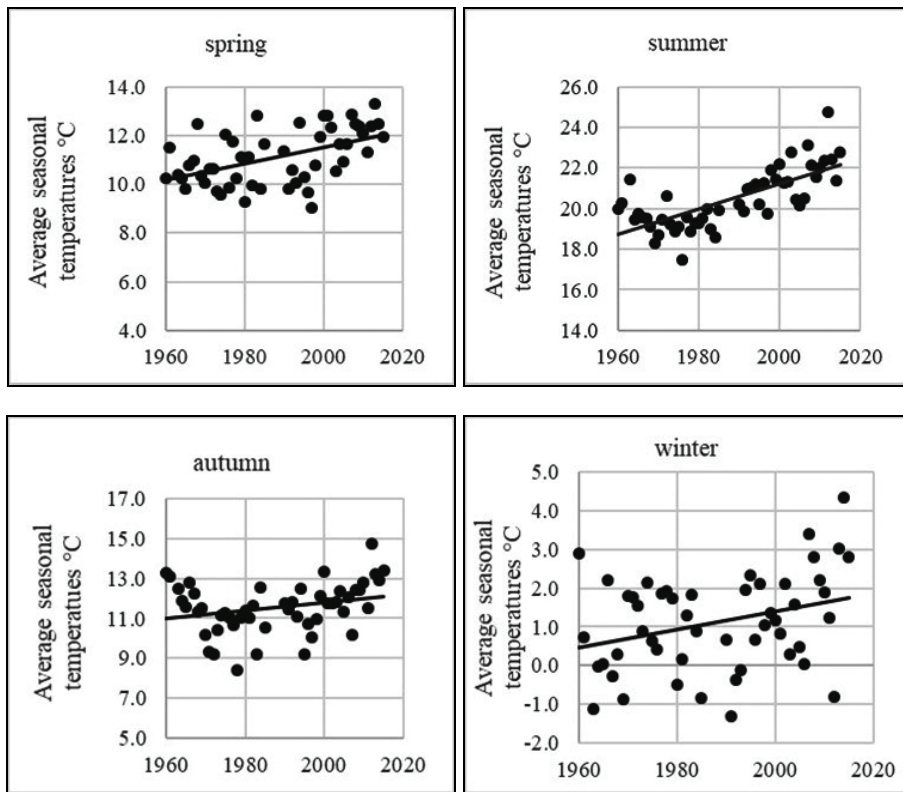


Figure 6. Linear trends of average seasonal air temperatures (°C) for meteorological station Pirot

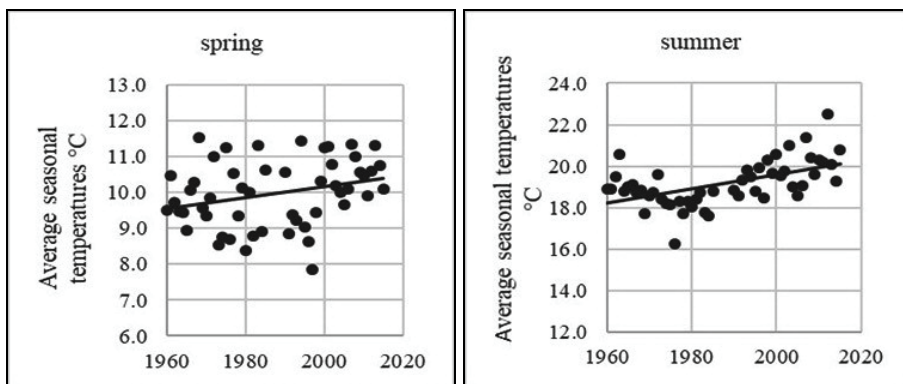


Figure 7a. Linear trends of average seasonal air temperatures (°C) for meteorological station Dimitrovgrad

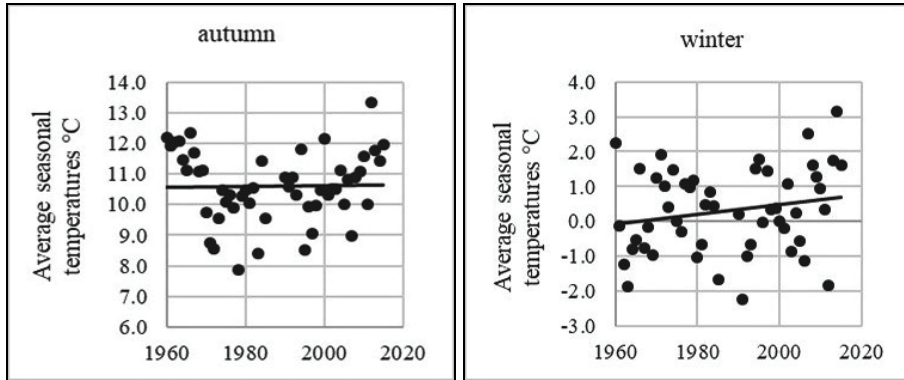


Figure 7b. Linear trends of average seasonal air temperatures (°C) for meteorological station Dimitrovgrad

If mean monthly precipitation is considered (Figures 8, 9, 10 and 11), then two periods of maximum and minimum precipitation can be observed. The first maximum is in late spring (May and June) for all stations, and the second is in autumn (November for Niš, Pirot and Dimitrovgrad and September and October for Bela Palanka). The first minimum is in January and the second is in August for Niš, Pirot and Dimitrovgrad and in July for Bela Palanka. It can be seen that all four stations have very similar precipitation regime. Taking in consideration that there are two periods of maximum and minimum precipitation, while continental regime has only one maximum and minimum, it was concluded that this part of Serbia has characteristics of two precipitation regimes — continental and Mediterranean. According to Rakićević (1976), Eastern Serbia has one transition type of precipitation regime which has characteristics of both continental and Mediterranean regimes. To be more specific, under the influence of Mediterranean precipitation regime in Eastern Serbia, maximum rainfall occurs in autumn, and under the influence of continental precipitation regime, maximum rainfall occurs in early summer. On the other hand, minimum rainfall in late summer is the result of Mediterranean regime influence, and minimum rainfall in winter is the result of continental. Therefore, in the valley of the Nišava River we have specific precipitation regime with characteristics of both continental and Mediterranean regimes, even though continental regime is more pronounced if the mean annual amount of precipitation and its distribution over months is taken into consideration.

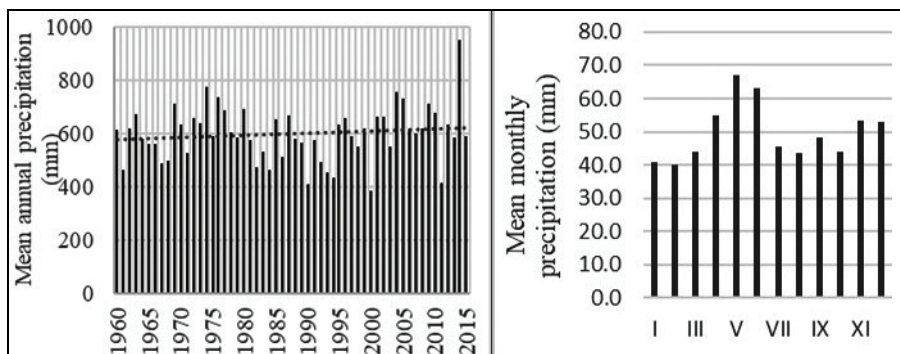


Figure 8. Mean annual precipitation and mean monthly precipitation (mm) for meteorological station Niš for period 1960–2015

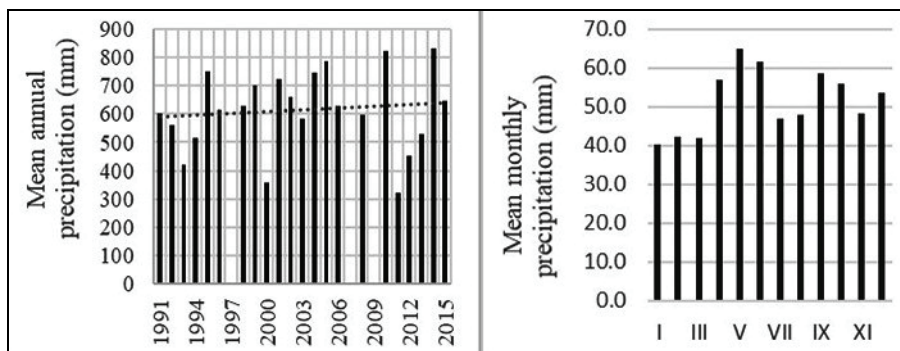


Figure 9. Mean annual precipitation and mean monthly precipitation (mm) for meteorological station Bela Palanka for period 1991–2015

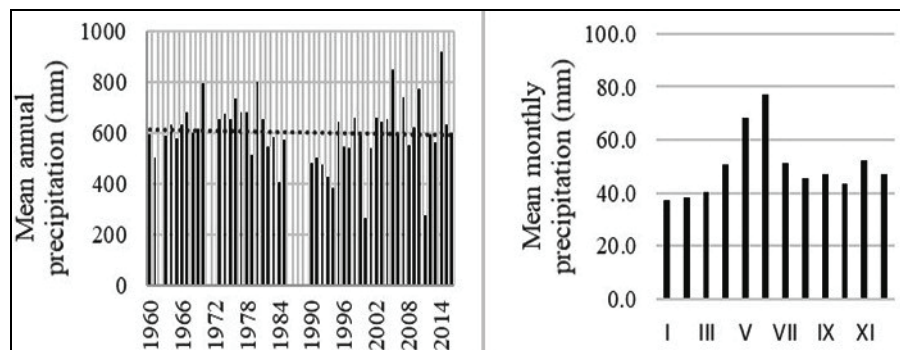


Figure 10. Mean annual precipitation and mean monthly precipitation (mm) for meteorological station Pirot for period 1960–2015

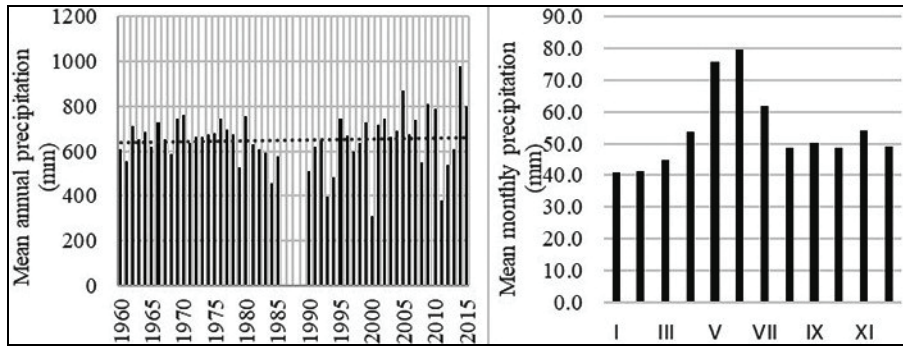


Figure 11. Mean annual precipitation and mean monthly precipitation (mm) for meteorological station Dimitrovgrad for period 1960–2015

Analyzing the trends of precipitation during different seasons (Figures 12a, 12b, 13, 14, 15a and 15b), an insignificant increasing trend for spring and autumn can be observed at all four meteorological stations (0.125 and 0.204 mm per year for Niš, 0.7254 and 0.1865 mm per year for Bela Palanka, 0.0683 and 0.1454 mm per year for Pirot, 0.1009 and 0.2324 mm per year for Dimitrovgrad). Insignificant negative trend of summer and winter mean amount of precipitation can be seen at all stations (-0.0415 and -0.0303 mm per year for Niš, -0.187 and -0.0809 mm per year for Pirot, -0.1144 and -0.0636 mm per year for Dimitrovgrad), except in Bela Palanka (-0.2197 and 0.1739 mm per year).

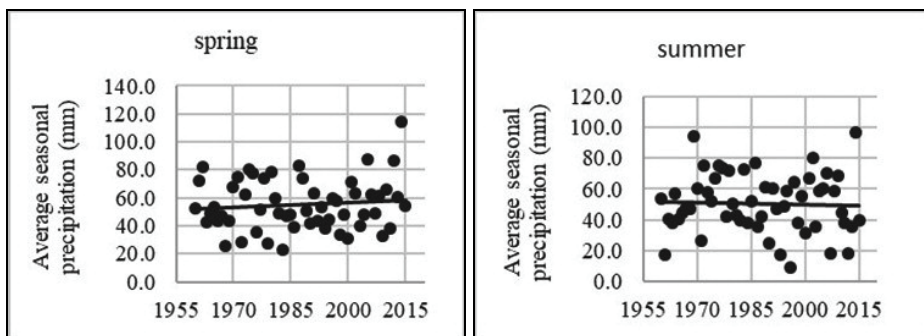


Figure 12a. Average seasonal precipitation (mm) in Niš for period 1960–2015

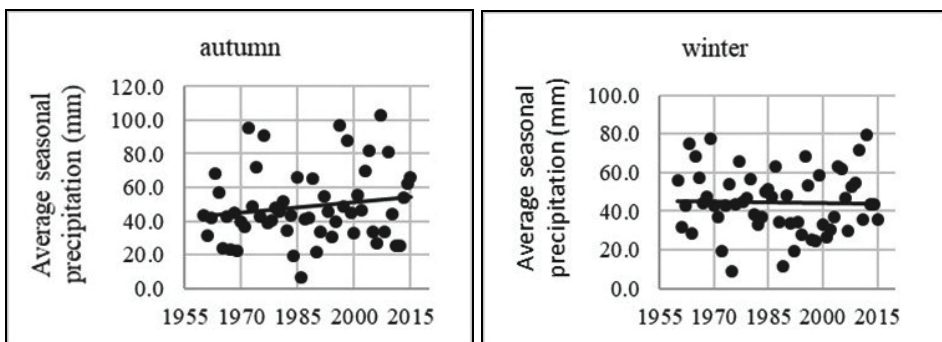


Figure 12b. Average seasonal precipitation (mm) in Niš for period 1960–2015

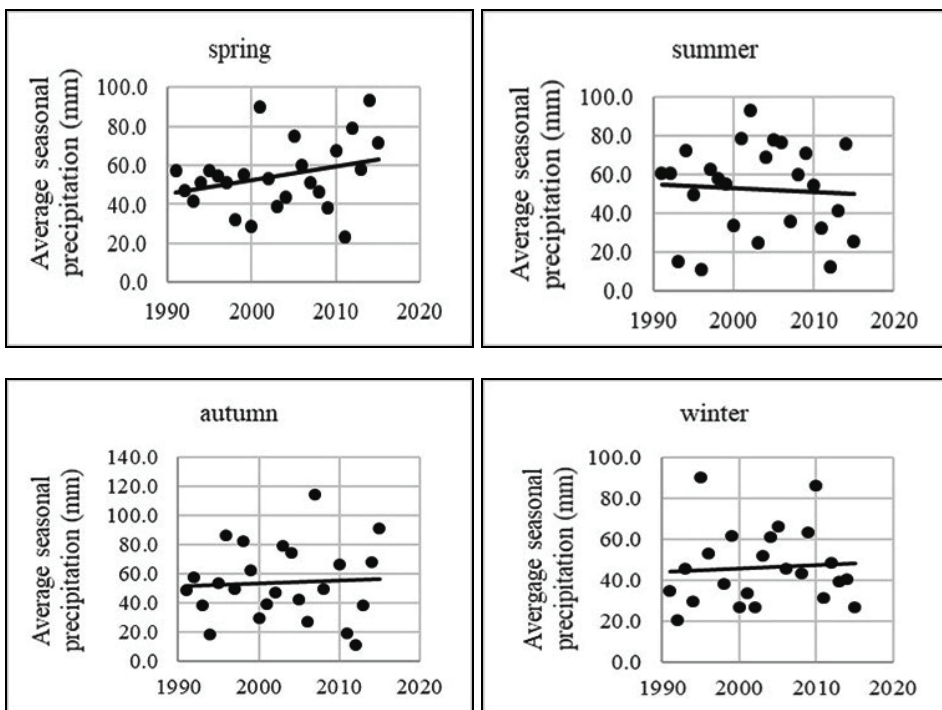


Figure 13. Average seasonal precipitation (mm) in Bela Palanka for period 1991–2015

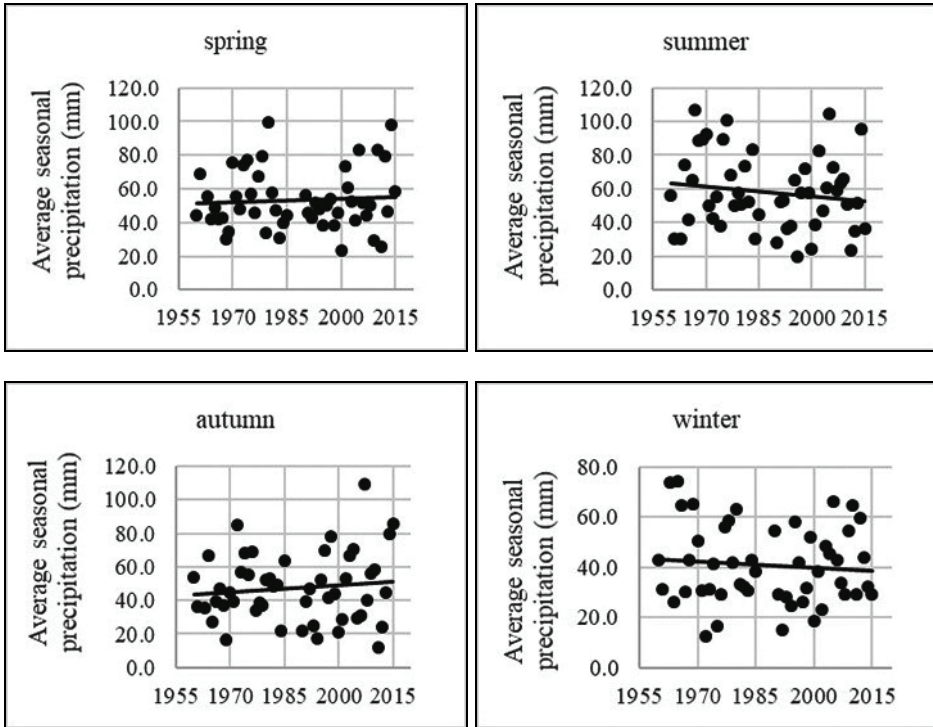


Figure 14. Average seasonal precipitation (mm) in Pirot for period 1960–2015

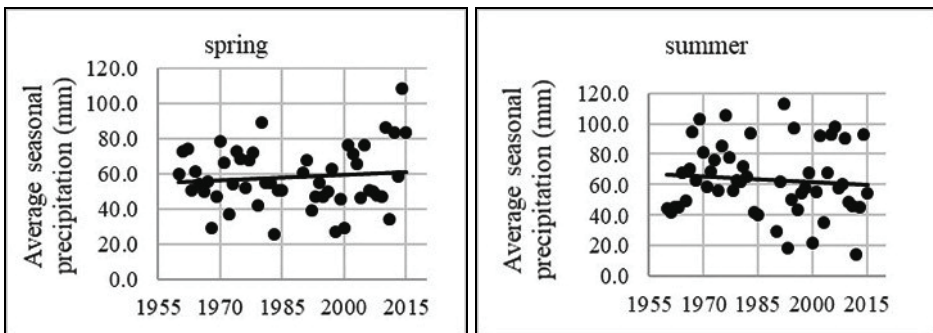


Figure 15a. Average seasonal precipitation (mm) in Dimitrovgrad for period 1960–2015

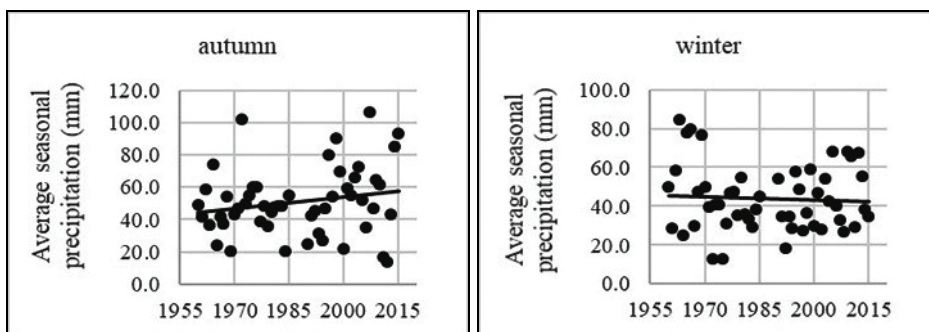


Figure 15b. Average seasonal precipitation (mm) in Dimitrovgrad for period 1960–2015

Conclusion

Based on the previously analyzed data on air temperature and precipitation and their trends in the Nišava river valley for the period 1960–2015, it can be concluded that inevitable changes in these climate parameters are happening and based on this analysis they will continue to be more prominent in the future.

When temperature is considered at all four meteorological stations along the Nišava River, there is a positive trend observed both for mean annual temperatures and average seasonal temperatures. Increasing air temperature during winter months will lead to less snow cover and the change in winter duration. Less snow cover can then influence underground water sources as well as ground (surface) water flows. On the other hand, increasing trend of temperature during summer months can lead to less amount of rainfall during this time which can result in occurrence of very dry periods that can in turn cause more regular forest fires. Increasing trend of air temperature can also have consequences in occurrence of drier periods due to increased evaporation which can influence amount of available drinking water and water resources, as well as agriculture.

If precipitation is considered for all four meteorological stations, it can be concluded that no significant change in mean annual precipitation for the observed period has occurred. However, one important change observed is the difference in amount of precipitation between consecutive years which can be very significant, especially from the year 2000 onwards. This, with a combination of the increase in temperatures, can cause very dry years and on the other hand more regular floods. Consequently, water resources will be endangered, and water supply of this region will face great problems.

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