CENSUS of Cities: LCZ Classification of Cities (Level 0) – Workflow and Initial Results from Various Cities

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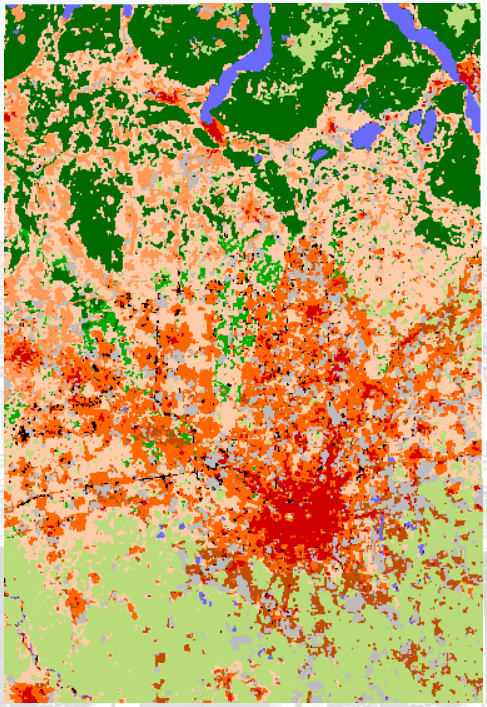


WUDAPT

- **Knowledge about** the footprint and **internal structure of urban areas** is **relevant for various applications**
- The World Urban Database and Portal Tool: international collaborative project for the **acquisition, storage and dissemination of climate relevant data** on the physical geographies of cities worldwide
- result will be a physical census of cities
- 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**

Level 2

- Detailed description of urban landscape parameters at a scale suited to boundary-layer models
- Use of all available databases (e.g. building footprints)

Level 1

- More precise parameter values for each LCZ
- Focus on aspects of form (e.g. building heights, street width) and functions (e.g. building use).
- Sampling of LCZ using GeoWiki

Level 0

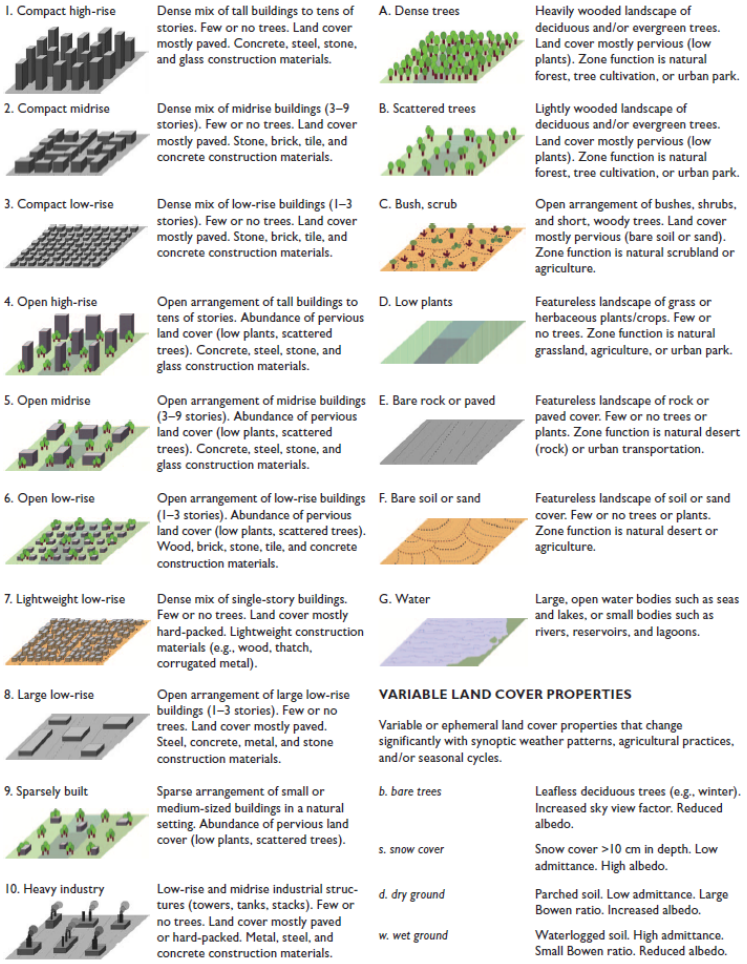
- Local Climate Zones (LCZ) along with parameter ranges
- Categorise city neighbourhoods into LCZ types
- Local experts provide training areas
- GoogleEarth, Landsat8 and Saga

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



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.
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.
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.
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.
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.
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.
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).
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.
9. Sparsely built	Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).
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.
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.
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.
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.
D. Low plants	Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
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.
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.
G. Water	Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.

VARIABLE LAND COVER PROPERTIES

Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles.

b. bare trees	Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo.
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.

Stewart & Oke 2012

Are LCZs suitable for mapping?

- Developed for measurement site description of UHI studies
- but also useful discretization of the landscape with respect to its surface layer climate
- Can an LCZ be assigned to any urban structure? (complete)
- And can only one LCZ be assigned to a given structure? (disjoint)

Bechtel et al. 2015

- no *overlaps* or *holes*, outliers excluded from the standard set
- scheme considers *a priori* knowledge about the frequency certain structures
- possibility to define subclasses (= mixtures between the standard classes)
- some areas fuzzy in terms of LCZ
- LCZ provide a disjoint and largely complementary discretisation
- well balanced between accuracy and universality

A simple mapping methodology

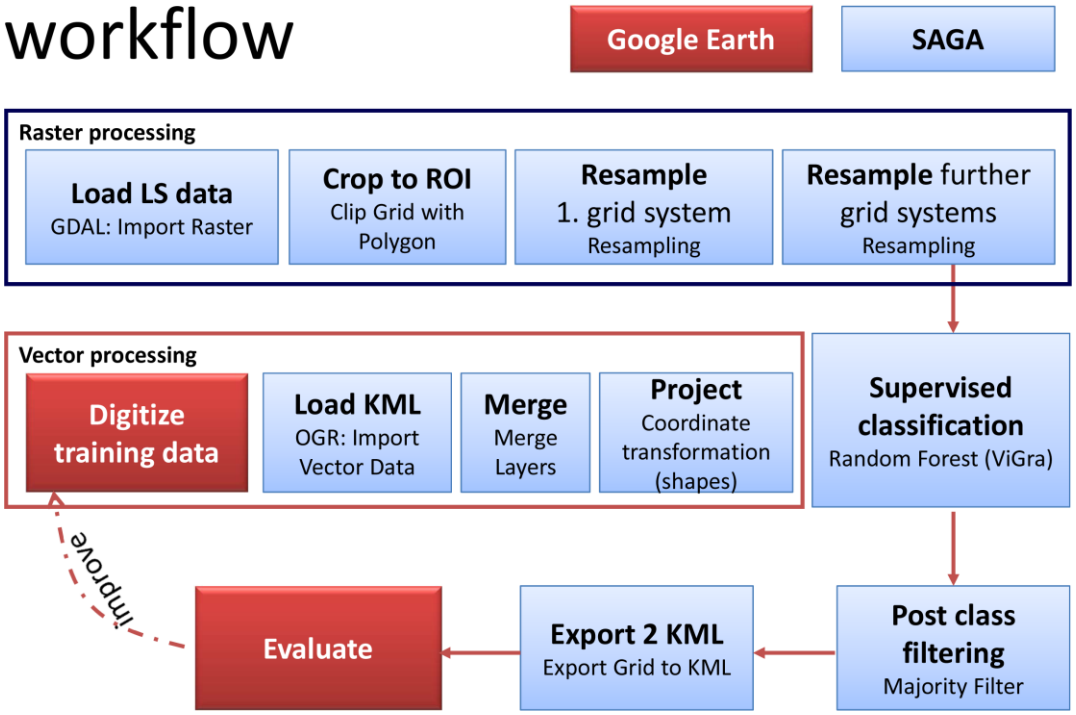
Requirements for LCZ mapping

- 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).

workflow


Google Earth
SAGA
Raster processing
Load LS data
GDAL: Import Raster
Crop to ROI
Clip Grid with Polygon
Resample
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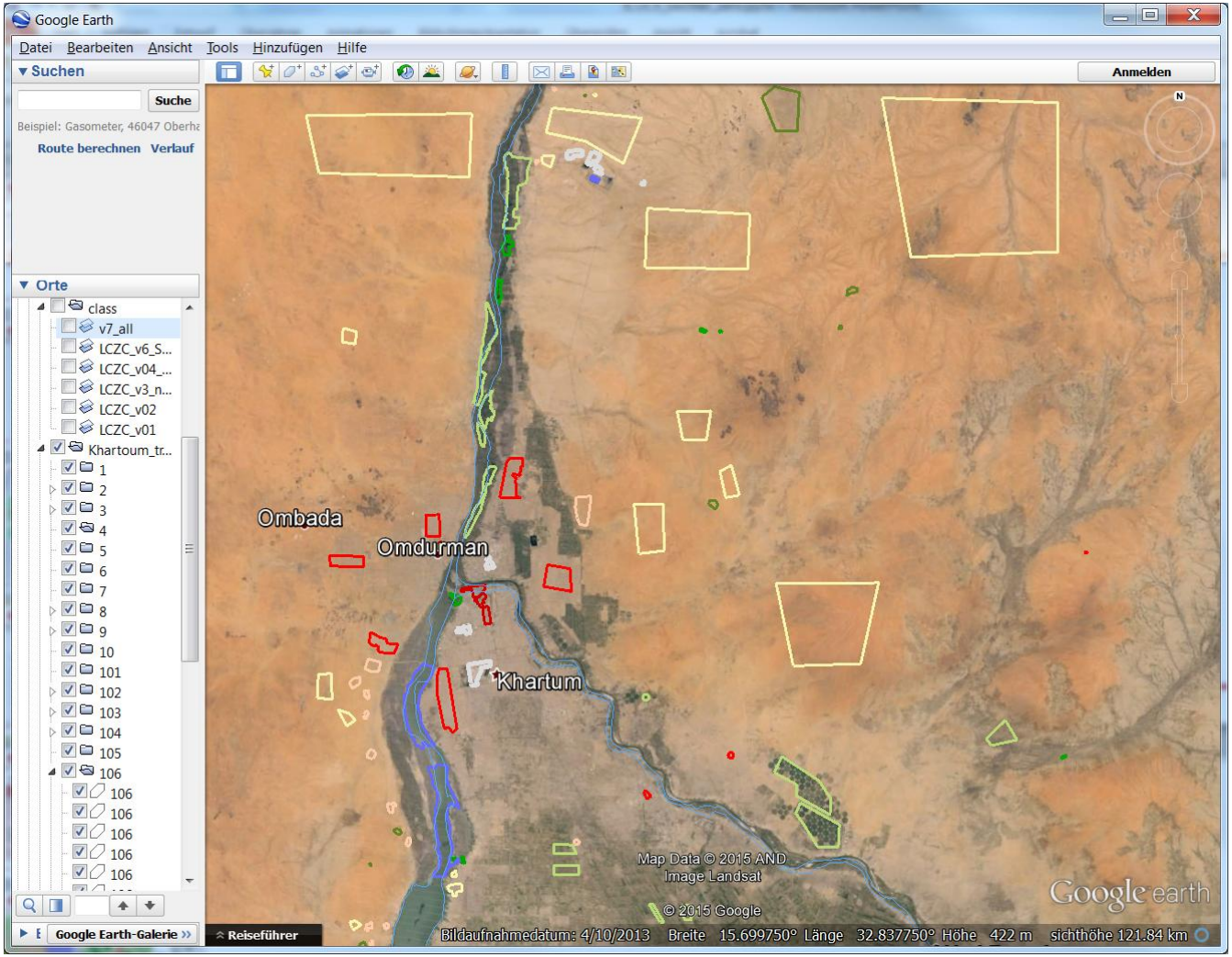
Resampling
Resample further grid systems
Resampling
Vector processing
Digitize training data
Load KML
OGR: Import Vector Data
Merge
Merge Layers
Project
Coordinate transformation (shapes)
Supervised classification
Random Forest (ViGra)
Post class filtering
Majority Filter
Export 2 KML
Export Grid to KML
Evaluate
improve


USGS
science for a changing world


Google Earth
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LCZC_v3_n...
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Ombada
Omdurman
Khartum
Map Data © 2015 AND
Image Landsat
© 2015 Google
Google earth
Google Earth-Galerie
Reiseführer
Bildaufnahmedatum: 4/10/2013 Breite 15.699750° Länge 32.837750° Höhe 422 m sichthöhe 121.84 km

Khartoum

ität Hamburg
LEHRE | DER BILDUNG

Local Climate Zone Classification

Data Objects	
Grids	
Grid System	**120; 959x 1043y; 425160x 1673280y**
>> Features	**35 objects (LC81730492013114LGN01_B1, LC81730492013**
<< LCZC	<create>
< LCZC (Filtered)	<not set>
Options	
Training Areas	**L:\LCZ\SAR\data\train\Khartoum_train_bb_v07.kmz**
Random Forest Tree Count	32
Class Definition File	**L:\LCZ\SAR\doc\cmap_WUDAPT_2015.txt**
Save LCZC as...	**L:\LCZ\SAR\data\class\KHAR[fs]all[tr]v0.7.kmz**

Okay
Cancel
Load
Save
Defaults

File Geoprocessing Map Window ?

Manager
Tools Data Maps
Tree Thumbnails
120; 959x 1043y; 425160x 1673280y

Messages
General Execution Errors

\SAR\data\feat\SAR\Entropy.sgrd...okay
[2015-07-16/17:04:58] Load grid: L:\LCZ\SAR\data\feat\SAR\GLCMCorrelation.sgrd...okay
[2015-07-16/17:04:58] Load grid: L:\LCZ\SAR\data\feat\SAR\GLCMMean.sgrd...okay
[2015-07-16/17:04:58] Load grid: L:\LCZ\SAR\data\feat\SAR\GLCMVariance.sgrd...okay
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[2015-07-16/17:04:59] Load grid: L:\LCZ\SAR\data\feat\SAR\MAX.sgrd...okay
[2015-07-16/17:06:36] Executing tool: Local

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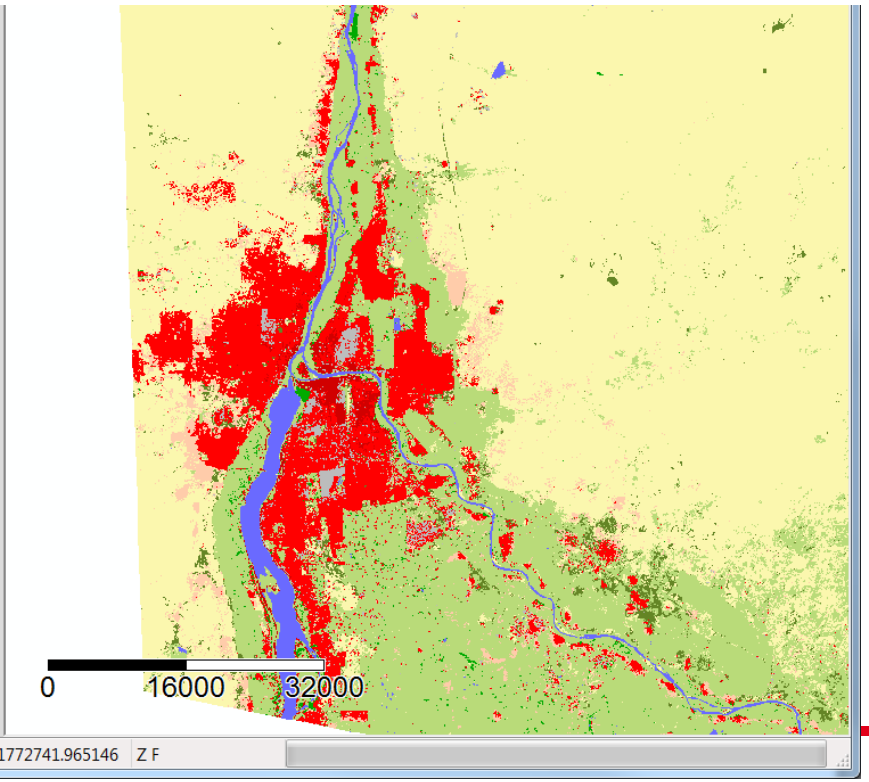

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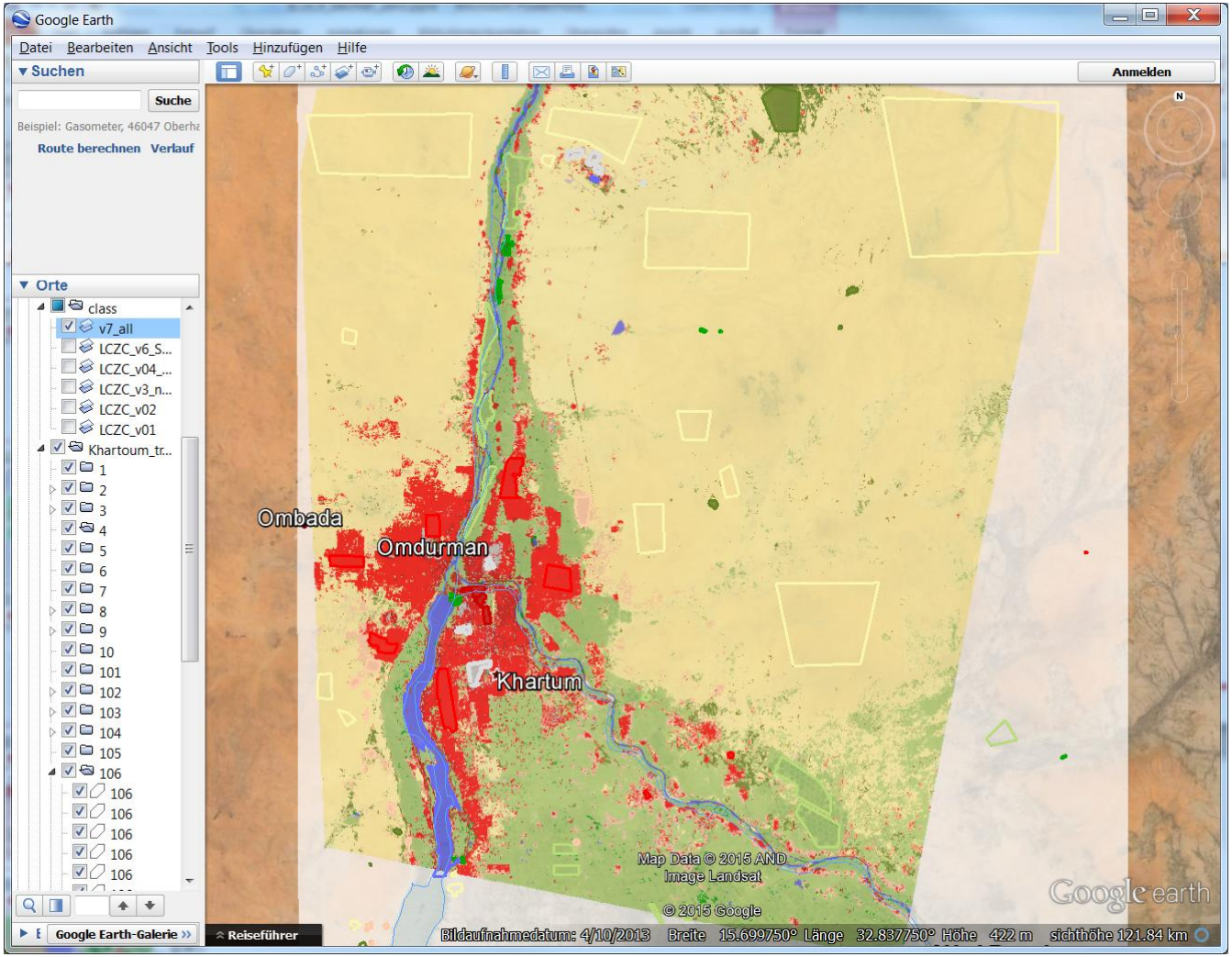
Google Earth
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LCZC_v02
LCZC_v01
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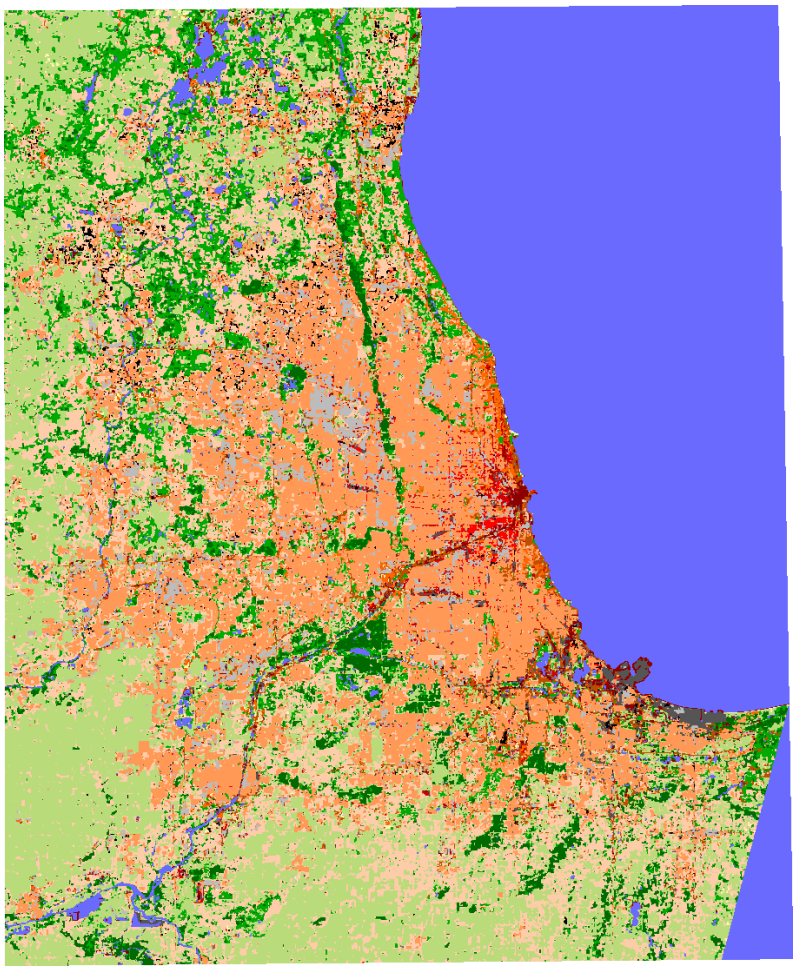
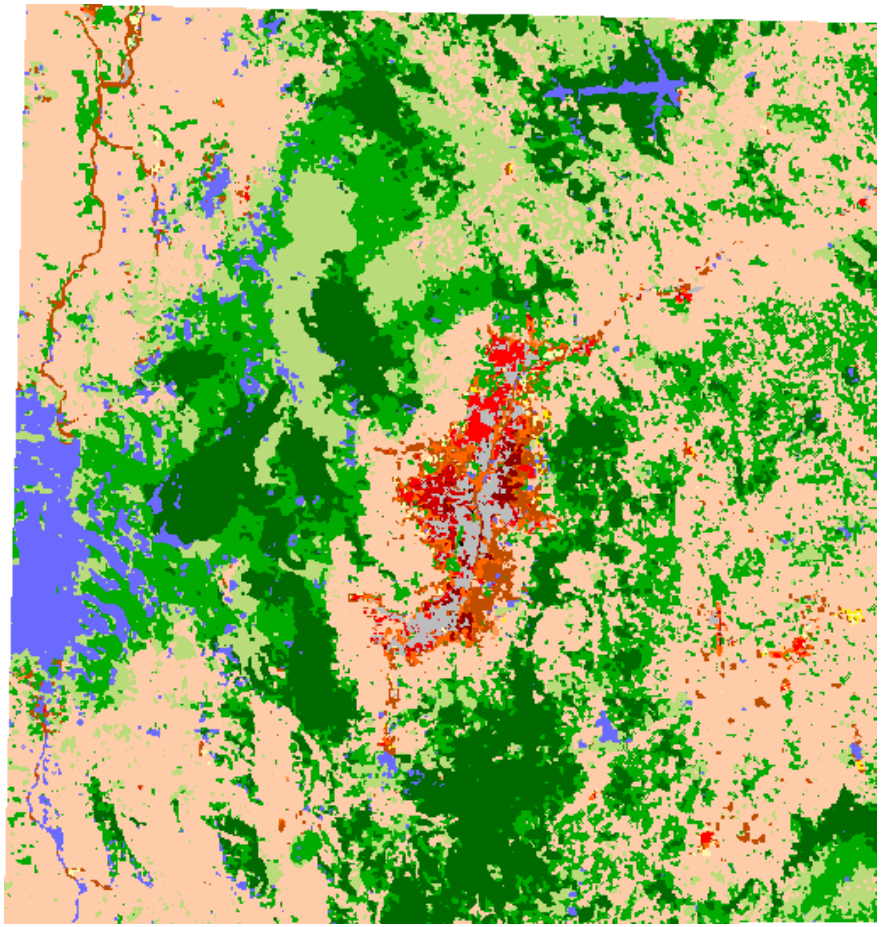
Google Earth-Galerie
Reiseführer
Ombada
Omdurman
Khartum
Map Data © 2015 AND
Image Landsat
© 2015 Google
Google earth
Bildaufnahmedatum: 4/10/2013 Breite 15.699750° Länge 32.837750° Höhe 422 m sichthöhe 121.84 km

Testcases

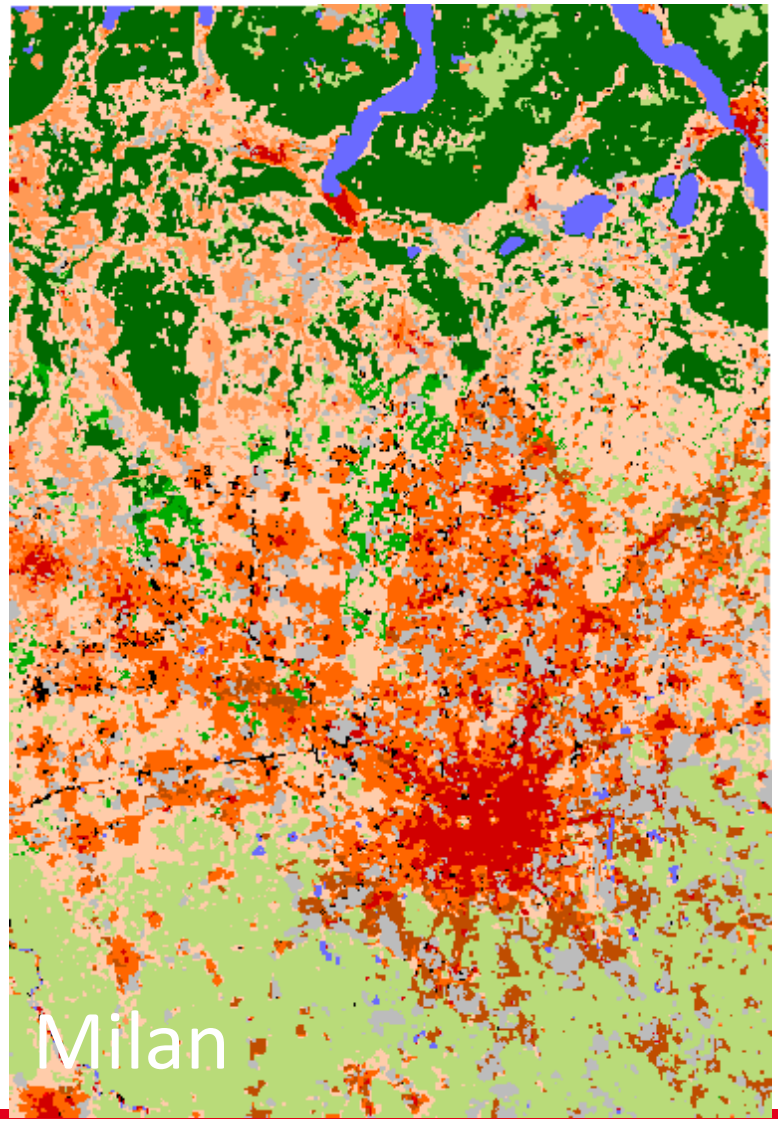
City	Köppen Climate Zone
Colombo, Kolkata, Medellin, Vitoria	Tropical/megathermal climates
Khartoum	Dry (arid and semiarid) climates
Budapest, Coimbra, Dublin, Guangzhuo, Houston, Milan, Nantes, Sao Paolo, Vancouver, Wageningen	Termperate/mesothermal climates
Beijing, Chicago	Continental/microthermal climates

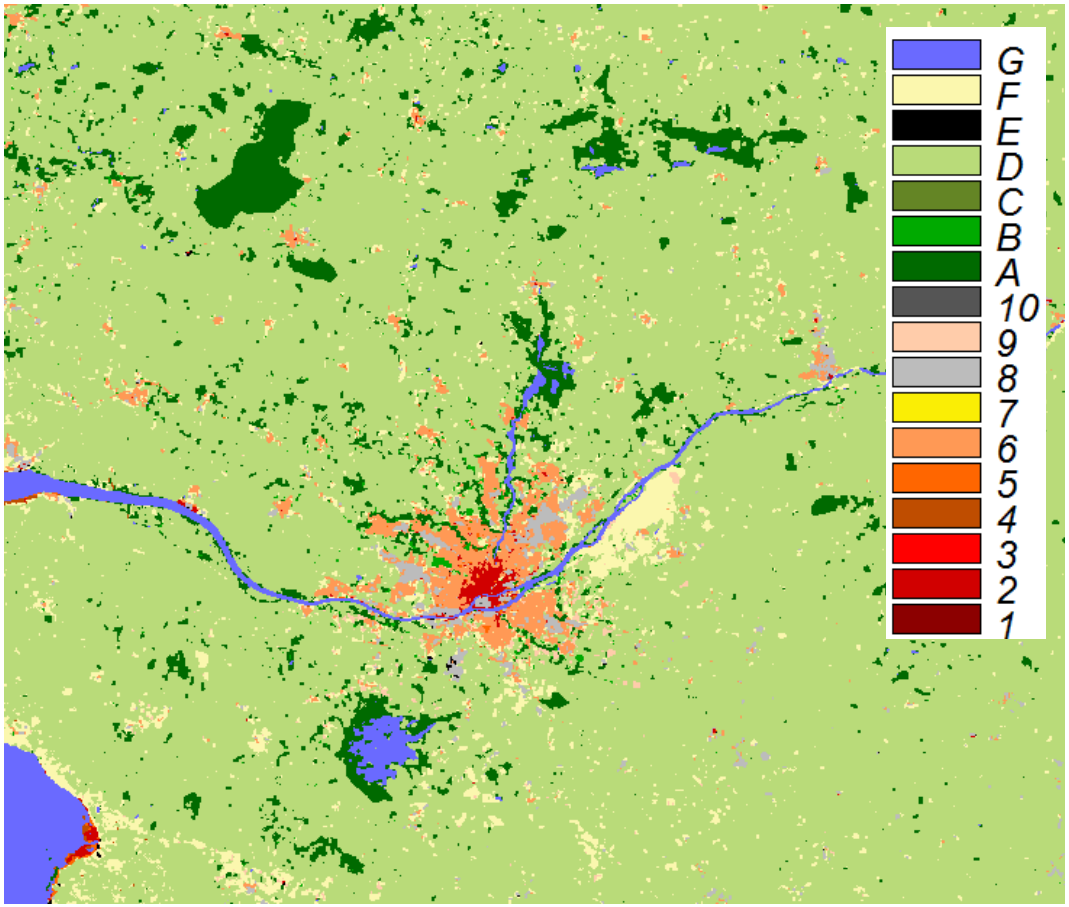




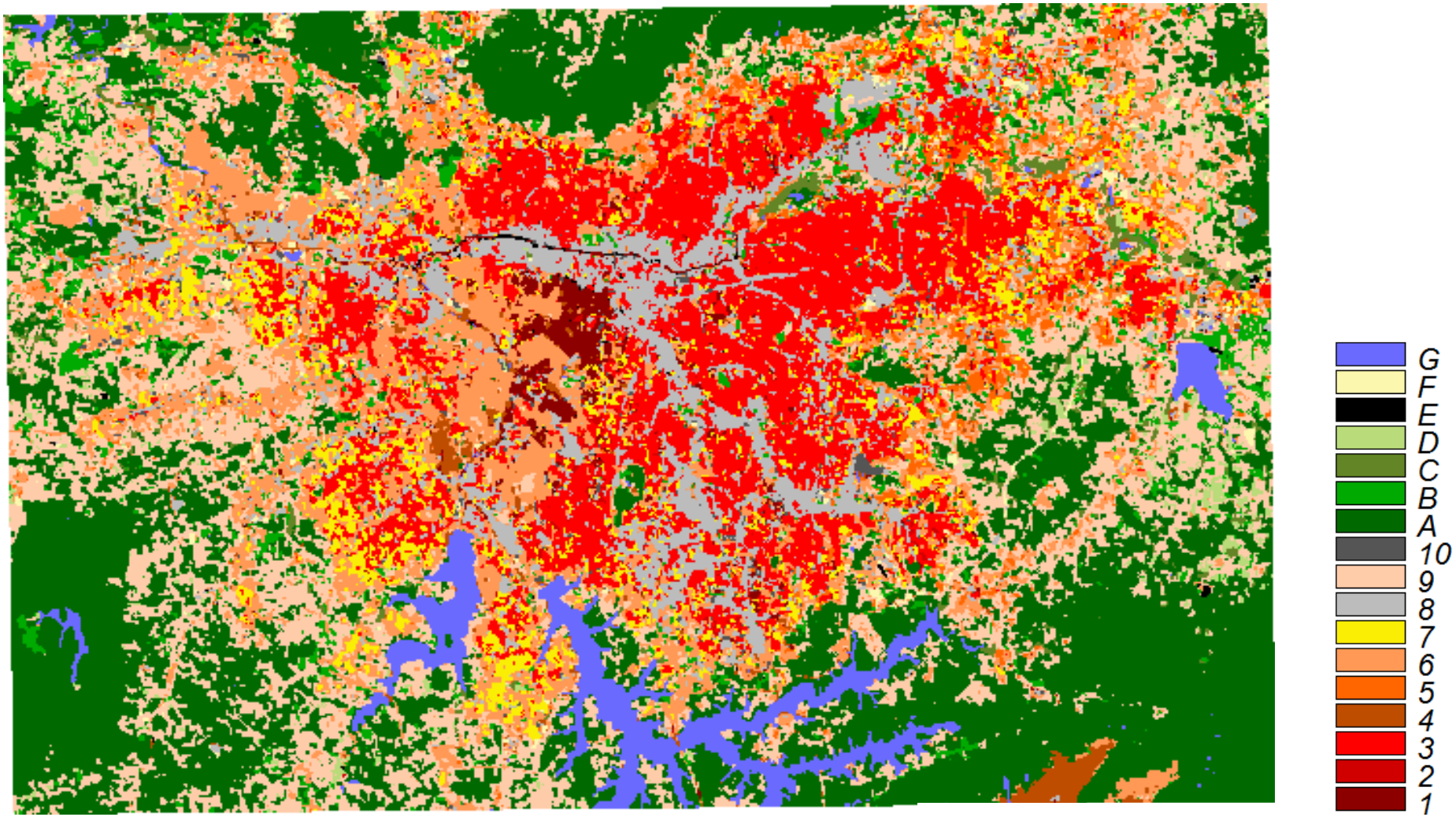
Chicago

Medelin





Nantes



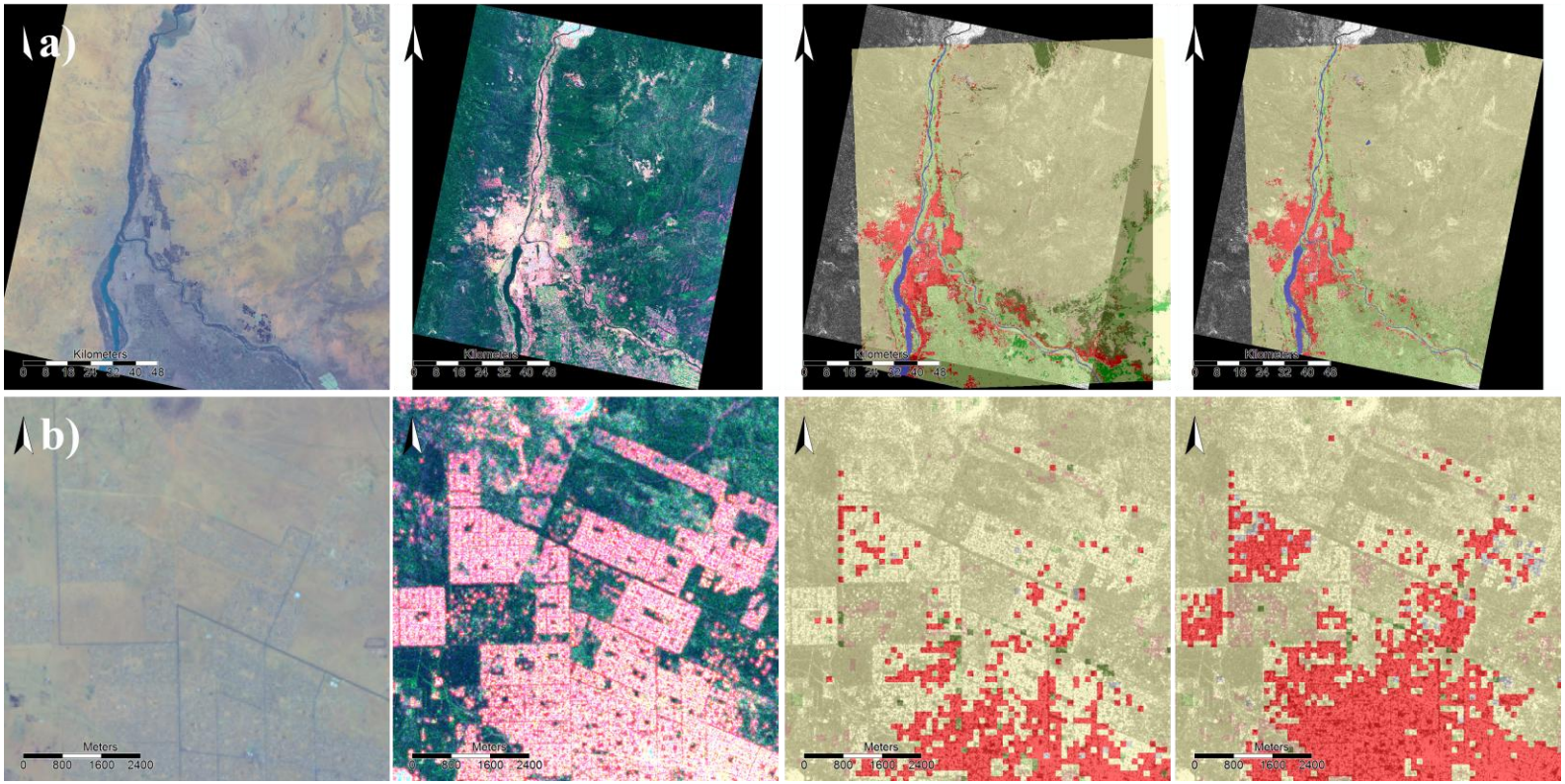
Sao Paulo

Lessons learned

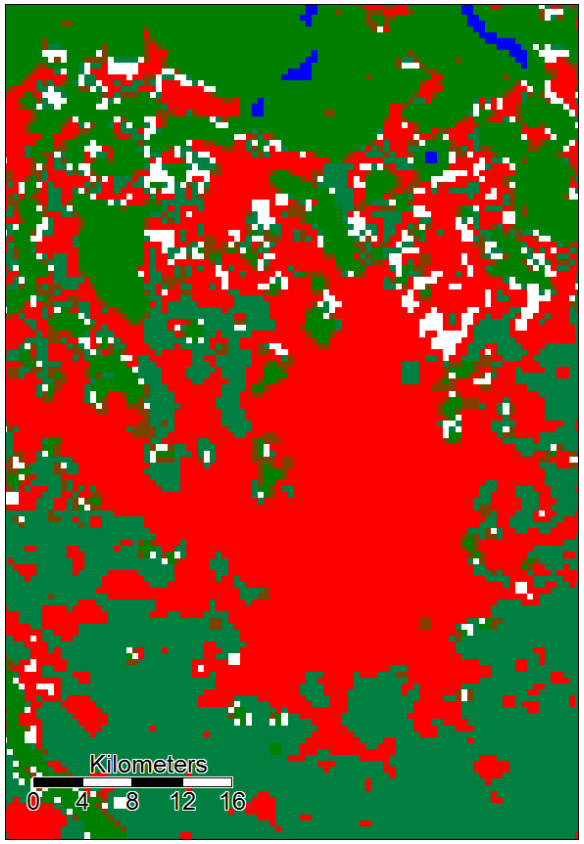
- Applicable in different parts of the world (climates and cultures)
- Good framework to compare settlement structures
- Spectral seperability difficult in arid areas
- Subclasses needed (some built-up areas are close to natural classes in climate response)

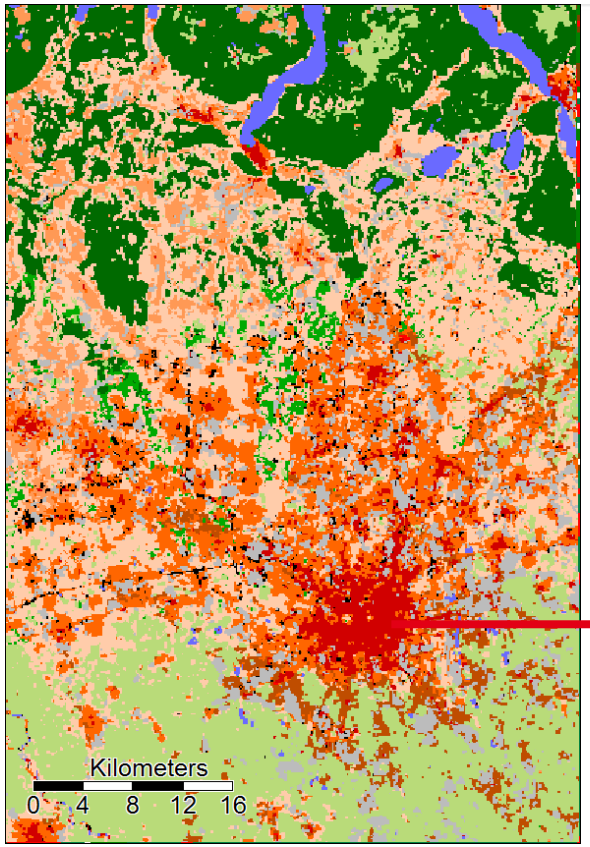
Outlook

LS1 [Bands 7-4-2]	SAR [$GLCM_{contr}$-A_{vv}-A_{vh}]	LCZ [RF, LS1]	LCZ [RF, all]



Achievements of level 0





LCZ **COMPACT MID-RISE** **2**

DEFINITION

Form: 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. ***Function***: Residential (multi-unit housing; multistorey tenements); commercial (office buildings, hotels, retail shops); industrial (warehouses, factories). ***Location***: Core (old city, old town; inner city, central business district); periphery (high-density sprawl). ***Correspondence***: UCZ2 (Oke 2004); A1, A2, A4, Dc2 (Ellefsen 1990/91).

ILLUSTRATION

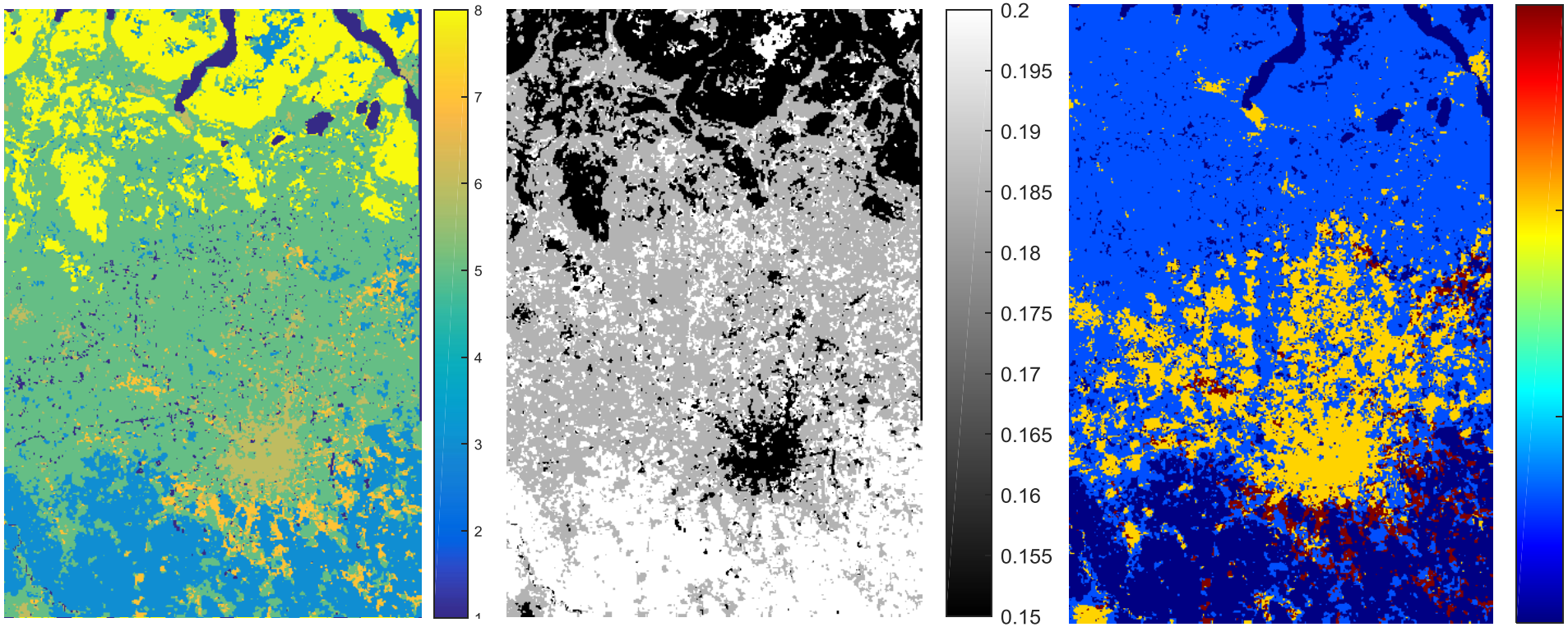
High angle

Low level

PROPERTIES

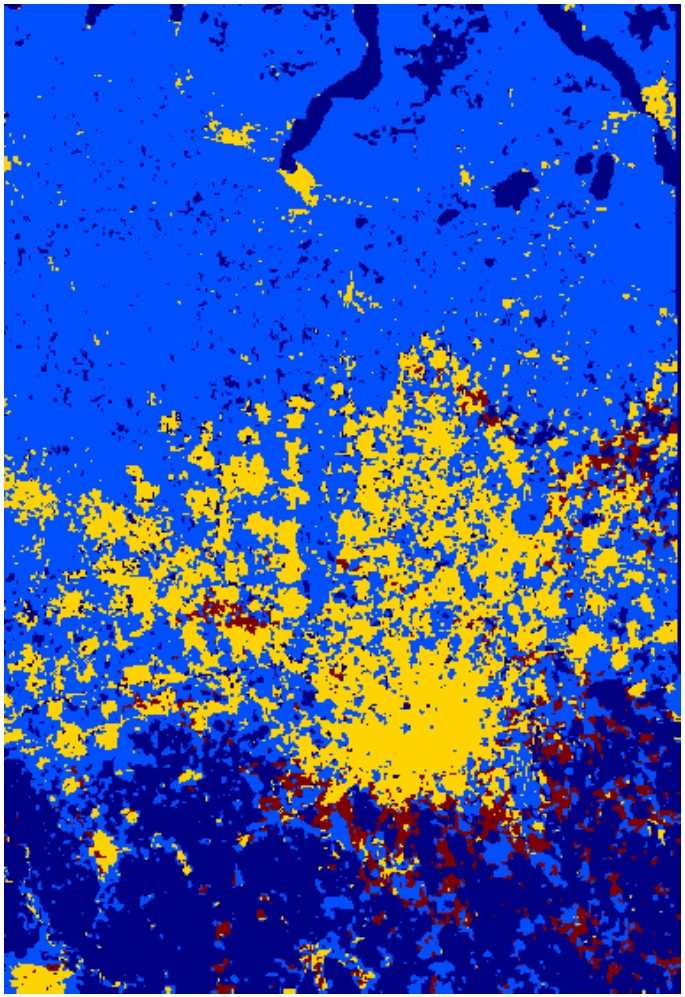
Sky view factor 0.3 – 0.6	0 .2 .4 .6 .8 1
Canyon aspect ratio 0.75 – 2	0 .2 .4 .6 .8 1 2 3
Mean building height 10 – 25 m	0 10 20 30 40 50
Terrain roughness class	1 2 3 4 5 6 7 8
Building surface fraction 40 – 70 %	0 20 40 60 80 100
Impervious surface fraction 30 – 50 %	0 20 40 60 80 100
Pervious surface fraction < 20 %	0 20 40 60 80 100
Surface admittance 1,500 – 2,200 J m^{-2} $s^{-1/2}$ K^{-1}	0 500 1,000 1,500 2,000 2,500
Surface albedo 0.10 – 0.20	0 0.1 0.2 0.3 0.4 0.5
Anthropogenic heat flux < 75 W m^{-2}	0 100 200 300 400

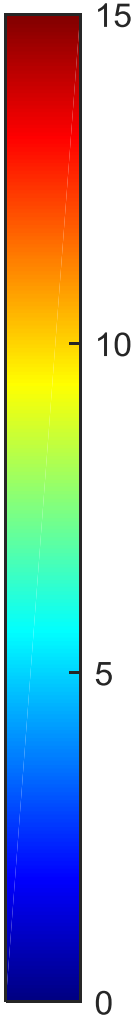
Stewart & Oke 2012

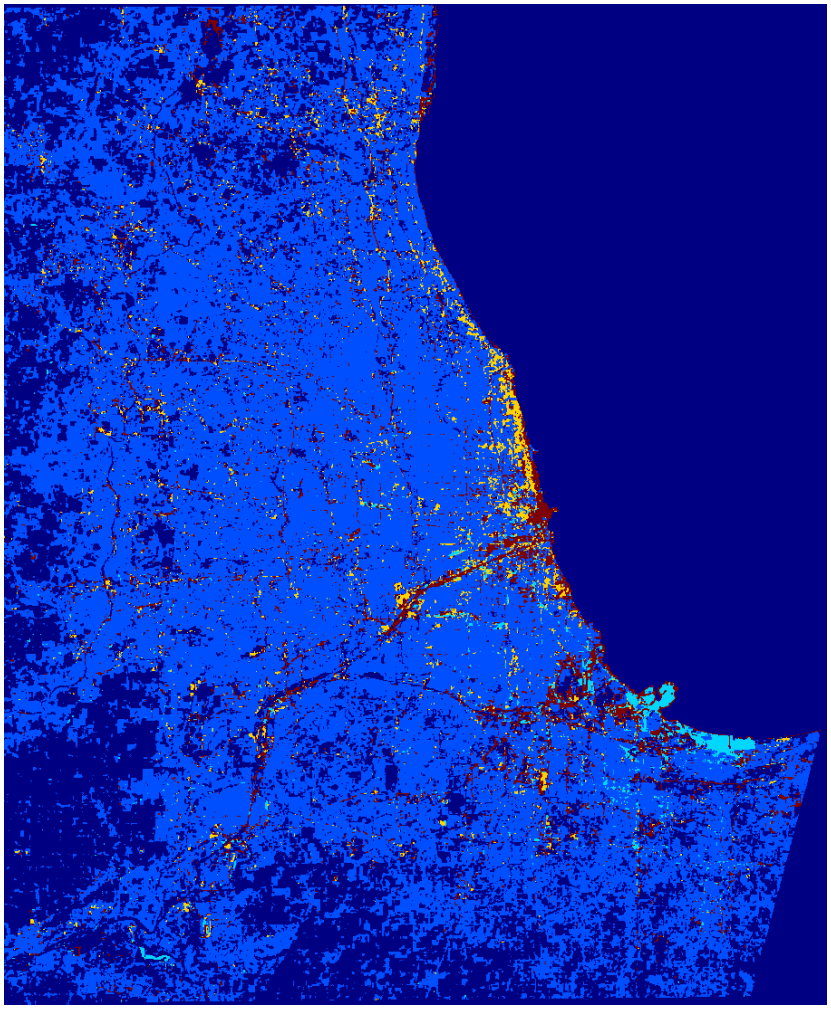


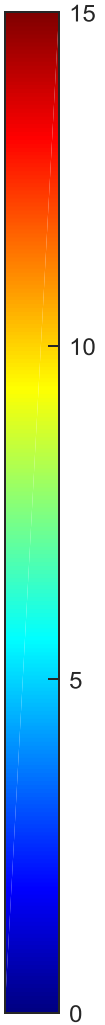
DRC min | **α mean** | **Height min**

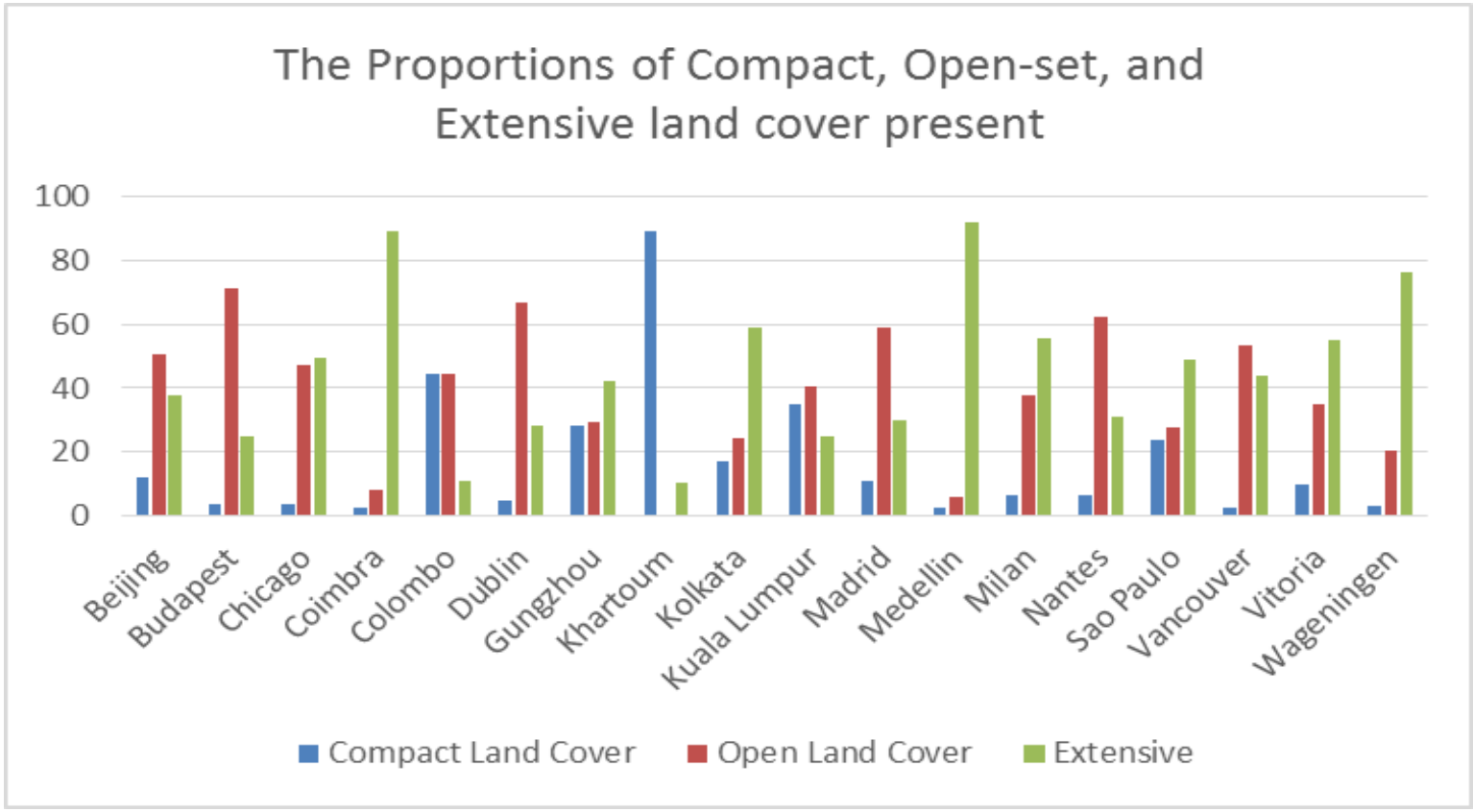
Height min










The Proportions of Compact, Open-set, and Extensive land cover present
100
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Beijing
Budapest
Chicago
Coimbra
Colombo
Dublin
Gungzhou
Khartoum
Kolkata
Kuala Lumpur
Madrid
Medellin
Milan
Nantes
Sao Paulo
Vancouver
Vitoria
Wageningen
Compact Land Cover
Open Land Cover
Extensive

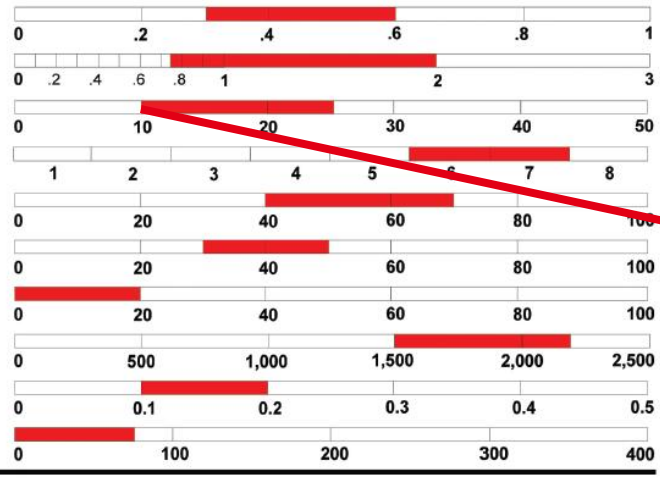
LCZ 2 — COMPACT MID-RISE

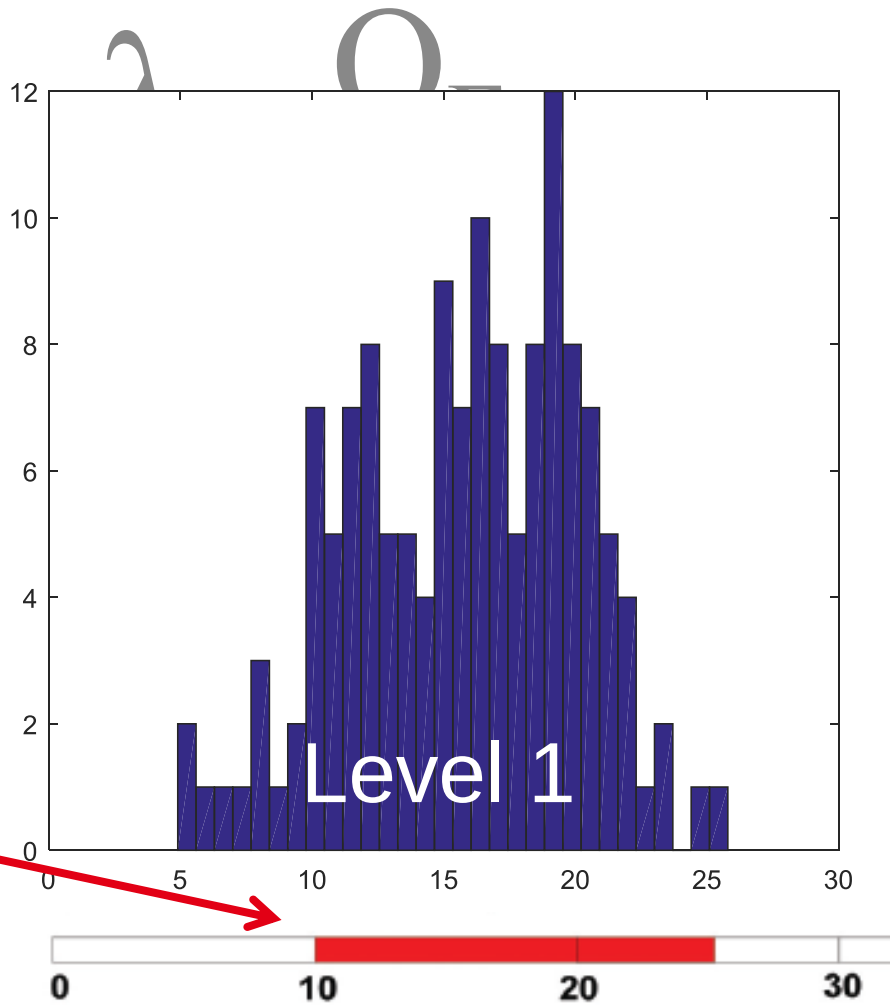
DEFINITION

Form: 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. ***Function***: Residential (multi-unit housing; multistorey tenements); commercial (office buildings, hotels, retail shops); industrial (warehouses, factories). ***Location***: Core (old city, old town; inner city, central business district); periphery (high-density sprawl). ***Correspondence***: UCZ2 (Oke 2004); A1, A2, A4, Dc2 (Ellefsen 1990/91).

ILLUSTRATION

PROPERTIES





Stewart & Oke 2012

Get involved

Classify your city

Manuals at wudapt.org

Attend workshop tomorrow

22nd July, at 4pm

Cassiopée room