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PRELIMINARY STUDY ON METHODS FOR IDENTIFYING URBAN HEAT ISLANDS – CASE STUDY – THE SOUTHERN AREA OF ROMANIA

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Abstract: *The urban heat island is the phenomenon by which cities become considerably warmer due to the absorption and retention of heat by built surfaces. The study of urban heat islands is a current topic in Romania as well. In this paper, we present a methodology for detecting climate change using extreme values of air temperature and atmospheric precipitation. Modeling urban heat islands (UHI) using GIS tools and climate software involves the integration of spatial and atmospheric data to analyze the temperature distribution and the impact of urban factors on the microclimate.*

In the case of this paper, we conducted a data collection covering the period 2017 -2025, regarding a series of atmospheric parameters from 58 locations related to air quality monitoring stations in 8 geographical areas of Romania. Due to the limitations of the size of the presented study, the limitation was made to the south-eastern area of Romania – which includes a set of 9 monitoring stations – 4 stations in Galaţi County and 4 stations in Brăila County.

The algorithm used includes: multivariate analysis - based on the PCA method, clustering - based on methods such as k-means to group the stations according to thermal behavior and comparative graphs between stations, thermal and vector maps (for wind), correlation and regression diagrams, etc. Using spatial interpolation procedures based on methods such as IDW or Kriging to create thermal maps, we managed to obtain a zonal classification: divide the city into zones (central, peripheral, green, etc.) and compare the essential parameters

Key words: *Heat islands, ICU, statistical analysis, GIS.*

1. INTRODUCTION

Urbanization applies a very complex action on the climate, both through the appearance of artificial surfaces and through changes in energy flows at ground level (1). The study of urban heat islands is a current topic in the world and particularly in Romania (2), especially in the context of climate change. Urban heat islands (UHI) represent urban areas where the temperature is significantly higher than in neighboring rural areas, due to build surfaces (concrete, asphalt), lack of vegetation and human activities (3). The study of urban heat islands (UHI) is essential for understanding and managing the impact of urbanization on local climate and population health.

In general, two methods have been developed to assess the intensity of UHI (4). First, UHI can be quantified by cross-sectional measurements across the city, considering the temperature values in the city center being compared with those in neighboring rural areas. Second, UHI can be quantified by remote sensing. The temperature in urban areas can be higher than in rural areas in any season, but the most significant impact occurs in the summer season, when urban heating (UHI) amplifies the natural warming of the atmosphere, leading to serious consequences for the lives of the urban population. This paper presents a study on heat islands in the south-eastern area of Romania (5).

2. STUDY AREA

The study area in this paper is represented by the 4 counties in South-Eastern Romania: Galati, Braila, Tulcea and Constanta. The monitoring stations are described in Table 1 and the position map in Fig.1.

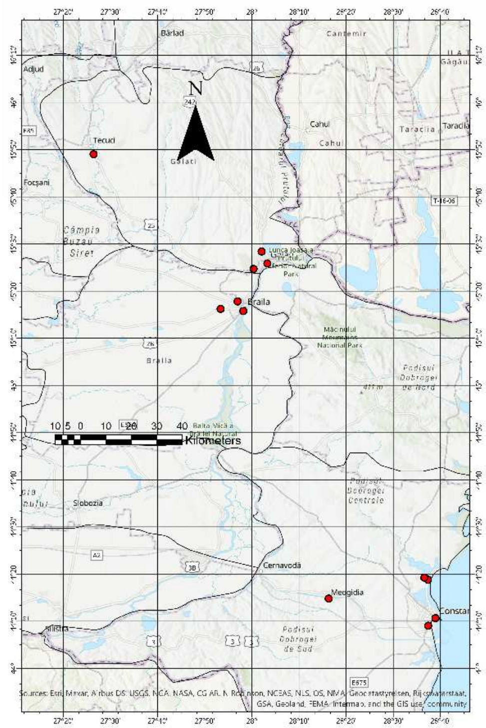

Fig. 1. The study area and the monitoring station.

Table 1

Coordinates of monitoring stations.

name	Longitude	Latitude
BR-2	27.96951	45.26314
BR-3*	27.88921	45.27087
BR-4	27.94946	45.29733
CT-2	28.64968	44.17648
CT-3*	28.62294	44.31226
CT-5	28.62382	44.14938
CT-6	28.61029	44.31964
CT-7	28.27169	44.24566
GL-2	28.05474	45.43154
GL-3*	28.03441	45.47416
GL-4	28.00597	45.41187
GL-5	27.43959	45.81826
TL-2	27.96951	45.26314

To substantiate the study, we took data from these stations belonging to the National Air Monitoring Network, with a resolution of 1 hour. (https:// www.calitateaer.ro/). For comparison, we considered two time periods for this work - 01.05.2017 - 30.10.2027 and 01.05.2024 - 30.10.2024. Each study period allowed the acquisition of 4360 records for each monitoring station considered.

3. RESULTS

In the first study period, temperature data were collected. statistical description of this data set – Table 2.

Table 2

Descriptive statistics – year 2017.

name	mean	min	max	Std. err
BR-2	22.28093	1.9300	101.00	11.87157
BR-3	24.09779	0.2200	101.00	19.36543
BR-4	22.37412	1.0200	101.00	14.12678
CT-2	20.62000	3.6400	35.760	5.37271
CT-3	19.89370	2.3000	34.65	5.47860
CT-5	19.82971	2.9000	34.79	5.63096
CT-6	21.03064	3.2600	101.00	8.23757
CT-7	20.67343	3.5400	37.04	6.27396
GL-2	22.41868	3.3800	101.00	14.07705
GL-3	20.71892	1.57	101.00	7.82870
GL-4	20.29117	1.78	38.32	6.63820
GL-5	19.69859	0.19	101.00	7.76760
TL-2	21.96625	3.63	101.00	12.19493

In the second study period, temperature data were collected. statistical description of this data set – Table 3.

Table 3

Descriptive statistics – year 2024.

name	mean	min	max	Std. err
BR-2	24.7626	2.28	101.00	22.88684
BR-3	23.6567	0.64	101.00	34.85308
BR-4	21.6532	0.27	38.97	7.25897
CT-2	25.0486	2.94	101.00	20.73079
CT-3	19.9603	1.96	35.68	6.10782
CT-5	19.8678	1.75	101.00	37.13336
CT-6	21.9125	3.70	101.00	35.66840
CT-7	26.9779	2.16	101.00	40.77141
GL-2	24.3494	3.25	101.00	39.32430
GL-3	20.8452	0.23	38.28	6.93306
GL-4	19.4897	1.30	36.34	7.04512
GL-5	29.8003	2.48	101.00	39.48418
TL-2	24.7626	2.28	101.00	22.88684

By comparing the two tables, a slight variation is observed, with a small increase for the values in 2024.

2.1 Statistical analysis for variability analysis

- **2.1.1 ANOVA analysis for diurnal variation**

Table 4 and Table 5 respectively present the ANOVA analyses for diurnal regimes for each station. It is observed that for suburban regime stations - considered as a benchmark, the variations have significant confidence factors ($p<0.05$).

Table 4

ANOVA results - Hourly values – year 2017.

name	F- value	p value
BR-2	F(23,4355) = 18.6043	0.0000
BR-3	F(23,4356) = 5.4572	0.0000
BR-4	F(23,4356) = 9.697	0.0000
CT-2	F(23,4346) = 1.8127	0.0101
CT-3	F(23,4346) = 53.1481	0.0000
CT-5	F(23,4346) = 0.6174	0.9207
CT-6	F(23,4346) = 0.0352	---
CT-7	F(23,4346) = 0.197	---
GL-2	F(23,4346) = 0.061	---
GL-3	F(23,4346) = 60.3463	0.0000
GL-4	F(23,4346) = 70.034	0.0000
GL-5	F(23,4346) = 0.0959	---
TL-2	F(23,4346) = 0.4046	0.0000

the stations for which the p-coefficient values show values that exceed the significance level are the stations where insignificant diurnal variations were recorded - i.e. points where urban traffic is intense (Table 4 and Table 5). For example, the GL-2 station is a point located in the city center.

Table 5

ANOVA results - Hourly values – year 2024.

name	F- value	p value
BR-2	F(23,4346) = 0.0146	---
BR-3	F(23,4346) = 0.0901	0.0000
BR-4	F(23,4356) = 9.697	0.0000
CT-2	F(23,4226) = 1.7512	0.0146
CT-3	F(23,4226) = 53.0891	0.0000
CT-5	F(23,4226) = 0.6041	0.9295
CT-6	F(23,4226) = 0.0354	---
CT-7	F(23,4226) = 0.1842	---
GL-2	F(23,4226) = 0.0618	---
GL-3	F(23,4226) = 57.3458	0.0000
GL-4	F(23,4226) = 66.6586	0.0000
GL-5	F(23,4226) = 0.0970	---
TL-2	F(23,4226) = 0.3725	0.9972

- **2.1.2 ANOVA analysis for week days variation**

Table 6 and Table 7 respectively present the ANOVA analyses for week days regimes for each station. It is also observed that for suburban regime stations - considered as a benchmark, the variations have significant confidence factors ($p<0.05$).

Table 6

ANOVA results – week days values – year 2017.

name	F- value	p value
BR-2	F(6,4372) = 11.2502	0.0000
BR-3	F(6,4373) = 25.1668	0.0000
BR-4	F(6,4373) = 6.4232	0.0000
CT-2	F(6,4363) = 4.4378	0.0002
CT-3	F(6,4363) = 1.1244	0.3452
CT-5	F(6,4363) = 0.1925	0.9790
CT-6	F(6,4363) = 0.7254	0.6291
CT-7	F(6,4363) = 0.5015	0.8076
GL-2	F(6,4363) = 0.7276	0.6274
GL-3	F(6,4363) = 0.8222	0.5525
GL-4	F(6,4363) = 0.8254	0.5500
GL-5	F(6,4363) = 1.367	0.2239
TL-2	F(6,4363) = 0.7412	0.6164

For each value, the number of records that was taken into account is also indicated. The fact that some stations in the monitoring network had short periods of time in which they did not record, determines that the numbers expressing df - degree of freedom, are slightly different.

Table 7

ANOVA results - week days – year 2024.

name	F- value	p value
BR-2	F(6,4363) = 0.9168	0.4815
BR-3	F(6,4363) = 0.9882	0.4313
BR-4	F(6,4363) = 0.8026	0.5678
CT-2	F(6,4243) = 5.2903	0.00002
CT-3	F(6,4243) = 1.4909	0.1770
CT-5	F(6,4243) = 0.2922	0.9409
CT-6	F(6,4243) = 0.2859	0.9439
CT-7	F(6,4243) = 0.8682	0.5173

GL-2	F(6,4243) = 0.3501	0.9102
GL-3	F(6,4243) = 1.1451	0.3332
GL-4	F(6,4243) = 1.0918	0.3646
GL-5	F(6,4243) = 0.7649	0.5975
TL-2	F(6,4243) = 1.3446	0.2335

- **2.1.3 ANOVA analysis for seasonal variation**

Table 8 and Table 0 respectively present the ANOVA analyses for seasonal regimes for each station. It is also observed that for suburban regime stations - considered as a benchmark, the variations have significant confidence factors ($p<0.05$).

Table 8

ANOVA results – season values – year 2017.

name	F- value	p value
BR-2	F(2,4367) = 399.4834	0.00000
BR-3	F(2,4367) = 2324.2048	0.00000
BR-4	F(2,4367) = 1547.211	0.00000
CT-2	F(2,4247) = 209.3507	0.00002
CT-3	F(2,4247) = 1527.432	0.0000
CT-5	F(2,4247) = 6188.3186	0.0000
CT-6	F(2,4247) = 3094.1177	0.0000
CT-7	F(2,4247) = 941.4329	0.0000
GL-2	F(2,4367) = 47873.2596	0.0000
GL-3	F(2,4367) = 1764.2583	0.0000
GL-4	F(2,4367) = 1612.0223	0.0000
GL-5	F(2,4367) = 11811.8539	0.0000
TL-2	F(2,4367) = 355.8158	0.0000

Table 9

ANOVA results - season values – year 2024.

name	F- value	p value
BR-2	F(2,4367) = 399.4834	0.0000
BR-3	F(2,4367) = 2324.2048	0.0000
BR-4	F(2,4367) = 1547.211	0.0000
CT-2	F(2,4367) = 235.4531	0.0000
CT-3	F(2,4367) = 1658.00	0.0000
CT-5	F(2,4367) = 6520.2138	0.0000
CT-6	F(2,4367) = 3225.287	0.0000
CT-7	F(2,4367) = 1118.597	0.0000
GL-2	F(2,4247) = 45926.3013	0.6274
GL-3	F(2,4247) = 1709.2399	0.5525
GL-4	F(2,4247) = 1562.9683	0.5500
GL-5	F(2,4247) = 11331.4774	0.2239
TL-2	F(2,4247) = 296.9620	0.6164

2.2 GIS numerical approach analysis

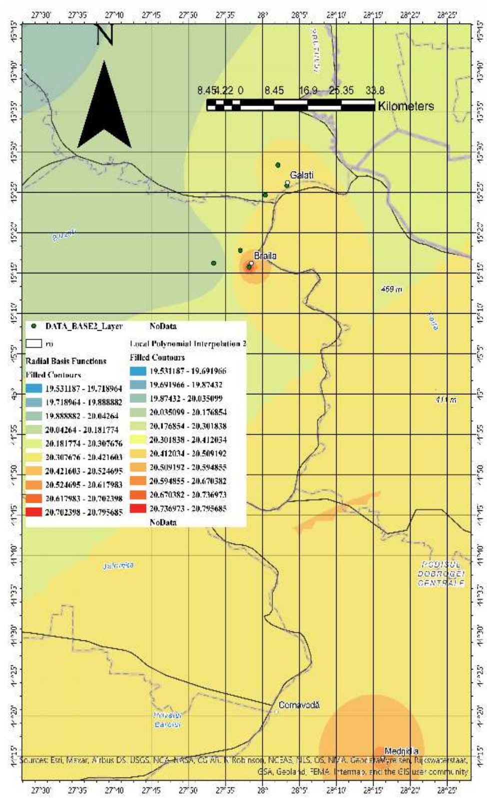

Fig. 2. Temperature distribution – year 2017

In the numerical approach, we used a first-order model to evaluate the urban heat island index (5) -UHII using the definition relation (1):

$$UHII_{thsh}(DH) = \\ = \{UHII'_{thsh} - \delta_{thsh}\} \times CF_p \times\times CF_{tp} \quad (1)$$

Or, equivalent:

$$UHII = \\ = \sum_{h=1}^{H(JJA)} [\mathrm{T}_{u,k,h} - \min(\mathrm{T}_{u,k,h}, \mathrm{T}_{nu,k,h})] \quad (2)$$

where $T_{u,k,h}$ is the urban temperature at time-step h, $T_{nu,k,h}$ is the nonurban temperature at time-step h, H is the number of time-steps, and k is the location index (census tract). The calculation yields a cumulative UHII (in degree-hours) over designated periods.

Figures 3 and 4 present the distributions of the average values obtained for the time intervals considered for the study. The interpolation used method ArcGIS procedure - Inverse Distance Weighted (IDW) interpolation - method often used in the literature (2).

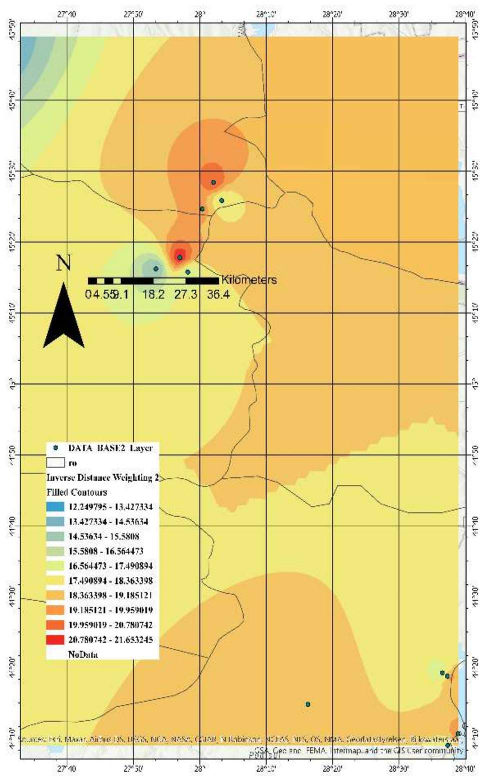

Fig. 3. Temperature distribution – year 2024

As it is well known, the Inverse distance weighted (IDW) interpolation is a spatial analysis method that estimates unknown values based on the assumption that closer known points are more similar than farther ones (1). I

t calculates a value for an unknown location(3) by taking a weighted average of nearby known points, where the weights are inversely proportional to the distance from the unknown point, often raised to a power (4).

By comparing the two maps, a significant difference in the temperature distribution is observed (2), with significantly increased values in the period May - October 2024 compared to the corresponding period in 2017.

In both maps, the existence of areas with lower temperatures is observed - in the South-West part of Galati municipality, in the area of the confluence with the Siret River.

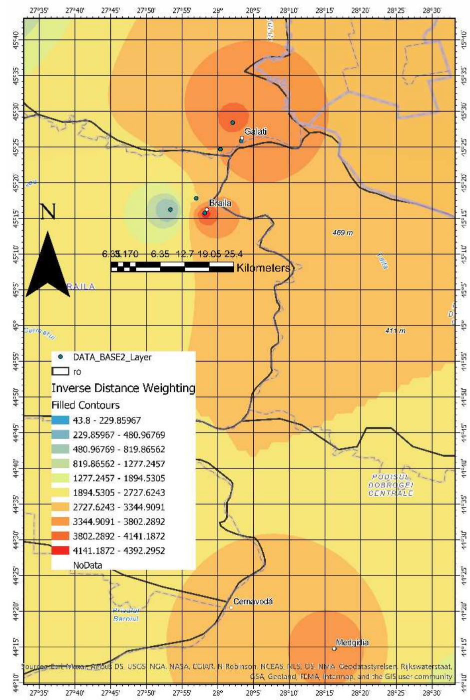

Fig. 4. UHII values distribution – year 2017

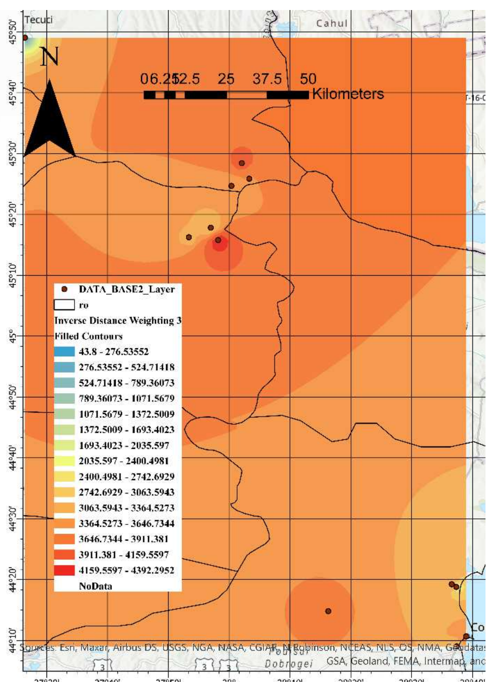

Fig. 6. UHII values distribution – year 2024

Figures 5 and 6 present the distributions of the UHII index values obtained for the time intervals considered for the study. The interpolation used method is IDW interpolation- method often used in the literature (2). It is observed that, if in 2017, in the central area of Galati city, for example, the

UHII index had a maximum value of over 3300, in 2024, in the central areas of Galati and Braila city, the UHII index exceeded the value of 3600.

4. CONCLUSIONS

The study concluded that the temperature of the city is not to be considered as that of the climate. Measuring the models and assessing UHII in individual cities can provide valuable data sets for further studies, while guiding urban planning and design policies.

In the assessments that can be carried out, cities that do not respect the appropriate urban structure, (such as places with extremely tall buildings, close together) can be identified. Naturally, tall buildings may be located on the outskirts of the city, rather than in the center;

- Cities that are expanding (horizontally and vertically) very rapidly and where reference UHI values can be used to assess the effect of urban land management policies.

5. REFERENCES

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Studiu preliminar privind metodele de identificare a insulelor de căldură urbane – studiu de caz – zona sudică a României

Rezumat: Încălzirea urbană reprezintă fenomenul prin care orașele devin mai calde din cauza absorbției și retenției căldurii de către suprafețele construite. În această lucrare este prezentată o metodologie de detectare a schimbărilor climatice prin analiza valorilor extreme ale temperaturii aerului și precipitațiilor. Studiul utilizează instrumente GIS și software climatic pentru modelarea distribuției temperaturilor și evaluarea impactului factorilor urbani asupra microclimatului. Baza de date acoperă perioada 2017–2025 și include 58 de locații, însă analiza detaliată a fost limitată la zona de sud-est a României (Galați și Brăila). Algoritmul aplicat integrează analiza multivariată (PCA), metode de clustering (k-means), corelații, regresii și interpolări spațiale (IDW, Kriging) pentru realizarea hărților termice și clasificarea zonală a orașului.

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