DOI:10.28974/idojaras.2025.4.4

IDŐJÁRÁS

Quarterly Journal of the HungaroMet Hungarian Meteorological Service
Vol. 129, No. 4, October – December, 2025, pp. 443–464

Evaluation of bioclimatic conditions for tourism activities in the Podrinje-Valjevo Region (Serbia)

Jelena Milenković*and **Milica Lukić**

University of Belgrade - Faculty of Geography, Belgrade, Serbia

**Corresponding author E-mail:* jelenamilenkovic311@gmail.com

(Manuscript received in final form November 22, 2024)

Abstract— To better understand outdoor thermal comfort on both seasonal and monthly levels, the current trends and anomalies in the Podrinje-Valjevo Region (PVR) over the past 30 years (1991–2020) and their impact on tourist activities, two bioclimatic indices, the Universal Thermal Climate Index (UTCI) and the Tourism Climatic Index (TCI), were utilized for the temporal assessment of bioclimatic conditions in Loznica and Valjevo. The results show that spring and autumn are the most favorable seasons for outdoor tourism activities, with April, May, September, and October being particularly optimal. According to UTCI, November has also become more bioclimatically favorable due to a rise in average monthly UTCI values. Additionally, UTCI data reveal a notable upward trend in seasonal anomalies, especially during autumn and spring, with average seasonal UTCI values increasing. Although TCI indicates that summer is particularly ideal for tourist outdoor activities and tourists' thermal comfort, UTCI highlights that summer months can cause significant thermal discomfort due to moderate heat stress. The results obtained can serve to more effective tourism planning in the Podrinje-Valjevo Region in Serbia.

Key-words: Podrinje-Valjevo Region, Loznica, Valjevo, Universal Thermal Climate Index, Tourism Climatic Index

1. Introduction

Climate plays a crucial role in the development of tourism and is considered a significant "pull" factor in selecting tourist destinations (*Hu* and *Ritchie*, 1993; *Scott et al.*, 2016; *Dann*, 1981; *Lohmann* and *Kaim*, 1999). Climate can be viewed as both a direct and an indirect tourism value, influencing various aspects of human activity. When the climate of a location attracts tourists because it enables certain activities, such as skiing, swimming, or heliotherapy, it serves as a direct tourism value. Conversely, climate also impacts the surrounding environment – such as vegetation, water bodies, and topography – which can enhance the region's appeal as a tourist destination, representing an indirect tourism value (*Stanković*, 2008). Additionally, unfavorable climatic conditions can restrict or inhibit tourism activities, highlighting the strong dependence of tourism on weather and climate conditions at the destination (*Grillakis et al.*, 2016). Since climate directly and indirectly influences tourism, impacting the development of various tourism types, tourist demand, and overall tourist satisfaction, the scientific community has begun to assess climate elements to determine favorable conditions for tourist activities. This assessment primarily relies on climate indices, which provide insights into how suitable a region's climate is for tourism activities.

Numerous studies in the scientific literature have been exploring climate tourism indices and the relationship between climate and tourism (*Besancenot et al.*, 1978; *Mieczkowski*, 1985; *de Freitas*, 1990; *Becker*, 1998; *Lise* and *Tol*, 2002; *Bigano et al.*, 2006). Understanding the effects of climate on specific tourist activities and predicting bioclimatic indicators can lead to more effective tourism planning at local, regional, and national levels (*de Freitas et al.*, 2008).

Bioclimate is a subfield of climatology that is particularly relevant to tourism. Bioclimatic evaluation of tourist sites offers significant potential and various advantages for planning tourism development. With over 100 bioclimatic indices available today, it is possible to describe the bioclimatic and microclimatic conditions of both outdoor and indoor environments, whether urban or rural, with great precision. In addressing climate change adaptation and mitigation, it is crucial to redefine the way we observe land use and incorporate new indicators that more comprehensively reflect the changing climatic conditions and outdoor thermal comfort for tourists. Some of those indicators should certainly be Universal Thermal Climate Index (UTCI) and Tourism Climatic Index (TCI).

The Universal Thermal Climate Index (UTCI) is one of the most frequently used indices in bioclimatic research worldwide and has found its significant application in contemporary tourism studies. *Błażejczyk et al.* (2020) have applied UTCI in the assessment of weather suitability for outdoor tourism in three different European regions (Ukraine, Poland, and Serbia). *Velea et al.* (2024) have conducted a study that addresses the characteristics of a climate service targeting tourists for selected urban destinations in Romania and Italy, with a particular focus on thermal stress information. *Pecelj et al.* (2018) have used UTCI in the geoecological assessment of the local environment for the purposes of recreational tourism. *Nam et al.* (2024) have investigated four European coastal regions in Germany, Spain, France, and Italy to support the planning and development of coastal areas and activities, in particular, beach tourism through a better understanding on the influence of heat stress on tourists, using UTCI. Furthermore, UTCI proved to be effective in the bioclimatic evaluation of rural and mountain tourist regions, etc. (*Stojićević*, 2016; *Pecelj et al.*, 2020). The importance of UTCI in bioclimatic research is also indicated by the fact that this index is recognized and recommended by the World Meteorological Organization (WMO) (*Kolendowicz et al.*, 2018).

Another bioclimatic index that is strongly related to tourism is the Tourism Climatic Index (TCI). TCI assesses climatic factors that significantly impact both the quality of the tourist experience and tourists' physical comfort (*Mieczkowski*, 1985). This index has been successfully applied in a range of studies on climate and tourism (*Oğur* and *Baycan*, 2024; *Cao* and *Gao*, 2022; *Kovács* and *Unger*, 2014; *Lukić et al.*, 2021; *Masoudi*, 2021; *Scott et al.*, 2016; *Noome* and *Fitchett*, 2019; *Sobhani* and *Safarian Zengir*, 2020; *Mohmoud et al.*, 2019; *El-Masry et al.*, 2022; *Scott et al.*, 2004; *Amelung* and *Viner*, 2006; *Perch-Nielsen et al.*, 2010; *Rutty et al.*, 2020).

This paper aims to apply both UTCI and TCI to evaluate the climate conditions for tourism activities in the Podrinje-Valjevo Region (PVR) in western Serbia. Additionally, it aims to compare these two bioclimatic indices to determine which one offers a more comprehensive understanding of the relationship between climate and tourists' physical comfort throughout the year. Valjevo and Loznica, being the largest settlements in the region, were selected for this climate evaluation due to their availability of the necessary data to calculate these climatic indices.

2. Materials and methods

2.1. Study area

The Podrinje-Valjevo Region (PVR) is located in northwestern Serbia, on the southern border of the Pannonian Basin (*Fig. 1*). Spanning from the Drina River in the west to Ljig and Dičina rivers in the east, the PVR forms a distinct morphostructural unit that gradually slopes northward towards the Jadar-Kolubara basin. The PVR is characterized by relatively low-altitude mountains, with the majority of the terrain (88.6%) ranging between 200 and 800 meters. The extensive length and breadth of the mountain range (117 km), its pronounced topographical features, the proximity to the Drina River, and the submountainous climate in the south have all contributed to the region's climatic diversity and the development of microclimatic zones.

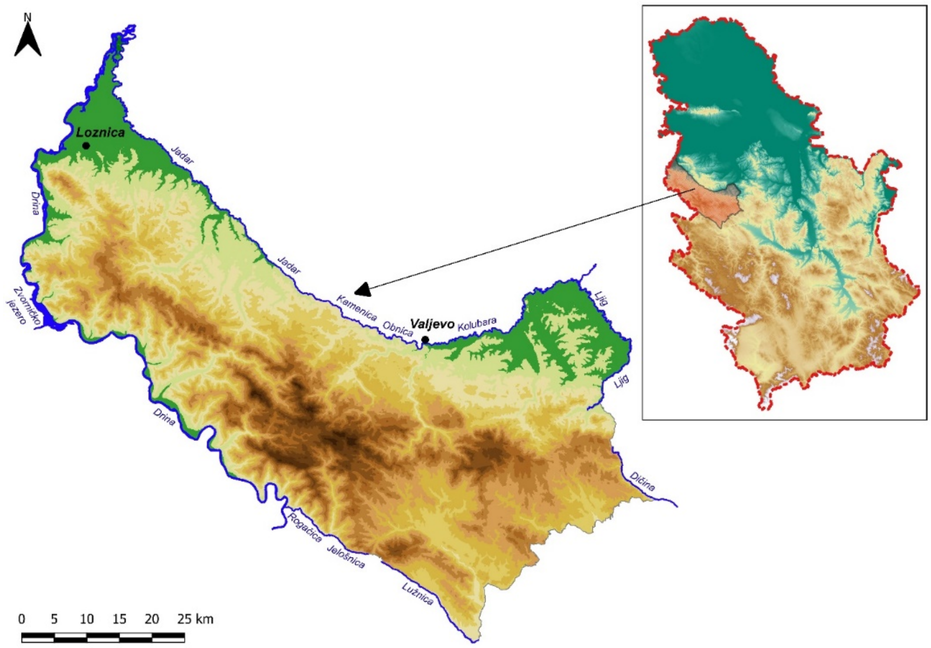

Fig 1. The Podrinje-Valjevo Region.

The PVR is situated within Serbia's humid continental climate zone, characterized by a continental precipitation regime (*Ćirković*, 1977). The region's proximity to the Pannonian Basin and its northern exposure contribute to its continental climate characteristics (*Simić*, 2016). Overall, the humid continental climate is marked by moderately warm summers and moderately cold winters, with relatively mild annual temperature variations (*Ćirković*, 1977; *Pjevač*, 1997; *Pjevač*, 2002). The transitional seasons are lengthy and typically lack extreme temperatures. Precipitation is heaviest at the end of spring and the beginning of summer, while it is least frequent at the start of autumn. In contrast, the subalpine climate found in mountainous areas above 800 meters is characterized by cooler, shorter summers, longer, harsher winters, and smaller annual temperature fluctuations (*Ćirković*, 1977).

In their study of Serbia's climate, *Ducić* and *Radovanović* (2005) classified the PVR as part of climatic subregion A-2. This subregion is defined by an average annual air temperature of approximately 9 °C and a temperature range of 20 °C throughout the year. The average air temperature in the hottest month of the mountains does not surpass 18.4 °C (*Ducić* and *Radovanović*, 2005).

2.2. Data description

The first phase of the research included the collection of meteorological data needed to conduct a bioclimatic analysis. The data set was taken from the Meteorological Yearbooks, for both meteorological stations (Valjevo 44°17'N, 19°55'E, 174 m, and Loznica 44°32'N, 19°14', 121 m), which are prepared and published by the Republic Hydrometeorological Service of Serbia (RHSS). Meteorological yearbooks are published annually, and on this occasion, publications for the period 1991–2020 were used. To calculate UTCI, the mean monthly values of the following meteorological parameters were used: air temperature (t), relative humidity (f), wind speed at 10 m above the ground (v10m), and cloud cover/cloudiness (N). To determine the UTCI values, the software "Bio Klima 2.6 – Universal tool for bioclimatic and thermophysiological studies" was used. On the other side, to calculate TCI, the mean monthly values of seven climatic parameters were used: average daily maximum air temperature, average daily air temperature, average daily minimum air humidity, average daily air humidity, total precipitation, total insulation, and average wind speed.

2.3. Universal Thermal Climate Index (UTCI)

The Universal Thermal Climate Index (UTCI) is one of the most commonly used bioclimatic indices for determining outdoor thermal comfort in urban environments and is widely used in various fields: urban planning, tourism, ecology, public health, etc. (*Lukić et al.*, 2021). *Błazejczyk et al.* (2013) defined UTCI (°C) as: "the air temperature of the reference condition that causes the same model response as actual conditions". The UTCI was derived from the "Fiala multi-node model" (*Fiala et al.*, 2011; *Blazejczyk et al.*, 2011, 2013). The reference environment for this model was defined by the ISB Commission (International Society of Biometeorology) as: (i) condition of calm air, i.e., wind speed (v10m) 0.5 m/s at 10 m above the ground; (ii) a mean radiant temperature (Tmrt) equal to air temperature; (iii) Relative humidity (f) of 50% (capped at 20 hPa for air temperatures over 29 °C) (*Blazejczyk et al.*, 2011, 2013; *Bröde et al.*, 2013).

It is important to note that for the determination of UTCI, in addition to meteorological parameters, it is necessary to use physiological parameters in order to represent thermal comfort through the assessment of human energy balance, where the metabolic rate (M) has a crucial position (*Bröde et al.*, 2011a, 2011b, *Pecelj et al.*, 2020). Physiological parameters (metabolic rate and thermal properties of clothing) are taken as universal constants in the model due to the evaluation by means of regression equation (*Lukić et al.*, 2021; *Pecelj et al.*, 2020, 2021). This implies an outdoor activity where an average person walks at a speed of 4 km/h (1.1 m/s), resulting in a heat production of 135 W/m2 of metabolic energy and clothing insulation, which is self-adapting according to the environmental conditions (*Pecelj et al.*, 2021; *Havenith et al.*, 2011).

According to UTCI, there are 10 different categories of thermal stress (*Table 1*). The UTCI is calculated as follows: UTCI = f (t,f,v,tmrt), where: t = air temperature (°C), f = relative humidity (%), v = wind speed (m/s), tmrt = mean radiant temperature (°C).

Table 1. UTCI categories of thermal stress (*Blazejczyk et al.*, 2013)

UTCI (°C)	Stress Category
UTCI>46	Extreme heat stress
38<UTCI<46	Very strong heat stress
32<UTCI<38	Strong heat stress
26<UTCI<32	Moderate heat stress
9<UTCI<26	No thermal stress
0<UTCI<9	Slight cold stress
-13<UTCI<0	Moderate cold stress
-27<UTCI<-13	Strong cold stress
-40<UTCI<-27	Very strong cold stress
UTCI<-40	Extreme cold stress

2.4. Tourism Climatic Index (TCI)

The Tourism Climatic Index (TCI) is a bioclimatic indicator that assesses climatic elements most affecting the quality of the tourist experience and tourists' physical comfort (*Mieczkowski*, 1985). As a quantitative and statistical measure of tourist comfort, TCI primarily relies on temperature and relative humidity. However, the calculation of TCI also incorporates three additional climatic elements: insolation, precipitation, and wind speed.

The TCI values are calculated using the following formula:

$$TCI = 2 \times (4CID + CIA + 2P + 2S + W),$$

where CID is the daytime comfort index (obtained by combining the maximum daily temperature and the minimum daily relative air humidity); CIA is the daily comfort index (obtained by combining the average daily temperature and the average daily relative air humidity) (*Fig. 2*); P is the average precipitation (mm); S is the average daily insolation (hours per day), and W is the average wind speed (m/s).

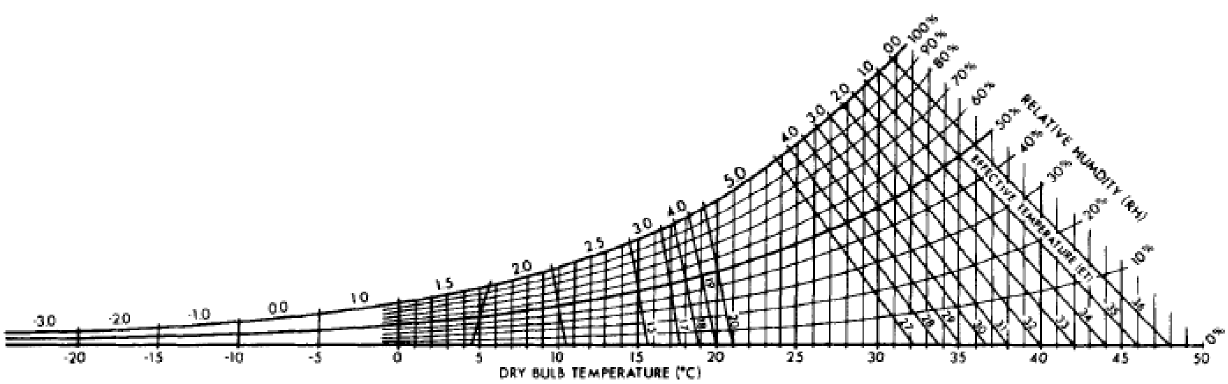

*Fig 2***.** Diagram of CID and CIA (*Mieczkowski*,1985).

Each parameter is scored between -3 (extremely unfavorable) and +5 (optimal) (*Table 2*). The total score is then multiplied by 2, allowing the maximum possible TCI score to be 100. TCI values are categorized as follows: ideal (90–100), excellent (80–89), very good (70–79), good (60–69), acceptable (50–59), possible (40–49), unfavorable (30–39), very unfavorable (20–29), extremely unfavorable (10–19), and impossible (<10) (*Table 3*) (*Mieczkowski*, 1985). It is important to emphasize that, despite being based on biometric literature and the available climate data of the time, the method used to evaluate these subindices and determine the final TCI values remains both descriptive and subjective.

Table 2. Matrix for assessing precipitation, insolation, and wind (*Mieczkowski*, 1985)

Points	**P (mm)**	**S (h)**	**W (m/s)**
5.0	≤14.9	>10	<0.8
4.5	15.0–29.9	9–10	0.8–1.5
4.0	30.0–49.9	8–9	1.6–2.5
3.5	50.0–59.9	7–8	2.6–3.3
3.0	60.0–74.9	6–7	3.4–5.4
2.5	75.0–89.9	5–6	5.5–6.7
2.0	90.0–104.9	4–5	6.8–7.9
1.5	105.9–119.9	3–4	-
1.0	120.0–134.9	2–3	8.0–10.7
0.5	135.0–149.9	1–2	-
0	150.0 or more	<1	>10.7
-0.5	-	-	-
-1.0	210.0–269.9	-	-
-1.5	-	-	-
-2.0	270.0–329.9	-	-

Table 3. Rating categories of TCI (*Mieczkowski,* 1985)

TCI	**Category**
90–100	ideal
80–89	excellent
70–79	very good
60–69	good
50–59	acceptable
40–49	marginal
30–39	unfavorable
20–29	very unfavorable
10–19	extremely unfavorable
<10	impossible

3. Results and discussion

The following text presents the results of a bioclimatic analysis of the PVR using two indices – UTCI and TCI – on both seasonal and monthly bases. This analysis aims to assess outdoor thermal comfort and tourists' physical comfort in the urban environments of Loznica and Valjevo over a 30-year period (1991–2020).

3.1. UTCI-based seasonal analysis of outdoor thermal comfort in Loznica and Valjevo

The conducted bioclimatic analysis of both urban environments (Loznica and Valjevo) showed a change in outdoor thermal comfort over 30 years (1991–2020). Climatic changes, longer and more frequent heat waves, and the increase in the average annual air temperature are reflected in the increase of UTCI annual and seasonal values – which may have a significant impact on tourist activities in the future.

Based on the data shown in *Table 4*, we can observe a continuous increase in the mean seasonal values of the UTCI during the last three decades. For instance, in Loznica, the average spring value of UTCI in the period 1991–2000 was 18.16 °C, in the period 2001–2010 it was 18.57 °C, and in the period 2011–2020, that value was 19.45 °C. The results for Valjevo show similar trends: during the first decade of research, the average spring UTCI value was 15.73 °C, during the second decade it was 16.7 °C, and during the third decade it reached 17.37 °C. Significant changes in terms of outdoor thermal comfort were also registered during the autumn season: the average autumn UTCI in Loznica for the period 1991–2000 was 18.34 °C, for the period 2001–2010 it was 18.49 °C, while during the period 2011–2020 it was 19.88 °C (the difference between the first and last decade of the researched period amounts to +1.54 °C). The fact that autumns in this part of Serbia are getting warmer, as well as that thermal discomfort is increasing, is also confirmed by the data for Valjevo: the average autumn value of UTCI in the period 1991–2000 was 17.08°C, and during the period 2011–2020, it was 18.62 °C (+1.54 °C). Significant changes were also registered during the summer season, both in Loznica and Valjevo, while they were slightly less pronounced during the winter.

Table 4. Average seasonal UTCI (°C) values in Loznica and Valjevo for the period 1991–2020, and average decade-long UTCI values for the 1st (1991–2000), 2nd (2001–2010), and 3rd decade (2011–2020).

Loznica	**Avg. UTCI winter**	**Avg. UTCI spring**	**Avg. UTCI summer**	**Avg. UTCI autumn**
1991–2000	7.39	18.16	28.71	18.34
2001–2010	5.73	18.57	28.61	18.49
2011–2020	8.10	19.45	29.63	19.88
Average for 1991–2020	7.07	18.72	28.98	18.90
Valjevo	**Avg. UTCI winter**	**Avg. UTCI spring**	**Avg. UTCI summer**	**Avg. UTCI autumn**
1991-2000	5.11	15.73	27.50	17.08
2001-2010	3.14	16.70	27.79	16.96
2011-2020	6.36	17.37	29.05	18.62
Average for 1991–2020	4.87	16.60	28.11	17.55

Fig. 3 shows the average seasonal UTCI in Loznica during the period 1991–2020 with trends. Based on the presented results, we can see that the most significant changes in bioclimatic conditions took place during the autumn months, considering that the average autumn UTCI values during the reference period achieved a positive trend of 0.069 °C/year. The maximum average autumn UTCI in Loznica was measured in 2019 (UTCI=21.13 °C). In the second place is the average spring UTCI, which achieved a positive trend, i.e., an increase in mean values at a rate of 0.062°C/year. The maximum average spring UTCI in Loznica was measured in 2018 (UTCI=21.54 °C). During the previous 30 years, the average summer UTCI increased at a rate of 0.038 °C/year, while the average winter values of the index increased at a rate of 0.028 °C/year. The maximum average summer UTCI was recorded in 2012 (31.45 °C), while the maximum average winter UTCI was recorded in 2014 (11.1 °C).

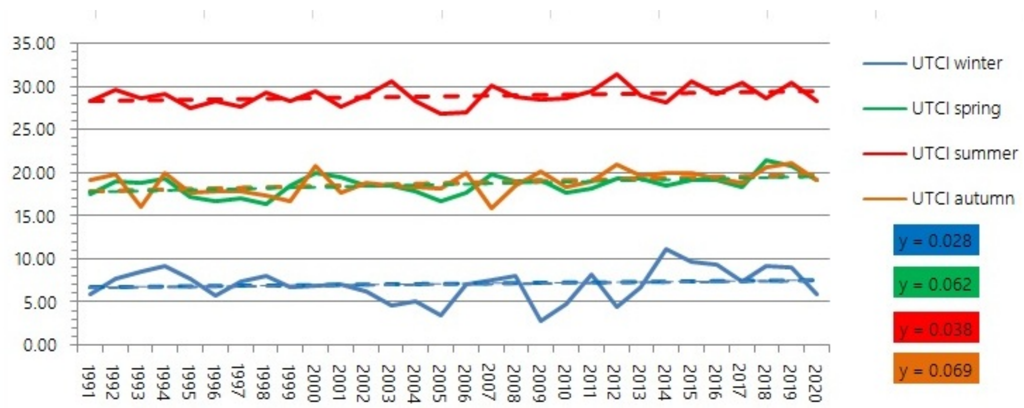

Fig. 3. Average seasonal UTCI during the period 1991–2020 in Loznica with trends.

To obtain a more detailed insight into the recorded changes in thermal comfort at the seasonal level in Loznica, the corresponding months were analyzed separately for each season. *Figs. 4.a* and *4.b*. show average monthly UTCI in the period 1991–2020 with trends for winter months (January, February, and December) and spring months (March, April, and May), while *Figs. 5.c.* and *5.d.* show average monthly UTCI with trends for summer months (June, July, and August) and autumn months (September, October, and November). Observing the obtained results, we can conclude that during all 12 months of the year, an increase in average monthly UTCI values was recorded, although the most noticeable changes were recorded during the autumn and spring months, especially November, March, and April. The average November UTCI value during the previous 30 years grew at a rate of as much as 0.145 °C/year. The average April UTCI values increased at a rate of 0.096 °C/year, while the average March UTCI values increased at a rate of 0.071 °C/year).

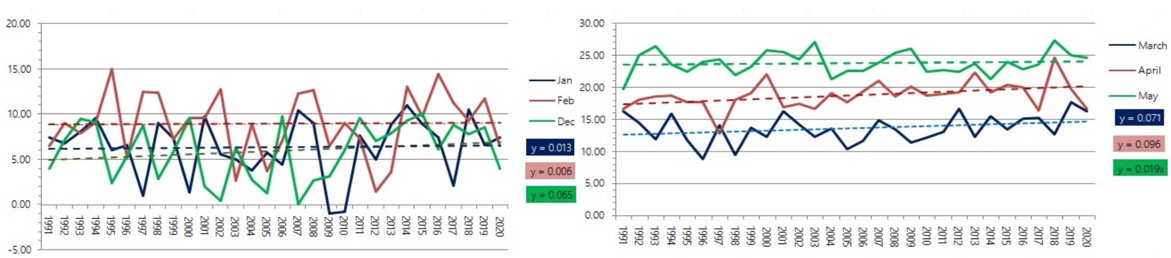

Fig. 4.a and *4.b.* Average monthly UTCI in the period 1991–2020 in Loznica with trends: winter months – January, February, December (left) and spring months – March, April, May (right).

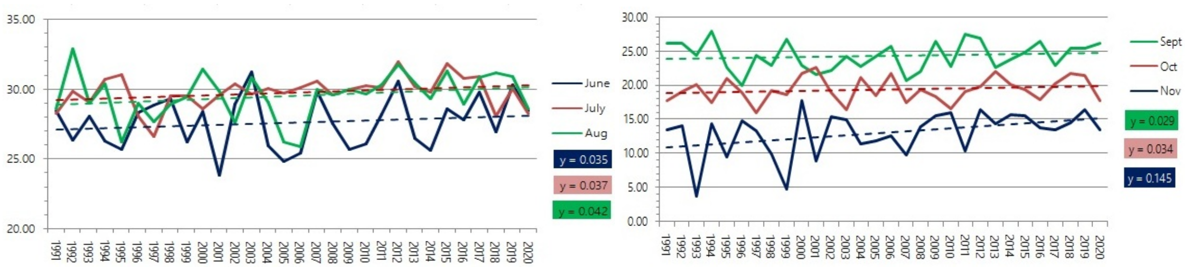

Fig. 5.c. and *5.d.* Average monthly UTCI in the period 1991–2020 in Loznica with trends: summer months – June, July, August (left) and autumn months – September, October, November (right).

Among the winter months, December especially stands out, where the average monthly UTCI values had a positive trend of 0.065 °C/year. The average February values of this index increased the slowest, at a rate of only 0.006 °C/year. The average January UTCI values had a positive trend of

0.013 °C/year. During the summer months, the rising trend of the average monthly UTCI values was relatively similar: for June it was 0.035 °C/year, for July it was 0.037°C/years and for August it was 0.042 °C/year.

Fig. 6 shows the average seasonal UTCI in Valjevo during the period 1991–2020 with trends. As in the case of Loznica, the most significant changes in the bioclimatic conditions of the local urban environment (Valjevo) were registered during autumn. The average autumn UTCI values during the past 30 years were increased at a rate of 0.076 °C/year. The maximum average autumn UTCI in Valjevo was recorded in 2019 (20.63 °C). The same growth rate of average seasonal values was reached by summer and spring UTCI with a positive trend of 0.073 °C/year. The maximum average summer UTCI in Valjevo was recorded in 2012 (30.81 °C), while the maximum average spring UTCI was recorded in 2018 (20.39 °C). The average winter UTCI has a positive growth trend of 0.063 °C/year. Its maximum seasonal value was measured in 2014 (9.21 °C).

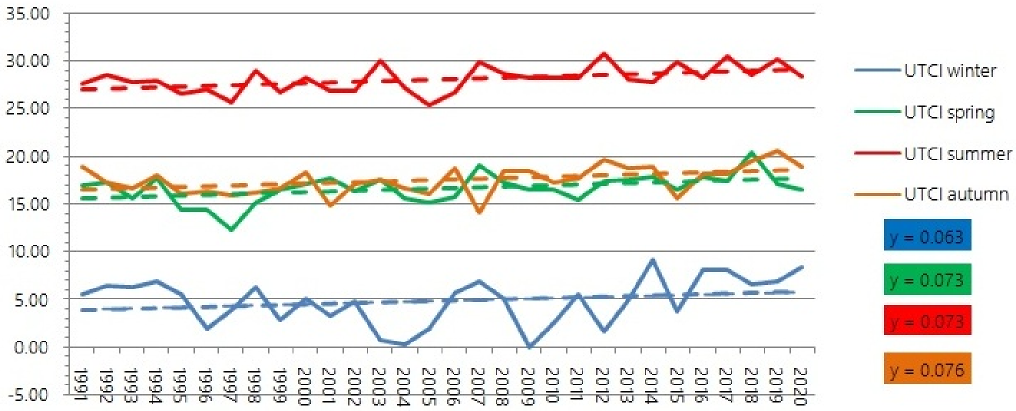

Fig. 6. Average seasonal UTCI during the period 1991–2020 in Valjevo with trends.

Figs. 7.a and *7.b.* show average monthly UTCI in Valjevo (1991–2020) with trends for winter months (January, February, and December) and spring months (March, April, and May), while *Figs. 8.c.* and *8.d.* show average monthly UTCI with trends for summer months (June, July, and August) and autumn months (September, Octobe,r and November). If we compare Valjevo and Loznica, we can conclude that more significant changes took place in Valjevo, where the average monthly values of the index grew at much higher rates. That difference is especially noticeable when we look at the summer months: for June the trend is 0.044 °C/year, for July it is 0.074 °C/year, and for August it is 0.103 °C/year. Considering the given values, we can expect more bioclimatically unfavorable summers in Valjevo, with more pronounced thermal stress that can have an impact on public health, tourism, and recreation. Apart from the summer months, autumn is also getting warmer: the average September UTCI value has a rising trend of 0.054 °C/year, the average October UTCI value has a rising trend of 0.061 °C/year, while the average November UTCI has a rising trend of 0.112 °C/year. Among the spring months, April stands out, with a trend of growth in average monthly UTCI values at a rate of 0.128 °C/year. Among winter months, December stands out, with a trend of growth in average monthly UTCI values at a rate of 0.133 °C/year.

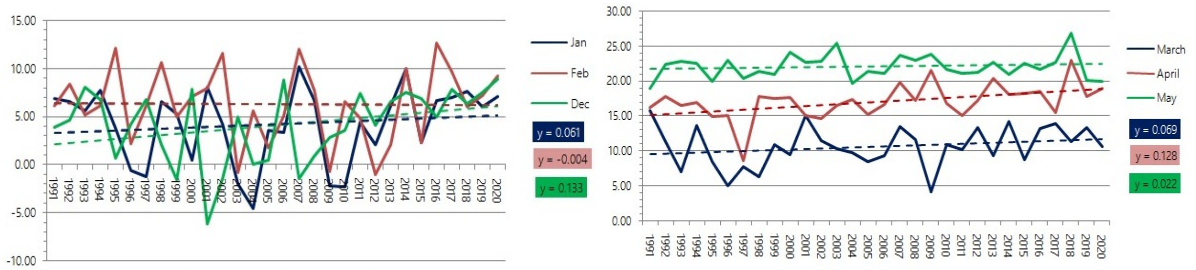

Fig. 7.a and *7.b.* Average monthly UTCI in the period 1991–2020 in Valjevo with trends: winter months – January, February, December (left) and spring months – March, April, May (right).

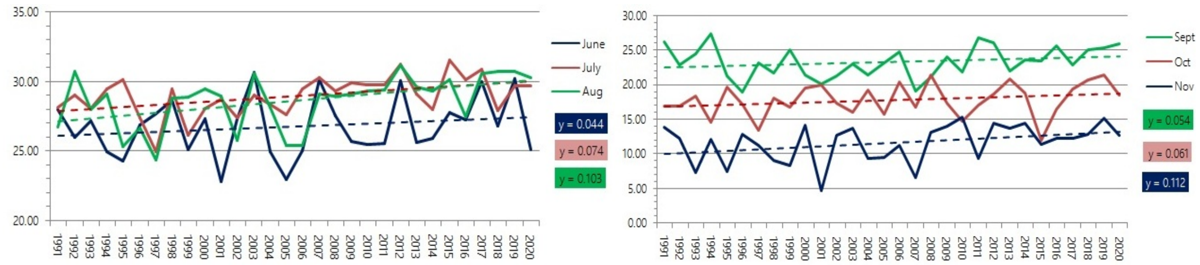

Fig. 8.c. and *8.d.* Average monthly UTCI in the period 1991–2020 in Loznica with trends: summer months – June, July, August (left) and autumn months – September, October, November (right)

The findings of this research are consistent with and further support the results of previous studies on climate, bioclimatic conditions, biometeorology, urban microclimates, and thermal comfort across Serbia. *Bajat et al.* (2014) analyzed the mean monthly air temperatures at 64 meteorological stations, including those in Loznica and Valjevo, over the period 1961–2010. Their research revealed a clear warming trend, particularly after 1989, with nearly all stations showing an increase in temperature ranging from 0.18 °C/decade to 3.63 °C/decade (or 0.36 °C/year). Similarly, *Unkašević* and *Tošić* (2013) analyzed daily minimum and maximum temperatures from 15 meteorological stations, including Loznica, over the period 1949–2009. Their findings highlighted a pronounced warming trend in Serbia's climate, which became particularly evident after 2000. In addition to the rise in mean daily temperatures and extreme temperature values, they also observed an increase in the number of "summer drop", and "tropical days" and "tropical nights", while the number of "ice days" decreased (*Unkašević* and *Tošić*, 2013). In his doctoral dissertation, *Stojićević* (2016) examined the annual and seasonal variations of the bioclimatic index UTCI in western Serbia from 1979 to 2013. Since the Podrinje-Valjevo Region is part of western Serbia and this study covers the period after 2013, the results were compared with those of Stojićević. Both studies observed similar trends, confirming the rising temperatures and changing bioclimatic conditions in the region. *Stojićević* (2016) has showed that in the area of western Serbia, the mean annual values of the Physiological Equivalent Temperature (PET) index are growing at an average rate of 0.065 °C/year. During the summer months, the mean values of the PET index grew at a rate of 0.098 °C/year. In the area of western Serbia, the statistically significant trend of the PET index value during the spring months was 0.081 °C/year, and during the autumn it was 0.042 °C/year. If we look at the annual and seasonal variations of the UTCI bioclimatic index during the researched period, an average increase in the mean annual UTCI values by 0.052 °C/year was registered. Autumn values of the UTCI index also record a rising trend of 0.037 °C/year, spring values show 0.064 °C/year, while summer UTCI values show a growing trend of 0.057 °C/year. Similar findings were also noted in a study by *Lukić* and *Đurić* (2021), which focused on thermal discomfort during the summer months over a ten-year period (2009–2018) in the cities of Loznica (Serbia) and Bijeljina (BiH). Their results of daily and monthly UTCI values revealed an increase in the number of days with "moderate", "strong", and "very strong" heat stresses.

3.2. TCI analysis of tourists' physical comfort in Loznica and Valjevo

In the PVR, TCI was calculated for the climatological stations in Valjevo and Loznica over a 30-year period (1991–2020) and for each decade within this span (1991–2000, 2001–2010, 2011–2020). *Table 5* presents the climate indicators used for TCI calculations at these stations, along with their average monthly values for the 30-year period. The TCI calculations revealed which months are most and least favorable for outdoor sports and recreational activities.

The TCI values for the period from 1991 to 2020 range from "marginal" to "excellent", indicating that the climate of the PVR is generally favorable for outdoor tourism activities. According to TCI results, the winter months – December, January, and February – are the least favorable for outdoor tourism due to their low temperatures, high relative humidity, and reduced sunlight. However, despite being the least favorable according to TCI, these months also bring snowfall, creating ideal conditions for snow-based sports and recreational activities in the region's mountainous areas. This is one of the major shortcomings of TCI that is observed in various studies that have employed this index (*Matzarakis*, 2006).

Table 5. Average monthly values of climatic parameters for Valjevo and Loznica

Valjevo	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XI**
T_{max}	5.8	8.4	13.2	18.4	22.8	26.5	28.7	29.0	23.9	18.8	12.9	6.5
T_{avg}	1.0	2.9	7.2	12.1	16.9	20.7	22.6	22.3	17.2	12.0	7.0	2.1
R_{min}	38.1	28.7	32.1	23.8	27.1	27.9	27.0	25.7	27.0	29.7	32.3	38.5
R_{avg}	83.2	77.3	70.4	68.3	70.0	69.3	67.0	67.7	73.8	78.6	80.8	83.9
P	49.0	49.1	58.2	58.5	87.6	102.8	76.5	66.3	64.9	65.3	54.2	60.1
S	2.4	3.5	4.8	6.1	7.2	8.3	9.5	8.9	6.6	5.0	3.2	2.1
W	1.1	1.4	1.8	1.7	1.5	1.5	1.5	1.5	1.4	1.2	1.2	1.2
Loznica	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XI**
T_{max}	5.7	8.4	13.4	18.6	23.2	26.8	28.8	29.2	24.0	19.0	12.6	6.5
T_{avg}	1.4	3.2	7.5	12.4	17.1	20.9	22.5	22.2	17.2	12.3	7.3	2.5
R_{min}	41.2	31.2	23.7	25.1	27.9	31.4	29.9	28.5	28.5	31.3	34.0	41.7
R_{avg}	82.8	77.2	69.7	67.8	69.4	69.7	68.1	69.0	74.5	79.3	81.6	83.5
P	63.0	54.5	65.0	63.4	90.9	107.2	80.4	69.9	71.1	74.1	68.8	72.3
S	2.1	3.2	4.8	6.2	7.3	8.4	9.5	9.1	6.5	4.8	2.8	1.7
W	0.7	0.9	1.1	1.0	1.0	1.0	1.0	0.9	0.7	0.6	0.6	0.8

T_{max} – maximum daily air temperature (°C), T_{avg} – average daily air temperature (°C), R_{min} – minimum daily relative humidity (%), R_{avg} – average daily relative humidity (%),
P – total precipitation (mm), S – total daily insolation (h), W– average wind speed (m/s).
Source: Meteorological yearbook of RHSS (1991–2020).

March and November are characterized by "acceptable" conditions for tourist comfort for both urban environments, with TCI values ranging from 50 to 59. "Good" climate conditions for tourism begin in April at both climatological stations. May is considered "very good" for tourist activities both in Loznica and Valjevo. The summer months – June, July, and August, as well as October – provide "excellent" conditions for outdoor tourism, with TCI values ranging from 80 to 86 for both urban environments (*Table 6*, *Fig. 9*).

Table 6. TCI values for Loznica and Valjevo, presented by decade and as a 30-year average (1991–2020)

Loznica	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	x̄
1991-2000	45	53	55	66	82	82	86	88	81	71	48	41	66.5
2001-2010	45	47	53	68	81	81	87	85	78	65	52	40	65.1
2011-2020	45	44	55	74	71	83	85	85	84	73	52	45	66.3
1991–2020	45	48	54	69	78	82	86	86	81	69	50	42	66
Valjevo	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**x̄**
1991-2000	48	52	56	61	81	81	87	87	80	62	53	44	66
2001-2010	48	50	52	63	82	81	86	84	75	60	51	42	64.5
2011-2020	46	47	54	71	70	85	84	87	85	74	55	46	67
1991–2020	47	49	54	65	78	82	85	86	80	65	53	44	65.8

Bioclimatic conditions for tourist activities: marginal (40–49), acceptable (50–59), good (60–69), very good (70–79), excellent (80–89). Source: independent data processing based on the data from Meteorological yearbook of RHSS (1991–2020).

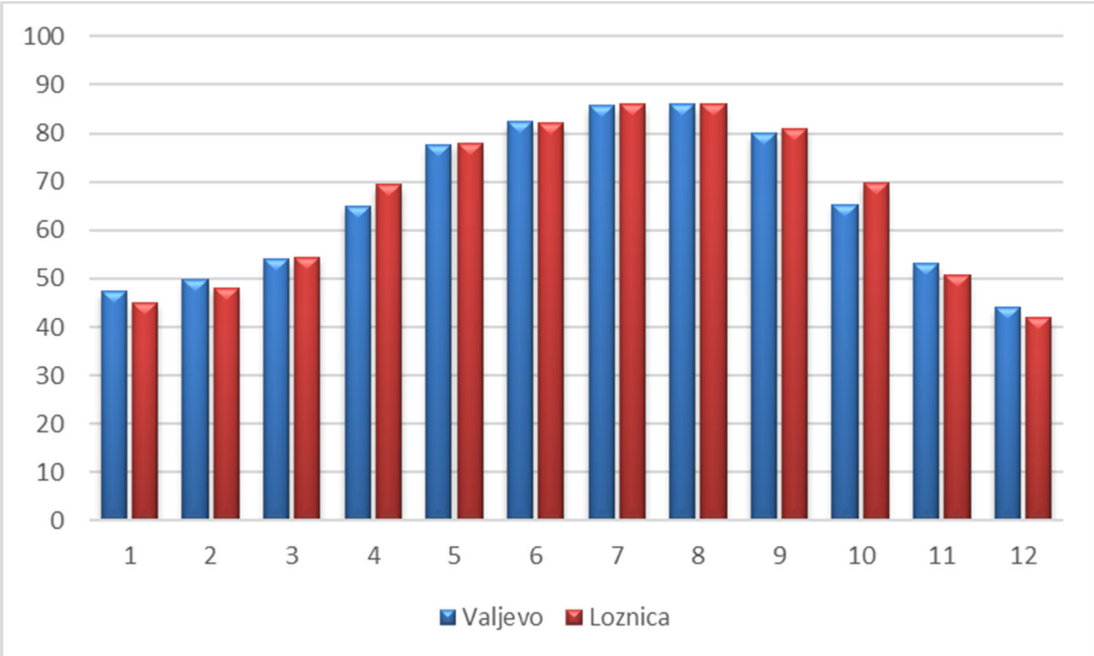

Fig. 9. TCI chart for the PVR (Valjevo and Loznica) over the 30-year period of 1991–2020.

High TCI values at the end of spring, during summer, and at the beginning of autumn are closely tied to the climatic conditions of these periods. During these periods, air temperatures rise, peaking in July and August. Conversely, relative humidity decreases starting in spring and hits its lowest in summer. Additionally, insolation is at its highest during this period. Interestingly, while May and June receive the most precipitation across all meteorological stations, TCI values for these months remain "very good" or "excellent". This is because the precipitation during these months typically falls as brief showers, providing a refreshing effect and generally benefiting outdoor activities for tourists.

Table 6 also presents the TCI values for Loznica and Valjevo, broken down by three decades over the 30-year span from 1991 to 2020. The data for both climatological stations show that in the first decade (1991–2000), the TCI values were “excellent” from May to September. In the second decade (2001–2010), the TCI values for both climatological stations were “excellent” from May to August, “very good” in September, and “good” in April and October. However, this pattern has changed in the last decade (2011–2020), primarily due to the significant effects of climate change. The third decade reveals notable changes in TCI values for both climatological stations, with March and November rated as “good”, April, May, and October as “very good”, and the summer months as “excellent” for tourism and physical comfort.

3.3. Comparative analysis of the climate index results for the PVR

The application of the UTCI and TCI climate indices to the PVR has revealed some similar results. Both indices indicate that spring and autumn are the most favourable seasons for outdoor tourist activities. However, while TCI suggests that summer is particularly ideal for tourist activities and tourists’ thermal comfort, UTCI indicates that summer months may induce moderate heat stress, leading to thermal discomfort for tourists.

The TCI index relies solely on climatic parameters and their mean monthly values, whereas the UTCI is a more complex bioclimatic index that incorporates both meteorological and physiological factors (such as metabolic rate and clothing thermal properties). Compared to other bioclimatic indices, the UTCI more effectively represents the temporal variability of thermal conditions, being more sensitive to outdoor factors like changes in air temperature, relative humidity, solar radiation, and wind speed (*Lukić et al.*, 2021; *Pecelj et al.*, 2021; *Blazejczyk et al.*, 2011). Moreover, the UTCI is particularly useful for detailed bioclimatic analysis based on daily and hourly meteorological data, offering a clearer picture of how bioclimatic conditions at a given location fluctuate throughout the day – from morning to evening and even at night. In contrast, the TCI provides a broader overview of the bioclimatic conditions in a specific area, without the ability to analyze the finer variability that the UTCI can reveal.

In most European countries, including Serbia, the summer season represents the peak of the tourist season. The TCI indicates that these months are generally the most favorable for outdoor tourist activities in the PVR. However, the effects of climate change have led to increasingly unfavorable bioclimatic conditions and extreme heat stress and thermal discomfort during July and August, as confirmed by the UTCI results. The thermal discomfort experienced in these peak summer months presents a health risk not only to vulnerable populations—such as the elderly, those with chronic health conditions, children, and pregnant women—but also to the general public, including athletes and recreational tourists. This was particularly highlighted by *Obradović-Arsić* and *Gledović* (2012), who studied the effects of climate on public health. They found that while the human body can usually adapt to outdoor conditions, sudden and extreme weather changes, such as high temperatures and heatwaves, can disrupt thermoregulation. These disruptions may cause biochemical changes, resulting in both physical and psychological health issues. The severity of these effects varies depending on age, health status, and individual characteristics. Additionally, a study by *Giannopoulou et al.* (2014) on air temperature and humidity's influence on human thermal comfort during the summer found, that when thermal discomfort persists into the night, sleep becomes difficult, leading to fatigue the next day. In such prolonged discomfort, the body does not have the opportunity to recover, resulting in significant thermal stress that impacts even healthy individuals with high physical capabilities.

Given these considerations, from a bioclimatic standpoint, summer months are the least favorable for tourists' outdoor activities due to the highest likelihood of health risks related to heat stress and elevated temperatures (*Savić et al.*, 2018). With the expected increase in heat stress in the PVR, as shown by the rising trend in average August UTCI values – 0.103 °C/year (or 1.03 °C/dec) in Valjevo and 0.042 °C/year (or 0.42 °C/dec) in Loznica –, it is recommended that tourists avoid engaging in physical activities, including walking, between 9 AM and 6 PM during the summer months.

Considering the proximity of Banja Koviljača Spa, a key center for medical and health tourism, it is important for tourism development experts to examine the connection between weather conditions and the onset of specific health issues. To support this, it is recommended to refer to the study by the Belgrade Emergency Medical Institute and the Republic Hydrometeorological Service of Serbia (*Grupa autora*, 1988), which identified diseases affected by weather changes, referred to as meteorotropic diseases. These include various heart conditions, high blood pressure, strokes, respiratory infections, asthma, rheumatic diseases, and more. This is particularly relevant for the elderly, individuals with chronic health conditions, and children visiting the Specialized Rehabilitation Hospital in Banja Koviljača.

While TCI is a commonly used climate index for tourism and can indicate favorable periods for tourist activities, this study reveals that the tourism industry cannot rely solely on TCI results, especially during the summer months. This index does not effectively capture thermal comfort for tourists, especially as temperatures rise each year. Therefore, it is necessary to use newer bioclimatic indices, such as UTCI, for a more thorough assessment of a region's climate for tourism activities and associated thermal stress. However, neither TCI nor UTCI are reliable for assessing winter tourism conditions. Although UTCI values during winter months indicate the potential for optimal tourist thermal comfort, this also points to rising temperatures due to climate change. This trend poses a threat to winter sports tourism, and if it continues, the PVR may be probably unable to support nature-based winter sports activities in the future. This will particularly affect the Maljen mountain and its Divčibare ski resort, a well-known winter sports destination in the PVR. The increasing winter temperatures are expected to raise the demand for artificial snowmaking, which could drive up ski pass prices and make it financially unfeasible for tourists (*Joksimović et al.,* 2020). Even with extensive artificial snow production, the rising winter temperatures could make it increasingly challenging to sustain winter sports tourism. As a result, there is a considerable risk that, in the future, Maljen could lose its Divčibare ski resort. Given these projections, the Maljen mountain and the entire Podrinje-Valjevo Region will need to explore alternative forms of tourism during the winter months in the coming years.

4. Conclusion

In this study, two climate indices (TCI and UTCI) were evaluated to assess tourism conditions in the Podrinje-Valjevo Region. Based on the conducted bioclimatic analysis, both climate indices have proved that the spring and autumn months are the most favorable for performing tourist activities, recreation, and being outdoors. However, while the results obtained from TCI assessment show that the summer months are the most favorable and “excellent” for outdoor activities, UTCI has proved otherwise, emphasizing the high potential of thermal discomfort for tourists due to moderate heat stress and high air temperatures. The disparity in results between the TCI and UTCI can be attributed to the fact that the TCI is based solely on climatic parameters and their mean monthly values, whereas the UTCI is a more complex bioclimatic index that takes into account both meteorological and physiological factors (such as metabolic rate and clothing thermal properties).

According to the UTCI results, the most favorable months for outdoor tourism activities are April, May, September, and October in both Loznica and Valjevo. Additionally, a notable increase in UTCI values was observed in November from 1991 to 2020. Specifically, the average November UTCI value in Loznica increased by 0.145 °C per year, while in Valjevo, it rose by 0.112 °C per year. The highest UTCI values, indicating the most severe heat stress, are recorded during the summer months, particularly July and August, posing potential health risks. This is of particular concern for tourists visiting the PVR during the summer, particularly vulnerable groups such as the elderly, those with chronic health conditions, children, and pregnant women. Therefore, it is recommended that tourists avoid physical activities, including walking, between 9 AM and 6 PM during the summer months.

With the recorded trends of increasing summer UTCI values in both examined urban environments, we can expect even more pronounced thermal discomfort in the future. The lowest monthly and seasonal UTCI values were measured as expected during the winter months, when cold stress categories of thermal comfort were the most prevalent – which means that the winter months are also less favorable for tourist purposes from the bioclimatic viewpoint. However, since winter sports tourism is inherently dependent on snowfall and low temperatures, cold stress is expected and does not pose a significant barrier to winter sports activities in the PVR. Nevertheless, winters in western Serbia, i.e., Podrinje-Valjevo Region, are getting warmer, as it is shown by the increasing trends of the December's UTCI values (in Loznica 0.065 °C/year; in Valjevo 0.133 °C/year). This warming trend raises concerns about the future viability of nature-based winter sports in this region.

In a changing climate, the frequency of extreme weather events and heat waves is increasing. These global shifts are also affecting local environments (*Čegar et al.*, 2023; *Malinović-Milićević et al.*, 2015), influencing thermal comfort and bioclimatic conditions at tourist sites. *Nam et al.* (2024) emphasizes that understanding how climate change will influence thermal comfort is crucial for the tourism and hospitality sectors to identify risks and opportunities, and maintain competitiveness. While climate is just one factor influencing tourist behavior, it has a significant impact on the overall experience at a destination. By understanding the region's optimal climatic conditions and adjusting tourism offerings accordingly throughout the year, visitors satisfaction can be greatly enhanced. Some studies also suggest that tourists may begin to prefer travel during seasons with lower risks of heat stress (*Ebi et al.*, 2021; *Nam et al.*, 2024). Therefore, incorporating bioclimatic research into tourism planning is essential for the PVR. Since autumn and spring are the most favorable seasons for outdoor tourism in this region, it is recommended that local tourism stakeholders focus on diversifying tourism offerings during these periods. Key areas for development could include ecotourism, rural tourism, adventure tourism (such as kayaking, climbing, cave exploration), and cultural tourism, among others.

This study focused on assessing TCI and UTCI for tourism activities in Loznica and Valjevo, two urban areas in the Podrinje-Valjevo Region. These cities were chosen because they are the only ones in the region with available data necessary for applying bioclimate indices. However, the study does not cover the bioclimatic conditions of the entire region due to the absence of climatological stations in the mountainous areas of the PVR. This is a significant limitation of the paper, as it prevents a comprehensive understanding of the region's bioclimatic conditions and their impact on tourism activities. Future research will aim to include climate evaluations of these mountainous areas once data becomes available, and to investigate the correlation between tourist visits over the past 30 years and climate indices in the PVR.

Acknowledgements: The study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract number 451/03/65/2024-03/200091).

References

Amelung, B., and *Viner, D.,* 2006: Mediterranean Tourism: Exploring the Future with the Tourism Climatic Index. *J. Sustain. Tourism 14*(4), 349–366. https://doi.org/10.2167/jost549.0

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. *Theor Appl Climatol*, 121, 289–301. https://doi.org/10.1007/s00704-014-1243-7

Becker, S., 1998: Beach Comfort Index – A New Approach to Evaluate the Thermal Conditions of Beach Holiday Resorts Using a South African Example. *GeoJournal 44*, 297–307. https://doi.org/10.1023/A:1006871805262

Besancenot, J., Mouiner, J., and *De Lavenne, F.*, 1978: Les conditions climatiques du tourisme littoral. *Norois 99*, 357–382.

Bigano, A., Hamilton, J.M. and *Tol, R.S.J.,* 2006: The Impact of Climate on Holiday Destination Choice. *Climatic Change 76*, 389–406. https://doi.org/10.1007/s10584-005-9015-0

Blazejczyk, K., Jendritzky, G., Bröde, P., Fiala, D., Havenith, G., Epstein, Y., Psikuta, A., and *Kampmann, B.*, 2013: An introduction to the Universal Thermal Climate Index (UTCI). *Geogr. Pol. 86*, 5–10. https://doi.org/GPol.2013.1

Blazejczyk, K., Epstein, Y., Jendritzky, G., Staiger, H., and *Tinz, B.*, 2011: Comparison of UTCI to selected thermal indices. *Int. J. Biometeorol. 56*, 515–535. https://doi.org/10.1007/s00484-011-0453-2

Blazejczyk, A., Pecelj, M., Skrynyk, O., Blazejczyk, K., and *Skrynyk, O.*, 2020: Weather suitability for outdoor tourism in three European regions in first decades of the twenty-first century. *Int. J. Biometeorol.*, Special issue: 1st European biometeorologists' meeting, https://doi.org/10.1007/s00484-020-01984-z

Bröde, P., Fiala, D., Blazejczyk, K., Holmér, I., Jendritzky, G., Kampmann, B., Tinz, B., and *Havenith, G.,* 2011a: Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). *Int. J. Biometeorol. 56*, 481–494. https://doi.org/10.1007/s00484-011-0454-1

Bröde, P., Krüger, E., Rossi, F.A., and *Fiala, D.*, 2011b: Predicting urban outdoor thermal comfort by the Universal Thermal Climate Index UTCI - a case study in Southern Brazil. *Int. J. Biometeorol. 56*, 471–480. https://doi.org/10.1007/s00484-011-0452-3

Bröde, P., Blazejczyk, K., Fiala, D., Havenith, G., Holmér, I., Jendritzky, G., Kuklane, K., and *Kampmann, B.*, 2013: The Universal Thermal Climate Index UTCI Compared to Ergonomics Standards for Assessing the Thermal Environment. *Ind. Health 51*, 16–24. https://doi.org/10.2486/indhealth.2012-0098

Cao, K., and *Gao, J.*, 2022: Assessment of climatic conditions for tourism in Xinjiang, China. *Open Geosciences 14(1)*, 2022, 382–392. https://doi.org/10.1515/geo-2022-0362

Ćirković, Lj., 1977: Klimatske osobine Zapadne Srbije. *Zbornik radova Geografskog instituta „Jovan Cvijić" SANU 29*, 105–133.

Čegar, N., Durlević, U., Dobrić, M., and *Vukašinović, S.*, 2023: A statistical analysis of temperature and precipitation in Belgrade, Serbia (1961–2020). *Forum Geografic 22(1)*, 5–15. https://doi.org/10.5775/fg.2023.090.i

Dann, G. M., 1981: Tourist Motivation an Appraisal. *Annals of Tourism Research 8*, 187–219. https://doi.org/10.1016/0160-7383(81)90082-7

Ducić, V., and *Radovanović, M.*, 2005: *Klima Srbije*. Zavod za udžbenike, Beograd.

Ebi, K., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., Honda, Y., Kovats R., Ma, W., and *Malik, A.*, 2021: Hot weather and heat extremes: health risks. *Heath and Health 398*, 10301, 698–708. https://doi.org/10.1016/S0140-6736(21)01208-3

El-Masry, E.A., El-Sayed, M.K., Awad, M.A., El-Sammak, A.A., and *El Sabarouti, M.A.*, 2022: Vulnerability of tourism to climate change on the Mediterranean coastal area of El Hammam–EL Alamein, Egypt. *Environ Dev Sustain 24*, 1145–1165. https://doi.org/10.1007/s10668-021-01488-9

Fiala, D., Havenith, G., Bröde, P., Kampmann, B., and *Jendritzky, G.*, 2011: UTCI-Fiala multi-node model of human heat transfer and temperature regulation. *Int. J. Biometeorol. 56*, 429–441. https://doi.org/10.1007/s00484-011-0424-7

de Freitas, C.R., 1990: Recreation Climate Assessment. *International J. Climatol. 10*, 89–103. https://doi.org/10.1002/joc.3370100110

de Freitas, C.R., Scott, D., and *McBoyle, G.*, 2008: A second generation climate index for tourism (CIT): specification and verification. *Int J Biometeorol 52(5)*, 399–407. https://doi.org/10.1007/s00484-007-0134-3
Giannopoulou, K., Livada, I., Santamouris, M., Saliari, M., Assimakopoulos, M., and *Caouris, Y.*, 2014: The influence of air temperature and humidity on human thermal comfort over the greater Athens area. *Journal Sustainable Cities and Society*, 10, 184–194. https://doi.org/10.1016/j.scs.2013.09.004
Grillakis, M.G., Koutroulis, A.G., Seiradakis, K.D., and *Tsanis, I.K.*, 2016: Implications of 2°C global warming in European summer tourism. *Clim. Serv. 1*, 30–38. https://doi.org/10.1016/j.cliser.2016.01.002
Grupa autora, 1988: Uticaj vremena na zdravlje ljudi – Studija Gradskog zavoda za hitnu i medicinsku pomoć Beograd i Republičkog hidrometeorološkog zavoda SR Srbije. Naučna knjiga, Beograd.
Havenith, G., Fiala, D., Blazejczyk, K., Richards, M., Bröde, P., Holmér, I., Rintamaki, H., Benshabat, Y., and *Jendritzky, G.*, 2011: The UTCI-clothing model. *Int. J. Biometeorol. 56*, 461–470. https://doi.org/10.1007/s00484-011-0451-4
Hu, Y. and *Ritchie, J.R.B.*, 1993: Measuring Destination Attractiveness: A Contextual Approach. *Journal of Travel Research 32*, 25–34. https://doi.org/10.1177/004728759303200204
Joksimović, M., Gajić, M., Vujadinović, S., Milenković, J., and *Malinić, V.,* 2020: Artificial Snowmaking: Winter Sports Between State-Owned Company Policy and Tourist Demand. *J. Hospital. Tourism Res. 45*, 1170–1187. https://doi.org/10.1177/1096348020957072
Kolendowicz, L., Półrolniczak, M., Szyga-Pluta, K., and *Bednorz, E.*, 2018: Human-biometeorological conditions in the southern Baltic coast based on the universal thermal climate index (UTCI). *Theor. Appl. Clim, 134*, 363–379. https://doi.org/10.1007/s00704-017-2279-2
Kovács, A., and *Unger, J.*, 2014: Modification of the Tourism Climatic Index to Central European climatic conditions – examples. *Időjárás 118(2)*, 147–166.
Lise, W., and *Tol, R.S.J.*, 2002: Impact of Climate on Tourist Demand. *Climatic Change 55*, 429–449. https://doi.org/10.1023/A:1020728021446
Lohmann, M., and *Kaim, E.,* 1999: Weather and holiday destination preferences image, attitude and experience. *The Tourist Review 54(2)*, 54–64. https://doi.org/10.1108/eb058303
Lukić, D., Petrović, M., Radovanović, M.M., Tretiakova, T.N., and *Syromiatnikova J.A.,* 2021: The Role of TCI and TCCI Indexes in Regional Tourism Planning. *European Journal of Geography 12(4)*, 006–015. https://doi.org/10.48088/ejg.d.luk.12.4.006.015
Lukić, M., Filipović, D., Pecelj, M., Crnogorac, Lj., Lukić, B., Divjak, L., Lukić, A., and *Vučićević A.,* 2021: Assessment of Outdoor Thermal Comfort in Serbia's Urban Environments during Different Seasons. *Atmosphere 12(8)*, 1084, https://doi.org/10.3390/atmos12081084
Lukić, M., and *Đurić, D.*, 2021: Comparative analysis of the outdoor thermal comfort in urban environments - case study of Bijeljina and Loznica. *Collection of papers „the 5th Serbian congress of geographers - Innovative approach and perspectives of the applied geography"*. University of Novi Sad, Faculty of Sciences, Department of geography, tourism and hotel management, Novi Sad, 361–370, ISBN 978-86-7031-589-1
Malinović-Milicević, S., Radovanović, M., Stanojević, G., and *Milovanović, B.*, 2015: Recent changes in Serbian climate extreme indices from 1961 to 2010. *Theor Appl Climatol 124*. https://doi.org/10.1007/s00704-015-1491-1
Masoudi, M., 2021: Estimation of the spatial climate comfort distribution using tourism climate index (TCI) and inverse distance weighting (IDW) (case study: Fars Province, Iran). *Arab J Geosci 14*, 363. https://doi.org/10.1007/s12517-021-06605-6
Matzarakis, A., 2006: Weather and Climate – Related Information for Tourism. *Tourism and Hospitality Planning & Development 3*, 99–115. https://doi.org/10.1080/14790530600938279
Mieczkowski, Z., 1985: The Tourism Climatic Index: A Method of Evaluating World Climates for Tourism. *The Canadian Geographer/Le Géographe canadien 29(3)*, 220–233.
Mohmoud, D., Gamal, G., and *Abou El Seoud, T.*, 2019: The Potential Impact of Climate Change on Hurghada City, Egypt, using Tourism Climate Index. *GeoJournal of Tourism and Geosites 25*, 496–508. https://doi.org/10.30892/gtg.25218-376
Nam, C., Lierhammer, L., Buntemeyer, L., Evadzi, P., Cabana, D., and *Celliers, L.*, 2024: Changes in universal thermal climate index from regional climate model projections over European beaches. *Climate Services 34*, 100447. https://doi.org/10.1016/j.cliser.2024.100447

Noome, K., and *Fitchett, J.M*., 2019: An assessment of the climatic suitability of Afriski Mountain Resort for outdoor tourism using the Tourism Climate Index (TCI). *J. Mt. Sci 16*, 2453–2469. https://doi.org/10.1007/s11629-019-5725-z

Obradović-Arsić, D., and *Gledović, Z*., 2012: *Medicinska geografija*. Univerzitet u Beogradu – Geografski fakultet, Beograd.

Oğur, A.A., and *Baycan, T.*, 2024: How to manage tourism development based on impacts of climate change in Turkiye. *Asia-Pacific Journal of Regional Science*, 1–24.

Pecelj, M.M., Lukić, M., Vučičević A, De Una-Alvarez, E., Esteves da Silva, C.G.J., Freinkin, I., Ciganović, S., and *Bogdanović, U.*, 2018: Geoecological evaluation of local surroundings for the purposes of recreational tourism. *Journal of Geografical Institute "Jovan Cvijic" SASA 68(2)*, 215–231. https://doi.org/10.2298/IJGI1802215P

Pecelj, M.M., Lukić, M.Z., Filipović, D.J., Protić, B., and *Bogdanović, U.M.*, 2020: Analysis of the Universal Thermal Climate Index during heat waves in Serbia. *Nat. Hazards Earth Syst. Sci. 20*, 2021–2036. https://doi.org/10.5194/nhess-20-2021-2020

Pecelj, M., Matzarakis, A., Vujadinović, M., Radovanović, M., Vagić, N., Đurić, D., and *Cvetković, M.,* 2021: Temporal Analysis of Urban-Suburban PET, mPET and UTCI Indices in Belgrade (Serbia). *Atmosphere 12*, 916. https://doi.org/10.3390/atmos12070916

Perch-Nielsen, S.L., Amelung, B. and *Knutti, R.*, 2010: Future climate resources for tourism in Europe based on the daily Tourism Climatic Index. *Climatic Change 103*, 363–381. https://doi.org/10.1007/s10584-009-9772-2

Pjevač, N., 1997: *Turistički potencijali Valjevskih planina*. Univerzitet u Beogradu – Geografski fakultet, Beograd, doktorska disertacija.

Pjevač, N., 2002: *Valjevske planine – mogućnosti razvoja turizma*. Zadužbina Andrejević, Beograd.

Polish Academy of Sciences, Institute of Geography and Spatial organization, Department of Geoecology and Climatology, 2010: BioKlima (Version 2.6), author: Prof. Krzysztof Błażejczyk, PhD. Retrieved from https://www.igipz.pan.pl/Bioklima-zgik.html

Republic Hydrometeorological Service of Serbia, 1991–2020: Meteorološki godišnjak - klimatološki podaci [Meteorological Yearbook - climatological data]. Retrieved from http://www.hidmet.gov.rs/latin/meteorologija/klimatologija_godisnjaci.php

Rutty, M., Scott, D., Matthews, L., Burrowes, R., Trotman, A., Mahon, R., and *Charles, A.,* 2020: An Inter-Comparison of the Holiday Climate Index (HCI:Beach) and the Tourism Climate Index (TCI) to Explain Canadian Tourism Arrivals to the Caribbean. *Atmosphere 11*, 412. https://doi.org/10.3390/atmos11040412

Savić, S., Marković, V.; Šećerov, I., Pavić, D., Arsenović, D., Milosevic, D., Dolinaj, D., Nagy, I., and *Pantelić, M.*, 2018: Heat wave risk assessment and mapping in urban areas: Case study for a midsized Central European city, Novi Sad (Serbia). *Nat. Hazards 91*, 891–911. https://doi.org/10.1007/s11069-017-3160-4

Scott, D., McBoyle, G., and *Schwartzentruber, M.*, 2004: Climate change and the distribution of climatic resources for tourism in North America. *Climate Research 27*, 105–117. doi:10.3354/cr027105

Scott, D., Rutty, M., Amelung, B., and *Tang, M.,* 2016: An Inter-Comparison of the Holiday Climate Index (HCI) and the Tourism Climate Index (TCI) in Europe. *Atmosphere 7*, 80. https://doi.org/10.3390/atmos7060080

Simić, S., 2016: *Vodni potencijal i hidrogeografska rejonizacija Valjevskih planina*. Univerzitet u Beogradu – Geografski fakultet, Beograd, doktorska disertacija.

Sobhani, B., and *Safarian Zengir, V.*, 2020: Evaluation and zoning of environmental climatic parameters for tourism feasibility in northwestern Iran, located on the western border of Turkey. *Model. Earth Syst. Environ 6*, 853–864. https://doi.org/10.1007/s40808-020-00712-1

Stanković, S., 2008: *Turistička geografija*. Zavod za udžbenike, Beograd.

Stojićević, G., 2016: *Bioklimatska slika Zapadne Srbije u funkciji turizma*. Univerzitet u Novom Sadu, Prirodno-matematički fakultet, Novi Sad, doktorska disertacija.

Unkašević, M., and *Tošić, I.*, 2013: Trends in temperature indices over Serbia: relationships to large-scale circulation patterns. *Int J Climatol 33*, 3152–3161. https://doi.org/10.1002/joc.3652

Velea, L., Chitu, Z., and *Bojariu, R.,* 2024: Thermal stress information as a tourism-oriented climate product: Performance analysis for selected urban destinations in Romania and Italy. *Heliyon 10*, e24682.