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STATISTICAL ANALYSIS OF THE MEAN RELATIVE VARIABILITY OF MONTHLY, SEASONAL AND ANNUAL PRECIPITATION AT THE MAIN SYNOPTIC STATIONS IN THE SOUTH MORAVA SUB-BASIN TO THE KORVINGRAD HYDROLOGICAL STATION

Milan Miletić[1], Jovana Vuletić[2]

Abstract: The aim of this work is to determine the variability of precipitation in the area of the sub-basin of the South Curve up to the hydrological station Korvingrad. Data from the synoptic stations Leskovac, Vranje and Kuršumlija for a period of 30 years (1991-2020) were used. The mean relative variability of monthly, seasonal and annual precipitation and their ten-year values were used to compare the results of all synoptic stations in the sub-basin. The results showed that the highest mean variability of precipitation in the studied period was recorded at the Vranje synoptic station (22.4%) and the lowest value at the station in Leskovac (18.4%). The comparison of ten-year values showed that the lowest values of mean relative variability of annual precipitation in the period 2001-2010 were recorded at all synoptic stations. The study showed that the extreme values of mean relative variability of precipitation occurred earlier or later during the second and third ten-year periods compared to the first ten-year period. The study showed that the values of mean relative variability of monthly precipitation were lowest in months with high precipitation.

Keywords: Precipitation, sub-basin of the South Morava, mean relative variability of precipitation, climate changes

[1] University of Belgrade – Faculty of Geography, Studentski trg 3/III, 11000 Belgrade, Serbia

[2] University of Niš – Faculty of Sciences and Mathematics, Department of Geography, Višegradska 33, Niš, Serbia
Corresponding author: milanmiletic181@gmail.com

Introduction

One of the biggest problems of our time is global climate change. Special attention is paid to the analysis of precipitation as one of the most important climate elements. It is believed that the change in precipitation in recent years is taking place on a global scale. In recent decades, precipitation has been concentrated in intense events where a large amount of precipitation can fall in a short period of time (Iwashima and Yamamoto, 1993; Karl et al., 1995; Suppiah and Hennessy, 1998; Trenberth, 1999). In all models of global precipitation circulation, the degree of evaporation has been shown to increase with an increase in global air temperature (Hense et al., 1988; Genfo et al., 1991; Ross and Elliot, 1996; Pierrehumbert, 1999). In some regions, evaporation is low, which is a consequence of low moisture in the soil. In such areas, droughts occur more frequently. Climatic changes are also noticeable at the regional level. Especially in the region of southern Europe, which is a climatic transition area between dry and wet areas, climatic changes can have the greatest impact (Lavorel et al., 1998). Родић and Павловић (1994) point out that the regional distribution of precipitation is uneven and irregularly distributed under the influence of factors such as latitude, longitude, distance from the sea, relief structure, and altitude. Measurement of precipitation and its analysis at monthly and annual scales is important for many economic sectors such as agriculture and water management (Дукић, 1998).

The sub-basin of the South Morava River up to the Korvingrad hydrological station is mostly located on the territory of Serbia and a smaller part on the territory of Northern Macedonia. The area of the sub-basin is 9396 km2 (Miletić, 2022). As a result of the development of the Pannonian basin, the sub-basin has a meridian extension direction (Павловић, 2019a).

The South Bend sub-basin belongs to the temperate-continental climate area. The highest areas of the sub-basin belong to the type of alpine climate (Павловић, 2019b). Томислав Ракићевић (1980) carried out the climatic regionalization of Serbia. The area of the South Curve sub-basin up to the hydrological station Korvingrad includes the climatic regions Gnjilanski, Vranjski, Vlasinski, Niško-leskovački and Kopaonički. There are three important (synoptic) meteorological stations in the sub-basin. These are: Vranje (432 m above sea level), Leskovac (230 m above sea level) and Kuršumlija (362 m above sea level). The average annual precipitation in the period 1991-2020 at the synoptic stations is: Vranje (606 mm), Leskovac (661 mm) and Kuršumlija (670 mm) (Hydrometeorological Service of the Republic of Serbia, 1991-2020).

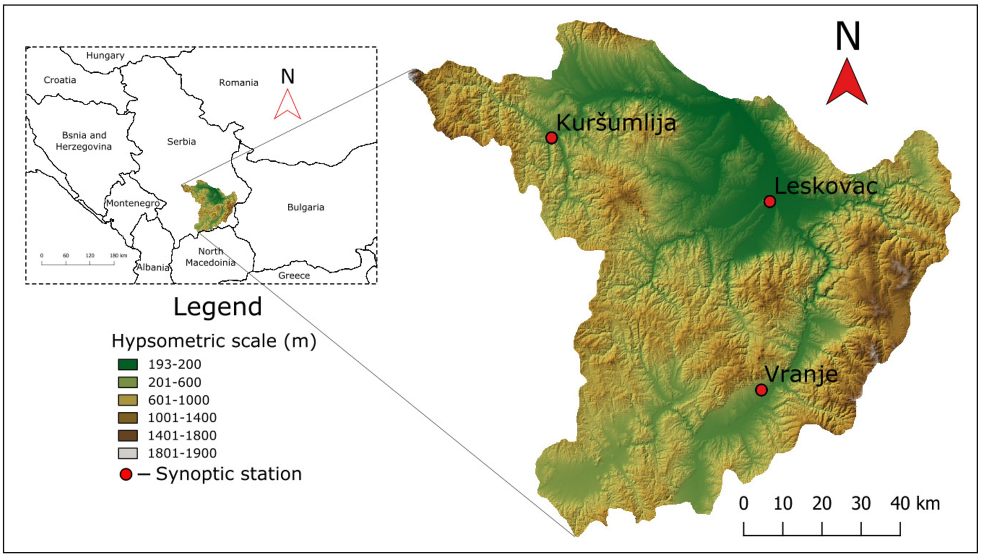

Figure 1. The position of synoptic stations on the territory of the South Morava sub-basin up to the Korvingrad hydrological station

The main task of the work is to determine the mean variability of precipitation at the synoptic stations in the sub-basin. In the work, data from the thirty-year period from 1991 to 2020 were used. The variability of precipitation is determined by the method of deviation from the mean of monthly and annual precipitation. Ten-year values of mean relative variability of seasonal precipitation were compared in the study. Precipitation variability has been highly variable in recent decades as a result of global temperature changes and evaporation (Šegota and Filipčić, 1996). The main objective of the work is to apply certain statistical methods to estimate the mean relative variability of monthly, seasonal and decennial precipitation in the analyzed period 1991-2020 at the synoptic stations Leskovac, Vranje and Kuršumlija.

Materials and methods

To determine the variability of precipitation in the sub-basin area, mathematical formulas were used to determine the mean absolute variability of annual precipitation, the mean relative variability of precipitation, and the coefficient of variation. According to Šegota and Filipčić (1996), precipitation variability is the mean deviation of annual precipitation from the multi-year average. To determine the variability of precipitation, the mean value of annual precipitation must first be determined. The difference between the amount of precipitation and the mean value of precipitation in a multi-year period represents the degree of variation (Šegota, 1969). For the analysis of the values, it is important to point out that a greater difference indicates a greater variability of precipitation and vice versa. Šegota and Filipčić (1996) presented the mean absolute variability of annual precipitation with a formula:

$$\overline{V_a} = \frac{1}{n}\sum_{i=1}^{n} \left|P_i - \overline{P_g}\right|$$

Where P_i represents the value of precipitation in the i-th year of the analyzed period, P_g the mean value of precipitation. In order to compare data from several meteorological stations that have different amounts of precipitation, it is necessary to use the formula for determining the mean relative variability of precipitation (Šegota and Filipčić, 1996):

$$\overline{V_r} = \frac{100\ \overline{V_a}}{\overline{P_g}}\ \%$$

The variability of precipitation for the three synoptic stations was determined using the standard deviation and coefficient of variation. Standard deviation is the average deviation of precipitation from its average. It is represented by absolute values. The coefficient of variation was determined as described by Maradin (Maradin, 2007). It represents the ratio of the standard deviation and the arithmetic mean by the formula:

$$V_k = \frac{100\,\sigma}{\overline{P}}\ \%$$

In which σ represents the value of the standard deviation and $\overline{P}$ mean value of the amount of precipitation for the analyzed period. Values of mean relative variability and coefficient of variation are expressed in %.

Results and discussion

The paper analyzed the variability of precipitation at three synoptic stations in the South Morava sub-basin up to the Korvingrad hydrological station in the period 1991-2020. Three ten-year periods (1991-2000, 2001-2010 and 2011-2020) were distinguished in this investigation. At the beginning of the study, the average monthly and annual precipitation had to be calculated. Figure 1 shows the mean monthly precipitation values at the synoptic stations in the sub-basin. The highest average monthly precipitation was measured in May at all three synoptic stations during the studied period. The determined values are: 69.4 mm in Leskovac, 63.1 mm in Vranje and 71.5 mm in Kuršumlija.

Analysing Figure 2, we conclude that there are two precipitation maxima at all three synoptic stations. The precipitation maximum in April, May and June is more pronounced than the maximum in October and November. The monthly average value of precipitation measured in Kuršumlija in July is 68.9 mm. It is a consequence of the geographical position and the morphology of the terrain. The lowest average values of monthly precipitation are measured in July, August and September at the meteorological stations Leskovac and Vranje, in Kuršumlija in August. In January and February, all three meteorological stations recorded the lowest precipitation amouns.

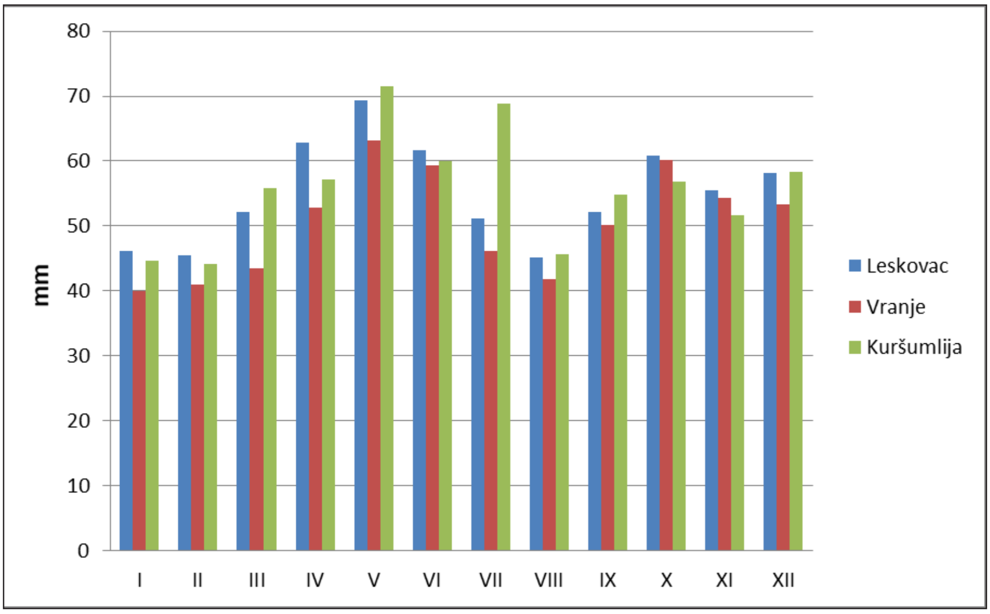

Figure 2. Average monthly rainfall at the synoptic stations Leskovac, Vranje and Kuršumlija in mm (1991-2020)

The average annual precipitation for the studied period is: 660.8 mm in Leskovac, 605.7 mm in Vranje and 669.6 mm in Kuršumlija. Kuršumlija has the highest average annual precipitation, although it is not located at the highest altitude. The morphology of the terrain is prominent, i.e. it is surrounded by mountains. Vranje, which is located at the highest altitude, has the lowest average annual precipitation. As a result, relief barriers from the north and west prevent the penetration of humid air during most of the year.

The variability of precipitation during the studied period shows different values at all synoptic stations (Table 1). The highest annual precipitation variability is recorded at the synoptic station in Vranje with 22.4%, and the lowest at the synoptic station in Leskovac with 18.4%. At the synoptic station in Kuršumlija the annual variability of precipitation is 20.4 %.

Table 1. Seasonal and annual mean relative variability of precipitation (%) at synoptic stations Leskovac, Vranje and Kuršumlija (1991-2020)

Station	Winter	Spring	Summer	Autumn	Year
Leskovac	30.9	30.1	40.2	42.5	18.4
Vranje	31.2	34.6	47.5	41.7	22.4
Kuršulija	32	31.6	43.6	41.1	20.4

In Table 1, in addition to the mean annual values of precipitation variability, seasonal values of the mean relative variability of precipitation for the analyzed period are presented. The greatest mean seasonal relative variability of precipitation is during summer and autumn. The highest seasonal variability of precipitation at the synoptic stations of Vranje and Kuršumlija is during summer (47.5% in Vranje and 43.6% in Kuršumlija), while in Leskovac it is during autumn and amounts to 42.5%. The lowest seasonal values of precipitation variability are during winter and spring. The lowest value of seasonal variability of precipitation in Leskovac (30.1%) and Kuršumlija (31.6%) is during spring, while in Kuršumlija during winter it is 31.2%.

By analyzing the mean relative variability of monthly precipitation (table 2), we can conclude that the highest values of precipitation variability are during the summer months. The highest values are recorded in August and amount to: 87.3% in Leskovac, 86.3% in Vranje and 71.6% in Kuršumlija.

Table 2. Monthly mean relative variability of precipitation (%) at synoptic stations Leskovac, Vranje and Kuršumlija (1991-2020)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Leskovac	60	46.4	61.9	59.4	41.2	55.2	50.9	87.3	70.3	62.3	65.4	53.3
Vranje	62.6	56.3	71.7	60.7	46.2	55.9	71.6	86.3	67.4	63.7	69.1	54.4
Kuršumlija	58	55.9	63.6	52.8	35.9	54.8	66.4	71.6	67.2	67.5	65.5	58.2

The lowest values at all three synoptic stations were recorded in May and are: 41.2% in Leskovac, 46.2% in Vranje and 35.9% in Kuršumlija. The values of mean relative variability of monthly precipitation can be explained by the presence of maximum and minimum precipitation. In periods when the mean monthly precipitation is higher, the mean relative variability of precipitation decreases. In contrast, the mean relative variability of precipitation increases during the periods of the year when precipitation is low, i.e. during the periods of the first and second precipitation minimum.

From Table 2 it can be concluded that there are two maxima and two minima of the mean relative variability of monthly precipitation. The maxima of mean relative variability of monthly precipitation coincide with the minima of precipitation during the year. The primary maximum of the mean relative variability of monthly precipitation is in the summer months, while the secondary maximum is in the winter months. The lowest mean relative variability of monthly precipitation occurs in May, which can be referred to as the primary minimum of mean relative variability of monthly precipitation. Here the primary maximum of annual precipitation comes to the fore. As the amount of precipitation increases, the mean relative variability of monthly precipitation decreases and vice versa.

The mean relative variability of seasonal precipitation in ten-year periods varies. In the first ten-year period 1991-2000. (Table 3) the mean relative annual precipitation variability had the lowest value in Kuršumlija (19.4%) and the highest in Vranje (23.3%). In the same period, the lowest relative variability of seasonal precipitation was measured at all synoptic stations in spring. The lowest value of relative variability of seasonal precipitation is 25.3% and was measured in Leskovac. The low values of relative variability of seasonal precipitation in spring can be explained by the higher amount of precipitation coinciding with the primary precipitation maximum in April and May. The highest values of relative variability of seasonal precipitation were measured at synoptic stations Vranje and Kuršumlija in summer and in Leskovac in winter (TTable 3). The high values of relative variability of seasonal precipitation in summer months can be explained by the lower amount of precipitation and high temperatures. In Leskovac, the mean relative variability of seasonal precipitation was significantly lower during summer, which can be explained by a slightly higher amount of precipitation during this period.

Table 3. Seasonal and annual mean relative variability of precipitation (%) at synoptic stations Leskovac, Vranje and Kuršumlija presented in ten-year periods

Period	Station	Winter	Spring	Summer	Autumn	Average anual
1991-2000. year	**Leskovac**	41.3	25.3	36.3	36.7	21.1
	Vranje	37.6	26.5	54.8	37.4	23.3
	Kuršumlija	43.8	30.9	47.1	34.9	19.4
2001-2010. year	**Leskovac**	26.1	21.1	42.4	39.7	11.3
	Vranje	27.4	29.8	40.4	35.5	15.1
	Kuršumlija	23.7	27.8	33.9	38.5	12.8
2011-2020. year	**Leskovac**	25.4	35	41.8	54.2	20.6
	Vranje	25.4	39	47.7	52.4	24.7
	Kuršumlija	28.9	32.8	50.3	49.9	23.7

In the second ten-year period 2001-2010. year (Table 3), the mean relative variability of annual precipitation at all three synoptic stations had significantly lower values compared to the first ten-year period 1991-2000. years. The lowest mean relative variability of annual precipitation was recorded in Leskovac 11.3%, while the highest was recorded in Vranje 15.1%. Analyzing the results from Table 3, we can conclude that the mean relative variability of seasonal precipitation during winter and spring in the analyzed period had significantly lower values. The lowest mean variability of seasonal precipitation in Leskovac in the second ten-year period was recorded during spring, while in Vranje and Kuršumlija during winter. The highest values of the same parameter were recorded in Leskovac and Vranje during summer, and in Kuršumlija during autumn.

In the third ten-year period 2011-2020. year (Table 3), the mean relative variability of annual precipitation at all synoptic stations records high values in relation to the first and second ten-year periods with only one exception. This is the case with Leskovac, where the mean relative variability of annual precipitation amounts to 20.6%, which is 0.5% less compared to the first ten-year period 1991-2020. years. It is significant for the research that the mean relative variability of seasonal precipitation had the lowest values at all synoptic stations during winter. The mean relative variability of seasonal precipitation increases linearly at all synoptic stations during spring, summer and autumn. The highest values of the same parameter at the synoptic stations Leskovac and Vranje were recorded during autumn, while in Vranje the highest value was recorded during summer. This phenomenon can be explained by extremely dry periods that in the last ten-year period were pronounced in the summer and autumn months when there was little precipitation.

From Table 2, we can conclude that there are two maxima and two minima of mean relative variability of monthly precipitation. The maxima of the mean relative variability of monthly precipitation coincide with the minima of precipitation during the year. The primary maximum of the mean relative variability of monthly precipitation is during the summer months, while the secondary maximum is during the winter months. The lowest mean relative variability of monthly precipitation is during May, which can be characterized as the primary minimum of mean relative variability of monthly precipitation. This is where the primary maximum of annual precipitation comes to the fore. With an increase in the amount of precipitation, the mean relative variability of monthly precipitation decreases and vice versa.

Conclusion

For all three synoptic stations located in the territory of the South Morava sub-basin up to the Korvingrad hydrological station, the continental type of annual precipitation flow is characteristic. One of the proofs is the increase in the amount of precipitation in late spring and early summer. That period can be characterized as the primary maximum of precipitation. The secondary maximum of precipitation occurs in the period from September to December. The least precipitation is recorded during winter and summer, so these periods are characterized as minimum precipitation.

The synoptic station Leskovac has the lowest mean relative variability of annual precipitation for the analyzed period and it is 18.4%. The weather station Vranje has the highest value of the mentioned parameter, which is 22.4%. In the same period, the mean relative variability of seasonal precipitation at the synoptic stations of Vranje and Kuršumlija has the highest values during the summer, while in Leskovac the highest value of the same parameter was recorded during the fall. The lowest values of the mean relative variability of seasonal precipitation at Leskovac and Kuršumlija stations were recorded during spring, while in Vranje the lowest value of the same parameter was recorded during winter.

The mean relative variability of seasonal precipitation in 10-year periods was subject to change. In the first ten-year period (1991-2000) the mean relative variability of seasonal precipitation at all synoptic stations had the lowest values during spring, while the highest values were recorded during summer and winter. In the second ten-year period (2001-2010) the maximum values of the mean relative variability of seasonal precipitation were highest during the summer. At the synoptic station in Kuršumlija, the maximum value of the same parameter was recorded during autumn. It is significant that the minimum values of mean relative variability of precipitation in the second ten-year period in Vranje and Kuršumlija were recorded during winter. It was during this period that the seasonal occurrence of the minimum seasonal relative variability of precipitation changed. In the same period, there was a shift in the maximum value of the mean relative variability of seasonal precipitation from the summer period to the autumn period, with the exception of the Kuršumlija synoptic station, where the highest value is recorded during the summer. In the last ten-year period (2011-2020) extreme values of the mean relative variability of seasonal precipitation occur at the beginning and end of the calendar year.

In the analysed period, the mean relative variability of monthly precipitation has the lowest values in the months in which the amount of precipitation is high and vice versa. We come to the conclusion that months in which there is more precipitation over a longer period of time do not have a large fluctuation in precipitation in contrast to months that have little precipitation. In the months with little precipitation, most often during the summer months, it is common for no precipitation to be recorded in them, or in some extreme cases for more precipitation than the multi-year average.

In the period 1991-2020. year numerous precipitation fluctuations were recorded both on a monthly and an annual level. In most cases, a decrease or increase in precipitation can explain the change in the mean relative variability of precipitation. As one of the proofs of climate change on the territory of Serbia and the sub-basin of South Morava up to the Korvingrad hydrological station is the change in the period of occurrence of minimum and maximum values of mean relative variability of precipitation. Based on the data, we can conclude that changes in the values of mean relative variability of seasonal and annual precipitation and changes in their occurrence can affect the state of water in the sub-basin. Global climate changes, which are manifested through rainfall variability, influence the worsening of water management problems in the South Morava sub-basin. Knowing the amount of precipitation and its variability on a monthly and annual level is very important for further research, which must be in the direction of the interdependence of precipitation with certain climatic elements.

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