BIOCLIMATIC STRESS WITHIN THE GETIC SUBCARPATHIANS

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Abstract. Weather greatly influences the state of comfort felt by a person. As all living beings, people also adapt in time to the climatic conditions, but the variability or the increase or decrease tendency of certain parameters may induce a supplementary stress. In order to highlight the favourability of the climate within the Getic Subcarpathians, there have been analysed certain bioclimatic indexes – skin stress index, lung stress index, bioclimatic stress and temperature equivalent to the wind cooling power. In spite of certain differences mainly imposed by local factors of influence, there is a great territorial homogeneity. Generally, climate is favourable to human activities all year long, the Subcarpathian area being one of the less stressful in the country. Skin stress is reduced, half of the year displaying relaxing climatic conditions. Hypotonic stress triggering thermolysis in summer is felt especially in July and August but only in the lower area, while hypertonic stress inducing thermogenesis appears in the months of the cold season. However, the moderate values of the cooling power of the wind, below 900 kcal/m^2/h, indicate a minimum skin stress (+1). The temperature equivalent to the wind cooling power supports the situation rendered by the previous index, the interval April – October displaying thermal comfort; only January, the month with the lowest mean temperatures and moderate wind speeds, is characterized by the state of increased discomfort. Lung stress is also reduced, only summer months, mainly July and August, being characterized by a moderate or increased lung stress (-2, -3). Consequently, the total bioclimatic stress is low, the stimulation degree being 1, except for Polovragi, where the value is 2. Thus, the values of the total bioclimatic stress index indicate that the region is highly favourable for human activities.

Keywords: Getic Subcarpathians, skin stress index, lung stress index, total bioclimatic stress, temperature equivalent to the wind cooling power (Tpr).

Rezumat. Stresul bioclimatic în Subcarpații Getici. Vremea influențează în mare măsură starea de confort resimțită de o persoană. Toate organismele, inclusiv oamenii, se adaptează în timp la condițiile climatice, dar variația sau tendințele de creștere și descreștere ale anumitor parametri pot induce un stres suplimentar. Pentru a ilustra favorabilitatea climatului din Subcarpații Getici, au fost analizați anumiți indici bioclimatici, precum indicele stresului cutanat, indicele stresului pulmonar, indicele bioclimatic total și temperatura echivalentă puterii de răcire a vântului. În ciuda unor diferențe, în mare parte induse de factorii locali de influență, s-a constatat o omogenitate teritorială ridicată. În general, climatul este favorabil desfășurării activităților pe tot parcursul anului, arealul subcarpatic fiind unul dintre cele mai puțin stresante din țară. Stresul cutanat este redus, circa jumătate din an prezentând un climat relaxant din acest punct de vedere. Stresul hipotonic, declanşator de termoliză pe timpul verii, se resimte mai ales în iulie și august, dar numai în arealele mai joase, în timp ce stresul hipertonic care induce termogeneză apare în lunile semestrului rece. Cu toate acestea, valorile moderate ale puterii de răcire a vântului, sub 900 kcal/m^2/h, indică un stres cutanat minim (+1). Temperatura echivalentă puterii de răcire a vântului susține imaginea redată de indicele anterior, intervalul aprilie – octombrie fiind unul caracterizat de confort termic; doar ianuarie, luna cu cea mai redusă temperatură medie și viteze moderate ale vântului, se caracterizează prin stare de disconfort mai accentuat. Stresul pulmonar este de asemenea redus, numai lunile de vară, mai ales iulie și august, prezentând stres moderat sau ridicat (-2, -3). În consecință, stresul bioclimatic total este redus, gradul de stimulare a climatului fiind 1, cu excepția stației Polovragi, unde valoarea este 2. Astfel, valorile indicelui de stres bioclimatic total susțin favorabilitatea climatică a regiunii analizate pentru activitățile umane.

Cuvinte cheie: Subcarpații Getici, stres cutanat, stres pulmonar, stres bioclimatic total, temperatura echivalentă a puterii de răcire a vântului (Tpr).

INTRODUCTION

The state of comfort or discomfort felt by a person, both physical and psychological, highly depends on weather conditions. In certain situations, such as sudden increases or decreases, a meteorological parameter can become a stress factor for the organism. The studies achieved so far indicate that the limits of the comfort state, especially of thermal comfort, are no identical at global level, as organisms, including human beings, adapt to environmental conditions in time (TEODOREANU & BUNESCU, 2007). The human body, which comes into contact directly with the environment through exposed skin, has to permanently adapt to the external weather conditions. When adaptation or thermoregulation is necessary, there occurs either thermogenesis or thermolysis according to the given conditions. In order to better emphasize and quantify the relation between climate and human health, there have been elaborated numerous indices – bioclimatic indices, even if they are mainly based on the same meteorological parameters, namely temperature, humidity and wind speed. Among these indices, we mention Summer/Winter Scharlau index (1950), Summer SIMMER index (PEPI, 1987), the skin and lung stress (BEÇANCENOT, 1974), THI index (introduced by WMO), Physiologically Equivalent Temperature-PET (HÖPPE, 1999; MATZARAKIS et al., 1999), etc. Bioclimatic indices were subject to different studies in Romania, as well. Summer and Winter Scharlau Index, Wind Chill Index, Relative Strain Index were calculated for Moldova (IONAC, 2006), Dobrudja (IONAC & CIULACHE, 2007), the Equivalent Effective Temperature (EET) for the Black Sea Shore (IONAC, 2007), Wind Cooling Power for the Danube Delta (IONAC & CIULACHE, 2004), THI was analysed for Moldova (LEONTIE et al, 2008), Oltenia Plain (VLĂDUȚ, 2011), skin and lung stress for Suceava Plateau (TEODOREANU & MIHĂILĂ, 2012), tropical and combined heat stress for the main cities from the Romanian Plain (MICU et al., 2013). Thus, bioclimatic resources are quite important in relation with our wellbeing state.

MATERIAL AND METHODS

The Getic Subcarpathians represent the hilly relief unit located between the Carpathian Mountains in the north and the Getic Piedmont in the South. Due to the local factors of influence, such as location in the south-western part of the country, proximity of the mountainous area, altitudinal range, exposure to certain air masses, etc., they display certain climatic particularities in terms of temperature, humidity, wind and precipitation patterns. Climatic parameters play an extremely important role for the state of comfort or discomfort experienced by the human body. The main bioclimatic indexes were calculated based on mean monthly values of air temperature, vapour pressure, wind speed and relative humidity. The data, obtained from four stations located in the area of interest, cover a mean period of forty years (1971-2010) (Fig. 1, Table 1).

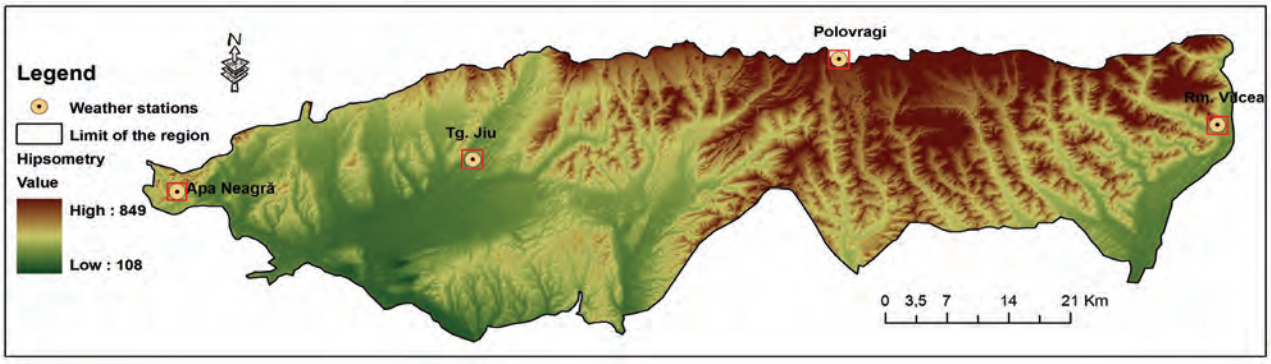

Figure 1. Location of the meteorological stations within the Getic Subcarpathians.

Table 1. Geographical coordinates of the considered meteorological stations.

No.	Station	Altitude (m)	Latitude	Longitude
1.	Apa Neagră	258	44°53`	44°53`
2.	Târgu Jiu	203	23°42`	23°42`
3.	Polovragi	531	45°00`	45°00`
4.	Râmnicu Vâlcea	237	22°52`	22°52`

The cooling power of wind represents the amount of heat (calories) a body at a temperature of 36.5°C loses per cm^2 per second. The formula of this index was initially proposed by Siple & Passel (1945) and then, in 1974, BEÇANCENOT, based on the values of the cooling power of wind, introduced the *skin stress index* (Table 2). The cooling power of wind was calculated according to the following formula:

$$P = (10\sqrt{v} + 10.45 - v) \times (33-t), \text{ where:}$$

P - cooling power expressed in $kcal/m^2/h$;
v – wind speed (m/s);
t – air temperature (°C);
33-t - air temperature measured in the meteorological shelter reported to conventional threshold 33°C.

Table 2. The cooling power of wind ($kcal/m^2/h$), skin stress index and its significance.

Cooling power ($kcal/m^2/h$)	Stress skin index	Type of stress
0-149	(-2) hypotonic	Stress induced by triggering thermolysis in summer
150-299	(-1) hypotonic	Stress induced by triggering thermolysis in summer
300-599	**0 relaxing**	**Thermoregulation is not necessary**
600-899	(+1) hypertonic	Stress induced by triggering thermogenesis in winter
900-1199	(+2) hypertonic	Stress induced by triggering thermogenesis in winter
1200-1499	(+3) hypertonic	Stress induced by triggering thermogenesis in winter
>1500	(+4) hypertonic	Stress induced by triggering thermogenesis in winter

Source: BEÇANCENOT, 1974

Thus, there are three main types of time according to the values of the cooling power of wind:
0 – 299 – hypotonic index (characteristic in summer when thermolysis is triggered);
300 – 599 – relaxing index (optimum values of temperature and wind for the human body);
600 – 1500 – hypertonic index (characteristic in winter, when thermogenesis is triggered).

Pulmonary stress index is based on water vapour pressure expressed in mb and it was introduced by BEÇANCENOT (1974). The correlations are rendered in Table 3. When water vapour pressure is below 7.5 mb, the stress is expressed by the tendency of dehydration or molecular concentration of the blood (usually in winter) and when it is above 11.7 mb, the stress is manifested by the tendency of hydration and dilution of plasma (summer) (TEODOREANU & MIHĂILĂ, 2012). The values between 7.5 and 11.6 mb indicate a balanced or equilibrated stress.

Table 3. Pulmonary stress index based on vapour pressure (mb).

Vapour pressure (mb)	Pulmonary stress index	Type of stress
0-4.0	(+2)	Dehydrating, in winter
4.1-7.4	(+1)	Dehydrating, in winter
7.5-11.6	0	Equilibrated
11.7-15.9	(-1)	Hydrating, in summer
16-21.1	(-2)	Hydrating, in summer
21.2-26.5	(-3)	Hydrating, in summer
26.6-31.1	(-4)	Hydrating, in summer

Source: BEÇANCENOT, 1974

The total bioclimatic stress is calculated according to the formula:
TS = SS + PS (BEÇANCENOT, 1974; TEODOREANU, 2002)

Table 4. Stimulation degree of the climate according to the values of bioclimatic stress.

Sum of positive stress	Stimulation degree
< 5	0
5-10	1
10-15	2
15-20	3
20-25	4
>25	5

Source: BEÇANCENOT, 1974

The temperature equivalent to the wind cooling power represents the effective temperature air would reach at certain wind speeds. The formula is:

$$T\,pr = [33 + (Td - 33) \times (0.474 + 0.454\sqrt{v} - 0.0454v)], \text{ where}$$

Td = air temperature (measured at the dry bulb thermometer) in °C
v = wind speed in m/s

The physiological effects, depending on the intensity of the caloric losses experinced by a human body, are rendered in Table 5.

Table 5. The cooling power of wind, temperature equivalent to the wind cooling power and their physiological effects.

Wind cooling power – Pr (W/m^2)	Temperature equivalent to the wind cooling power – Tpr (°C)	Physiological effects
Pr = 200 – 400	Tpr > +10	Comfort
Pr = 400 – 600	+10 ≥ Tpr >-1	Slight discomfort
Pr = 600 – 800	-1 ≥ Tpr > -10	Increased discomfort
Pr = 800 – 1000	-10 ≥ Tpr >-18	Very cold
Pr = 1000 – 1 200	-18 ≥ Tpr >-29	Hypocaloric stress
Pr = 1200 – 1 400	-29 ≥ Tpr >-50	Risk of frostbite in case of prolonged exposure
Pr > 1400	Tpr ≤-50	Risk of instantaneous frostbite

Source: TEODOREANU & MIHĂILĂ, 2012 apud. IONAC & CIULACHE, 2008

RESULTS

Thermoregulation is triggered by the hypothalamus when our body experiences a temperature increase or decrease in order to maintain the inner temperature constant (36.5°C according to the majority of studies). In relation to the external stressors, body temperature mainly depends on air temperature, humidity (water vapour pressure, relative humidity) and wind speed. The favourability of the climatic conditions of a certain region for different activities is better highlighted by bioclimatic indexes.

3.1 Skin stress index is emphasized by the values of the cooling power of the wind. The values indicating an ideal climate from this point of view are between 300 and 600 $kcal/m^2/s$, meaning thermoregulation is not necessary. The area of the Getic Subcarpathians generally display favourable conditions determined by the 'shelter' effect developed at the foot of the mountains – low wind speed and moderate temperatures during the year. According to the

mean monthly values, at least six months, generally during the warm half of the year, the climate is relaxing, triggering no thermoregulation (Fig. 2).

The most favourable conditions are registered at the stations located closer to the mountains, namely Polovragi and Apa Neagră, where all the values are above the threshold of 300 kcal/m^2/s. Thus, starting with April till October, the skin stress index is 0 at the aforementioned stations. In case of the other stations, the pattern is slightly different. Thus, the period characterized by the 0 skin stress index is interrupted by a period marked by hypotonic stress (the cooling power of wind is below 300 kcal/m^2/s), overlapping the hottest part of the summer months. However, even if thermolysis is triggered, the hypotonic stress is reduced, -1, which means that the human can easily lose heat. The period characterized by a relaxing climate also starts earlier, by the end of March at Râmnicu Vâlcea and the beginning of April at Târgu Jiu, and ends later in the first case (mid-November). In the months of the cold half of the year, thermogenesis is necessary, within the entire studied region. The most stressful month is January, the values of the cooling power of the wind being close to the upper threshold of 900 kcal/m^2/s, but they correspond to a reduced hypertonic stress of +1.

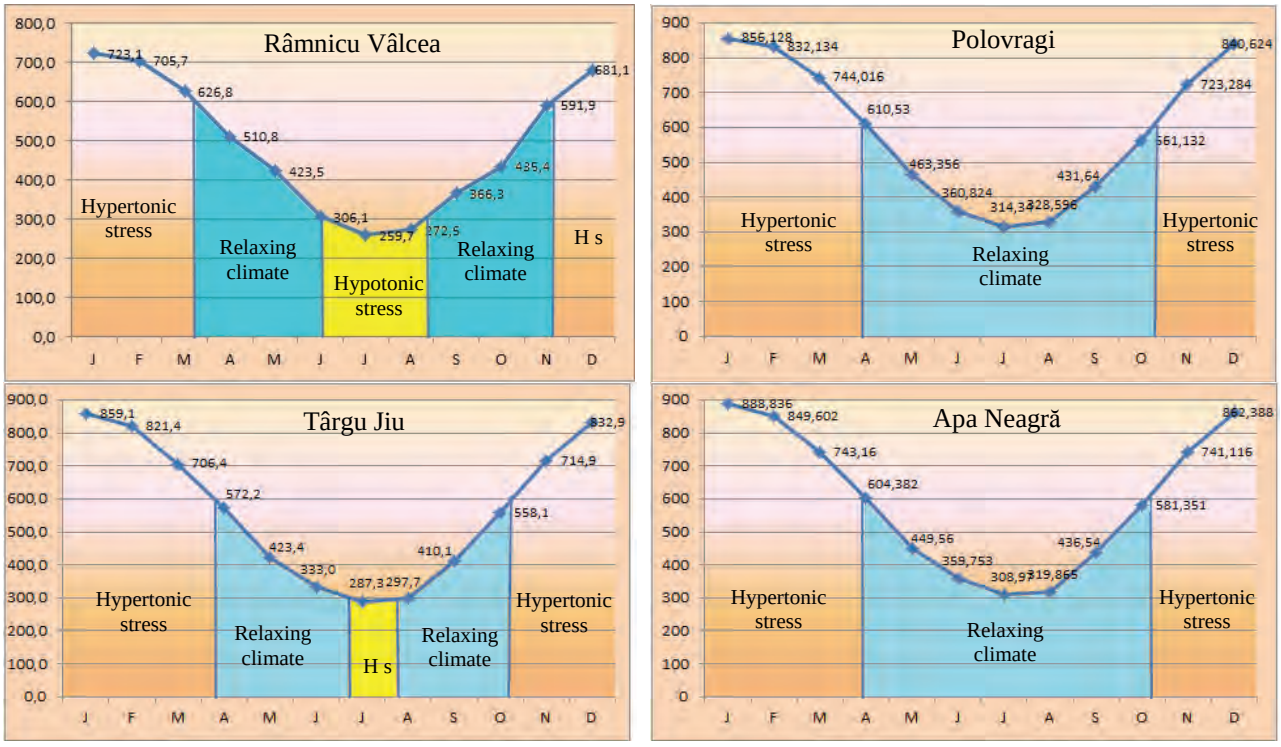

Figure 2. The cooling power of the wind and the skin stress index within the Getic Subcarpathians.

3.2 Temperature equivalent to the wind cooling power can be used to complete the general image emphasized by the wind cooling power index. Thus, the values of index underline an increased territorial uniformity. Comfort state, values of Tpr > +10°C, characterizes the interval April – October within the entire area of study. November and December are months characterized by a slight discomfort, while January by increased discomfort. However, the values of Tpr in January are close to the -1°C threshold, which means that the state of discomfort is not that high (Table 6).

Table 6. Monthly average values of the temperature equivalent to the wind cooling power within the Getic Subcarpathians.

STATION	J	F	M	A	M	J	J	A	S	O	N	D
Râmnicu Vâlcea	-1.095	1.021	5.764	11.739	17.015	20.34	19.74	19.27	16.44	10.86	5.36	0.86
Polovragi	-1.47	-0.114	0.6	11.2	16.91	20.15	21.95	20.99	16.32	10.62	4.27	-0.23
Târgu Jiu	-1.61	0.644	6.37	13.17	18.72	22.26	24.33	22.7	17.29	11.19	4.67	-0.15
Apa Neagră	-2.163	-0.128	5.42	12.18	18.02	22.09	23.62	22	17	10.71	4.29	-0.56
Comfort				Slight discomfort				Increased discomfort				

3.3 Lung stress index is obtained based on the water vapour pressure as a smooth respiratory exchange depends on it (TEODOREANU, 2002). Thus, the values of the vapour pressure between 7.5 and 11.6 mb indicate a balanced stress or no stress. The values below 7.5 mb stand for a dehydrating stress, mainly experienced during the cold months of the year, when the drier air determines a dehydration of the mucosae, inclusively at pulmonary level. The values above 11.7 mb, characteristic to the warmer months, determine the reverse phenomenon, namely hydration of the mucosae. According to the mean monthly values of the water vapour pressure, the Getic Subcarpathians display an

increased similarity. Thus, a balanced stress is generally characteristic to spring and autumn months – April (also May at Apa Neagră) and October and November (except for Polovragi where only October presents a balanced stress).

The highest number of months characterized by a balanced stress, 4, is registered in the west, while the lowest, 2, in the central-northern part of the studied region. Dehydrating stress is characteristic to the interval December – March at Râmnicu Vâlcea and Târgu Jiu, corresponding to the 4th coldest months, while in the west, at Apa Neagră, the interval overlaps only winter months. The highest number of months with dehydrating stress is registered at Polovragi, the interval starting with November and ending with March. However, there are no differences in terms of stress intensity, the values being similar in all the cases, +1.

The period with hydrating stress is common at all the stations, namely May – September, covering 5 months. In this case, there are registered differences between months and stations. Thus, only May and September display a slight hydrating stress, -1, at all the stations, as well as June, with the exception of Apa Neagră, where the stress is moderate. July and August generally have a moderate hydrating stress, -2, except for the same station, Apa Neagră, where the stress is increased, -3 (Fig. 4).

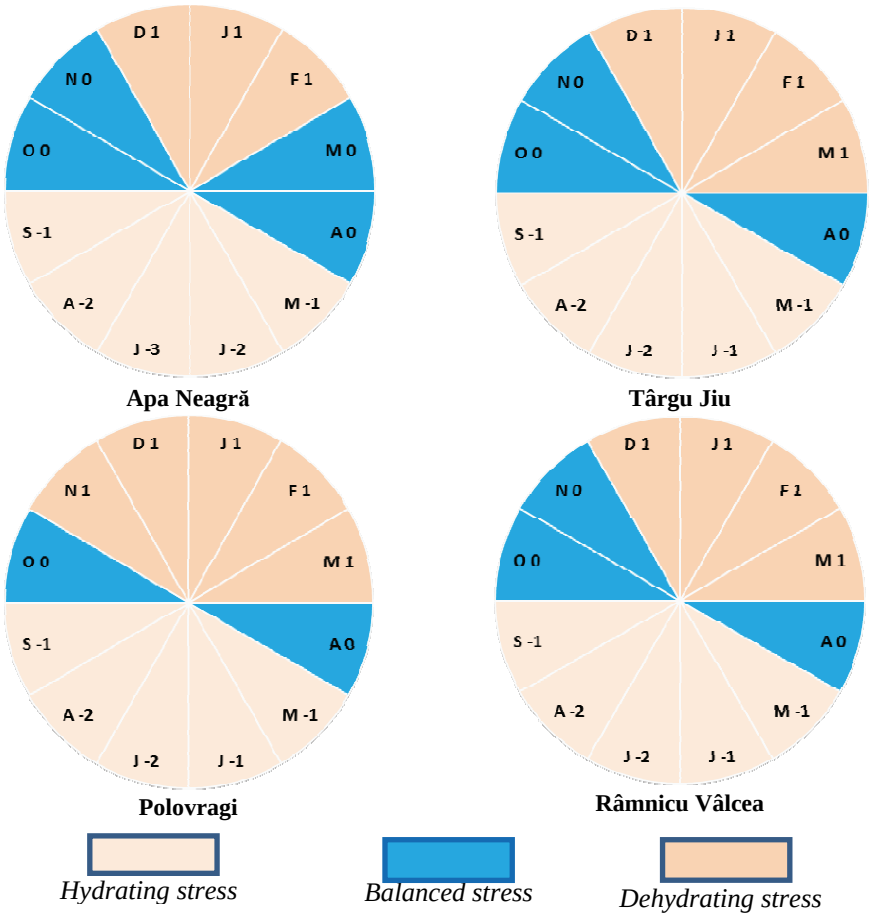

Figure 4. Lung stress index within the Getic Subcarpathians.

3.4 Total bioclimatic stress index is obtained by adding all the positive monthly values of both skin stress index and lung stress index. This, according to the studies made for the Romanian territory, it displays the highest value in the mountains (over 100) and the lowest (under 30), in the hilly area of the Subcarpathians (TEODOREANU, 2012). In the region of the Getic Subcarpathians, this pattern is maintained, namely the values of this index are below 30. The highest value is registered at Polovragi, 11 conventional units (stimulation degree 2), which corresponds to a moderate stimulation degree of the climate, while at the rest of the stations, the stimulation degree is 1. The values of the total bioclimatic stress index indicate that the region is highly favourable for human activities (Table 7).

Table 7. Total bioclimatic stress and the stimulation degree of the climate within the Getic Subcarpathians.

Station	Skin stress index	Lung stress index	Sum of positive stress	Stimulation degree of the climate
Râmnicu Vâlcea	4	4	8	1
Polovragi	6	5	11	2
Târgu Jiu	5	4	9	1
Apa Neagră	6	3	9	1

CONCLUSIONS

Compared to other hilly regions of the country, bioclimatic stress within the Getic Subcarpathians is reduced due to the action of the local factors on the background of the general climatic factors. However, as the analysis was based on mean values (temperature, wind speed, water vapour tension), there was emphasized only the average situation. There are cases, when temperature increase or decrease for example, greatly reduce thermal comfort even in this region, climate becoming a stressor for human heath state. Generally, the spring and autumn months are the least stressful for the human body, referring both to skin and lung stress. With reference to the extreme seasons, winter and summer, lung stress is more pronounced in summer (hydrating stress), especially at lower altitudes, compared to winter when the stress is slight within the entire region. Skin stress is especially felt in the months of the cold season, but the values indicate a slight hypertonic stress (+1). Hypotonic stress is registered only in July and August at lower altitudes. The temperature equivalent to the wind cooling power also indicates a state of comfort from April till October. November, December and February are months characterized by a slight discomfort, while January is classified as month with increased discomfort, but the values of the index are close to the slight discomfort threshold. Consequently, the stimulation degree of the climate is 1 except for Polovragi, the station located at the highest altitude, where the stimulation degree is 2. The use of bioclimatic indexes enabled us to highlight a climate characterized by an increased degree of favourability for human life and activities.

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