A country scale assessment of the heat hazard-risk in urban areas

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Partners

The LST_cci project aim:

- to provide an accurate view of temperatures across land surfaces globally over the past 20 to 25 years and meet the requirements of Global Climate Observing System (GCOS) for climate applications by developing techniques to merge archived data from a variety of satellites into a combined long-term satellite record for climate.

https://climate.esa.int/en/projects/land-surface-temperature/about/

- Objectives
- Study area
- Data and methods
- Results
- Conclusion and further developments

Acknowledgement

This study has received funding from the European Space Agency (ESA) within the framework of the Land Surface Temperature project under the Climate Change Initiative (LST_cci).

Objectives

- To perform a country-scale assessment of the Heat Hazard-Risk (HHR) over the most populated urban areas in Romania
- To develop an EO-based service to produce the real-time HHR monitoring and to support the urban planning at country scale

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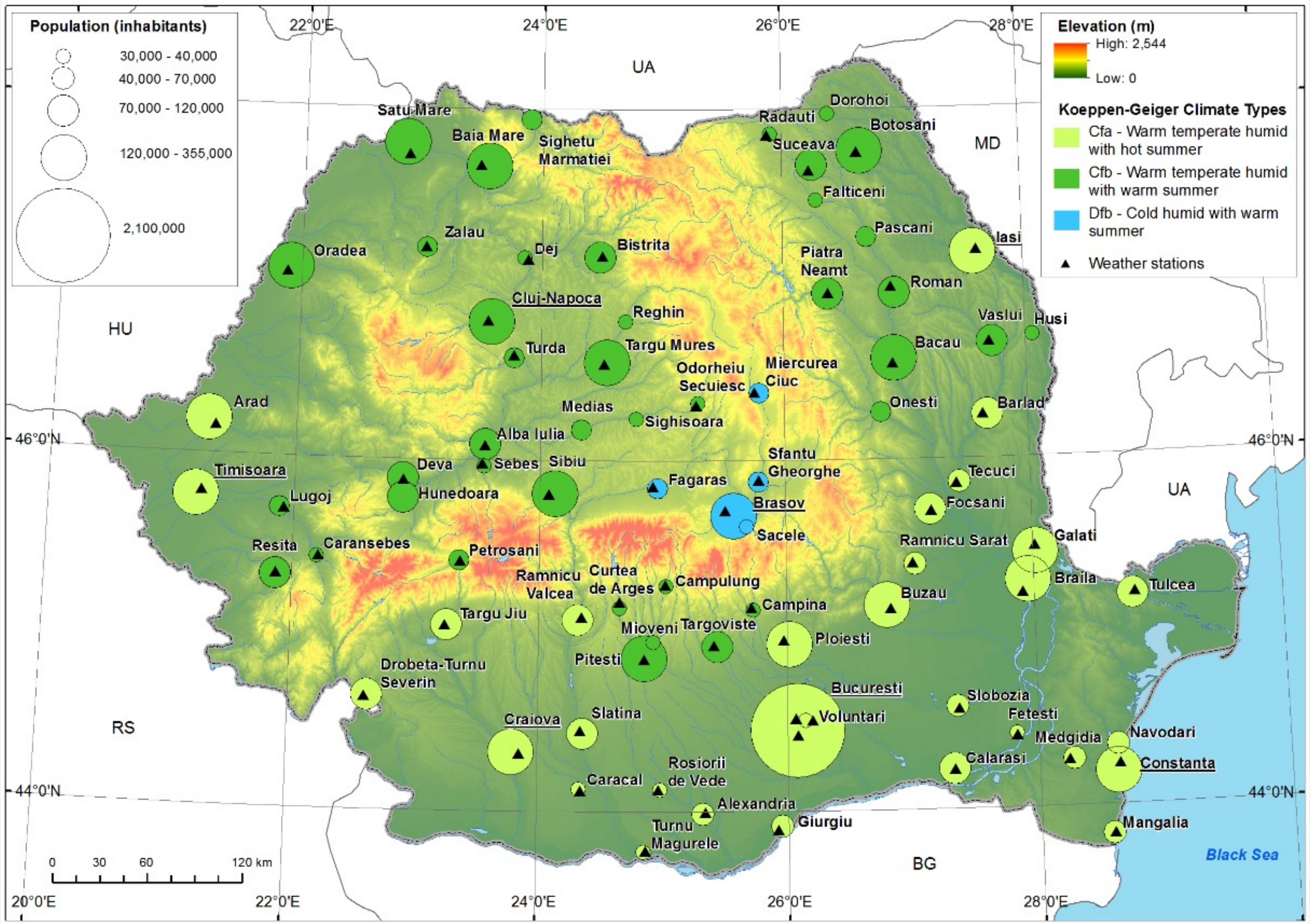
Study area

- 77 cities in Romania
- at least 30,000 inhabitants



Data and methods

- **Risk matrix approach; R = HH x V**
- **HH = Heat Hazard** triggered by high temperatures (i.e. Land Surface Temperature LST)
- **V = Vulnerability** associated with (1) urban structure (i.e. Local Climate Zones LCZ), and (2) population density (i.e. PD).

Data and methods

- **Step 1:** Computing the **Heat Hazard layer**
- **Step 2:** Computing the **Vulnerability layer**
- **Step 3:** Computing the **Heat Hazard-Risk**

Data and methods. Step 1: Computing the Heat Hazard (HH) layer

- MODIS LST_cci products (LST_cci): customised TERRA_MODIS_L3C and AQUA_MODIS_L3C produced within the project LST_cci+ (CCI LST, 2020).
- The products are available four times per day, i.e., 2 night- and 2 day-time images, at 1 km spatial resolution.
- The overpass time of the images used in this study ranges between 08:01 and 12:12 UTC (daytime), and between 19:01 and 01:12 UTC (nighttime).
- Time span: 2000-2018

Data and methods. Step 1: Computing the Heat Hazard (HH) layer

$$HH = \sum(nLST_{d40} + nLST_{n20})$$

HH = cumulated number of cases when LST > 40°C (TX >=30 hot days) during daytime ($nLST_{d40}$), and/or LST > 20°C (TN >=20 °C nocturnal discomfort index) during nighttime ($nLST_{n20}$)

Data and methods. Step 1: Computing the Heat Hazard (HH) layer

LST_cci and T2m median values (°C) and differences (diff) in July, averaged over 5 population-size based classes of cities in Romania

	Class 1	*Class 2*	*Class 3*	*Class 4*	*Class 5*
LST_CCI_night	23.4	18.9	19.1	18.1	17.6
T2m_night	21.2	19.1	19.3	18.8	18.4
LST_CCI_day	44.0	38.3	37.9	37.9	37.7
T2m_day	30.0	28.0	28.0	27.9	27.6
diff LST_CCI - T2m_night	**2.2**	**-0.2**	**-0.2**	**-0.7**	**-0.8**
diff LST_CCI - T2m_day	**14.0**	**10.3**	**9.9**	**10.0**	**10.1**

Source: Cheval et al (2022). MODIS-based climatology of the Surface Urban Heat Island at country scale (Romania). *Urban Climate*, 41, 101056. https://doi.org/10.1016/j.uclim.2021.101056

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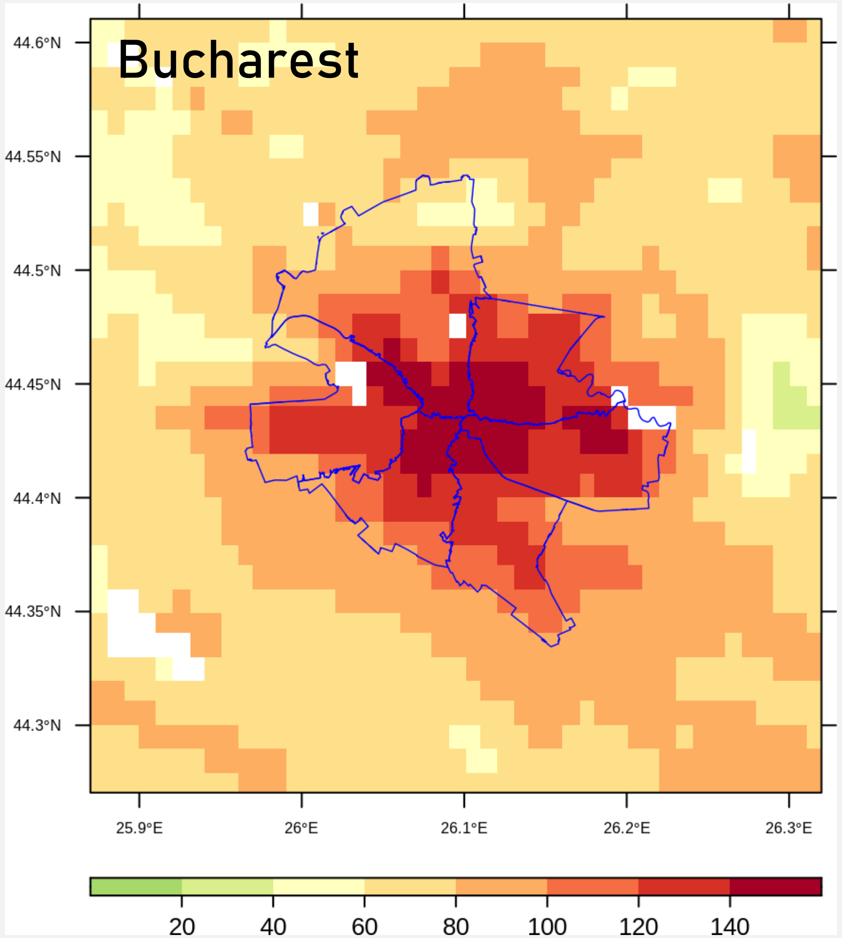
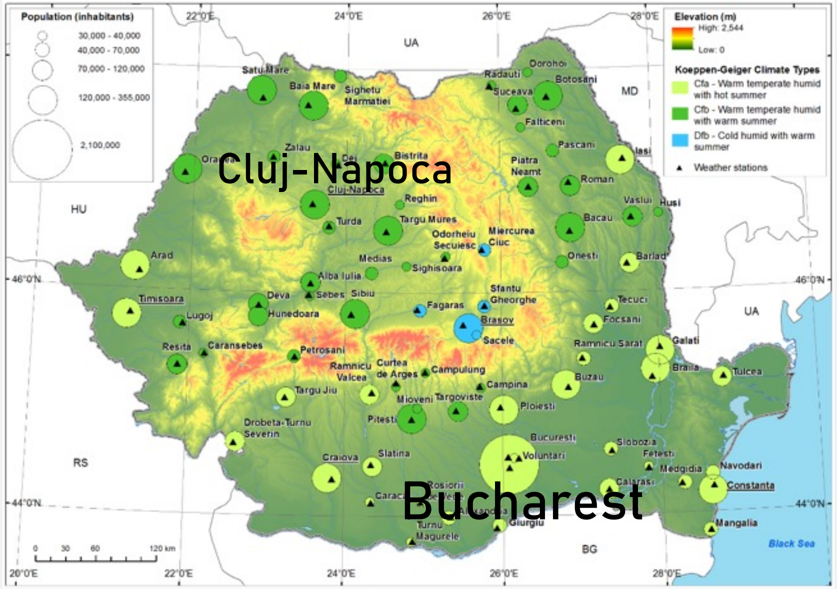
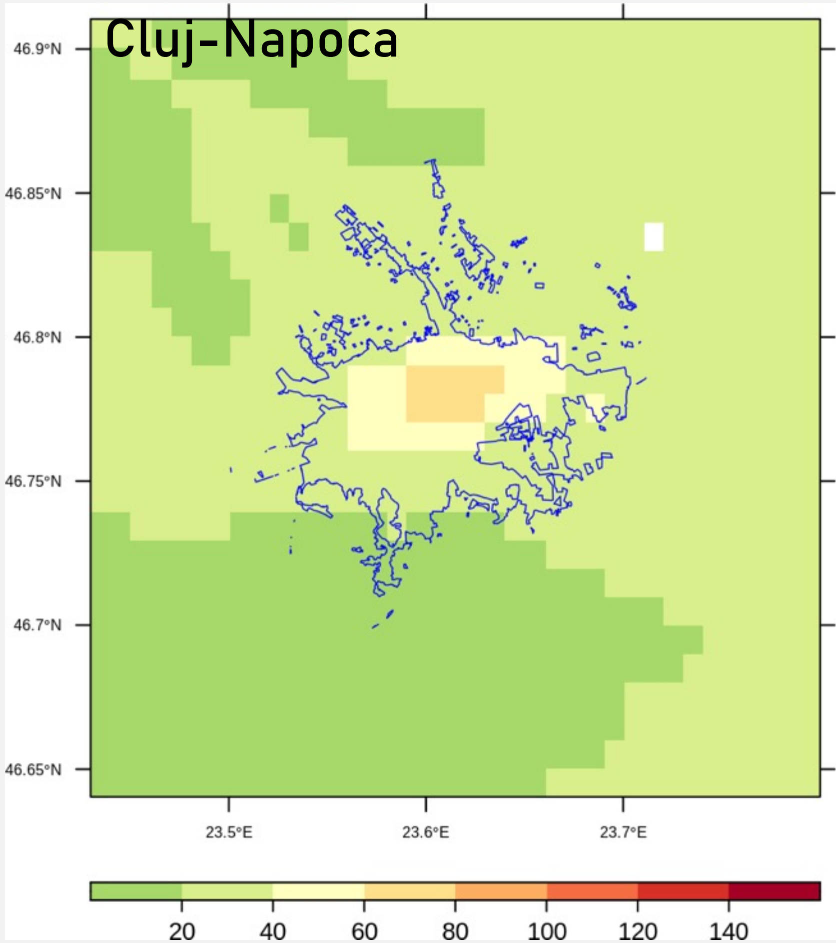
Data and methods

- Step 1: Computing the heat hazard (HH) layer

Average number of cases when daytime LST > 40°C and/or nighttime LST > 20°C







Data and methods. Step 2: Computing the Vulnerability layer (LCZ)

- The LCZ information were extracted from a database characterising the urbanised landscapes of Europe
- The LCZ derived within the World Urban Database and Access Portal Tools (WUDAPT) project (Demuzere et al., 2019), available at https://www.wudapt.org/
- The LCZ were classified in 5 vulnerability classes at the city level, i.e. decreasing from 5 for the most urbanized LCZ to 1 for the lowest urbanized LCZ

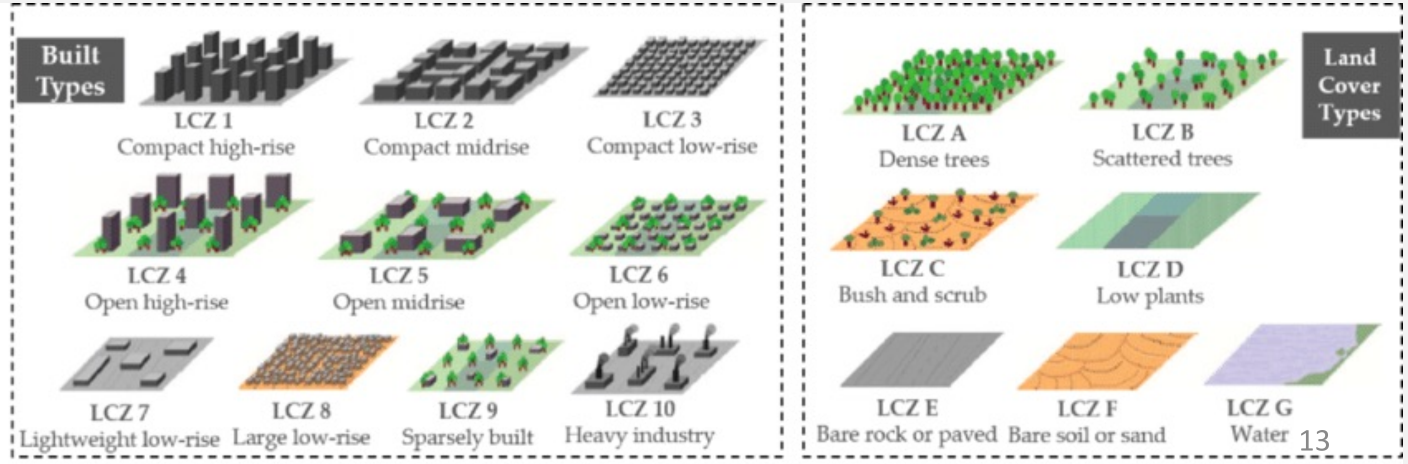
Data and methods. Step 2: Computing the Vulnerability layer (LCZ)

Vulnerability classes (VC) of the LCZ as derived from the quintile-based classification of the summer average night- and day-time LST (LST_N and LST_D) in Bucharest.

VC=1 is the lowest vulnerability and VC=5 is the highest vulnerability associated with LCZ

LCZ	1	2	3	4	5	6	7	8	9	10	A	B	C	D	E	F	G
LST_N	NA	22.1	20.3	20.7	20.9	18.7	NA	20.3	17.8	NA	NA	18.1	19.0	17.8	18.8	19.1	9.0
LST_D	NA	31.2	29.8	29.1	29.8	27.5	NA	29.5	26.3	NA	NA	26.2	28.6	26.8	27.9	28.3	5.6
VC (Vulnerability classes)	NA	5	5	5	5	2	NA	4	1	NA	NA	1	3	1	3	3	1

LCZ extracted from a European database characterising the urbanised landscapes derived within the World Urban Database and Access Portal Tools (WUDAPT) project (Demuzere et al., 2019)



Data and methods. Step 2: Computing the Vulnerability layer (PD)

- The population density (PD): number of inhabitants per 100 m2;
- PD retrieved from the Joint Research Centre (JRC) database (Joint Research Centre, 2016);
- PD classified in 5 quintile-based vulnerability classes, i.e. decreasing from 5 for the highest PD to 1 for the lowest PD values.

Data and methods. Step 2: Computing the Vulnerability layer (V)

$$V = \frac{LCZ + PD}{2}$$

- Urban vulnerability (*V*) to *HH* was computed as the average between the quintile-based LCZ and quintile-based PD

Data and methods. Step 3: Computing the Heat Hazard-Risk

Heat hazard-risk matrix combining HH (defined by LST_cci), and V (defined by LCZ and PD)

$$HHR = HH \times V$$

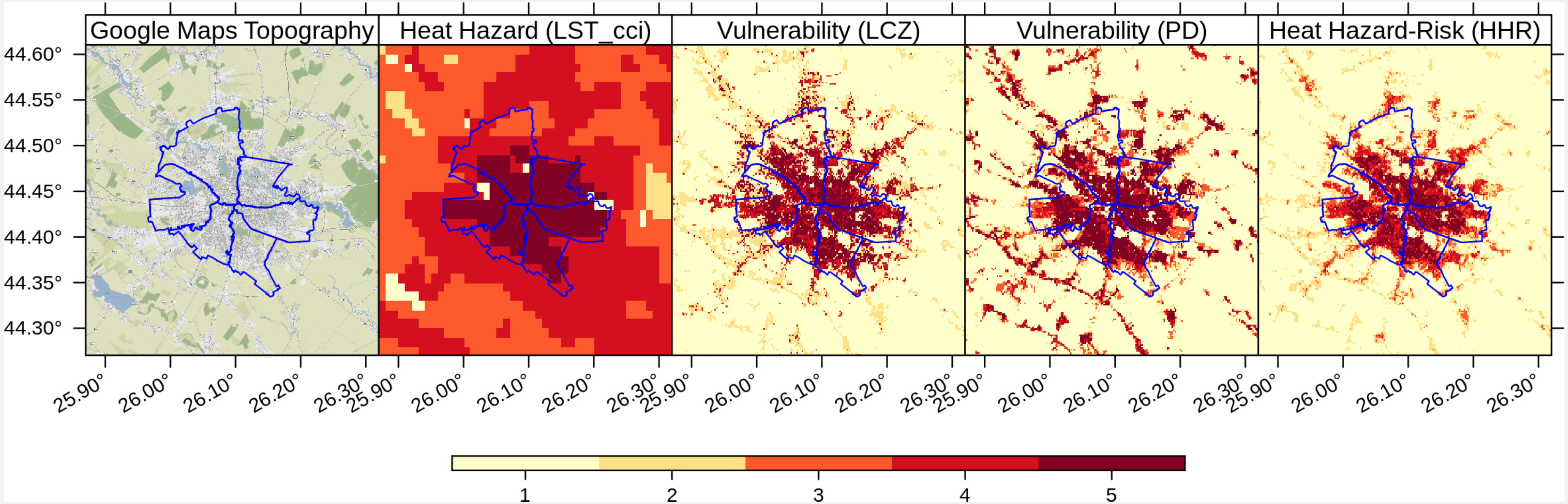
V (LCZ; PD)	HH (LST_cci)				
	1 (very low)	2 (low)	3 (average)	4 (high)	5 (very high)
5 (very high)	5	10	15	20	25
4 (high)	4	8	12	16	20
3 (average)	3	6	9	12	15
2 (low)	2	4	6	8	10
1 (very low)	1	2	3	4	5

HHR classes

1 <= HHR <=5: very low risk (HHR=1)
6 <= HHR <=10: low risk (HHR=2)
11 <= HHR <=15: average risk (HHR=3)
16 <= HHR <=20: high risk (HHR=4)
21 <= HHR <=25: very high risk (HHR=5)

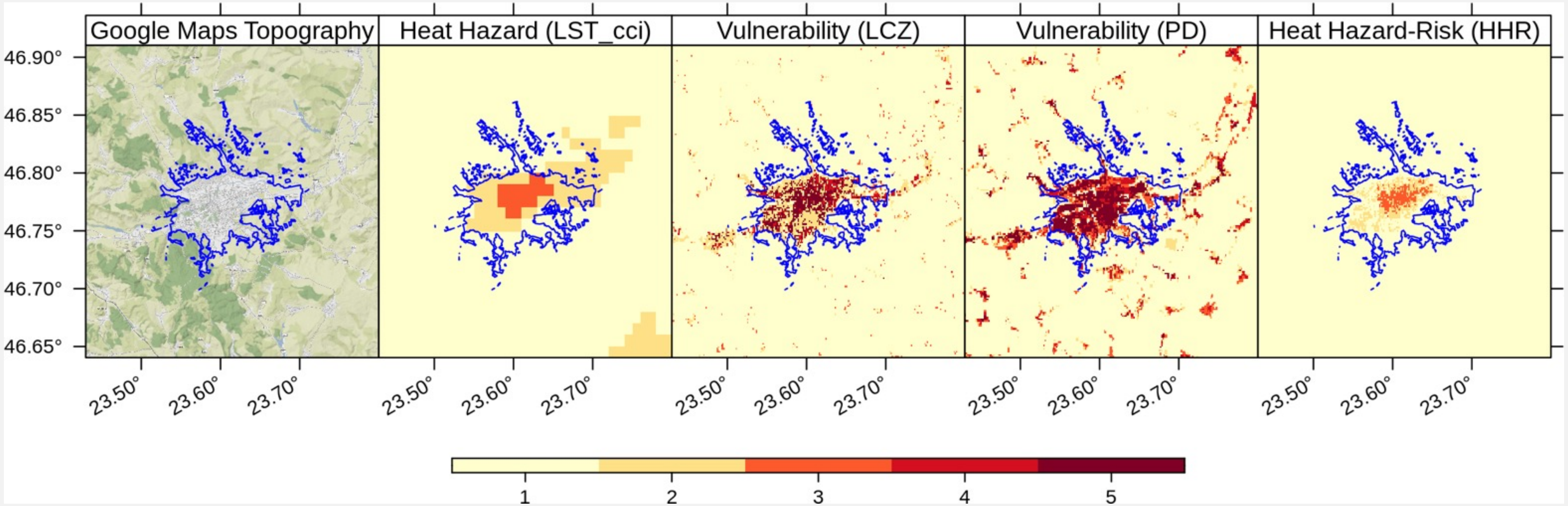
Results

The HHR and predictors considered in this study (HH computed as a function of LST, and V derived from LCZ and PD) in Bucharest (Romania)



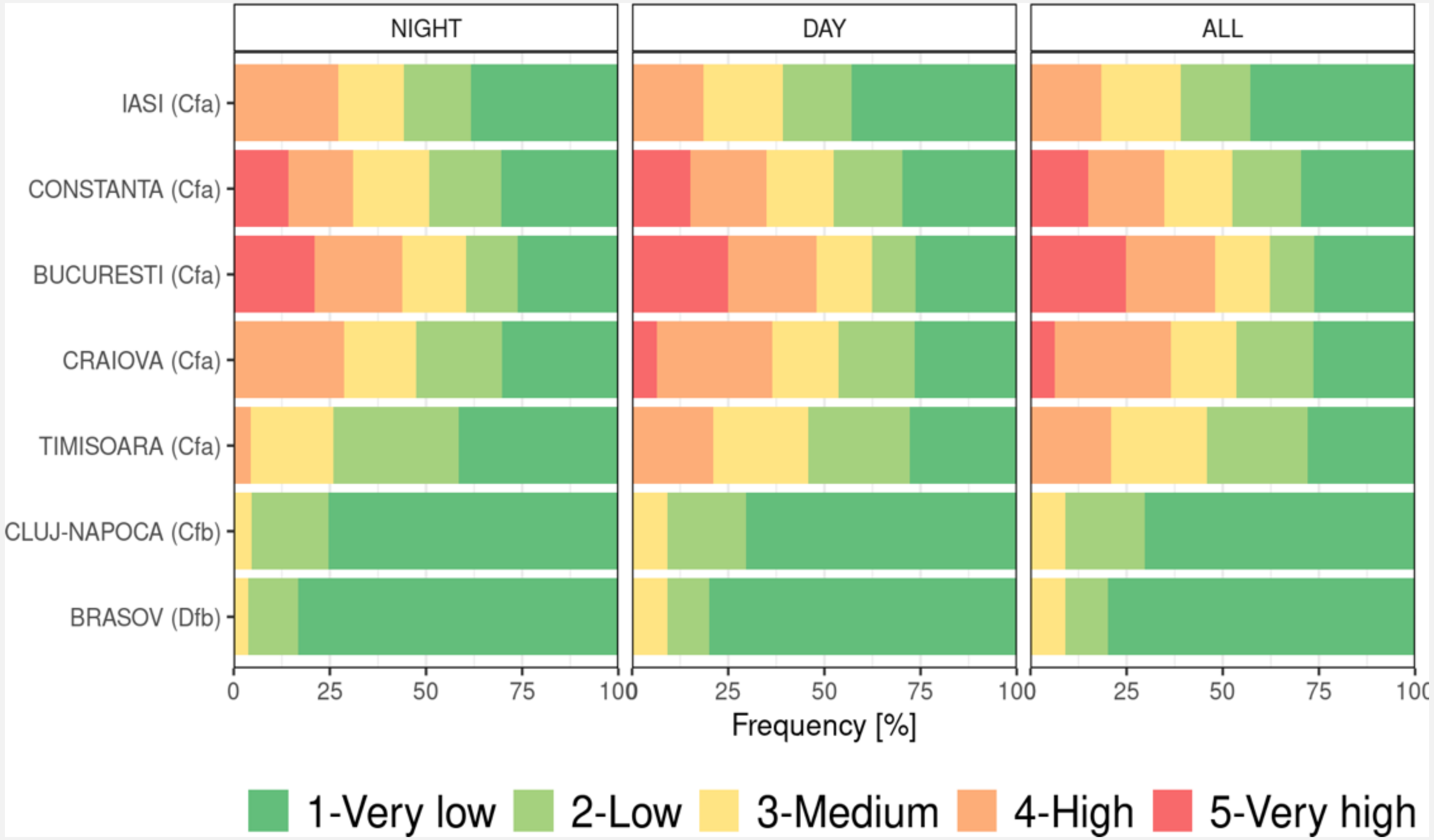
Results

The HHR and predictors considered in this study (HH computed as a function of LST, and V derived from LCZ and PD) in Cluj-Napoca (Romania)



Results

Frequency (%) of HHR categories in selected cities



METEO ROMANIA

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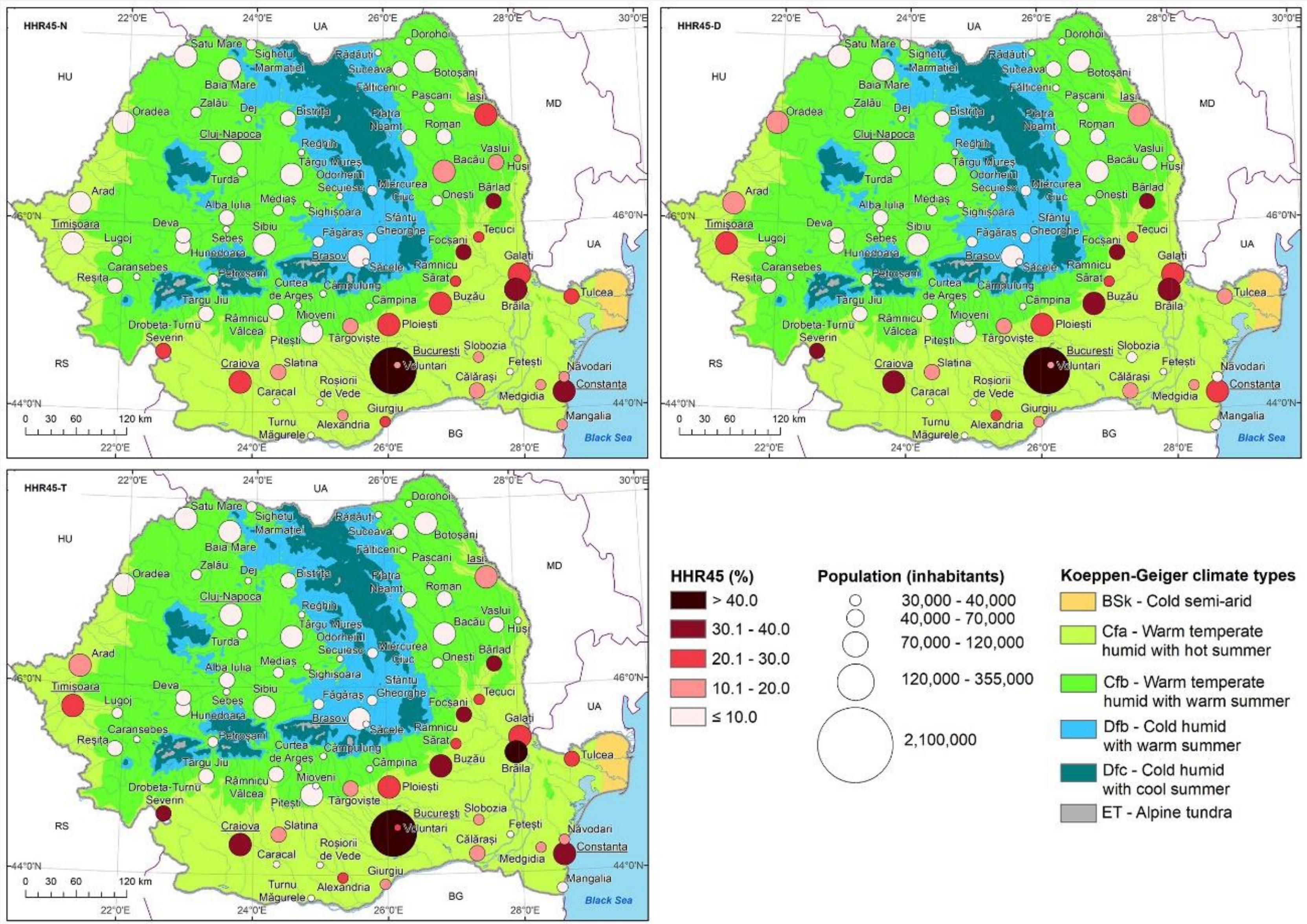
Results

Percentage of surface (%) affected by high <u>and</u> very high HHR, for night- (N), day-time (D), and all-day (T)

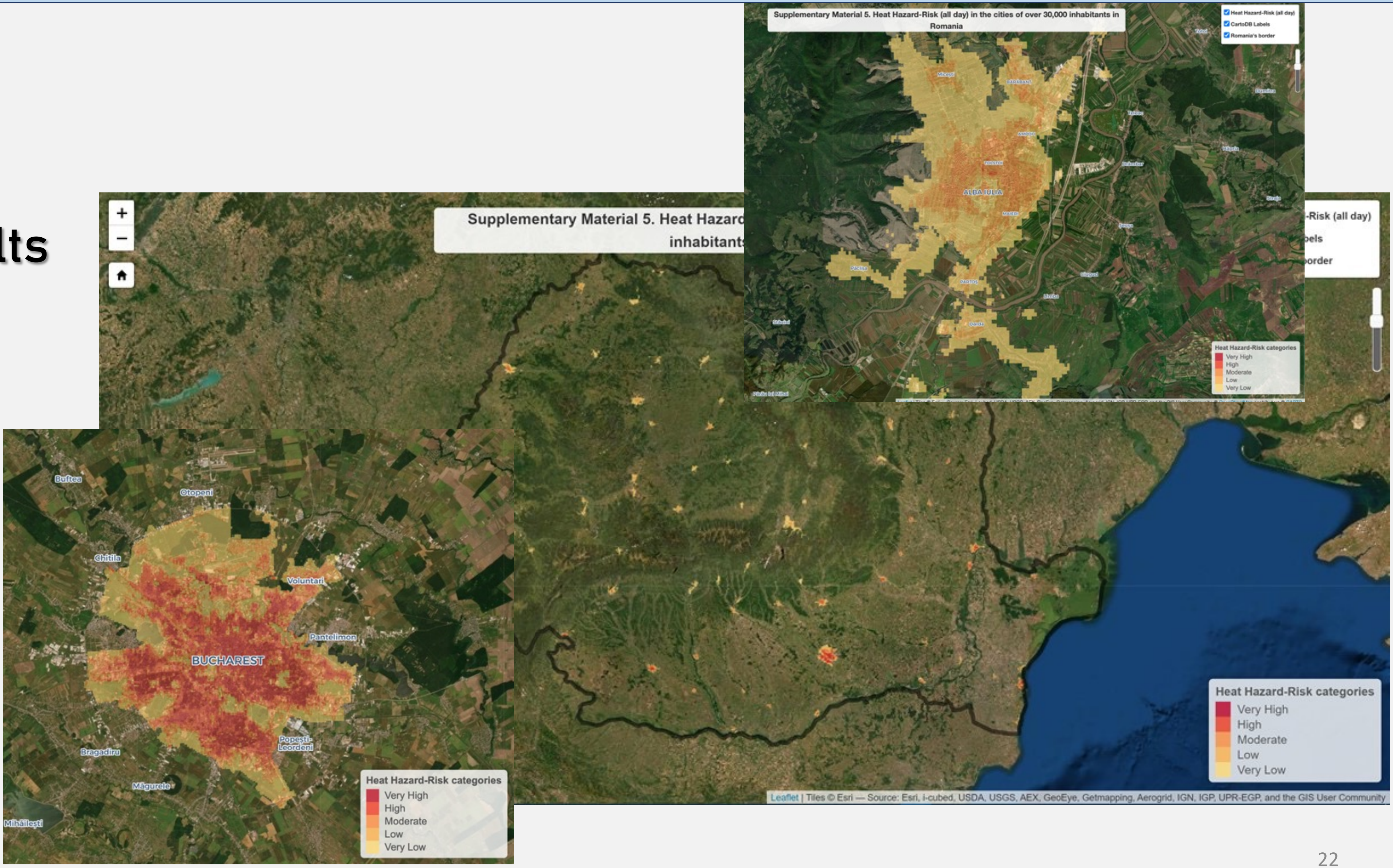


Results

Pearson's correlation coefficient between the HHR45 (% of the cities covered by high or very high HHR) and potential triggering factors in the analysed urban areas

HHR	Altmax (m a.s.l.)	Altmin (m a.s.l.)	Area (km^2)	Pop (inhab)	LST-N (°C)	LST-D (°C)
HHR45-Night	-0.581	-0.611	0.362	0.439	0.742	0.627
HHR45-Day	-0.557	-0.583	0.426	0.459	0.666	0.702
HHR45-Total	-0.589	-0.607	0.409	0.459	0.727	0.660

Results


Supplementary Material 5. Heat Hazard-Risk (all day) in the cities of over 30,000 inhabitants in Romania
Heat Hazard-Risk (all day)
CartoDB Labels
Romania's border
ALBA IULIA
Heat Hazard-Risk categories
Very High
High
Moderate
Low
Very Low
Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community
Buftea
Otopeni
Chitila
Voluntari
Pantelimon
BUCHAREST
Popești-Leordeni
Bragadiru
Măgurele
Mihăilești
Heat Hazard-Risk categories
Very High
High
Moderate
Low
Very Low

Further development

Project funded by The Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI):

Synergies between Urban Heat Island and Heat Wave Risks in Romania: Climate Change Challenges and Adaptation Options (SynUHI) 2022-2024

Specific objectives:

- SO1: Integrated assessment of the UHI
- SO2: Exploring the synergies between UHI and HWs.
- SO3: Climate change and urbanization impact on the synergies between the UHI and HWs.

Conclusion

- Satellite remote sensing has an excellent potential to (1) support the analysis of the HHR at the urban level and (2) provide results comparable and relevant at the country scale.
- The study reveals the influence of the (1) geographical context (i.e., landforms and land cover), (2) climatic factors (i.e., regional climate) and (3) urban characteristics (i.e., city size) on the HHR.

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Thank you!