Agenzia Spaziale Italiana

Space It Up!

SPOKE 7: SPACE FOR THE SUSTAINABLE DEVELOPMENT OF THE PLANET

Politecnico di Torino

POLITECNICO MILANO 1863

ISPRS GEOSPATIAL WEEK 2025 DUBAI

Tutorial: urban monitoring and analysis with remote sensing and spatial information technology

Urban Heat Island and Local Climate Zone mapping

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6th April 2025 I Geospatial Week 2025 I Dubai

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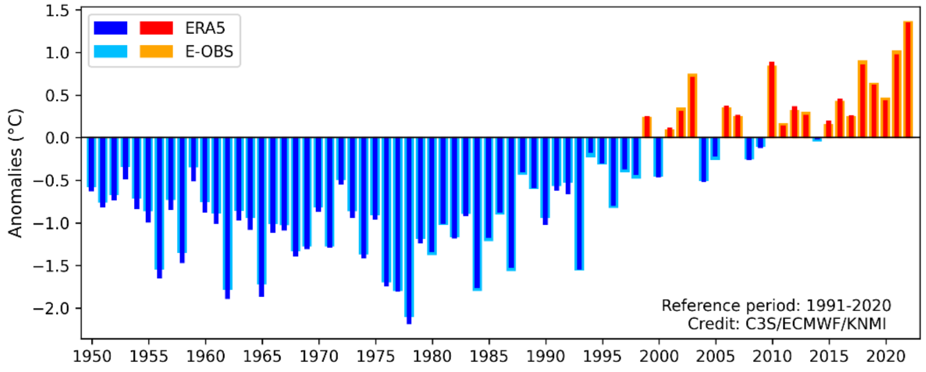
Tutorial: introduction

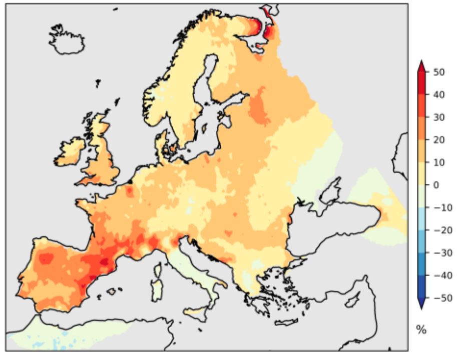
Background

Europe is a hot spot of **climate change** and is experiencing an increasing frequency of heatwaves

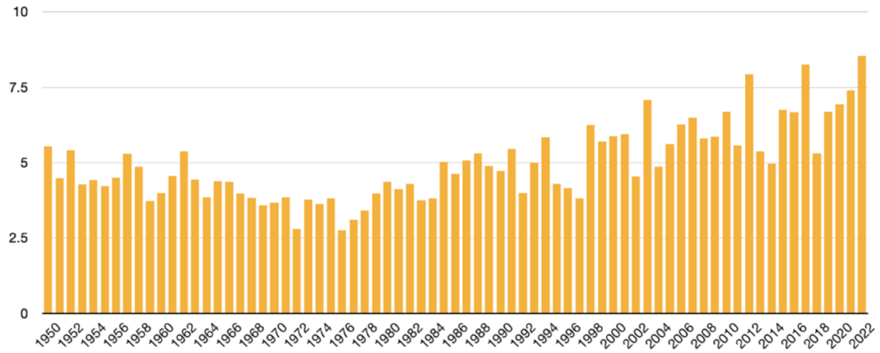
European Summer temperature anomalies



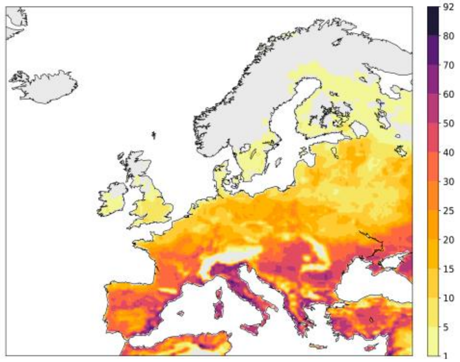
Number of 'warm daytimes' anomaly in Summer 2022



% days with very strong heat stress in summer – Southern Europe



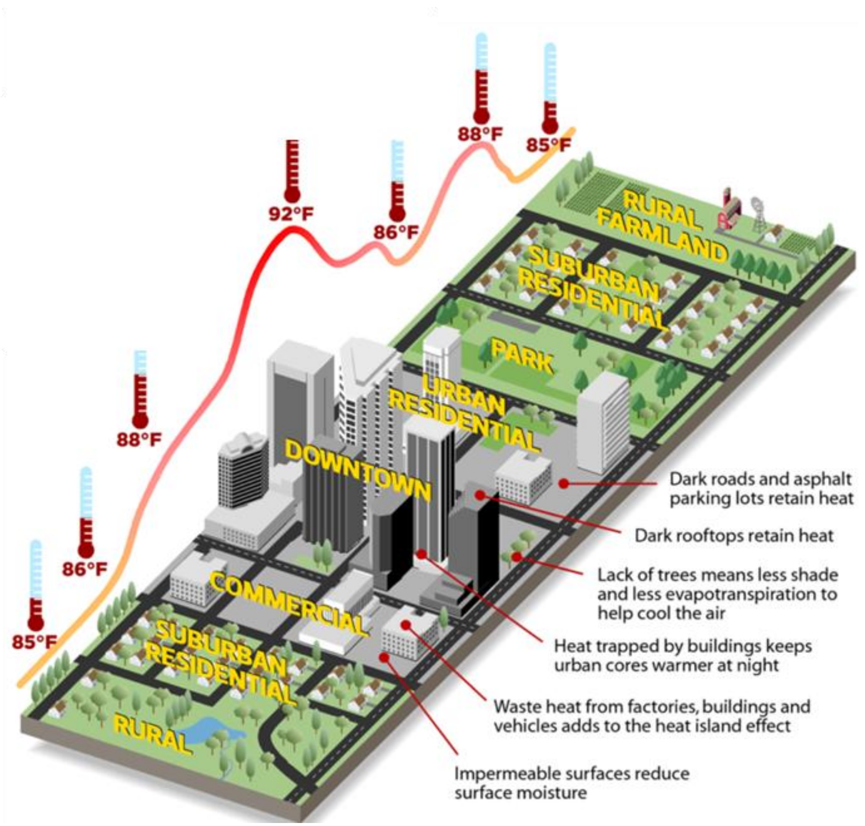
Number of days that experienced strong heat stress in 2022



This, along with increasing urbanisation, intensifies the **urban heat island (UHI)** in cities

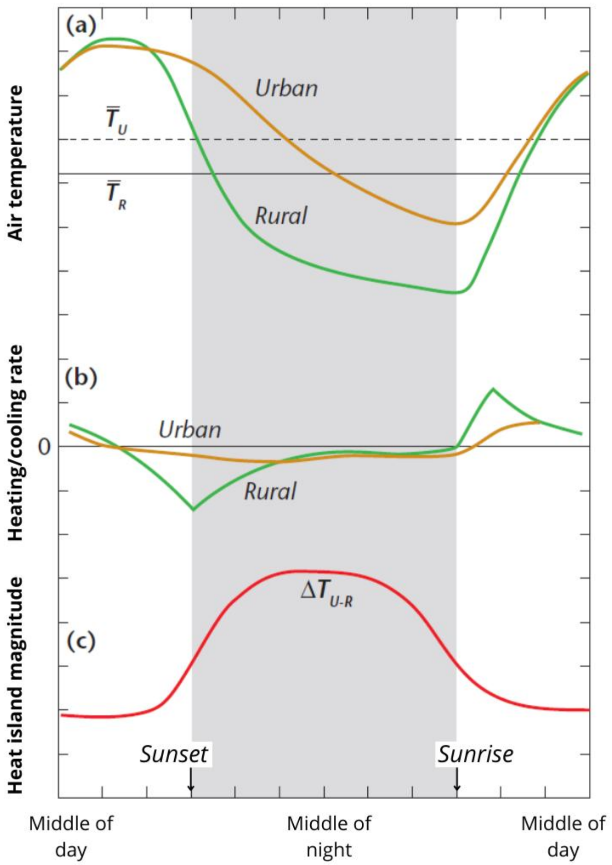
Background

UHI occurs where temperature in urban areas is higher than in the surrounding periurban and rural environment



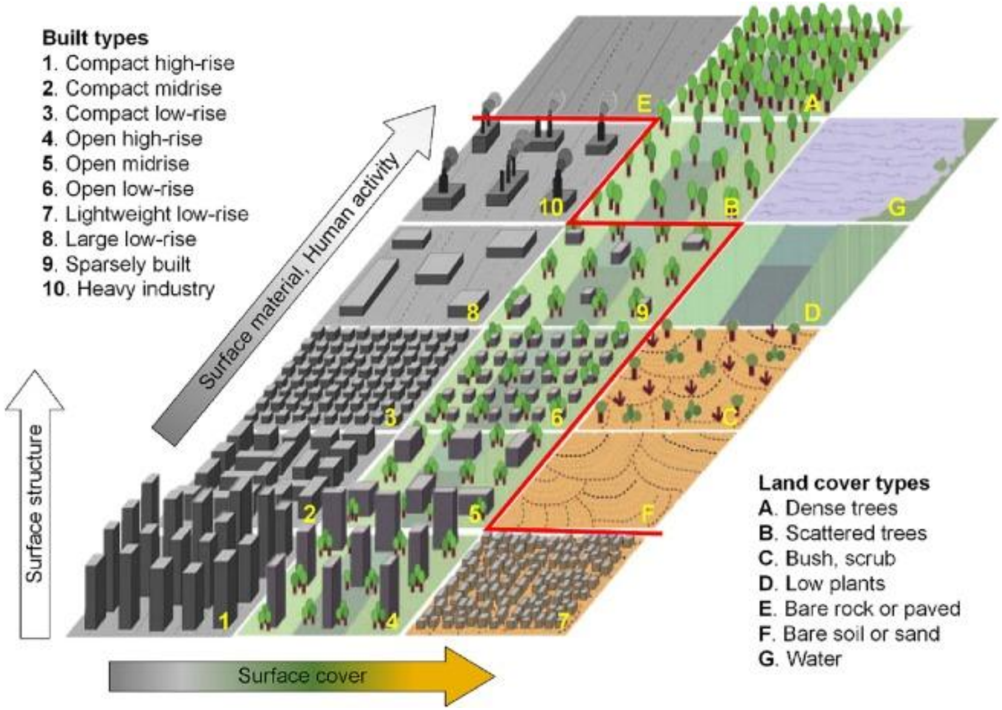
SOURCE: D.S. Lemmen and F.J. Warren, Climate Change Impacts and Adaptation

UHI is driven by building geometry and land cover and is more intense in late afternoon/evening

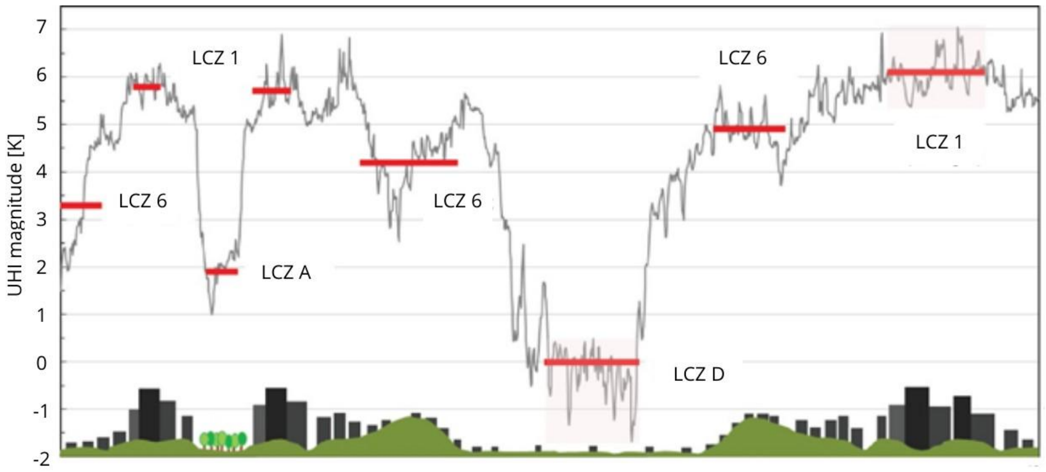


The Local Climate Zone system

- Well-established framework for the **UHI analysis**
- Classes defined based on **urban morphology** and **land cover**
- Measurable physical and thermal properties – called **Urban Canopy Parameters (UCPs)**
    - **Physical properties**: Sky View Factor, Aspect Ratio, Building surface fraction…
    - **Thermal properties**: Surface admittance, surface albedo, anthropogenic heat output…



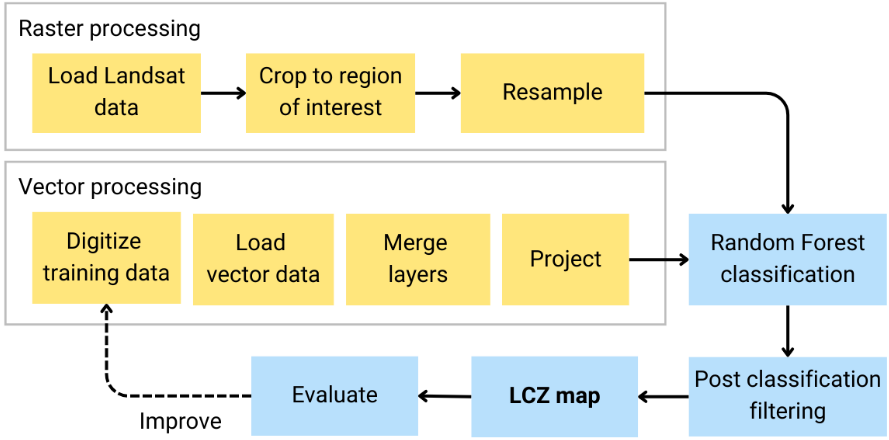
The logical structure of LCZ system is **supported by observational** and **numerical modeling data** of air temperature at screen height



Methods for LCZ mapping

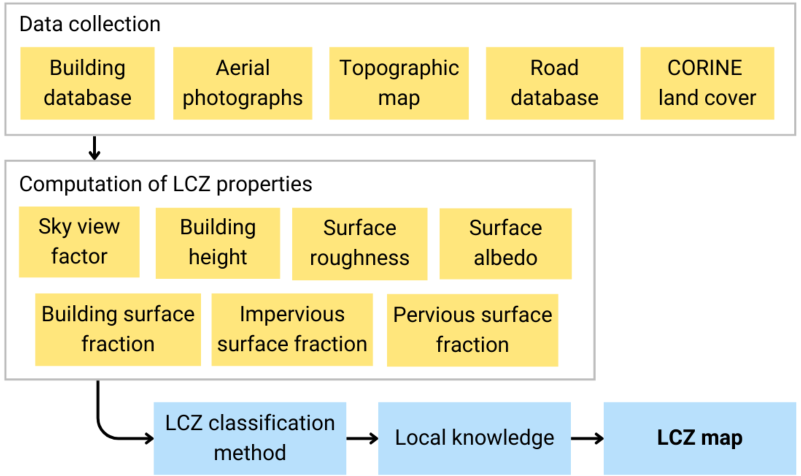
The methods for LCZ mapping include mainly Remote Sensing (RS) and GIS-based methods or combined approaches

RS-based: supervised classification of multispectral satellite imagery (WUDAPT methodology)



Limitation: satellite imagery do not contain necessary information on urban morphology

GIS-based: combination and reclassification of geospatial data describing urban morphology and land cover



Limitation: necessary data are usually not available

Combined RS and GIS-based method based on the integration of:

- Multispectral satellite imagery (e.g., Landsat 9)
- UCP layers computed from multiple geospatial data
- Supervised classification algorithm (e.g., Random Forest)

Tutorial: hands-on exercise on LCZ mapping

Material

Goals and requirements

- **Goals**
  - Compute an LCZ map for the Metropolitan City of Milan, using one Landsat 9 acquisition (bands from B2 to B7 plus B10) and ancillary UCPs; the classification is carried out with the Random Forest algorithm.
  - Compare the LCZ map produced with an interpolated air temperature map representing the average summer evening conditions.

- **Software requirements**
  - QGIS (Long Term Release) for data visualization
  - Google Colab for Python code

Material

- The **workflow** has been implemented in a Colab Notebook (*notebook.ipynb*) and it involves the following steps:
  - plotting: data exploration and visualization
  - classification in LCZs
  - accuracy assessment
  - comparison with air temperature map

- Provided **data** includes:
  - Interpolated air temperature map from the CLIMAMI project (*CLIMAMI_media_ESTATE_UHI_2200.tif*)
  - Classified map (*classified_RF_20230618_medianfilter_30m.tif*)
  - Pre-processed Landsat image (*L09bands_20230618.tif*)
  - Study area (*study_area_20230618.gpkg*) and boundaries of the metropolitan city (*CMM.gpkg*)
  - Training (*training_set_20230618_30m*) and testing (*testing_set_20230618_30m*) samples in vector (*.gpkg*) and raster (*.tif*) format.
  - Urban canopy parameters: building height (*building_30m_20230618.tif*), canopy height (*canopy_height_ETH_30m_20230618.tif*), impervious surface fraction (*imperviousness_30m_20230618.tif*), building surface fraction (*percentage_buildings_30m_20230618.tif*), sky view factor (*SVF_30m_20230618.tif*).

https://tinyurl.com/lcztutorialGWS

Tutorial: hands-on exercise on LCZ mapping

Workflow and data description

Workflow

In the tutorial, we will follow a combined Remote Sensing and GIS-based approach for LCZ mapping using Landsat 9 imagery and UCP layers*

1. Pre-processing of satellite imagery
2. Computation of UCPs in GIS environment
3. Collection of training and testing samples
4. Random Forest classification
5. Post-classification filtering
6. Accuracy assessment

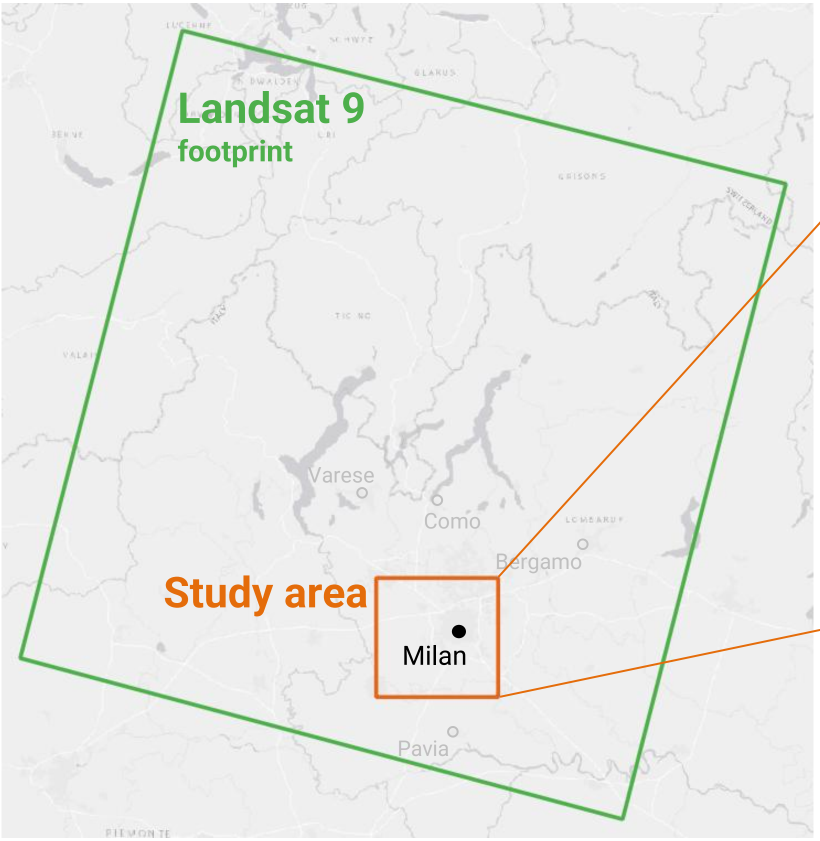
*Simplified version of the methodology described in the following publication:

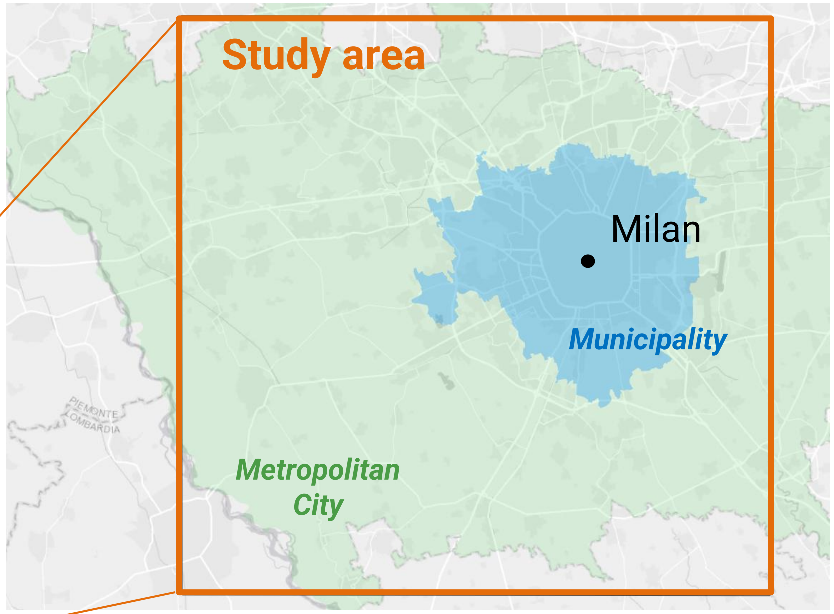
Vavassori et al. (2024). **A combined Remote Sensing and GIS-based method for LCZ mapping using PRISMA and Sentinel-2 imagery**

https://doi.org/10.1016/j.jag.2024.103944

Study area and data

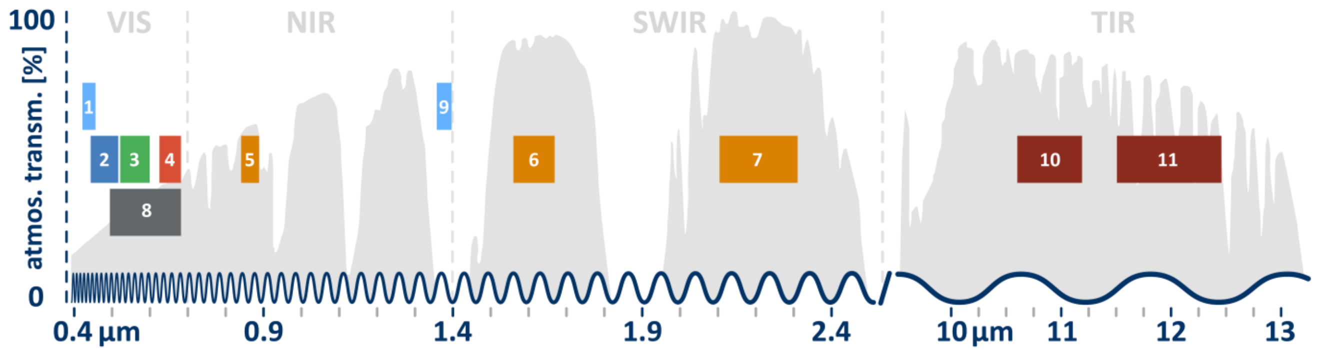
Study area: Metropolitan City of Milan (North Italy) restricted to an area of approximately 36km x 36km





Satellite imagery:
Landsat 9 acquisition of 18th June 2023

Band	Description	Wavelength [μm]	Resolution [m]
1	AEROSOL	0.435 – 0.451	30
2	BLUE	0.452 – 0.512	30
3	GREEN	0.533 – 0.590	30
4	RED	0.636 – 0.673	30
5	NIR	0.851 – 0.879	30
6	SWIR-1	1.566 – 1.651	30
7	SWIR-2	2.107 – 2.294	30
8	PAN	0.503 – 0.676	15
9	CIRRUS	1.363 – 1.384	30
10	TIR-1	10.600 – 11.190	100
11	TIR-2	11.500 – 12.510	100

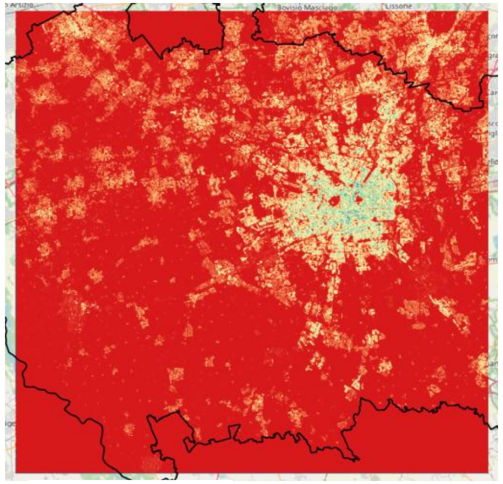


Study area and data

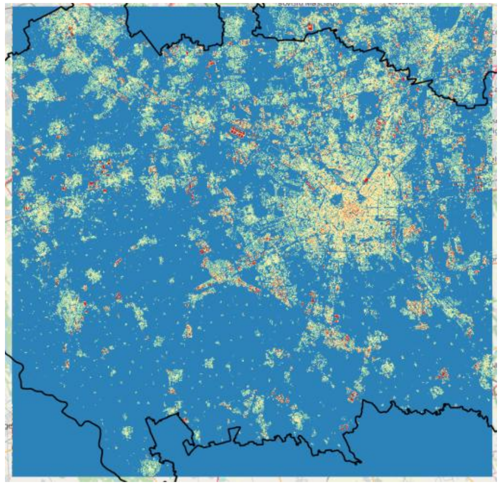
Urban Canopy Parameters (UCPs): computed in GIS environment from multiple global, European, or local geospatial layers

Data	Source	Resolution	UCP computed from it
Geo-topographic database (built-up layer)	Lombardy Region Geoportal	1:2.000 (scale)	Building Heights and Surface Fraction
Copernicus Imperviousness Density	Copernicus Land Monitoring Service	10m	Impervious Surface Fraction
ETH Global Sentinel-2 Canopy Height	Google Earth Engine Catalog	10m	Tree Canopy Height
ALOS DSM: Global v3.2	Google Earth Engine Catalog	30m	Sky View Factor

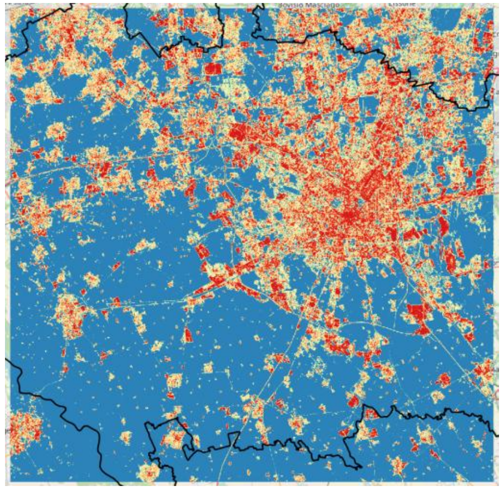
Sky View Factor



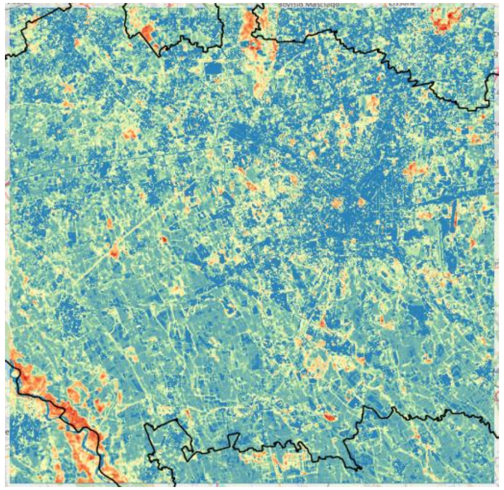
Building Surface Fraction



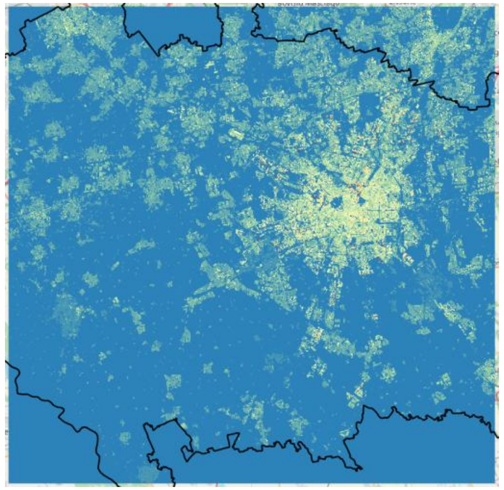
Impervious Surface Fraction



Tree Canopy Height



Building Height



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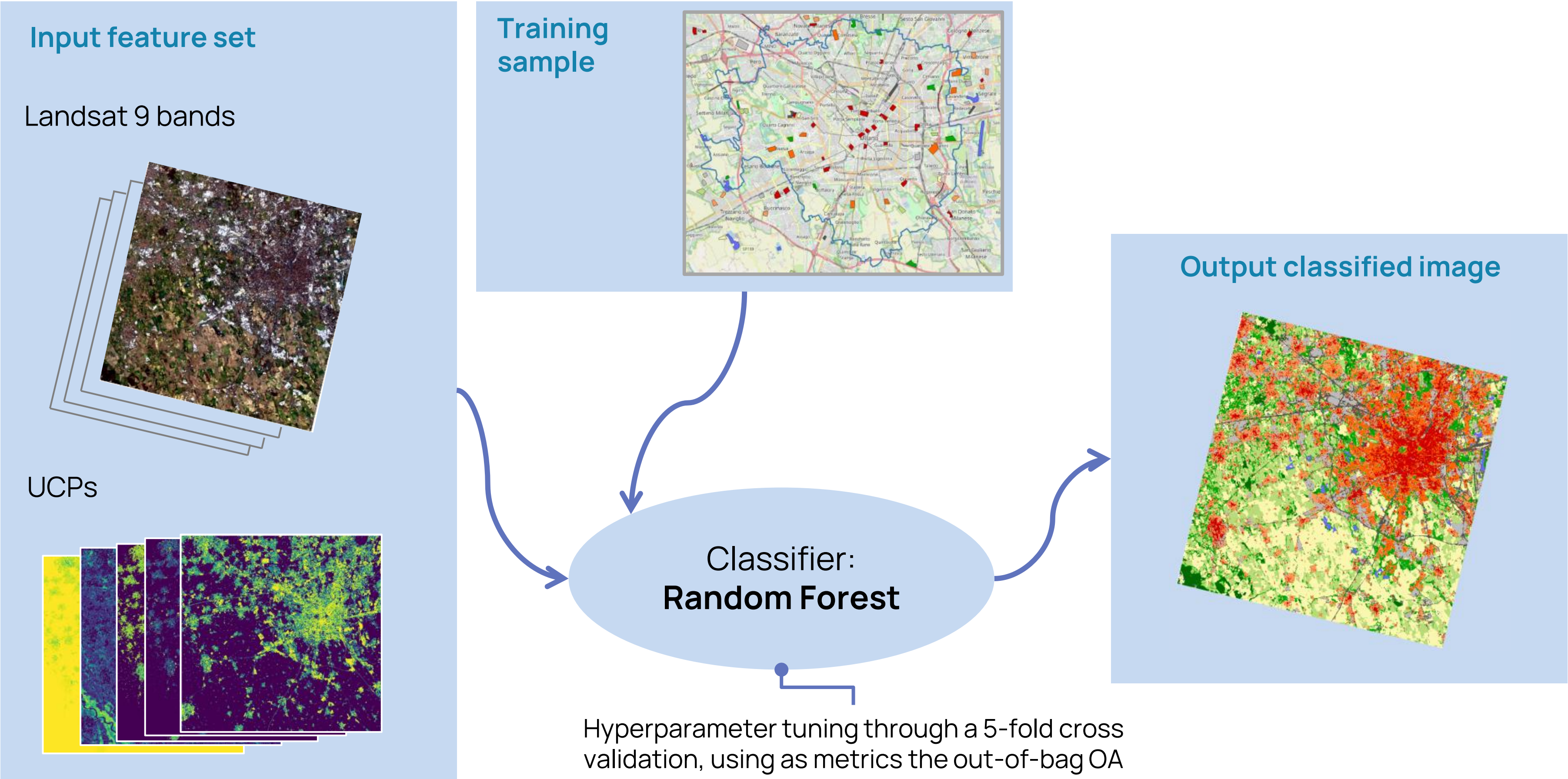
Classification

Combined RS/GIS-based method for LCZ mapping is based on the integration of

- Multispectral Landsat 9 satellite image (**RS-based**)
- Open, regional/global geospatial data for computing the UCPs (**GIS-based**)
- Application of a supervised classification algorithm (**Random Forest**)



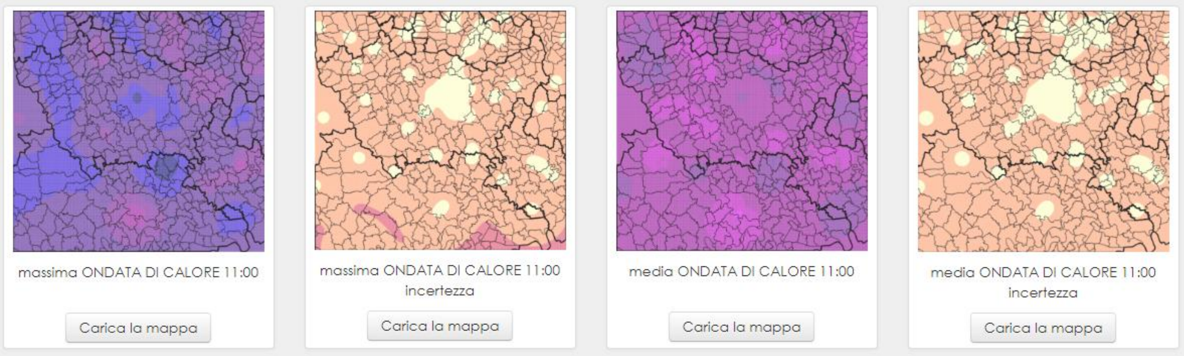
Tutorial: hands-on exercise on LCZ mapping

Comparison with air temperature

Air temperature data

CLIMAMI project
(Osservatorio Metorologico Milano Duomo)
https://www.progettoclimami.it/home-eng

ATLANTE, CATALOGO & DATABASE CLIMAMI



CLIMAMI project products

- Intrpolated maps of air temperature (average and extreme weather conditions)
- Computed using in-situ measurements from meteorological stations and Sentinel-3 LST
- Maps computed with data from the period 2016-2019, for summer (June-August) and winter (December-February), daytime (10-12 am) and nighttime (9-11 pm)

For the tutorial

- We will use the map relative to the **average summer nighttime conditions**
- The map is compared with the LCZ map computed in the previous step, to derive insights into the temperature ranges across LCZs

Any questions?

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Thank you for your attention

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