

## → MAPPING URBAN AREAS FROM SPACE CONFERENCE

### Local Climate Zones as a new standard for mapping urban areas?

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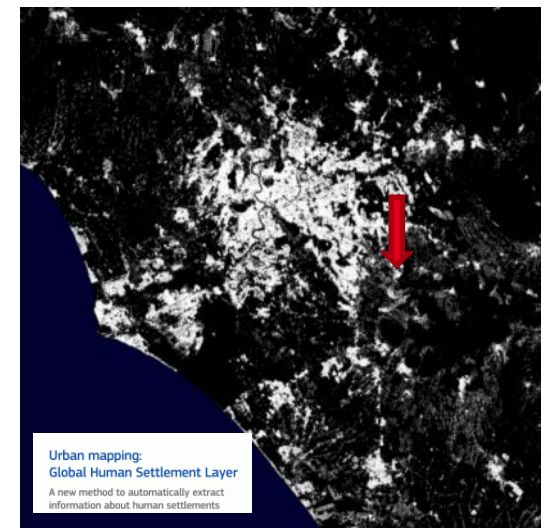
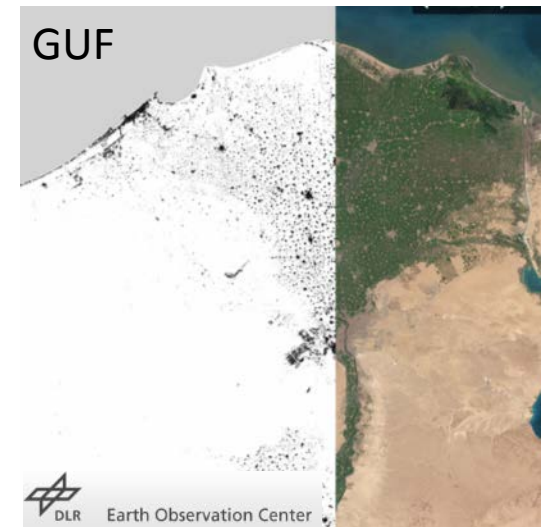
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## Motivation

- Great progress in mapping urban areas (Global Urban Footprint, Global Human Settlement Layer)
- Unprecedented mapping capabilities and data access (Sentinel 1 & 2, Landsat 8)

### BUT ...

- Mostly based on build-ups (= cover), not morphology, structure or function
- Approaches regarding **urban structural types** lack standardization and consistency
- Challenge: Urban morphologies depend on culture, history, and climate

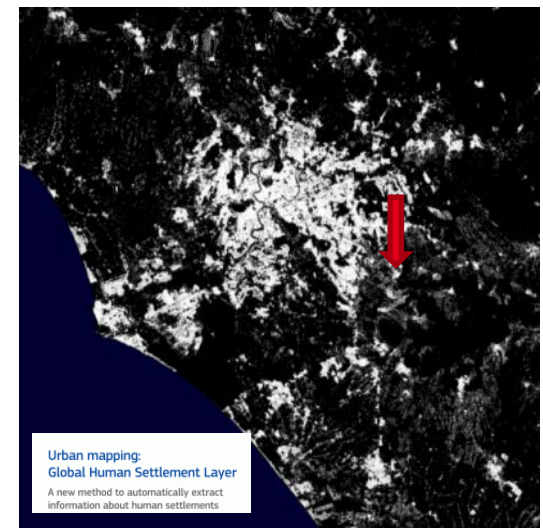
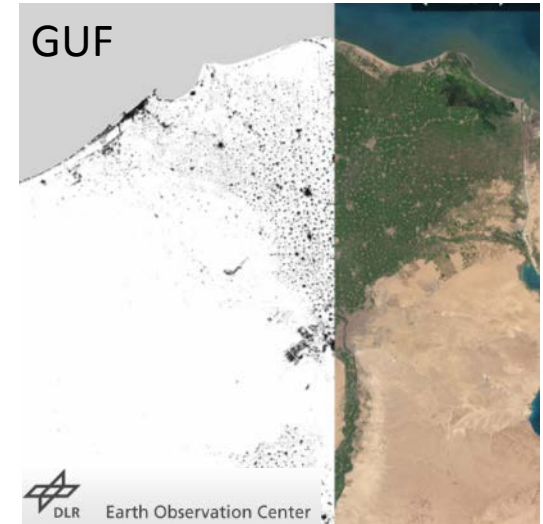


# wanted

Generic typology of urban structures

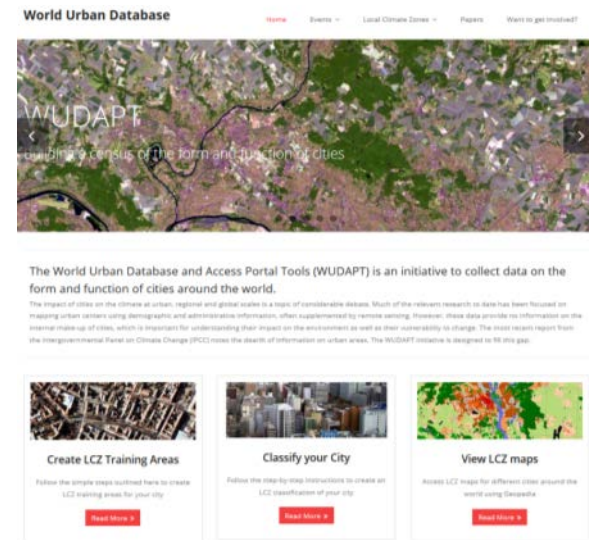
Information about their physical properties

Mapping methodology



# WUDAPT

- World Urban Database and Access Portal Tools
- Knowledge about footprint and internal structure of urban areas is relevant for various applications
- international collaborative project for the **acquisition, storage and dissemination of climate relevant data** on physical geographies of cities
- Aim: worldwide **physical census of cities by crowdsourcing**
- describe the **form** (surface cover, the construction materials and geometry) **and function** (metabolism, i.e. exchange of energy, water and materials) of cities **in different levels of detail**





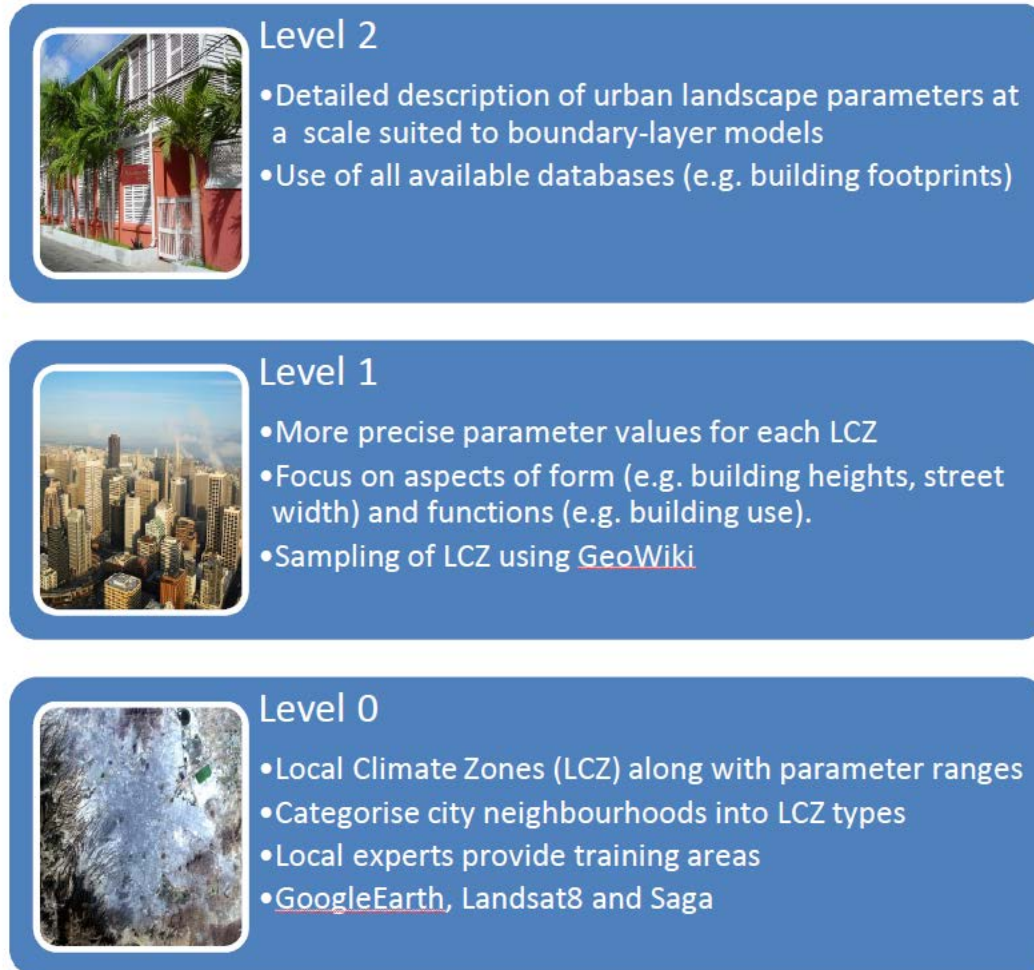


Fig. 1. WUDAPT's data hierarchy

# The landscape universe

## Local Climate Zones (Stewart & Oke 2012)

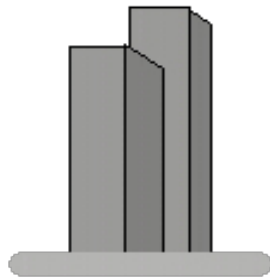
- *regions of uniform surface cover, structure, material, and human activity that span hundreds of meters to several kilometers in horizontal scale*
- *Each LCZ has a characteristic screen-height temperature regime*
- Generic, no cultural bias
- Large number of geometric, thermal, radiative, metabolic, and surface cover properties
- standardized physical description of cities

1. Compact high-rise	Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.	A. Dense trees	Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
2. Compact midrise	Dense mix of midrise buildings (3-9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	B. Scattered trees	Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
3. Compact low-rise	Dense mix of low-rise buildings (1-3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	C. Bush, scrub	Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.
4. Open high-rise	Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	D. Low plants	Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
5. Open midrise	Open arrangement of midrise buildings (3-9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	E. Bare rock or paved	Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation.
6. Open low-rise	Open arrangement of low-rise buildings (1-3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.	F. Bare soil or sand	Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture.
7. Lightweight low-rise	Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal).	G. Water	Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.
8. Large low-rise	Open arrangement of large low-rise buildings (1-3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials.	<b>VARIABLE LAND COVER PROPERTIES</b>	
9. Sparsely built	Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).	b. bare trees	Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo.
10. Heavy industry	Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials.	s. snow cover	Snow cover >10 cm in depth. Low admittance. High albedo.
		d. dry ground	Parched soil. Low admittance. Large Bowen ratio. Increased albedo.
		w. wet ground	Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.

# Constructing the LCZ Framework

## 1. Height of roughness features

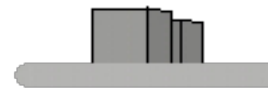
### Buildings



highrise  
> 25 m



midrise  
10-20 m

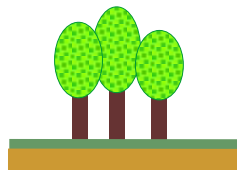


lowrise  
< 8 m

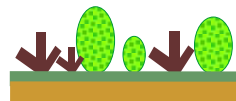


no rise  
0 m

### Vegetation



trees  
> 3 m



bush  
1-2 m



grasses  
< 1 m



soil  
0 m

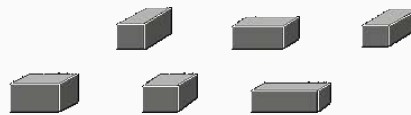
# Constructing the LCZ Framework

## 2. Packing of roughness features

### Buildings



compact  
 $H/W > 1$



open  
 $H/W < 1$



sparse  
 $H/W < 0.25$

### Vegetation



compact  
 $H/W > 1$



open  
 $H/W < 1$

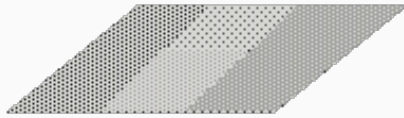


sparse  
 $H/W < 0.25$

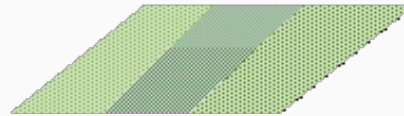


# Constructing the LCZ Framework

## 3. Surface cover around roughness features



impervious  
concrete/rock

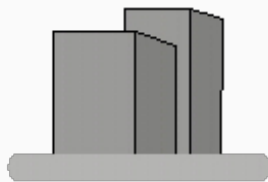


pervious  
low plants

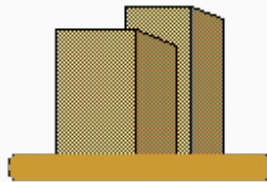


pervious  
soils

## 4. Thermal admittance of materials

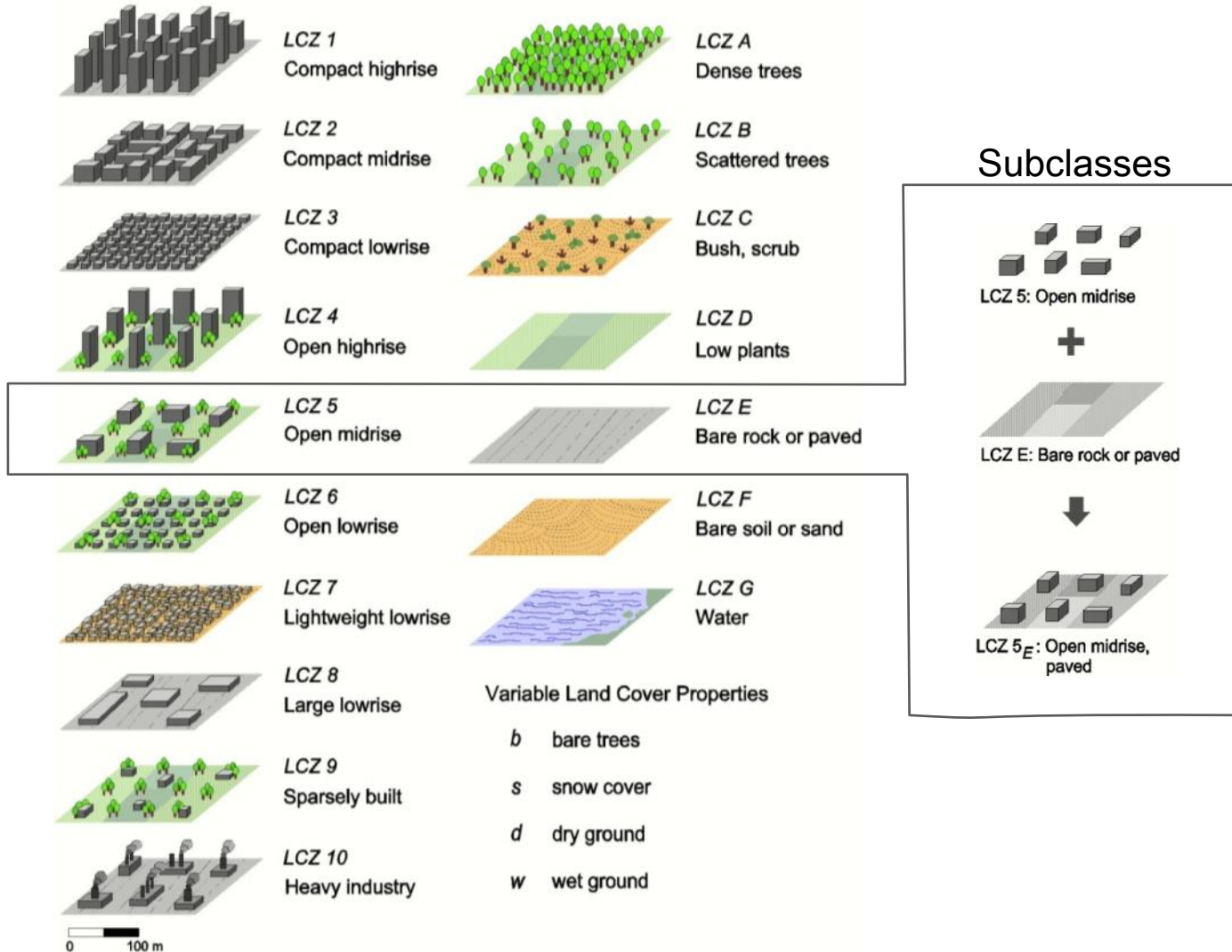


heavy  
concrete, stone



lightweight  
sheet metal, wood

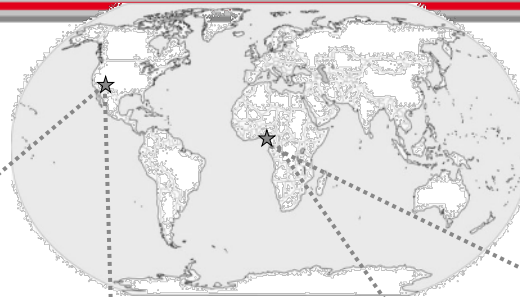
# Local Climate Zones (LCZ)



# International comparisons

Los Angeles  
USA

Akure  
NIGERIA

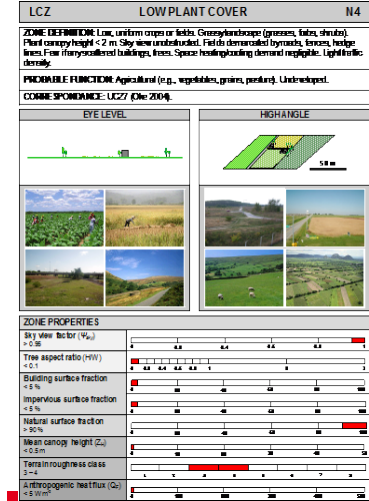
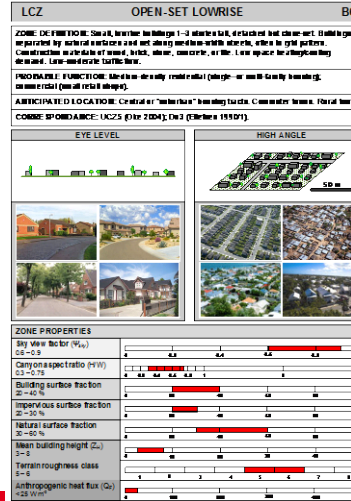
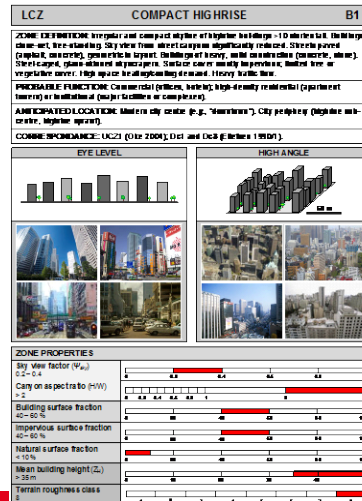


LCZ 1

LCZ 8

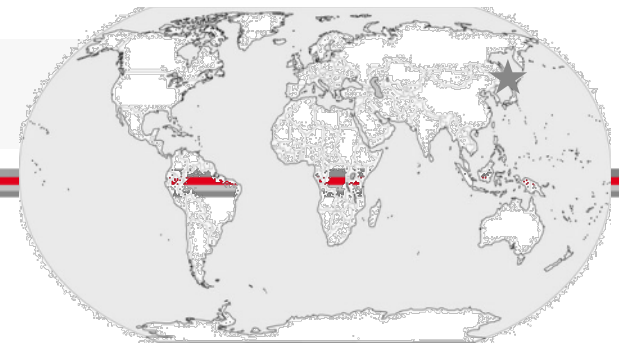
LCZ 6

LCZ D

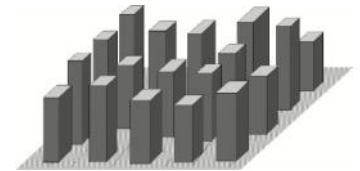




# CLASSIFYING LCZs



## Sendai, JAPAN



LCZ 1

Compact high-rise

### Visual Clues

Few if any trees

Little or no green space

Tightly packed buildings

10+ stories tall

Diurnal temperature range:

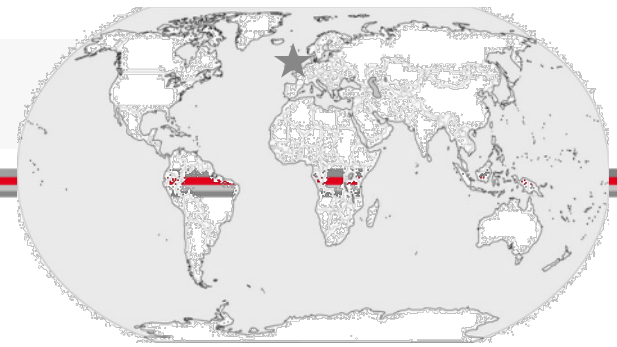
**small**

medium

large

# CLASSIFYING LCZs

## London, UK



LCZ 2

Compact mid-rise

### Visual Clues

Few if any trees

Little or no green space

Tightly packed buildings

3 – 9 stories tall

Diurnal temperature range:

**small**

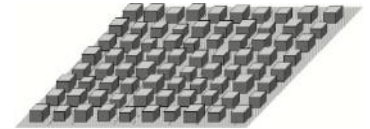
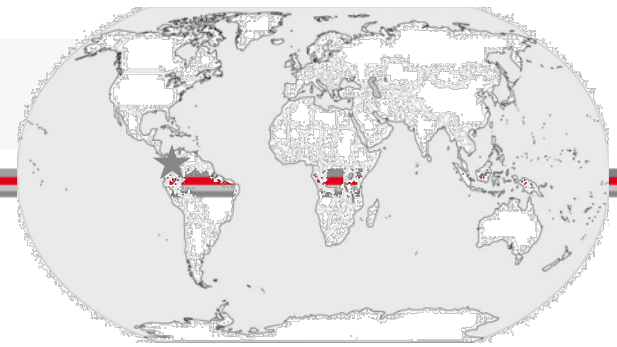
medium

large



# CLASSIFYING LCZs

## Medellin, COLOMBIA



LCZ 3

Compact low-rise

### Visual Clues

Few if any trees

Little or no green space

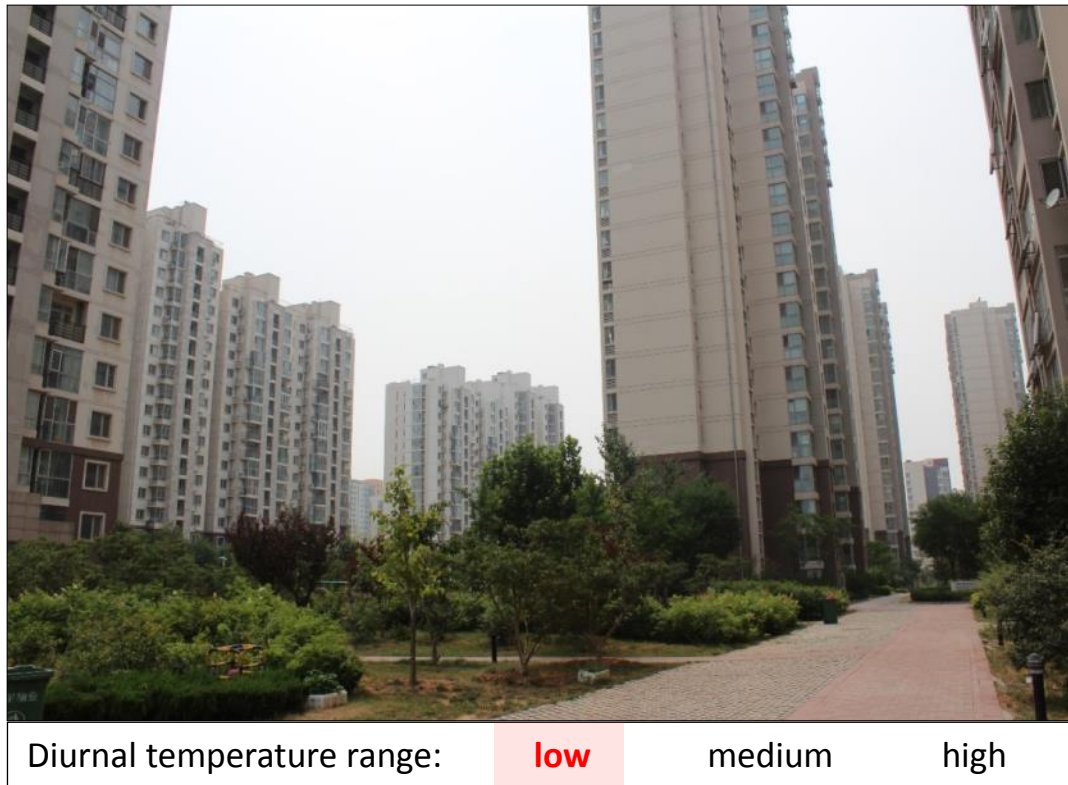
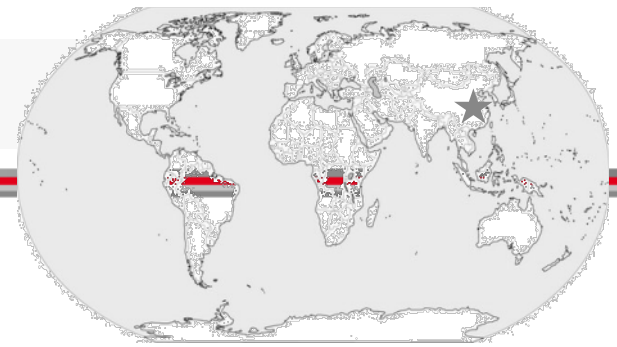
Tightly packed buildings

1 – 3 stories tall

Diurnal temperature range:    small    **medium**    large

# CLASSIFYING LCZs

## Jinan, CHINA



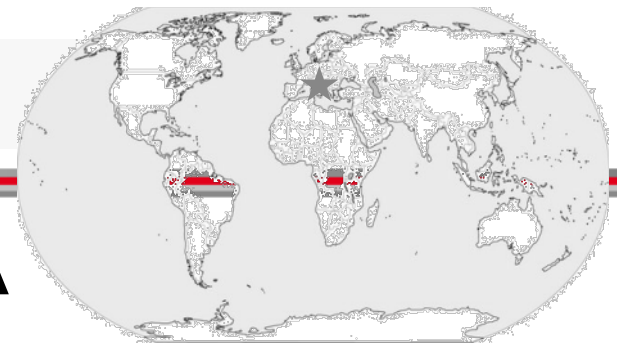
### LCZ 4 Open high-rise

#### Visual Clues

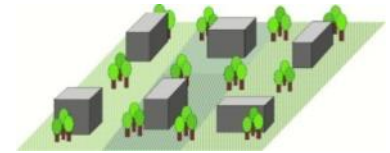
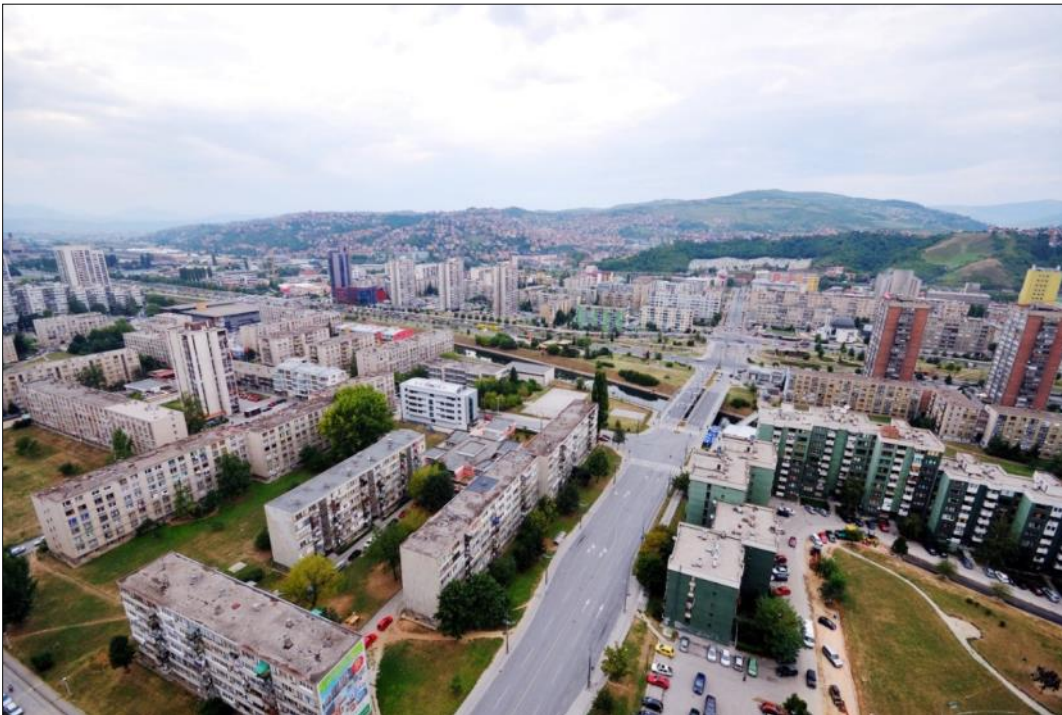
Abundance of trees and pervious cover  
Openly arranged buildings  
10s of stories tall



# CLASSIFYING LCZs



## Sarajevo, BOSNIA & HERZEGOVINA



LCZ 5

Open mid-rise

### Visual Clues

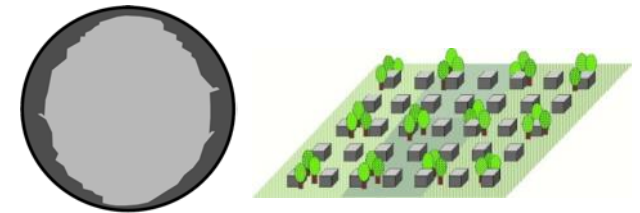
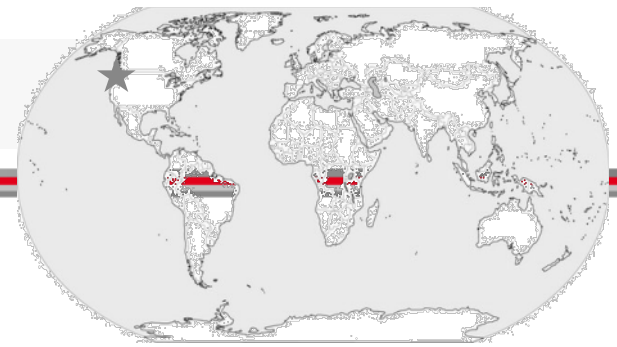
Abundance of trees and  
pervious cover

Openly arranged buildings  
3 – 9 stories tall

Diurnal temperature range:    small    **medium**    large

# CLASSIFYING LCZs

## Seattle, USA



LCZ 6

Open mid-rise

### Visual Clues

Abundance of trees and  
pervious cover

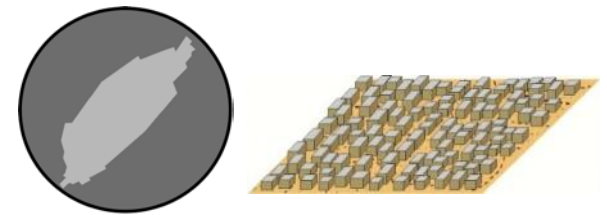
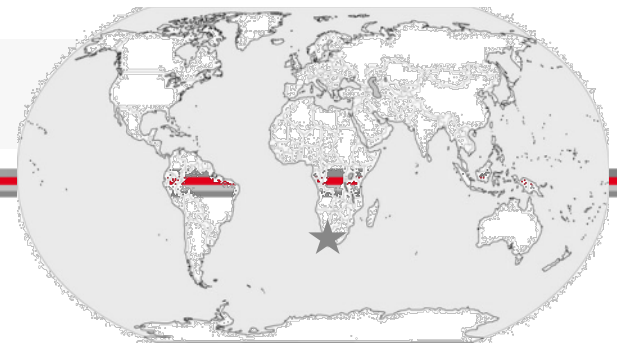
Openly arranged buildings  
1 – 3 stories tall

Diurnal temperature range:    small    **medium**    large



# CLASSIFYING LCZs

## Cape Town, SOUTH AFRICA



LCZ 7

Lightweight low-rise

### Visual Clues

Few or no trees

Land cover hard-packed

Lightweight building materials

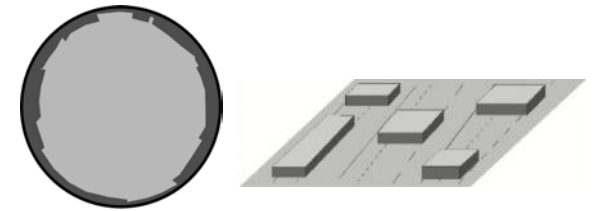
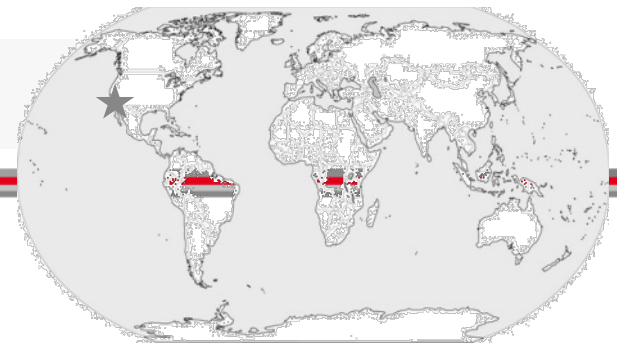
1 – 2 stories tall

Diurnal temperature range:      small      medium      **large**



# CLASSIFYING LCZs

## Los Angeles, USA



LCZ 8

Large low-rise

### Visual Clues

Few if any trees

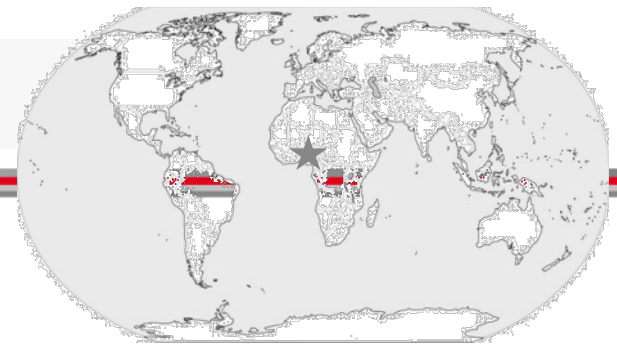
Land cover mostly paved

Large, openly arranged buildings, 1 – 3 stories tall

Diurnal temperature range:      small      **medium**      large

# CLASSIFYING LCZs

## Akure, NIGERIA



Diurnal temperature range:    small    medium    **large**



LCZ 9  
Sparsely built

### Visual Clues

Natural setting

Abundance of pervious cover

Sparse arrangement of small or mid-sized buildings

# LCZ properties: 'Level 0' data

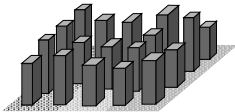
## LCZ COMPACT HIGHRISE 1

### DEFINITION

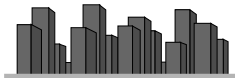
**Form:** Dense and irregular mix of tall buildings to tens of stories. Buildings free-standing, closely spaced. Sky view from street level significantly reduced. Buildings of steel, concrete, and glass construction. Land cover mostly paved; few or no trees. High space heating/cooling demand. Heavy traffic flow. **Function:** Commercial (office buildings, hotels); residential (apartment towers). **Location:** City core (downtown, central business district). Periphery (highrise subcentre, highrise sprawl). **Correspondence:** UCZ1 (Oke, 2004); Dc1 and Dc8 (Ellefsen, 1990/91).

### ILLUSTRATION

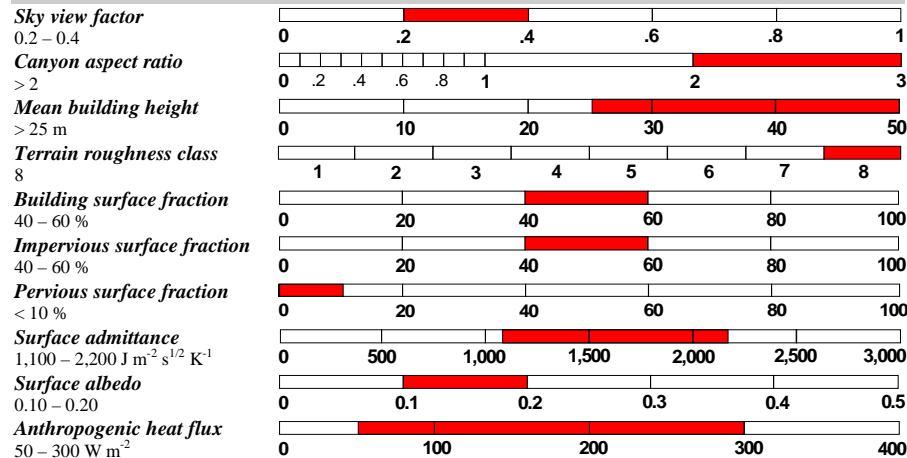
High angle



Low level



### PROPERTIES



### Sources for property values:

- Parent schemes (UCZ, UTZ, other)
- Urban climate literature
- Urban climate community

### Why do we give a range of values for each property?

- Reduces the number of standard classes
- Eases the classification process
  - no need for exact measurements
  - preserves generality

## Requirements for LCZ mapping

- simple workflow in the form of a protocol
- enabling local operators with different backgrounds to derive a LCZ map
- Universal
- as objective as possible
- computationally efficient
- fiscally inexpensive (based on free and widely available data and software)

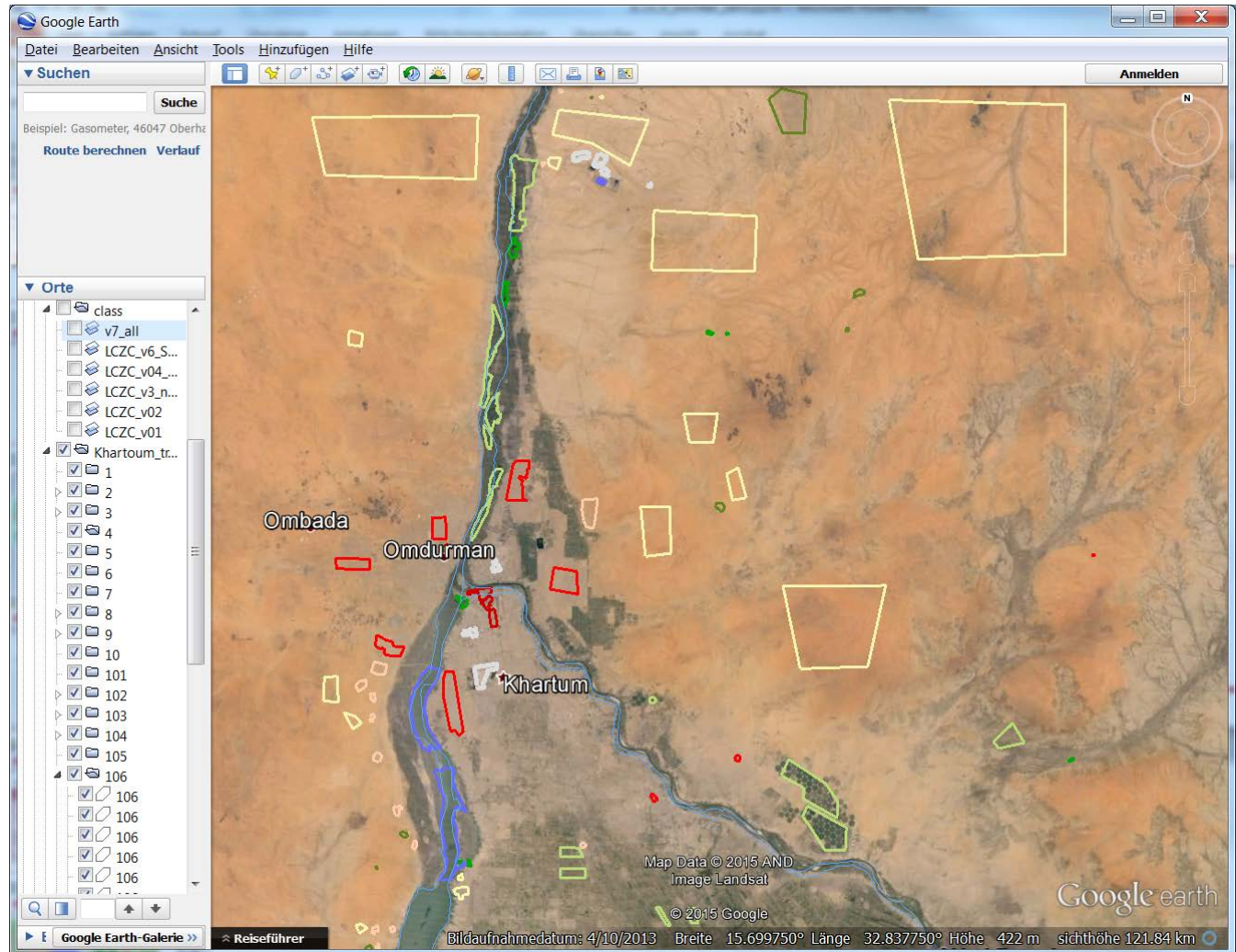
## LCZ mapping schemes evaluated

- manual sampling of grid cells using Geo-Wiki (Mills 2013)
- digitisation of homogenous LCZs
- GIS-based approach using building data (Lelovics et al. 2014)
- object based image analysis (Gamba et al. 2012; Weng 2014)
- supervised pixel-based classification (Bechtel 2011; Bechtel and Daneke 2012).
- [Identification from gridded LCZ parameters (Mitraka et al. 2015)]





# Khartoum







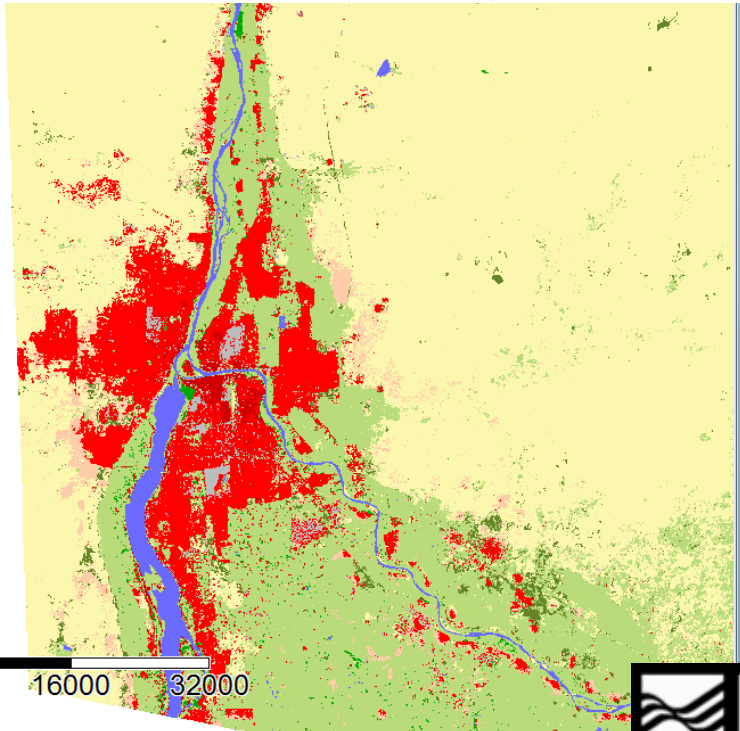
### Local Climate Zone Classification

<b>Data Objects</b>	
Grids	
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<< <b>LCZC</b>	<create>
< <b>LCZC (Filtered)</b>	<not set>
<b>Options</b>	
<b>Training Areas</b>	L:\LCZ\SAR\data\train\Khartoum_train_bb_v07.kmz
Random Forest Tree Count	32
<b>Class Definition File</b>	L:\LCZ\SAR\doc\cmap_WUDAPT_2015.txt
<b>Save LCZC as...</b>	L:\LCZ\SAR\data\class\KHAR[fs]all[tr]v0.7.kmz

Okay  
Cancel  
Load  
Save  
Defaults

Unit	
Z-Scale	1
Z-Offset	0
Show Cell Value	<input type="checkbox"/>
Memory Handling	Normal
<b>Display</b>	
Transparency	0
Show at all scales	<input checked="" type="checkbox"/>
Interpolation	None
<b>Colors</b>	
Type	Lookup Table
<b>Lookup Table</b>	
Table	(columns: 5, rows: 17)

Apply   Restore   Load   Save



File Geoprocessing Map Window ?

Manager

Tools Data Maps

Tree Thumbnails

120; 959x 1043y; 425160x 1673280y

Messages

General Execution Errors

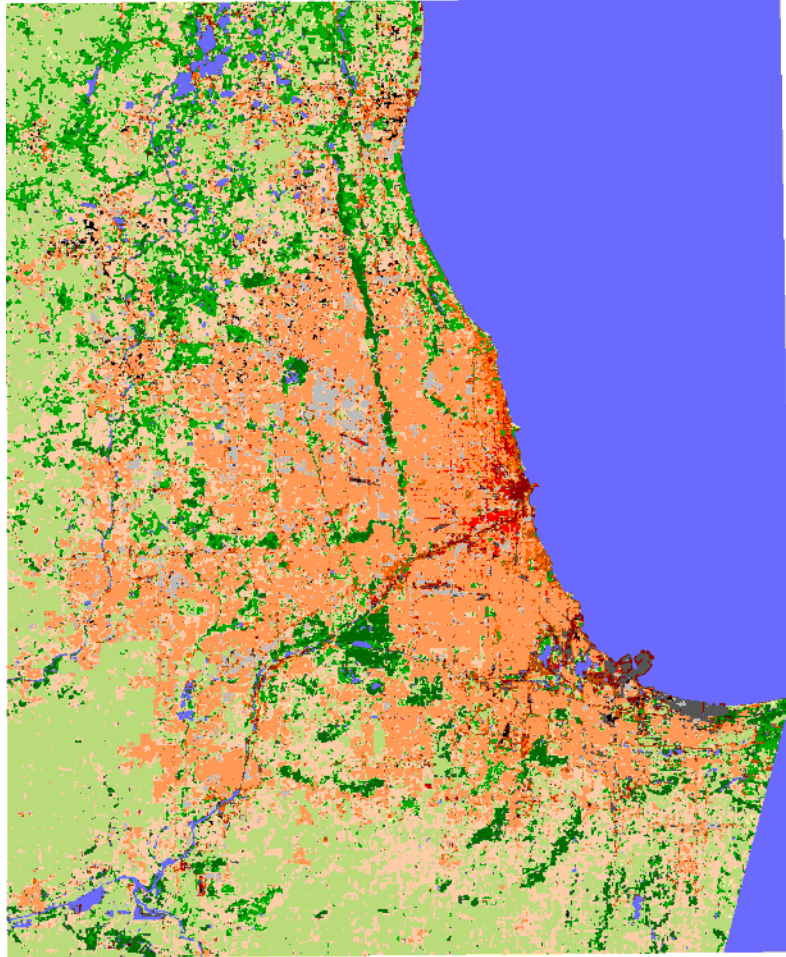
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[2015-07-16/17:04:58] Load grid: L:\LCZ\SAR\data\feat\SAR\Intensity_VH.sgrd...okay
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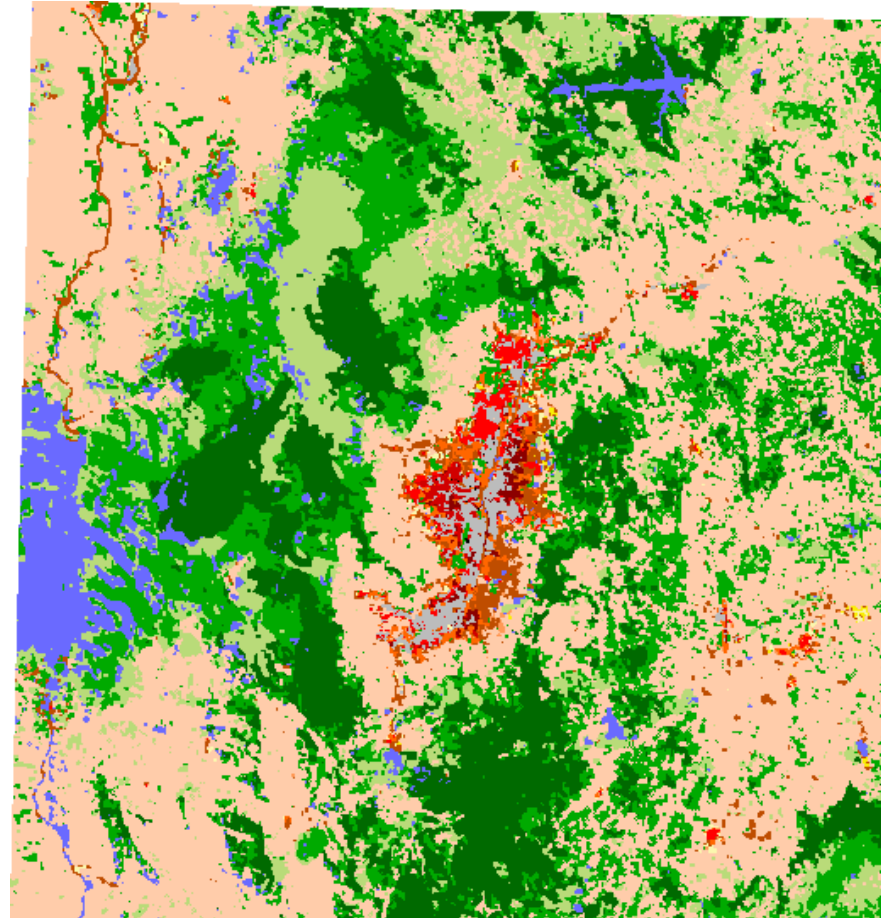
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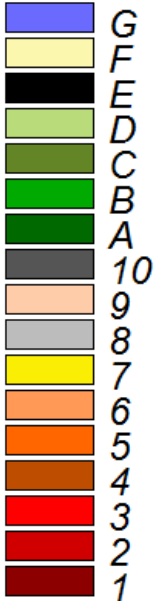




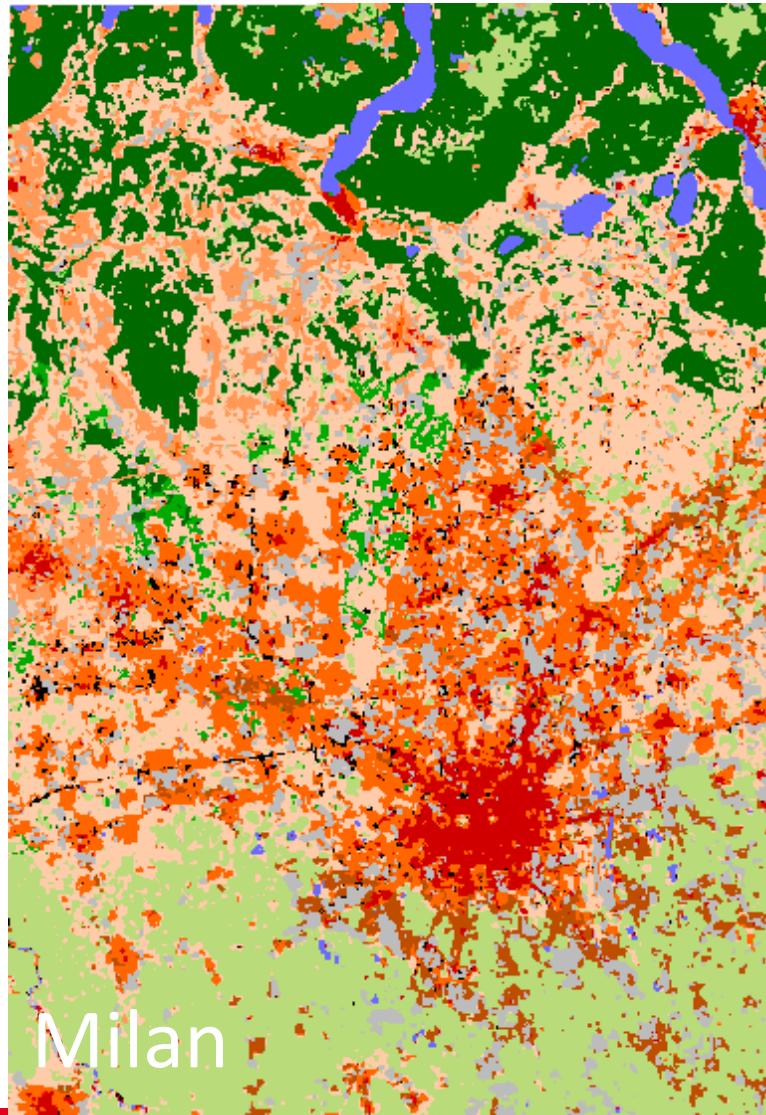
Chicago



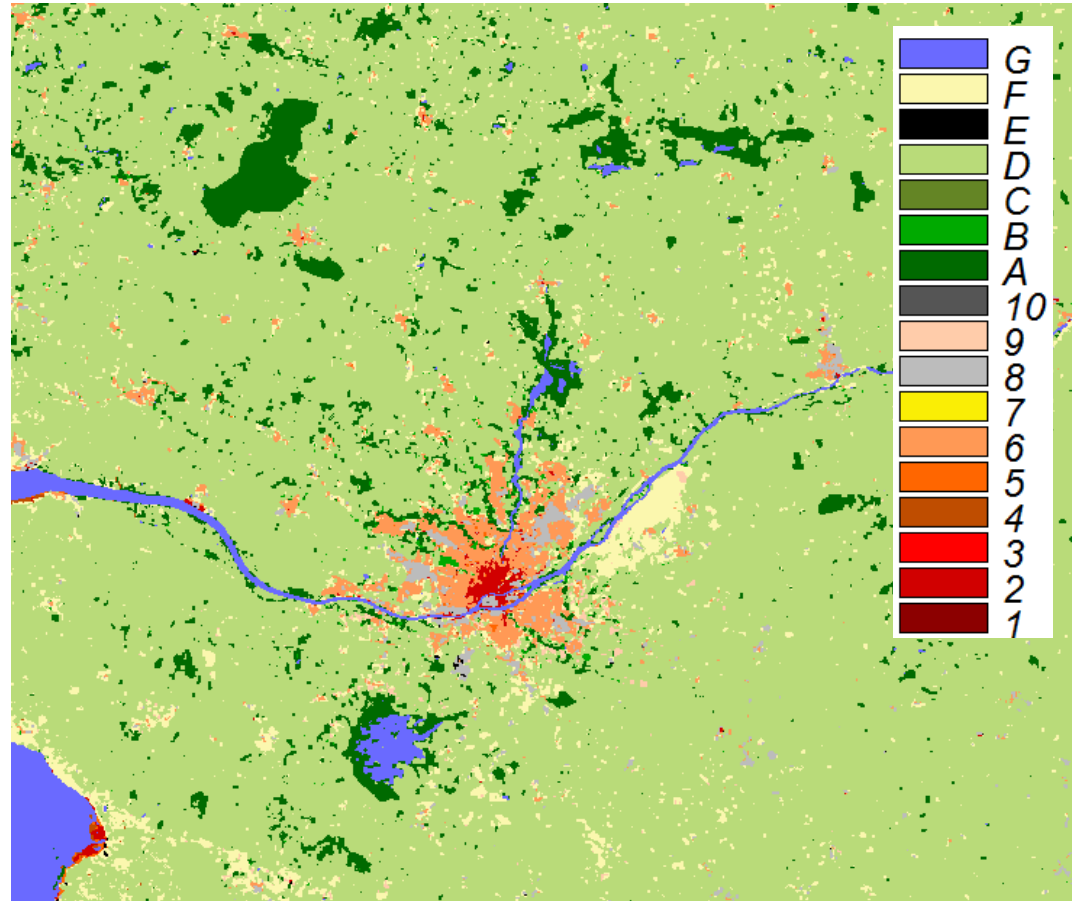
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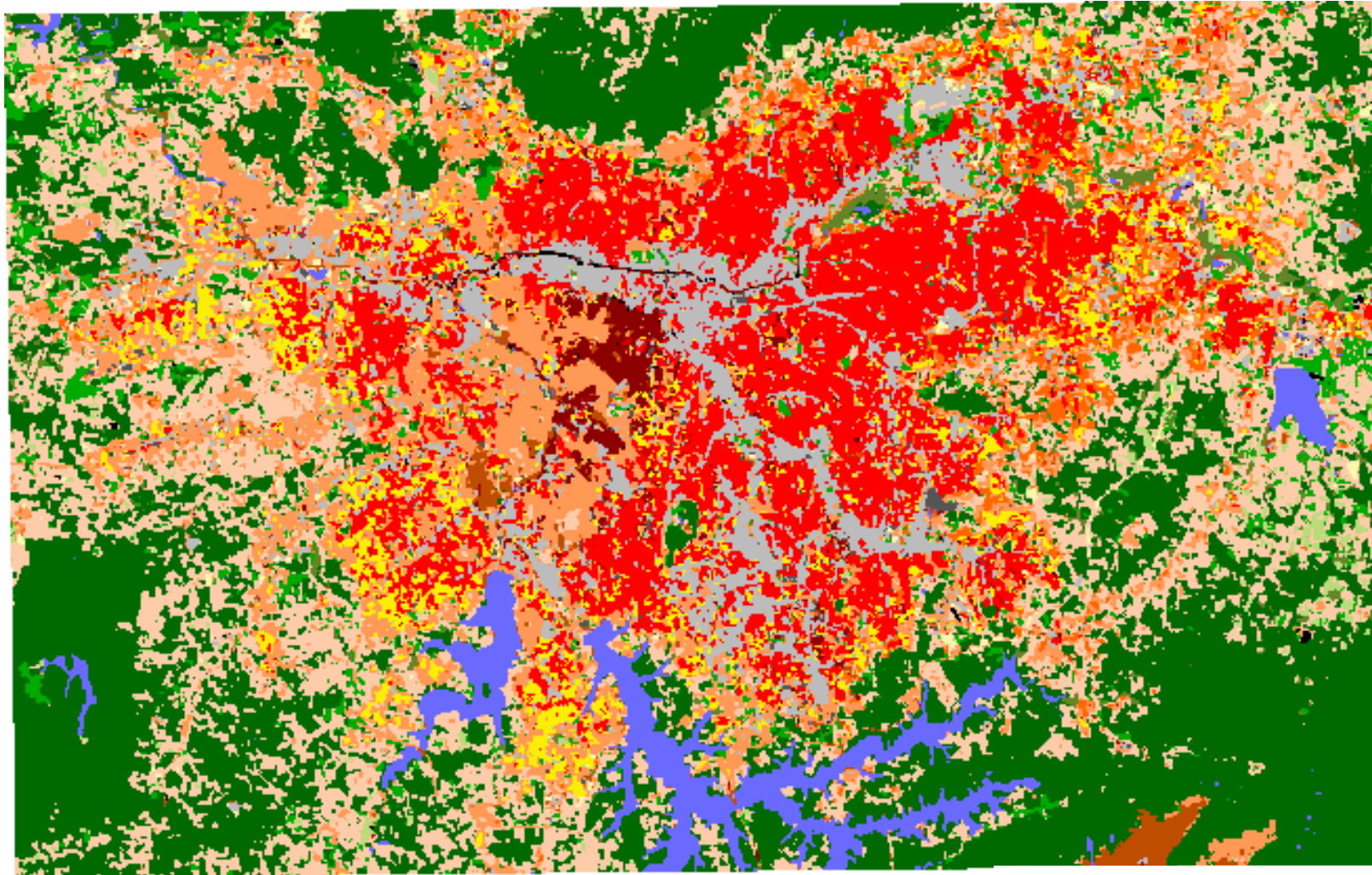




Milan

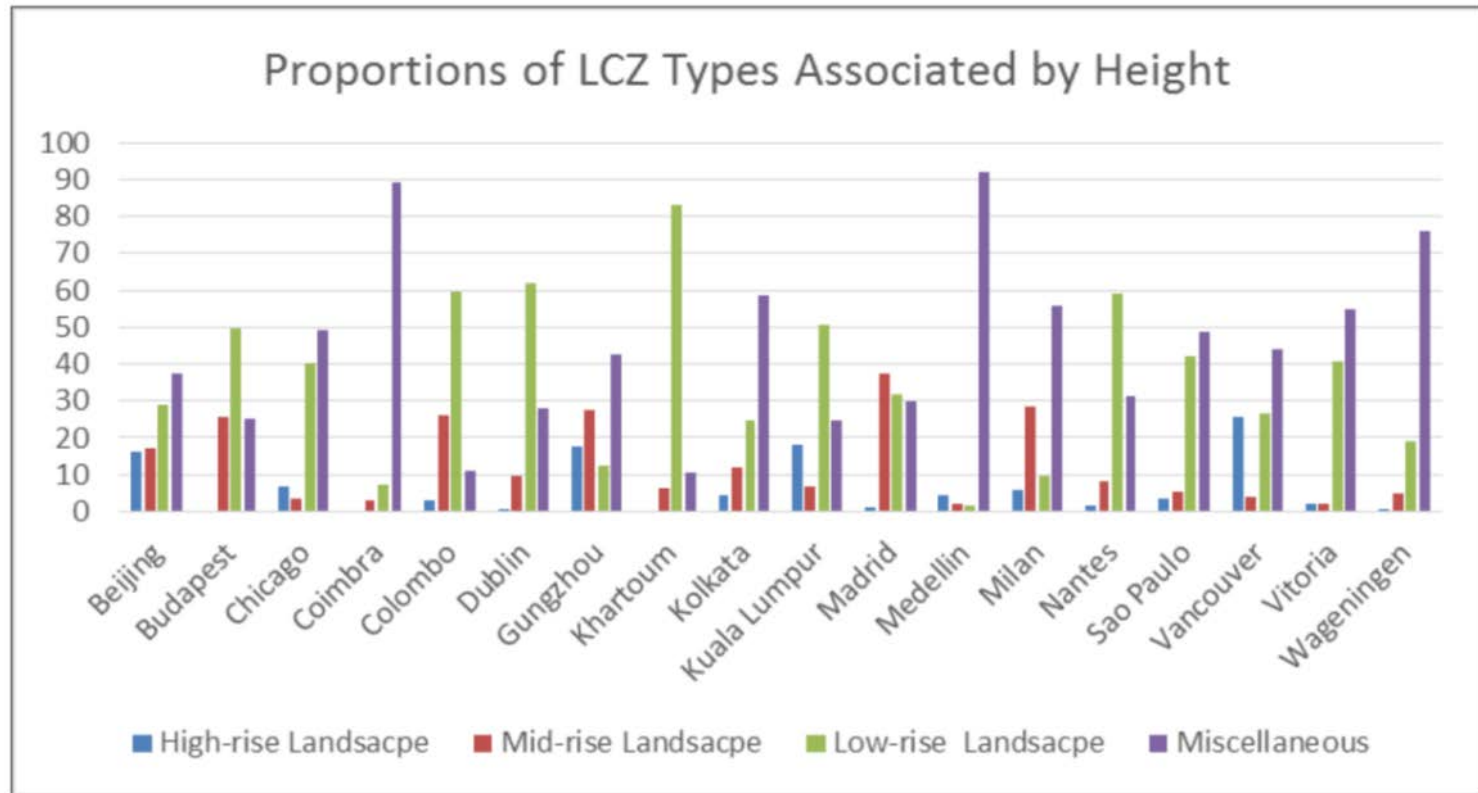


Nantes

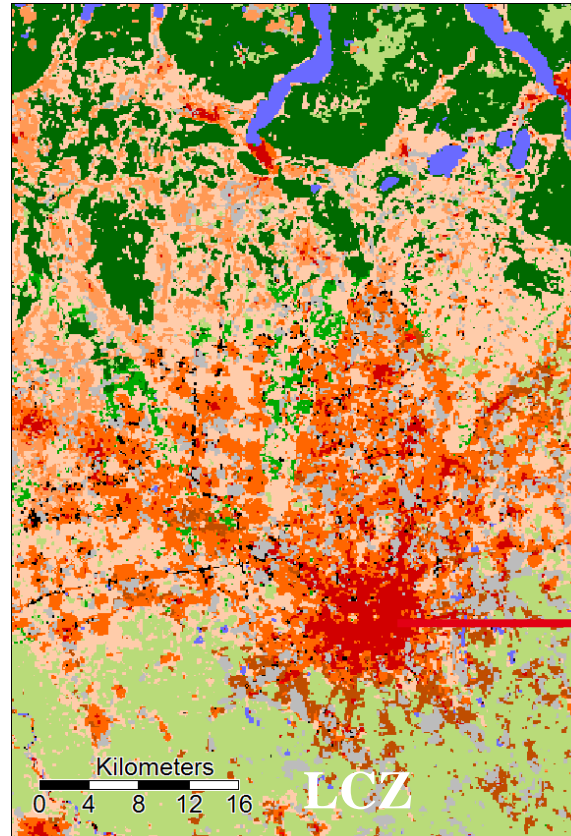
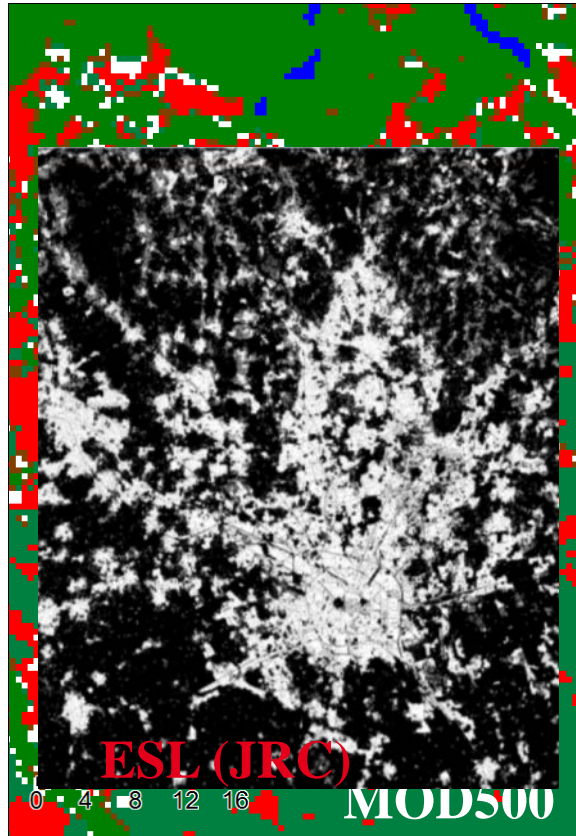


Sao Paulo

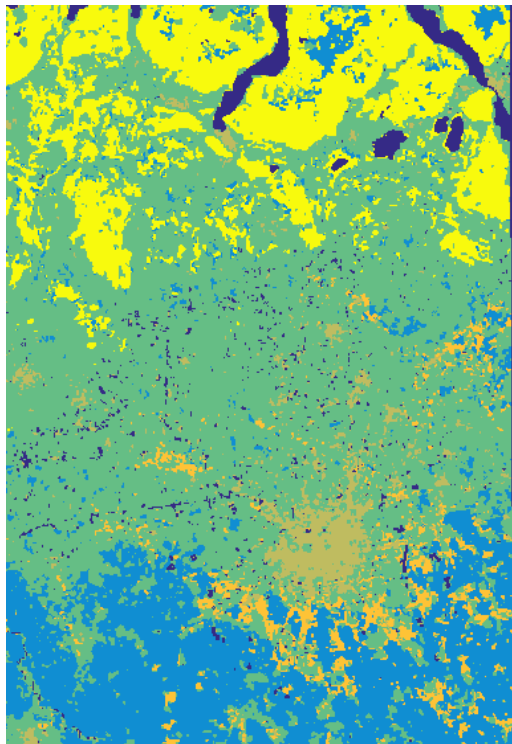




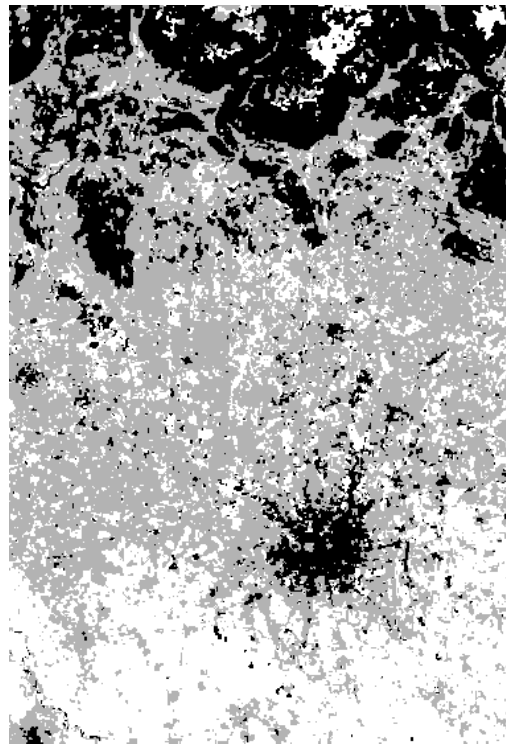
# Achievements of level 0



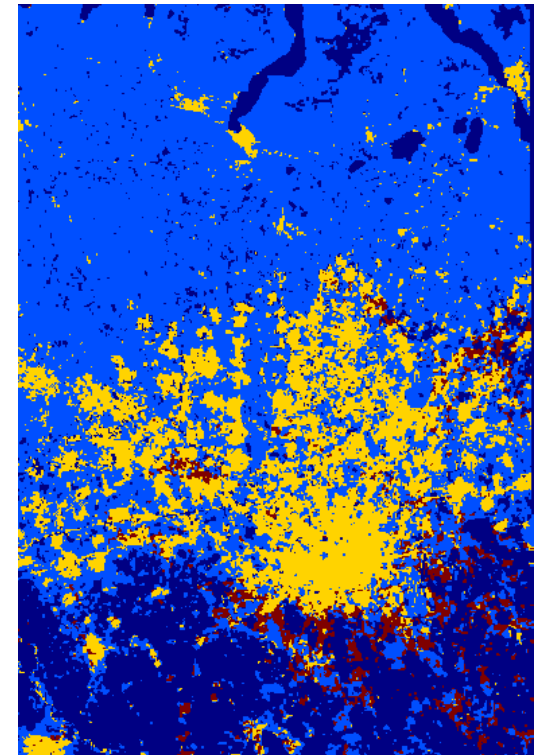
LCZ	COMPACT MID-RISE	2
<b>DEFINITION</b>		
<p><i>Form:</i> Attached or closely spaced buildings 3–9 stories tall. Buildings separated by narrow streets and inner courtyards. Buildings uniform in height. Sky view from street level significantly reduced. Heavy construction materials (stone, concrete, brick, tile); thick roofs and walls. Land cover mostly paved or hard-packed. Few or no trees. Moderate space heating/cooling demand. Moderate to heavy traffic flow.</p> <p><i>Function:</i> Residential (multi-unit housing; multistorey tenements); commercial (office buildings, hotels, retail shops); industrial (warehouses, factories). <i>Location:</i> Core (old city, old town); inner city, central business district; periphery (high-density sprawl). <i>Correspondence:</i> UCZ2 (Oke 2004); A1, A2, A4, Dc2 (Ellefsen 1990/91).</p>		
<b>ILLUSTRATION</b>		
<p><i>High angle</i></p> 		
<p><i>Low level</i></p> 		
<b>PROPERTIES</b>		
<i>Sky view factor</i> 0.3 – 0.6		
<i>Canyon aspect ratio</i> 0.75 – 2		
<i>Mean building height</i> 10 – 25 m		
<i>Terrain roughness class</i> 1 – 8		
<i>Building surface fraction</i> 40 – 70 %		
<i>Impervious surface fraction</i> 30 – 50 %		
<i>Pervious surface fraction</i> < 20 %		
<i>Surface admittance</i> 1,500 – 2,200 J m <sup>-2</sup> s <sup>-1/2</sup> K <sup>-1</sup>		
<i>Surface albedo</i> 0.10 – 0.20		
<i>Anthropogenic heat flux</i> < 75 W m <sup>-2</sup>		



**DRC min**



**$\alpha$  mean**

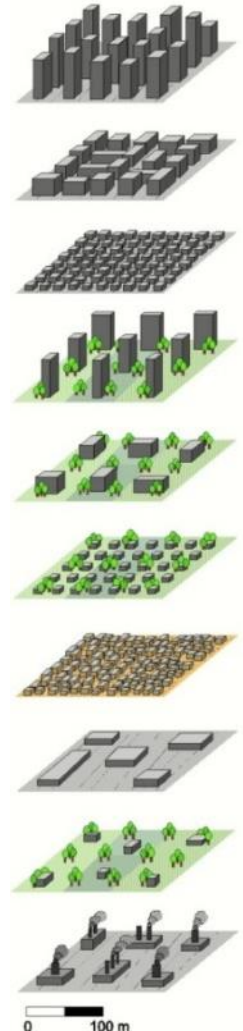


**Height min**



## Summary

- Next generation of global urban mapping products should focus on form and function
- **Local Climate Zones** are a generic typology of urban structures -> Discretisation of (urban) landscapes
- Can be mapped using EO data
- climatic and physical property information
- Good empirical evidence in urban climatology but potentially a much wider scope (infrastructure, health, emergency response, energy, ...)
- Simple mapping methodology proofed concept but **more sophisticated approaches welcome!**



## World Urban Database

Home Events Local Climate Zones Papers Want to get involved?



The World Urban Database and Access Portal Tools (WUDAPT) is an initiative to collect data on the form and function of cities around the world.

The impact of cities on the climate at urban, regional and global scales is a topic of considerable debate. Much of the relevant research to date has been focused on mapping urban centers using demographic and administrative information, often supplemented by remote sensing. However, these data provide no information on the internal make-up of cities, which is important for understanding their impact on the environment as well as their vulnerability to change. The most recent report from the Intergovernmental Panel on Climate Change (IPCC) notes the dearth of information on urban areas. The WUDAPT initiative is designed to fill this gap.



### Create LCZ Training Areas

Follow the simple steps outlined here to create LCZ training areas for your city

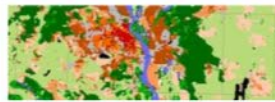
[Read More >](#)



### Classify your City

Follow the step-by-step instructions to create an LCZ classification of your city

[Read More >](#)



### View LCZ maps

Access LCZ maps for different cities around the world using Geopedia

[Read More >](#)

## Further information

Bechtel B, Alexander PJ, Böhner J, Ching J, Conrad O, Feddema J, Mills G, See L, Stewart I (2015) Mapping Local Climate Zones for a Worldwide Database of the Form and Function of Cities. *ISPRS Int J Geo-Inf* 4:199–219

Bechtel B, Daneke C (2012) Classification of Local Climate Zones Based on Multiple Earth Observation Data. *IEEE J Sel Top Appl Earth Obs Remote Sens* 5:1191–1202

Stewart ID, Oke TR (2012) Local Climate Zones for Urban Temperature Studies. *Bull Am Meteorol Soc* 93:1879–1900

Stewart ID, Oke TR, Krayenhoff ES (2014) Evaluation of the “local climate zone” scheme using temperature observations and model simulations. *Int J Climatol* 34:1062–1080

Check website (nice course exercise)

Dont buy it – beat it!

Contribute to level 2

Contact me

# Special Issue: The Application of Thermal Urban Remote Sensing to Understand and Monitor Urban Climates

By: Benjamin Bechtel, Iphigenia Keramitsoglou,  
Simone Kotthaus, James A. Voogt, Klemen Zakšek

[http://www.mdpi.com/journal/remotesensing/special\\_issues/tirurbcli](http://www.mdpi.com/journal/remotesensing/special_issues/tirurbcli)

- Monthly open-access journal
- IF: **3.180** (2014); 5-Year IF: 2.729 (2014)
- Rapid Publication: First decision: **34** days/Publication: **11** days
- Rigorous Reviews: **3** qualified review reports





## LS1 [Bands 7-4-2]

## SAR [GLCM<sub>contr</sub> -A<sub>vv</sub> -A<sub>vh</sub>] [RF, LS1]

## LCZ [RF, LS1]

## LCZ [RF, all]

