STUDY OF THE URBAN HEAT ISLAND IN IASI MUNICIPALITY USING REMOTE SENSING AND GIS

Paul-Marian GHERASIMI[1], Mihai DIMA [1], Ioana AGAPIE (MEREUȚĂ) [1], Cornel DUDĂU[1]

e-mail: gheraspaul@gmail.com

Abstract

Current climate change in urban areas is manifested due to the rapid urbanization of cities around the world. The island of urban heat is represented by a metropolitan area significantly warmer than the environment. It is important to find a balance between urban expansion and the temperatures recorded in these areas to guarantee sustainable urban development. This paper is a study to highlight the temperature of the ground surface (LST values) both during the day and at night, for the area of Iasi municipality. Remote sensing and GIS techniques were used for the case study. In order to make LST maps, MODIS images, taken daily by the Terra and Aqua satellites between 2013-2018, were used as primary data. Also, a number of 8 sensors were installed on the ground in the study area in order to monitor the temperature in the 2013-2018 period. The conslusions of the study indicate the need and the importance of carrying out such analyzes in the study of environmental issues..

Key words: GIS, heat urban island, LST, MODIS, remote sensing

Concerns are currently being raised about the possible contribution of urban heat islands to global warming. While some lines of research have not detected a significant impact, other studies have concluded that heat urban islands can have measurable effects on global climate phenomena.

The phenomenon was first investigated and described by Luke Howard in the 1818. Research in urban areas has concluded that the temperature of the atmosphere and the earth's surface has increased significantly in urban areas compared to the environment. (Kumar A. *et al*, 2021).

Urban growth and the expansion of cities have dramatically changed the biophysical environment. Rapid urbanization has significant influences on various aspects of quality of life. For this reason, research to determine urbanization patterns and quantify their impact is a priority.

One of the major implications of urbanization is the development of the island of urban heat. The temperature of the earth's surface is increased due to anthropogenic discharges of heat, energy consumption, increased coverage of the earth's surface with artificial materials with high thermal capacities (Kumar S. *et al*, 2012).

Landsat ETM images are widely used to observe and model the biophysical characteristics of the earth's surface. In addition to obtaining land use maps, satellite imagery is useful for determining the temperature of the earth's surface. (Kumar S. *et al*, 2012).

To monitor the UHI (urban heat island) on a larger spatial scale, a ground temperature monitoring system must be set up and this is very expensive. The temperature of the earth's surface derived from satellite image processing is an affordable solution to solve this problem. (Muzaky H., Jaelani L. M., 2019).

Vegetation can provide colder microclimates through the process of evapotranspiration. Thus, the creation of urban vegetation areas is an extremely effective solution for reducing UHI and thus some of the worst effects of current climate change can be reduced. Terrestrial surface temperature (LST) is considered a reliable indicator of UHI because there is a close link between LST and the air temperature at the terrestrial surface. (Farina A., 2012).

Temperature changes are closely related to atmospheric carbon dioxide concentrations. The degree of concentration depends on human interventions and the amount of sunlight that reaches the earth's surface. Landsat satellite images are used to estimate land surface temperature and urban thermal conditions (Nwilo P. C. și colab., 2012).

According to the US Environmental Protection Agency, urban heat islands fall into two categories: SUHI (surface urban heat islands) and

[1]"Gh. Asachi" Technical University, Iași, Romania

AUHI (atmospheric urban heat islands). SUHI values are determined by satellite measurements using remote sensing and AUHI values are determined from fixed or mobile weather stations installed on the earth's surface (Sekertekin A., Zadbagher E., 2021).

MATERIAL AND METHOD

The studied area is represented by the city of Iași located in the North East of Romania, in the plain of Moldova. The city is crossed by the Bahlui River, a tributary of the Jijia River and has a predominantly continental climate (figure1).

In summer, dry weather and high temperatures predominate and in winter the region is frequently dominated by blizzards.

Geographically the study area is located between northern latitudes 47°12' to 47°06' and eastern longitudes 27°32' to 27°40'.

Figure 1 **Study area. Framing on the map of Romania, Iași County**

The research material is represented by the images acquired by the MODIS satellite system, taken daily by the Terra and Aqua satellites. The LST maps are processed in the ArcMap software and the results obtained will be detailed in this study.

When MODIS images are used as primary data to create LST maps, the calculation formulas vary depending on the type of images used.

In this paper, the images taken daily to determine the urban heat island were used, both during the night and during the day. This type of image is called MOD11A1 Version 6

Thus, to determine the LST values, for this type of image, it is necessary to multiply the pixel values by a factor provided by the manufacturer and transform from Kelvin degrees to Celsius degrees.

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RESULTS AND DISCUSIONS

For the period 2013-2018, only the days were selected, which fall into the category of heat waves according to the climatological definition, from May to September, which fell into one of the following categories:

- Under 30^0C
- Between 30^0C -35^0C
- Over 35^0C

Also, the night temperatures related to these days were analyzed, which were categorized as follows:

- Under 20^0C
- Between 20^0C -25^0C
- Over 25^0C

Next, the images (LST maps) were resampled and interpolated using the Spline technique.

$$S(x,y) = T(x,y) + \sum_{j=1}^{N} \lambda_j R(r_j)$$

where: j = 1, 2, ..., N, N - number of points, λj - solutions of the linear system - coefficients, rj - distance between points.

The maps corresponding to the LST values for the analyzed periods (daytime and nighttime temperatures) are presented below:

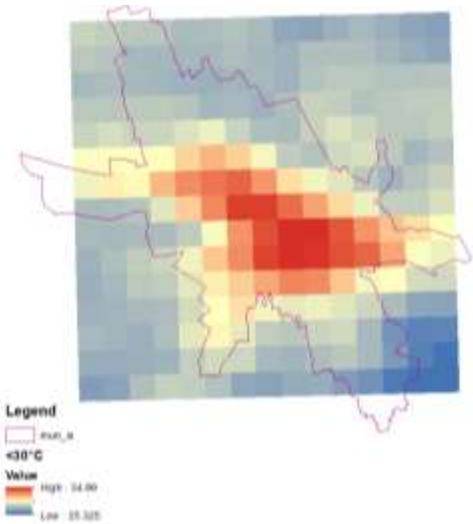


Figure 2 **The values of LST mun. Iași during May-September (2013-2018) for temperatures under 30⁰C**

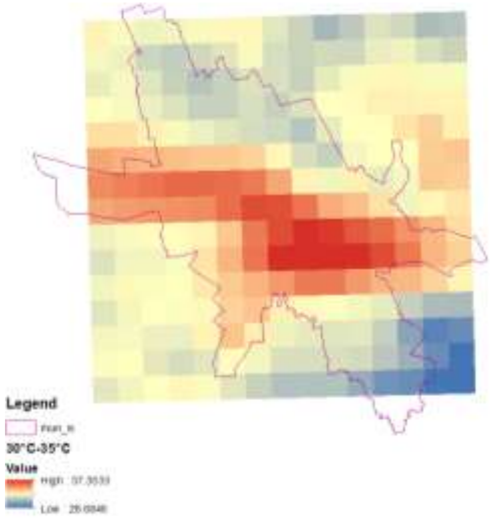


Figura 3 **The values of LST mun. Iași during May-September (2013-2018) for temperatures between 30⁰C-35⁰C**

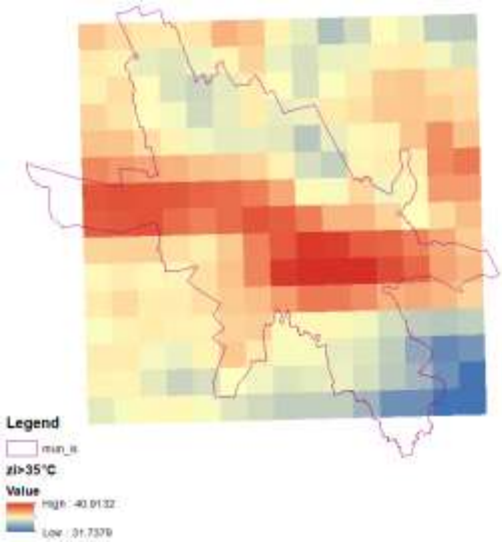


Figura 4 **The values of LST mun. Iași during May-September (2013-2018) for temperatures over 30⁰C**

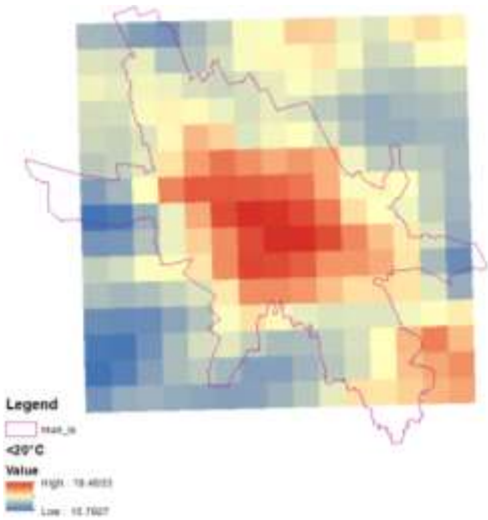


Figura 5 **The values of LST mun. Iași during May-September (2013-2018) for night temperatures under 20⁰C**

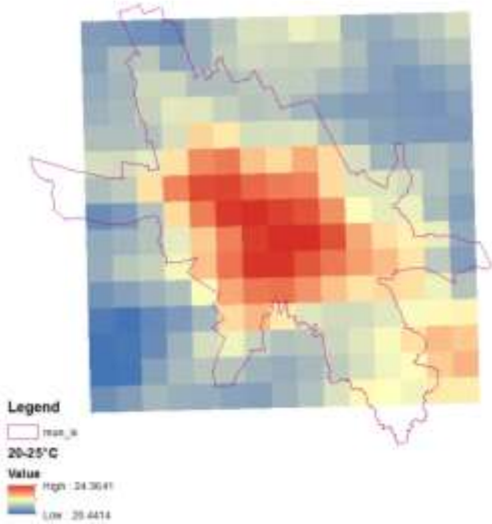


Figura 6 **The values of LST mun. Iași during May-September (2013-2018) for night temperatures between 20⁰C-25⁰C**

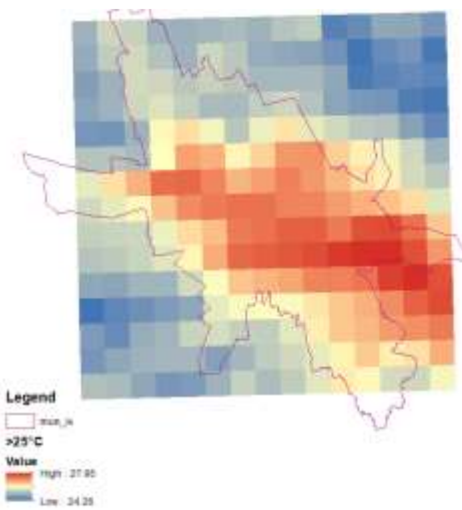


Figura 7 **The values of LST mun. Iași during May-September (2013-2018) for night temperatures over 25⁰C**

The study of the relationship between soil temperature and meteorology was possible with the help of a number of 8 sensors installed on the ground. They monitored the temperature according to meteorological regulations, in the shade, 1.5 meters above the ground, in a protected area (cage), during 2013-2018. The scheme of their arrangement is presented in *figure 8*. The data taken by these sensors will be compared with those obtained using satellite techniques and the correlation coefficient for a linear function will be determined.

Based on the statistical data on the data provided by the sensors, for the analyzed period, the linear correlation between them and the data provided by modern technology (remote sensing) was studied. The graphs and linear coefficients are presented below (*figure 9*, *figure10*).

It can be seen that during the night the linear coefficients have a value much closer to 1 (0.8-0.86) than during the day, when the values are around 0.5, which confirms and specifies the literature, that the heat island is much more obvious at night than during the day.

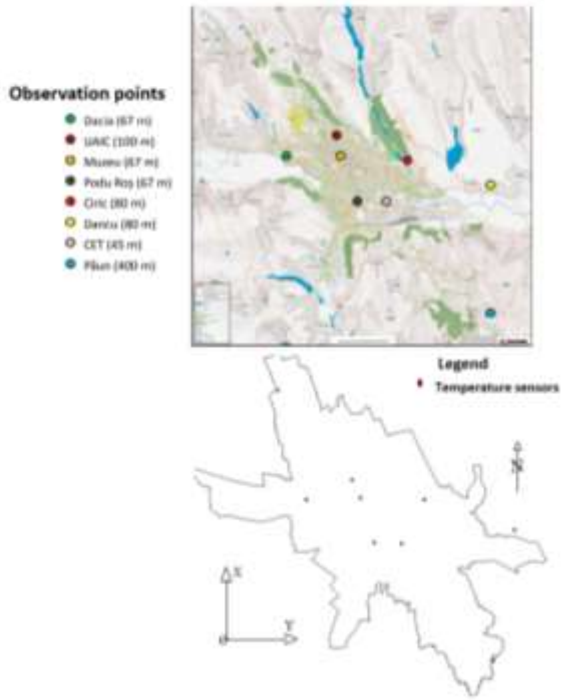


Figure 8 **Location of observation points and temperature sensors on the map of Iasi**

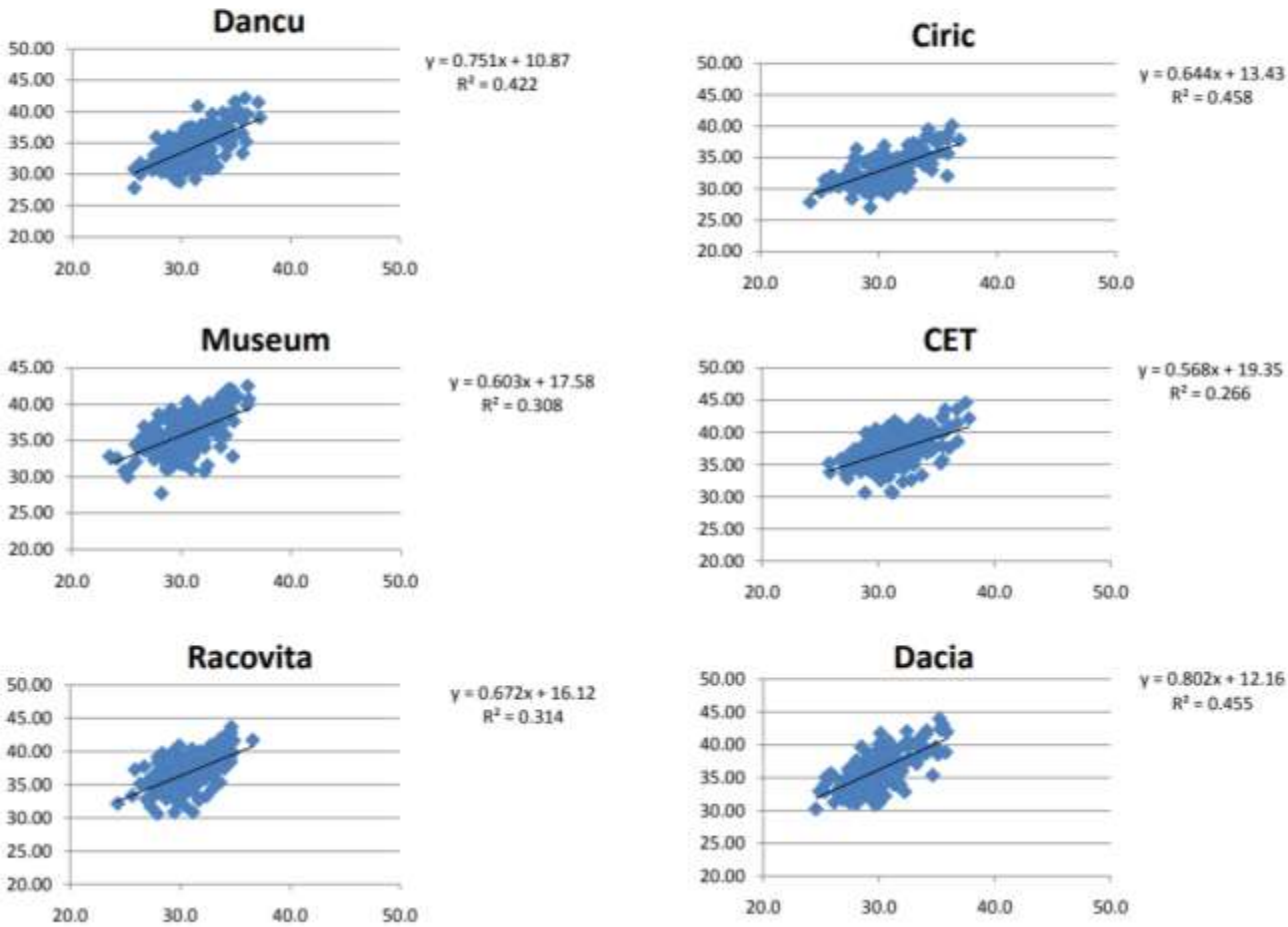


Figure 9 **Graphs of linear coefficients during the day**

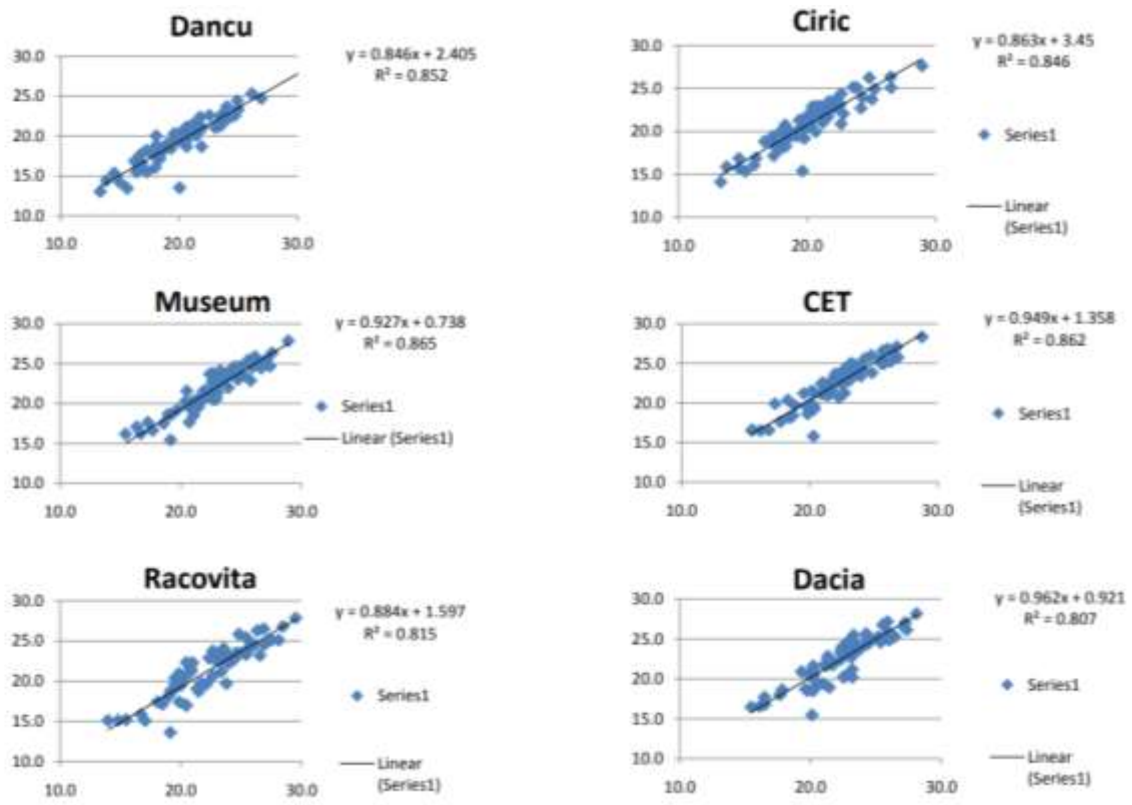


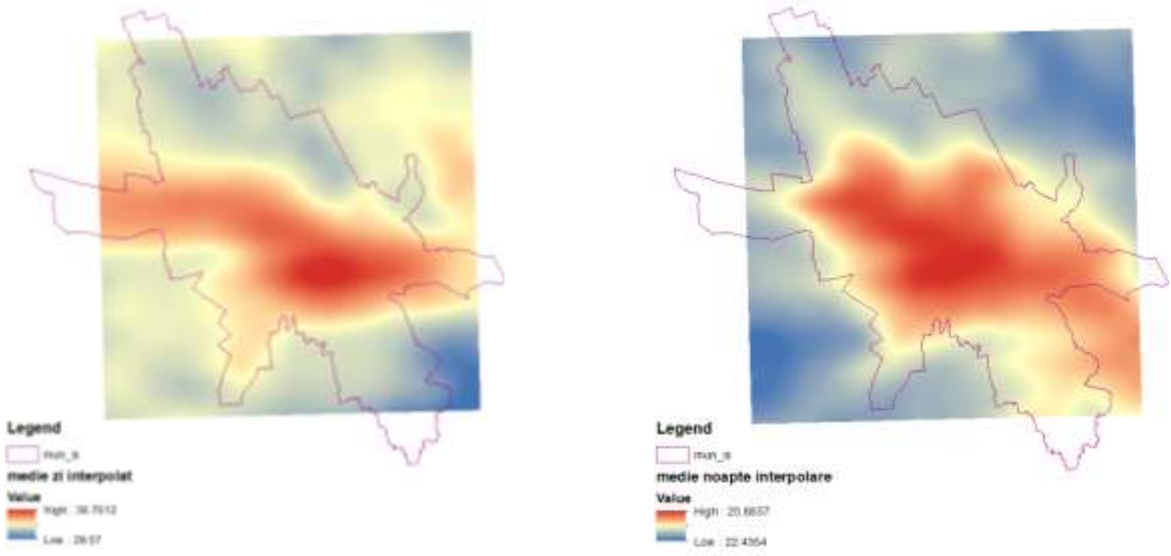
Figure 10 **Graphs of linear coefficients during the night**

ESRI is number 1 in the GIS markets as a result of the company's extensive experience and significant number of users.

ArcMap software was used to perform GIS analysis. This software is able to create thematic maps, GIS projects directly exploitable for editing and updating GIS data.

After the interpolation in ArcMap of the LST values obtained in the first part of the study, the maps with the interpolated LST values for the analyzed period resulted.

The final maps with the representation of the LST values were made by averaging the values obtained during the day and at night for the analyzed period.



a. b.

Figure 11 **The values of LST mun. Iași in the period may-september (2013-2018) for temperatures: a – interpolated day averages; b – interpolated night averages**

Using the specific functions of the software used (ArcMap) the radiant temperatures for the built area were determined.

The graphic expression and statistical data are presented below, both for day time and for night time.

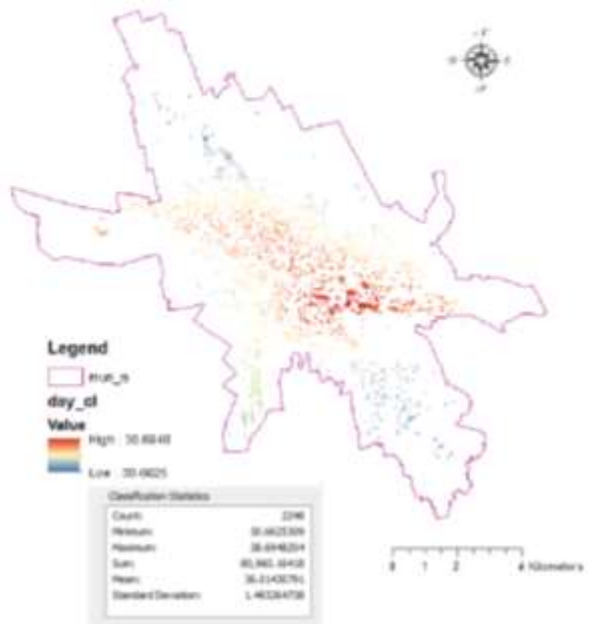


Figure 12 **Map of the radiant temperature distribution for the built-up area during the day on the territory of Iași municipality**

The statistical data show that the average temperature is 36°C, the data being determined with a standard deviation of 1.5°C.

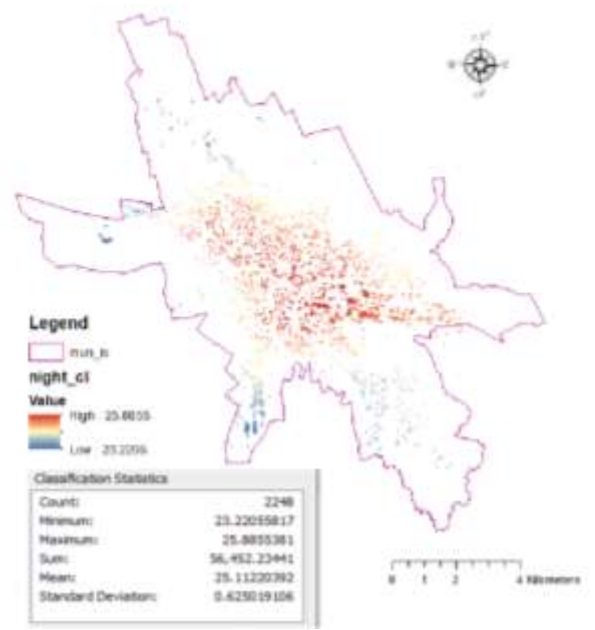


Figure 13 **Map of the radiant temperature distribution for the built-up area during the night on the territory of Iași municipality**

CONCLUSIONS

It can be seen that during the night the average temperature was 25.1°C, given that they varied in the range of 23.2-25.9°C, with a standard deviation of 0.65°C.

Thus, it can be seen that the average temperature at night is much closer to the maximum value, compared to the case during the day, which emphasizes once again that during the night the heat island is much stronger than during the day.

Geodetic and photogrammetric methods have an increasingly important weight in the study of environmental issues.

Active remote sensing has become a benchmark in providing data for environmental and quality of life research. An obvious example is the satellite images provided by satellite systems that are part of the field of passive remote sensing to determine the islands of urban heat.

Considering the fight against climate change, the determination of urban heat islands is a very important factor, as they represent the areas where extreme weather events have the largest share.

From the data taken by the meteorological sensors and the MODIS satellite data, it resulted that in Iași is an urban heat island, strongly amplified by the built-up area, as specified in the specialized literature.

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