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A statistical analysis of temperature and precipitation in Belgrade, Serbia (1961-2020)

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Abstract

The most significant effects of climate change are related to temperature and precipitation. Changes in precipitation and temperature patterns affect water resource capacity, agricultural activities, global biodiversity and emergency management. In this study, using two statistical models (Mann-Kendall and Pettit's test), climate data for the territory of Belgrade in the time interval 1961-2020 were processed. Trends were analyzed: average annual temperatures, average monthly temperatures, annual and monthly precipitation amounts. The aim of the research is to determine the statistical significance of the increasing/decreasing temperature and precipitation trends on a monthly and annual basis. Based on the obtained results, it was determined that the changing point of the annual temperature is in 1997, while a statistically significant increasing trend was observed in all months except November. The increasing trend recorded by the precipitation amount is 0.345 mm/year, but without statistical significance. The most significant results corresponding to July and October.
Keywords: *Trend, Mann-Kendall test, Pettit's test, precipitation, air temperature, City of Belgrade*

Introduction

Climate change is reflected in large fluctuations in climate averages that persist for decades or even longer periods. Although climate change occurs on a global scale, impacts often vary from region to region. In the 20th century numerous climatic anomalies were observed-poor monsoon years around the turn of the century, rapid Arctic warming into the 1920s, the Dust Bowl drought and heat waves in North America in the 1930s and drought in Australia, and cold winters and hot summers in Europe in the 1940s. These anomalous events occurred during a period of strong global-scale warming, which can be attributed to a combination of external forcing (particularly, greenhouse gas increases, combined with a hiatus in volcanic events) and internal decadal variability. During the 20th century, in most European regions, a temperature increase was observed (Trajkovic & Kolakovic, 2009; Gocic & Trajkovic, 2013; Hegerl et al.,2018). Climate reconstructions show that summer air temperatures in Europe in period 1986–2015 have been the warmest for at least 2000 years, and that they lie significantly outside the range of natural variability (Luterbacher et al., 2016). Based on data from 210 weather stations on the territory of Europe, temperature increase amounts 0.051°C/year in the period 1985-2020. The highest increase was recorded in spring, the lowest in autumn (Twardosz et al., 2021). Vyshkvarkova and Sukhonos (2022) investigating the spatial distribution of temperature and precipitation extremes in Eastern Europe, conclude that there are positive and statistically significant trends for warm extremes in all seasons, with maximum values in the winter season. In contrast, negative trends were obtained for cold extremes.

Each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global surface temperature in the first two decades of the 21st century (2001–2020) was 0.99 (0.84 to 1.10) °C higher than 1850–1900. Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C). Hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe. Globally averaged precipitation over land has likely increased since 1950, with a faster rate of increase since the 1980s. Mid-latitude storm tracks have likely shifted poleward in both hemispheres since the 1980s, with marked seasonality in trends (IPCC, 2021) According to NOAA (2022), all years in the period 2013-2021 belongs to the category of ten warmest years since measurements were made. Since 1981, the average increase in global temperature is 0.18°C per decade. In 2021 the western parts of the USA, southern South America, northern Africa and the Middle East were characterized by significantly below-average precipitation. A significant increase in annual precipitation during 2021 was observed in northern South America, eastern Europe, western and eastern parts of the Australian coast, and South Asia. Across Southern Europe, below-average rainfall was recorded in July. Dry conditions with high temperatures contributed to the spread of fires in southern and southwestern Turkey, as well as in north-eastern Spain. In Spain, during July 2021, only 57% of the average amount of July precipitation fell. However, parts of western Europe faced torrential rainfall that caused flooding between July 13 and 15. Some locations received at least twice their normal monthly precipitation in only three days. According to preliminary reports, over 140 deaths are attributed to the floods.

Branković et al. (2013) determined for Croatia that the positive trends of the average annual temperature are caused by a statistically significant increasing trend in the summer months. The highest trend values were obtained for summer, followed by winter and spring. As the research conducted by Gocic & Trajkovic (2013) shows, there is a significant increase in temperatures in the northern, central and eastern parts of Serbia. A constant annual increase in maximum daily temperatures from 1974-2003 in Belgrade and Niš was observed by Milanovic et al. (2014). The results of the Pettit's test of average annual temperatures in the area of Sokobanja in the period 1946–2012 indicate that 1991 was a changing point in the temperature increase (Radivojević et al. 2015).

Luković et al. (2014) investigated the trend of precipitation in Serbia in the period 1961-2009. No significant trend of total annual precipitation has been detected for the whole territory of Serbia. Very slight tendencies toward drier conditions on a seasonal scale during winter and spring and wetter conditions during autumn. An increase in autumn amounts of precipitation over central parts of Serbia is a result of a significant increase in October precipitation. The results obtained by Malinovic-Milicevic et al. (2016) indicate a significant increasing trend in the amount and intensity of precipitation in Serbia during autumn. Bandyopadhyay & Perveen (2006) and Gajbhiye et al. (2015) point out that changes in the amount and frequency of precipitation, as a result of climate change, directly affect water flows, runoff, groundwater reserves and soil moisture. Determining the change in rainfall patterns is crucial for any kind of development program and planning that includes effective management of water resources, but also the food production sector.

The objectives of this study are to investigate the temperature and precipitation trends at annual and monthly level in Belgrade in the period 1961-2020 using the Mann-Kendall test. The Pettit's test was used to determine if there were changing point years of both parameters. The paper will also present a comparative analysis of the values of selected parameters in two climatological periods 1961-1990 and 1991-2020 and inter–annual variability of precipitation.

Study area

The study area is Belgrade, the capital of the Republic of Serbia (Figure 1). It covers an area of 360 km², while the wider city area covers 3 222 km². It is located in the Pannonian Plain, on the southern edge of the Pannonian Basin. It lies at the confluence of two large European rivers - the Sava and the Danube rivers, and partly belongs to the Balkan Peninsula, partly to Central Europe (Drazic et al., 2014).

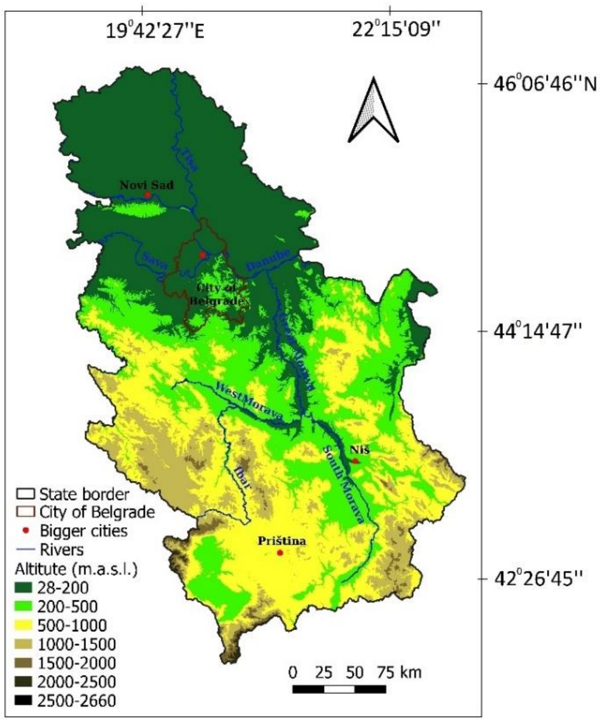

Figure 1: Geographic position of Belgrade in the Republic of Serbia

The study area map was obtained in geographic information systems, which play a major role in the analysis of phenomena and processes in the environment (Ćurić et al., 2022)

Belgrade is located in the zone of moderate continental climate (Meteologos, 2012). The climate of Belgrade is characterized by a great variability of the meteorological elements, which is caused by the circulation of air masses with different physical features. For the territory of the city, intrusions of polar and tropical air are characteristic. Relief has a significant influence on the microclimate of the capital of Serbia. It is characterized by the vast Pannonian plain in the north and the undulating surfaces of northern Šumadija and Avala Mountain (511 m) in the south. The Sava and the Danube rivers, at the confluence of which the city is located, are also significant factors.

Warm and cold periods often occur in all seasons. Cold and moist air are intruding from the northwest and west, and heavy precipitation is brought by the cyclones from the western Mediterranean Sea, which move eastward through the Sava and Danube valleys. Northern intrusions across the Pannonian plain cause a noticeable drop in temperature, while intrusions of cold air from the northeast, from the Carpathians, in winter, cause cold, windy and mostly dry weather. At the beginning of May, the intrusions of moist and cold air appear. Local showers and thunderstorms are frequent in May and June. Shorter and longer dry periods are characteristic in summer (Unkašević, 1994). Dominant winds are košava, west and north-west winds (Meteoblue, n.d.).

Data and methods

The data come from the Republic Hydrometeological Service of Serbia (RHMSS) measured at the weather station Belgrade (Serbia). The coordinates of the meteorological station are 44°48ˈN and 20°28ˈE and it is located at an altitude of 132m (Hidmet, n.d.). The paper analyzed mean monthly and mean annual air temperatures, monthly and annual precipitation during two climatological periods - 1961-1990 and 1991-2020.

The Mann-Kendall test (Mann 1945, Kendall, 1975) was used for trend analysis. The test belongs to the group of non-parametric statistical trends that treats series that are not normally distributed, and its use is based on multi-year data series. Mann–Kendall is commonly used to detect monotonic trends in climatological and hydrological research. The Z statistic was used to test significance. A positive Z value indicates an increasing trend, while a negative Z value indicates a negative trend (Helsel & Hirsch, 2002; Westra et al., 2013; Pohlert, 2015). The null hypothesis of the Mann-Kendall test is based on the assumption that there is no monotonic trend in the time series. Control statistic is used to test the null hypothesis (Kendall, 1975).

The Mann-Kendall (S) Statistic is computed as follows (Kendall, 1962):

$$S = \sum_{i=1}^{n-1} k \sum_{j=i+1}^{n} sign(Tj - Ti),$$

where Ti and Tj are the values of sequence i, j; n is the length of the time series and:

$$Sign\ (Tj - Ti) = \begin{cases} 1\ if\ Tj - Ti > 0 \\ 0\ if\ Tj - Ti = 0 \\ -1\ if\ Tj - Ti < 0. \end{cases}$$

If the Z value (significance level) is greater than 1.96 (which corresponds to the significance threshold of 0.05), we conclude that there is a monotonic trend in the time series, and otherwise, if the value is lower, the trend does not exist (Stojković et al., 2014). Sen's estimate of the slope (Sens's estimate) shows us the estimate of the slope of the linear trend and the average value of changes in a unit of time (Salmi et. al., 2002; Ahmad et. al., 2015).

In order to detect significant changes in time series of climatological data, the Pettit's test was used. The Petit test also belongs to the group of non-parametric tests and is most often used to detect sudden changes (points of change) in climatological data. The Pettit test is a method that discover a significant change in the mean value of a time series when the exact time of the change is unknown. According to Pettitt's test, if x_1, x_2, x_3, …x_n is a series of observed data which has a change point at t in such a way that x_1, x_2 …, x_t has a distribution function F1(x) which is different from the distribution function F2(x) of the second part of the series x_{t+1}, x_{t+2}, x_{t+3} …, x_n. The non-parametric test statistics Ut for this test may be described as follows (Pettit, 1979):

$$Ut = \sum_{i=2}^{n} r \sum_{j=1}^{i-1} sign(Xi - Xj),$$

$$sign\ (Xi - Xj) = \begin{cases} 1\ if (Xi - Xj) \\ 0\ if\ (Xi - Xj) \\ -1\ if\ (Xi - Xj). \end{cases}$$

The test statistic counts the number of times that a member of the first sample exceeds a member of the second sample. The null hypothesis of Pettitt's test is the absence of a changing point. The test statistic (K) may be described as:

$$K = Max\ |Ut|$$

When the value of the test statistic is less than the chosen confidence interval, the null hypothesis is rejected and there is no distinct change point in the time series (Jaiswal et al., 2015).

The inter–annual variability of precipitation was obtained by subtracting the annual total of each year from the mean annual total over the study period and dividing the difference by the standard deviation of the series. Thus, obtaining a new series in which the mean equals to zero and the variance to 1. The obtained values enable the division of all years into three categories as follows (Kutiel et. al., 2015):

Dry (D) when $z < -0.5$
Normal (N) when $-0.5 \le z \le 0.5$
Wet (W) when $0.5 < z$

Results and Discussion

Temperature

The average annual air temperature in Belgrade in the period 1961–2020 is 12.5 °C. The warmest month is July with an average temperature of 22.8 °C, and the coldest is January with an average temperature of 1.1 °C (Table 1). The warmest year in the observed period was 2019 (14.8 °C), and the coldest year was 1980 (10.8 °C).

The mean annual air temperature in Belgrade shows an increasing trend of 0.042 °C/year with a significance level of 0.001. There is an increasing trend of mean monthly temperatures. Only in November the temperature increase is not statistically significant. There is a distinct trend of growth in the summer months (June, July, August) – 0.046 °C/year, 0.06 °C /year and 0.075 °C /year respectively (Table 2, Figure 2).

Table 1: Average annual and monthly temperatures in Belgrade (1961–2020)

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
T_A (°C)	1.1	3.3	7.7	13.0	17.7	21.0	22.8	22.6	18.1	12.9	7.5	2.7	12.5

Source: Republic Hydrometeorological Service of Serbia, Climate Yearbooks 1961-2020

Table 2: Mann-Kendall test results for average annual and average monthly air temperatures in Belgrade (1961-2020)

Month	Trend (Z)	Sen's estimate (B)	Level of significance (α)
January	2.45	0.045	*
February	1.88	0.048	+
March	2.44	0.046	*
April	2.98	0.043	**
May	1.95	0.026	+
June	**3.68**	**0.046**	***
July	**5.20**	**0.060**	***
August	**4.95**	**0.075**	***
September	1.89	0.027	+
October	2.09	0.032	*
November	1.29	0.023	
December	2.67	0.041	**
Year	**6.07**	**0.042**	***

**** - significance level 0,001; **- significance level 0,01; *- significance level 0,05; +- significance level 0,1*

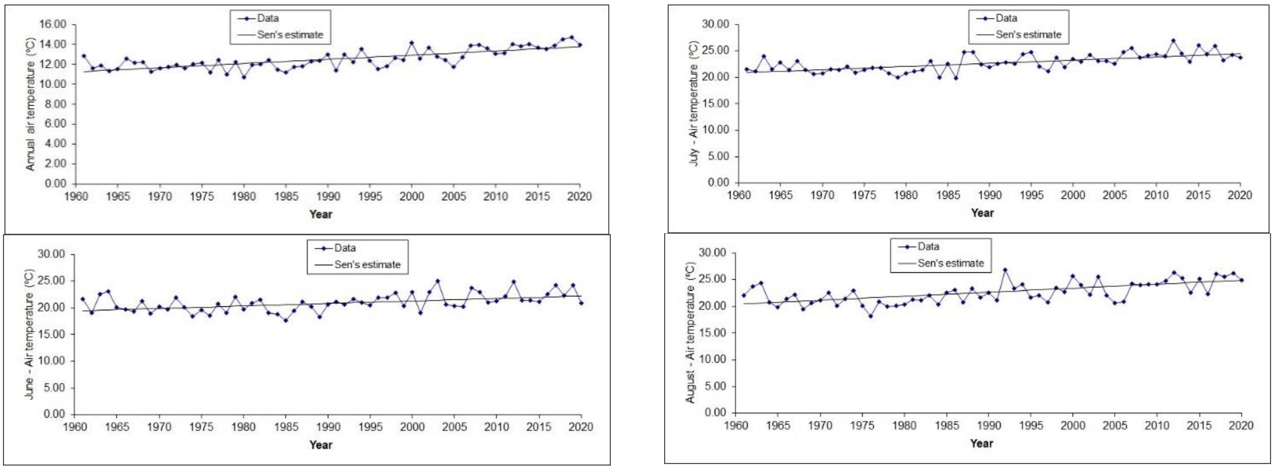

Figure 2: Trend of average annual air temperature and average temperatures of summer months in Belgrade (1961 - 2020)

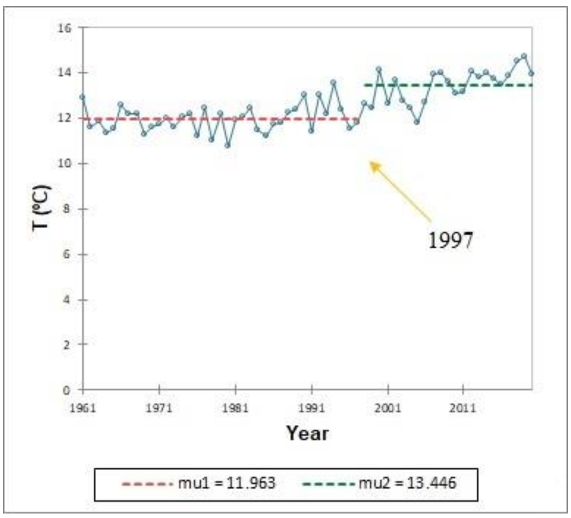

Figure 3: Pettit's test results for average annual temperatures in Belgrade (1961-2020)

The statistically significant changing point year according to the Pettit's test is 1997 (p=0.0001). The period after 1997 recorded an average annual air temperature of 13.4 °C compared to 11.9 °C in the period from 1961 to 1997 (Figure 3).

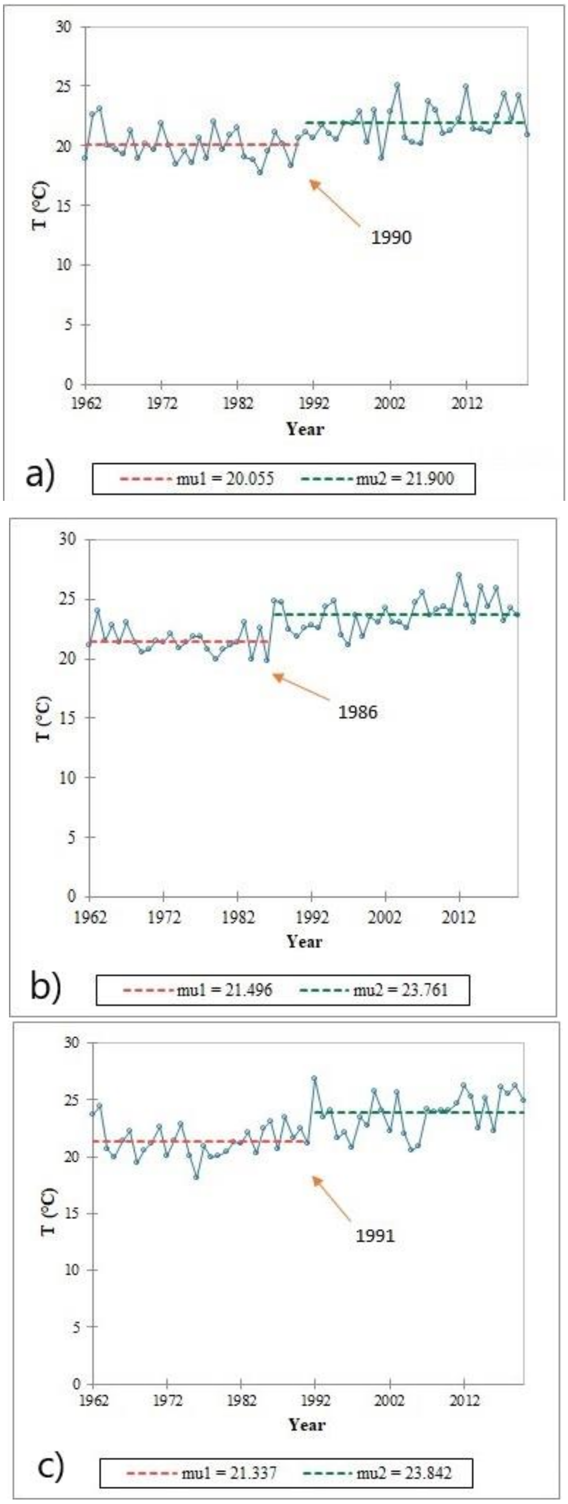

Figure 4: Pettit's test results for mean monthly air temperatures in June (a), July (b) and August (c) in Belgrade (1961-2020)

Since the statistically most significant increasing trends were recorded in the summer months, it was investigated whether there is a changing point for each of them. The average June temperature in the sixty-year period is 21.7 °C, and in 1990 there was a change (increase) in the average monthly temperature from 20.1 °C to 21.9 °C (p=0.0001). The average monthly temperature in July in Belgrade in the observed period is 21.5 °C. The statistically significant year in the average temperature change is 1986 (p p=0.0001). Until the mentioned year, the average temperature was 21.5 °C, so it corresponds to the sixty-year average. After 1986, the average July temperature in Belgrade rose to 23.8 °C. Since 1991 (p=0.0001), the average air temperature in August has increased by 2.5 °C; from 21.3 °C to 23.8 °C (Figure 4).

Table 3: Results of Pettit's test for average annual and monthly temperatures in Belgrade (1961-2020)

Parameters	Level of significance (p)	Changing point (year)	Change (°C)
Average annual temperature	0.0001	1997	+1.483
Average temperature in June	0.0001	1990	+1.845
Average temperature in July	0.0001	1986	+2.292
Average temperature in August	0.0001	1991	+2.505

The results indicate that the temperature in Belgrade is inevitably rising. An increasing trend without statistical significance was only observed in November, while in all other months the results showed a statical significant increasing trend. Pešić and Milovanović (2016) used the same methodology to determine temperature changes in the area of Šumadija (Serbia) in the period 1961-2010. They obtained a statistically significant increasing trend of annual temperature at almost all stations. The second highest mean annual temperature increase is in Belgrade (0,03°C/year), which is similar to obtained results in this paper (0,04°C/year). In Serbia, in the region of Vojvodina and Kosovo and Metohija positive air temperature trends were also obtained (Gavrilov et al., 2015; Gavrilov et al., 2016; Gavrilov et al., 2018). The average temperatures increasing trend indicates that the warming of the climate system is present in the entire territory of Bosnia and Herzegovina according to the results obtained by Trbić et al. (2017). The warming trend is more pronounced since 1990, the highest values in the period 1961–2015 were obtained in the warmest part of the year and in the area of Banja Luka and Bijeljina. In the region, temperature increase is also dominant in Montenegro (Burić et al., 2014).

Table 4: Average temperature (°C) in Belgrade during two climatic periods 1961-1990 and 1991-2020

Climatic periods	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII	Annual
1961-1990	0.4	2.8	7.2	12.4	17.2	20.1	21.8	21.4	17.7	12.5	7.0	2.3	11.9
1991-2020	1.9	3.8	8.3	13.6	18.2	21.9	23.8	23.8	18.5	13.3	8.1	3.0	13.2

Source: Republic Hydrometeorological Institute of Serbia, Meteorological yearbooks 1961–2020

Since the data of two climatological periods were used, the data on the average values of air temperature by period - from 1961 to 1990 and from 1991 to 2020 - are presented (Table 4). The average temperatures in Belgrade in the last period are higher during all months compared to the average temperatures in the period from 1961 to 1990. The biggest difference is in the summer months – August (2.4 °C), July (2 °C) and June (1.8 °C). In the same months, trend analysis showed the most significant increases in temperature. In the period from 1961-2010, according to research by Bajat et al. (2014), a significant increase in temperature in the summer period at 22 meteorological stations in Serbia was established

In July 2012, the highest average monthly temperature (27 °C) in the observed period was recorded. During 2012, which is characterized as extremely hot and dry year, temperatures in Serbia were above 35 °C for more than 50 days. Temperatures were extremely high in 2007, and precipitation were unevenly distributed (Živanović et al., 2020). The absolute maximum temperature of 43.6 °C in Belgrade was measured on July 24, 2007. On the same date, the highest temperature of 44.9 °C in the Republic of Serbia was measured in Smederevska Palanka (Anđelković, 2007). The largest number of fires (28,548) in the period from 2000 to 2010 occurred in 2007 (Živanović et al., 2020).

Precipitation

The average annual amount of precipitation in Belgrade in the period from 1961 to 2020 is 691.8 mm. On average, at monthly level, the highest amount of precipitation is in June 93 mm and May 71.5 mm, then in September 55 mm. The "driest" month is February with an average of 44 mm of precipitation (Table 5).

Table 5: Average amounts of precipitation in Belgrade (1961–2020)

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average pre-cipitation (mm)	48.9	44.0	49.1	55.1	71.5	93.0	66.4	53.2	55.0	47.6	51.9	56.1	691.8

Source: Republic Hydrometeorological Service of Serbia, Meteorological yearbooks 1961–2020

Table 6. Mann-Kendall test results for annual and monthly precipitation in Belgrade (1961-2020)

Month	Trend (Z)	Sen's estimate (B)	Level of significance (α)
January	0.44	0.128	
February	0.59	0.155	
March	0.27	0.074	
April	-1.47	-0.243	
May	1.01	0.277	
June	0.85	0.386	
July	**-1.65**	**-0.416**	**+**
August	0.78	0.208	
September	-0.15	-0.026	
October	**2.67**	**0.592**	**
November	-1.39	-0.283	
December	-0.99	-0.283	
Year	0.24	0.345	

**** - level of significance 0,001; **- level of significance 0,01; *- level of significance 0,05; + - level of significance 0,1*

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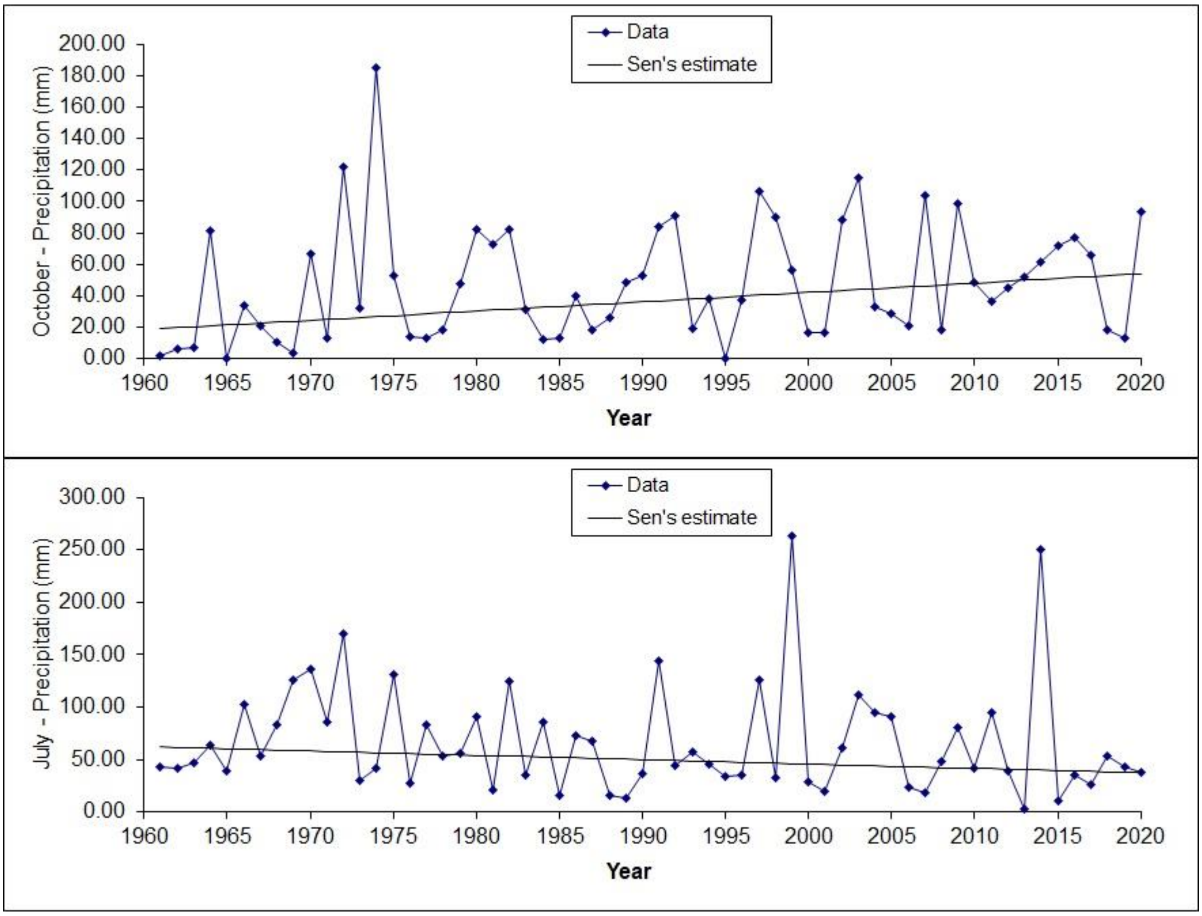

Figure 5: Precipitation trend in July and October with Sen's estimate in Belgrade 1961-2020

At the annual level, non-significant increasing trend was observed. In July, there is a decrease in the amount of precipitation (0.416 mm/year) with a significance level of 0.1. Decreasing precipitation trend is also present in April, September, November and December, but they are not statistically significant. The precipitation increase is observed in January, February, March, May, June, August but without statistically significance, while in October the increasing trend (0.592 mm/year) has a level of significance of 0.01 (Table 6, Figure 5). Changing point wasn't detected in the amount of precipitation.

No significant changes in the annual amount of precipitation were obtained in the work. Luković (2013) obtained the same results at the state level in the period 1961-2009, and Gocić and Trajković (2013) didn't found significant rainfall trend at most station in the period 1980-2010. In current paper, the most significant increasing trend was obtained in October (autumn), similar to research by and Gocić and Trajković (2013) and Tošić et. al. (2014) which obtained a significant precipitation increase during autumn and winter.

It is difficult to find similar rainfall results in the literature over a wider area. The area of south-eastern and central Europe recorded either decreases in precipitation from −20 to 0 mm/decade or an increase in precipitation from 0 to 20 mm/decade, whereby the boundary of change from the negative to the positive trend passes through Serbia to around 22° eastern longitude, but it is a generalized survey (EEA, 2017; Milentijević et al., 2020;). For most parts of Serbia, the mean annual precipitation trend for the period 1961 to 2010 falls in between −5 and +5 and +5 and +15 mm/decade (Milovanović et al., 2017). Popov and Svetozarevich (2021), analyzed annual rainfall trend on 15 weather station in Serbia The least increase in the period 1991-2019 has been observed at the stations of Belgrade, Novi Sad and Zrenjanin. The highest values are reported at Kopaonik station (84.5 mm/decade) and Crni Vrh station (70.1 mm/10 decade).

During the period 1961-2010, a slight positive trend in the annual precipitation was obtained in the eastern part of Croatia, while changes in the annual rainfall wasn't record in Hungary. (Klapwijk et al. 2013, Gajić - Čapka et al.,2015). During the period 1961-2013 some stations in western Romania recorded a statistically significant increase in the mean annual precipitation, on the other hand, the stations in the southwest of Romania recorded a statistically significant decrease in the mean annual precipitation (Croitoru et al. 2016).

The difference in monthly precipitation between the two climate periods (1961-1990 and 1991-2020) varies. A decrease in monthly precipitation is observed in the winter months (December, January and February) and in

March, April and November. The largest decrease in monthly precipitation between the two periods is in April – 7,3 mm (Table 7). The largest increase (14,5 mm) in monthly precipitation in the second thirty-year period is in October.

According to the explained methodology, in the period 1961-2020 20 dry years and 17 wet years were observed. The driest year was 2000, with z score -2.30 and total amount of precipitation of 367.7 mm. The wettest year was 2014, when 1095.1 mm of precipitation was recorded (z=2.86). Three consecutive D years are observed at the beginning of the period (1961–1963) and in the last decade of the period (2011–2013). During the entire period, no more than two consecutive W years were recorded (1969–1970, 1977–1978, 1980–1981, 2004–2005, 2009–2010). From 1964-1968 a long sequence of N years was recorded. From 1998-2020, only five N years were recorded (Figure 6).

Table 7: Average amount of precipitation (mm) in Belgrade during two climate periods 1961-1990 и 1991-2020

Climatic Periods	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
1961-1990	49.3	44.4	49.5	58.8	70.7	90.4	66.5	51.2	51.4	40.3	54.3	57.5	684.4
1991-2020	48.4	43.5	48.6	51.5	72.4	95.6	66.4	55.1	58.6	54.8	49.6	54.8	699.2

Source: Republic Hydrometeorogical Service f Serbia, Meteorogical yearbooks 1961–2020

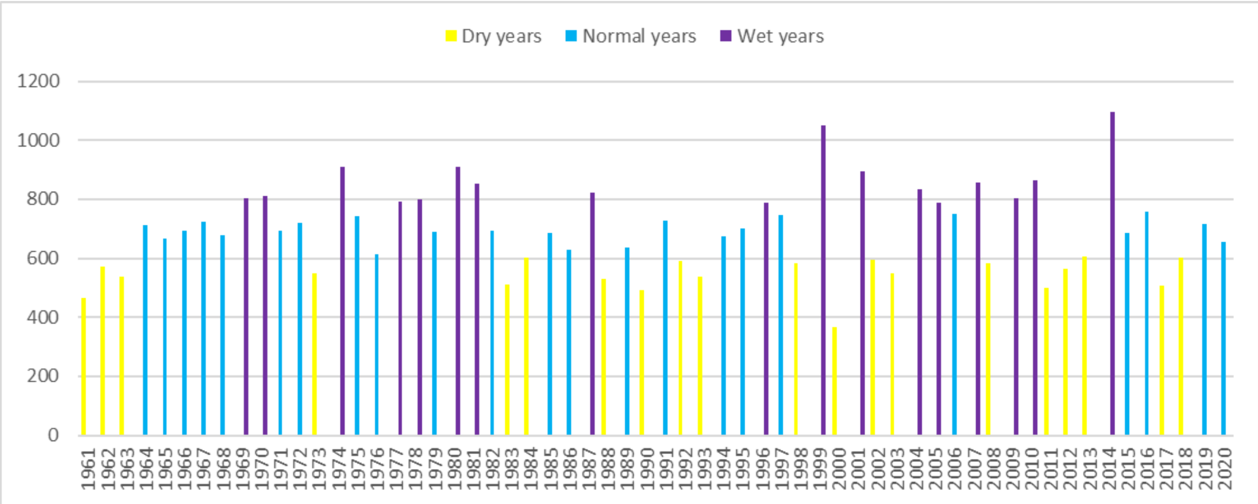

Figure 6: Annual amount of precipitation and classification of years in Belgrade 1961–2020

Conclusions

In this research, temperature and precipitation data in Belgrade in the period 1961-2020 were analyzed. Presented results were obtained using two non-parametric tests: Mann-Kendall test and Pettit's test. The Mann-Kendall test with Sen's estimate indicates the existence of statistically significant trends and shows numerical changes on an annual basis. Pettit's test was used to identify changing points in the observed time series.

The results indicate an unequivocal increase of average annual and monthly temperatures. The increasing trend is statistically significant on annual level (0.042°C/year) and during all months except November. By applying the Pettit's test, we came to the result that the changing point in the increase of the average annual temperature was 1997. The aforementioned trends can be explained by the effects of global warming, which have an impact on a regional and global scale.

The analyzed precipitation data for the same time series indicate that a trend without greater statistical significance is established. Statistically significant change at the annual level was not obtained. A statistically significant trends were detected in October (0.592 mm/year) and July (-0.416 mm/year). By monitoring the precipitation data in the research area, it was concluded that there is no significant changing point in the time series.

In order to reach a general conclusion about the change of climate elements, a comparative analysis of the data of two climate periods (1961–1990) and (1991–2020) was made. This indicates an increase in both temperature and precipitation amounts in the second thirty-year period (1991-2020). The analysis of the inter-annual precipitation variability has shown that in the last two decades the number of N years has decreased and the frequency of D and W years has increased, which points to a possible increase of extreme climate events.

This research provides an insight into the dynamics of the climate in recent decades. It can be a firm base for the future study of climate changes in the area of Serbia, the Balkan Peninsula and Europe. Those research, firstly, must include the analysis of trends at the seasonal level, in order to accurately observe the time of year when the greatest trend decrease/increase occurs. In addition, a more complete analysis of the factors that influenced such a state of the climate should be done. Presented study should contribute a better understanding of recent climate change in Serbia. As recent studies have revealed (Tvardosz et.al., 2021), Europe continues to experience extremely cold winter months, which means that today's warming is a complex and spatially variable process (Hegerl et al., 2018; Krauskopf & Huth, 2020) that must be monitored on a continuous basis to assess its economic and social potential.

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Conflicts of interest

The authors declare no conflict of interest.

Author contribution

Conceptualization, S.V. and M.D; methodology, U.D.; formal analysis, investigation and writing—original draft preparation, N.C; writing—review and editing, U.D., M.D, S.V. All authors have read and agreed to the published version of the manuscript.

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