

Research article

Evaluation of the bioclimate of the Piatra Neamț tourist resort

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Abstract: Background: The study responds to real needs of knowing the bioclimate of some tourist resorts in order to develop different types of tourism, in which the bioclimate plays a significant role. In Romania, a similar study was carried out for the resort towns of Vatra Dornei and Tg. Ocna. **Methods:** The research is based on time series of weather elements from 1961-2021. These series were used for the calculation of the bioclimatic index of the physiological equivalent temperature (PET) which allows the analysis of the temporal peculiarities of the bioclimate. In order to highlight in a new perspective the relationship between biocli-mate and tourism in the Piatra Neamț resort, we created climate-tourism schemes (CTIS). **Results:** PET values ranged between a maximum of 35.7°C (severe thermal stress due to heating) and a minimum of - 29.3°C (extreme thermal stress due to cooling). The mean PET value was 8.8°C (indicating moderate cold stress). The period of the year with biocli-matic comfort, for hiking, visiting, outdoor sports, climatotherapy, balneotherapy corresponds to the interval April (3rd decade) - October (1st decade). **Conclusions:** Tourists who want to plan their vacation in Piatra Neamț will benefit from non-restrictive bioclimatic conditions from the end of April to the beginning of October. During the cold season, with a layer of snow, winter sports can be practiced.

Keywords: bioclimate, bioclimatic comfort, bioclimatic stress, PET index, CTIS

Introduction

Weather conditions and climate are natural resources that influence the tourism and recreation potential of a region [1-3]. Through its elements (temperature, precipitation, wind) the climate can influence, positively or negatively, health tourism, sports tourism and all outdoor tourist activities [4-7].

To characterize the climatic and bioclimatic conditions of a region or locality, a series of climatic and bioclimatic indices have been developed that include one, two or more meteorological variables. These indices help us form an overview of the climatic / bioclimatic potential of the studied region / locality and choose the best time of the year to visit that tourist destination [4, 8].

On the contact between the Eastern Carpathians and the Moldavian Subcarpathians where the city of Piatra Neamț is located, there are natural conditions favorable for tourism activities in nature. At Piatra Neamț, elements specific to the mountainous, Carpathian environment are intertwined with that of the hilly areas. The contact region between the Eastern Carpathians and the Moldavian Subcarpathians due to its first-class tourist resources has been analyzed from a bioclimatic point of view in studies in which we find a series of general references [9-12] or in applied studies where we find direct

references about the geographical area where the Piatra Neamț tourist resort falls [8, 13, 14].

In our study, we evaluated the annual regime of the bioclimate of the Piatra Neamț resort for an average year, using daily meteorological data corresponding to the period 1961–2021, based on the PET bioclimatic index, and we created climate-tourism schemes (CTIS) that allow us to directly relate tourism activities to climatic and bioclimatic conditions. Also, for the time period 2017–2021, we detailed the analysis based on PET and CTIS on three intervals of a day, representative of the tourist activity, namely, for the 7.00 a.m., 2.00 p.m and 7.00 p.m.

2. Data and methods

2.1. PET calculation

To evaluate the climate and bioclimate of the Piatra Neamț tourist resort city, we used *daily* gridded meteorological data (average air temperature, relative humidity, cloudiness and average wind speed) for the period 1961–2021. The interval 1961–2013 was covered by Rocada gridded data [15], and for the period 2014–2021 we used the data provided by the POWER Project [16]. We add the *hourly* data (2017–2021) used for the analysis of the PET index and the CTIS at 9.00 a.m., 2.00 pm and 7.00 pm [16]. These data were processed using the *RayMan* program [17–20] for PET calculation. In addition to the mentioned meteorological elements for PET calculation we used time series of solar radiation and series of adjacent information on clothing, personal data on subjects (age, sex, height, weight) and on human activity [21]. In our study we considered the subjects (tourists, locals) to be men / women, aged 35 years, 1.75 m tall with an average weight of approx. 80 kg.

Basically, the PET index expresses in °C the temperature felt by an individual under certain conditions of temperature, humidity, pressure and wind and can be calculated by gender and age group. In our analysis we determined the frequency of different degrees of thermal perception and physiological stress (Table 1).

Table 1. Ranges of physiological equivalent temperature (PET in °C) for different degrees of thermal perception and degrees of physiological stress [17, 18]

PET (°C)	Thermal perception	Grade of physiological stress
< 4.1	Very cold	Extreme cold stress
4.1 – 8.0	Cold	Strong cold stress
8.1 – 13.0	Cool	Moderate cold stress
13.1 – 18.0	Slightly cool	Slight cold stress
18.1 – 23.0	Comfortable	No thermal stress
23.1 – 29.0	Slightly warm	Slight heat stress
29.1 – 35.0	Warm	Moderate heat stress
35.2 – 41.0	Thief	Strong heat stress
> 41	Very hot	Extreme heat stress

For an effective exploitation of climatic resources, the tourist should know quite well the course of bioclimatic conditions during an average year. These conditions are analyzed using degrees and levels of thermal comfort according to the PET index (Table 1).

2.2. Realization of CTIS

Climate-tourism schemes highlight the interdecadal development during an average year and for certain characteristic hours of biometeorological conditions in a specific place, the frequencies of different climatic and bioclimatic factors relevant for tourism [8]. For each element or climatic / bioclimatic parameter, favorability thresholds were established based on previous rigorous studies (Table 2).

Table 2. Indexes, elements, and parameters relevant for tourism and recreation; Thresholds and their authors

Parameter	Thresholds	References
Thermal comfort	$18^{\circ}\text{C} < \text{PET} < 29^{\circ}\text{C}$	[18]
Heat stress	$\text{PET} > 35^{\circ}\text{C}$; $\text{PET} > 41^{\circ}\text{C}$	[22]
Cold stress	$\text{PET} < 0^{\circ}\text{C}$; $\text{PET} < 4^{\circ}\text{C}$; $\text{PET} < 8^{\circ}\text{C}$	[18, 21]
Sunshine days; cloudiness	Cloud cover < 4 octas; cloud cover $< 5 / 8$	[23]
Fog	relative humidity $> 93\%$	[18]
Dry days (dehydrating)	Vapor tension between 0 and 7.4 hPa	[24]
Normal days (hygrically balanced)	Vapor tension between 7.5 and 11.6 hPa	[24]
Humid days (hydrating)	Vapor tension > 11.6 hPa	[24]
Days with snow layer	Snow layer ≥ 1 cm	[25]
Dry day	Precipitation ≤ 1 mm	[18]
Lightrain	Precipitation ≤ 5 mm	[18]
Wet day	Precipitation > 5 mm	[26]
Stormy day	Wind speed $> 8 \text{ ms}^{-1}$	[27]

CTIS software was used [18, 28, 29] and were processed both meteorological data daily (1961-2021), as well as the hourly data (2017-2021).

Climate-tourism schemes include three components:

-*thermal components*: heat stress ($\text{PET} > 35^{\circ}\text{C}$), cold stress ($\text{PET} < 4^{\circ}\text{C}$), thermal comfort ($18^{\circ}\text{C} < \text{PET} < 23^{\circ}\text{C}$);

-*physical components*: dry days (with precipitation < 1 mm), days with light rain (precipitation < 5 mm), rainy days (precipitation > 5 mm), dry days - dehydrating days (with water vapor pressure between 0 and 7.4 hPa), normal days – hygric balanced (with water vapor pressure between 7.5 and 11.6 hPa) and humid days (with water vapor pressure above 11.6 hPa);

-*aesthetic components*: sunny days ($< 4 / 8$ octas), foggy days ($\text{RH} > 93\%$), windy days ($> 8 \text{ m/s}$).

Data for each component were calculated by days and decades. In the first phase, we performed the CTIS in percentages on frequency intervals of 5 %, on the interval 0 – 100 %. This first percentage scheme, [18, 28, 5, 25] allows a very precise assessment of the decadal duration / frequency of each analyzed component.

Then we made the qualitative version of the CTIS, where the percentages were replaced by seven climate classes, from ideal to unfavorable for tourism, by applying a 14 % probability interval.

3. Study area

Piatra Neamt resort is located in NE Romania (Figure 1A and B), being a tourist destination with numerous natural advantages: *i*) the geographical location in a submountain depression, at an average altitude of 345 m, crossed by the picturesque Bistrita valley with its tributary Cuiejdi (Figure 1C), *ii*) the relief of hills and mountains in the surroundings (is surrounded by high and wooded hills such as Pietricica - 528 m, Cozla - 650 m, Cernegura - 850 m and Cărloman - 617 m), *iii*) shelter climate with the manifestation of mountain-valley winds [30], *iv*) forest vegetation that maintains clean and ozonated air [14]. At Piatra Neamt, in the sedative-indifferent bioclimate with invigorating nuances,

tourists can practice a lot of prophylactic, balneo-climato-therapeutic or post-therapeutic procedures [31]. There is also a rich cultural-historical heritage and a series of tourist facilities: parks for relaxation, rest and leisure, swimming pool, ski slope, chair lift and gondola lift, equestrian base, water sports on Bâta Doamnei lake.

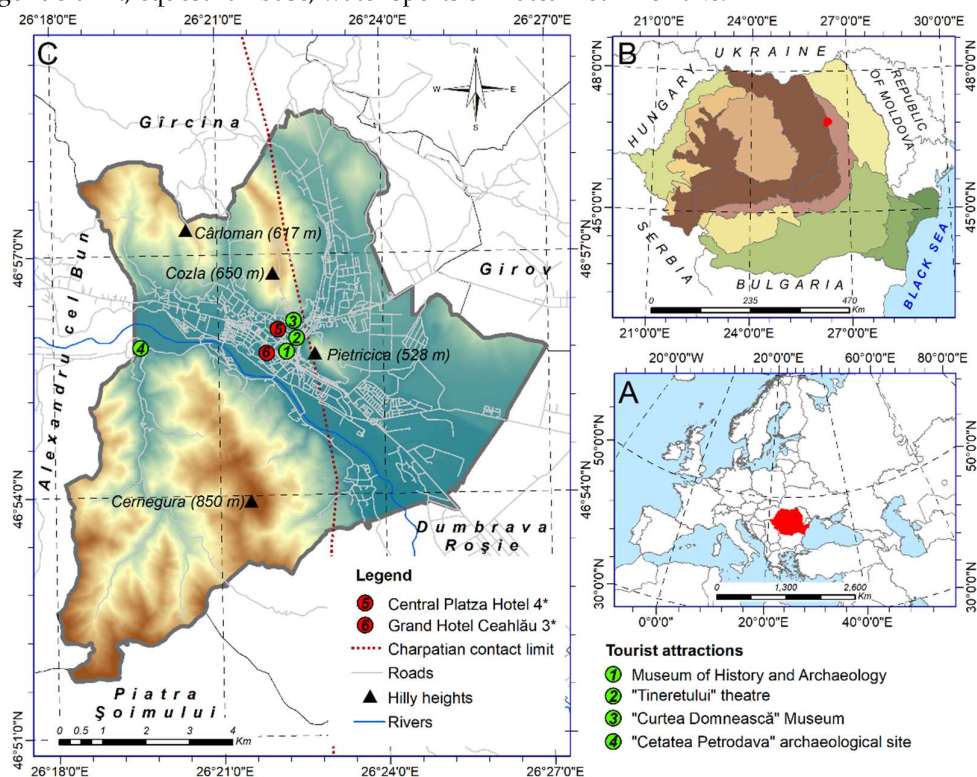


Figure 1. The location of the resort town of Piatra Neamț within Europe – A, Romania – B; altimetry, hydrography and the major tourist infrastructure of the researched territory – C

The resort city of Piatra Neamț was documented in 1431. The town has an ancient history with traces of some Geto-Dacian fortified settlements discovered in the surrounding villages (Bâta Doamnei, Calu, Cozla). Today Piatra Neamț has 85,055 inhabitants [32] and is an important economic and tourist center for the north-east of Romania. Historical and archeological monuments can be visited in the city (The Royal Court Museum, Archaeological Site "Bâta Doamnei Hill", with the Petrodava Fortress, Fortified settlement - Archaeological Site of Piatra Neamț, Point "Bâta Doamnei Hill" or "Troian Citadel"), but also The History and Archeology Museum, the Youth Theater or the Zoo Park.

The resort is a landmark for tourism in the north-eastern part of Romania, being a starting point either for the mountain routes leading to Ceahlău and Bicăzului Gorges, or to Târgu Neamț, on the way to the monasteries. The Piatra Neamț resort has an accommodation capacity of 1,183 places and was visited by 38,658 tourists in 2021 [32].

4. Results

4.1. Major climatic and bioclimatic characteristics of the Piatra Neamț tourist resort outlined on the basis of the PET index

The geographical location and the natural setting determine a number of climatic peculiarities: the global solar radiation is between 111–115 kcal cm⁻² year⁻¹, the annual duration of the Sun's brightness reaches the value of 1968.3 hours, and the cloudiness shows average annual values of 4.9 octas). Between December and February, cloudiness has the highest average values, over 5.5 octas, and in the July - September period cloudiness has average values below 4 octas [33].

The average annual temperature is 8.6°C, and the average thermal amplitude is 10.3°C. Relative humidity has average values of 78 %, the period with the highest values being the cold season. Average annual precipitation is moderate, with the multiannual average being 628.8 mm. The average wind speed is 3.6 m s⁻¹, with the wind blowing frequently from the W (22.3 %) and NW (18.7 %) directions. There were no days with atmospheric calm at Piatra Neamț during the analyzed period (1961-2021).

From a bioclimatic point of view, the resort city of Piatra Neamț belongs to the level of the sedating-indifferent bioclimate, but in the area of the resort you can also feel the influences of the stimulating mountain bioclimate from the western proximity of the city, especially through the local air circulation (mountain winds, from the Ceahlău massif, which bring cold, clean air from its crests, especially at night).

Over the entire interval analyzed at Piatra Neamț, the daily calculated values of PET gave an average value of this index of 8.8°C, positioning the population and tourists of the resort city in average bioclimatic conditions characterized by moderate stress due to cooling (Table 1 and Table 3). Extreme diurnal PET values ranged from a maximum of 35.7°C (indicating severe heating stress) to a minimum of -29.3°C (indicating extreme cooling stress (Table 1 and diurnal PET values). Multiannual PET synthetic statistical data show that various degrees of stress caused by cold are specific for 74.9 % of the days of an average year (Table 3, cells marked in blue), and stress caused by heat for 12.0 % of days (Table 3, cells marked in yellow). Thermal comfort is specific for 13.1 % of the days of an average year (Table 3, cells marked in green).

Table 3. Average, maximum and minimum value of PET. Share of PET (%) by class at Piatra Neamț in the analysis interval (1961-2021)

PET values (°C) (averages and extremes)	PET average			PET max			PET min			
	8.78			35.7			-29.3			
PET										
PET value ranges (°C)	<-10	-10-0.0	0.1-4	4.1-8	8.1-13	13.1-18	18.1-23	23.1-29	29.1-35	35.1-41
Percentages owned	5.1	20.2	11.6	10.5	13	14.5	13.1	9.7	2.3	0
	74.9						13.1	12.0		

To observe the connection between the PET index and the climatic elements, we calculated the Pearson Coefficient using the Excel program. From Table 4 it can be seen that the PET - air temperature correlation level is very strong and positive (0.96). PET and relative humidity correlate negatively, strongly and statistically representatively (-0.58), and with wind and cloudiness it has negative correlations, with little statistical significance (-0.31 and -0.24, respectively).

Table 4. The coefficient values of Pearson correlation established between the PET index and the average daily values of air temperature, relative humidity, wind speed and cloudiness at Piatra Neamț (1961-2021)

PET	The correlation coefficient
PET-T	0.96
PET-U	-0.58
PET-V	-0.31
PET-N	-0.24

An analysis of the thermal perception indicated by the decadal PET values at Piatra Neamț, for an average year from 1961-2021, shows (both for tourists and for citizens) that the *comfort range* (PET values between 18.1 - 23.0°C) appears starting from the first decade (D1) of April and is maintained until the first decade (D1) of November. If in D1 and D2 of April and D1 of November, the frequency of comfort reaches values of 1 - 2 %, in the months of May-September, the frequency of days with comfort increases up to 20 - 30 % and even above this last threshold (especially in the decades of June) (Figure 2).

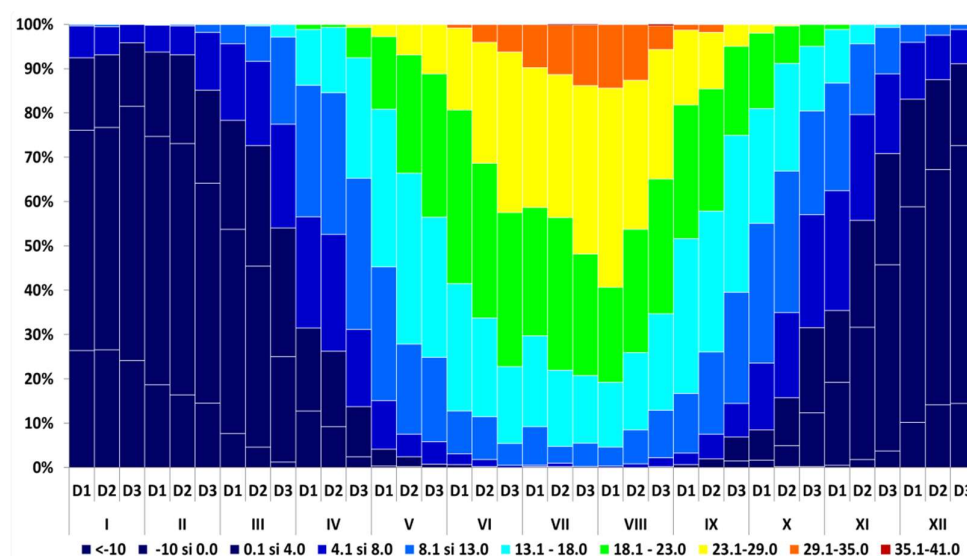


Figure 2. Annual regime of decadal frequencies of days with different PET values at Piatra Neamț (1961-2021)

Cold stress is recorded in all the decades of the months of the year. During the decades of the summer months, mild and moderate cold stress days generally account for less than 30% of the total time. In the decades related to the autumn and spring months, the stressful days due to the cooling of the air reach higher and higher weights, and the intensity of the discomfort increases as we approach winter in the September-November interval, or the weights and intensities of the discomfort due to cooling decreases as we move away from the winter season, the spring in the March-May interval. For example, in D1 of March and D3 of November at Piatra Neamț, the days are only with thermal discomfort, while in D3 of May, respectively in D1 of September, the days with cooling discomfort have approx. 55 % as weight. The lowest values of PET correspond to the months of December - February, when in all decades, the frequency of days with extreme cold stress exceeds the 80 % threshold (in D3 of January, the frequency of these days rises to 95 %).

Heating discomfort makes its presence felt from D3 in April to D2 in October. It holds the highest weights in the summer months (the maximum weight – 50-60 % being held by D3 in July, respectively D1 in August). *Mild heat stress* (PET values between 23.1 – 29.0°C) occurs from D3 of April to D2 of October. The frequency of this class exceeds 30 % in the months of June - August. *Moderate heat stress* (PET values between 29.1 – 35.0°C) has a low frequency (between 1 – 15 %), and occurs from D1 of June to D2 of September. The third

class, *strong stress caused by heat* (PET values between 35.1 - 40.1°C) occurs sporadically, on days in July and August, but its frequency has the lowest values: 1-2 %.

Our analysis also captures PET values at three times of the day: 9:00 a.m., 2:00 p.m., and 7:00 p.m. For this analysis we used hourly data for the period 2017-2021.

PET index at 9.00 am had a calculated mean value of 9.6°C. In the interval 2017-2021 it rose to a maximum of 39.2°C and fell to a minimum of -19.9°C. Discomfort from cooling at 9:00 a.m. has a high weight, 68.3 %, thermal comfort holds 12.8 % of the 9:00 am analyzed, and discomfort from heating reaches 18.9 %.

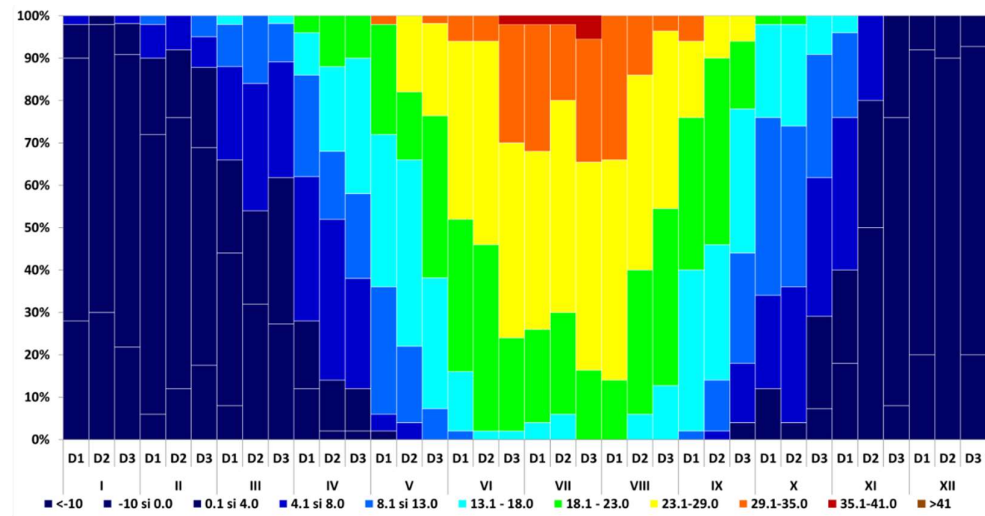


Figure 3. Annual regime of decadal frequencies of days with different PET values at 9:00 a.m. in Piatra Neamț (2017-2021)

The bioclimatic comfort is felt from April (D1) to October (D2). The highest weight (30-40 % of the hours taken into account) of bioclimatic comfort was recorded in the months of May (D3), June (D1, D2), August (D2, D3) and September (D1, D2). Discomfort due to heating at 9.00 am occurs starting from the days from D1 of May to D3 of September. The highest weight is held by the days when at 9:00 a.m. weak thermal stress due to heating is dominant (PET values between 23.1-29.0°C; on the days from D1 of June to D2 of August they have weights of 30 -40 %), followed by those with moderate stress (PET between 29.1-35.0°C, with weights of 15-30 % between D3 June and D2 August), and the days when at 9.00 a.m. there is strong thermal stress through heating were identified from D3 of June to D3 of July with weights of 2-5 %. (Figure 3)

PET index at 2.00 p.m. had an average value of 14.9°C, with a maximum of 41.9°C and a minimum of -17.2°C. Cooling discomfort decreases overall at this time to 56.7 %, and heating discomfort rises to 32.9 % (compared to 18.9 % at 9:00 a.m.). Comfort has an average weight of 10.4 % overall at 2:00 p.m. Bioclimatic comfort is manifested as a characteristic of the bioclimate from March (D1) to November (D1). The highest weight (over 20 - 30 %) of bioclimatic comfort was recorded in the months of April (D3), May (D1-D3) and June (D1), September (D1 and D3) and October (D2). It is specific at 2:00 p.m. in the months of spring and early summer, respectively early and mid-autumn.

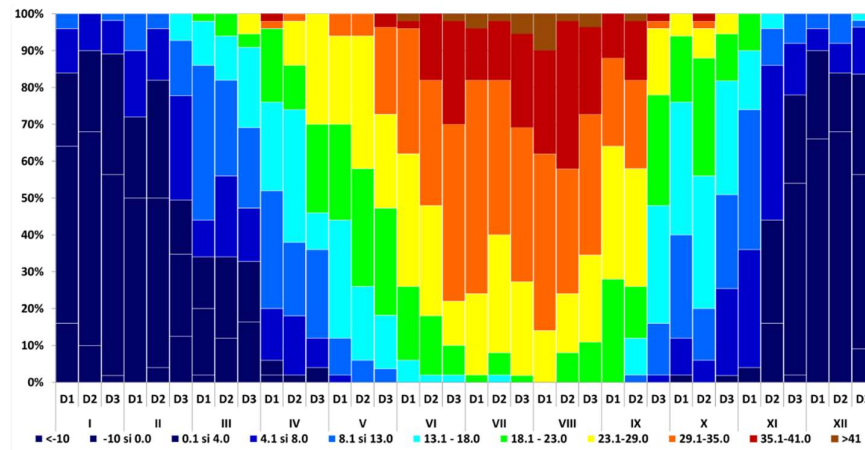


Figure 4. The annual regime of the decadal frequencies of days with different PET values at 2.00 p.m. at Piatra Neamț (2017-2021)

The discomfort caused by heating at 2:00 p.m. corresponds to the summer months and includes the 3 classes of stress: mild stress (PET = 23.1 - 29.0°C), moderate stress (PET = 29.1 - 35.0°C) and strong stress (PET = 35 - 41°C) with weights of 80-100 % in D1 from August. The discomfort due to cooling at 2.00 p.m. is practically continuous from D2 November to D3 February, and in D2 January it reaches the highest degree (Figure 4).

PET index at 7.00 p.m. had an average value of 2.2°C, with a maximum of 21.9°C and a minimum of -22.3°C. At 7.00 p.m. the discomfort due to cooling has a maximum weight (99 %). Bioclimatic comfort holds only 1 % of the 7.00 p.m of the 2017-2021 period and was manifested between D3 in May and D1 in September.

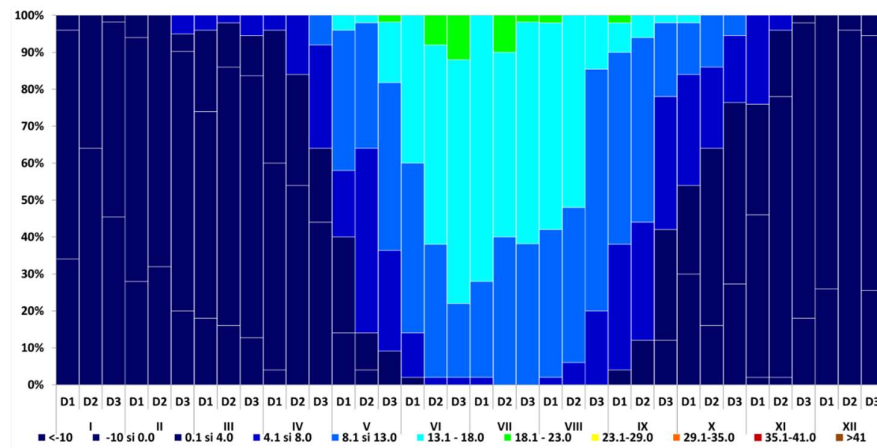


Figure 5. Annual regime of decadal frequencies of days with different PET values at 7.00 p.m. at Piatra Neamț (2017-2021)

In D2-D3 June and D2 July in the analyzed interval, before sunset, comfort reached its maximum frequency (10-15 %) (Figure 5).

The average annual regime of the monthly values of the PET index divided by the 3 hours highlights some interesting aspects (Figure 6).

At 9.00 a.m. PET rises from the beginning of the year until June, then falls slightly until December. The highest values (above 25°C) are recorded in the months of June, July and August, when the temperature values are the highest, and the lowest values (below 0°C) occur in the months of December, January and February when the thermal values are the lowest and the relative air humidity reaches the annual maximum. Comfort values bioclimatically correspond to the May-September interval. The monthly PET values at 9.00 a.m. exceed those at 7.00 p.m. month by month. The difference between the two time intervals is between 2°C in December and 14°C in June.

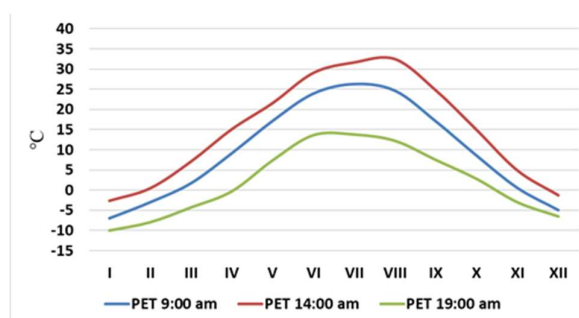


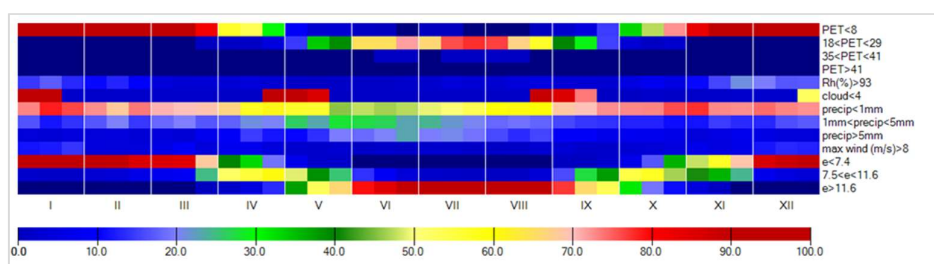
Figure 6. Average regime annual of the monthly values of the PET index (°C) at 9:00 a.m., 2:00 p.m. and 7:00 p.m. at Piatra Neamț (2017-2021)

At 2.00 p.m. PET has the highest values, with a maximum (33°C) recorded in August. High values, above 25°C, are reached between May and September, and the lowest, slightly below 0°C, in December and January. The bioclimatic comfort overlaps the months of May - June and September - October.

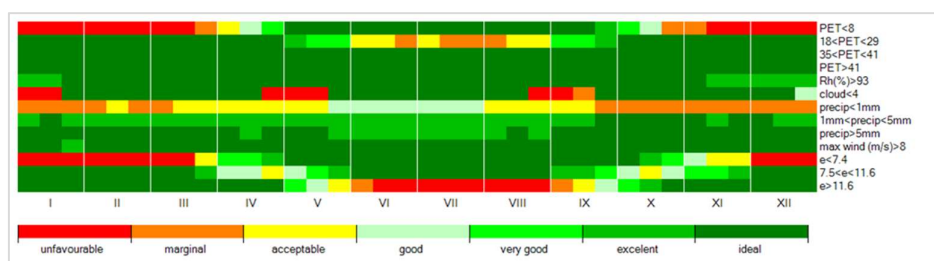
7.00 p.m. corresponds to the lowest values of the PET index (-10°C in January). Average monthly values of summer days, at this time, are between 10-15°C.

4.2. Analysis of the favorability of the bioclimate for tourists and residents of the resort city of Piatra Neamț through CTIS

CTIS for Piatra Neamț shows that stress caused by cold ($PET < 18^{\circ}\text{C}$) it is effectively produced from the first decade of November to the end of March (Figures 7a and b). However, it can cause discomfort through its manifestation including in the summer months during which it has weights below 10 %. The period with relative thermal comfort for sites in the temperate climate zone according to bioclimatologists in the value range $18 < PET < 29^{\circ}\text{C}$ overlaps the May-September interval, with the highest production frequency (over 40 %), in the months of June, July and August (Figure 7a). With very low production frequencies (below 15 %), heat stress ($PET > 35.1^{\circ}\text{C}$) is practically negligible at Piatra Neamț. This type of stress by frequency and intensity can create mild discomfort in a maximum of 5-15 % of summer days, especially in the midday hours. That is why in the bioclimatic balance from Piatra Neamț, the discomfort caused by heating must be positioned at the appropriate level of importance, but it must not be neglected, especially in the current context of climate warming



a



b

Figure 7. Climate-tourism scheme for Piatra Neamț resort (1961-2021): in percentages - a and by classes of favorability / unfavorability - b

In terms of relative humidity (fog), precipitation and strong wind, Piatra Neamț has favorable conditions for living and practicing tourism for most of the year. Thus, strong wind ($> 8 \text{ m s}^{-1}$) has a frequency of 10-15 % in the cold season and only 3-4 % in the warm season. Cloudiness ($> 5/8$ octas) does not present serious restrictions for outdoor tourism activities: conditions are acceptable (August, D1), good and very good throughout the year. Days with precipitation (between 1 mm and $< 5 \text{ mm year}^{-1}$ respectively $> 5 \text{ mm year}^{-1}$) are rare, having a frequency of 15 - 20 % throughout the year. Only short-term, quantitatively weak precipitation ($< 1 \text{ mm year}^{-1}$) can create slight discomfort from September to April and in May-June. Fog is not an impediment to tourism either: conditions are from very good to ideal throughout the year. For the eyes, respiratory tract and lungs, from D2 November to D2 April the days are predominantly dehydrating, and during the summer they are predominantly hydrating (Figures 7a, b).

CTIS at 9.00 a.m highlights the dominance of bioclimatic comfort and the lack of bioclimatic restrictions for most of the analyzed indicators and for most of the decades of the year. There are also a number of exceptions that we will point out. Cold stress ($\text{PET} < 18^\circ\text{C}$) is present from November (D3) to February (D3) with a weight of 50 %. From March, the weight of stress caused by the cold begins to decrease (30 - 40 %), to drop below 5 % from May. And heat stress ($35^\circ\text{C} < \text{PET} < 41^\circ\text{C}$) has a low weight (5 - 15 %) between D3 June and D2 August (Figures 8a, b).

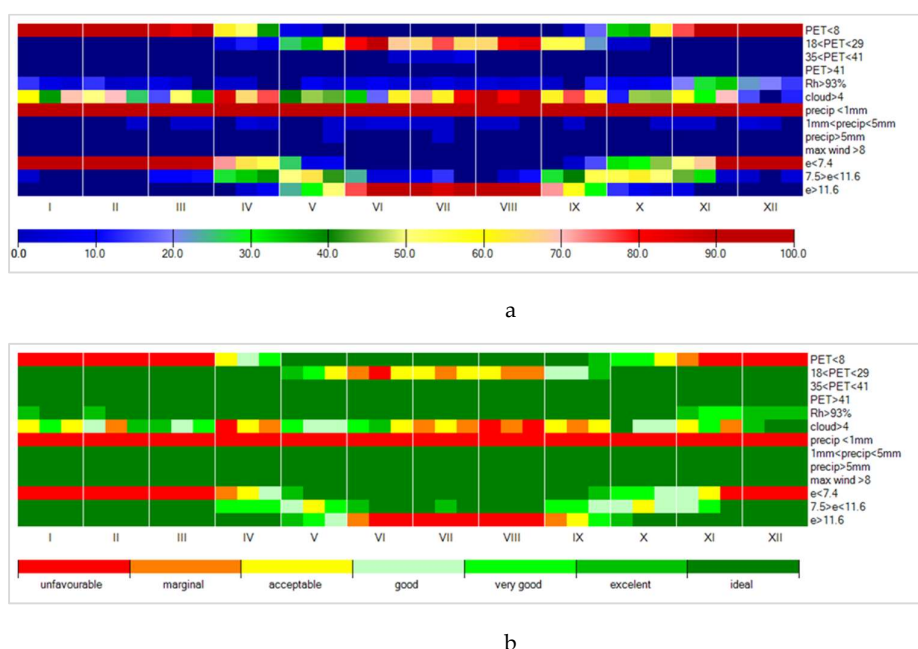


Figure 8. Climate-tourist scheme for Piatra Neamț resort at 9:00 a.m. (2017-2021): in percentages - a and by classes of favorability / unfavorability - b

Cloudiness above 5 octas has higher frequencies at 9.00 a.m. in the interval D2 June - D3 October, days with low precipitation, with drizzles raise restrictions at this time in all decades of the year, dehydrating days are more frequent in the interval D3 November - D3 February, and hydrating raise minor problems in 4 of the 9 decades of the summer months (Figures 8a and b).

At 2.00 p.m. cooling discomfort poses minor problems to locals and tourists between D1 December and D1 February. Value range with thermal comfort ($18^\circ\text{C} < \text{PET} < 29^\circ\text{C}$) corresponds to classes "very good", "excellent" and "ideal", it covers at 2 p.m. all months of the year. (Figures 9 a, b). The stress due to the heat is felt with low frequency (below 30 % of the considered 2.00 p.m) in the months of June, July, August.

Days with cloudiness over 5 octas at 2 p.m. generate a slight discomfort distributed in 75 % of the decades of the year, and days with light rain or drizzle, due to the high decadal frequency, constitute an aesthetic element that induces discomfort to the population and tourists. 2:00 p.m. with low or high humidity values do not raise real problems due to the frequency and duration of the manifestation of locals or tourists (Figures 9a and b).

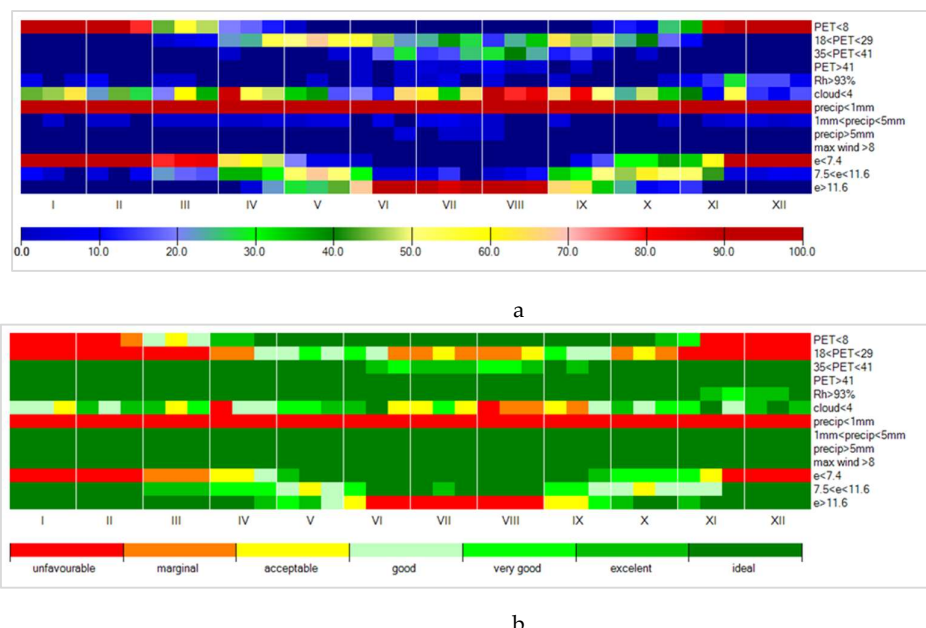


Figure 9. Climate-tourist scheme for the Piatra Neamt resort at 2.00 p.m. (2017-2021): in percentages- a and by classes of favorability / unfavorability- b

CTIS at 7.00 p.m. indicates decadal frequencies of cold stress (PET < 18°C) over 35 % from October (D1) to May (D1).

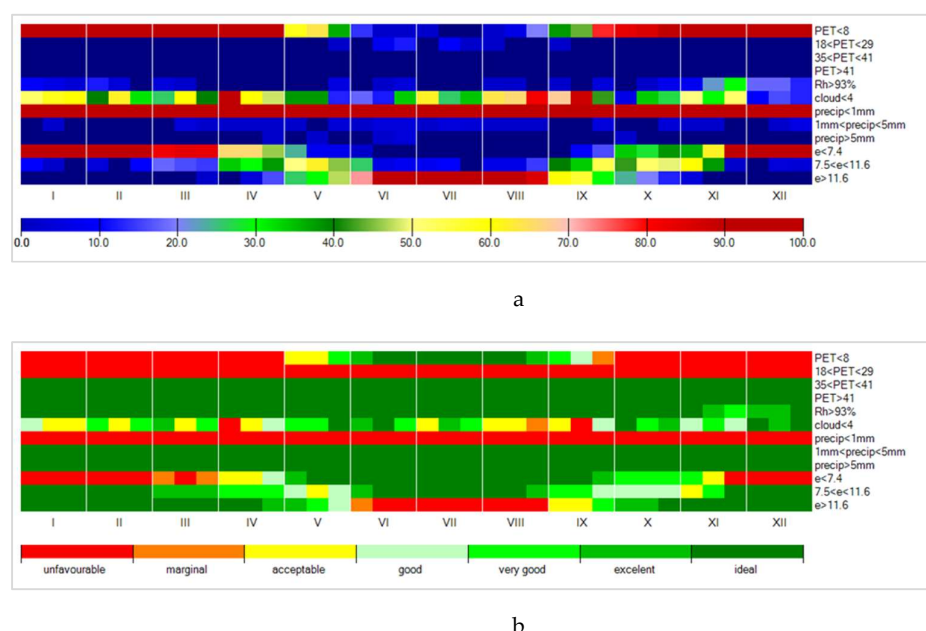


Figure 10. Climate-tourist scheme for Piatra Neamt resort at 7.00 p.m. (2017-2021): in percentages- a and by classes of favorability / unfavorability- b

7.00 p.m. with thermal comfort (18°C < PET < 29°C) are specific to the months of June, July, August and have a low frequency (15 - 25 %). They are also possible in the other

decades, but have a very low frequency (below 5 %). The discomfort caused by the heat is non-existent at 7.00 p.m. At 7:00 p.m., the comfort is affected to a small extent by the occurrence of light rain episodes in all decades of the year. Also, between D3 November and D2 February, dehydrating hours are more frequent (around 50 %) (Figures 10a and b).

5. Discussions

The Subcarpathian region was bioclimatically analyzed in some studies [8, 13] that considered several tourist resorts (Băltătești and Slănic Moldova). Thus, in Băltătești (a subcarpathian resort located 20 km north of Piatra Neamț), the thermal stress caused by cold weather starts from November (D3) and lasts until March (D2), and in Slănic Moldova (a subcarpathian resort located 80 km south of Piatra Neamț) thermal stress caused by cold starts later, in December (D1), and lasts less, until February (D2). Differences also occur in the onset/end of heat stress periods. In Slănic Moldova, the period of heat stress is longer, from April to October, and in Băltătești from May to September. The periods of bioclimatic comfort mostly overlap in the 3 resorts (Băltătești, Piatra Neamț and Slănic Moldova) being a bioclimatic reality from April to October. Minor differences appear between the three resorts in terms of the onset or end decades of comfort or bioclimatic stress due to warming or cooling. They are inherent in the fact that there are a number of differences between the positions and geographical characteristics of the three resorts. The results of our study are compatible with other bioclimatic research that referred to the contact area between the Eastern Carpathians and the Moldavian Subcarpathians [11, 12].

We have identified for the first time the meteorological elements with variability and real impact on tourism in Piatra Neamț. From this point of view we can say that the wind speed, the cloudiness, the humidity and the precipitation are not restrictive with the locals and the tourists throughout the whole year. The role played by the geographical location, in a submountain depression, with a sheltered climate is obvious in the case of the Piatra Neamț resort. The air temperature leaves its mark more strongly on the bioclimatic characteristics of the Piatra Neamț resort. This explains the average PET value of 8.8°C, one that corresponds to a moderate stress caused by cold, stress that has a temporal coverage of 74.9 % of the duration of a year.

In order to characterize the bioclimate and other elements that influence the climate-tourist potential of the Piatra Neamț resort, we used CTIS for which we had daily and hourly climate data. The hourly CTIS was compiled for the first time for a bioclimatic and climate-tourism study in Romania. These data very well indicate favorable and restrictive conditions for tourism. We identified the periods of the year with optimal conditions for outdoor tourist activities as being from D2 April to D2 October.

6. Conclusions

In this study, the climatic and bioclimatic conditions of Piatra Neamț were analyzed, as well as their variations throughout the year. The PET index and the CTIS tourism climate schemes were grouped by decades, providing the analysis with a high level of detail, but at the same time flexible and easy to approach, the grouping by decades also satisfying the needs of planning stays by potential tourists.

The most representative type of weather at Piatra Neamț is the one that induces stress in different degrees due to the cooling of the atmosphere. It has a multi-year share of 74.9 %. The discomfort caused by the cold at Piatra Neamț is present in the days of the winter months, but also in those of the transitional seasons. PET values fall below the comfort threshold during these days and months, and snow cover may cover the urban area for a long period (36,3 days), which makes outdoor activities (including tourism) more difficult. During these days and months, tourists arriving at Piatra Neamț must be properly equipped and take precautions to protect themselves against thermal stress due to the cooling of the atmosphere and the active surface. On the other hand, during periods with a layer of snow, winter sports can be practiced to the full, constituting an advantage

in terms of the tourist attractiveness exercised by Piatra Neamț. Days with mild thermal discomfort due to cooling are specific to Piatra Neamț during the summer, too.

The most comfortable for tourist activities at Piatra Neamț are the days of May, June and September when thematic comfort is maximum and the weather is generally pleasant. Comfort owns 13.1 % of the time at Piatra Neamț. The months of July and August present mild or moderate discomfort with midday heat. *Discomfort due to heating* sums up 12.0 % of the time at Piatra Neamț. On the whole, however, the May-September period offers tourists coming to Piatra Neamț good and very good conditions for walks, hikes, excursions and other outdoor activities. The months of April and October are transition months in which thermal comfort and discomfort alternate between day and night, but which change in weight between their beginnings and endings.

Overall, CTIS at Piatra Neamț bears the imprint of the stressful time due to low temperature values. The other physical and aesthetic components that make up the CTIS matrix do not restrict tourism activities.

The most favorable time of day for people and outdoor tourist activities at Piatra Neamț overlaps in the summer with the hours of the first part of the day and from the afternoon to the evening when the thermal values are moderate and the humidity and wind speed are low. On the other hand, in winter, spring and autumn, the most comfortable hours are those in the middle of the day, when the thermal values are the highest.

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