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An Approach for Improving Local Climate Zones Automatic Classification, Including Physic-Morphological Urban Features

Ahmed Eldesoky [*]; Nicola Colannino [**] & Eugenio Morello [**]

* Università IUAV di Venezia
** Laboratorio di Simulazione Urbana Fausto Curti, DASTU, Politecnico di Milano

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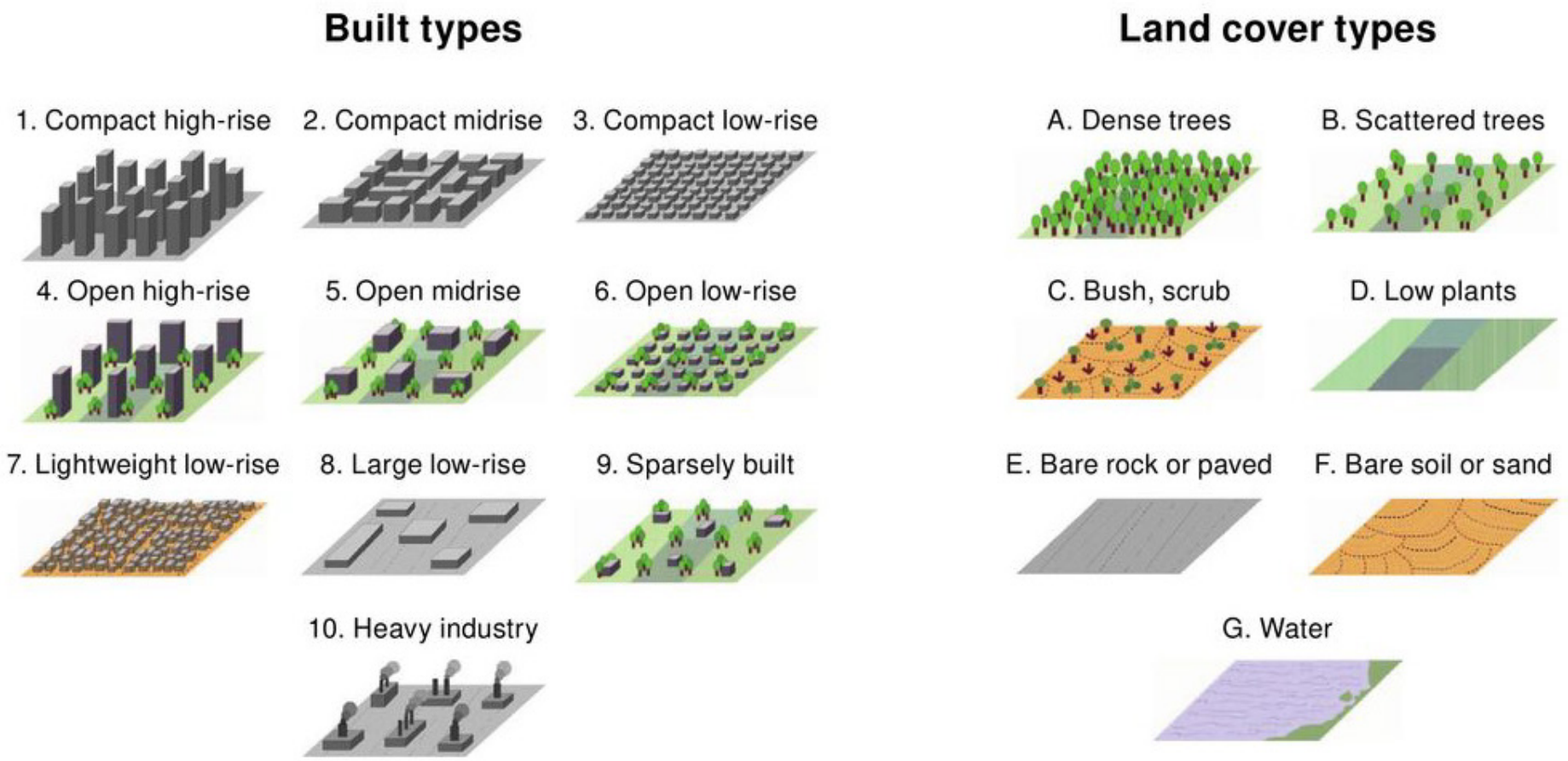
INTRODUCTION

- **Climate change** is among the top concerns globally in the recent years;
- In urban areas, **extreme heatwaves** and the **urban heat island (UHI) effect** are clear manifestations of such a concern, with serious implications on **human comfort and health**;
- The concept of **Local Climate Zones (LCZs)** by Stewart and Oke (2012) opens promising opportunities for better **assessing the UHI phenomenon at the local scale**;
- In particular, LCZs are defined as *"regions of uniform surface cover, structure, material, and human activity that span **hundreds of meters to several kilometers** in horizontal scale"* (Stewart & Oke, 2012);
- They relate the micro and local **physical and morphological features** of the urban environment to **microclimate**.

INTRODUCTION

LCZs scheme



Stewart, I. D., & Oke, T. R. (2012). Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society*, *93*(12), 1879-1900.

INTRODUCTION

Applying LCZs to cities

- Several methods have been introduced to apply the concept of LCZs to cities. This vary between **manual sampling** and **GIS/remote sensing-based** approaches;

- **The World Urban Database and Access Portal Tools (WUDAPT)**, introduced by Mills *et al*. (2015), is among the most ambitious initiatives to build a **worldwide urban climate database** and generate **effective, automatic GIS-based LCZs classification** based on **publicly available data**;

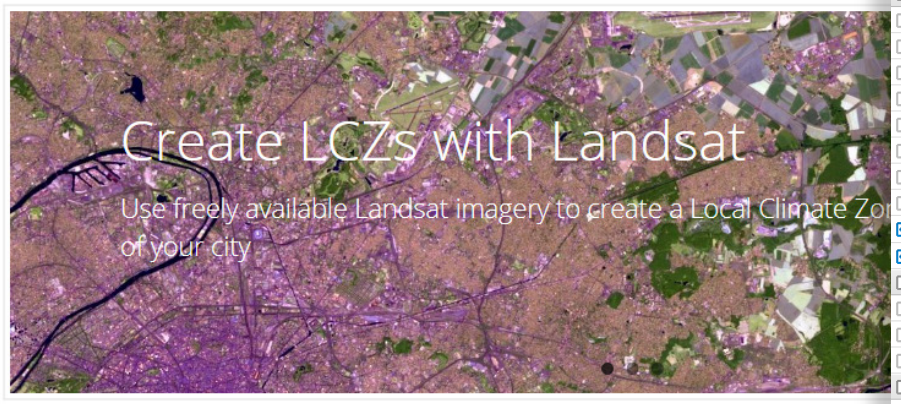
- The WUDAPT project has three level products of urban climate data: **Level 0** at regional and city scale, **Level 1** at the neighborhood scale, and **Level 2** at building scale;

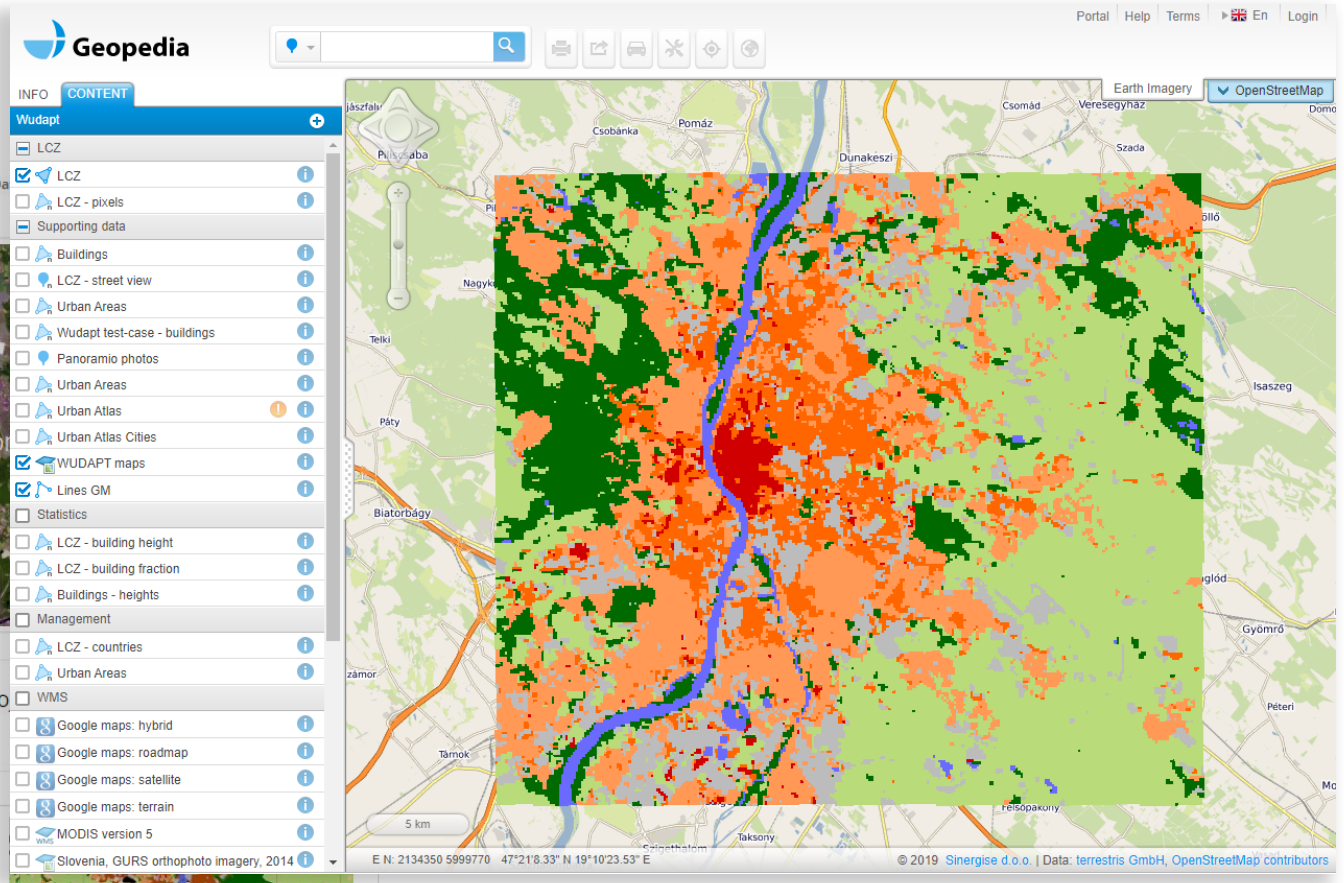
- In level 0 product, each LCZ is mapped, using a **supervised classification**, by utilizing freely available **multispectral** and **thermal** satellite imagery (e.g. Landsat 7 or 8) and **training samples** defined through very high-resolution aerial in a **systematic manner**.

INTRODUCTION

WUDAPT project

http://www.wudapt.org/

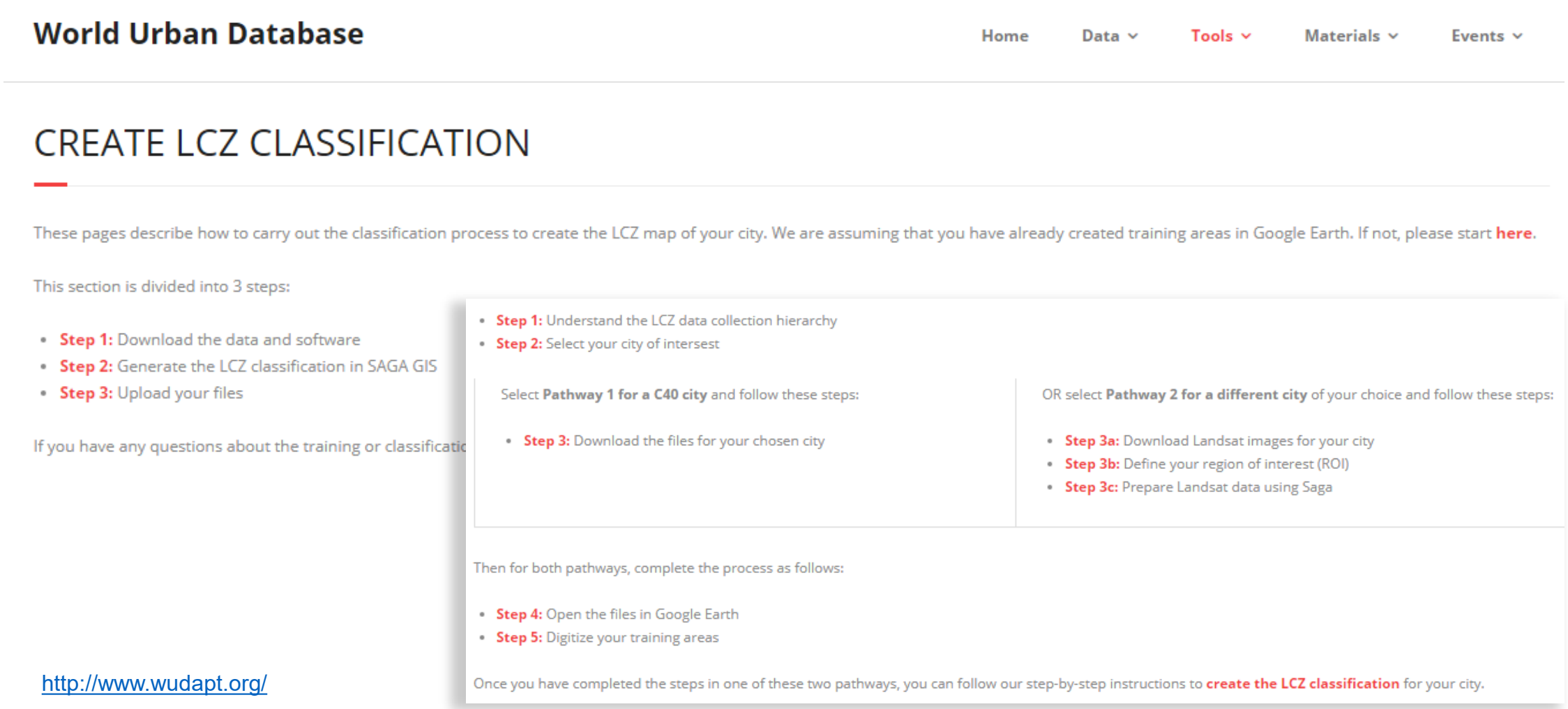




https://geopedia.world/

INTRODUCTION

WUDAPT project



World Urban Database

Home Data Tools Materials Events

CREATE LCZ CLASSIFICATION

These pages describe how to carry out the classification process to create the LCZ map of your city. We are assuming that you have already created training areas in Google Earth. If not, please start **here**.

This section is divided into 3 steps:

- **Step 1:** Download the data and software
- **Step 2:** Generate the LCZ classification in SAGA GIS
- **Step 3:** Upload your files

If you have any questions about the training or classificatic

- **Step 1:** Understand the LCZ data collection hierarchy
- **Step 2:** Select your city of intersest

Select **Pathway 1 for a C40 city** and follow these steps:

- **Step 3:** Download the files for your chosen city

OR select **Pathway 2 for a different city** of your choice and follow these steps:

- **Step 3a:** Download Landsat images for your city
- **Step 3b:** Define your region of interest (ROI)
- **Step 3c:** Prepare Landsat data using Saga

Then for both pathways, complete the process as follows:

- **Step 4:** Open the files in Google Earth
- **Step 5:** Digitize your training areas

Once you have completed the steps in one of these two pathways, you can follow our step-by-step instructions to **create the LCZ classification** for your city.

http://www.wudapt.org/

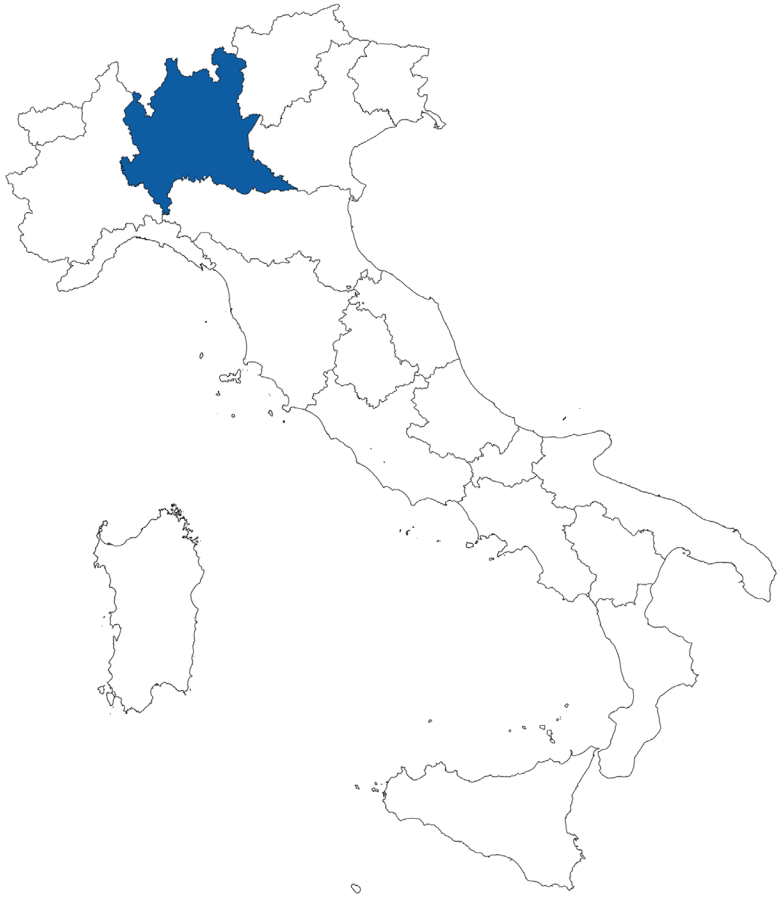
RESEARCH GAP, OBJECTIVE, AND DATA

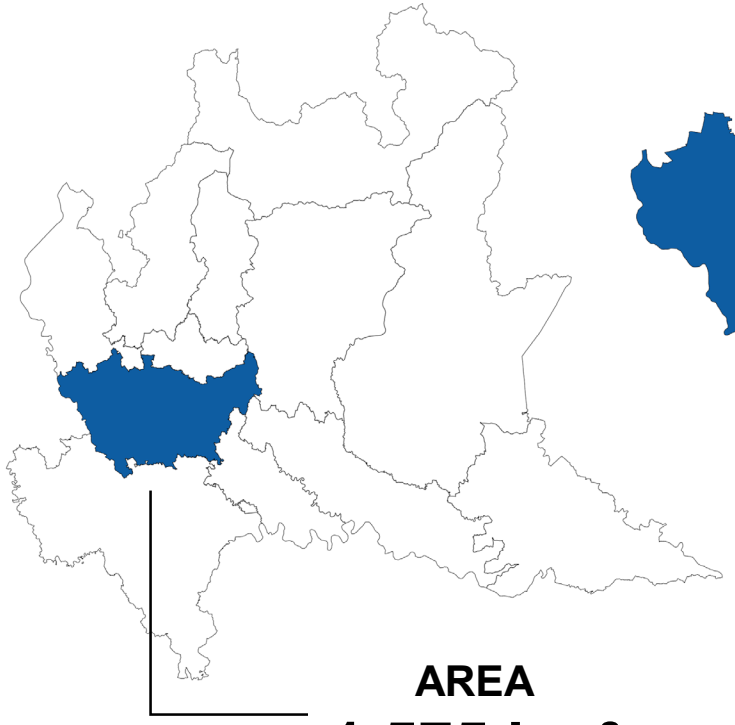
Gap: Although WUDAPT level 0 product results provide a **multi-categorical**, **comprehensive** classification, LCZ maps are relatively **rough** and frequent quality assessments demonstrate **moderate overall accuracy** (i.e. 50 – 60%). Besides, only **few freely available** satellite data provide **thermal information**.

Objective: To test the possibility of improving the quality of LCZ maps, relying on **physic-morphological** urban features of the urban setting and without additional thermal information.

Data: We used free **Landsat 8 (level 1)** satellite imagery, acquired for a **summer day** during the **daytime** (15/08/2018 10:10 AM), and where the **cloud cover** over the area of interest was **less than 10%**. Also, **high quality digital topographic database (DTDB)** of building footprints, where building heights information is available, was obtained from *Geoportale della Lombardia.*

STUDY AREA





The Metropolitan City of Milan (CMM)

AREA
1,575 km²

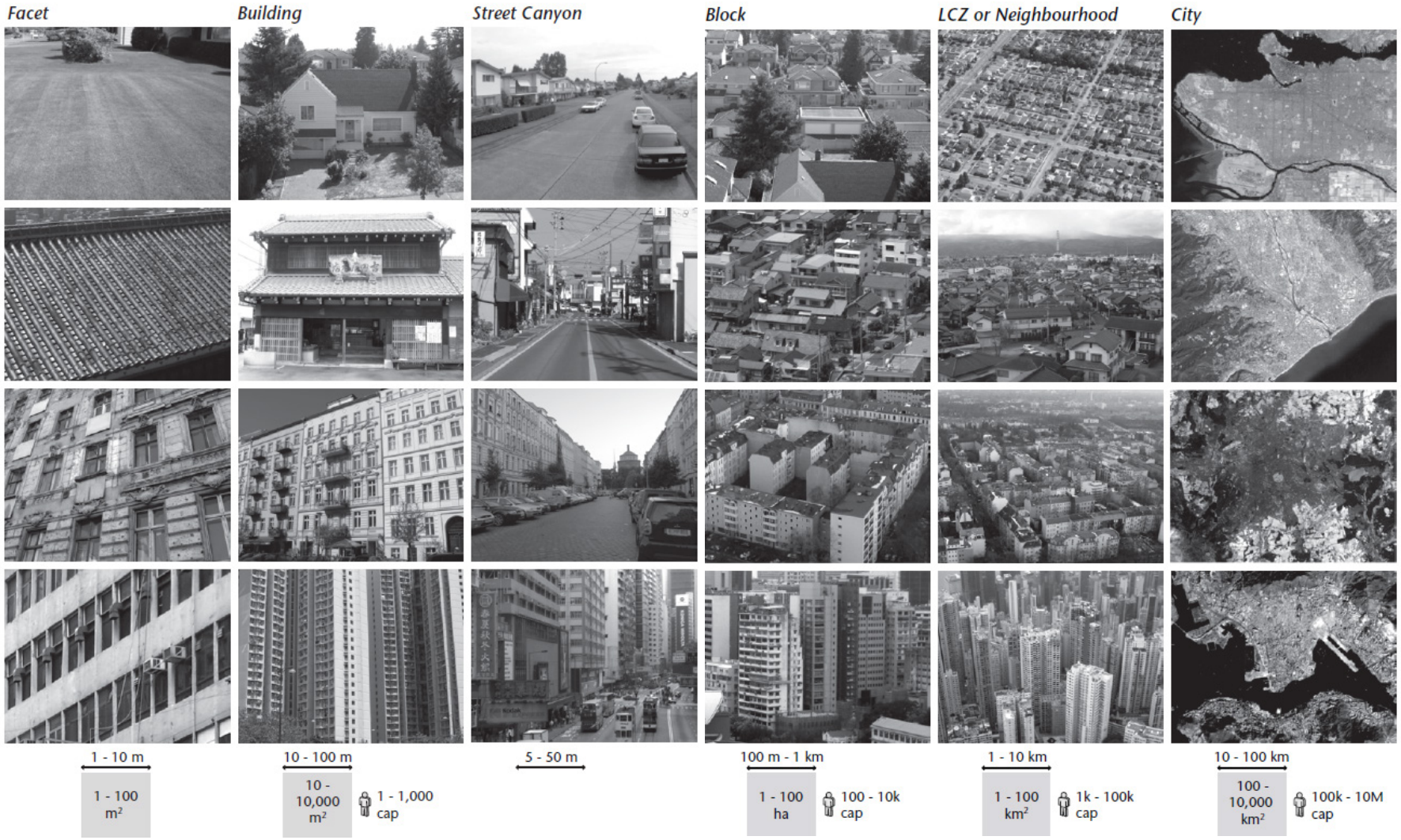
According to the National Plan of Adaptation to the Climate Change (PNACC), the metropolitan city of Milan is one the **most vulnerable** areas to the risk of **extreme heatwaves** in Italy.

METHODOLOGY

The proposed methodology for improving the quality of LCZ maps touches upon two main crucial points in urban climatology, i.e. **scale and surface homogeneity** and **urban surface properties** through three main steps:

- **First**, **finer spatial resolution** (i.e. 30 m rather than 100 m) input data are used for conducting the **pixel-based classification**;
- **Second**, **smaller-sized training samples** are digitized, reaching the scale of some **lower scale urban units**, that can influence upon the microclimate;
- **Third**, **multispectral satellite imagery** is combined together with **physical and morphological features** of the urban setting. In particular, we take into account **surface albedo** (both narrow and broadband albedo), **Normalized Difference Vegetation Index** (NDVI), **building heights**, and **Sky View Factor** (SVF) as main variables.

1. Scale and surface homogeneity



Oke, T., Mills, G., Christen, A., & Voogt, J. (2017). *Urban Climates*. Cambridge: Cambridge University Press. doi:10.1017/9781139016476

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1. Scale and surface homogeneity: LCZs scale range

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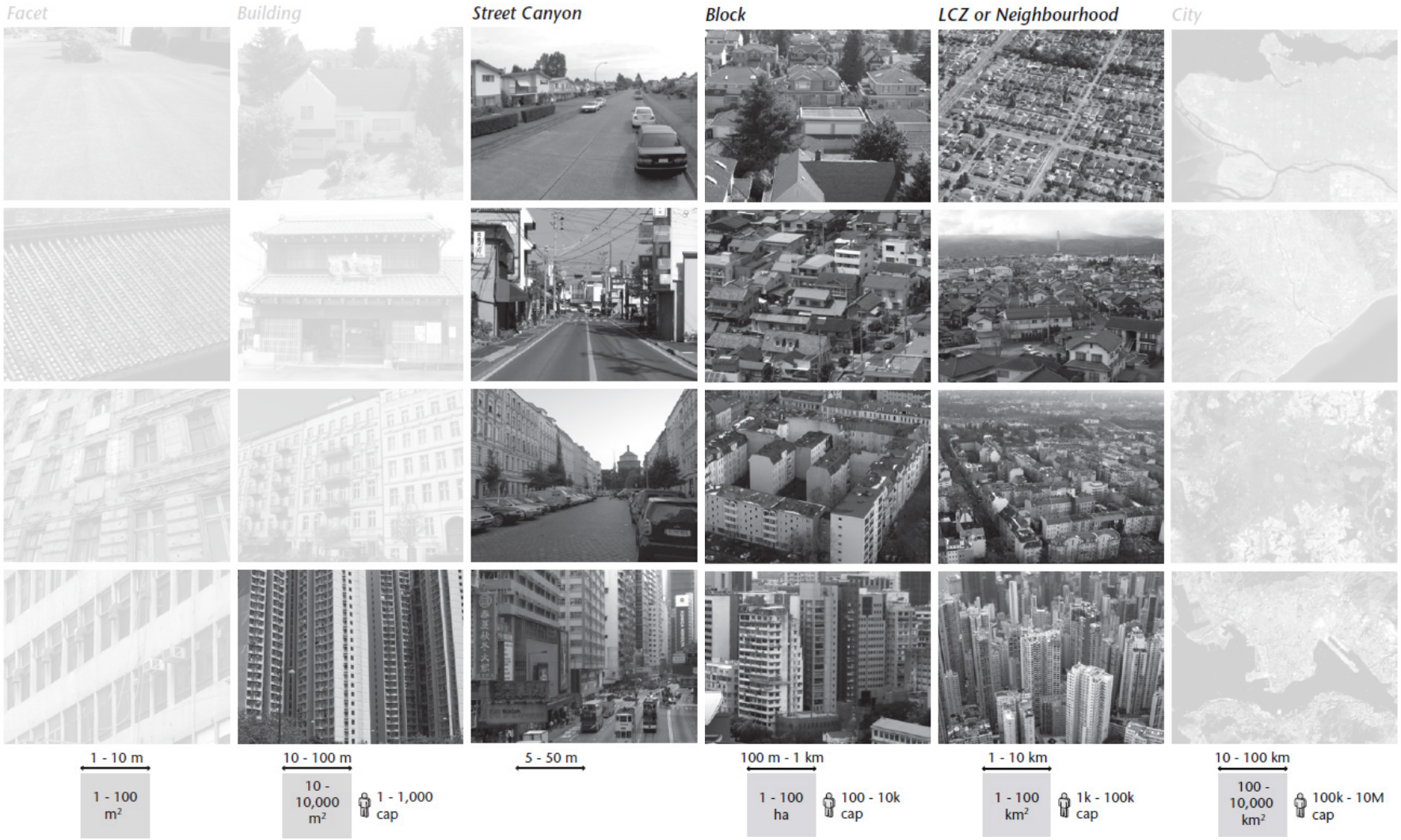
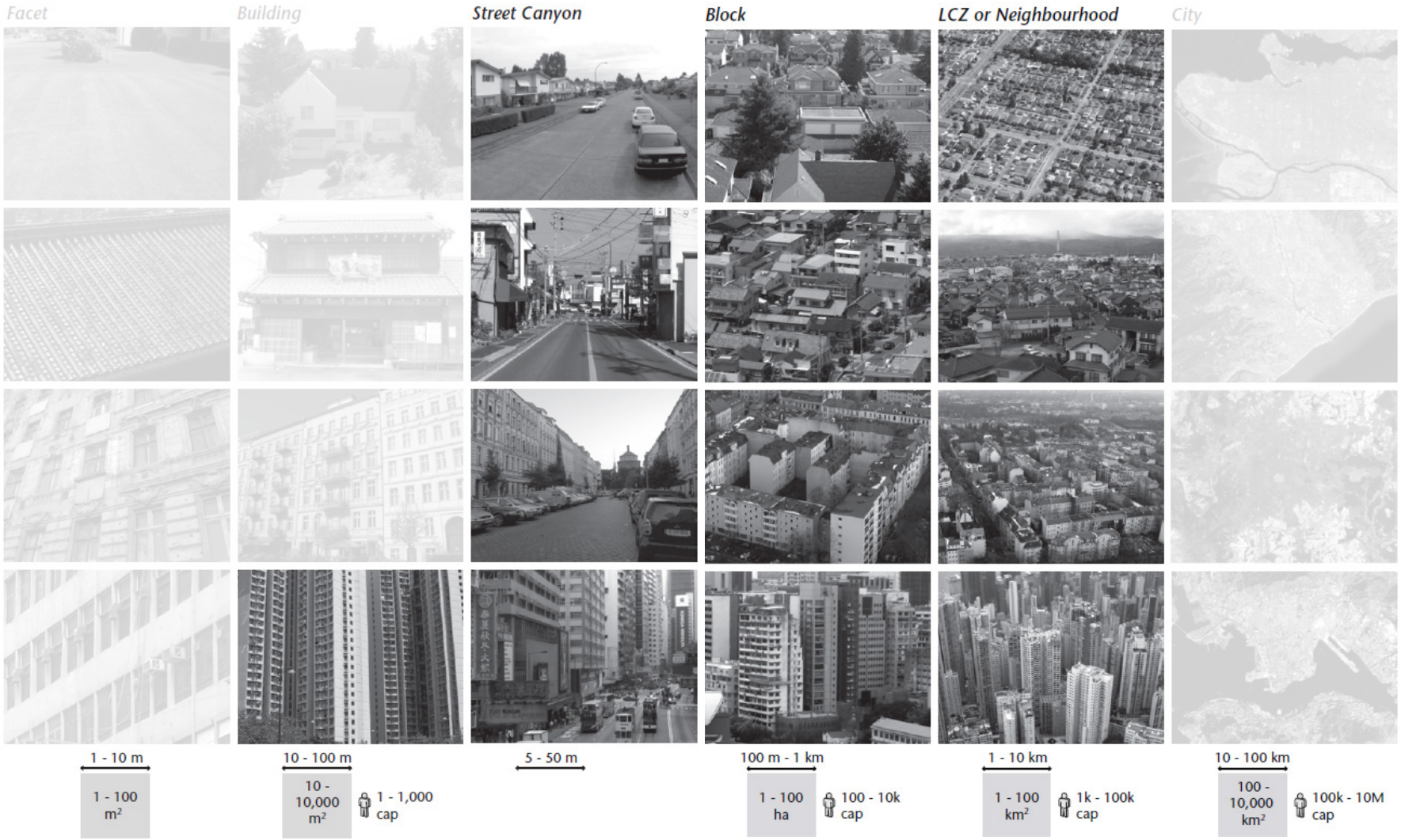


Oke, T., Mills, G., Christen, A., & Voogt, J. (2017). *Urban Climates*. Cambridge: Cambridge University Press. doi:10.1017/9781139016476

1. Scale and surface homogeneity: WUDAPT Level 0

Oke, T., Mills, G., Christen, A., & Voogt, J. (2017). *Urban Climates*. Cambridge: Cambridge University Press. doi:10.1017/9781139016476

1. Scale and surface homogeneity: Proposed range

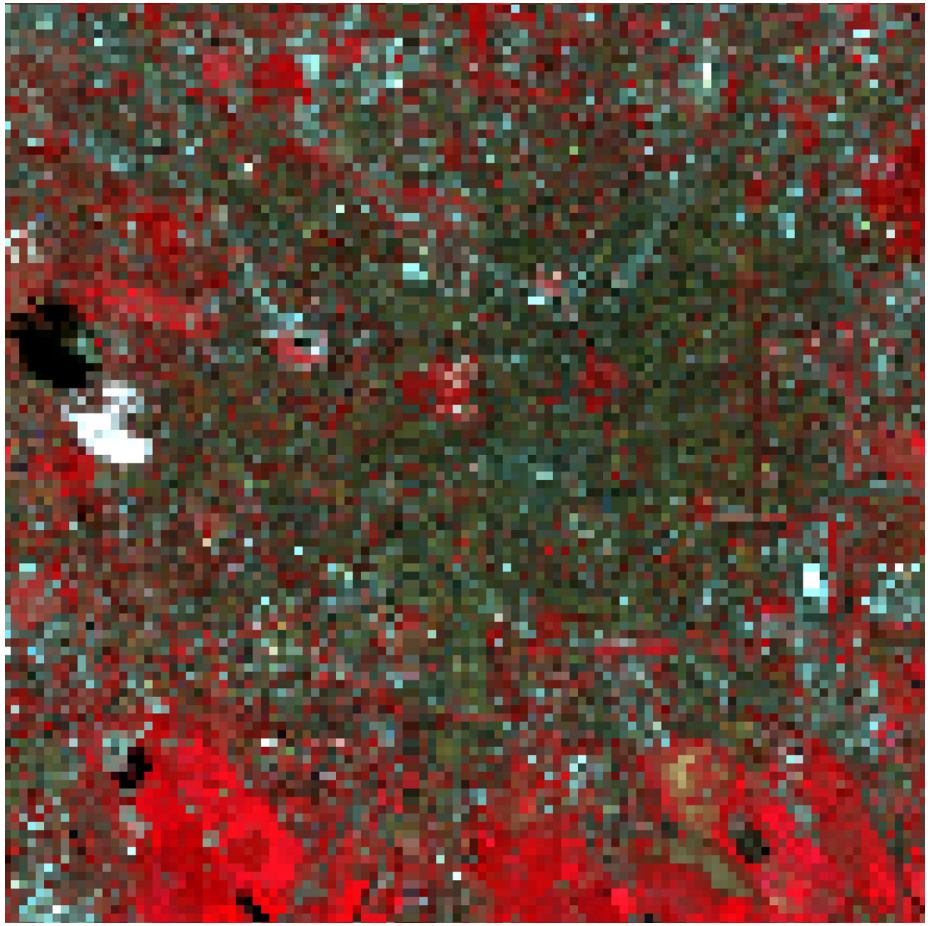


Oke, T., Mills, G., Christen, A., & Voogt, J. (2017). *Urban Climates*. Cambridge: Cambridge University Press. doi:10.1017/9781139016476

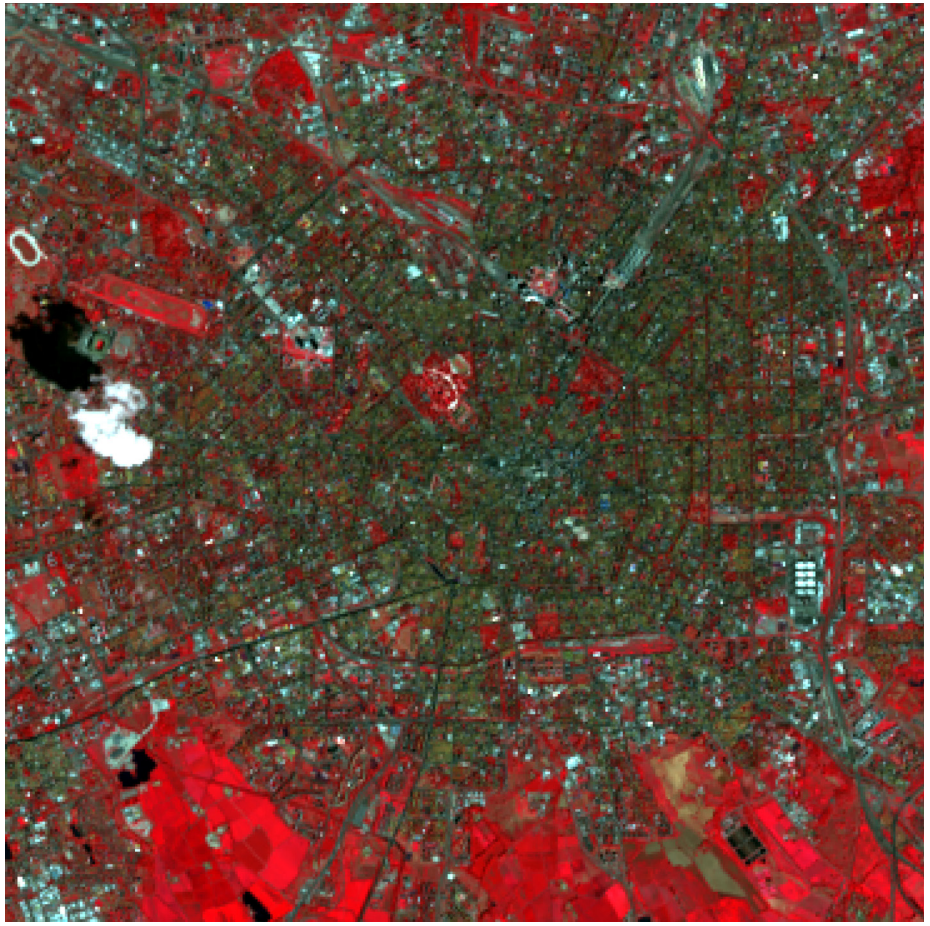
Defining Local Climate Zones (LCZs) for CMM

Training samples for the LCZ classification in the Metropolitan City of Milan

Utilizing finer resolution input data

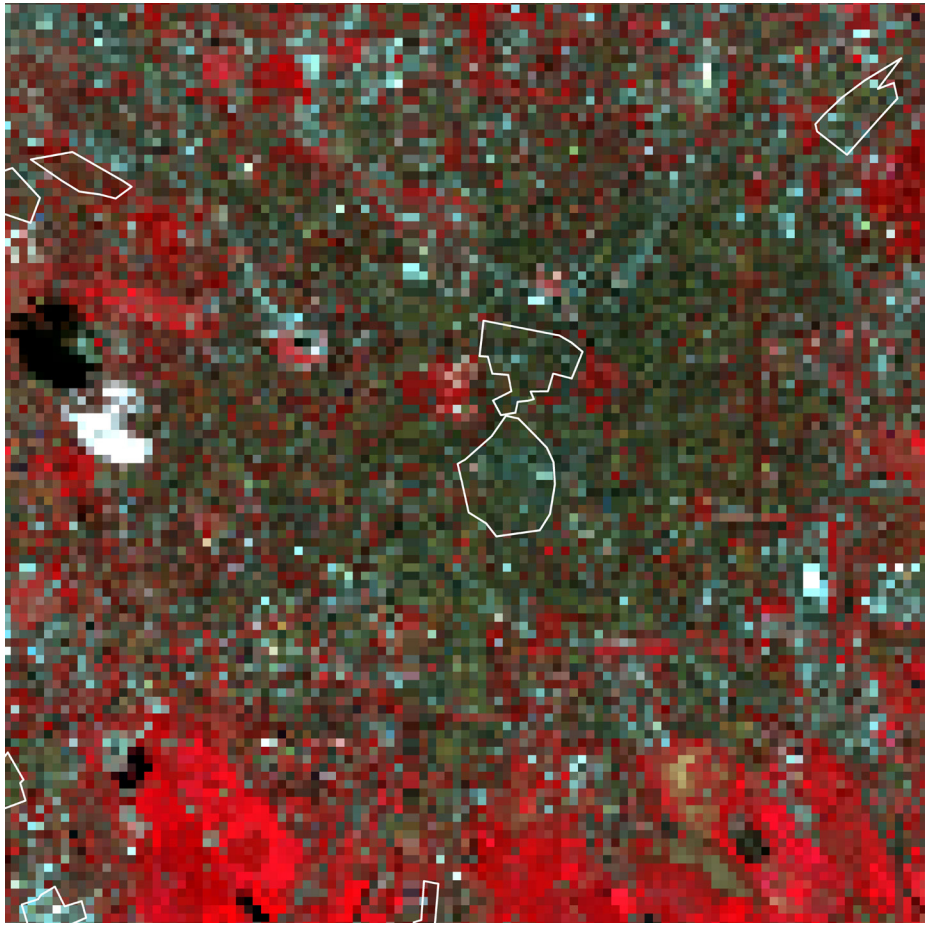


Landsat imagery (100 m) used in WUDAPT as raw data for the pixel-based classification.

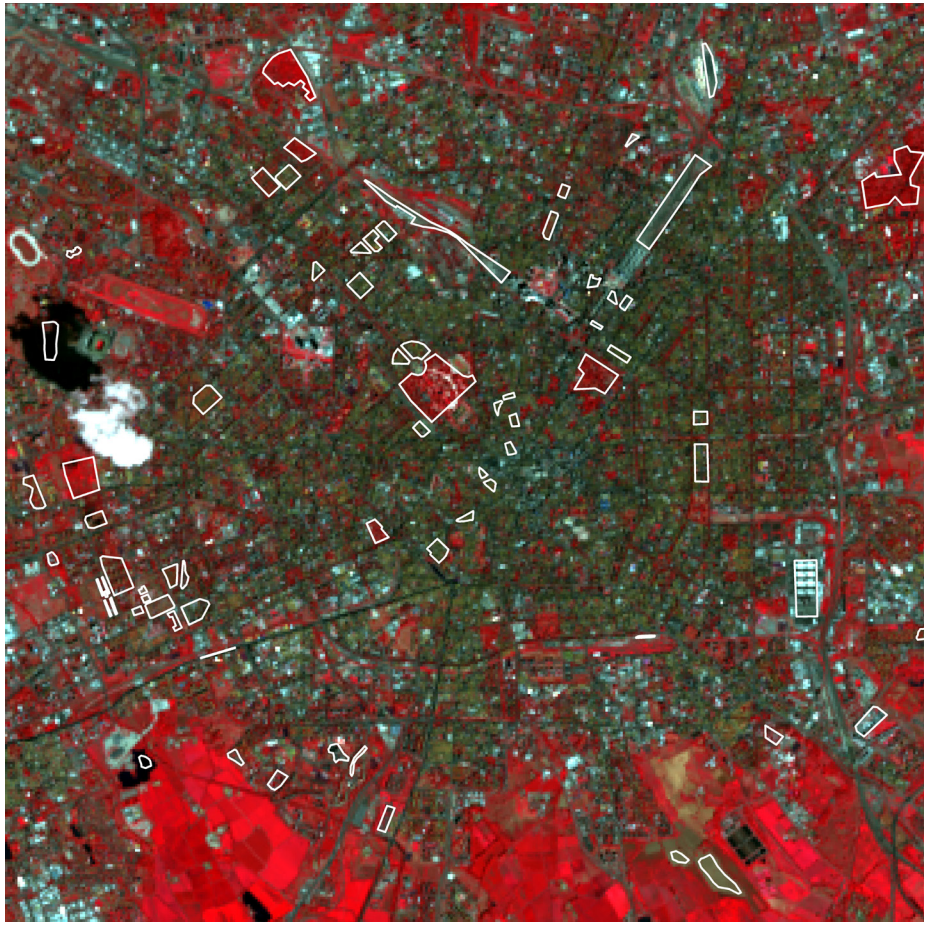


Landsat imagery (30 m resolution) as raw data for the pixel-based classification in the proposed methodology.

Digitizing smaller averaged-sized training data

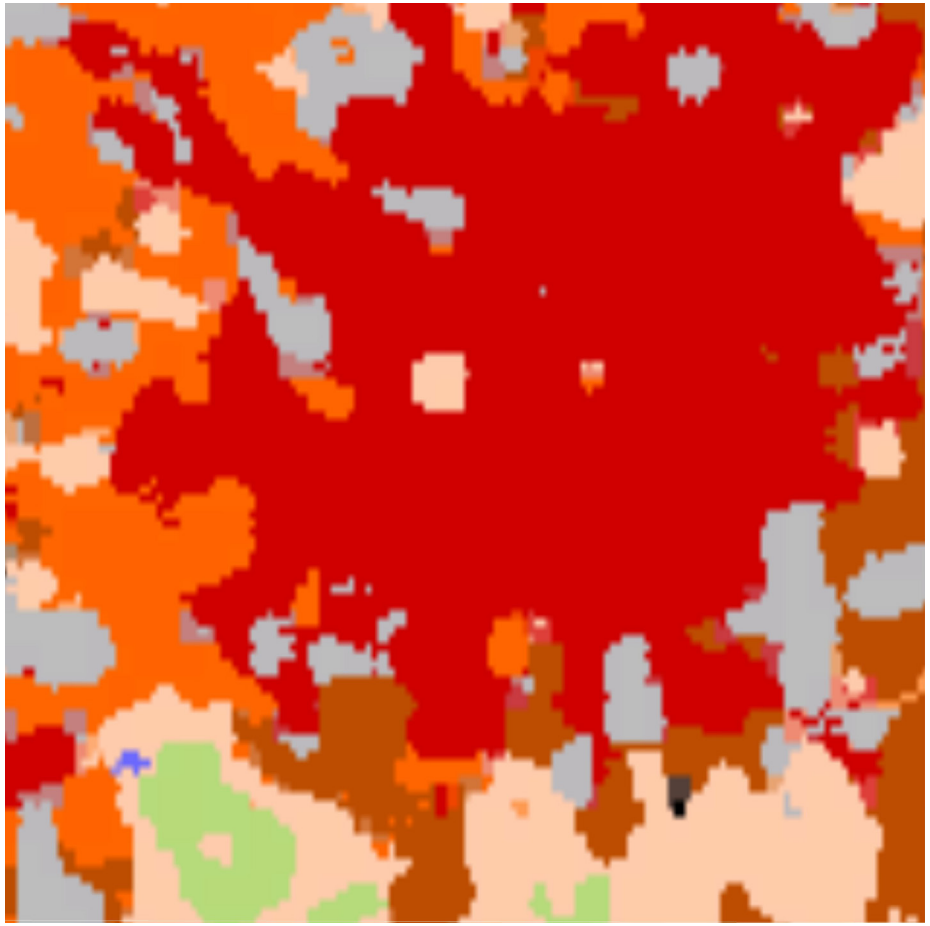


Training areas used in WUDAPT level 0 method (> 1 km^2 and >200 m wide).

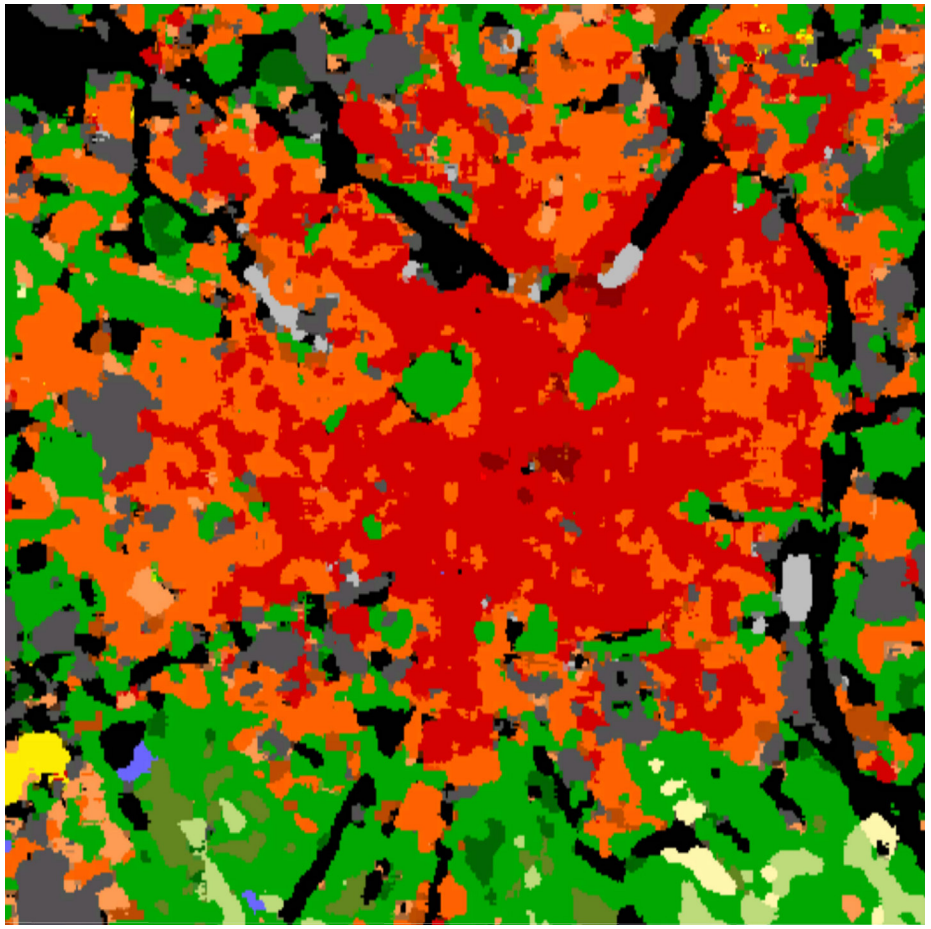


Training areas used in the proposed methodology (up to 250 m wide).

Anticipated output quality



LCZ map as obtained by WUDAPT level 0 method and input data.



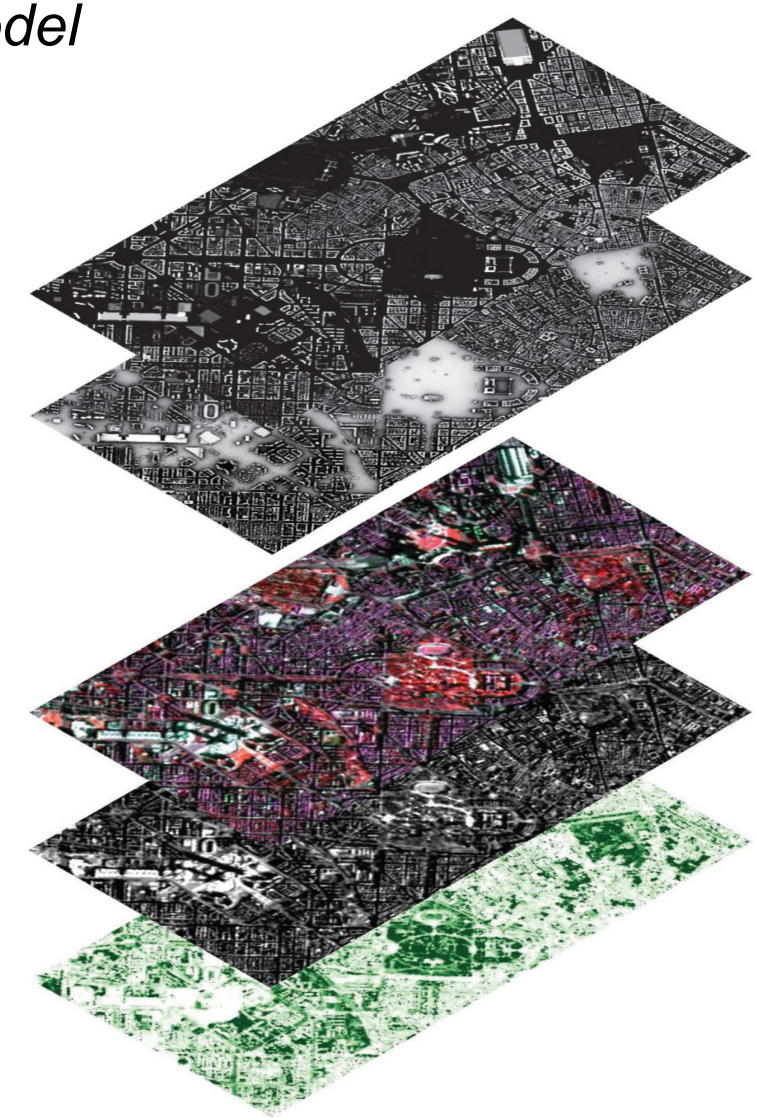
LCZ map as obtained by using finer spatial resolution input data and smaller averaged sized training samples.

2. Urban Surface Properties

A Physic-Morphological model

Morphological Features

Physical Features



Buildings Height

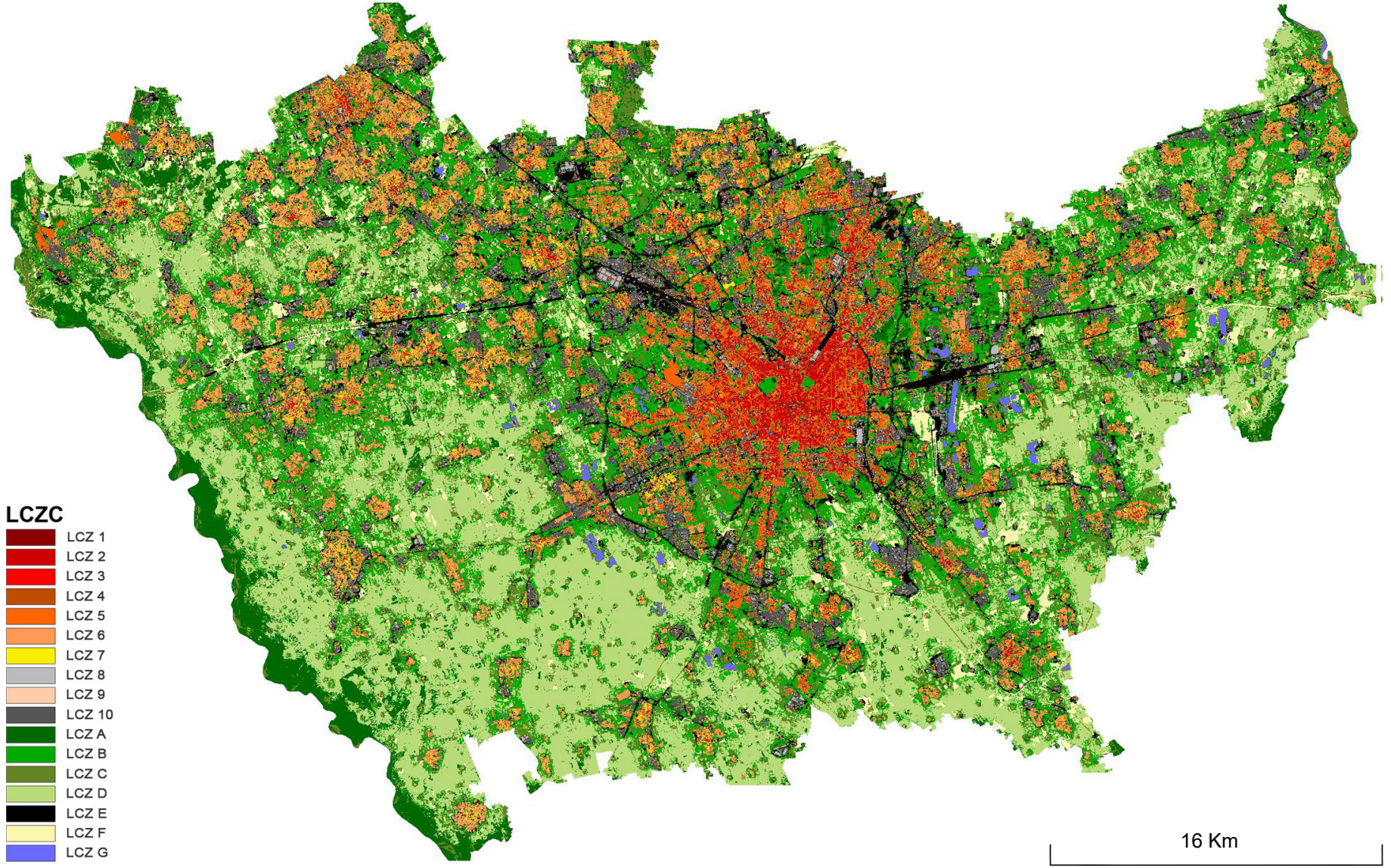
Sky View Factor (SVF)

Broadband Albedo

Narrowband Albedo

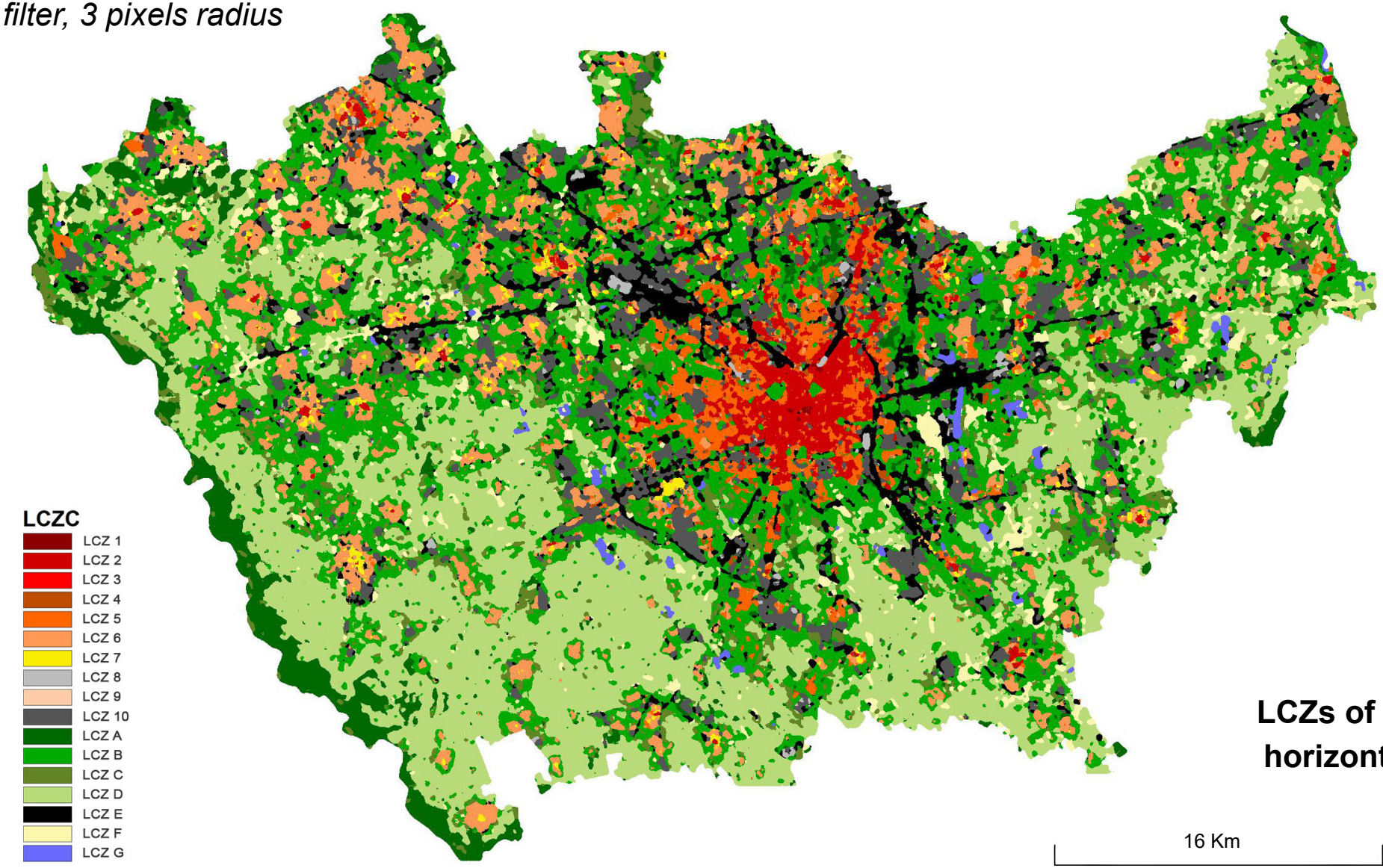
Normalize Difference Vegetation Index (NDVI)

The output of the Physic-Morphological model



The output of the Physic-Morphological model

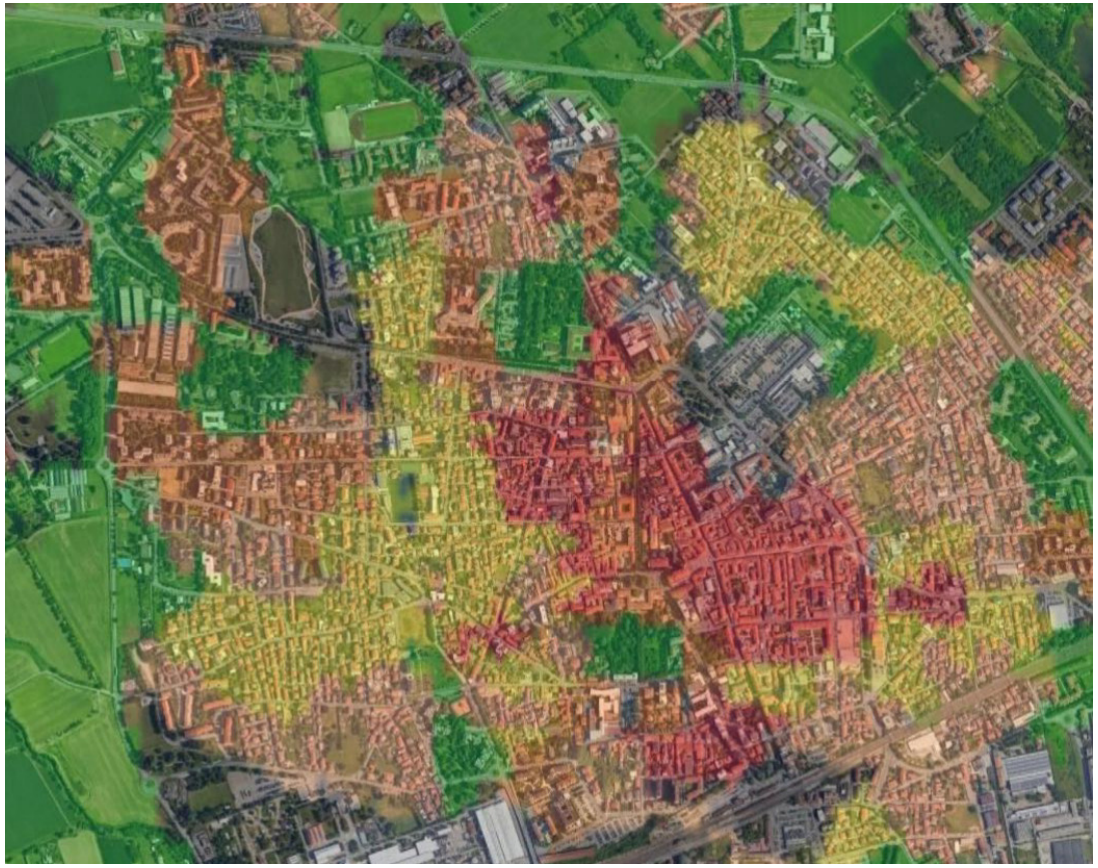
Majority filter, 3 pixels radius



LCZs of 210 m in horizontal scale

Applicability in climate planning and design

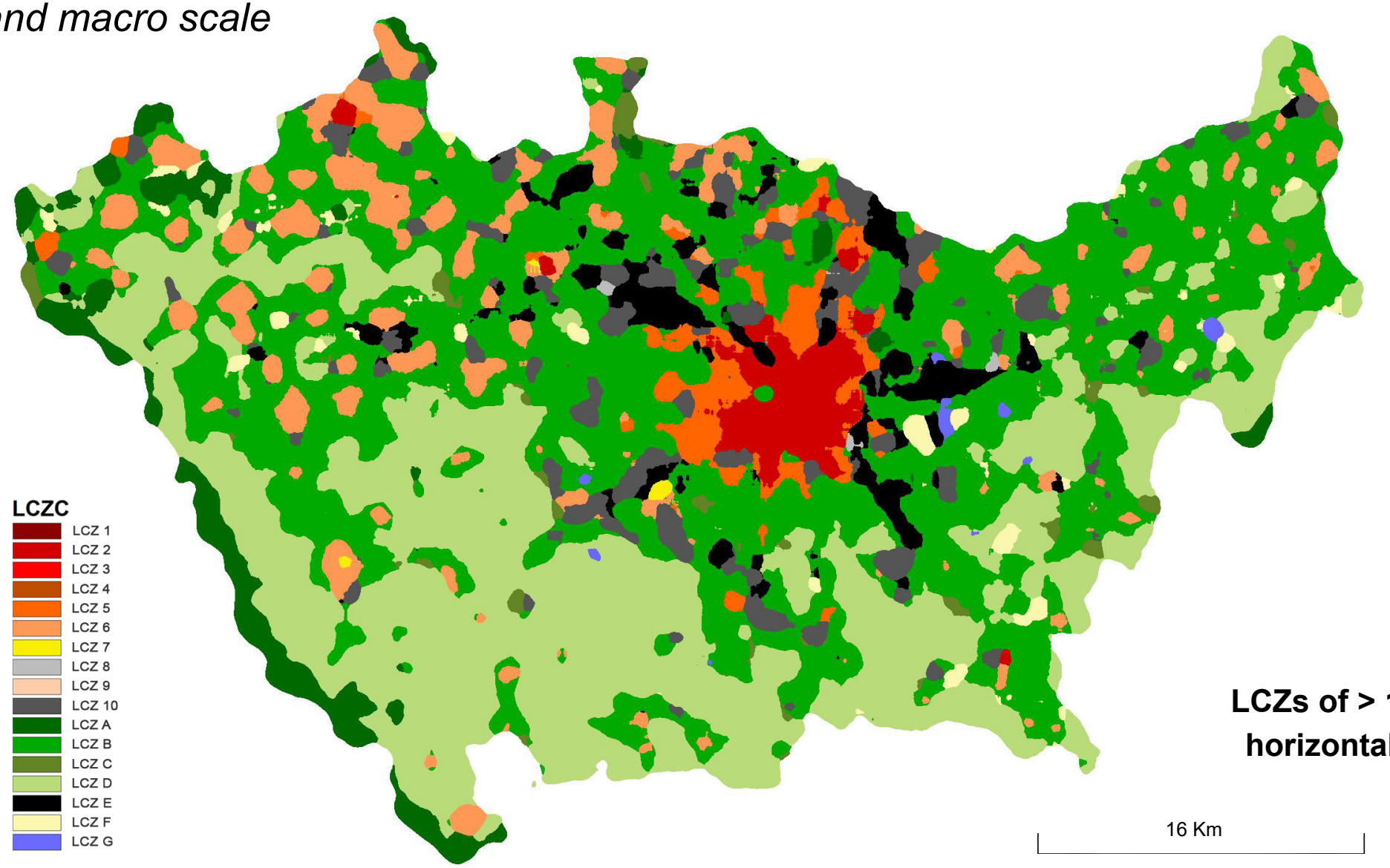
Micro and local scale



A zoom-in for two different patches within the Metropolitan city of Milan, based on the realized LCZs map, and where the resolution of the classification offers promising applications for climate planning and design at this micro and local scale.

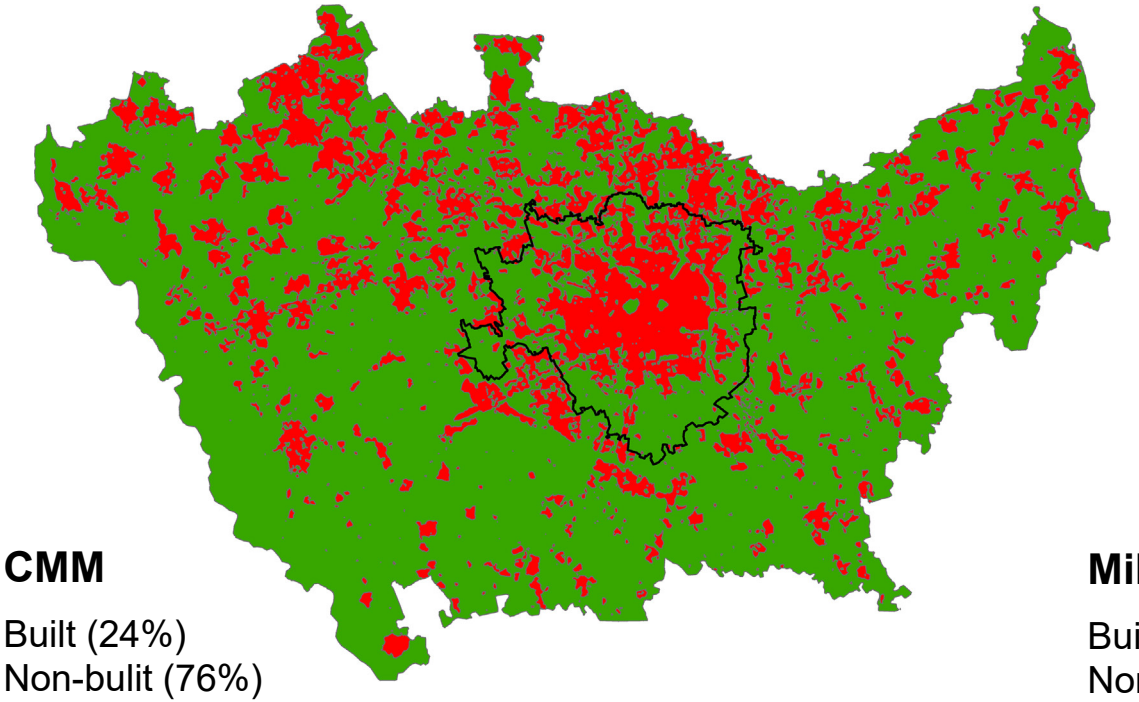
Applicability in climate planning and design

Meso and macro scale



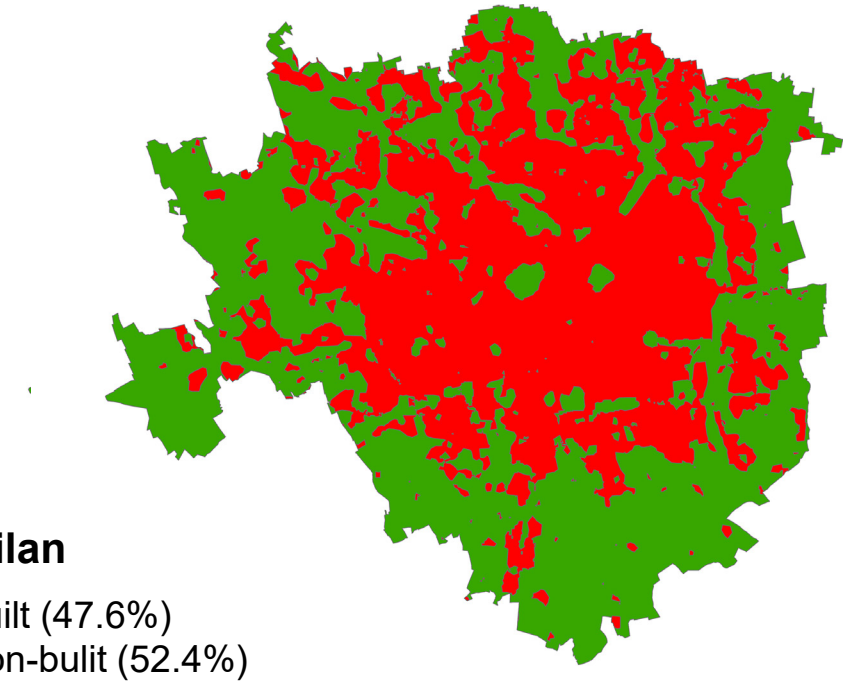
LCZs of > 1 Km in horizontal scale

Land occupation (built vs non-built)



CMM

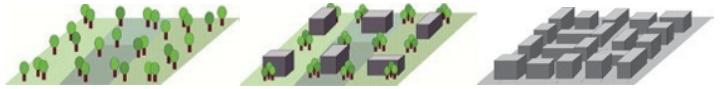
Built (24%)
Non-bulit (76%)



Milan

Built (47.6%)
Non-bulit (52.4%)

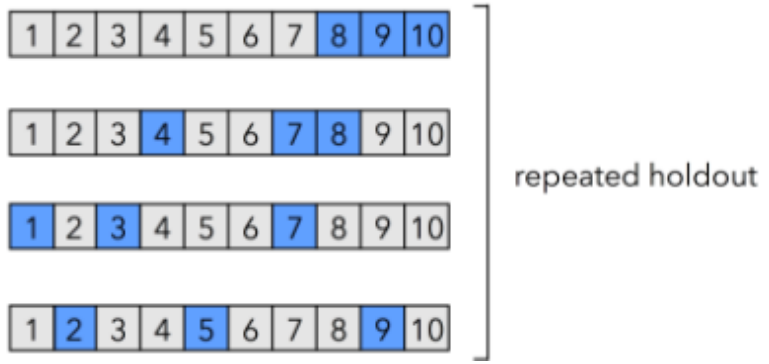
LCZ B (27.9%)
LCZ D (27.3%)
LCZ 6 (9.3%)
LCZ 10 (7.5%)
LCZ E (6.6%)



LCZ B (27.9%)
LCZ 5 (18.4%)
LCZ 2 (16.5%)
LCZ E (13.7%)
LCZ 10 (8.3%)

ACCURACY ASSESSMENT

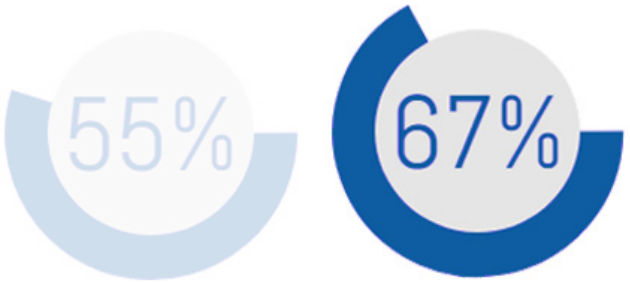
- Assessing the level of accuracy of the LCZ classification has been always challenging, since there is not enough, **independent test data (ground truth)**;
- Three approaches are usually used to assess the accuracy of the LCZ maps; these are **cross-validation**, **manual review**, and **cross-comparison** with other data;
- Here, we used the **repeated holdout cross validation** approach, using different subsamples for 25 iterations;
- In particular, the **original sample data** is separated into **two portions**, i.e. for training and testing (we used **half** of the original training data **for learning** and the **other half for testing**), where, **for each iteration, a different random subset of the data is used**.



RESULTS

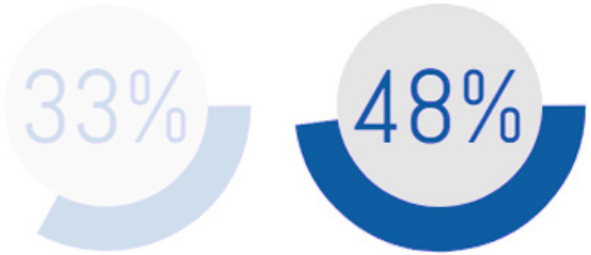
Standard accuracy measures were calculated, using a **confusion matrix**

OA for all testing polygons



(a) (b)

OA of all built types

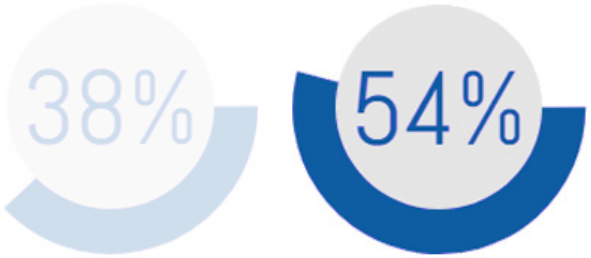


(a) (b)

Kappa coefficient

(a) (b)

OA of all built types *

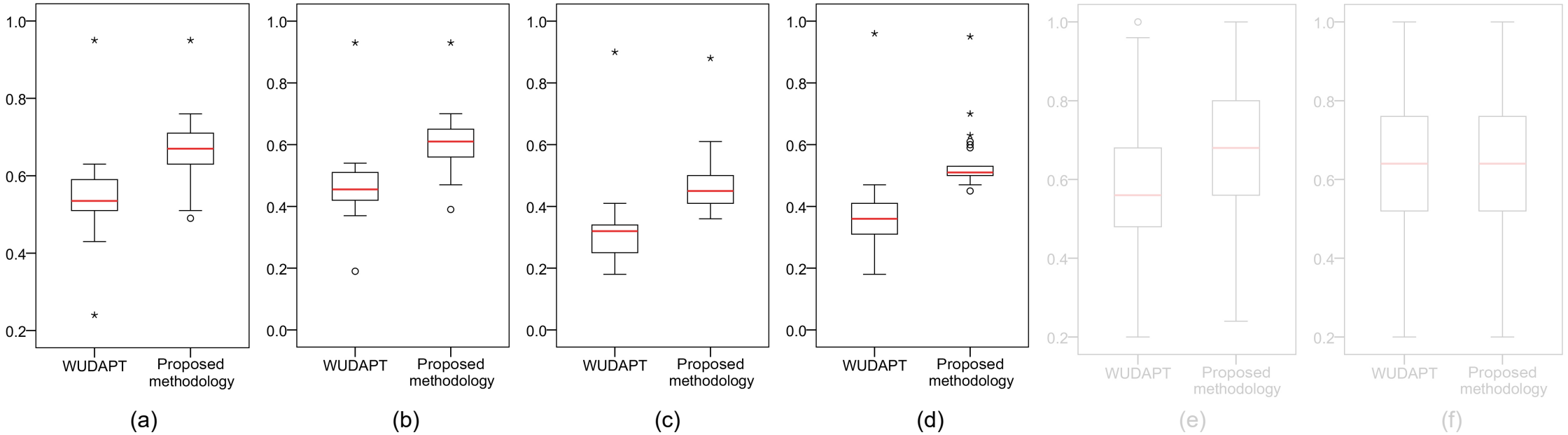


(a) (b)

(excluding LCZ 3 and 9)

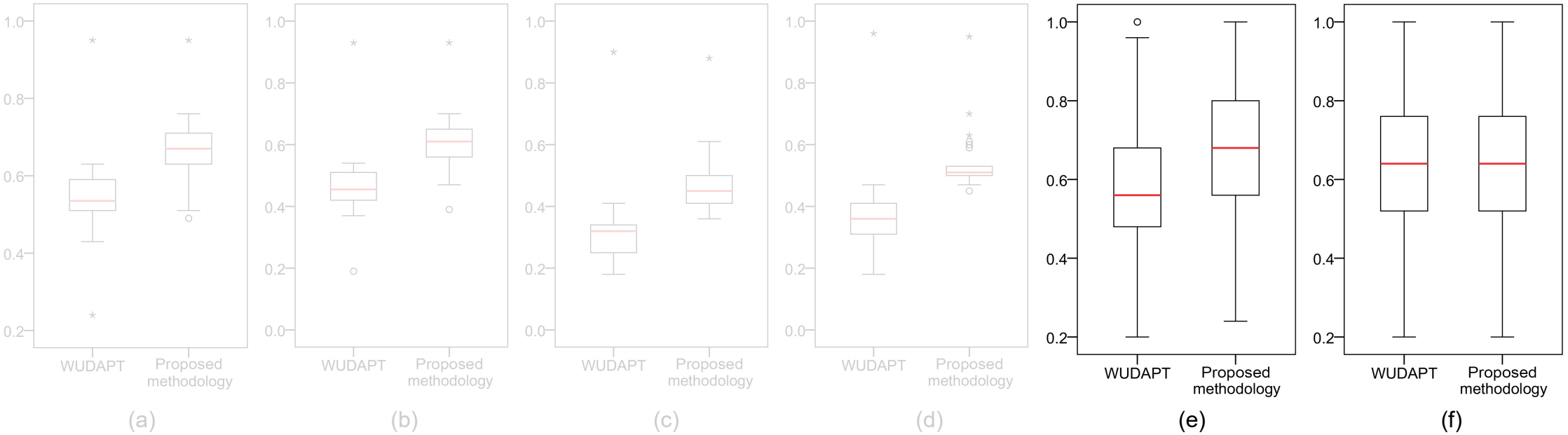
a) The WUDAPT level 0 product;
b) (b) The proposed methodology

RESULTS



Boxplots of the distribution of the accuracy measures across the 25 iterations. (a) Overall accuracy for all testing polygons; (b) Kappa coefficient for all testing polygons; (c) Overall accuracy of all built polygons; (d) Overall accuracy of all built polygons (without LCZ 3 and 9); (e) Certainty of the built local climate zones; (f) Certainty of non-built local climate zones

RESULTS



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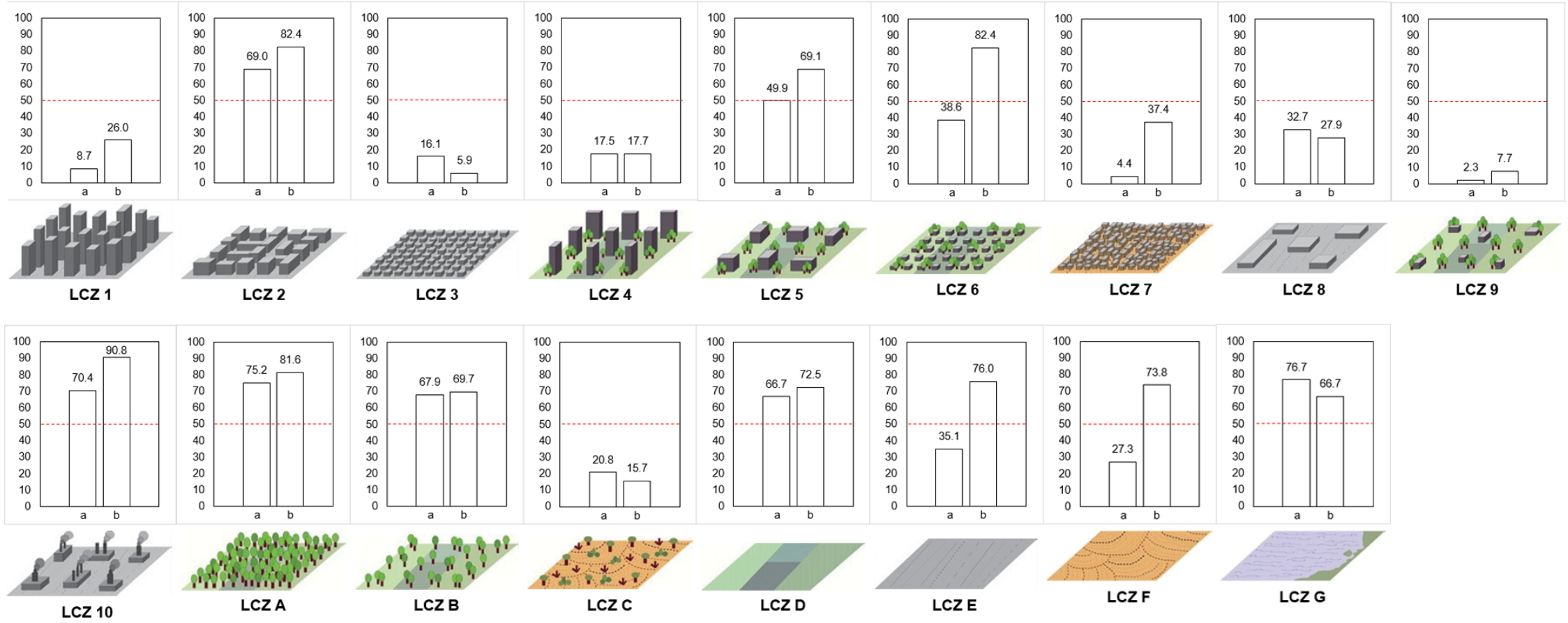
RESULTS



The producer's accuracy (%) per each LCZ type. (a) The WUDAPT level 0 product; (b) The proposed methodology

RESULTS

7 LCZs

Remarkable improvement

(LCZ 1, 5, 6, 7, 10, E, and F)

4 LCZs

Slight improvement

(LCZ 2, 9, A, and D)

2 LCZs

No/very little improvement

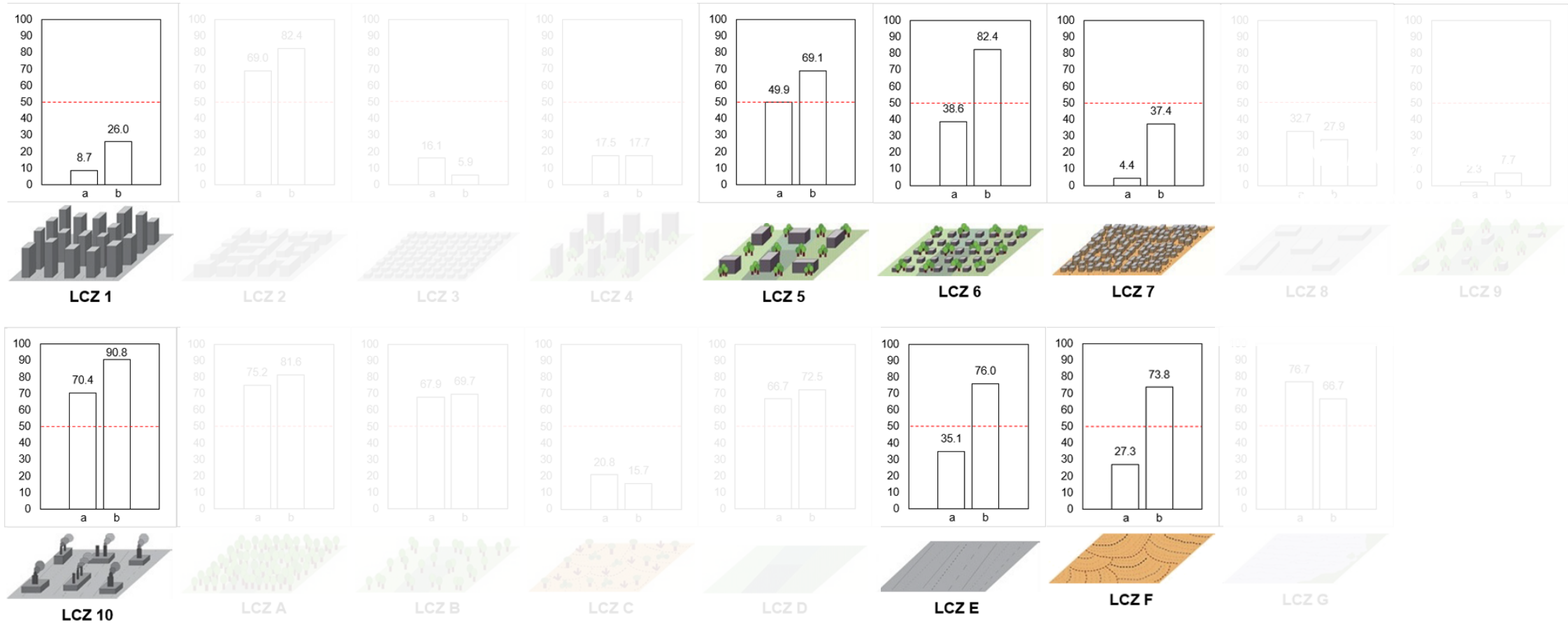
(LCZs 4 and B)

4 LCZs

Lower accuracy

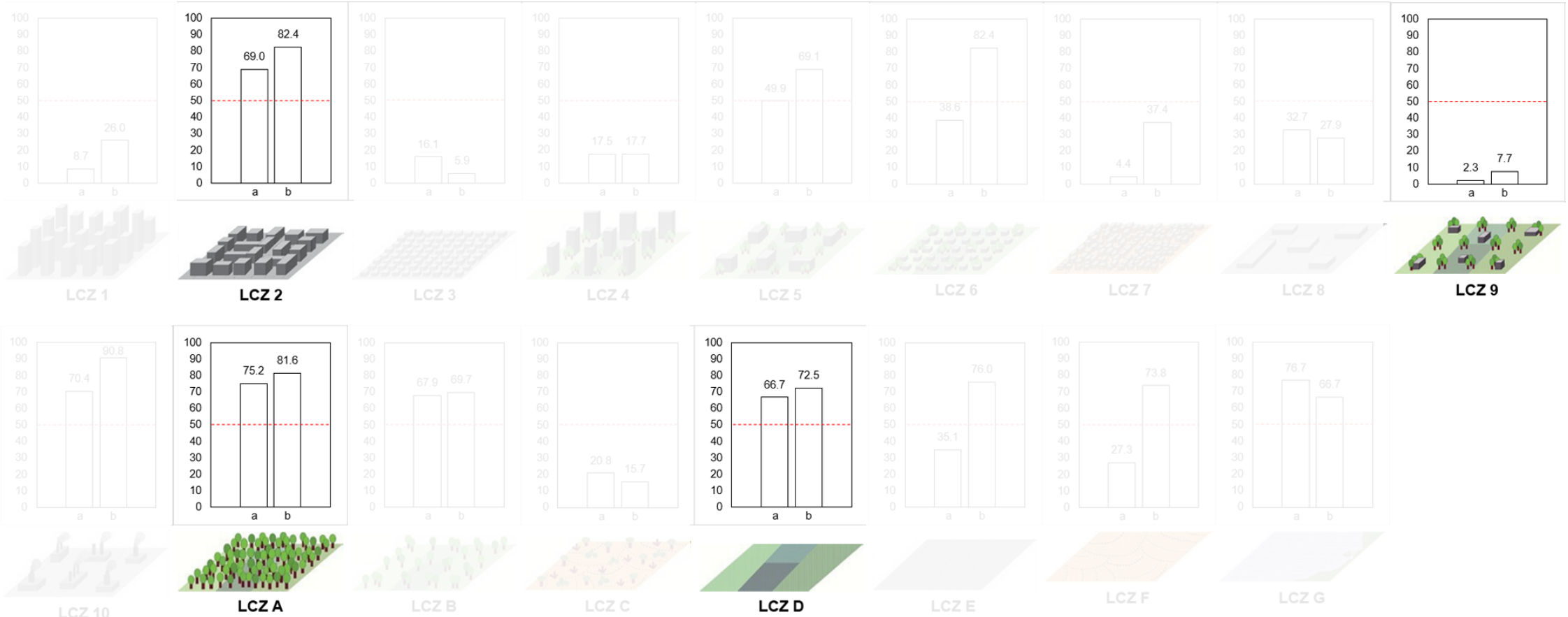
(LCZ 3, 8, C, and G)

Remarkable improvement



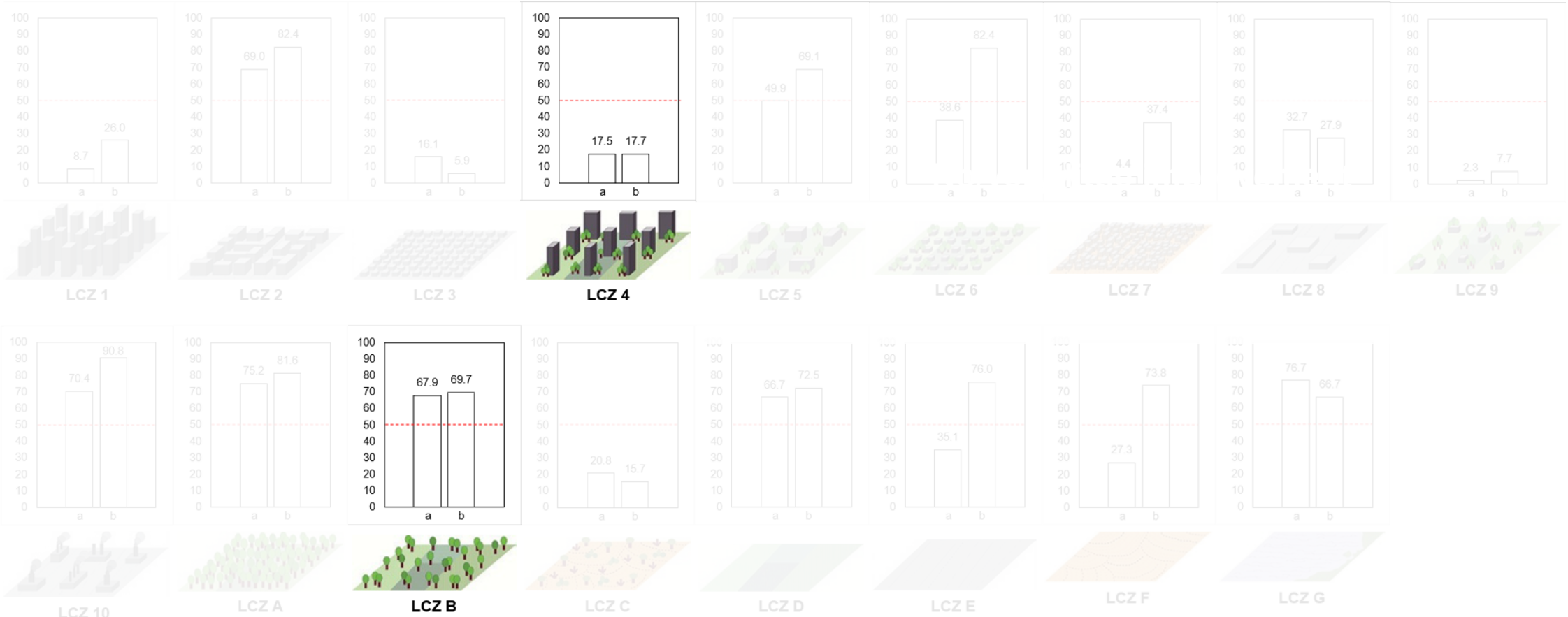
The producer's accuracy (%) per each LCZ type. (a) The WUDAPT level 0 product; (b) The proposed methodology

Slight improvement



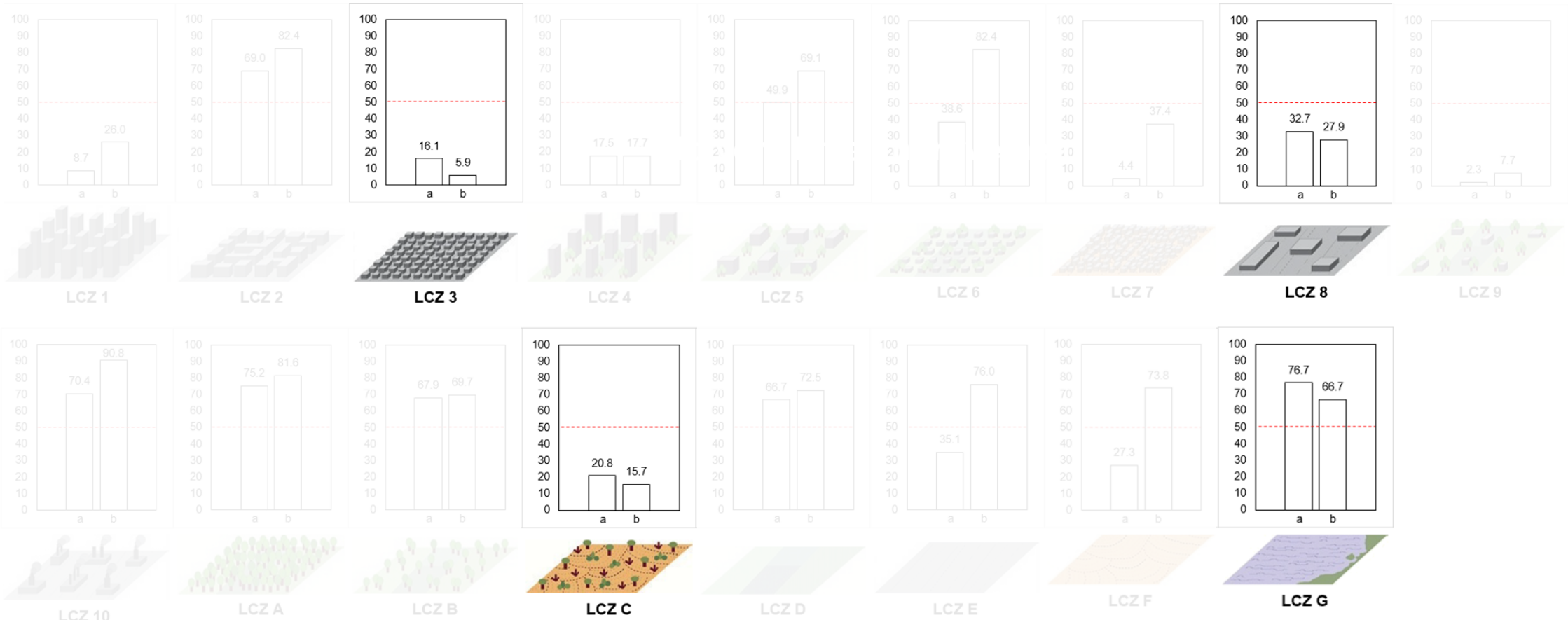
The producer's accuracy (%) per each LCZ type. (a) The WUDAPT level 0 product; (b) The proposed methodology

No/very little improvement



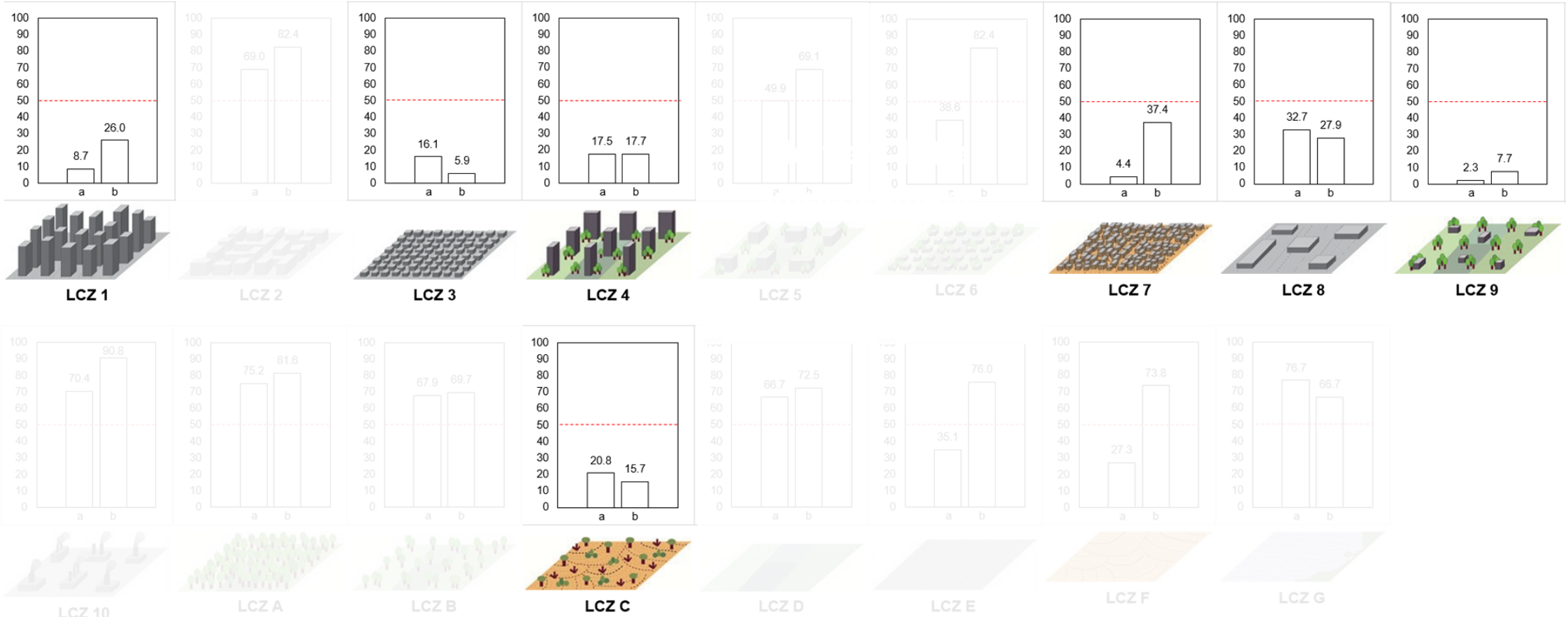
The producer's accuracy (%) per each LCZ type. (a) The WUDAPT level 0 product; (b) The proposed methodology

Lower accuracy



The producer's accuracy (%) per each LCZ type. (a) The WUDAPT level 0 product; (b) The proposed methodology

Overall low accuracy (< 50%)



The producer's accuracy (%) per each LCZ type. (a) The WUDAPT level 0 product; (b) The proposed methodology

SUMMING UP

- We have proposed an improvement methodology for the local climate zones (LCZs) classification, in the framework of WUDAPT initiative;
- We have utilized **medium resolution satellite optical imagery** (30 m), combined with **physical and morphological features** of the urban setting, to conduct a **pixel-based classification**;
- Further, we have digitized **smaller-sized training samples** (up to 250 m in horizontal length), using vey high resolution aerial imagery, to generate a **fine-scale LCZ classification** (hundreds of meters), suitable for better studying the urban climate phenomena at the micro and local scale (e.g. UHI);
- We assessed the quality of the output of maps of the proposed methodology against the WUDAPT level 0 product using standard accuracy measures through a confusion matrix.

CONCLUSIONS

- The results of the accuracy assessment showed a noticeable **improvement by 12%** in the overall accuracy with correspond to the WUDAPT level 0 product.

- Also, the overall accuracy, considering only the **built-up classes**, is **higher by 15%**, which demonstrates the effectiveness of the proposed approach in mapping fine-scale LCZs **without additional thermal information**;

- This ascertains **the physic-morphological nature of the LCZs** which are intrinsically related to certain temperature regimes and comfort levels (Stewart & Oke, 2012);

- The WUDAPT level 0 method is best suitable for mapping coarse scale LCZs map (> 1 km2 and > 200 m wide). However, mapping finer resolution maps will require a better description of the morphological and physical features of the urban setting.

LIMITATIONS AND FUTURE WORK

- There are still limitations in identifying some individual LCZ types for many reasons: some are **user-related**, e.g. **the subjectivity, the size and the quality of the training samples**. Others are related to the **universality of the LCZ scheme** with correspond to the heterogeneous nature of the internal urban structure among cities.

- It would be of interest, in future work, to evaluate the effect of using **different sets of training samples** (e.g. in terms of area, perimeter, quantity, etc.), on the OA of the output maps.

- Also, **multi-seasonal satellite images** and **higher quality elevation models** (e.g. LIDAR derived digital surface model) could be utilized for better **reliability** and **representativeness.**

- We would like also, to investigate the possibility of **readapting** the standard LCZ classification scheme by describing new **site-specific LCZ types** that are related to certain micro and local climate conditions.

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THANK YOU FOR YOUR ATTENTION

Ahmed Eldesoky [*]; Nicola Colannino [**] & Eugenio Morello [**]

* Università IUAV di Venezia
** Laboratorio di Simulazione Urbana Fausto Curti, DASTU, Politecnico di Milano

ahmed.eldesoky@iuav.it
labsimurb@polimi.it

IUAV

POLITECNICO MILANO 1863
DIPARTIMENTO DI ARCHITETTURA E STUDI URBANI
DEPARTMENT OF ARCHITECTURE AND URBAN STUDIES