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BIOCLIMATIC REGIONALIZATION OF MOLDOVA WEST OF THE PRUT RIVER

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Abstract. Bioclimatic research for the regionalization of Moldova west of the Prut River (hereinafter Moldova), focused on the use of various climate indexes, is scarce. Using 9 bioclimatic indexes (THI, Pr, Tpr, ISH, TEE, DI THOM, HUMIDEX, SSI and ISE) calculated based on statistical and cartographic methods, we identified, delineated and outlined the major characteristics of the three bioclimates of Moldova. Following our analysis, three bioclimatic regions were identified: the cold, wet and windy bioclimate, the comfortable bioclimate and the warm-dry and contrasting bioclimate. They fall broadly within the existing bioclimatic regionalization and provide new, complementary quantitative and qualitative information.

Introduction.

Knowing the limitations imposed by bioclimate on the human body is necessary, both from practical and theoretical points of view. Analysis of the evolution and distribution of atmospheric parameters with impact on the human body for the territory located between the Prut River and the peaks of the Eastern Carpathians has already become of particular interest to us. This territory, characterized by geographical variation and complexity in terms of climate particularities, comprises around 3.8 million inhabitants. Thus, knowing bioclimatic particularities of Moldova is fully justified, even if we only refer to the significant number of people living in this region, under its specific bioclimatic conditions.

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1. Study area

Our study area totals 46260 km^2 and overlaps the territory of the historical province Moldova, with the counties of Suceava, Botoşani, Neamţ, Iasi, Bacău, Vaslui, Vrancea and Galaţi.

2. Data used

To achieve this regionalization, we used monthly averages for the following climatic elements: air temperature, relative air humidity, water vapor pressure and wind speed, for the interval 1961-2013. The data were recorded at 14 meteorological stations (listed in **Tab.1**.), included in the National Meteorological Administration network.

3. Methods and material

The bioclimatic regionalization of Moldova employed in the present study was particularly based on the values of three bioclimatic indexes: the thermo-hygrometric index - THI, the Wind-chill Index - Pr and the wind-chill equivalent temperature - Tpr. This is because these indexes are applicable without restriction, for all the months of the year and for all the stations in the study area. Given that the TPR Index provides less accurate results for summer months, such biases were taken into account in our bioclimatic regionalization. The values of other bioclimatic indexes were also considered in our analysis, although with a lower importance.

Tab.1. The meteorological stations in Moldova ordered from north to south, based on latitude

No.	Meteorological station	Altitude (m a.s.l.)	Latitude	Longitude
1	Rădăuți	383	47° 50' 16.222" N	25° 53' 25.562" E
2	Botoșani	121	47° 44' 08.274" N	26° 38' 43.907" E
3	Suceava	356	47° 37' 58.368" N	26° 14' 25.924" E
4	Cotnari	275	47° 21' 29.882" N	26° 55' 32.206" E
5	Poiana Stampei	917	47° 19' 28.730" N	25° 08' 03.977" E
6	Iași	99	47° 10' 15.416" N	27° 37' 41.819" E
7	Roman	221	46° 58' 08.707" N	26° 54' 42.515" E
8	Ceahlău Toaca	1805	46° 58' 38.978" N	25° 56' 59.718" E
9	Vaslui	101	46° 38' 45.966" N	27° 42' 51.898" E
10	Bacău	182	46° 31' 54.803" N	26° 54' 44.984" E
11	Târgu Ocna	239	46° 16' 21.702" N	26° 38' 27.673" E
12	Bârlad	173	46° 13' 58.931" N	27° 38' 39.909" E
13	Focșani	49	45° 41' 15.047" N	27° 11' 59.134" E
14	Galați	67	45° 28' 22.469" N	28° 01' 56.159" E

Next to THI, Pr and Tpr, another bioclimatic index used with good results but only for nine months of the year (September to May) was the winter

SCHARLAU index - ISH. In addition, we used several other indexes, however, with reduced importance in the analysis due to their restrictive applicability limits or poor results, as follows:

- the equivalent effective temperature - TEE, for the interval June - August;
- the Thom Discomfort Index (DI THOM) - which was considered for the months July and August;
- the HUMIDEX-index for the interval June-August;
- the Summer SIMMER Index - SSI, for July and August;
- the summer SCHARLAU Index - ISE, for the interval May - September.

All nine indexes used in the regionalization (of which four main, i.e., THI, Pr, Tpr, ISH, and five secondary, namely TEE, DI THOM, HI, SSI and ISE) were calculated using the formulas [1-9] shown in **Tab.2.**

The calculation of these indexes was based on monthly averages of meteorological elements (see **Tab.2** for details) and was performed using the Microsoft Excel software. The analysis and spatial distribution of the values of these indexes was performed using ArcGIS v 9.3.1 and several analysis methods such as linear regression, ordinary kriging and the combined regression with ordinary kriging.

Tab.2. Calculation formulas for bioclimatic indexes, as proposed by different studies

Calculation formulas*	References
$THI\,°C = T_{usc} - (0.55 - 0.0055 \cdot UR) \cdot (T_{usc} - 14.5);$ **[1]**	Kyle (1994)
$Pr = \left(10\sqrt{V} + 10{,}45\right) \cdot (33 - t);$ **[2]**	Siple and Passel (1945); modified by Beçancenot (1974)
$Tpr = \left(33 + (T_{usc} - 33) \cdot (0.474 + 0.454\sqrt{v_1} - 0.0454v_1)\right);$ **[3]**	Ionac and Ciulache, (2008)
$ISH = T_{usc} - Tc$ **[4a]**; $Tc = (-0.0003 \cdot UR^2) + (0.1497 \cdot UR) - 7.7133;$ **[4b]**	Scharlau (1950)
$TEE = 37 - \frac{37 - t}{0{,}68 + 0{,}00014f + \frac{1}{1{,}76 + 1{,}4v^{0{,}75}}} - 0{,}29\left(1 - \frac{f}{100}\right);$ **[5]**	Missenard (1937)
$DI\,Thom\,(°C) = (0.8 \cdot T_{usc}) + [0.08 \cdot (U_r - 3.2)];$ **[6]**	Thom and Bosen (1959)
$HUMIDEX = T_{usc} + \left(0.555 \cdot (e - 10)\right);$ **[7]**	Masterton and Richardson (1979)
$SSI = 1.98 \cdot \left(T_{usc} - \left(0.55 - 0.0055 \cdot (UR)\right) \cdot (T_{usc} - 58)\right) - 56.83;$ **[8],**	Pepi (2000)
$ISE = Tc - T_{usc}$ **[9]** and $Tc = (-17.089 \cdot \ln(UR)) + 94.979;$ **[9b]**	Scharlau (1950)

*where 'T_{usc}' and 't' are the dry-bulb temperature measured inside the meteorological shelter (°C), 'Tc' is the critical temperature (°C) 'V', 'v' and 'v_1' represent wind velocity (m/s^{-1}), 'f' and 'UR' are the relative air humidity (%) and 'e' the actual water vapor pressure (hPa).

To achieve this bioclimatic regionalization of Moldova we organized all previously analyzed indexes in three main categories:

i) The time interval characterized by bioclimatic discomfort due to overcooling, which includes four major types of bioclimatic conditions: excessive cold, very cold, cold, and chill. These types of bioclimatic conditions were assigned grades from -4 (very cold bioclimatic conditions) to -1 (cool bioclimatic conditions) (**Tab.3**). The first category characterizes the cold season (October to March) which is generally marked by the bioclimatic discomfort due to overcooling.

ii) The time interval characterized by bioclimatic discomfort due to overheating, which comprises three major types of bioclimatic conditions: warm, hot and torrid, for which we assigned grades from 1 (warm) to 3 (torrid). This category characterizes the warm season of the year (April to September) largely marked by bioclimatic discomfort due to overheating.

iii) The time interval characterized by bioclimatic comfort, which was assigned the grade 0, shifted alternatively towards the two seasons of the year based on the month when a given index was graded with 0 following cartographic analysis.

Tab.3. The grades assigned to bioclimatic conditions and which have been linked to each climatic index based on its computed monthly values

Assined cartographic analysis grade	***Bioclimatic conditions***	***Type of bioclimatic comfort/discomfort***
-4	Excessive cold	Bioclimatic discomfort due to overcooling
-3	Very cold	
-2	Cold	
-1	Chill	
0	Comfort	Bioclimatic comfort
1	Warm	Bioclimatic discomfort due to overheating
2	Hot	
3	Torrid	

By employing modern methods in GIS, such as reclassification and interrogation, we centralized these indices at a monthly time resolution for each of the seasons of a year; then we centralized them using cartographic algebra. Each part of the studied territory was assigned a cartographic grade (indicating a

certain bioclimatic condition and hence a type of bioclimate) for the cold season and another grade for the warm season.

4. Results and discussion

Five types of bioclimatic conditions were spatially outlined for the cold season **(Fig. 1).** These reflect a long-term (1960-2013) bioclimatic situation and can thus be considered 5 sequential semi-annual types of bioclimate (4 characterized by bioclimatic discomfort due to overcooling and one by comfort) where the thermal component is dominant.

We identified the following:

i) Territories where bioclimatic comfort is felt on average at multi-annual timescales (most of the Moldova Plain, the southern half of the Siret River corridor, the southern half of the Bârlad Plateau); during the cold season, in specific cases, bioclimatic conditions can attain glacial features generated by the Crivăț wind or by the persistence of anticyclonic baric fields favoring thermal inversions;

ii) A type of cool bioclimate comprising the Subcarpathian region, the northern part of the Moldova Plain, the entire Suceava Plateau and the Central Moldavian Plateau;

iii) A type of cold bioclimate characterizes the base of the Eastern Carpathian peaks, including intramontane depressions;

iv) A very cold bioclimatic specific to elevations between 1000 and 1300 m a.s.l.;

v) The bioclimate characterized by excessive cold, located at altitudes above 1300 m a.s.l..

The bioclimatic conditions characterized by discomfort due to overcooling are related to a cold climate, high cloudiness, reduced duration of sunshine, relatively humid air, moderately heavy rainfall, thick and persistent snow layer and frequent fog. Bioclimatic stress is high, both at the skin level as a result of low temperatures and particularly strong winds and at the lungs level due to low water vapor tension over most of the studied territory. The air is clean, free of pollutants as a result of the active dynamics, chemical and bactericidal action of solar ultraviolet rays.

By centralizing through computation the cartographic analysis grades assigned to bioclimatic indexes for the warm season of the year, four areas with differentiated bioclimatic features resulted **(Fig.2**), as follows:

i) An area characterized by torrid bioclimatic conditions, observed in the Lower Siret Plain, with average daily temperatures often exceeding 30 °C;

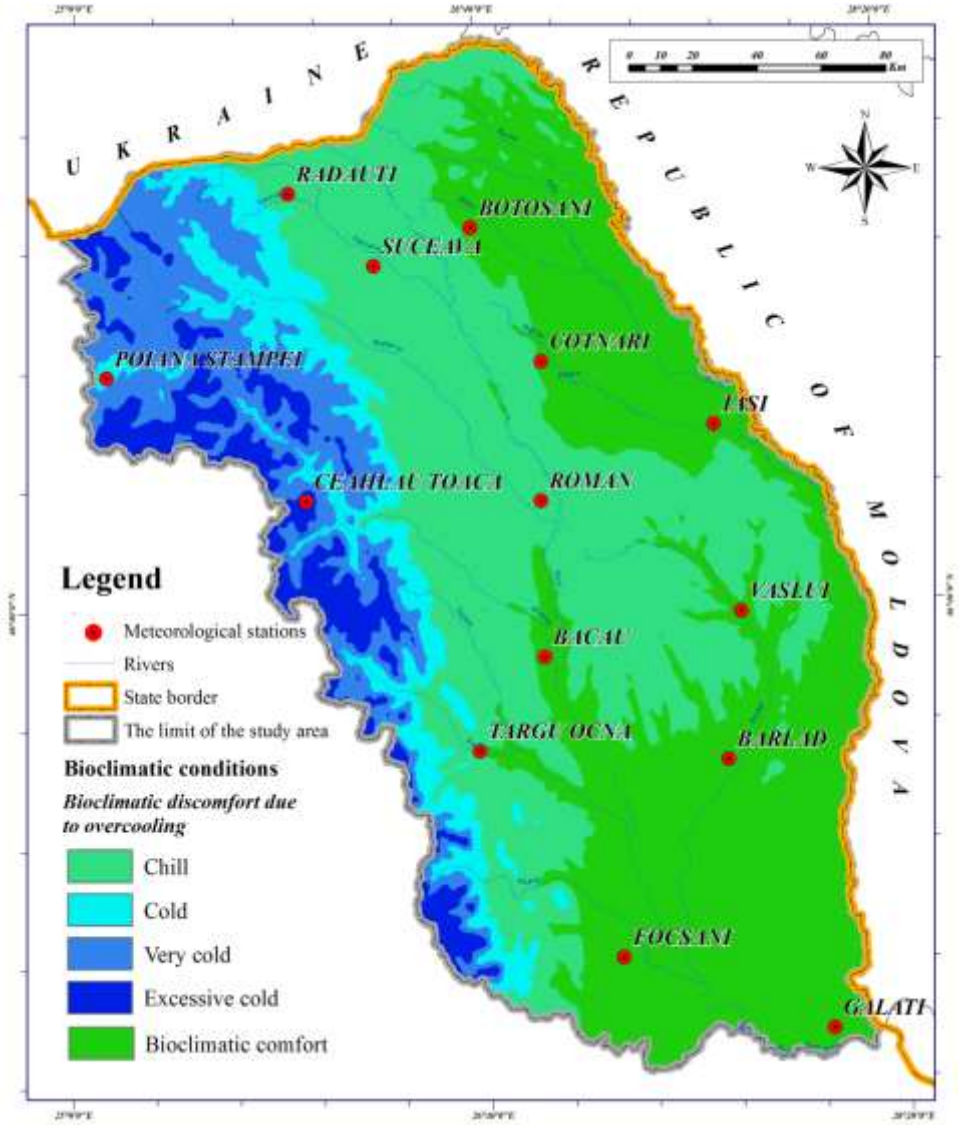

Fig.1. Centralization of the bioclimatic indexes and identification of the bioclimatic conditions for the cold season of the year in Moldova

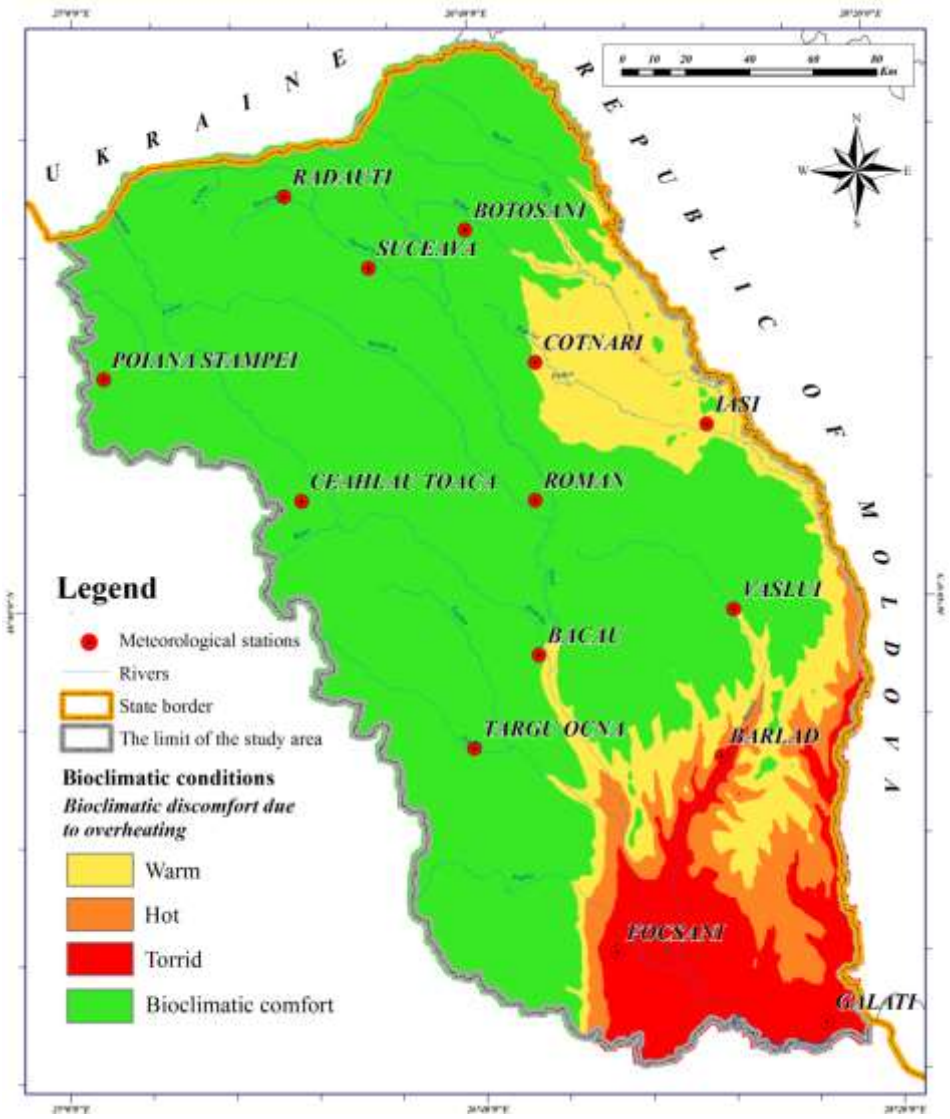

Fig.2. Centralization of the bioclimatic indexes and identification of the bioclimatic conditions for the warm season of the year in Moldova - daily averages over 26°C.

ii) A hot territory extended in the south of the region between 100 and 200 m a.s.l., characterized by high temperatures with average daytime values exceeding 26 °C;

iii) A territory with warm bioclimatic conditions characteristic of altitudesbetween 200 and 300 m a.s.l. in the southern part of the Moldova Plain, Prut Valley and Bârlad Plateau;

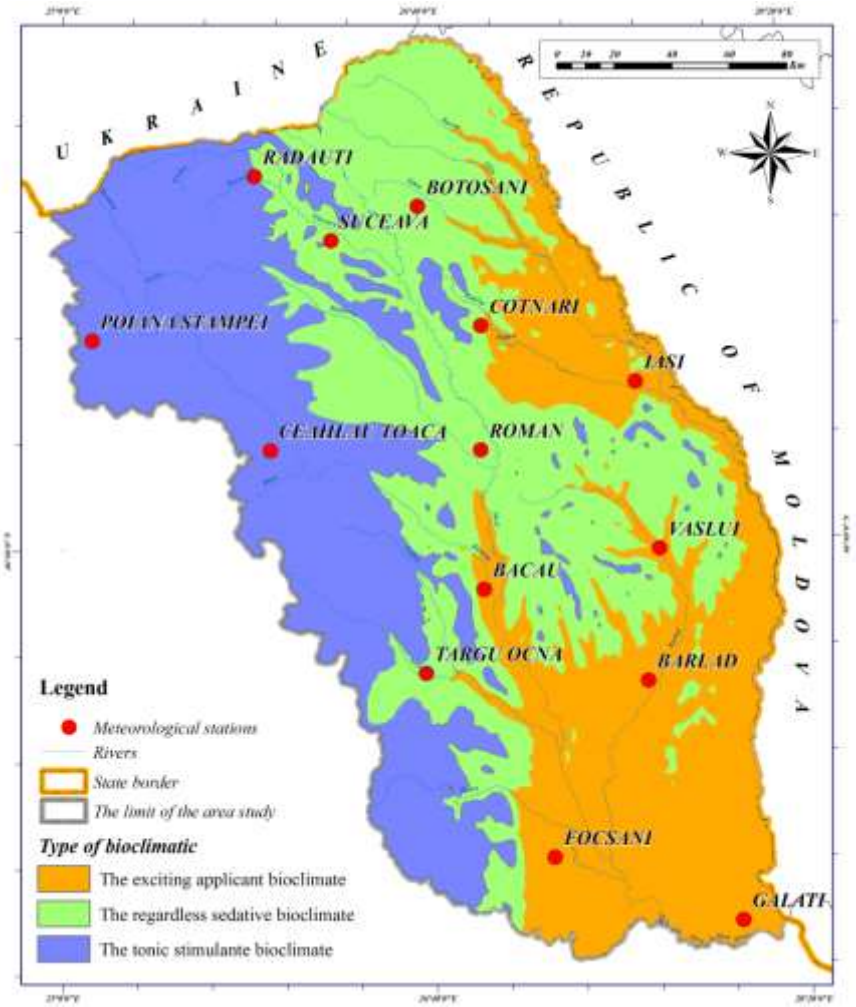

Fig.3. General bioclimatic map of Moldova with the resulting types of bioclimate

The rest of our study area (over 2/3) displays comfortable bioclimatic conditions in terms of thermal, hygric and dynamic characteristics.

To construct a general bioclimatic map, we combined the two seasons mentioned above, thus obtaining three clearly distinct bioclimates **(Fig.3).**

The first bioclimate is generally characterized by cold conditions with excessive humidity and strong dynamics and bioclimatic discomfort due to overcooling. It characterizes the mountain and subcarpathic areas (above 600 - 700 m a.s.l.), as well as high hilly areas (450-600 m a.s.l.) in the Suceava Plateau, the Moldavian Coast and the Bârlad Plateau (facing north and fully exposed to atmospheric circulation). It represents about 1/3 of the Moldova territory west of the Prut River.

The second type of bioclimate is comfortable from the thermal, hygric and dynamic points of view and characterizes the north - northwestern and central areas of the Moldova Plateau and eastern edges of the Moldova Subcarpathians. *Bioclimatic comfort* is specific to plateau and hilly areas (between 200 and 250 m, 600 and 700 m respectively), i.e., the Suceava Plateau, The Siret River corridor, the northern half of the Moldova Plain, the marginal hilly coast of Moldova Plain, Bârlad Plateau. This type of bioclimate represents ≈ 1/3 of the territory of Moldova west of the Prut River. Thermal comfort is maximum and the skin stress, lung stress and cardiovascular system stress are minimal.

The third type of bio-climate is warm, dry and with a contrasting seasonal dynamics and characterizes the eastern and south - eastern parts of Moldova. The area displaying bioclimatic discomfort due to overheating overlaps the climate of the lowlands (below 250 - 200 m a.s.l.) and represents approx. 1/3 of the study area. It is characterized by harsh, frosty winters and hot summers, enhanced air dryness, high sunshine duration and rather active dynamics.

These three identified bioclimates have a clear territorial distribution, overlapping the tonic-stimulant, sedative-indifferent and turn-applicant bioclimatic zones, which were identified in the regionalization of Romanian bioclimates proposed by Teodoreanu (1977; 1984) and Bogdan (1980).

Conclusions.

After processing the nine bioclimatic indexes, we argued for the presence of three distinct bioclimates in Moldova: i) cold, wet and windy, ii) comfortable and warm, iii) dry and contrasting. For the territory of Moldova we can identify many similarities between the *cold, wet and windy bioclimate* (identified in this paper) and the *tonic-stimulant bioclimate* specific to mountain areas (above 700 – 800 m a.s.l.).

The second type of bioclimate identified, the *comfort bioclimate* can be associated with the *sedative-indifferent bioclimate* which overlaps the plateau and hilly areas (between 200 and 300 m, 700 and 800 m respectively).

The third type of identified bioclimate, the *hot, dry and contrasting bioclimate* is similar to the *turn-applicant bioclimate* and overlaps the climate of plain areas (below 200 m a.s.l.).

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