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[Lecture]

Climate Aridity Changes and Their Impact on Agricultural Production - Case Study: South Serbia

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Abstract: This paper analyzes climate aridity trends in South Serbia and their agricultural impacts across two periods (1961–1990 and 1991–2024). Meteorological data from five stations (Niš, Leskovac, Vranje, Dimitrovgrad, and Kuršumlija) were used to calculate the Lang rain factor, Emberger index, and Selyaninov hydrothermal coefficient. The results indicate rising summer temperatures, prolonged growing seasons, and localized aridity increases. While the hilly-mountainous region periphery and Leskovac basin remain stable due to increased precipitation counterbalancing thermal stress, the Vranje basin exhibits significant aridification, with declining values across all indices.

Keywords: aridity, climate, South Serbia, Emberger index, Selyaninov coefficient

Introduction

The increase in air temperature, the variability of the amount of precipitation in terms of pluviometric regime and the increasing pressures of socioeconomic factors have influenced the assessment of droughts and climate aridity to become important topics both at the global and regional levels. In the context of global climate change, it is necessary to analyse the factors that influence the

change in aridity, but also the occurrence of extreme climatic phenomena such as heat waves, extreme precipitation, floods and droughts (Gocić et al., 2025; Burić et al., 2023).

Due to the change in temperature regime and precipitation regime, there is a change in the aridity of the climate in a certain area. A significant lack of precipitation, in relation to the average values for a certain territory, is the main cause of the drought. Drought differs from other natural disasters, because its duration is significantly longer and it covers large areas. The consequences of drought are long-lasting and have a complex impact on the reduction of water resources and the weaker adaptation of both natural ecosystems and society as a whole (Trajković, 2019). Unlike drought, which is a temporary phenomenon, aridity is a permanent feature of the climate and occurs in areas with a low amount of precipitation, and is a consequence of the general circulation of the atmosphere, relief and other climatic regional factors (Maliva and Missimer, 2012).

The subject of research in the paper is the change in climate aridity in the area of South Serbia and its impact on agricultural production. South Serbia is a region whose natural boundaries can be identified with the South Morava drainage basin. The South Morava valley represents the morphological backbone of this region, while the peripheral parts of the region are hilly and mountainous.

According to Köppen's climate classification, the South Morava valley belongs to the modified continental type of climate (Cfw'ax). The mountain rim of the region belongs to the modified temperate-continental climate type (Cfw'bx). The highest parts of the region, such as the Vlasina plateau, Kukavica, Suva and Radan mountain, belong to the subalpine climate (Dfw'bx) (Gajić and Krstić, 2025).

The analysis of aridity in South Serbia is important because it has an intensive agricultural production of the main crops (maize, wheat), with significant production of fruits and vegetables. Given that most of the land is not irrigated, agriculture is highly dependent on climatic conditions. A decrease in precipitation is often accompanied by high temperatures in the summer, greater evaporation and

insolation, which leads to a significant decrease in soil moisture. This causes water stress in agricultural crops and results in reduced yields.

Methods and data

Climatological parameters for five synoptic weather stations in South Serbia were used to determine the climate aridity trend. The selected stations are located in basins where agricultural production is the most intensive and which have the best quality agricultural soil in the region. The stations Niš, Leskovac and Vranje are located in the valley of South Morava, and the stations Dimitrovgrad and Kuršumlija are located in the valleys of the largest tributaries of South Morava - Nišava and Toplica, respectively.

The paper analyzed climatological data for the period 1961–2024. In order to determine the change in climate aridity, the data are divided into two climatological periods. The first period is from 1961–1990, and the second period 1991–2024. The data were chosen in order to include the longest possible period of measurement and to include the entire lowland and basin area of South Serbia. The data were taken from the meteorological yearbooks of the Republic Hydrometeorological Service of Serbia. Gocic and Trajkovic (2014) regionalized Serbia according to drought vulnerability. The region of South Serbia belongs to the P3 region of moderate precipitation with an average of about 630 mm per year. This region also records a slightly higher frequency of extreme droughts.

For the purposes of determining the trend of aridity and climate-related lack of moisture, several indicators were used. Lang's rainfall index (I_L) represents the ratio between the annual amount of precipitation and the mean annual air temperature. This index in South-Eastern Europe more often records a drop in value during the summer months, which indicates an increased aridity of the climate.

Emberger index (IE) unlike simple aridity ratios, measures the relationship between water availability and atmospheric evaporation by utilizing temperature extremes and annual rainfall. The formula for this index is:

$$IE = \frac{2000 \cdot P}{M^2 - m^2}$$

where the parameters represent: P - total mean annual precipitation in mm; M - average maximum temperature of the hottest month; m - average minimum temperature of the coldest month. Both average temperatures are converted to Kelvin.

Selyaninov's hydrothermal coefficient (HTC) is a bioclimatic index designed to evaluate agricultural drought and moisture availability during the active plant growing season. The formula for this coefficient is:

$$HTC = \frac{10 \cdot \Sigma P}{\Sigma T}$$

where the parameters represent: ΣP - the sum of daily precipitation in mm over the active growth season; ΣT - the sum of active daily average air temperatures in °C over active growth season; 10 - scaling factor applied to represent the temperature sum in a simplified potential evaporation format.

Results and discussion

According to the results of Lang's rainfall index for two climatological periods (1961-1990 and 1991-2024), all stations, with the exception of Leskovac, recorded a slight decrease in this index, which indicates an increase in aridity. The stations Niš, Leskovac and Vranje are located in the semiarid zone, while the stations on the periphery of the region, Dimitrovgrad and Kuršumlija, are in the subhumid or moderately humid zone. According to the Emberger index, the entire area of Southern Serbia is characterized by a subhumid climate (values between 60 and 100).

The only station that recorded a significant increase in this index is Leskovac, due to a noticeable increase in humidity, i.e. an increase in the total annual amount of precipitation. On the other hand, the Vranje station recorded a significant increase in aridity, because temperatures during the summer months increased significantly, and

the amount of precipitation remained the same during both climatological periods. Also, all stations have a trend of significantly milder winters, which also affects the value of this index.

Table 1. Values of Lang Rainfall index (I_l), Emberger index (IE) and Selyaninov's hydrothermal coefficient (HTC)

Station	I_l		IE		HTC	
	1961-1990	1991-2024	1961-1990	1991-2024	1961-1990	1991-2024
Niš	51.8	49.1	64.6	65.2	0.96	0.95
Leskovac	55.1	57.2	61.2	66.8	0.99	1.06
Vranje	57.0	52.3	65.0	61.3	1.05	0.99
Dimitrovgrad	65.4	63.7	69.8	69.9	1.22	1.22
Kuršumlja	63.7	63.0	70.6	71.2	1.18	1.21

The values of Selyaninov's coefficient show that the region of South Serbia is on the margin of an arid and slightly arid climate. Changes in the thermal regime affect a lower risk of freezing in the winter, but also a significantly higher heat stress of agricultural crops in the summer. Also, the entire region is characterized by the extension of the vegetation period, due to higher temperature sums (for example, at the Leskovac station, the temperature sums increased by about 214°C).

Stations in South Serbia also recorded the largest increase in mean monthly and maximum temperatures during July and August, which significantly increases evapotranspiration. What stands out as an advantage, especially at the Leskovac, Kuršumlja and Dimitrovgrad stations, is that the increase in the amount of precipitation during the growing season compensates for the increase in thermal energy.

Conclusions

The analysis of the aridity trend for the area of South Serbia clearly shows that climate changes are taking place in the direction of a

significant increase in summer temperatures (both minimum, maximum and average) and an increase in the sum of effective temperatures during the growing season. Agricultural production, however, depends on the local trend of precipitation, with the hilly and mountainous areas of the region being in a much better position. At most stations, the increase in annual precipitation, as well as precipitation during the growing season, manages to match or overcome heat stress, while soil moisture remains satisfactory. The Vranje basin in the south of the region, however, records a significant increase in aridity, which requires special adjustment measures and the use of irrigation in agricultural production.

References

- Burić D., Mihajlović J., Ducić V., Milenković M., Anđelković G. (2023) Contribution to the study of climate change in Serbia using continentality, oceanity and aridity indices, *Időjárás* 127(3), 379–399.
- Gajić, M. and Krstić, F. (2025) *Geografija Srbije* 1, Beograd: Univerzitet u Beogradu – Geografski fakultet.
- Gocić, M., Milentijević, N., Ivanović, M., Tošić, I., Živanović, S., Martić Bursać, N., Stričević, Lj. (2025) Spatial and temporal variability of aridity indices in the region of Souther and Eastern Serbia, *Theoretical and Applied Climatology*, 156.
- Gocic, M., Trajkovic, S., (2014) Spatiotemporal characteristics of drought in Serbia, *Journal of Hydrology* 510, 110–123.
- Maliva, R., Missimer, T. (2012) *Arid Lands Water Evaluation and Management, Environmental Science and Engineering*, Springer-Verlag, Berlin, Heidelberg,
- Meteorološki godišnjak I (1961-2024). Beograd: Savezni hidrometeorološki zavod (do 1990); Republički meteorološki zavod (od 1991).

Trajković, S. (2019) *Prostorno-vremenske karakteristike suša u Srbiji. In Geohazard u Srbiji u 21. veku – znanje je najbolji bedem protiv stihije. Ciklus predavanja / Srpska akademija nauka i umetnosti, knj. 5. Beograd: Srpska akademija nauka i umetnosti, 25–41.*