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SPATIAL PROCESSING AND ANALYSIS OF AIR TEMPERATURE DATA IN THE EXTRA-CARPATHIAN REGION OF ROMANIA USING GEOGRAPHIC INFORMATION SYSTEMS

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Rezumat. *Procesarea și analiza spațială a datelor climatice reprezintă un instrument esențial pentru evaluarea variabilității regimului termic la scară regională și pentru susținerea aplicațiilor inginerești bazate pe informații geospațiale. Prezentul studiu are ca obiectiv procesarea și analiza spațială a datelor de temperatură a aerului în regiunea extracarpatică a României, utilizând sisteme informaționale geografice, pentru perioada 2012–2017, prin raportare la intervalul de referință climatologică 1981–2010. Datele furnizate de Administrația Națională de Meteorologie au fost integrate într-un mediu GIS și prelucrate prin metode de analiză spațială pentru obținerea distribuțiilor sezoniere ale temperaturii aerului. Analiza comparativă a evidențiat o variabilitate spațială și sezonieră pronunțată a temperaturii aerului, cu valori mai ridicate în special în sezoanele de primăvară și vară față de media multianuală de referință. Metodologia propusă oferă un cadru tehnic stabil, aplicabil în ingineria climatică, ingineria mediului și analiza geospațială regională.*

Abstract. *The processing and spatial analysis of climatic data are essential for assessing thermal regime variability at the regional scale and supporting engineering applications based on geospatial information. This study aims to process and spatially analyze air temperature data in the extra-Carpathian region of Romania using Geographic Information Systems, for the period 2012–2017, relative to the 1981–2010 climatological reference interval. Air temperature data provided by the National Meteorological Administration were integrated into a GIS environment and processed using spatial analysis techniques to derive seasonal temperature distributions. Comparative analysis revealed significant spatial and seasonal variability of air temperature, with higher values observed particularly during spring and summer compared to the long-term mean. The proposed methodology provides a reproducible technical framework applicable to climate engineering, environmental engineering, and regional geospatial analysis.*

Keywords: air temperature, climate variability, spatial analysis, geographic information systems, Romania

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1.Introduction

The processing and spatial analysis of climatic datasets represent an essential component of engineering-oriented studies focused on environmental assessment, territorial planning, and the design of infrastructure sensitive to climatic conditions [1,2]. Air temperature is one of the most important climatic parameters used as an input variable in a wide range of engineering applications, including regional climate assessments, energy analyses, and environmental impact studies [3].

The development of Geographic Information Systems has enabled the efficient integration, processing, and spatial representation of large volumes of meteorological data, providing robust tools for analyzing the spatial and temporal variability of climatic parameters [1,4]. GIS-based approaches facilitate the transformation of point-based meteorological observations into continuous spatial representations, allowing the identification of regional patterns and seasonal variations of the thermal regime [4,5].

In the context of regional-scale engineering applications, the analysis of seasonal air temperature variability is particularly relevant, as it supports the assessment of thermal conditions used in energy balance calculations, thermal comfort evaluations, and climate risk analyses [3,6]. The comparison of recent observation periods with climatological reference intervals enables the identification of changes in the thermal regime and provides valuable information for supporting technical decision-making and updating datasets used in engineering design [6,7].

Beyond engineering approaches based on the processing and spatial analysis of climatic data, the variability of the thermal regime has been extensively investigated in climatic and interdisciplinary studies, which highlight significant changes in air temperature at regional and continental scales. Existing research indicates consistent trends in thermal regime modification across Europe and its southeastern regions, including the extra-Carpathian area of Romania, based on climatological analyses and long-term data series [8–17]. Although developed from climatic, environmental, or interdisciplinary perspectives, these studies provide a relevant comparative context for interpreting thermal variations identified through engineering-based spatial analysis methods and support the validity of using GIS approaches in the assessment of regional climate variability.

2. Materials and methods

The analysis of the thermal regime was conducted using climatological data provided by the National Meteorological Administration (NMA) [16,17] for the period 2012–2017, with the climatological reference interval 1981–2010 used for comparison. The study focused on monthly and seasonal mean air temperature values, analyzed for the main climatic seasons: spring, summer, autumn, and winter.

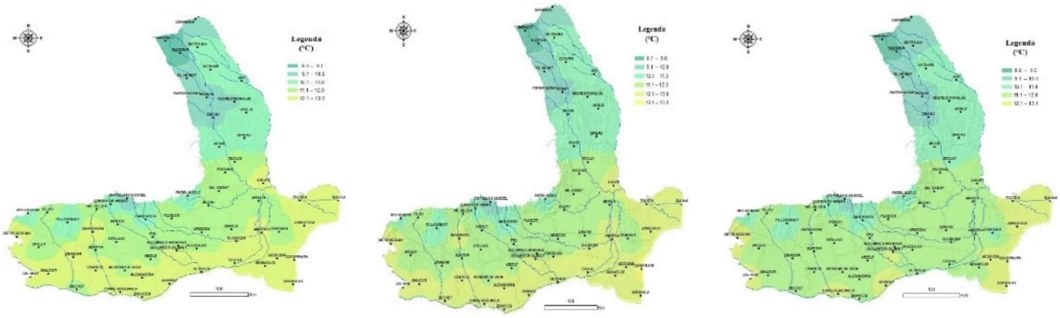
Data processing and spatial representation were performed in a GIS environment using ArcGIS software. Climatic data were interpolated to generate continuous spatial distributions of air temperature, and seasonal thematic maps were produced to highlight the spatio-temporal variability of the thermal regime. A comparative analysis approach was applied to identify differences between the analyzed period and the reference interval, considering both spatial distribution patterns and the magnitude of temperature values.

The interpretation of results was carried out from an engineering perspective by evaluating spatio-temporal variations in air temperature in relation to seasonal climatic indicators relevant to climate engineering, environmental engineering, and energy-related analyses. The adopted methodological framework enables the coherent integration of climatological data into geospatial analyses and provides a reproducible approach for assessing regional-scale thermal regime variability.

3.Analysis of the average monthly thermal regime in the extra-Carpathian area of Romania

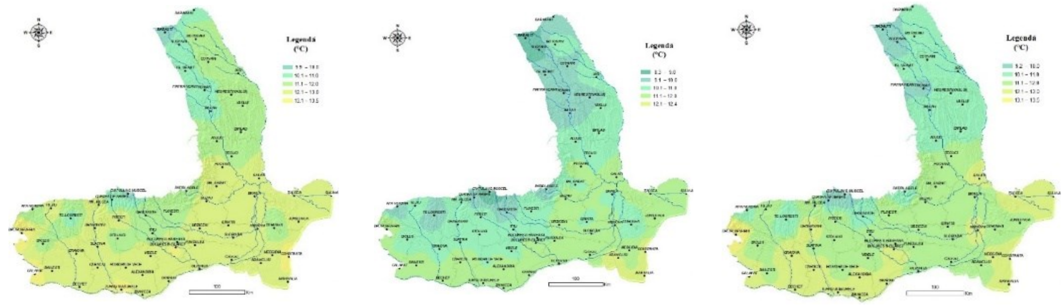
The average monthly temperature regime in the extra-Carpathian area of Romania can vary significantly depending on the season and specific location. In winter (January), we have an average monthly temperature in the extra-Carpathian area that can vary between -4°C and 2°C. Temperatures can drop below 0°C and there can be periods of frost. In spring (April) signs of warming begin to appear. Average temperatures can vary between 8°C and 16°C. Summer is the warmest month of the year (July). Average temperatures can reach 25°C or more, and on some days they can even reach 30°C or more. In autumn (October), average temperatures gradually decrease. In October, temperatures can vary between 12°C and 18°C.

These values are only general estimates and may vary depending on certain factors, such as altitude, the influence of local relief and climate change.



2012 2013 2014

Fig. 1. a. Average annual air temperature distribution in the extra-Carpathian region for the period 2012-2017 (source: created in ArcGIS based on ANM data)



2015 2016 2017

Fig. 1. b. Average annual air temperature distribution in the extra-Carpathian region for the period 2012-2017 (source: created in ArcGIS based on ANM data)

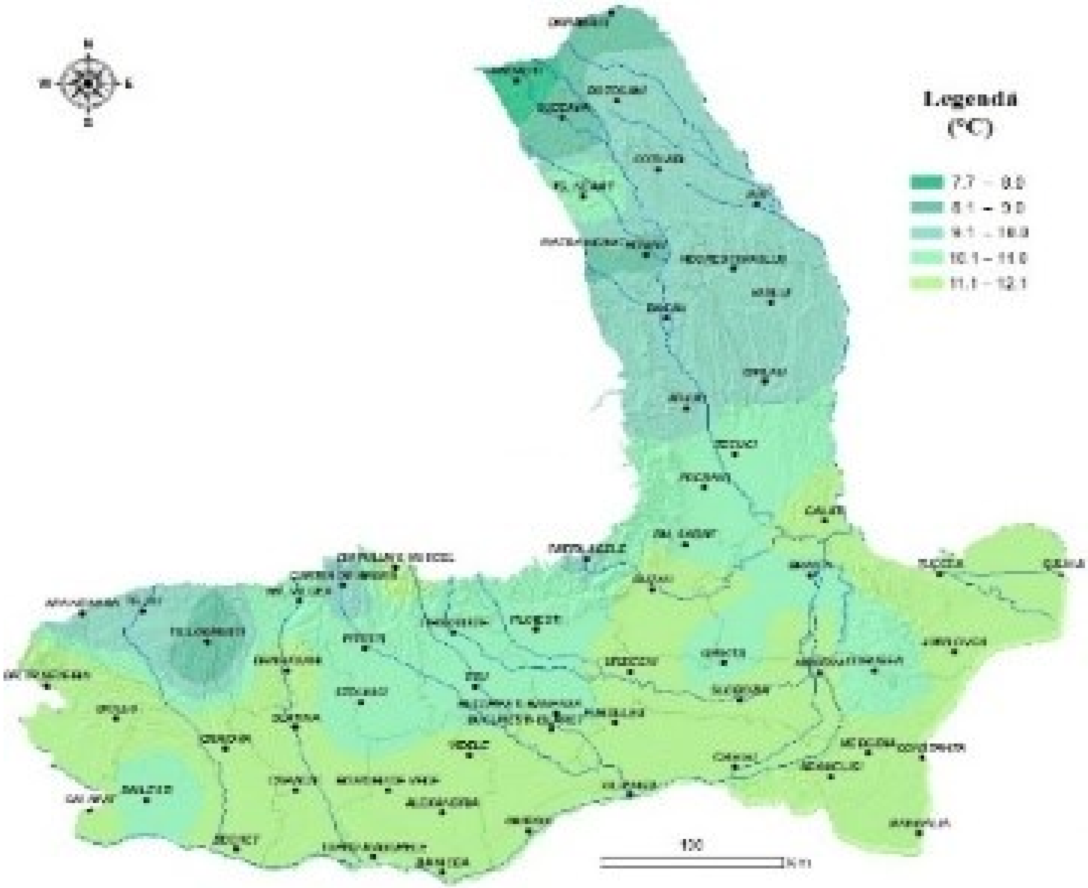


Fig. 2. Distribution of multiannual average temperature values in the extra-Carpathian region for the reference period 1981-2010 (source: created in ArcGIS based on ANM data)

Thus, in figures 1.a, 1.b and 2 the distribution of the annual average air temperature (°C) is presented in the extra-Carpathian region of Romania for the period 2012-2017 and for the reference period 1981-2010. Thus, it is observed that in 2012, 2015 and 2017 the average monthly air temperatures were up to almost 13°C, and in 2013, 2014 and 2016 they reached up to 12°C, recording values close to the multiannual average 1980-2010.

3.1. Analysis of the thermal regime for the spring season

In the spring season, average temperatures are positive throughout the country, reaching and exceeding 10ºC in Oltenia, the southern and eastern part of the Romanian Plain, Dobrogea, the Danube Delta and the Black Sea coast. In these areas, in some places, average spring temperatures of 11ºC are reached and exceeded.

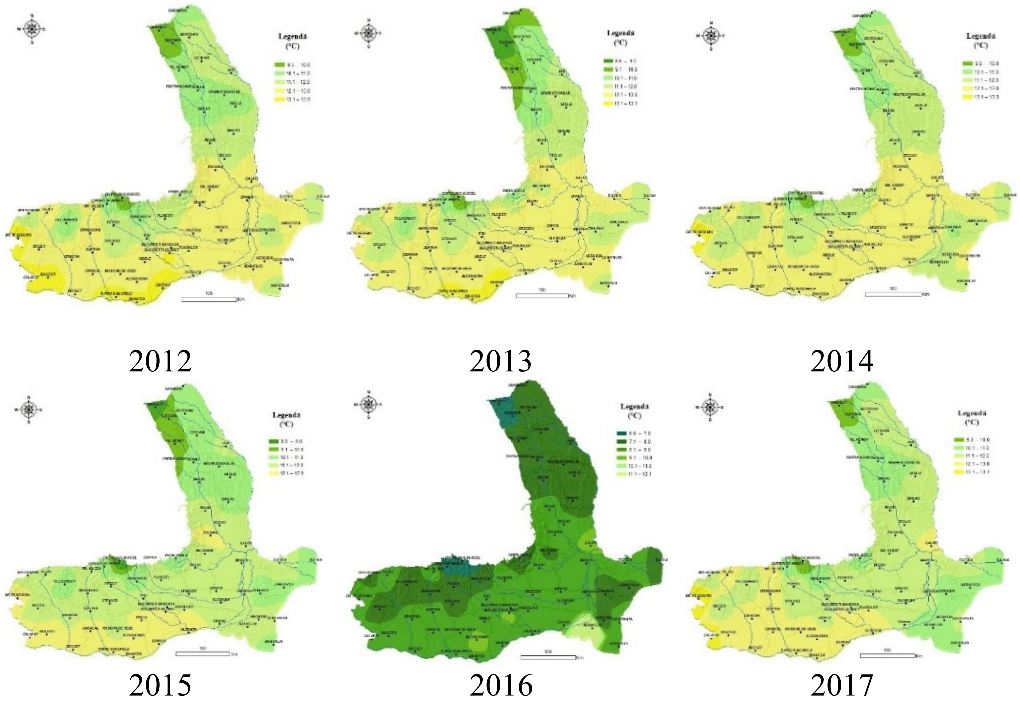


Fig. 3. Distribution of average annual temperature values for the spring season in the extra-Carpathian region for the period 2012-2017 (source: created in ArcGIS based on ANM data)

Figures 3 and 4 present the distribution of average annual air temperatures (°C) in the spring season for the period 2012-2017 and for the reference period 1981-2010. Thus, it can be seen that in 2012, 2013, 2014, 2015 and 2017, the average monthly air temperatures ranged between 8°C and 14°C, compared to the multiannual average for the period 1981-2010, recording values between 8°C and 12°C. Also, higher temperatures are observed for the entire Extracarpathian region for the period 2012-2017, which indicates an earlier start of the vegetation season than in the reference period.

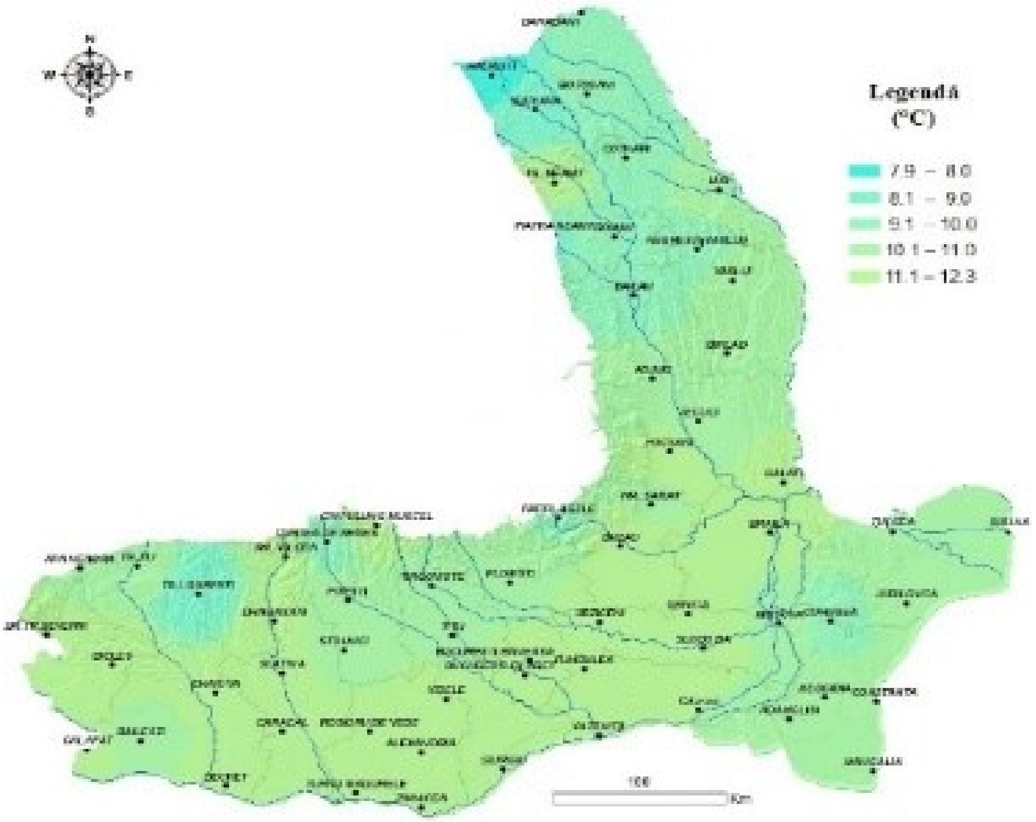


Fig. 4. Distribution of multiannual average temperature values for the spring season in the extra-Carpathian region for the reference period 1981-2010
(source: created in ArcGIS based on ANM data)

From the analysis of the maps, it can be seen that for 2016, slightly lower temperatures are identified for the spring season. The year 2016 is below the multiannual average of the 1981-2010 period, with values between 6°C and 12°C. This finding indicates the following aspect, for this year the start of the vegetation season is slightly delayed compared to the reference period.

3.2. Analysis of the thermal regime for the summer season

Figure 5 highlights the distribution of average temperature in the summer season during the period 2012-2017 and which was compared with the distribution of average temperature in the summer season for the reference period 1980-2010 (Fig. 6).

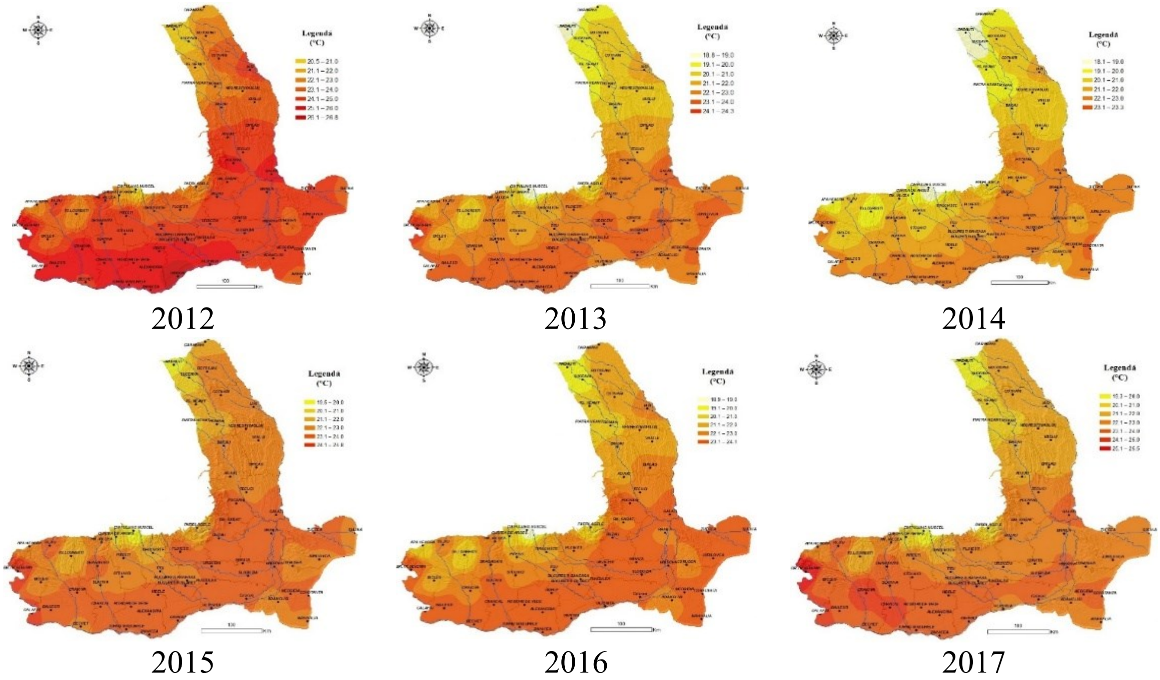


Fig. 5. Distribution of average temperature values for the summer season in the extra-Carpathian region during the period 2012-2017 (source: created in ArcGIS based on ANM

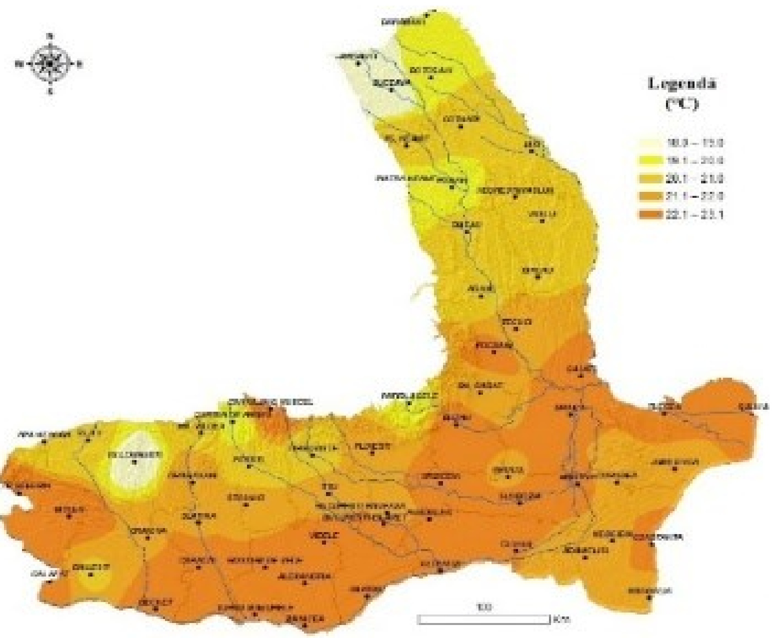


Fig. 6. Distribution of multiannual average temperature values for the summer season in the Extracarpathian region for the reference period 1981-2010
(source: created in ArcGIS based on ANM data)

Thus, it is noted from the comparison of the two figures that, in all years from 2012-2017, the average monthly air temperature was between 18°C and 27°C, higher values compared to the reference period 1981-2010.

For the reference period in the extra-Carpathian space, the temperature variation in this season varied in the value range between 18°C and 23°C. It is also noted that in 2012 the values in this season ranged between 21°C and 27°C, values much higher by 3°C ... 5°C compared to the multiannual average reference period 1981-2010, higher.

3.3. Analysis of the thermal regime for the autumn

In the autumn season, average temperatures return to values close to those of the spring season. The highest values are recorded for the coastal area, where values of 13°C were exceeded.

In this area, the largest differences between the temperatures of the spring and autumn seasons also occurred, on average by 3°C. In the rest of the extra-Carpathian territory, the differences between the average temperatures of the two seasons are significantly reduced to 1.5°C.

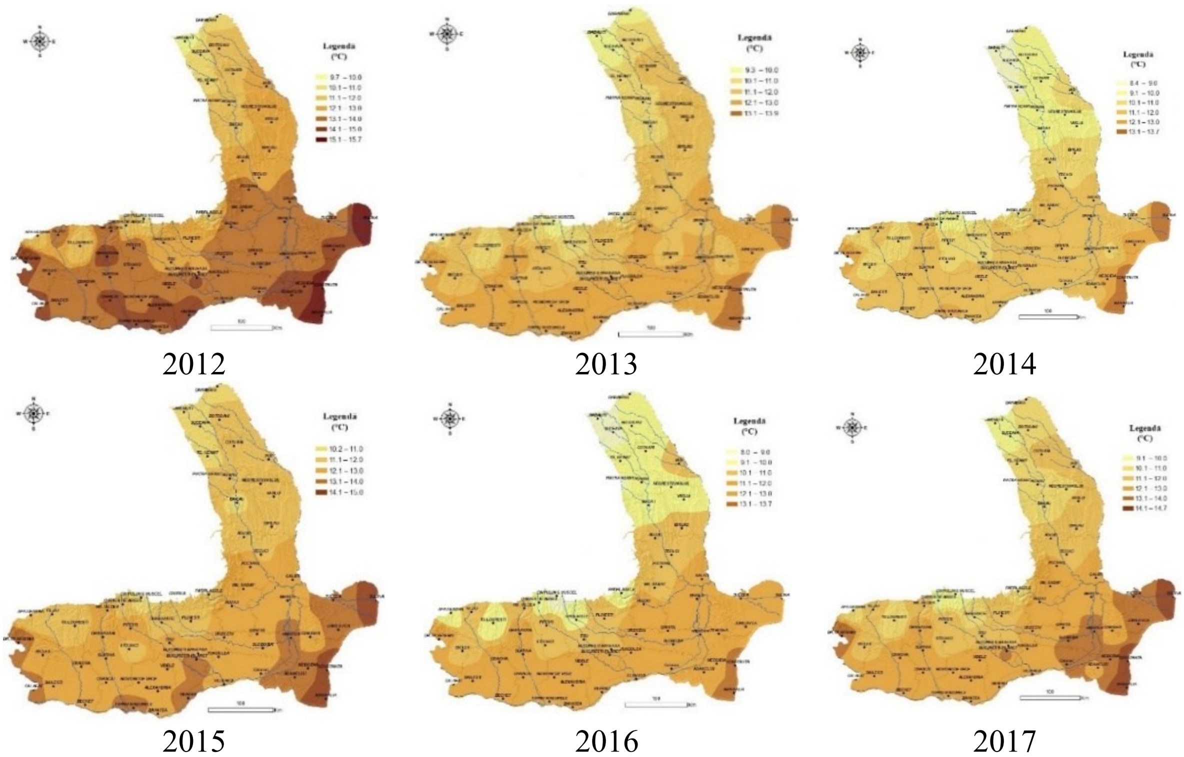


Fig. 7. Distribution of average annual temperature values for the autumn season in the extra-Carpathian region during the period 2012-2017 (source: created in ArcGIS based on ANM data)

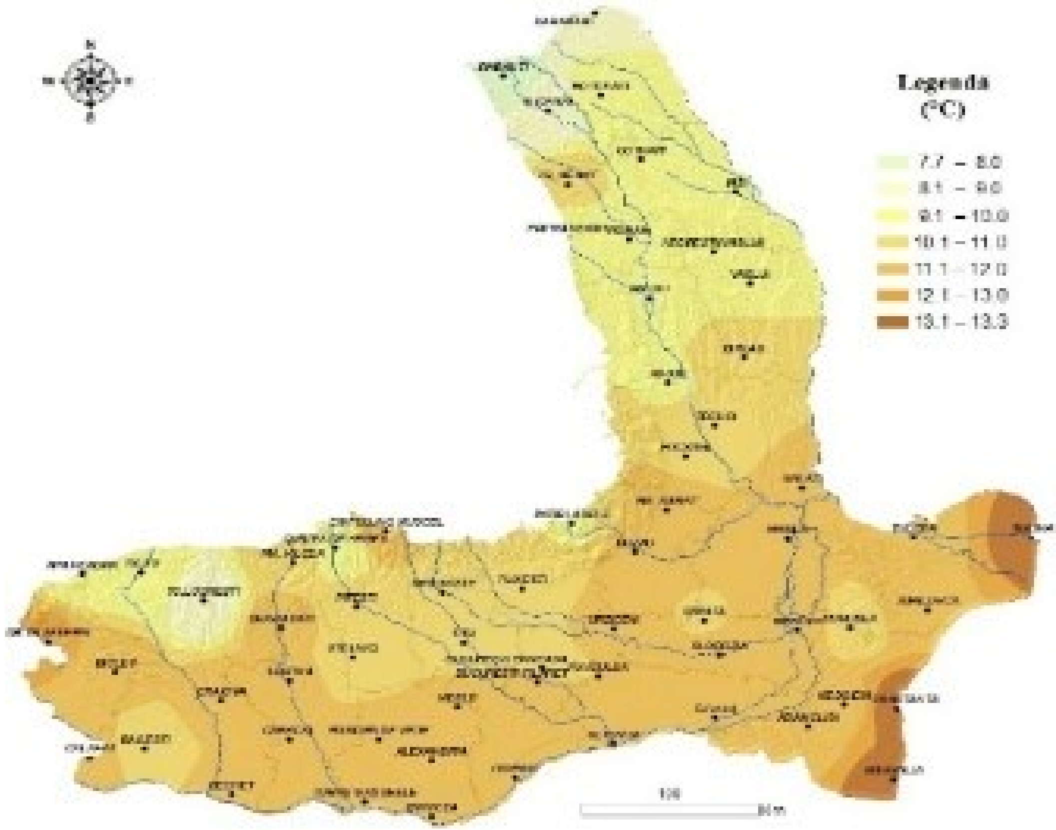


Fig. 8. Distribution of multiannual average temperature values for the autumn season in the extra-Carpathian region for the reference period 1981-2010
(source: created in ArcGIS based on ANM data)

In figure 7, the spatial distribution of temperature variation in the extra-Carpathian region in the autumn season for the period 2012-2017 is represented and in fig. 8 the distribution of average air temperature in the Extra-Carpathian region in the autumn season for the reference period 1980-2010 is represented.

From the analysis of the two figures it resulted that, in 2013, 2014, 2015, 2016 and 2017, the average monthly air temperatures were located in the range between 8°C and 15°C, higher values than the temperature values recorded in the reference period where the temperature values are located in the range 8°C and 13°C. It is found that the temperatures are lower by 2°C compared to the period 2012-2017.

Another aspect identified is related to the fact that in 2012 higher temperature values were recorded in the autumn season than the value in the reference period 1981-2010, these being between 10°C and 16°C. This may indicate a longer duration of the ripening period compared to the reference period.

3.1. Analysis of the thermal regime for the winter season

In the winter season, average temperatures are negative in most of the territory of our country. Average positive temperatures of the winter season are located on limited areas of the territory of our country, such as: the Black Sea coast, where in the southern part they reach and exceed 2ºC, the eastern part of Dobrogea and the Danube Delta, areas where the average winter temperature is between 0ºC and 1ºC, the Danube Plain west of Calafat, where average winter values oscillate around 1ºC.

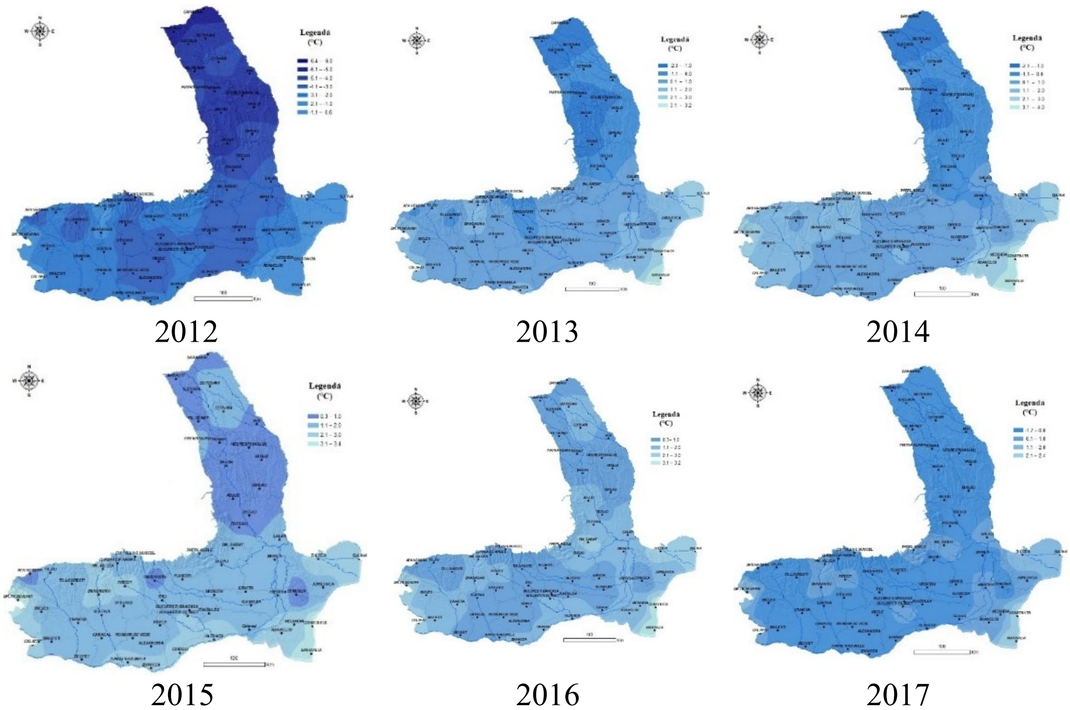


Fig. 8. Distribution of average annual temperature values for the winter season in the extra-Carpathian region during the period 2012-2017
(source: created in ArcGIS based on ANM data)

In figure 8 the spatial distribution of temperature variation in the extra-Carpathian region in the winter season for the period 2012-2017 is represented and in fig. 9 the distribution of air temperature in the extra-Carpathian region in the winter season for the reference period 1981-2010 is represented. From the analysis of the two figures it resulted that, in 2013, 2014, 2015, 2016 and 2017 the average temperature value for this season was between 0°C and 4°C, higher values than the average value in the period 1981-2010, where the values were between -3°C and 2°C.

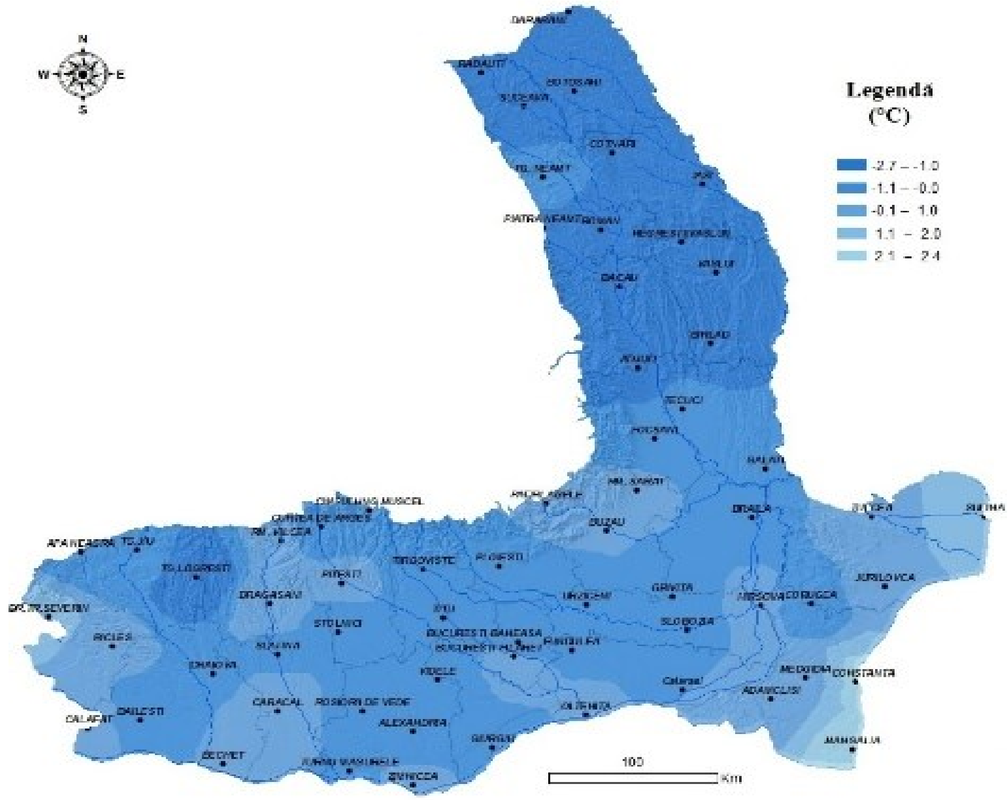


Fig. 9. Distribution of multiannual average temperature values for the autumn season in the extra-Carpathian region for the reference period 1981-2010
(source: created in ArcGIS based on ANM data)

It is worth noting that in 2012, lower air temperature values were recorded than the temperature value recorded in the reference period 1981-2010, when it was within the range of -6°C and 1°C. This highlights the fact that, for the analysis period 2012-2017, a year was recorded when the temperature in the winter season was much lower than the reference period.

Regarding the semi-annual variation of air temperature, it is found that in the cold season, the value calculated from the monthly averages for the period October-March, has positive values for areas with altitudes < 500 m, reaching the highest values in the coastal area of the Black Sea, approaching a value of 5ºC. High values (≥ 4ºC) are found along the Danube, west of Calafat and locally in the southern part of the Dobrogea Plateau.

The average temperature for the warm semester, which is determined between April and September, registers positive values, up to 19ºC along the Danube. Analyzing the thermal difference (the difference between the highest and lowest temperature values) across the country, for the two semesters, it results that in the warm semester it is around 17ºC, while in the cold semester it has a significantly lower value, 11ºC.

4. Technical implications of seasonal thermal regime variability

The variability of the thermal regime identified for the period 2012–2017 in the extra-Carpathian region of Romania has significant implications from the perspective of engineering applications that rely on climatic and geospatial data. The spatio-temporal differences in air temperature highlighted through GIS-based analysis influence the input parameters used in various fields of climate engineering, environmental engineering, and territorial analysis.

Higher air temperature values recorded during the spring season, compared to the 1981–2010 reference period, indicate a modification of the seasonal thermal regime, with implications for the establishment of initial conditions used in regional climate assessments. More frequent exceedance of positive thermal thresholds affects the temporal distribution of temperatures and should be considered in energy analysis models, thermal comfort assessments, and the design of infrastructure sensitive to climatic variability.

During the summer season, elevated air temperature values and the extension of periods with high mean temperatures highlight the need to integrate thermal variability into engineering applications aimed at thermal stress assessment, energy management, and climate risk analysis. Years characterized by pronounced positive thermal anomalies, such as 2012, emphasize the importance of using updated climatic datasets in planning and design processes.

The autumn season, characterized by higher mean temperatures compared to the reference interval, indicates a modification of the seasonal distribution of air temperature, with implications for assessing the duration of the active thermal regime.

This feature is relevant for engineering applications that employ seasonal climatic indicators, such as energy balance calculations or regional sustainability assessments.

Overall, the spatial analysis performed using Geographic Information Systems demonstrates the capability of the applied methodology to identify regional variations in the thermal regime and to provide relevant information for engineering applications.

The integration of the obtained results into a GIS framework enables their use in comparative analyses, climate impact studies, and geospatial data-driven decision-making processes, contributing to the development of technically sound approaches for assessing regional climate variability.

Conclusions

Conclusion (1).

The processing and spatial analysis of air temperature data using Geographic Information Systems enabled the assessment of spatio-temporal variability of the thermal regime in the extra-Carpathian region of Romania. The integration of climatological data into a GIS environment facilitated the generation of seasonal air temperature distributions and their comparison with the 1981–2010 climatological reference interval.

Conclusion (2).

The results highlight significant spatial and seasonal differences in air temperature, particularly during the spring and summer seasons, demonstrating the effectiveness of spatial analysis techniques in identifying regional thermal variability patterns. The applied methodological approach allows for coherent and reproducible processing of climatic datasets and can be extended to similar analyses at different spatial scales or in other regions.

Conclusion (3).

Overall, the proposed methodology provides a technical framework applicable to climate engineering and environmental engineering, supporting the integration of geospatial analysis into regional climate variability assessments.

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