Distribution of V.Boksha's Bioclimatic Index in Ukraine and the Development of an Automated Application for Its Determination

M. Pavliuk (*Volyn JAS Regional Department,*) ***V. Fedoniuk, N.Vavdiiuk** *(Lutsk National Technical University)*, **Yu. Fedoniuk** *(Lesya Ukrainka Volyn National University)*

SUMMARY

In connection with global climate change and the increasing number of manifestations of weather sensitivity, the influence of weather conditions and meteorological variables on human health is attracting growing interest. Bioclimatic indices (BCIs) are indicators that serve as a qualitative tool for assessing climate comfort in a region. Based on the analysis of the dynamics of one of the BCIs – the climate pathogenicity index of V. Boksha – an assessment of climate comfort in Ukraine was carried out for 2018 – 2023 for 26 cities, and an automated application for calculating this indicator was developed. The temporal and spatial dynamics of V. Boksha's BCI and, accordingly, the comfort of Ukraine's climate were determined. The results were visualized in graphs, charts, and GIS-based maps. It was found that climate comfort during the year ranges from optimal in the warm period to irritating in winter, reaching acute values on certain days, the number of which varies from 5–9 (Uzhhorod, Kyiv) to 30–31 (Rivne, Sumy). Average monthly index values throughout the year range from 5 to 10 (May – August) to 25–32 (January – February). The analysis showed an increase of the comfortable period in Ukraine in 2018 – 2023 by 1.5–2 months compared to its duration in the 20th century. An automated application – an online index calculator – was developed, allowing its determination for a selected settlement. The results of the calculations of BCI, performed using the automated application, can complement daily weather forecasts to inform people about the comfort of weather conditions.

Keywords: Climate comfort mapping; Climate of Ukraine; Bioclimatic indices; V. Boksha's bioclimatic index; Online index calculator

Corresponding Author: ecolutsk@gmail.com

Introduction

Weather and climate comfort is a comprehensive assessment of their favorability for humans. In connection with global climate change and the growing number of manifestations of weather dependence, its study is becoming increasingly relevant, as weather comfort affects the manifestations of weather sensitivity – the human body's reactions to the influence of weather and climatic factors. Scientists have developed over a hundred integral indicators (bioclimatic indices) used to mathematically assess climate comfort. Bioclimatic indices (hereinafter – BCIs) are indicators that serve as a mathematical tool for the quantitative and qualitative assessment of climate comfort in a region. The issues of analyzing weather comfort for humans, the definition of bioclimate, and the methods of its assessment using BCIs, in the order of their study by Ukrainian and foreign authors, are analyzed in the works of Shevchenko O.H. (2016), Fedoniuk V.V., Kartava O.F., Ivantsiv V.V. (2016), Malytska L.V. (2017), Kuchcik M., Błażejczyk K., Halaś A. (2021), Çağlak S. (2024). The classical approach, substantiated by Lee H., Holst J., Mayer H. (2013), involves giving preference to complex BCIs with multiple parameters for a qualitative assessment of climate comfort conditions. At the same time, the growth of regional manifestations of climate change in Ukraine in recent years, analyzed by Fedoniuk V., Pankevych A., Romaniuk D., Vovk O., Fedoniuk Yu. (2025), requires updating approaches to assessing climate comfort and repeating studies of its spatiotemporal variability. In this context, the aim of this work was to analyze the dynamics and variations of climate comfort in Ukraine based on the assessment of the temporal and spatial distribution of V. Boksha's BCI in Ukraine and to develop an automated application for index calculation.

Method and Theory

The general (or total) pathogenicity index I_{sum} by V.G. Boksha, which comprehensively reflects the meteorological conditions of a given period, as well as heliophysical and geophysical factors, is determined as the sum of several terms, each calculated from a separate meteorological indicator. This BCI characterizes weather dynamics according to such parameters as changes in temperature, relative humidity, wind speed, and cloudiness; it also takes into account the interdiurnal variability (fluctuation) of air temperature and atmospheric pressure. The calculation method for the BCI used in this work was first presented in the works of Boksha V.G. , Bohutskyi B. V. (1980), and refined by Katerusha H. P. (2020); this index is one of the classical ones in bioclimatology. The initial meteorological data for the calculations were taken from the open electronic archives of the European Meteorological Agency (2024). The refined calculation method for the BCI described by Katerusha H. P. (2020) was applied. The pathogenicity index by V.G.Boksha is determined by the following formula, in points:

$$\boldsymbol{I_{sum} = i_t + i_f + i_v + i_n + i_{\Delta t} + i_{\Delta p}} \quad \text{(points)}$$

The values i_t, i_f, i_v, i_n, $i_{\Delta t}$, and $i_{\Delta p}$ are the components of the total index, or pathogenicity indices for individual meteorological factors: 1) pathogenicity index of air temperature: $i_t = 0.02(18 - t)^2$ for $t \leq 18$ °C, $i_t = 0.2(t - 18)^2$ for $t > 18$ °C; 2) pathogenicity index of humidity $i_f = (f - 70)/2$; 3) pathogenicity index of wind $i_v = 0.2v^2$; 4) pathogenicity index of cloudiness $i_n = 0.06n^2$, where $n = 10 - (10Sf/Sm)$; 5) pathogenicity index of air temperature change $i_{\Delta t} = 0.3\Delta t^2$; 6) pathogenicity index of atmospheric pressure change $i_{\Delta p} = 0.06\Delta p^2$. If heliographic observations are not conducted at a meteorological station and the values Sf and Sm are unknown, the i_n term is excluded from calculations (in many Ukrainian cities meteorological stations do not monitor solar radiation). Without considering i_n, the threshold values of the I_{sum} index are: optimal (less than 10 points), irritating (10–29), and acute (I_{sum} = 30 or more). This gradation was applied. In this way, the index values for 26 cities in Ukraine were calculated for the period 2018-2023. The data obtained were analyzed and visualized using MS Excel statistical tools and GIS tools from GS Surfer and MapInfoProfessional software.

To calculate the current index values in real time, current data from an automated meteorological station installed on the territory of Lutsk National Technical University (Lutsk, Ukraine) was used. The script was implemented in Python. Since the weather station whose data was used to calculate the

BCI is connected to the online service (Ecowitt), API requests were applied to import the data into the program. In Python, this procedure is carried out by the Requests library. Microsoft's VScode was used as the development environment, which has a large number of plugins for Python, GitHub & GitHub workflow plugins, and a built-in interface for VCS (version control system). The resulting data from the BCI script is displayed in near real time on the Google's Blogger platform (a free platform supporting widgets with an option to add JS scripts).

Results

The bioclimatic index of V.G. Boksha (I_{sum}) during the studied period shows a distinct annual cycle across all cities in Ukraine (see maps in Fig. 1). The lowest values (< 10) are observed in the warm period (April to September, with minimums in April – May and September), and the highest in winter (December – February, index above 25). At the same time, during the warm period there is also a certain increase in July – August (probably related to high temperature contrasts and low relative humidity at this time). In different regions of Ukraine, the annual range may differ: it is higher in the south-eastern regions (Luhansk, Donetsk) due to greater continentality of the climate. Analysis of the dynamics of individual components of the index also shows a clear annual pattern, which determines the changes in the total index. In 26 cities of Ukraine, the average for the study period 2018 – 2023 varied from 8.8–9.7 (Kyiv, Zhytomyr, Odesa, Simferopol) to 13.7–14.2 (Rivne, Ternopil, Luhansk). The average for 2018 – 2023 for the whole territory of Ukraine was 11.8, which is lower than the values determined by V.G. Boksha at the end of the 20th century for our territory within the temperate climate zone (12–15). Thus, a decrease of the index and its approach to optimal values is observed, which may be related to manifestations of climate change.

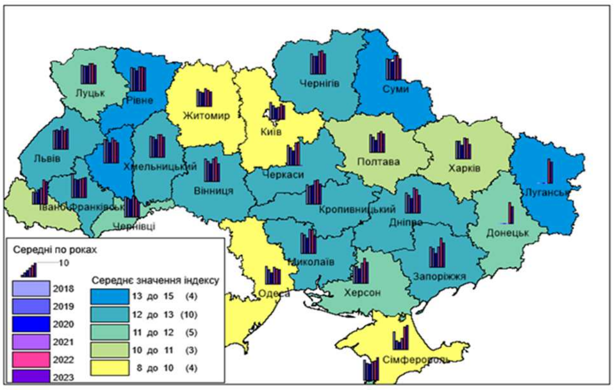

Figure 1. *Distribution of average annual values of the V.G. Boksha bioclimatic index in Ukraine in 2018 – 2023. Note: bar charts – average annual values of the index in cities by individual years, cartogram and isolines – average value for 2018 – 2023.*

Thus, the most optimal values are for Kyiv, Zhytomyr, Odesa, Sevastopol, and Simferopol (less than or close to 10). The index is also quite low (and therefore favorable) in a number of other cities: Poltava, Kharkiv, Kherson, Donetsk, Lutsk, Chernivtsi (10–12 points). The highest irritating values characterize Luhansk, Sumy, Rivne, Khmelnytskyi (annual index in the range 13–15). In general, for the territory of Ukraine, the average annual values are favorable and are within the optimal or slightly irritating values (from 8.8 in Kyiv to 14.2 for Luhansk). The spatial distribution of the index depends not only on the geographical location of the city, but also on local microclimatic conditions. For example, the lowest value in Kyiv may be explained by the fact that the meteorological station is located in the city itself: a large metropolis forms a climate with a smoothed course of meteorological indicators. However, analysis of the isoline map allows the conclusion that there is a general decrease in annual values from the northeast to the southwest of Ukraine.

Analysis of the distribution of the average monthly index was carried out for February and June, as months with the most extreme and most optimal index values (according to V.G. Boksha,1980). For February, a general decrease from the northeast of Ukraine to the southwest is also observed. The cities with the lowest values in February are Uzhgorod, Chernivtsi, Odesa, Zhytomyr, Kyiv, and

Crimean cities (14–16), and those with the highest values are Rivne, Ternopil, Sumy, Kharkiv, and Zaporizhzhia (23–25). In June, the distribution is different: the lowest values are in the north-eastern and central regions (Zhytomyr, Kyiv, Chernihiv, Poltava, Kharkiv, Donetsk, Luhansk, where the index is below 5). The highest June values are in Chernivtsi, Ivano-Frankivsk, Mykolaiv, Zaporizhzhia, and Crimea (7–10).

According to the analysis for 2018 – 2023, January is the most uncomfortable month, and August is the most comfortable in terms of the index in Ukraine. The shift of the most comfortable and least comfortable periods from June and February to January and August is, in our opinion, due to the influence of global climate change, which leads to the lengthening of the warm season in Ukraine and the shortening of the cold season.

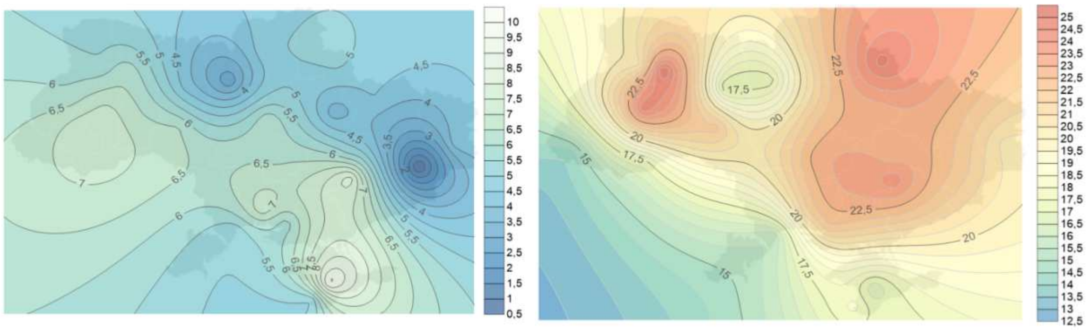

Figure 2. *Distribution of average monthly values of the V.G. Boksha bioclimatic index in summer and winter in Ukraine in 2018 – 2023 (left – average monthly values in June, right – in February).*

The results of the analysis of the number of days with different index categories (optimal, irritating, and acute) are shown in Fig. 3. Throughout the year, less than 5–10% of days have acute index values (from 5–10 acute days in Uzhhorod, Odesa, Kyiv, Sevastopol to 25–32 such days in Rivne, Ternopil, Dnipro, Sumy, Zaporizhzhia, Kropyvnytskyi) and over 90% of days have optimal or irritating values. The number of optimal and irritating days is comparable. The maximum number of days with an optimal index (about 200) is observed in Kyiv, Odesa, Simferopol, Uzhhorod, Zhytomyr, and Donetsk, while the minimum (less than 160) is in Luhansk, Rivne, Ternopil, and Sevastopol. Thus, the spatial distribution of days with different BCI categories is also not directly dependent on geographic location but is determined by local microclimatic conditions.

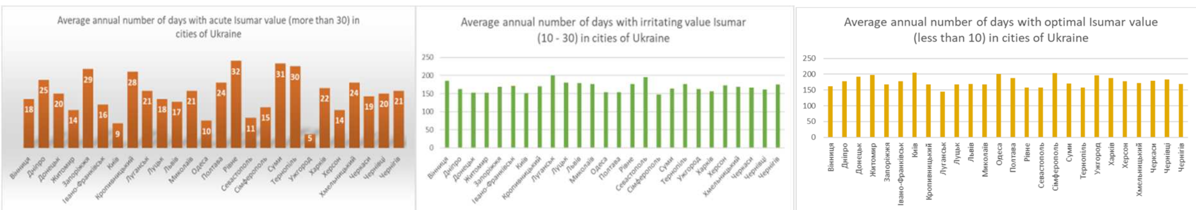

Figure 3. *Average annual number of days with different categories of the V.G. Boksha bioclimatic index in cities of Ukraine during 2018 – 2023.*

As noted, meteorological sensitivity is a contemporary issue, with public demand for information on the comfort of weather and climatic conditions for human health and productivity. Several weather websites already include bioclimatic parameters in their daily forecasts. Therefore, two automatic online calculators for calculating the V. Boksha index were developed and made publicly available for use by anyone interested in assessing the favorability of climate and weather conditions for humans. The results are published in test mode on a thematic blog pogoda3kota.blogspot.com.

Conclusions

Thus, as a result of the analysis of the temporal and spatial dynamics of the V.G. Boksha bioclimatic index within Ukraine during 2018 – 2023, it was found that climate comfort varies from optimal in the warm period (April – September) to irritating in winter (December – February), with acute values occurring on individual days, ranging from 5–9 days (Uzhhorod, Kyiv) to 30–31 days (Rivne, Sumy). Average monthly index values throughout the year fluctuate between 5 and 10 (May – August) and 25–32 (January – February). The highest, irritating values are observed during the three-month winter period (December – February, index can exceed 25–30), while the lowest, optimal values are found in the longer six-month warm period (April – September, index below 10). Analysis of the annual distribution of days with different index categories showed an extension of the favorable and comfortable period in Ukraine by 1.5–2 months compared to its duration in the 20th century, as determined by V.G. Boksha. The average index calculated for Ukraine for 2018 – 2023 was 11.8, which is lower than the range defined at the end of the 20th century (12–15). Thus, a general decrease in the BCI is observed, with its values approaching optimal levels across the country. The calculated BCI values can be added to weather forecasts to inform about the comfort of meteorological conditions.

References

Boksha, V.G. & Bohutskyi, B.V. (1980). *Medical Climatology and Climatotherapy*. Kyiv, Zdorovya. 261p.

Çağlak, S. (2024). A New Model Approach to Mapping Bioclimatic Comfort Conditions. *Theoretical and Applied Climatology, 155* (4), 3313–3327. https://doi.org/10.1007/s00704-023-04816-3.

European Meteorological Agency Weather Archive (accessed: 25.12.2024). URL: https://www.ecad.eu/dailydata/customquery.php.

Fedoniuk, V.V., Kartava, O.F. & Ivantsiv, V.V. (2016). Economic Evaluation of Recreational and Tourist Potential of Regional Landscape Parks of Ukraine. *Actual Problems of Economics*, *1* (175), 209–216. URL: http://nbuv.gov.ua/UJRN/ape_2016_1_25.

Fedoniuk, V., Pankevych, A., Romaniuk, D., Vovk, O. & Fedoniuk, Yu. (2025). Monitoring the Dynamics of the Urban Heat Island over Lutsk. Monitoring of Geological Processes and Ecological Condition of the Environment. 18th International Scientific Conference. Publisher: European Association of Geoscientists & Engineers. Conference Proceedings, April 2025, Volume 2025. pp. 1–5. https://doi.org/10.3997/2214-4609.2025510036.

Katerusha, H.P. (2020). Methodological Guidelines for Practical Work in the Discipline "Aspects of Environmental Climatology" for First-Year Full-Time Master's Students, 103 "Earth Sciences" (Educational Program "Meteorology and Climatology"). Odesa, ODEKU. 40p. URL: http://eprints.library.odeku.edu.ua/id/eprint/8609.

Kuchcik, M., Błażejczyk, K., & Halaś, A. (2021). Changes in Bioclimatic Indices. In *Climate Change in Poland: Past, Present, Future*. Cham: Springer International Publishing. pp. 471–491. https://doi.org/10.1007/978-3-030-70328-8_19.

Lee, H., Holst, J., & Mayer, H. (2013). Modification of human-biometeorologically significant radiant flux densities by shading as local method to mitigate heat stress in summer within urban street canyons. *Advances in Meteorology*, *2013*(1), 312572. http://dx.doi.org/10.1155/2013/312572.

Malytska, L.V. (2017). Discomfort of Weather Conditions during the Winter Period in Ukraine. *Ukrainian Hydrometeorological Journal*. (20), 26–36. URL: http://uhmj.odeku.edu.ua/dyskomfort-pogodnyh-umov-zymovogo-periodu-v-ukrayini.

Shevchenko, O.H. (2016). Comparative Analysis of Bioclimatic Indices for Assessing the Comfort of Urbanized Environment in the Warm Period. *Hydrology, Hydrochemistry and Hydroecology*, (3), 105–115. URL: http://nbuv.gov.ua/UJRN/glghge_2016_3_13.