

[<https://doi.org/10.69646/aob260925>]

[Poster]

Changes in Temperature and Precipitation Regimes in the Šumadija Region, 1961–2024

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Abstract: Climate change is a major focus of contemporary research due to its effects on temperature and precipitation regimes. This study assesses changes in temperature and precipitation regimes in the Šumadija Region, Serbia, over the 1961–2024 period. Climatological data from three synoptic stations (Belgrade, Smederevska Palanka, and Kragujevac) were analyzed using the Mann–Kendall and Pettitt tests, while climatic aridity was assessed using the Pinna Combinative Index. The results reveal statistically significant increasing trends in mean annual and monthly air temperatures at all three stations. The Pettitt test identified 1998 as a change point in the temperature series. In contrast, no statistically significant trend was detected in mean annual precipitation. Despite the observed intra-annual redistribution of precipitation and increasing climatic aridity, all three stations remained classified as humid according to the Pinna Combinative Index. Continuous monitoring is essential for understanding regional climate dynamics and assessing the impacts of climate change.

Keywords: temperature regime, precipitation regime, Šumadija Region.

Introduction

Climate change has the greatest impact on the two most important climatic elements: air temperature and precipitation. Variations in temperature and precipitation regimes are evident at the global, regional, and local levels, making them one of the key scientific issues of today and the subject of numerous studies. These changes significantly affect natural and socio-economic processes worldwide and therefore need to be continuously monitored. Accordingly, the aim of this paper is to examine changes in temperature and precipitation regimes in the Šumadija Region over the period 1961–2024.

Studies conducted in Serbia and across Southeastern Europe indicate an unequivocal upward trend in air temperatures, both in terms of mean annual and mean monthly values. Some authors have examined variations in air temperature (Milovanović et al., 2022), identifying considerable regional differences. Climate change is also associated with variations in precipitation amounts and precipitation regimes, as well as with the increasingly frequent occurrence of extreme precipitation events. This is also evident in Central and Southeastern Europe (Zeder & Fischer, 2020). Changes in precipitation regimes affect the occurrence of droughts, increased climatic aridity, and other natural hazards, such as floods and landslides. However, most studies conducted in Serbia have focused on the analysis of extreme precipitation events and their trends (Tošić et al., 2025; Bezdan et al., 2024; Malinović-Milićević et al., 2018).

The Šumadija Region is located in the central part of Serbia. It is characterized by specific morphological features and tectonomorphogenesis, which are clearly reflected in its climatic characteristics. The region is broadly open towards the Pannonian Plain to the north, while towards the south it gradually transitions into the mountainous terrain of the Dinarides. Consequently, Šumadija is exposed to the influence of different air masses. The northern part of the region, known as Low Šumadija, is characterized by a continental climate, whereas the southern part, known as High

Šumadija, exhibits the characteristics of a temperate warm and humid climate (temperate-continental climate).

Methods and data

For the purposes of this study, three synoptic stations were selected. The Belgrade station (132 m) is subject to the specific influence of the urban heat island, which has significantly affected the temperature regime since the mid-20th century. The Smederevska Palanka station (121 m) records climatic conditions in the lower part of Šumadija, while the Kragujevac station (181 m) represents the conditions of a basin surrounded by mountains (Rudnik, Gledić Mountains, and Kotlenik) in the higher part of Šumadija. To determine trends in temperature and precipitation regimes, climatological data for the period 1961–2024 were used (Meteorological yearbooks, Republic Hydrometeorological Service of Serbia). Changes in mean annual air temperature and mean annual precipitation were analyzed using several statistical methods: the Mann–Kendall test, the Pettitt test, and the Pinna Combinative Index.

The Mann–Kendall test is a non-parametric statistical method widely used to identify monotonic trends in time series data. It determines whether a statistically significant upward or downward trend is present over time and is suitable for datasets containing outliers or non-linear trends, as it does not require a specific probability distribution. The null hypothesis (H_0) assumes that the observations are independent and identically distributed, indicating no significant trend, whereas the alternative hypothesis (H_1) assumes the presence of a statistically significant upward or downward trend (Sen, 1968). In this study, the Mann–Kendall test was applied to assess trends in temperature and precipitation regimes during the 1961–2024 period. The Pettitt test is a non-parametric method widely used in climatology to detect abrupt changes or change points in time series. It does not require assumptions regarding the probability distribution of the data. The null hypothesis (H_0) assumes that the data are homogeneous throughout the observation period, with no significant

change in the location parameter, whereas the alternative hypothesis (H_1) assumes a statistically significant shift in the location parameter at a specific point in time (Pettitt, 1979). In this study, the Pettitt test was used to identify change points in temperature and precipitation regimes during the 1961–2024 period.

The Pinna Combinative Index (I_p) was also used in this study. This index builds upon the De Martonne Aridity Index by introducing an additional term for regions experiencing a pronounced dry season (Andrade & Corte-Real, 2016). The index is calculated using the following equation:

$$I_p = \frac{1}{2} \cdot \left(\frac{P}{T + 10} + \frac{12P'_d}{T'_d + 10} \right)$$

where P and T represent the annual mean values of precipitation and air temperature, respectively, while P'_d and T'_d represent the mean values of precipitation and air temperature, respectively, in the driest month. According to the Pinna Combinative Index, values below 10 indicate a dry climate, values between 10 and 20 indicate a semi-dry climate, and values above 20 indicate a humid climate.

Results and discussion

The Mann–Kendall test for the Belgrade station indicates a pronounced upward trend in mean monthly and annual air temperatures. The most pronounced warming is observed during the summer months, with August showing the highest rate of increase, approximately 0.76 °C per decade. November is the only month in which no significant increasing trend is detected. The Pettitt test also identified a statistically significant change point in the mean annual air temperature at the Belgrade station. Since the obtained p -value ($p < 0.001$) is lower than the significance level of 0.05, the null hypothesis is rejected, indicating a statistically significant change in the time series. The Pettitt test identified 1998 as the change point.

During the period 1961–1997, the mean annual air temperature was 11.9 °C, whereas during the period 1998–2024, it increased to 13.6 °C. The Mann–Kendall test for the Smederevska Palanka station also indicates a significant increase in mean monthly and annual air temperatures over the analyzed period. The highest rates of increase were observed during the summer months, particularly in August, whereas the mean monthly temperatures in May and November did not exhibit a significant upward trend. Similar to the results obtained for Belgrade, the Pettitt test identified a statistically significant change point in the temperature series, with a p-value below 0.001. The identified change point is 1998, indicating a pronounced structural shift in the mean annual air temperature. During the period 1961–1997, the mean annual air temperature was 11.8 °C, increasing to 12.4 °C during the period 1998–2024.

Similar changes in the thermal regime were observed at the Kragujevac station. A clear upward trend in mean annual air temperature was identified. In the higher, southern part of Šumadija, in addition to the increase in mean monthly temperatures in July and August, a pronounced increase in mean January temperatures was also observed. The Pettitt test produced results similar to those obtained for the other two stations, identifying 1998 as the change point between the two periods. The mean annual air temperature was 11.0 °C during the period 1961–1997, increasing to 12.5 °C during the period 1998–2024.

In contrast to the temperature regime, which clearly exhibits an increasing trend at all three stations, the applied statistical methods did not reveal a statistically significant increasing or decreasing trend in mean annual precipitation. Furthermore, according to the Pinna Combinative Index, all three selected stations are characterized by a humid climate based on the mean values for the 1961–2024 period. The lowest index value was recorded at Kragujevac station (32), while the values for Belgrade and Smederevska Palanka stations were both 34.

Conclusions

The results obtained using the applied methods indicate that all three selected stations in the Šumadija Region are characterized by a humid climate. A statistically highly significant increasing trend in mean annual and monthly air temperatures was identified in Šumadija ($p < 0.01$), contributing to an increase in potential evapotranspiration. Trends in annual precipitation totals are generally not statistically significant, but they indicate intra-annual redistribution, with moisture deficits occurring during the winter and late summer periods. The Pettitt homogeneity test clearly identifies 1998 as the change point in the temperature series for the study region. This year divides the observed time series into two climatically heterogeneous sub-periods: the first, 1961–1997, which was cooler, and the more recent period, 1998–2024, which was warmer.

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