

## THE BIOCLIMATIC STRESS DUE TO OVERHEATING IN THE SOUTHERN DOBRUDJAN TABLELAND AREA

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**Key words:** bioclimatic indices; space and time variation; bioclimatic stress due to overheating; Southern Dobrudjan Tableland area.

**Abstract.** The present study, regarding the extent and intensity of bioclimatic stress due to overheating in Southern Dobrudjan Tableland area, is based on the analysis of the geographical distribution and of time variation of some relevant bioclimatic indices for the summer period: The Summer Scharlau Index (ISE), The Relative Strain Index (RSI) and the Summer Simmer Index (SSI). In order to highlighten the areas of bioclimatic discomfort, we have processed the air-temperature and humidity data from six weather stations in the area of reference, for 30 years (1971-2000). The results we have obtained, fully concordant with world-wide approaches, emphasize that the bioclimatic stress due to overheating gets more intense in the central-continental and eastern sea-side parts of the territory under study, in July and August.

### Introduction

The development of more detailed researches based on the analysis of bioclimatic indices proved quite necessary to modern society, in our modern times, especially because no matter how complex the studies on the influence of the climatic factors on physiological, psychological or behavioral reactions of humans might be, they don't fully reveal its state of comfort or dicomfort, but their continuous action and permanent change really make human body do great efforts to adapt to ever-changing weather and climatic parameters.

The analysis of spatial and temporal actions and variations of bioclimatic factors is generally approached from a wholistic perspective, referring to all environmental factors that might differently influence human health and well-being. And this present type of analysis, dealing with the bioclimatic stress due to overheating, offers credible information about the intensity of physiological comfort or, on the contrary, of discomfort, that people living in a specific geographical area actually feel day by day, during the warm season, in the long run of their lives.

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The subjective perception of the bioclimatic comfort that human body really feels under certain environmental conditions may quantitatively be expressed by some biometeorological and/or bioclimatic indices, which can reflect the weather's or climate's effect on human health either from the point of view of each individual factor's specific way of action on human body (such as air-temperature, humidity, air pressure, solar radiation, wind etc.) or from the perspective of a combined action between two, three or more such factors of influence.

The detailed analysis of the space and time variation of such bioclimatic indices on a unitary scale of reference is extremely useful to identify the main areas and periods of bioclimatic stress or risks which the people in the region of study are exposed to. In this respect, we must also add that we have specifically chosen the Southern Dobrudjan Tableland area mostly because of its greatest thermal and wind potential in Romania [2] and consequently, because of its risk potential to human health and well-being.

Therefore, we have analyzed the space and time distribution of some relevant bioclimatic indices specific of the warm season: the *Summer Scharlau Index* (ISE), the *Relative Strain Index* (RSI) and the *Summer Simmer Index* (SSI) and we have accordingly identified the areas of bioclimatic risk due to overheating in the Southern Dobrudjan Tableland area, showing that the dynamics of the bioclimatic factors depend both on the periodical (namely annual climatic changes) and on the unperiodical (depending on weather contexts) variations of climate's characteristics.

To be more convincing, our analysis visually renders information, in the form of accompanying tables and maps, not only about the extent of the potential harmful bioclimatic areas, but also about their intensity, which may represent useful items of assessment when appreciating the climatic and touristic potential of the region under study.

### **1. Input data and methods**

The present study was basically developed by computing the air-temperature and humidity monthly means for a 30 years' period (1971-2000). These weather data were collected from all the six weather stations functioning in the region of reference (Cernavodă, Medgidia, Adamclisi, Constanța, Mangalia and Hârșova).

Then we have calculated the corresponding values of three relevant bioclimatic indices specific of the warm season (ISE, RSI and SSI) and, by taking into account their characteristic limits of applicability, we could ultimately contour the bioclimatic areas of risk due to overheating in the region of study. However, according to their specific ranges of application, we could validate as correct only the values falling within the June-August interval for the RSI and SSI indices and June-September for the ISE index [6].

## 2. Results and discussions

The *Summer Scharlau Index (ISE)*, experimentally derived by K. Scharlau [11] in order to calculate the *critical temperatures*, which represent the corresponding air-temperature values **above** which, according to the actual values of air-humidity, the human body feels physiologically uncomfortable because of the heating processes, clearly reflects that the hot-humid climatic conditions may be harmful, by greatly increasing the radiation and evaporation exchange rates of the human body. Therefore, this index may be calculated only for air-temperature values ranging from + 17°C to +39°C and for air-humidity values higher than 30%.

By strictly observing these limits, the corresponding values of the ISE index on the Southern Dobrudjan territory could be relevantly validated only from June to September and their spatial distribution during these four summer months, visualised in a coloured scale of grades [7] clearly shows the prevalence of the comfort area all over the region of study (Fig 1).

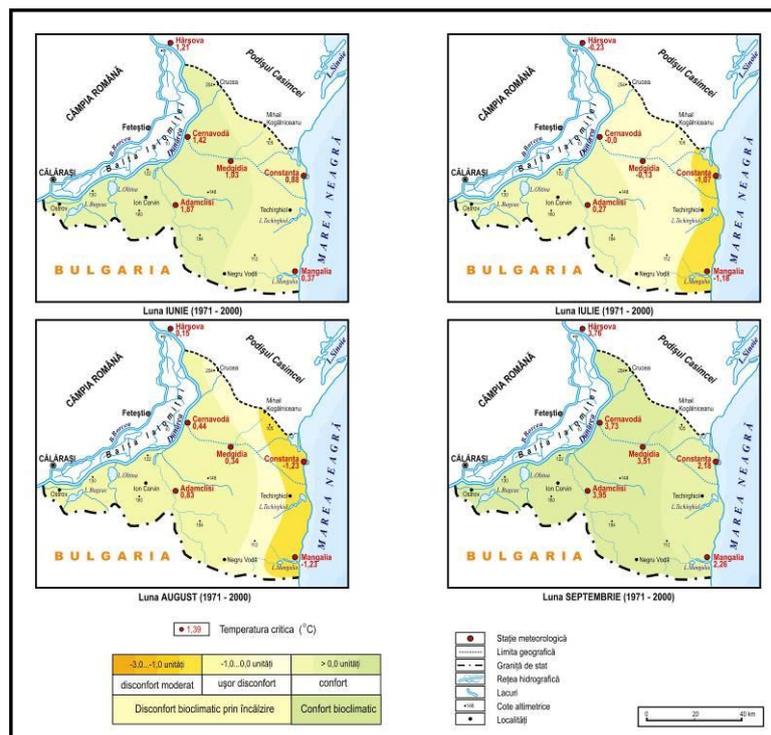


Fig. 1 – Spatial distribution of the ISE index (units) in the Southern Dobrudjan Tableland Area (1971 – 2000)

However, one may notice that both June and September are wholly characterized by comfortable bioclimatic conditions, although these are weaker to the eastern seaside areas and stronger to the western Danubean and inner-continental areas. The corresponding values of the ISE index accordingly range from a maximum of 3,76 units in September, to a minimum of 0,37 units in June [3].

In June, the lowest ISE value reached 0,37 units at Mangalia and its highest value exceeded 1,87 units at Adamclisi, while in September, the lowest ISE value maintained around 2,18 units at Constanța, and its highest value reached 3,95 units at Adamclisi.

In July, the area of bioclimatic discomfort due to overheating extends well from the eastern seaside areas to the central-continental areas of the region under study, mostly due to the increase of the evaporation rates over the Black Sea, while the western areas, bordering the right banks of the Danube River, still maintain under comfortable bioclimatic conditions from Adamclisi to Cernavodă.

The area of bioclimatic heat stress extends widely to the central, southern and northern rims of the region under study and gets more intense to the sea-shore areas, where the ISE values go as low as – 1,18 units at Mangalia.

In August, the area of bioclimatic comfort, characteristic of the south-western and central tableland areas, extends gradually to E, becoming dominant all over the western (Adamclisi, Cernavodă, Hârșova) and central areas (Medgidia). In the same month (August), the ISE values range from -1,23 units at Mangalia and 0,83 units at Adamclisi. We must also notice that, both in July and August, the heat-stress area is milder in the central parts of the Dobrudjan territory and more intense on the seaside strip along the Black Sea [4].

In September, the whole Dobrudjan territory is under the influence of comfortable bioclimatic conditions again, mainly due to the general yearly trend of air-temperature decrease towards fall.

By analyzing the ISE values from June to September for the whole period of reference (1971-2000), one may easily notice that they range from -1,23 units at Constanța and Mangalia (on the Black Sea shore) in August, to +3,95 units at Adamclisi, in September. For reference, the actual values of the ISE index are shown in Table 1, for each weather station and summer month.

The mean multiannual value of the ISE index for the whole period of reference (1971-2000) roughly range from +0,005 units at Mangalia to +1,73 units at Adamclisi.

The yearly variation of the ISE values reveal: neutral bioclimatic conditions (comfort) in June and highly different conditions from July to September, as follows: bioclimatic comfort in 61,1% cases (for all the three summer months at Adamclisi; in August and September at Hârșova, Cernavodă and Medgidia; in September only at Constanța and Mangalia), overheating conditions of bioclimatic stress in 38,9% cases (starting with warm sensations at Hârșova, Cernavodă and

Medgidia in July, leading to overheating risks at Constanța and Mangalia, in July and August).

Tab. 1 – The annual variation of the ISE index (units) on the Southern Dobrudjan Tableland area, 1971 – 2000

Period / month		WESTERN DANUBEAN AREA		CENTRAL CONTINENTAL AREA		EASTERN SEASIDE AREA	
		HARȘOVA	CERNAVODĂ	ADAMCLISI	MEDGIDIA	CONSTANȚA	MANGALIA
1971	VI	1,21	1,42	1,87	1,03	0,88	0,37
	VII	-0,23	-0,08	0,27	-0,13	-1,07	-1,18
2000	VIII	0,15	0,44	0,83	0,34	-1,23	-1,23
	IX	3,76	3,73	3,95	3,51	2,18	2,26
<b>1.</b>	<b>Mean</b>	<b>1,22</b>	<b>1,37</b>	<b>1,73</b>	<b>1,18</b>	<b>0,19</b>	<b>0,05</b>

The periods and areas of bioclimatic overheating stress, characteristic of the warm season (June-August), could also be highlighted by means of the **Relative Strain Index (RSI)**, whose values may quantitatively be derived from air-temperature ( $^{\circ}\text{C}$ ) and vapour pressure (hPa) according to Kyle's formula [8]. As the RSI could only be applied for air-temperatures values higher than  $+26^{\circ}\text{C}$ , even if relative humidity values were highly variable, we could compute its corresponding values solely for the three specific summer months: June, July and August. If air-temperatures maintain below  $+26,0^{\circ}\text{C}$ , then the RSI values automatically indicate only comfortable bioclimatic conditions and, as far as the Southern Dobrudjan Tableland Area is concerned, we could see that air-temperatures kept below  $+23,0^{\circ}\text{C}$  all over the summer months, meaning that the corresponding values of the RSI index point to generalised conditions of bioclimatic comfort all summertime. However, by taking a closer look at the spatial distribution of the RSI values on the Dobrudjan territory, we can notice a slight increase of values from its south-western to its north-eastern areas.

The precise values of the RSI index actually range from -0,002 units to +0,005 units. In June, the RSI values are negative and the value difference between weather stations hardly reaches 0,02 units, with a slight increase northward. In July and August, the RSI values become positive, being higher in July (when they reach almost 0,05 units at Cernavodă) and lower in August (when they get as high as 0,03 units at Cernavodă too).

The maps presented in Fig. 2 confirm the spatial direction of increase of the RSI values during both summer months (July and August), from SW to NE. The analysis of the monthly values also confirms this tendency of warm sensations

increase from June to July, shortly followed by a corresponding gradual decrease from July to August.

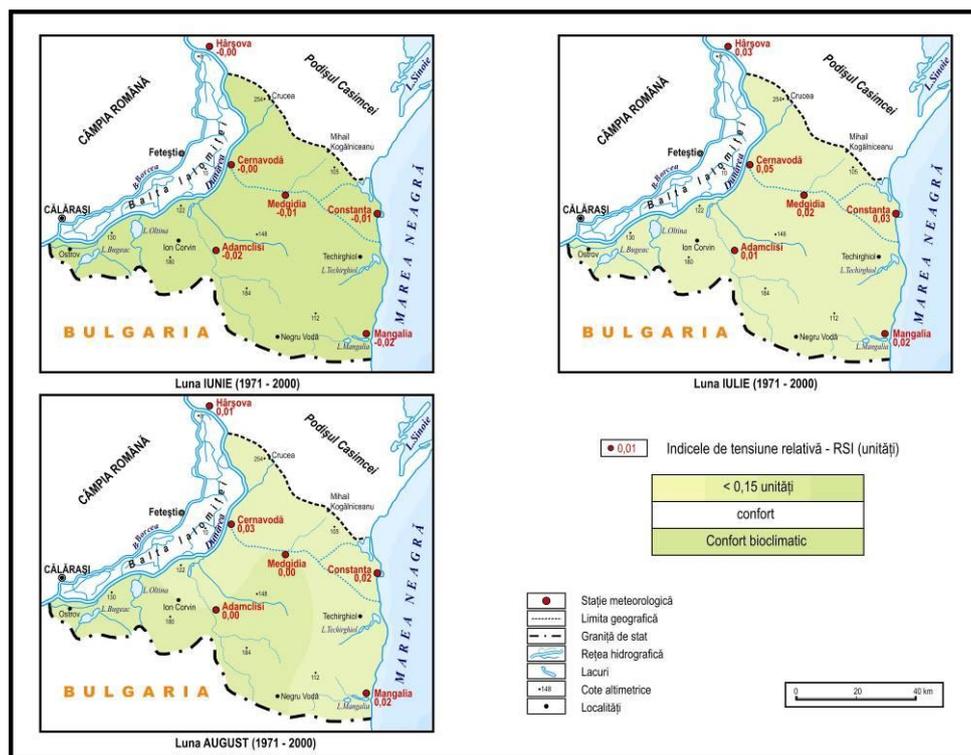


Fig. 2 - Spatial distribution of the RSI index (units) in the Southern Dobrudjan Tableland Area (1971 – 2000)

By analyzing the RSI values from June to August for the whole period of reference (1971-2000), we can notice variations from -0,02 units at Adamclisi and Mangalia, in June, to +0,05 units at Cernavodă, in July; the actual values computed for each weather station and month being given in Table 2.

The mean multiannual (1971-2000) values of the RSI index, which could be computed on condition that air-temperature values exceeded  $+26,0^{\circ}\text{C}$ , range from +0,00 units at Adamclisi, Medgidia and Mangalia, to +0,02 units at Cernavodă.

The annual variation reveals that all summer months are characterized by comfortable bioclimatic conditions, with positive values of the RSI index in July and August, and negative values in June. The maximum values were recorded in July all over the Southern Dobrudjan territory.

Tab. 2 - The annual variation of the RSI index (units) on the Southern Dobrudjan Tableland area, 1971 – 2000

Period / month		WESTERN DANUBEAN AREA		CENTRAL CONTINENTAL AREA		EASTERN SEASIDE AREA	
		HARȘOVA	CERNAVODĂ	ADAMCLISI	MEDGIDIA	CONSTANȚA	MANGALIA
1971	VI	-0,00	-0,00	-0,02	-0,01	-0,01	-0,02
	VII	0,03	0,05	0,01	0,02	0,03	0,02
2000	VIII	0,01	0,03	0,00	0,00	0,02	0,02
Mean		<b>0,01</b>	<b>0,02</b>	<b>0,00</b>	<b>0,00</b>	<b>0,01</b>	<b>0,00</b>

The **Summer Simmer Index (SSI)**, presented by W.J. Pepi [9, 10] at the 80<sup>th</sup> AMS Conference, which took place in 2000, best describes the bioclimatic stress due to overheating, especially on condition that air-temperature values range from +22<sup>0</sup>C to +53<sup>0</sup>C and, since the analysis of this bioclimatic index shows little variation in the area of reference in June, we could therefore compute its values only for some of the weather stations taken into consideration (namely: Hârșova, Cernavodă, Medgidia și Constanța) in July and August, when air-temperatures maintained higher than the threshold required (+ 22,0<sup>0</sup>C).

The spatial distribution of the SSI values shows that in June, unlike the previously-mentioned bioclimatic indices, the bioclimatic stress due to overcooling becomes dominant over most of the Dobrudjan territory, but for an island-area of comfort around Cernavodă city (Fig. 3). However, the cooling bioclimatic conditions are quite intense in the south-western parts of the tableland area, where the SSI index reaches its lowest value (23,69<sup>0</sup>C at Adamclisi) and get milder to the north-eastern parts, where the SSI index reaches its highest value (25,01<sup>0</sup>C at Cernavodă).

In July, the SSI values are more differently distributed in space, approximately 75% of the tableland area of study being characterised by comfortable bioclimatic conditions (especially the central-continental, south-western and north-eastern parts), while the remaining 25% of the territory (namely a rather narrow strip stretching from Cernavodă in the NW to Constanța in the SE), keeps under the influence of bioclimatic stress due to overheating, responsible for warm physiological perceptions all day long.

In August, due to the general cooling trend of air-temperatures, all the Dobrudjan territory falls back under the influence of comfortable bioclimatic conditions, with the SSI values ranging from 25,64<sup>0</sup>C at Adamclisi to 27,60<sup>0</sup>C at Constanța. Nevertheless, the corresponding physiological sensations are closer to comfort in the south-western parts, and get weaker and weaker, that is comfort turns into a rather temporary state, to the north-eastern parts, mainly because the

climatic continentalism gets more intense to the drier central parts of the Dobrudjan territory [5].

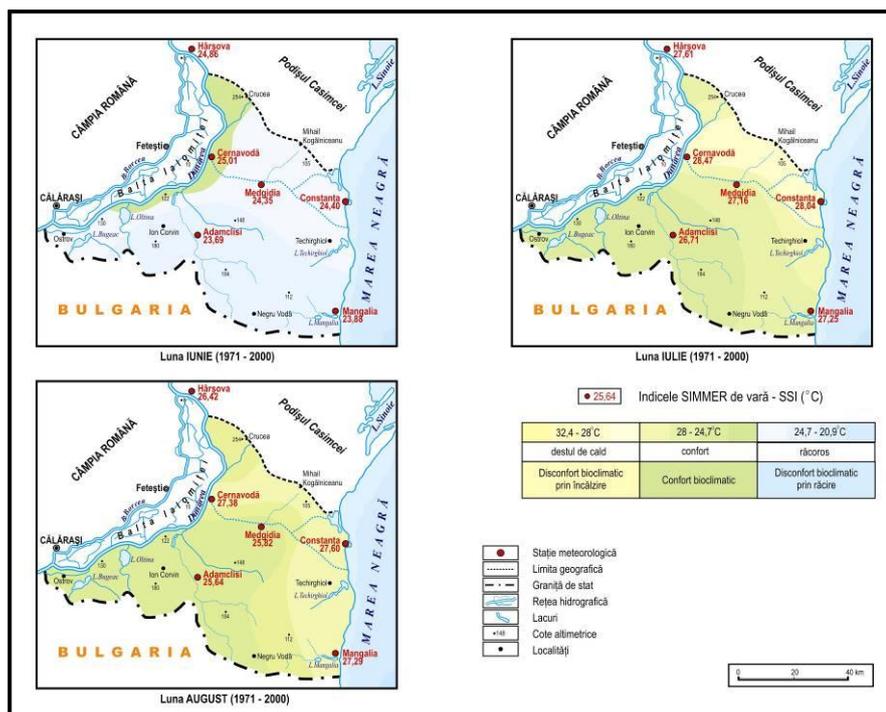


Fig. 3 - Spatial distribution of the SSI index ( $^{\circ}\text{C}$ ) in the Southern Dobrudjan Tableland Area (1971 – 2000)

Tab. 2 - The annual variation of the SSI index ( $^{\circ}\text{C}$ ) on the Southern Dobrudjan Tableland area, 1971 – 2000

Period / month	WESTERN DANUBEAN AREA		CENTRAL CONTINENTAL AREA		EASTERN SEASIDE AREA		
	HARȘOVA	CERNAVODĂ	ADAMCLISI	MEDGIDIA	CONSTANȚA	MANGALIA	
1971	VI	24,86	25,01	23,69	24,35	24,40	23,88
-	VII	27,61	28,47	26,71	27,16	28,04	27,25
2000	VIII	26,42	27,38	25,64	25,82	27,60	27,29
<b>Mean</b>		<b>26,29</b>	<b>26,95</b>	<b>25,34</b>	<b>25,77</b>	<b>26,68</b>	<b>26,14</b>

If analyzing the results obtained by computing the corresponding values of the SSI index during summer months (June-August), for the whole period taken into consideration (1971-2000), we may notice that it ranges between +23,69°C at Adamclisi (in June) and +28,47°C at Cernavodă (in July). The actual values of the above-mentioned bioclimatic index, as they have been calculated for each weather station and summer month, are given in Table 3.

The mean annual value of the SSI index for the same period of reference ranges from +25,34°C at Adamclisi to +26,95°C at Cernavodă. The annual variation proves that the comfortable bioclimate dominates over almost all of the Southern Dobrudjan Tableland area, but for some small island-areas of bioclimatic discomfort due to overheating which become evident during midsummer (July), around the Constanța and Cernavodă towns. However, we must also notice that this warming trend is very slow, since, at the beginning of summer (June) the central and eastern parts of the territory under study are characterised by a discomfortable bioclimate due to overcooling.

### **Conclusions**

The main conclusion of this study is that the bioclimatic risk due to overheating generally depends not only on the variation of radiative and dynamic climate-inducing factors, but also on the local physical, geographical factors which play an important role in diversifying the climatic and, consequently bioclimatic, conditions of the Southern Dobrudjan Tableland area. Human comfort directly depends on weather and climate as long as their ever-changing spatial and time changes require a permanent effort of adaptation from all physiological systems of integration and control.

Therefore, during summer, that is more precisely between June and July, when the advections of hot, dry tropical air from the southern and south-western parts of Europe get more intense [1], a general state of bioclimatic strain due to overheating becomes dominant in the south-eastern parts of the country, unlike the rest of the territory, thus generating stressful reactions of response. The state of well-being that human body actually perceives in certain conditions of air-temperature and humidity greatly depends on the heat exchange processes between the human body and the surrounding environment, especially on hot and humid days, when the heat loss of the human body is increased by the intense evaporation of sweat at skin surface.

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