The assessment of the caloric stress conditions in the Eastern Romanian Plain

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Abstract: The thermal comfort is an expression of the satisfaction feeling in relation to the weather conditions. A variable environment is a permanent source of stress for the human being. To maintain the human body in a thermal balance is possible only if the thermo-regulatory mechanism does not make significant efforts to create a state of physiological comfort. The present study proposes an assessment of the Relative Stress/Tension Index (RSI) regime specific of the Eastern Romanian Plain, for the period between 1990 and 2020. This type of assessment is useful in adopting the most efficient strategies for the adaptation and mitigation to the bioclimatic conditions in the vulnerable regions. Applicability is possible through personal adjustments to cope with the heat stress, realistic planning of living, recreation and health care facilities etc. In general, the detailed assessment of the bioclimatic indices is interesting and useful in studying their space and time variation. It is also useful to apply a single reference scale for people to make appropriate decisions about exposure to outdoor conditions, regardless of the time of day. Along with the presentation of the weather, it is necessary to describe the conditions of the comfort or the physiological risk related to the climate.

1. Introduction

The human body faces different comfortable or uncomfortable states, regardless of the time of day or the environment in which it is located. In general, these conditions have more or less significant consequences on the population and implicitly, on the active environment of a human society. Stress is among the most well-known situations that generate discomfort at the level of the human body. The word stress, of English origin, related to other words, can have different meanings, such as: request, tension, pressure, effort, pressing etc. The term stress has been introduced in the medical language since 1936 and it was proposed by the Canadian scientist Selye Hans IV. Regardless of the stress factor - cold, heat, bacteria etc., the human body emits a response. When an unpleasant situation arises, a state of indisposition sets in and a disturbing physical symptom appears. Thus, the adaptation syndrome or Selye syndrome imposes itself in the specialized literature. Statement possible following the finding that stress is part of the daily life of humans, having two basic component elements, namely the stress agent and the state of the human body. Considering that people are not identical and that they respond differently to stress, Roesch and colleagues, in 2002, present stress as a: "...subjective component... in the sense that what is challenging, easy or even relaxing for one person, for another person it can become threatening or impossible to achieve...".

At the same time, the human body is subjected to and performs a permanent activity of adapting to the conditions of the surrounding environment in order to maintain...
homeostasis within the limits of normality. Thus, we can say that there is a correlation
and a complex and obvious system of relationships between the human body and
weather conditions. Regardless of when a state of stress sets in, it can be presented as an
adverse in physiological and psychological terms. These states that influence the human
body can be identified, in general, when a person is no longer able to cope with the
demands to which he is subjected on a daily basis. The emotional, physical and mental
expression through which we express the feeling of satisfaction, in general, bears the
name and indicates the thermal comfort. In the case of the present study, the thermal
comfort is analysed in accordance with the meteorological conditions. A variable
environment is a constant source of stress for the human being. Keeping the human body
in a thermal balance is possible only if the thermoregulatory mechanism does not make
significant efforts to create a state of physiological comfort.

2. Datasets and methodology

The present study proposes an evaluation of the regime of a caloric stress index -
Relative Strain/Tension Index (RSI), specific to the summer in the Eastern sector of the
Romanian Plain. The Eastern sector of the Romanian Plain, from a geographical point of
view, extends between the Argeș and Prut rivers (Neguț et al., 2000) (Figure 1a). This
sector consists of three extensive plains, respectively: Ialomița Plain, Bărăgan Plain and
Buzău-Siret Plain (Geography of Romania, vol. V, 2005). In this part of the country: the
winter is cold; the summer extremely hot; the amount of atmospheric precipitation is
low; relative air humidity and cloudiness show average values; wind speed is low; the
atmospheric pressure and the duration of the Sun's shine show increased values.

In the Romanian scientific studies, the Relative Strain/Tension Index (RSI) is
presented as being that: "... which allows the evaluation of the bioclimatic conditions of
calic stress, being applicable to the latitude of our country, only during the summer ..."
(Ionac et al., 2008).

Figure 1. The geographical position of the Eastern Romanian Plain (A) and the
meteorological stations (B) (Source: processing CorelDraw after ArcGis, 2022)
In order to fulfil objective, the analysis of the results of the calculated bioclimatic data was used. The results were obtained following the application of the mathematical calculation formula for the period between 1990 and 2020. The mathematical calculations were based on the monthly averages of temperature (°C) and relative air humidity (%), obtained from 12 meteorological stations located in the analyzed territory (Figure 1b). Meteorological stations can be considered fixed points - PO - useful in the analysis (Sfîcă et al., 2018, Ichim et al., 2020). These are representative for the local climatic conditions and for the coverage of all the surfaces and existing component elements on the analysed land. The observations were made in meteorological shelters with classic thermometers at a height of 2 m above ground level.

By means of these calculated data, the indicator of the caloric stress or relative tension was analysed and represented in the form of graphic and cartographic representations. The results have been obtained using the calculation formula presented in the *Bioclimatic Atlas of Romania* (Ionac et al., 2008). The colour range used in the graphic and cartographic representations, specifies the limits of applicability and the value thresholds (in units) according to the work *The bioclimatic potential of the South Dobrogea Plateau* (Grigore, 2012).

This type of assessment is useful in adopting adaptation and mitigation strategies to bioclimatic conditions in vulnerable regions. Knowing the regime of this index, for example, we can easier identify: specific personal adjustment methods to deal with the thermal stress; we can realize a realistic planning of the home or a recreation area (De Freitas, 2003, Höppe, 1999); we can improve the conditions within the health units (World Health Organization, 2011); we can choose different daily activities etc.

The state of the thermal comfort depends on a wide range of factors. The environmental factors (representing the thermal action on the human body) refers to air temperature, air speed, relative humidity, caloric solar radiation etc., and the personal ones are related to clothing, metabolic heat, state of well-being, state of illness, age group etc. Comfort should be seen as thermal neutrality, general satisfaction, without anxiety, while discomfort refers to the sensations of heat and cold perceived by a person at a given moment, thus, being more difficult to quantify globally (Lee et al., 1966).

Analysing the results from the Romanian literature, there can be noticed that a detailed assessment of the bioclimatic indices is interesting and useful in studying the space and time variation. Also, it would be useful to apply a single reference scale so that people expose themselves appropriately and their activity is not affected. Together with the presentation of the weather, it is necessary to describe the comfort conditions or the physiological risk related to the climate (Grigore et al., 2020). The presentations must also comply with the ISO 7330-2005 standard, where the universally accepted definition for the thermal comfort is: "... that state of mind that expresses satisfaction with the thermal environment ..." (www.iso.org, 2022). Knowledge of the thermal comfort provides adequate warning for future extreme climate scenarios and for adequate preparation of people and their livelihoods against extreme climate conditions (Kalkstein et al., 1993). The purpose of the present study was to evaluate the thermal discomfort or comfort using one of the indicators that highlight the states through which the human body tries to adapt, so that the individual can achieve their daily goal activities.

Thus, the bioclimatic factor must be seen as a working tool in the scientific research. This factor offers a multiple range of possible assessments of the positive or negative potential that the climate of a region has on the human health and the activities specific to the geographical region. Humans at high ambient air temperatures cannot maintain a balance between the heat generated by the body and the heat lost. Thus, the heat generated is greater than the heat lost and for this reason, heat stress can occur (Asghari et al., 2017, Nassiri et al., 2017). As it is defined by the United Nations Framework Convention, the global changes and warming produced by the greenhouse gases have caused heat waves, especially in warm seasons, putting many people at risk of hyperthermia and other heat-related complications. Not only workers, but also all people in the community, especially the elderly and children are at risk, being vulnerable
(Heidari et al., 2018), military and athletes being another group at high risk through heat exposure (Asghari et al., 2017, 2020).

3. Results and discussions

In time adaptation to the climate conditions of all organisms (including humans) is normal and necessary. We only have to pay attention to the fact that organisms react differently to the variation or increasing/decreasing trends of certain climatic parameters that can induce additional stress. The Relative Strain Index – RSI, is applicable only during the summer. They are using the monthly values of the air temperature and the real water vapor pressure (a meteorological element that can be calculated in its turn) that offers a synthetic and suggestive image for the areas of bioclimatic intensity and how the main economic activities in the studied can be disrupted, if the human organism is stressed by the installation of the thermal discomfort. Considering the reference system used in obtaining the mathematical formula, it was found that the period of the bioclimatic comfort is installed when the RSI registers values lower than or equal to 0.15 units, and the bioclimatic discomfort through heating when these indices register values that vary between 0.15 and 0.45 units. Also, the analysis must consider the fact that after the year 2000, the Eastern area of the Romanian Plain faced a gradual increase in air temperature, establishing summers with long dry periods. Respecting the limits of applicability and the biometeorological thresholds, it is found that during the analysed period, the bioclimatic discomfort through heating prevails, the sensitive people being affected (Table 1). In cases of older and sick people, the RSI values equal to 0.20, actually representing the maximum limit of tolerance, above which heat stroke is almost unavoidable (Ciulache, 2006).

Table 1. The annual regime of the Relative Strain/Tension Index – RSI (units) in the Eastern sector of the Romanian Plain (1990 – 2020)

<table>
<thead>
<tr>
<th>Meteorological station</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tecuci</td>
<td>0.14</td>
<td>0.21</td>
<td>0.20</td>
<td>0.18</td>
</tr>
<tr>
<td>Focșani</td>
<td>0.18</td>
<td>0.24</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>Buzău</td>
<td>0.16</td>
<td>0.26</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>Galați</td>
<td>0.19</td>
<td>0.26</td>
<td>0.25</td>
<td>0.22</td>
</tr>
<tr>
<td>Brăila</td>
<td>0.19</td>
<td>0.26</td>
<td>0.25</td>
<td>0.23</td>
</tr>
<tr>
<td>Urziceni</td>
<td>0.20</td>
<td>0.25</td>
<td>0.27</td>
<td>0.24</td>
</tr>
<tr>
<td>Grivița</td>
<td>0.23</td>
<td>0.29</td>
<td>0.29</td>
<td>0.27</td>
</tr>
<tr>
<td>Călărași</td>
<td>0.19</td>
<td>0.24</td>
<td>0.27</td>
<td>0.23</td>
</tr>
<tr>
<td>Târgoviște</td>
<td>0.15</td>
<td>0.21</td>
<td>0.24</td>
<td>0.20</td>
</tr>
<tr>
<td>Ploiești</td>
<td>0.15</td>
<td>0.20</td>
<td>0.23</td>
<td>0.19</td>
</tr>
<tr>
<td>Titu</td>
<td>0.17</td>
<td>0.21</td>
<td>0.24</td>
<td>0.20</td>
</tr>
<tr>
<td>Bucharest-Băneasa</td>
<td>0.22</td>
<td>0.26</td>
<td>0.30</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Thus, in June, the following situation was identified: in three points we identify values of bioclimatic comfort - Tecuci (0.14 units), Târgoviște and Ploiești (0.15 units) respectively; in two other analysed points, namely Bucharest-Băneasa and Grivița, hypercaloric stress was recorded for 50.0% of the inhabitants (RSI having a variation between 0.20 and 0.25 units), meaning the inhabitants are exposed moderate discomfort; in the rest of the analysed area, a slight bioclimatic discomfort is felt, with hypercaloric stressful conditions possibly affecting for 25.0% of the sensitive people, that
is the elderly and individuals with various chronic diseases (RSI recording values between 0.15 and 0.20 units) (Table 1).

The months of July and August are predominantly characterized by a moderate hypercaloric stress, affecting 50.0% of the inhabitants due to overheating bioclimatic discomfort (RSI varies between 0.20 and 0.25 units).

The rest of the age categories were also included in this category, regardless of the activities being performed. In five analysed points (representing approximately 35.0% of the analysed area): Buzău, Galați – in July, Călărași – in August, Urziceni, Grivița and Bucharest-Bâneasa – in July and August, the RSI values were above 0.25 units, all residents being affected by hypercaloric stress due to overheating (Table 1).

By analysing the cartographic representations reflecting the space distribution of the RSI index (Figure 2), one can see that the RSI values are permanently maintained within the limits of the bioclimatic discomfort for most sensitive people (0.15 ≤ RSI ≤ 0.25). As regards the share of the three types of bioclimatic conditions over the analysed period (Figure 2), most of this geographical region (83.33% of its total area) is characterized by a slight discomfort, generally affecting only the most sensitive people. Only in the central (Grivița) and in the South-Western parts of the studied area (Bucharest-Bâneasa), there is an evident discomfort state affecting all inhabitants.

The space distribution of the RSI for the month of June indicates (Figure 3):

- a bioclimatic comfort prevailing over an area of 25.01% of the total analysed territory, along a contact line with the Subcarpathians (in the North, over an area of approximately 8.34%, and in the West, an area of approximately 16.67%);
- a gradual increase of discomfort from the West to the East of the analysed geographical region, due to overheating (on an area of 60.00%, with a wide range of 5 units, between the RSI isotherm of 0.15 - 0.20; and on another of 15.00%, with a range of 2 units, between the RSI isotherm of 0.20 - 0.25).
Figure 3. The space distribution of the Relative Strain Index (RSI) (units) in the Eastern sector of the Romanian Plain (2000–2020) of June (Source: processing in Corel Draw, 2022)

In July and August (Figure 4 and 5), on approximately 42.00% of the whole plain territory, a pronounced discomfort sets in, between RSI isotherms of 0.25-0.30 units, affecting all people alike, regardless of age category and the activities they perform, the most affected areas being located in the South-Western, Central, North-Eastern and South-Eastern parts. The rest of the analysed plain region is under the influence of a moderate discomfort.

From the analysis of the obtained data, it is found that in the summer, the Eastern sector of the Romanian Plain, between the Argeș and Prut rivers, is exposed to an increased risk of overheating and the installation of a moderate bioclimatic discomfort, all people being affected, regardless of age category, health status, force, field of activity or short-term or long-term submitted activity.

RSI values generally vary from the North-West to South-East, from the region located on a high alluvial plain area, at the contact with the Subcarpathians, to the typical lowland region, located in the heart of the steppe plain, where dry continental climatic influences are significantly increased (Urziceni, Grivița, etc.).

A special case is represented by the South-Western periphery of the analysed geographical region, which is actually characterized by an intense risk of overheating for the entire exposed population (RSI values between 0.25 and 0.30) because it represents an industrialized area, with an increased population density etc., subject to warm and dry advections of tropical and continental air masses. Throughout life, the human body is constantly exposed to variable environmental conditions.

Air temperature variations are a constant factor of the environmental stress, and the human skin changes permanently. In hot and humid summer days, the heat loss of the human body is increased. This is possible through the intense evaporation of water (i.e. sweat) on the human skin, but also through the evaporation of aqueous humors from the lungs and upper respiratory tract.
Figure 4. The space distribution of the Relative Strain Index (RSI) (units) in the Eastern sector of the Romanian Plain (2000 – 2020) of July (Source: processing in Corel Draw, 2022)

Figure 5. The space distribution of the Relative Strain Index (RSI) (units) in the Eastern sector of the Romanian Plain (2000 – 2020) of August (Source: processing in Corel Draw, 2022)

Detailed analysis of bioclimatic indices is interesting and helpful in studying their variation in space and time, on a unique reference scale to describe people's weather, climate-related comfort or physiological risk.
4. Conclusions

Organisms, in general, including the human body, from a physiological point of view, constantly adapt to the external conditions. The body aims to reach the state of thermal comfort and well-being. Even if, in certain situations, heat or cold impose a greater stress on the human body and thermal adaptation becomes difficult (children and the elderly or people with health problems falling into this category).

The RSI index can be used as a simple and empirical index in the assessment of the thermal stress (the basis of the calculation formula being the temperature values and the relative humidity of the air not exactly suitable for hot and dry climates).

Methodologically, RSI however, creates a better picture of the daytime summer conditions involving thermal comfort or discomfort. This index indicates that the greatest thermal discomfort is reached in July and August.

In the future analyses, other bioclimatic indices will be targeted, which have the ability to describe the parameters of the human energy balance in other terms. Current research involves deepening the operating mechanism and the way of manifestation of climatic and bioclimatic systems, because any change in their evolution affects the individual components, as well as the relationships between them.

There can easily be drawn the conclusion that in the bioclimatic conditions with the risk of overheating (0.20 ≤ RSI ≤ 0.30), in which more than 50.0% of the population is exposed to risk, most of the Eastern sector of the Romanian Plain presents a potential danger to human health. During the summer, the entire region is characterized by a pronounced lack of comfort for more sensitive people. RSI values are not significantly variable in space and time, but they highlight the potential risk caused by overheating quite well.

The study indicates an increase in the Relative Tension Index, compared to other analyzed time intervals and that the adaptation strategies of the population aimed at the process of personal adjustment, first of all. The environmental adjustments, in average and economically prosperous human settlements are not significant. This implies, in fact, a redirection of the regional policy towards sustainable development, in order to reduce the impact of many development actions on the human society, in general.

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