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AN EVALUATION OF SUMMER DISCOMFORT IN NIŠ (SERBIA) USING HUMIDEX

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Abstract: The bioclimatic analysis of the central area of the city of Niš conducted in this paper is based on the use of the bioclimatic index Humidex, which represents subjective outdoor temperature that one feels in warm and humid environment. The purpose of this research is to observe the index change on a daily basis during the hottest part of the year (June, July, and August) over the period from 1998 to 2017. For the purposes of this analysis, hourly (7:00, 14:00), maximum and mean daily values of meteorological parameters (air temperature and relative humidity) were used, for the period of 20 years (1998–2017), which were measured at Niš weather station (43°19'N, 21°53'E, at an altitude of 202 meters). The findings indicate a gradual change in the bioclimatic characteristics of this area during this period, especially over the last decade. After 2007 there has been a decrease in the total number of the days described as "comfortable". However, there has been an increase in the index values in all the other heat stress categories characterized by a higher or lower degree of thermal discomfort. The years 1998, 2000, 2003, 2007, 2011, 2016, 2015, and 2017 stand out as adverse years.

Keywords: bioclimatic conditions; Humidex; urban area; Niš

Introduction

The human body is exposed to various influences in an urban area. One of the most important influences is microclimatic ones. The human organism has the ability to respond to environmental conditions and acclimatize to them, but exposure to high temperatures and long period of heat waves may overcome the resistance of body and be harmful for human health (Basarin, Lukić, & Matzarakis, 2016). Bioclimatic studies of urban areas conducted during summer period are particularly significant. Namely, due to the formation of urban heat islands, which are characteristic of cities, heat stress which occurs during the day, persists to certain extent during the night as well, which diminishes the possibility of regeneration and recovery of the human body after the heat load that it has suffered (Gulyás, 2005). Bioclimatic indices enable us to see not only how the environmental conditions affect

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human health but also their effect on the plants and animals inhabiting a certain area and various anthropogenic activities such as agriculture, forestry, natural resources management, urban planning, tourism etc. (Perkins & Alexander, 2012).

The application of heat index Humidex to urban climate research is widespread. Geletič, Lehnert, Savić, and Milošević (2018) employed this index to assess thermal comfort of the city of Brno, using air temperature and relative humidity data. The city was divided into local climate zones in order to access the differences in intra-urban thermal comfort. Conditions of great discomfort (Humidex > 40) were recorded mainly in the afternoon hours (from 13:00 to 18:00). Recently, Hamdi et al. (2016) used Humidex with a 1-km resolution dynamic downscaling technique to perform simulations within the A1B scenario of the ARPEGE-Climate global climate model for Brussels, Belgium. An empirical approach to map apparent temperature (Humidex) at the local scale, which relies on publicly available weather station, observations and spatial data layers combined in a randomforest regression model, was demonstrated for Greater Vancouver, Canada by Ho, Knudby, Xu, Hodul, and Aminipouri (2016). Bokwa and Limanowka (2014) investigated the impact of land use on heat stress in urban areas, on the example of Krakow and its surroundings. In the study, the bioclimatic index Humidex was applied, and the results showed significant differences in the number of very hot days and the number of heat waves, between urban and rural areas. Oleson et al. (2013) have used five indices of heat stress (the NWS Heat Index (HI), Apparent Temperature (AT), Simplified Wet Bulb Globe Temperature, Humidex, and Discomfort Index) in order to analyze interactions between urbanization, heat stress, and climate change, in the wider area of the U.S. and southern Canada. The authors were focused on analyzing the peak heat stress summer months (June, July, August), and they used an urban canyon model coupled to a land surface model to quantify present-day and projected mid-21st century rural and urban heat stress for boreal summer. Mekis, Vincent, Shephard, and Zhang (2015) have studied trends in severe conditions in Canada during the period of 60 years. The changes in extreme heat and extreme cold events represented by Humidex and wind chill indices are analyzed for 1953–2012 at 126 climatological stations. The results show that extreme heat events, defined as days with at least one hourly Humidex value above 30, have increased significantly at more than 36% of the stations. On the basis of Humidex analyzed on the territory of Athens (June–August 2009) with the aim of determining the effect that air temperature and humidity have on thermal comfort and in view of the data obtained at 26 weather stations, it was concluded that the highest index values were measured in the central part of the city and that the highest degree of thermal discomfort was recorded in July (Giannopoulou et al., 2014). The assessment of outdoor environmental bioclimatic conditions for the purposes of smart urban planning which was carried out by means of Humidex in the area of the city of Hardec Karlove (the Czech Republic) for the period from June to August 2011–2014, shows that July is the most adverse month, with the highest rate of "great discomfort" category. Since different parts of the city were analyzed, the index values measured in the central part are much higher than the values of the environment rich in vegetation and water bodies. This shows a higher risk in densely built urban districts (Středová, Středa, & Litschmann, 2015). It is also interesting to see the use of Humidex for the purposes of determining the indoor thermal comfort in commercial i.e. business facilities. The occupants of these facilities (staff members and clients) spend most of the day here. Therefore, the relationship between the outdoor and indoor thermal comforts, especially in summer, can affect their psychological and physical state and performance at work (Rana, Kusy, Jurdak, Wall, & Hu, 2013). In the immediate environment of Serbia, there is one example of applying Humidex in the assessment of bioclimatic conditions of Banja Luka (Republic of Srpska) for recreational purposes. Pecelj et al. (2010)

presented a day by day distribution of different degree of comfort caused by actual weather conditions in Banja Luka during the period of five years (July and August, 2000–2004).

The findings of the studies exploring different aspects of the weather and bioclimatic conditions in Serbia indicate a steady increase in the average annual air temperature and show that these changes are especially noticeable during the summer. Therefore, we tend to face extreme weather conditions more and more frequently and they have an adverse effect on the processes in natural ecosystems, people's health and various economic activities. An analysis conducted by Tošić and Unkašević (2013) shows that for the past six decades there has been a continuous rise in maximum daily temperatures (within the period 1949–2007), the number of hot and tropical days (within the period 1949–2009) and the rate of droughts, which are becoming more and more severe, whereas the annual precipitation has been on the decline. According to Unkašević and Tošić (2009a) in terms of duration, intensity and the heat wave severity in the hottest summers occurred in the period from 1946 to 1952, 1988 to 1998 (particularly from 1992 to 1995) and from 2000 to 2003. The longest heat waves were recorded in 1952, with 53 days in Belgrade and 62 days in Niš (out of the total number of the days in the year). The summer of 1994 in Belgrade and 2003 in Niš are characterized by the greatest number of consecutive tropical days (21 and 29 days, respectively) (Unkašević & Tošić, 2009a). Unkašević and Tošić (2011) particularly singled out the heat wave that occurred in Serbia in 2007 and lasted from 14 July to 27 July. The highest maximum temperatures ever were measured nearly on the whole territory of Serbia and the greatest temperature increase of 3.1 °C, compared to the previous absolute maximum temperature, dating back to 1888, was recorded in Belgrade. Other authors also came up with similar findings. Basarin et al. (2016) have applied PET to the analysis of heat and cold waves and human thermal conditions in Novi Sad, Serbia. They have revealed that there is a steady increase of the number of days above the defined threshold, the number of heat waves and average duration of heat waves per year since 1981 (for the investigated period 1949–2012).

The main goal of this paper is to describe and analyze the bioclimatic conditions and their impact on the quality of life and residence of inhabitants, workers and tourists of the city of Niš by using the heat index Humidex. In the light of climatic changes and other negative factors resulting from this global phenomenon, it is becoming a true challenge to minimize their effects, establish sustainability and improve living conditions in urban areas (Stevović, Mirjanić, & Djurić, 2017). As a result, the need has arisen to observe various conditions in urban environments, the most prominent being the weather and bioclimatic conditions in local and regional environments.

Material and methods

The city of Niš is set in the valley of the River Nišava and it is the most important economic and administrative centre of southern Serbia. After Belgrade and Novi Sad, Niš is the third largest Serbian urban center with high population density, a lot of economic activities and a high degree of urbanization. According to the 2011 census (Statistical Office of the Republic of Serbia, 2014), the city has a population of 183,164, while the urban area of Niš with all of the five city municipalities (Medijana, Palilula, Pantelej, Crveni krst, and Niška banja) has 260,237 inhabitants. According to Köppen's climate classification, the Nišava valley belongs to the Cfwax type—the Danube type of moderately warm and humid climate characterized by hot summers, the highest precipitation recorded at the beginning of summer and somewhat dry winters (Prokić, 2018). Compared to other cities in this valley (Dimitrovgrad, Pirot, and Bela Palanka), Niš is the hottest one with an average annual temperature of 11.8 °C (Prokić, 2018).

For the purposes of this paper the authors have conducted a bioclimatic analysis of the hottest part of the year—June, July, and August, which is based on the data obtained at the Niš weather station (43°19'N, 21°53'E, at an altitude of 202 meters), located in the city center at the Niš Fortress. The meteorological data used in this research are taken from the Meteorological Yearbook for the period 1998–2017 (Republic Hydrometeorological Service of Serbia, 1998–2017). The objective of the research is to observe daily changes in the values of the index discussed during the hottest part of the year during the period of 20 years (1998–2017). The research involved analyzing Humidex values, which were calculated on the basis of the hourly values of meteorological parameters that were recorded at 7:00 and 14:00 ($Humidex_{07h}$ and $Humidex_{14h}$), mean Humidex, which was calculated on the basis of mean daily temperature and humidity values ($Humidex_{daily\ value}$) and $Humidex_{Tmax}$, which was calculated at the time of the day when maximum daily temperature (Tmax) was recorded. The Humidex index was calculated by applying the BioKlima 2.6 software package (Institute of Geography and Spatial Organization Polish Academy of Sciences, 2010)

Humidex (°C) is defined as a heat index that represents the subjective outdoor temperature that a human feels in a hot and humid environment. In other words, it is used as a measure of heat resulting from the combination of excessive humidity and a high temperature (Masterton & Richardson, 1979; Pecelj et al., 2010; Rana et al., 2013; Středová et al., 2015). If the Humidex value reaches ≥ 35, we can say that the environmental conditions are becoming potentially dangerous. Therefore, we can expect that the feeling of discomfort will occur in the outdoor environment, as well as various medical problems and even some more serious health disorders, such as severe fatigue and heatstroke (Dankers & Hiederer, 2008).

The reason of using Humidex in this research was the fact that Humidex is a simple thermal comfort index based on just two meteorological parameters. The index gives us reliable insight in extreme heat conditions which are caused by high air temperature and humidity (humidity is especially significant because it increases the impact of extreme heat events). Extreme heat conditions occur when Humidex exceeds specific thresholds (Humidex > 30). Its results are directly comparable with temperature in degrees Celsius and its values are associated with the corresponding degrees of thermal comfort, rendering the index "widely understandable" as Geletič et al. (2018) point out. This index is particularly suitable for the assessment of bioclimatic conditions in a certain area during the hot part of the year, late spring and especially the summer months. The findings of the research conducted so far show that this index is used mainly in bioclimatology, geoecology, health care, climatic therapy, tourism (spa and health tourism, for sports and recreational purposes), urban planning, urban design, but it is also used for architectural design of cities. The simplicity of this model makes bioclimatic conditions more understandable for Serbian urban and spatial planners, but not only for them, but also for experts from other fields of social and ecological activities, where the climatic and biometeorological conditions of a given area are considered.

This model was first proposed during the 1960s and it was called Humiture (Lally & Watson, 1960), and later it was established by the Canadian meteorologists (Masterton & Richardson, 1979). Using the two main dimensions of heat stress, the Canadian meteorologists devised the Humidex range (Table 1) and proposed a formula for calculating this index, which was adopted later. It is calculated as follows:

$$HUMINDEX = t + 0.5555 \cdot (vp - 10)$$

Where

$$vp = 6.112 \cdot 10^{[7.5 \cdot t/(237.7 + t)]} \cdot f/100)$$

In this formula, vp is air vapour pressure (hPa), t is air temperature (°C) and f is relative humidity (%). According to Environment Canada, Humidex-related hazards are as follows Table 1.

Table 1
The scale of Humidex and the degree of comfort

Range of Humidex	Degree of comfort	
<29	Comfortable	A little discomfort, fatigue with prolonged physical activity is possible
30–39	Some discomfort	Exhaustion due to heat is possible with prolonged physical activity
40–44	Great discomfort	Avoid strenuous physical activity, possible heat cramps or heat exhaustion
45–54	Dangerous	Prolonged physical activity can lead to heat stroke
>55	Very dangerous	A heat stroke is unavoidable if physical activity continues

Note. Adapted from *Climate change, health impacts and urban adaptability: Case study of Gold Coast City. Urban Research Program, Research Monograph 11* (p. 11) by S. Baum, S. Horton, D. Low Choy, and B. Gleeson, 2009, Brisbane, Queensland: Griffith University; *Humidex, a method of quantifying human discomfort due to excessive heat and humidity* (p. 45) by J. Masterton and F. A. Richardson, 1979, Toronto, Canada: Environment Canada, Atmospheric Environment.

Results and discussion

The bioclimatic analysis we have conducted shows that bioclimatic conditions in Niš underwent certain changes over the period of 20 years (1998–2017), particularly over the last ten years. The findings that have been obtained are in keeping with the previously conducted research related to the observation of heat waves and their frequency, the occurrence of extreme temperatures in the hotter part of the year, the occurrence of drought across the region etc. (Drljača, Tošić, & Unkašević, 2009; Prokić, 2018; Unkašević & Tošić, 2009a, 2009b, 2011). The years 2007 and 2012 stand out as particularly adverse years in terms of extreme temperatures, maximum mean temperatures and the number of heat waves during summer season. On the territory of Serbia the year 2012 was the second hottest year since 1951, with the greatest number of tropical days recorded within the period 1951–2012 (Republic Hydrometeorological Service of Serbia, 2013). Year 2007 saw the highest recorded temperature in Serbia according to analysis of maximum daily summer temperatures within the period 1949–2007 (Tošić & Unkašević, 2013). In addition, this study shows that the years 1998, 2000, 2003, 2011, 2016, 2015, and 2017 stand out as adverse ones on the territory of Niš in terms of bioclimatic conditions.

Figures 1, 2, and 3 show the frequency and presence of all Humidex categories expressed in percent (%), which were recorded during June, July and August in the past two decades. Bioclimatic conditions are more favorable in the morning, when the air temperature is lower and it generally feels much more pleasant to be outdoors. In the morning (7:00) the prevalent category during the three-month period discussed here is the one defined as “comfortable” (Humidex < 29). The same applies to average daily index values, where we can also see the largest percentage of days with Humidex values below 29, when the feeling of outdoor discomfort is less intense. Then there are days characterized by “some discomfort” (30–39). Taking into account all the three months, we can see the largest number of such days in July and the smallest number of them in June.

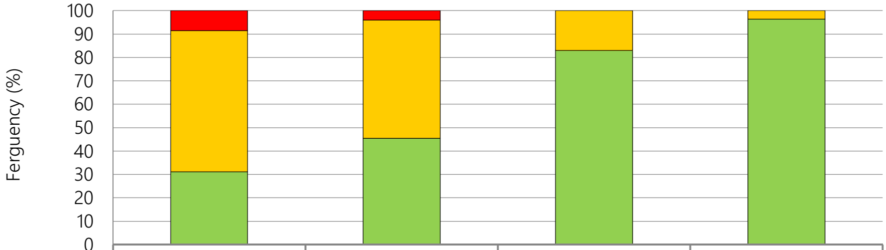
Bioclimatic conditions in Niš are generally more adverse in July and August and this especially refers to the values recorded at 14:00 ($Humidex_{14h}$) and during the parts of the day when maximum temperature ($Humidex_{Tmax}$) was measured. The part of the value range representing “some discomfort" (30–39) and "great discomfort" (40–44) categories predominates in the graphs (Figure 1, 2, and 3). Therefore, the findings certainly indicate that there is an increased likelihood that the weather conditions will have an adverse effect on the local population.

Under these conditions of the environment, the body temperature rises and it can cause certain medical problems i.e. health risks such as rash, thermal cramps, fatigue accompanied by nausea, dizziness, headache, a sudden rise in body temperature (sunstroke), and, finally, the most severe state—heatstroke. Here the most vulnerable social groups are the delicate ones: children, elderly people and chronic patients. In addition, there are people doing hard physical work: construction laborers, mining and power industry workers, transport system workers etc. and finally, people doing other kinds of strenuous physical work, for instance sportspersons (Baum et al., 2009).

In order to endure the heat stress which it is exposed to, the human body starts "defending" itself and releasing a large amount of liquid through sweating, which leads to the increased risk of dehydration, dizziness or other manifestations of medical problems. June and July are considered to be the hottest months of the summer season, when there is a higher frequency of health disorders which are caused by weather conditions during prolonged stay in a hot environment. In some cases heat waves caused by high temperatures can cause some problems, particularly affecting delicate people or patients. This risk is higher in urban areas as a larger amount of heat accumulates when asphalt and concrete surfaces and facilities absorb the heat, which can later lead to higher temperatures, even during the night. There are also some other anthropogenic sources of heat that additionally reinforce adverse bioclimatic conditions during the summer, for example traffic, lighting, reduced wind speed in urban areas etc. (Giannopoulou et al., 2014).

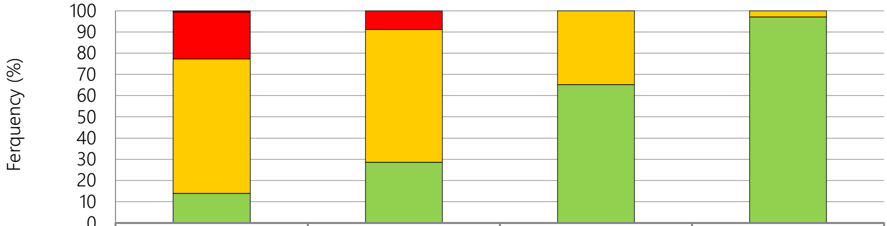
As regards the heat stress category termed "dangerous" (45–54) during the discussed period of 20 years, there are only a few cases of the Humidex exceeding its threshold value. Interestingly, in the first of the two decades under consideration only two such days were recorded: 2 July 1998 (Humidex = 45.9) and 24 July 2007 (Humidex = 45.2). The year 2007 is remembered as the year that saw the highest temperature on record in Serbia.

That year's maximum temperature was recorded in Smederevska Palanka on 24 July 2007 (t_{max} = +44.9 °C) (Republic Hydrometeorological Service of Serbia, n.d.), which also coincides with that year's highest value of the index discussed. After 2007 an increase was observed in the index value of all the categories of heat stress, which also refers to the "dangerous" category. Although the number of such days remained the same (2), the values were higher. In 2012 the maximum index value was 53.6 (2 August), when Humidex was closest to the category "very dangerous" (Humidex > 55), which simultaneously represents the highest index value in the last 20 years. With its average temperature of 26.9 °C, July 2012 was the hottest one ever since meteorological data started being recorded and August, with its average temperature of 26.4 °C was the second hottest August in the last 120 years (Republic Hydrometeorological Service of Serbia, 2013). Another day that stands out is 27 July 2016, when the maximum index value was 46.4. In the period from 1998 to 2017 not a single "very dangerous day" was recorded (Humidex > 55). Nevertheless, considering the tendency of ever increasing daily temperatures this is not unlikely to happen in the future.



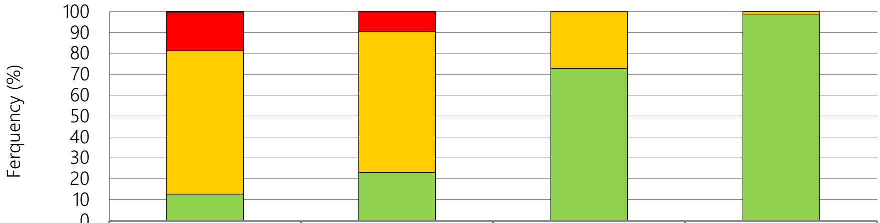
	Humidex Tmax	Humidex 14h	Humidex daily value	Humidex 07h
Great discomfort	8.50	4.00	0.00	0.00
Some discomfort	60.33	50.50	17.00	3.67
Comfortable	31.17	45.50	83.00	96.33

Figure 1. Frequency of the Humidex heat stress categories during June (1998-2017) in Niš



	Humidex Tmax	Humidex 14h	Humidex daily value	Humidex 07h
Dangerous	0.64	0.00	0.00	0.00
Great discomfort	22.10	8.87	0.00	0.00
Some discomfort	63.39	62.58	34.84	2.90
Comfortable	13.87	28.55	65.16	97.10

Figure 2. Frequency of the Humidex heat stress categories during July (1998-2017) in Niš



	Humidex Tmax	Humidex 14h	Humidex daily value	Humidex 07h
Dangerous	0.65	0.00	0.00	0.00
Great discomfort	18.06	9.52	0.00	0.00
Some discomfort	68.55	67.42	27.10	1.61
Comfortable	12.74	23.06	72.90	98.39

Figure 3. Frequency of the Humidex heat stress categories during August (1998-2017) in Niš

Previous studies show that weather and bioclimatic conditions in Serbia have been changing year by year, especially in terms of the increase in maximum daily temperatures, heatwave duration and more and more frequent periods of drought (Basarin et al., 2016; Drljača et al., 2009; Pecelj et al., 2017; Prokić, 2018; Unkašević & Tošić, 2009a, 2009b, 2011). All of these lead to more and more adverse conditions that do not only have a negative effect on humans, the quality of life and work in urban and rural areas, but also on local natural ecosystems. Another inevitability is the way that climate change, as a global phenomenon, leads to a change in microclimatic and bioclimatic conditions on a local and regional level. These conditions have been becoming more and more extreme for decades now and this is corroborated by the findings of this paper.

Figure 4, 5, and 6 show the ratio of the total number of days for each category of heat stress during the months of June, July, and August (1998–2017). If the first decade of the research (1998–2007) and the second one (2008–2017) are observed separately, it becomes evident that during the second decade in all the time periods that have a specific index value ($Humidex_{Tmax}$, $Humidex_{14h}$, $Humidex_{07h}$, $Humidex_{daily\ value}$) there was a decline in the number of days defined as "comfortable". On the other hand, there was an increase in all the other categories characterized by a lower or higher degree of discomfort. For instance, if we look at the data obtained in July for $Humidex_{Tmax}$, we can see that the number of comfortable days dropped from 51 (1998–2007) to 35 (2008–2017), whereas the number of days characterized by "some discomfort" rose from 184 to 209. The changes do not only refer to the hottest part of the day but also the average daily values. An increase can even be observed in the morning values ($Humidex_{07h}$), where there is a tendency of decline in the number of "comfortable days" (from 304 to 298), whereas the number of days with "some discomfort" rose from 6 (1998–2007) to 12 (2008–2017). We have singled out the values recorded in July since the research has shown that this particular month is the most adverse one in terms of the bioclimatic conditions on the territory of the city of Niš during the summer. However, it is important to highlight the fact that a similar change was observed in June and August, as well, during the period of the two decades.

In August there is a significant increase in the total number of the days belonging to the category of "great discomfort" (40–44), particularly for $Humidex_{Tmax}$ and $Humidex_{14h}$. For instance, when it comes to $Humidex_{Tmax}$ the number of such days rose from 48 (1998–2007) to 64 (2008–2017) and $Humidex_{14h}$ shows a rise from 27 (1998–2007) to 32 (2008–2017). $Humidex_{daily\ value}$ shows a decline in the number of days characterized by a "comfortable" subjective feeling during the stay in an outdoor environment (it dropped from 234 to 218). At the same time, the total number of days characterized by "some discomfort" rose from 76 to 92. June saw a decline in the number of "comfortable days" in all the indexes discussed in the paper and an increase in the days characterized by "some discomfort". It is particularly necessary to underscore the fact that the most significant change in June during the two decades is the consistent increase in the number of days belonging to the category of "great discomfort" (from 6 to 18).

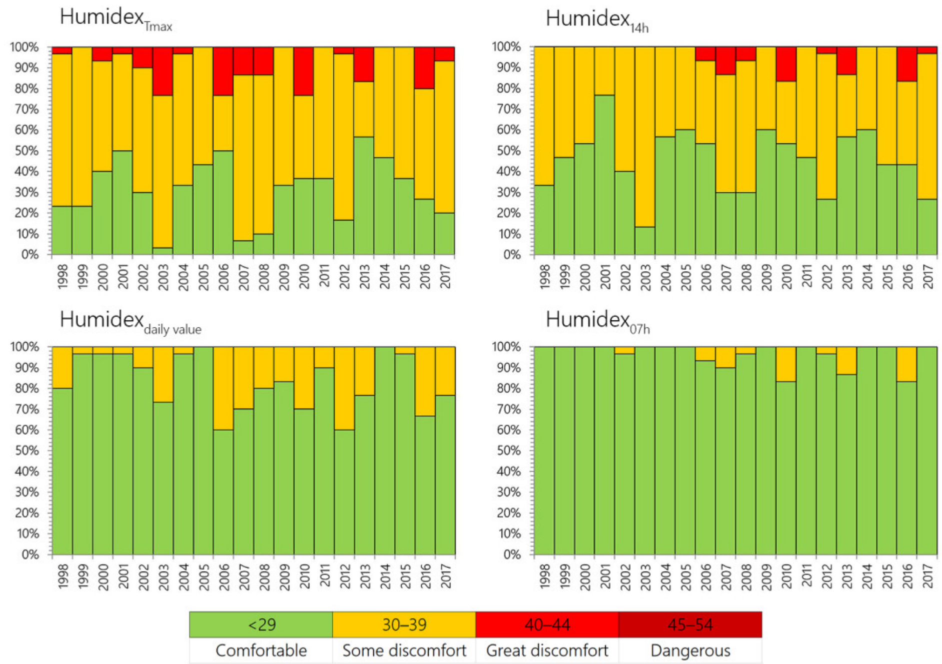


Figure 4. Humidex heat stress categories in total, June (1998-2017) in Niš

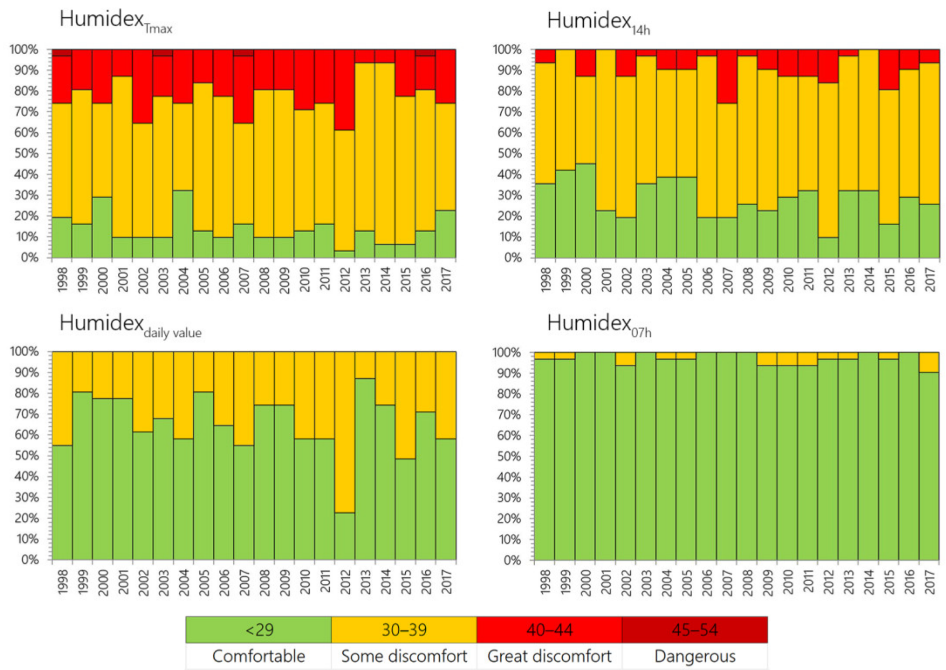


Figure 5. Humidex heat stress categories in total, July (1998-2017) in Niš

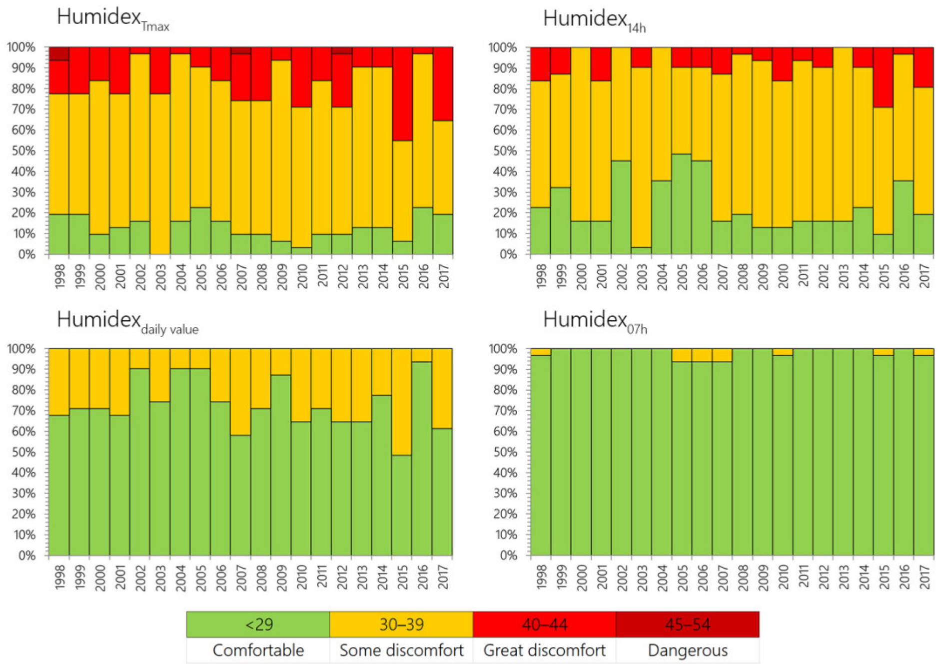


Figure 6. Humidex heat stress categories in total, August (1998-2017) in Niš

In order to give a more thorough insight in the changes recorded in the analyzed period, we have especially observed the values of Humidex measured at 14:00. As a result of that, we have given Figure 7, 8, and 9 which show time series of the number of days for categories of heat stress according to $Humidex_{14h}$ for the whole summer (June, July, and August). This enables the simple insight of the changes of summer discomfort over the analyzed period. The results show that the most significant changes in thermal discomfort are related to the category of stress "great discomfort" during all the three months of the investigated period. The highest growth trend of this category was recorded in June (1998–2017), amounting to 1.3 days/10 years. Next is the category of "some discomfort" with the growth trend of 1.3 days/10 years during July (1998–2017). The last one is a "comfortable" category with a negative trend over all the three months, especially in July, where the trend was —2.05 days/10 years. $Humidex_{14h}$ has been singled out because the data are similar to the $Humidex_{Tmax}$ values and they best reflect bioclimatic conditions during the hottest part of

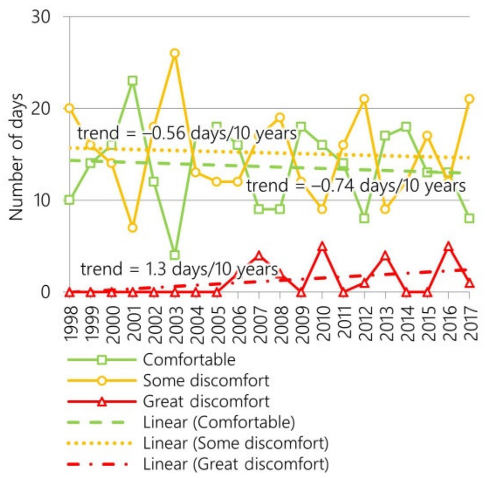


Figure 7. Time series of the number of days for categories of heat stress according to $Humidex_{14h}$, June (1998–2017)

the day, especially between 14:00 and 15:00. This is a particularly critical period because it is at this time that the greatest heat load occurs. Loss of electrolytes and evaporation are more intense, which is a great stress for the body and can later lead to more severe health problems. The data clearly show an increase in the values if the first and second decades are compared. During the period from 2008 to 2017 the average index value gradually rose, $Humidex_{14h}$ value exceeded 40 more and more often, whereas the number of "comfortable days" (Humidex < 29) dropped from 87 (1998–2007) to 56 (2008–2017). Apart from the index increase, it has been observed that heat waves (prolonged periods of very high air temperatures) occurred more and more frequently during the second decade, with three or more consecutive days belonging to the "great discomfort" category (40–44) and that this happened in July, as well as in August (indexes $Humidex_{14h}$ and $Humidex_{Tmax}$).

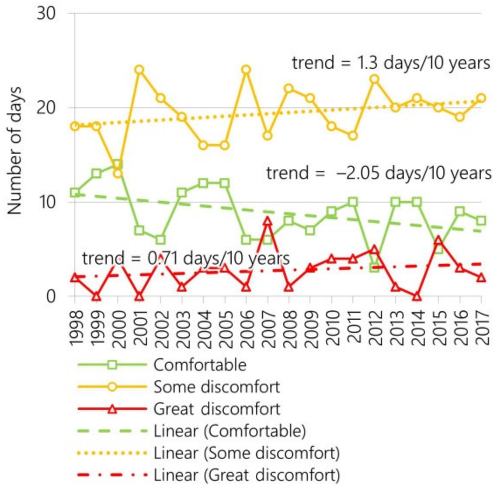


Figure 8. Time series of the number of days for categories of heat stress according to $Humidex_{14h}$, July (1998–2017)

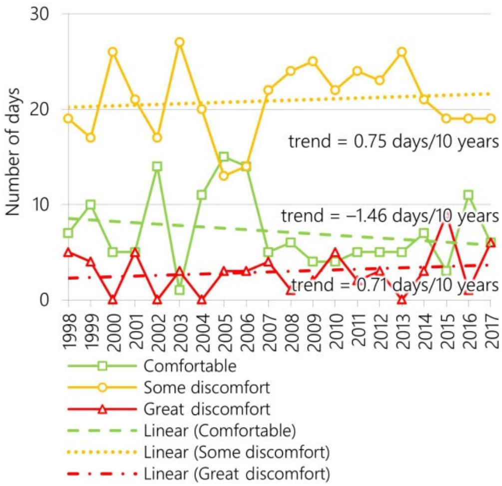


Figure 9. Time series of the number of days for categories of heat stress according to $Humidex_{14h}$, August (1998–2017)

Conclusion

In this paper we have conducted a bioclimatic analysis based on the data for Niš weather station using the bioclimatic index Humidex, which represents a subjective perception of the temperature that the human body feels in an outdoor environment. Humidex enables us to observe how the weather conditions affect the human body and various activities done by human beings in an outdoor environment and we can do so in a very simple manner—by using the data related to only two meteorological parameters: air temperature and relative humidity. Under normal conditions the human body cools down by sweating, i.e. perspiration. However, if the relative air humidity is high, the perspiration speed decreases, thus weakening the ability of the body to cool down, which can cause a certain degree of discomfort or, in some cases, more severe health problems.

The period that has been analyzed includes the months of June, July and August from 1998 to 2017. The data for the first decade (1998–2007) and the second one (2008–2017) have been observed separately. The research shows that bioclimatic conditions in Niš are more adverse during

July and August, particularly in the hottest part of the day, characterized by the highest index values. Precisely at this time the human body suffers the most intense heat load. In the period of 20 years, 2007 and 2012 stand out as the most adverse ones. The highest index value was recorded in August 2012 (53.6), when Humidex was closest to the "very dangerous" category (Humidex > 55). Furthermore, the findings show that in the three-month period (June, July, and August) during the two decades there was a considerable decline in the number of days characterized by the subjective perception of "comfort" in an outdoor environment. Conversely, there was an increase in the number of days characterized by a lower or higher degree of discomfort, accompanied by a rise in the Humidex values in all the categories of heat load.

This paper corroborates the fact that weather and bioclimatic conditions in Serbia are changing, thus leading to more and more adverse conditions, which particularly have a negative effect on the health and quality of life of people living in urban areas. These results help us to better understand the process of climate change, its impact on local bioclimatic conditions and how it affects human beings and ecosystems in urban environment. Also, one of the outcomes of the research is emphasizing the Humidex as a simple, easily understandable methodological framework for the presentation of basic assessment of bioclimatic conditions of urban areas to the wider community. Further research should be focused on the application of modern bioclimatic indices, following the world trends in the field of bioclimatology.

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