TREND ANALYSIS AND TIME SERIES DECOMPOSTION ON HYDROLOGICAL PROFILE MOJSINJE IN THE JUZNA MORAVA RIVER BASIN

DOI: https://doi.org/10.18509/GBP23015d
UDC: 519.246.8:556.535.047(282.2:497.11)

Dobrić Milica
Durlević Uroš
Čegar Nina
Faculty of Geography, University of Belgrade, Belgrade, **Serbia**

ABSTRACT

The Juzna Morava basin covers an area of 15,469 km^2, its surface area and hydrological peculiarities require constant research. Imbalances of small, medium and large waters, torrential and erosive events are frequent. Average flows are statistically obtained values, which are most often used in practice when analyzing and preparing studies for further monitoring purposes The non-parametric Mann-Kendall test and Sen's slope estimation were applied for trend observation, and the Pettit test was used to determine the breaking point in the analyzed time series. Data collected on the hydrological profile of Mojsinje (Juzna Morava) in the time interval 1961-2020 were processed The average annual flow (Qavg) is the most important hydrological indicator for observing trends in longer time series; mean monthly and seasonal flows were also analyzed. Based on the applied tests, it was determined that the water level on the hydrological profile decreases (-0.70m^3/s/year) without statistical significance, while the results obtained for May are the most significant (-2.10m^3/s). The breaking point of the average discharges for most of the data series was recorded in the early 1980s (1982–1984), which coincides with the pluviometric regime in the basin. The analysis of seasonal hydrological events in the basin shows negative trends, most significant in winter. In order to determine wet and dry years, they have been classified according to water richness using the SDI index.

Keywords: flow, Moisinje, Juzna Morava, Man Kendall test, Pettit's test

INTRODUCTION

The United Nations classifies water resources as critical natural resources on which the development of society, the economy, and the ecosystem depend substantially [43]. In a global sense, it can be said that water is inexhaustible, but if we consider the amount of water suitable for human use, water pollution, certain areas threatened by water shortages or sanitary water, then water resources should be considered limited.

The flow regime is capable of integrating several components of a river basin. This hydrological variable has a variation in time and can be directly influenced by the climate (mainly by precipitation), basin physical characteristics and anthropic alterations, such as the changes in the use and occupation of the soil and damming of fluvial waters [7],[15],[31],[34]. Anthropic activities combined with climate change have contributed to changes in the hydrological cycle [14]. Increasing weather and climate extreme events have exposed millions of people to acute food insecurity and reduced water security, with the largest impacts observed in many locations and/or communities in Africa, Asia, Central and South America, Small Islands and the Arctic. Roughly half of the world's population currently experience severe water scarcity for at least some part of the year due to climatic and non-climatic driver [18]. According to the IPCC AR6 Synthesis Report (2022) continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation, and very wet and very dry weather and climate events and seasons

Average annual flow (Qavg) is the basic indicator for studying the water regime of river courses and the main indicator for observing trends in longer time series. In recent decades, about 31 percent of 145 main rivers in the world have shown significant statistical changes in their annual flow [43],[8]. Statistical methods such as linear regression tests, direct correlation analysis, and non-parametric analysis including Mann–Kendall, modified Mann–Kendall, Sen's slope, and innovative trend analysis (ITA) are widely used to detect trend and change point in historical series of climatic and hydrological variables [24],[36],[16],[40],[19].

Observing changes in longer hydrological time series is important for scientific and practical research [22]. Numerous authors have studied the river flow in Iran [33], Canada [40], China [1], Portugal [6], South Africa [28]. Statistical analysis of mean annual and seasonal flows was the subject of numerous hydrological studies in Serbia: on the example of the Nišava River [25], [9], [10], Sava river [39] Zapadna Morava [21], Južna Morava [3],[23],[30],[32].

In this paper, the mean annual, monthly and seasonal discharges in the Južna Morava River were analyzed. The data obtained on the hydrological profile of Moisinje in Južna Morava for the period (1961-2020) were analyzed using the Mann Kendall and Pettit's test. The aim of the work is to determine whether there is a statistically significant trend in the change of flows, as well as aburpt change. The Južna Morava was chosen for the study area because its valley has enormous national, geostrategic and socioeconomic importance. Although the river and its tributaries are not navigable, it represents the main backbone for the life and work of people in the valley.

STUDY AREA

The course of the Juzna Morava was formed in a tectonic trench, which was created in the middle of the Tertiary, more precisely in the oligo-miocene. During the existence of the Pannonian Sea, in the Pontian stage, the valley of today's Juzna Morava represented a bay that stretched to the south to the Grdelica Gorge [29]. According to Gavrilović Lj. and Dukić D. [4], Juzna Morava is formed by the joining of Binačka Morava and Preševska Moravica near Bujanovac, belongs to the Black Sea basin, and the average flow at the mouth is 100 m^3/s. The length of its course is 295 km, and if its source arm, i.e. Binačka Morava, is taken into account, the total length of the course is 343 km. The area of the South Morava basin is 15,469 km^2, of which 85% belongs to Serbia, while smaller parts belong to Bulgaria and North Macedonia. Near Stalać, it merges with Zapadna Morava, forming Velika Morava.

Figure 1. Juzna Morava basin

Juzna Morava has a complex valley which, according to Marković [29], consists of a series of gorges and structural basins with an average height above sea level of 657m. South Morava has 157 tributaries, the most important of which are: Vlasina, Veternica, Jablanica, Pusta reka, Toplica, Vranjska reka, Sokobanjska Moravica and Nišava (the longest).

Climatological features of the researched area are characterized by a moderate continental climate with an average annual amount of precipitation in the basin of 550 mm and in the river valley 1300 mm per year. The average annual air temperature is in the range of 10–12ºC in the lowest parts of the basin, while in the mountainous parts (above 1500 m) temperatures are below 3ºC [2]. Most of the rivers in the South Morava basin belong to the pluvio-nival type of water regime, with maximum flows in March and April, and minimum flows in August and September. Based on previous research on natural hazards in the territory of Serbia, the South Morava valley from Vladičini Han to Stalac has been classified as a potential flood zone [23].

There are 6 hydrological profiles in South Morava and they are (going from the source to the mouth): Vranjski Priboj, Vladičin Han, Grdelica, Korvingrad, Aleksinac and the most upstream, which was also analyzed in the work of Mojsinja.

DATA AND METHODS

During the research, the data werw taken from Republic Hydrometerological Institute (RHMZS), [42], measured on the hydrological profile of Mojsinje in the time interval 1961-2020. The average annual flow (Qavg) is the main hydrological indicator by which trends are observed in longer time series, and in addition to it, the following were analyzed: average maximum and minimum annual and monthly flows, the resulting analysis of flows by season is presented.

At the beginning of the research, the ranking years by water level was carried out using the SDI index (Streamflow Drought Index). The water content of a given year actually shows how much excess or lack of water occurs in relation to the normal, or usual, water content, represented by the mean value of annual flows. The Streamflow Drought Index (SDI) is often used to rank small water bodies [26]. Calculating the index is simple. For each year, the mean flow for the studied period is subtracted from the flow value and the result is divided by the standard deviation of all flows. In this way, positive values are obtained indicating that the flow is above the average and negative values if the flow is below the average [10].

The Mann-Kendall test [24], [11] 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 value of Z indicates an upward trend, while a negative value of Z indicates a negative trend [17]. The null hypothesis of the Mann-Kendall test is based on the assumption that there is no monotonic trend in the time series. Control statistics are used to test the null hypothesis [11]. If the Z value (significance level) is greater than 1.96 (corresponding to the significance threshold of 0.05), we conclude that there is a monotonic trend in the time series, otherwise, if the value is lower, the trend does not exist [39]. Sen's estimate of the slope (Sens's estimate) shows us the estimate of the slope of the linear trend and shows us the average value of changes in a unit of time [34]. Therefore, it is necessary to use several full cycles of the time series, in order to create a representative trend [39]. In order to detect significant changes in the time series of hydrological data, the Petit test (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 hydrological data. The Pettit test is a method that detects a significant change in the mean of a time series when the exact time of the change is unknown. X 1, x 2, x 3, …x n is a sequence of observed data that has a change point ut such that x 1, x 2 …, x t has a distribution function F 1 (x) that differs from the distribution function F 2 (x) of the second part of the sequence x t+1, x t+2, x t+3 ..., x n. 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).

RESULTS AND DISCUSSION

Some river streams are extremely rich in water, while other streams barely had enough water to cover the stream bed in certain years, for this reason, in hydrological and geographical studies, the method of classification from year to year according to water wealth is of great importance, which indicates a multi-year trend the flow of the river.

Based on the mean annual flow value, for the observed series of data (1961-2020) and with calculated standard deviations, years were classified according to water wealth.

For each year, the mean flow value for the studied period is subtracted from the flow value and the result is divided by the standard deviation of all flows. In this way, positive values are obtained indicating that the flow is above average and negative values if the flow is below average. The higher the index values, the waterier the year and vice versa. Eight categories of years were distinguished by water content [10].

Table 1. Classification of water years on the hydrological profile of Moisinje (1961-2020)

SDI index categories	Year
Extremly watery >2	1963, 2010
Very watery 1.5-2	1980,2015
Moderately watery 1.0-1.5	1962, 1965, 1970, 1973, 1976,2005, 2018
Medium watery 0.0-1.0	1965, 1969, 1974, 1975, 1977,1978, 1981,1984, 1987, 1996, 1997, 1999, 2003, 2006, 2009, 2016,
Medium dry -1.0-0.0	1961,1964, 1966, 1971,1972,1979,1982,1983,1985,1986,1988,1989,1990, 1991,1992,1993,1995,1998,2000,2002,2004,2007,2008, 2012,2017,2020,
Moderately dry 1.5-1.0	1968,2000,2001,2010,2013,2019,
Very dry 2.0-1.5	1994
Extremly dry <2	1993

The index applied to the data series (1961-2020) gave the following results. In the 60-year period, there are the fewest extreme (1) and very dry (1) years, then extreme (2) and very wet (2), moderately dry (6), moderately wet (7), and the highest frequency of slightly wet (17) and slightly dry (23) years.

By using the Log-Pearson III distribution as a statistical basis for ranking years according to water content, categories are obtained whose boundaries are expressed in flow values. This is a problem if we want to compare rivers that have different flow values, which is often the case. Therefore, it is necessary to introduce indices that would eliminate the absolute magnitudes of flows. The water content of a given year actually shows how much excess or lack of water occurs in relation to the normal, or usual, water content, represented by the mean value of annual flows. One of the indixes is the Streamflow Drought Index (SDI), which is often used to rank small water bodies [26].

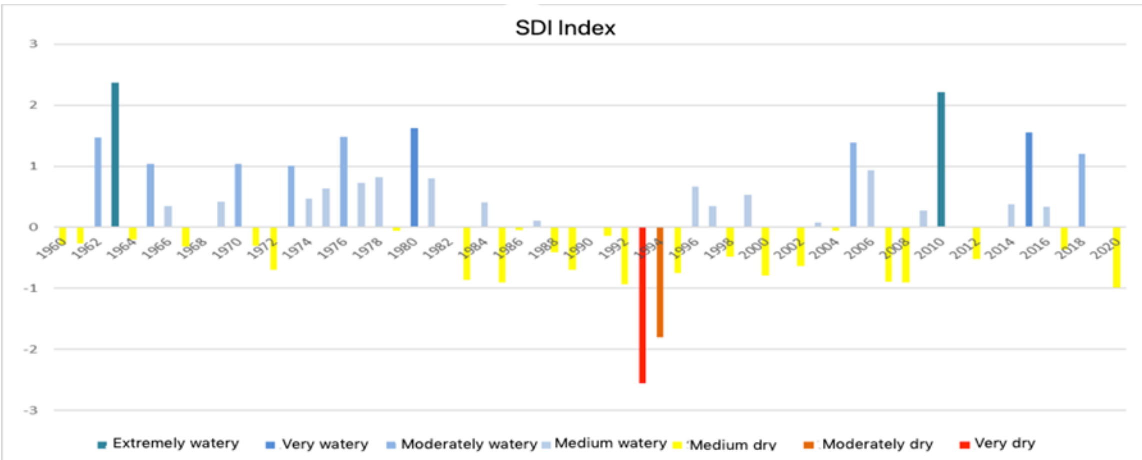

Figure 2. Graphic representation of the distribution of years by water content and hydrological profile of Moisinje (1961-2020)

Flow is the most important element of the water regime and is closely related to the water level. Average flows are statistically obtained values, which are most often used in practice when analyzing and creating studies for the needs of further monitoring.

Table 2. Average annual and average monthly flow, average annual and average monthly maximum and minimum flow on the hydrological profile of Moisinja (1961–2020) [42].

	Jan	Feb	March	Apr	May	June	July	Avg	Sep	Okt	Nov	Dec	Year
Average flow Q avg (m^3/s)	93.4	141.3	178.8	175.3	131.3	86.0	47.0	30.0	26.7	35.1	52.0	78.3	**89.6**
Average minimum flow Qmin (m^3/s)	50.3	67.6	94.7	97.1	70.4	44.8	26.9	18.9	**17.2**	21.4	26.7	40.3	**21.8**
Average maximum flow Qmax (m^3/s)	202.8	311.8	366.6	**384.0**	272.1	198.9	103.8	54.9	56.3	73.2	127.6	185.9	**244.5**

The flow is a variable hydrological element, it changes under the influence of primarily the physical and geographical factors of the watershed. There is no doubt that the climate of the watershed is the most important factor in these changes, primarily precipitation and its regime, on which the flow itself depends the most. Juzna Morava valley lacks precipitation. A continental rainfall regime is represented here, with a maximum in May and June. In June, 12% to 13% of the total annual precipitation falls. The least amount of precipitation occurs in February and October, when it falls from 5% to 6% of the total annual amount of precipitation. Due to the higher altitude, Vlasina and Krajište receive a higher amount of precipitation than the valley of Juzna Morava. The mountains of the region receive larger amounts of rain and snow, over 1000 mm [29].

The average mean annual flow of the Juzna Morava near Mojsinje for the observation period 1961 - 2020. is 89.6 m^3/s. The maximum mean monthly flows are recorded in March and April, and the minimum in August and September. Large spring waters with a maximum in March and April are conditioned by the melting of snow in the higher parts of the basin and the pluviometric regime. After that, there is a decrease in average flows and low water occurs in summer and early autumn with a minimum in August and September, due to less rainfall and high evaporation, then the flow increases constantly until April.

The movement of the average minimum and maximum flow follows the movement of the annual average, so the absolute minimum flow occurs in August (18.9 m^3/s) and September (17.2 m^3/s), while the absolute maximum in March (366.6 m^3/s) and April amounts to (384.0 m^3/s).

Table 3. Mann-Kendall test results for mean annual and mean monthly flow measured on the hydrological profile in Moisinje (1961-2020)

	Trend(Z)	Sen's estimate (B)	Level of significance (α)
January	-1.00	-0.329	/
February	-1.31	-0.678	/
March	-0.53	-0.360	/
April	-0.42	-0.277	/
May	**-2.10**	**-0.876**	*
June	-1.41	-0.382	/
July	-0.77	-0.115	/
August	0.94	-0.093	/
September	-0.89	-0.058	/
October	0.63	-0.052	/
November	-0.04	-0.008	/
December	-0.28	-0.105	/
Per year	**-1.97**	**-0.424**	*

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

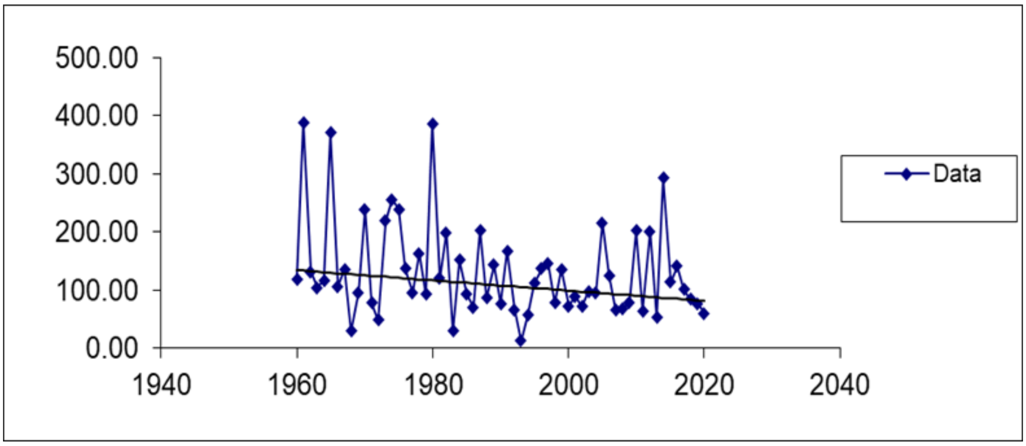

Figure 3. Trend of mean annual flow on the hydrological profile of Moisinje (1961-2020)

The trend method provides more concrete values and a clearer insight into the changes that occur over a longer period of years. According to Table 2 and Figure 2, we see that the trend obtained by applying the Mann-Kendel test showed that the level of significance is minimal, i.e. marked with 0.05 for the entire analyzed period, and that the value of Z is negative, and that the total loss according to the trend line by Sen's method (-0.424 m^3/s) which means that it is decreasing in trend units for the observed period.
The trend applied to the average monthly flow data showed that the value is significant only in the month of May and that Z= -2.10, and the level of significance marked with *(0.05), the trend is decreasing along the trend line (-0.876 m^3/s). So we applied the Petit test on those values.

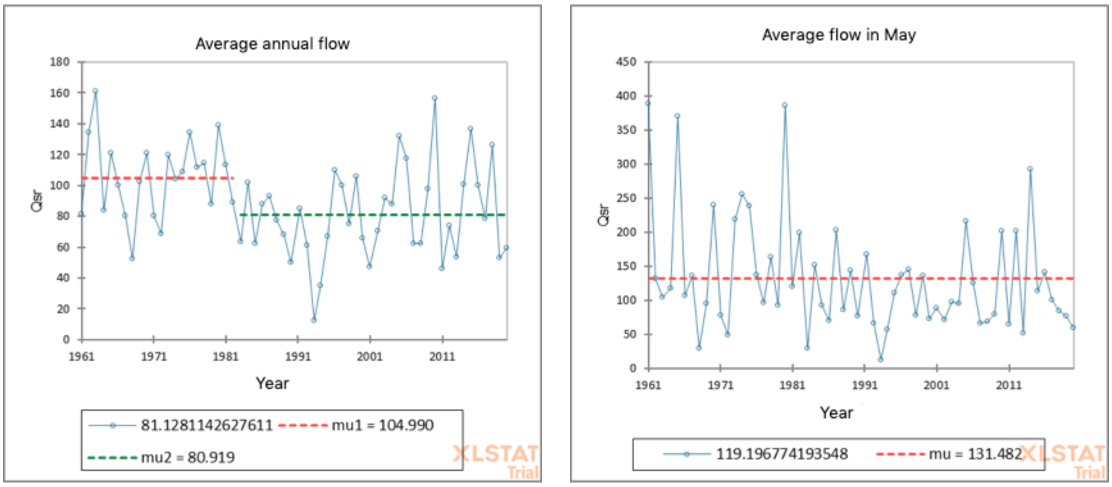

Figure 4. Graphic representation of the results of the Pettit's test for the mean annual flow and the average conflict in the month of May measured at the Moisinje hydrological profile (1961-2020)

According to Petit's test, significant changes were determined in the series of data, when the point of change was not clearly defined. According to the test, the statistically significant breaking year for the time series of 60 years is 1982 and the value is p=0.020. Which tells us that the flow that year at the hydrological station decreased from 104.99 m^3/s to 81.12 m^3/s, that is, there is a change in the negative direction. The fact that the significance level is less than 0.05, the alternative hypothesis is accepted and it can also be concluded that the observed time series are not homogeneous. The most statistically significant trend was recorded in the month of May, so the Petit test was also applied to the average monthly flows obtained for the month of May where we come to the result that 1982 was marked as a point of change, which is without major statistical significance. We classified the average flows according to the seasonal hydrological profile of Moisinje analyzed for the period 1961-2020. Average monthly flows are grouped into four climatological periods with the aim of seeing the regularity and trend of flow movements. It is important to emphasize that in the analysis of the winter period, we analyzed December from the previous calendar year. For the analysis of seasonal flows, the most important influencing factors are climatic factors, i.e. temperature, amount of precipitation and the pluviometric regime that follows the seasons.

Table 4. Mann-Kendall test results for mean seasonal flow on the Moisinja hydrological profile (1961-2020)

Climatological seasons	Trend(Z)	Sen's slope estimate (B)	Level of significance (α)
Winter period (December, January, February)	-1.12	-0.391	/
Spring period (March, April, May)	-1.-88	0.61569	/
Summer period (June July August)	-0.90	-0.146	/
Autumn period (September, October, November)	0.56	0.066	/

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

The trend obtained by applying the Mann-Kendell test on the values of the series of data of mean monthly flows grouped by seasons do not show greater statistical significance. We have data on the establishment of a negative trend that follows the winter, summer and spring periods in which it is most prominent (-0.615 m^3/s), while a positive trend appears in the autumn period (0.066 m^3/s). The increase in the autumn period on the hydrological profile of Moisinje is a logical sequence because it follows the pluviometric regime and the gradual increase of precipitation in the researched area. According to Majkic& Urosev [12], who conducted a similar study (2014), in the autumn period, a slight and gradual autumn increase in flow was observed at 86% of hydrological stations in Serbia. Since the application of the test did not lead to the establishment of a trend with a higher level of significance, the Petitt test was not applied to this series of data.

CONCLUSIONS

The study of changes in the values of hydrological parameters in long time series and the observation of trends are important data for understanding the global state of water in river basins. In this research of the mean annual flow values in the Juzna Morava basin, on the hydrological profile of Moisinja for the period 1961-2020. were used as a basic hydrological indicator. The non-parametric Mann-Kendall test with Sen's estimate of the slope (Sen's estimate) was used to analyze a series of data in order to determine whether there are statistically significant trends and to quantify changes on an annual basis.

The general conclusion is that the annual flows are the highest during the spring months, and the lowest in the summer and autumn periods. Based on the applied tests and methods, it was determined that the water content on the hydrological profile is decreasing and that the Z value is negative, and that the total loss according to the Sen's method trend line is (-0.424 m^3/s), which means that it is decreasing in the trend unit for the observed period. The trend applied to the average monthly flow data showed that the value is significant only in the month of May and that Z= -2.10, and the level of significance is marked with 0.05, and it decreases along the trend line (-0.876 m^3/s). The analysis of average monthly flows by season resulted in the establishment of a negative trend that follows the winter, summer and spring periods in which it is most prominent (-0.615 m^3/s), while a positive trend appears in the autumn period (0.066 m^3/s). The amount of precipitation has the greatest influence on changes in river flow in the Juzna Morava basin due to its intensity, shape and pluviometric regime. In addition to the influence of physical and geographical factors, the flow of the Juzna Morava is also influenced by anthropogenic activities, i.e. water management activities.

The research can serve as a starting point for subsequent hydrological research, which could be based on the study of minimum and maximum flows for the research area, and the study and definition of extremes.

The results of the study contribute to the understanding of the water quality of the Juzna Morava stream, and can be useful to emergency management services, the energy sector and the local governments within which the Juzna Morava flows.

Acknowledgements

The study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract number 451-03-68/2022-14/200091).

REFERENCES

[1] Ali, R., Kuriqi, A., Abubaker, S., & Kisi, O. (2019). Long-Term Trends and Seasonality Detection of the Observed Flow in Yangtze River Using Mann-Kendall and Sen's Innovative Trend Method. Water, 11(9), 1855. https://doi.org/10.3390/w11091855

[2] Bajat, B., Blagojević, D., Kilibarda, M., Luković, J. and Tošić, I. (2014). Spatial analysis of the temperature trends in Serbia during the period 1961–2010. Theoretical Applied Climatology, 121, 289–301. https://doi.org/10.1007/s00704-014-1243-7

[3] Blagojević, B., Mihailović, V., Blagojević, J., & Radivojević, D. (2021). The hydrological and environmental aspect of low flow assessment in ungauged basins - a case study in the Južna Morava river basin. Architecture and Civil Engineering, 19(3), 261-278 https://doi.org/10.2298/FUACE211219020B

[4] Gavrilović, Lj., & Dukić, D. (2002). Rivers of Serbia. Institute for Textbook [In Serbian: Гавриловић, Љ., и Дукић, Д. (2002). Реке Србије. Завод за уџбенике].

[5] Gocic, M. & Trajkovic, S. (2013). Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia. Global and Planetary Change, 100, 172-182. https://doi.org/10.1016/j.gloplacha.2012.10.014

[6] Da Silva, R. M., Santos, C. A. G., Moreira, M., Corte-Real, J., Silva, V., & Mediros, I. (2015). Rainfall and river flow trends using Mann–Kendall and Sen's slope estimator statistical tests in the Cobres River basin. Natural Hazards, 77, 1205–1221. https://doi.org/10.1007/s11069-015-1644-7

[7] Dias, L. C. P., Macedo, M. N., Costa, M. H., Coe, M. T., & Neill, C. (2015). Effects of land cover change on evapotranspiration and streamflow of small catchments in the Upper Xingu River Basin, Central Brazil. Journal of Hydrology: Regional Studies, 4, 108–122. https://doi.org/10.1016/j.ejrh.2015.05.010

[8] Dinpashoh, Y., Singh, V. P., Biazar, S. M. & Kavehkar, S. (2019). Impact of climate change on streamflow timing (case study: Guilan Province). Theoretical and Applied Climatology, 138 (1), 65–76.

[9] Ducić, V., & Luković, J. (2009). Possible causes of contemporary Nisava River discharge variability. Bulletin of the Serbian Geographical Society, 89(4), 255-276.

[10] Đokić, M. (2015). Nišava - a potamological study [Doctoral dissertation, Department of Geography of the Faculty of Economics, University of Niš].

[11] Kendall, M. (1962). Rank corelation methods. Hafner Publishing Company.

[12] Kovačević-Majkić, J., & Urošev, M. (2014). Trends of mean annual and seasonal discharges of rivers in Serbia. Journal of the Gographical Institute "Jovan Cvijić", 64(2), 143-160. https://doi.org/10.2298/IJGI1402143K

[13] Liang, L. & Liu, Q. (2014). Streamflow sensitivity analysis to climate change for a large water –limited basin. Hydrology Process, 28, 1767-1774. https://doi.org/10.1002/hyp.9720

[14] Ferreira, L. V. F., Rodrigues, N. L., Da Silva, D. D., Teixeira, B. D. de S., & De Almeida T. L. (2021). Time series trends of streamflow and rainfall in the Santo Antonio River Basin, Brazil. Engenharia Agrícola, 41(1), 47-55. https://doi.org/10.1590/1809-4430-Eng.Agric.v41n1p47-55/2021

[15] Frederice, A. and Brandão, J. L. B. (2016) Efeito do Sistema Cantareira sobre o regime de vazões na bacia do rio Piracicaba. Revista Brasileira de Recursos Hídricos, v. 21, n. 4, p. 797–810, https://doi.org/10.1590/2318- 0331.011615150

[16] Hamed, K. H., & Rao, A. R. (1968). A modified Mann-Kendall trend test for autocorrelated data. Journal of Hydrology, 204, 182–196.

[17] Helsel, D. R., Hirsch, R. M., Ryberg, K., Archfield, S., & Gilroy, E. (2002). Statistical methods in water resources: U.S. Geological Survey Techniques and Methods. Supersedes USGS Techniques of Water-Resources Investigations, 4. https://doi.org/10.3133/tm4A3

[18] IPCC. (2022). Summary for Policymakers. In H-O. Pörtner, D. C. Roberts, E. S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.), Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 3-33). Cambridge University Press. https://doi.org/10.1017/9781009325844.00

[19] Jaiswal, R. K., Lohani A. K., & Tiwari H. L. (2015). Statistical Analysis for Change Detection and Trend Assessment in Climatological Parameters Environ. Process, 2, 729–749. https://doi.org/10.1007/s40710-015-0105-3

[20] Jesper, R. (2022). Statistical analysis of possible trends for extreme floods in northern Sweden. River Research and Applications, 38, 1041–1050.

[21] Langović, M., & Manojlović S. (2014). Trends of mean annual river discharges in the Zapadna Morava river basin. Bulletin of the Serbian Geographical Society, 97(2), 19-45.

[22] Liang, L., & Liu, Q. (2014). Streamflow sensitivity analysis to climate change for a large water –limited basin. Hydrology Process, 28, 1767-1774. https://doi.org/10.1002/hyp.9720

[23] Manojlović, S., Sibinović S., Srejić, T., Haduda, A., & Sabri, I. (2021). Agriculture Land Use Change and Demographic Change in Response to Decline Suspended Sediment in Južna Morava River Basin (Serbia). Sustainability, 13, 3130. https://doi.org/10.3390/su13063130

[24] Mann, H. B. (1945). Nonparametric tests against trend. Econometrica: Journal of the Econometric Society, 13, 245–259.

[25] Mustafić, S. (2012). Geographical factors as determinants of erosion intensity on the example of the Nišava basin [Doctoral dissertation, Faculty of Geography, University of Belgrade].

[26] Nalbantis I. (2008). Evaluation of a Hydrological Drought Index. European Water, 23(24), 67-77.

[27] Ocokoljić, M. (1994). Cyclicality of dry and wet periods in Serbia. Geographical Institute "Jovan Cvijić" SANU.

[28] Owolabi, S. T., Belle, J. A., & Mazinyo, S. (2022). Quantifying Intra-Catchment Streamflow Processes and Response to Climate Change within a Climatic Transitional Zone: A Case Study of Buffalo Catchment, Eastern Cape, South Africa. Mathematics, 10, 3003. https://doi.org/10.3390/ math10163003

[29] Pavlović, M. (2018). The nature of Serbia. Faculty of Geography [In Serbian: Павловић, М. (2018). Природа Србије. Географски факултет].

[30] Petrović, A. M. (2015). The Torrential Floods in the Južna Morava River Basin. Proceedings of the II International Conference on Natural Hazards, 356–362.

[31] Rodriguez, D. A., Tomasella, J., & Linhares, C. (2010). Is the forest conversion to pasture affecting the hydrological response of Amazonian catchments? Signals in the Ji-Paraná Basin. Hydrological Processes, 24(10), 1254–1269. https://doi.org/10.1002/hyp.7586

[32] Petrović, A. M., Ristić, R. (2015). Spatiotemporal Review of the Torrential Flood Phenomenon in the Morava River Basin. Spatium, 34, 64–69. https://doi.org/10.2298/SPAT1534064P

[33] Salarijazi M., Ali Mohammad A. A., Adib A., & Daneshkhan, A. (2012). Trend and change-point detection for the annual stream-flow series of the Karun River at the Ahvazhydrometric station. African Journal of Agricultural Research, 7(32), 4540-4552. https://doi.org/10.5897/AJAR12.650

[34] Salemi, L. F., Groppo, J. D., Trevisan, R., Moraes, J. M., Ferraz, S. F. de B., Villani, J. P., Duarte-Neto, P. J., & Martinelli, L. A. (2013). Land-use change in the Atlantic rainforest region: Consequences for the hydrology of small catchments. Journal of Hydrology, 499, 100–109. https://doi.org/10.1016/j.jhydrol.2013.06.049

[35] Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association, 63(324), 1379–1389.

[36] Sen, Z. (2012) Innovative trend analysis methodology. Journal of Hydrology Engineering, 17(9), 1042–1046.

[37] Simić, S. (2016). Water potential and hydrogeographic reionization of the Valjevo mountains [Doctoral dissertation, Faculty of Geography, University of Belgrade].

[38] Stahl, K., Hisdal, H., Hannaford, J., Tallaksen, L.M., Lanen, H. A. J., Sauquet, E., Demuth, S., Fendekova, M., & Jodar, J. (2010). Streamflow trends in Europe: evidence from a dataset of near – natural catchments. Hydrological and Earth System Sciences, 14, 2367-2382.

[39] Stojković, M., Plavšić, J., & Proharska, S. (2014). Dugoročne promene godišnjih i sezonskih proticaja: primer reke Save. Vodoprivreda, 46, 29-48.

[40] Yue, S., Pilon, P., & Cavadias, G. (2002). Power of the Mann–Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series. Journal of Hydrology, 259, 254–271.

[41] Zuo, D., Xu, Z., Yang, H., & Liu, X. (2012). Spatiotemporal variations and abrupt changes of potential evapotranspiration and its sensitivity to key meteorological variables in the Wei River basin, China. Hydrological Processes, 26(8), 1149–1160. https://doi.org/10.1002/hyp.8206

[42] Republički hidrometeorološki zavod (1961-2020). Hidrološki godišnjaci. Available at: https://www.hidmet.gov.rs

[43] UNESCO (2012). Protection of the Quality & Supply of Freshwater Resources: Application of Integrated Approaches to the Development, Management & Use of Water Resources. Available at: https://www.un.org/esa/dsd/agenda21/res_agenda21_18.shtml.