IS THE BIOCLIMATE OF SUCEAVA PLATEAU COMFORTABLE OR UNCOMFORTABLE? ANALYSIS BASED ON TEE AND THI

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Keywords: Equivalent Effective Temperature, Air baths, Temperature Humidity Index

Abstract: The present study approaches in the first part the bioclimatic comfort or discomfort of the Suceava Plateau during the hot season based on the two most representative bioclimatic indexes (equivalent effective temperature - TEE and Temperature Humidity Index (THI). The study is completed in the second part by the analysis focused on the cold season, a period for which two other major bioclimatic indexes have been used (cooling wind power - P, equivalent temperature cooling wind power - TPR) plus an index derived from previous indices (skin stress index). We used a fifth index (pulmonary stress) to see whether the bioclimate in Suceava Plateau is stressful for the human body. The study was completed by the calculation of the total stress index and the degree of stimulation of Suceava Plateau bioclimate.

Introduction
Suceava Plateau is a geographical area in the North-East of Romania, lying on an area of approximately 9000km², with an average altitude of 250-450m, a forest and steppe area inhabited by about 660000 people (Romanian Geography, Vol IV, 1992). From the economic and infrastructural point of view, it is considered a well developed and arranged geographical subunit. In Suceava Plateau or in the immediate vicinity, numerous sights are located, of which we mention: the Saint John Monastery of Suceava, Sucevița, Putna, Arbore, Slatina, Probota, Dragomirna monasteries, weather resorts Cacica, Solca, Gura Humorului, a lot of hotels, tourist pensions which annually attract a large number of visitors.

The continental climate with Baltic influences, cold winters, rich snow layer and comfortable summers in a varied landscape of gentle hills well wooded, meandering wide valleys with rich and quality water resources, is also a reason to

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spend a pleasant holiday or vacation for rest, relaxation or training and conditioning.

Previous studies on the bioclimatic characteristics of the Romanian regions (Bogdan, 1983; Teodoreanu, 1993; Berlescu, 1996, 1998) revealed a sedative, tonic and relaxing bioclimate in Suceava Plateau, with stimulating and tonic properties, especially in the western part of the region, useful to climatic-therapy during all months of the year.

Several bioclimatic indices – the most representative for the year or for summer (Part I) or for cold (part II) – were analyzed to detail the average bioclimatic features or the most particular periods of time and to highlight the annual and night-day regime in Suceava Plateau.

1. Data and method. The database used focuses on meteorological observations related to temperature, humidity and wind speed from the weather stations of the Suceava Plateau between 1960 - 2008. If applicable for the case studies, we used daily or hourly data for shorter samples. The formula used to calculate TEE was the Missenard formula (1937) and the THI formula for moisture temperature index expressed in units and recommended by WMO. The level of analysis descended from general (system/distribution, based on average data outlined) to case studies (as exemplified by the hourly data and daytime objective). Since the subject is very large, we had to divide the analysis into two parts: one mainly dedicated to the warm season of the year (based on bioclimatic indexes equivalent effective temperature – TEE and temperature-humidity index – THI) and the other part dedicated to the cold season (in this case based on the following research bioclimatic indexes: cooling power of the wind – P and, closely related, we have examined the stress of the skin, the equivalent temperature cooling power of the wind – TPR, and for the unity of the approach, the study is completed by the total lung stress analysis and the stimulation degree of the Suceava Plateau climate).

2. Results and Discussions
2.1. TEE - equivalent effective temperature. TEE is a bioclimatic indicator representing the effective temperature experienced by the human body in different climatic environmental conditions. It can be followed with good results during the warm season (summer), expressing the relation [I] given by the air temperature in the dry bulb - $T^\circ(C)$, the wind speed - $v$ (m/s) and the relative humidity $f$ (%) in accordance with the Missenard formula, 1937 (Krawczyk, 1975; Teodoreanu 2003, 2007).
Is the bioclimatic of Suceava Plateau comfortable or uncomfortable?

The thermal comfort is given by a narrow range between 16.9\(^\circ\) and 20.8\(^\circ\) TEE, where under normal conditions, wearing relaxing clothes, whose albedo is average in rest position, the body doesn’t lose or gain significant heat. Under or above this range, the body feels cold or hot, which brings metabolic changes, in order to maintain the internal body temperature constant (thermal homeostasis). The intervals of thermal comfort vary on the globe depending on latitude and human race (14.4 to 20.6\(^\circ\) TEE - United Kingdom, 16.7 to 21.8\(^\circ\) TEE – Yakovenko region of the Russian Federation, 18 - 22\(^\circ\) TEE - U.S., 23.3 – 29.4\(^\circ\) TEE – tropical countries - Teodoreanu, Bunescu, 2007).

Tab.1 – The weather stations in the Suceava Plateau (position and altitude)

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Meteorological Station</th>
<th>Lat.</th>
<th>Long.</th>
<th>Alt. (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radauti</td>
<td>47(^\circ)50'</td>
<td>26(^\circ)53'</td>
<td>339</td>
</tr>
<tr>
<td>2</td>
<td>Suceava</td>
<td>47(^\circ)38'</td>
<td>26(^\circ)15'</td>
<td>352</td>
</tr>
<tr>
<td>3</td>
<td>Fălticeni</td>
<td>47(^\circ)28'</td>
<td>26(^\circ)20'</td>
<td>348</td>
</tr>
<tr>
<td>4</td>
<td>Roman</td>
<td>46(^\circ)55'</td>
<td>26(^\circ)50'</td>
<td>216</td>
</tr>
</tbody>
</table>

N. Z. Mihailov (Baibakova et. al, 1964, according to Teodoreanu, 2002), classified the air baths according to TEE, as it follows:

- Cold baths 1 – 8.9\(^\circ\) TEE,
- Moderately cold baths 9 – 16.8\(^\circ\) TEE,
- Comfortable air baths from 16.9 – 20.8\(^\circ\) TEE,
- Moderately warm air bath from 20.9 – 22.9\(^\circ\) TEE,
- Hot air baths 23 – 27\(^\circ\) TEE,
- Hot air baths > 27\(^\circ\) TEE.

Calculating the average values of TEE based on data from the weather stations of the Suceava Plateau (Table 1), on a period of 48 years, we can observe that although the geographical location (altitude, latitude, longitude - tab. 1) is quite different, the results are similar (the monthly and annual average TEE was lower in the northern plateau with approximately 2\(^\circ\) TEE in Radauti, city situated in a depression, compared to the southern plateau, at Roman – tab. 2, Fig. 1).
Moreover, if we analyze the obtained data, we will determine that only in July and August and in the southern plateau (Roman, Fig. 1), there are comfortable outdoor baths, which underlines what the researchers found, namely that in
bioclimatology, average values are not edifying. This is explained by the fact that the human body can bear higher temperatures during the day and lower temperatures during the night.

In addition, certain periods, depending on the atmospheric circulation, are colder or warmer, and the body is exposed to instantaneous conditions of temperature – humidity – wind and not to average values, which are only required for comparisons to other regions.

For a more real result of thermal comfort, daily average values of TEE were calculated for 38 years at the Suceava weather station (Fig. 2) and then the daily values for 2000 (warm year $t^\circ C$ annual average = 9.3$^\circ C$; 1.5$^\circ C$ above the annual average), at the same weather station (Fig. 3).

![Fig. 2 – Annual average values of TEE in Suceava (1970 - 2008)](image)

We conclude that the TEE evolution outlined through average daily values is not a relevant way to valorise this bioclimatic index. The unification and limitation of these TEE index values underneath certain thresholds could even lead to wrong conclusions about the nature of the air thermal baths (which during summer days, according to the classification in question, are only moderately cold). The level of particularization of the analysis on diurnal average values is not relevant enough.

Fig. 3, applied only for the year 2000, is more probative and allows us to see a concrete case that since April-May moderate cold-air baths have often been recorded, the approximate thermal comfort is asserted during the summer months and in September and October the air baths become again moderately cold air, the average ratings being interrupted on short periods of time by periods of slight cold
or warm discomfort. In the cold season, in Suceava, even in warm years like 2000, air baths are cold.

Fig. 3 – The evolution of the diurnal annual values of TEE to Suceava in 2000

For more details, the hourly TEE values were calculated over a period of four years at the Suceava weather station (by positioning them in the centre of the plateau, this station can be considered the most representative geographical subunit ever investigated) for each month of the year, which allows us to find that discomfort by cooling is predominant in most of the months, both during the day and the night.

Only in June and on the diurnal range 7-8 a.m. ÷ 6-7 p.m. weather condition is close to thermal comfort, and in July and August, the thermal comfort is recorded on a shorter interval between 8-9 a.m. and 5-6 p.m. (Fig. 4).

An analysis of the July 2007 heat wave period, which covered the whole country, affecting a large part of the population especially in the plains and hills in the south and east of the country, proved that this period was uncomfortable even in the plateau area of the northeast of the country, hourly average values of the period July 16 – 22, 2007 fitting in the area of a heat discomfort over 21°TEE to almost 28°TEE.

Even during the night hours before sunrise, at 4 a.m., when there was minimal daily average for this period, the effective temperature felt by the human body exceeded the limit of comfort (Fig. 5).
2.2. Temperature Humidity Index (THI)

There are two methods for calculating this index and for its expression: "dimensionless", "by unit" or calibrated on the temperature scale, i.e. °C degrees”. The significant values start from the point where the discomfort is high (80 units, respectively 40°C).

The weather parameters required to calculate the thermal comfort index (ITU), expressed both in units and in the one calibrated in degrees are the air temperature at 2m height and the relative humidity.

![Fig.4 – Average diurnal evolution (2005 - 2008) hourly values of TEE (°C) to Suceava](image1)

![Fig. 5 Evolution of TEE value in Suceava during the heat of 16-22.VII.2007](image2)
The moisture-temperature index expressed in units recommended by the WMO (Dragotă, 2003, Marina 2006, Teodoreanu and Bunescu, 2007) is obtained using the formula [2]:

\[
ITU = \left( T \times 1.8 + 32 \right) - \left( 0.55 - 0.0055 \times U \right) \left[ \left( T \times 1.8 + 32 \right) - 58 \right]
\] [2], where:

- \( T \) = temperature \(^\circ\text{C}\) meteorological shelter height (2m); \( U \) = relative humidity (%) at the same level.

Thermal comfort or discomfort is assessed in accordance with the following scale values: \( \text{THI} \leq 65 \) units indicates the comfort, \( 66 \leq \text{THI} \leq 79 \) indicates the alert and \( \text{THI} \geq 80 \) units shows discomfort.

This index has a limited applicability in the Suceava Plateau for the warm season of the year. Its utility is especially validated in situations of discomfort during the summer, and it is an ideal indicator of the time conditions when the temperature-humidity complex exceeds the alert threshold of discomfort. However, situations of discomfort caused by high values of temperature – humidity complex, have a lower frequency in the Suceava Plateau compared to other subunits/geographical units (the Plain of Moldavia, Cris Plain, Baragan).

Calculating the monthly average values of the THI index at the weather stations, we can find the comparable bioclimatic conditions in the entire plateau, and also the inefficiency of the index in all months of the year showing values below the alert threshold, except in July and August, when in the south of the plateau, the values are above the alert threshold (fig. 6, tab. 3).

If we calculate the daily values of the THI for the daily values during the year on a longer period of time (39 years, Suceava weather station), we can notice that for the maximum values (theoretical values which result from calculations that included daytime maximum values of every month for a period of 39 years of air temperature and relative humidity), the alert threshold is exceeded only during the summer months, while the average values remain within the comfort range (fig. 7). Calculated for one year (in 2000, which was a very warm year), the average daily values of THI show that on some days and specific days groups, they can exceed the alert threshold (Fig. 8).

An isopleth of the THI index for average values is also totally inconclusive, showing a nucleus during the summer months, during the day hours possibly ranging within the alert group (Fig. 9). The analysis of hourly values by months for a period of several years is more conclusive, showing the alert state in the summer months during the hot sunlight hours (Fig. 10).
Is the bioclimatic of Suceava Plateau comfortable or uncomfortable?

Fig. 6 – The regime of the annual ITU values (units) at meteorological stations in Suceava Plateau (1960 - 2008)

Tab. 3 – Average monthly values of ITU (units) in Suceava Plateau (1960-2008)

<table>
<thead>
<tr>
<th>ITU</th>
<th>I</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rădăuți</td>
<td>27.0</td>
<td>29.7</td>
<td>36.5</td>
<td>47.3</td>
<td>56.8</td>
<td>62.1</td>
</tr>
<tr>
<td>Suceava</td>
<td>28.9</td>
<td>30.8</td>
<td>37.7</td>
<td>48.1</td>
<td>57.2</td>
<td>61.9</td>
</tr>
<tr>
<td>Fălticeni</td>
<td>29.0</td>
<td>31.2</td>
<td>38.2</td>
<td>48.8</td>
<td>57.4</td>
<td>62.7</td>
</tr>
<tr>
<td>Roman</td>
<td>26.9</td>
<td>30.4</td>
<td>38.6</td>
<td>50.4</td>
<td>59.1</td>
<td>64.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ITU</th>
<th>I</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rădăuți</td>
<td>64.2</td>
<td>62.8</td>
<td>55.6</td>
<td>47.2</td>
<td>38.1</td>
<td>30.2</td>
</tr>
<tr>
<td>Suceava</td>
<td>64.4</td>
<td>63.2</td>
<td>56.5</td>
<td>48.3</td>
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<tr>
<td>Fălticeni</td>
<td><strong>65.0</strong></td>
<td>64.0</td>
<td>57.3</td>
<td>49.0</td>
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<td>32.3</td>
</tr>
<tr>
<td>Roman</td>
<td><strong>66.7</strong></td>
<td><strong>65.7</strong></td>
<td>58.9</td>
<td>49.3</td>
<td>39.4</td>
<td>30.5</td>
</tr>
</tbody>
</table>

Besides, we should note that the state of alert, which would mean a possibility of thermal discomfort and potential health problems, (highlighted by the media especially during those periods) is generally the result of temperatures of 25-30°C (normal for summer months in our country, for which the body is adapted), which shows that this index is only usable under conditions of high heat waves (due to anticyclonic periods, invasion of continental and maritime tropical air and highlighted through the succession of days and tropical nights or canicular days).
Fig. 7 – The annual trend of the maximum, medium and maximum diurnal average values of ITU (units) to Suceava from 1970 to 2008.

Fig. 8 – Annual evolution of ITU (units) diurnal values in Suceava in 2000.

But even in these cases, respectively during the canicular weather on July 16 to 22, 2007 in Suceava Plateau, the THI values exceeded the critical threshold of 80 units only at noon hours (Fig. 11). This aspect differentiates the Suceava Plateau from a bioclimatic point of view, where summer heat waves have not the size and intensity of the other Romanian extra-Carpathian subunits.
Conclusions

TEE as bioclimatic index has a greater relevance for the warm season of the year, because the classifications in terms of the thermal air baths (Mihailov, 1961; Baibakova, 1964; Teodoreanu, 2002), are limited to positive temperatures. The thermal character of the winter air baths in Suceava Plateau is more uniform and located below the high value of cold baths, although the actual change in TEE allows us to appreciate the detailed nature of atmospheric air heat related to the human body.

For the warm period (and especially for summer days) we notice that, given the comfortable character of the average air baths, during an anticyclonic period (Fig. 5), in Suceava Plateau, TEE values exceed by far the upper thermal comfort threshold, especially during the day. Moreover, during the night, heat discomfort can occur several nights in sequence, not being cancelled during the diurnal period specific to the minimum daytime values. The uncomfortable alternations of days and nights due to high levels of TEE are therefore highlighted for the Suceava Plateau too, a geographical subunit regarded as having a cool climate.

We did not intend to highlight/emphasize this aspect, but in the last 30 years, in the current climate trends, such episodes have become more and more frequent. This index proves its usefulness especially for such synoptic situations.

THI is a bioclimatic index for Suceava Plateau which has a limited temporal applicability in the summer months. Only in these months and only in the southern half of the plateau, the THI index can exceed the threshold of 65 units, which biologically indicates the body entrance in the alert state. Considering this situation, the limited timeframe of 7 – 9 a.m. ÷ 18 – 20 p.m. from June to August, there may be days and nights (single or in groups) when the THI values are above the threshold of 80 units, case in which the body experiences discomfort. Although
less frequent in the Suceava Plateau compared to other extra-Carpathian geographical areas, the weather conditions characterized by discomfort while

Fig. 10 – Diurnal regime of the ITU (units) to Suceava for the months May to August (2005 - 2008)

Fig. 11 – The trend of diurnal ITU values in Suceava between 16th - 22. VII. 2007

heating under high atmospheric humidity, can create significant problems in the overall socio-economic system or human body in particular.
Is the bioclimatic of Suceava Plateau comfortable or uncomfortable?

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