Towards computation of urban local climate zones (LCZ) from OpenStreetMap data

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Abstract

Urban environment is characterized by complex interactions with atmosphere due to a high concentration of heterogeneous surfaces. These interactions produce a specific urban climate that is characterized by so-called heat island and volatile atmospheric processes. Contemporary meso-scale meteorological models are becoming capable of assimilating information about urban land cover and geometry to produce more precise weather and climate forecasting results. One way to describe the complex mosaic of urban surfaces is to generalize their possible combinations to a limited number of common and frequently occurring types — local climate zones (LCZs). There are numerous methods to compute LCZs from different kinds of spatial data including proprietary spatial databases and imagery. In this study we expose preliminary findings on how land cover information can be extracted from OpenStreetMap data and used both to assess the quality of LCZs derived from space imagery and to obtain characteristics needed to direct computation of LCZs.

Keywords: local climate zones, urban land cover, urban canyon, OpenStreetMap, Landsat.

1. Introduction

Local climate zones (LCZ) are defined as regions of uniform surface cover, structure, material, and human activity that span hundreds of meters to several kilometres in horizontal scale (Stewart & Oke 2012). 17 types of LCZs are distinguished, which include 10 built types and 7 land cover types (Figure 1). Each LCZ has a characteristic screen-height temperature regime and is ordered by one (or more) distinguishing surface property, which in most cases is the height/packing of roughness objects or the dominant land cover (Stewart & Oke, 2012). Multiple methods of deriving LCZs have been developed, including GIS-based method (Unger et al., 2014), object-oriented (Gamba et al., 2012) and pixel-based (Bechtel & Daneke, 2012) classification of space imagery. Currently, there is a user-friendly open-access technology of deriving LCZ from Landsat imagery (Bechtel et al., 2015). This technology is utilized in WUDAPT crowdsourcing project that aims at collecting data on the form and function of cities around the world (The World…, 2014). At the same time it was shown that it is possible to derive urban canyon and land cover paremeters from OpenStreetMap data (Samsonov, Konstantinov, 2014).

In this paper we propose several aspects, in which OSM data can be used to facilitate the computation of local climate zones:

- To derive land cover data that is needed for calculation and assessment of LCZs.
- To assess the reliability of LCZs derived via pixel-based classification of space imagery
- To calculate derivative urban space characteristics needed to compute local climate zones directly.

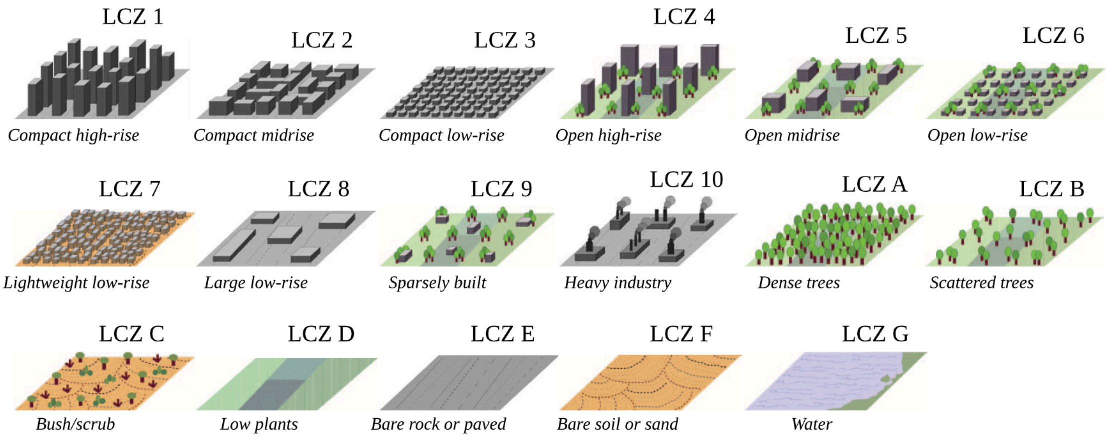

Figure 1: Local climate zone types (Stewart & Oke 2012).

2. Deriving land cover information from OSM data

Local climate zones classification at basic level utilizes information about buildings, vegetation, water, other surfaces and also the type of economic activity at zone (such as industrial or residential). This information can be retrieved from OSM XML database, but needs to be organized in a way that is appropriate for further GIS processing. First, it can be split into the abovementioned categories by applying the suitable queries (Table 1).

№	Name	Query	Fields
1	Landuse	<landuse> IS NOT NULL AND NOT <landuse> IN ('forest')	NAME, LANDUSE, RSDNTL
2	Vegetation	<natural> IN ('wood', 'scrub', 'heath') OR <landuse> IN ('forest')	NATURAL, LANDUSE, WOOD, NAME
3	Buildings	<building> IS NOT NULL AND NOT <building> IN ('no', 'entrance')	BUILDING, A_STRT, A_SBRB, A_HSNMBR, B_LEVELS, NAME
4	Surface	<natural> IN ('beach', 'sand', 'fell', 'grassland', 'heath', 'scree', 'scrub')	NATURAL
5	Water	<natural> IN ('water', 'wetland') OR <waterway> = 'riverbank'	NAME, NATURAL, WATERWAY, WETLAND
6	Roads	<highway> IN ('motorway', 'motorway_link', 'trunk', 'trunk_link', 'primary', 'primary_link', 'secondary', 'secondary_link', 'tertiary', 'tertiary_link', 'residential', 'unclassified', 'road', 'living_street', 'service', 'track', 'pedestrian', 'footway', 'path', 'steps', 'bridleway', 'construction', 'cycleway', 'proposed', 'raceway')	NAME, REF, HIGHWAY, ONEWAY, BRIDGE, TUNNEL, MAXSPEED, LANES, WIDTH, SURFACE

Table 1: Basic layers derived from OpenStreetMap data

Next, the roads should be converted to polygonal objects to be further considered as impervious surfaces. The width of one lane is estimated depending on the road / street class in accordance with Russian technical standards (GOST… 2006, SP… 2011b). The total road width W is derived by multiplying the lane width on the number of lanes. Finally, each road segment is buffered by $W/2$ to obtain polygonal representation of the road. Also, the building height is approximated by multiplying the number of floors on the standard floor height, which depends on the type of building (residential / non-residential) according to Russian technical standards (SP…2011a, SP…2014). The type of building is derived from building tags, and if the tag is simply "building = yes" — from the underlying landuse type available from corresponding layer.

The next step was the integration of the six designated layers (including buffered roads) into a single topologically correct coverage. For this purpose, Dissolve-Erase-Merge technology was proposed:

1. Each layer undergoes the Dissolve procedure, which eliminates overlapping objects.

2. Starting from the first priority (current) layer, its areas are erased in the next layer.

3. The current layer is merged with the next erased layer. This merged layer becomes current.

Steps 2-3 are repeated as long as there are subsequent layers. The procedure is illustrated in Figure 2.

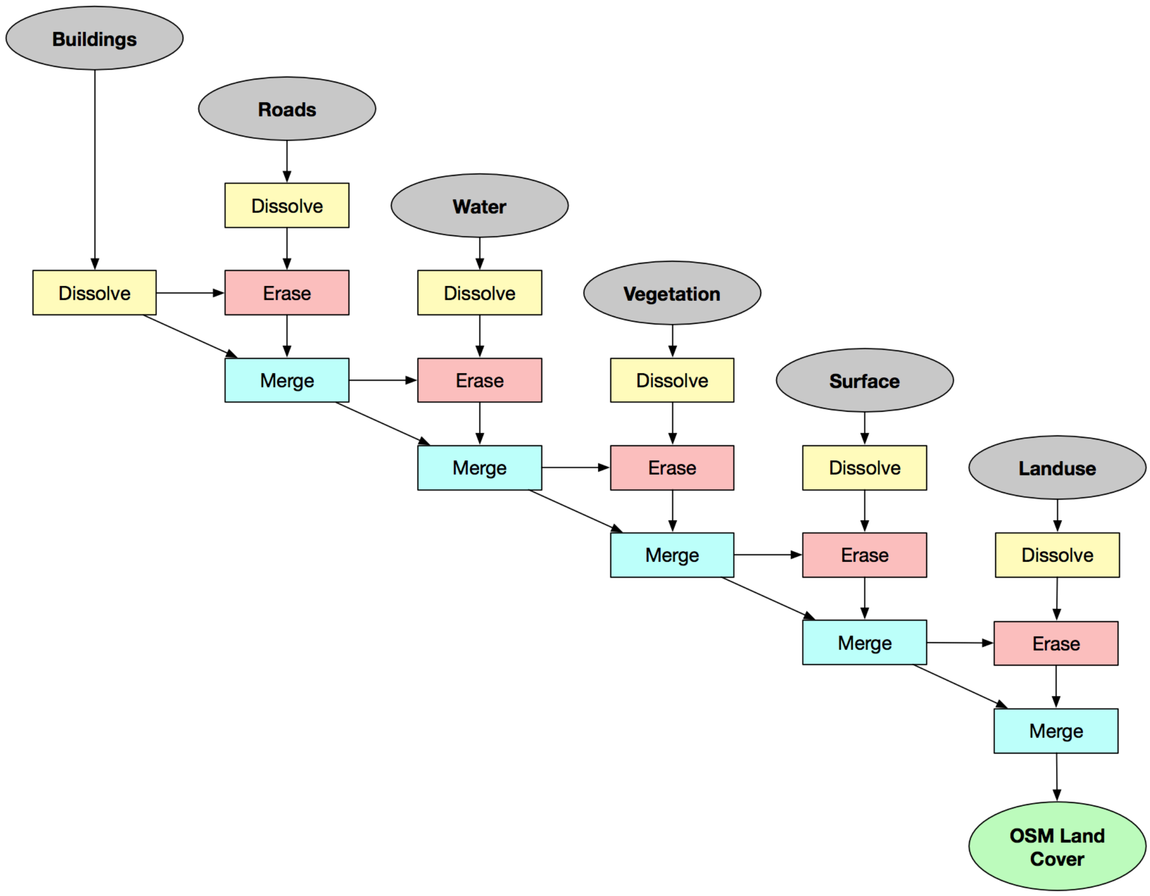

Figure 2: Derivation of OSM Land Cover using Dissolve-Erase-Merge strategy.

After the land cover layer is derived, we classify each object and obtain the classification that can be assimilated by meteorological models and used for calculation of LCZs (Table 2). An example of derived land cover is presented in Figure 3. "Other" areas are not covered by any OSM object and therefore cannot be attributed a particular type. All stages of deriving OSM land cover are automated in Python programming language.

Land cover type	Query
Buildings	"BUILDING" is not NULL
Roads	"HIGHWAY" is not NULL
Grass	”LANDUSE" in ('grass', 'grassland', 'meadow') or "SURFACE" = 'grass' OR "NATURAL" = 'grassland'
High vegetation	"LANDUSE" in ('forest','logging') OR "NATURAL" in ('tree', 'tree_row', 'wood') OR "WOOD" IS NOT NULL
Low vegetation	"LANDUSE" in ('orchard', 'vineyard', 'scrub', 'farm', 'farmland', 'greenfield') or "NATURAL" = 'scrub'
Mixed vegetation	"LANDUSE" in ('cemetery', 'garden', 'park' , 'natural_reserve')
Surface (impervious)	"LANDUSE" = 'parking' or ("SURFACE" in ('asphalt' , 'asphalt;compacted' , 'asphalt;concrete' , 'asphalt;gravel' , 'brick' , 'cobblestone' , 'concrete' , 'concrete:lanes' , 'concrete:plates' , 'granite' , 'paved' , 'paving_stones' , 'pebblestone' , 'stone') AND "HIGHWAY" IS NULL)
Water	"NATURAL" in ('water', 'waterway', 'wetland') OR "WATERWAY" IS NOT NULL OR "LANDUSE" = 'reservoir'
Industrial	"LANDUSE" in ('construction' , 'garage' , 'garages', 'industrial', 'military' , 'railway' , 'retail' , 'depot', 'commercial')
Residential	"LANDUSE" in ('residential', 'allotments')

Table 2: Land Cover classification from OpenStreetMap data

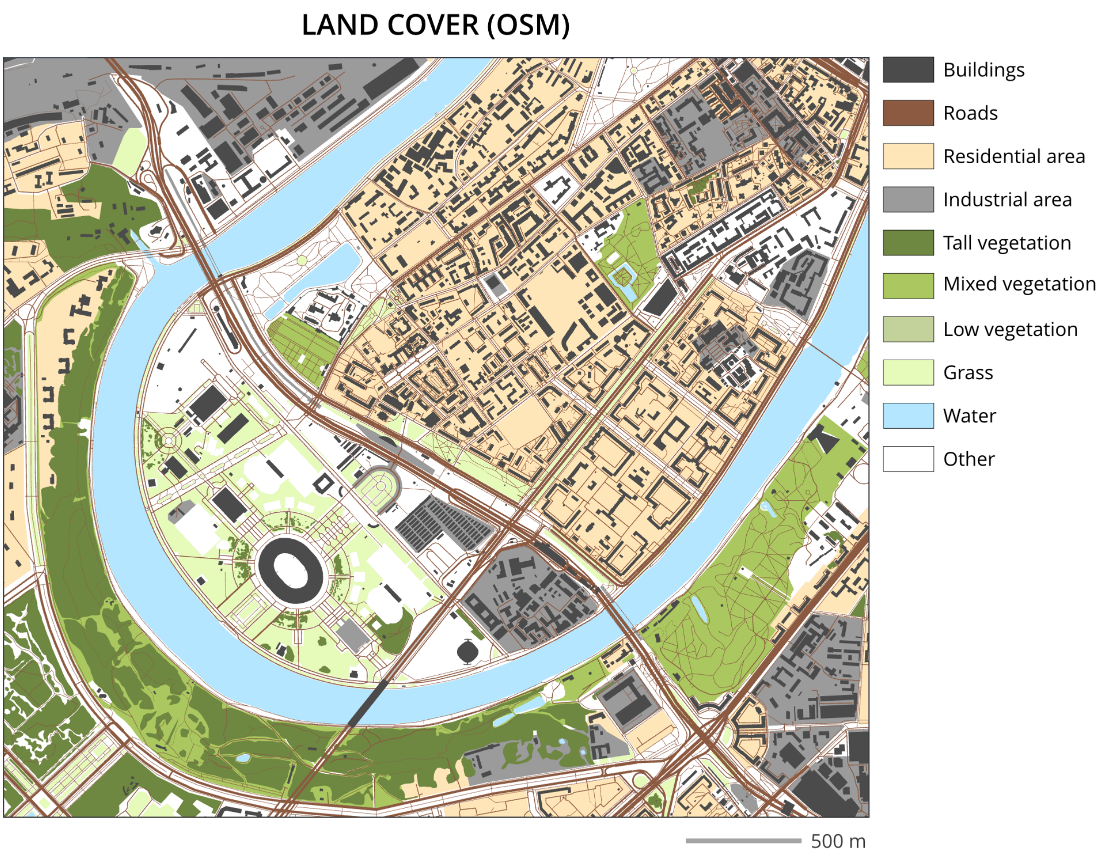

Figure 3: A fragment of land cover layer obtained from OpenSreetMap data.

2. Verifying WUDAPT LCZs using the OSM land cover

Using the standard methodology of WUDAPT project (Bechtel et al., 2015), based on random forest Landsat classification local climate zones in Moscow have been derived (Figure 2). The open high-rise and open midrise classes are the most widespread in the main city rounded by large circular MKAD highway (24% and 22% of area respectively). The center of the city inside the smallest Garden Ring is comprised by compact midrise built-up. The compact high-rise, bush/scrub and bare soil LCZ types were not recognized in Moscow, except for compact high-rise Moscow-City district that is too small to be represented in the resulting map. Airports and railway hubs are extracted as large paved areas.

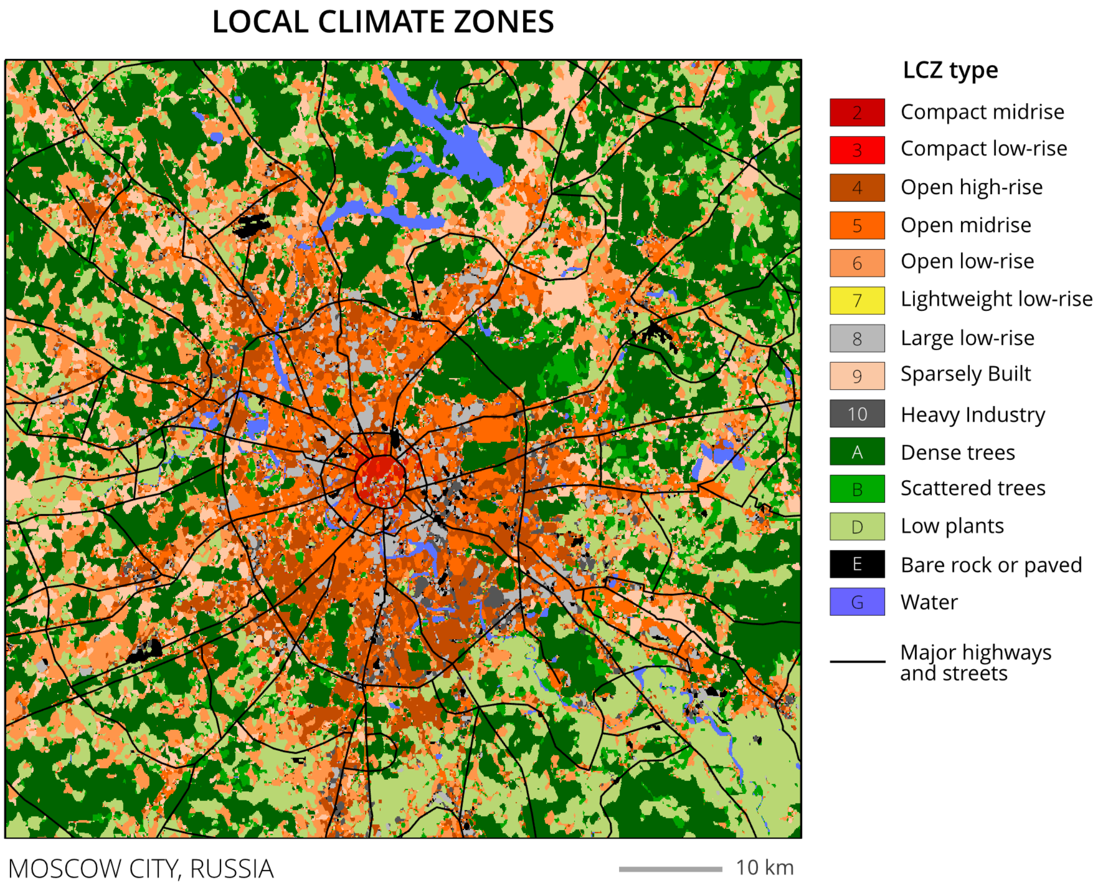

Figure 4: Local Climate Zones in Moscow.

To assess the real geographic content of derived zones, we calculated the fraction of each OSM land cover class inside each type of LCZ (Figure 5). Generally, the distribution of various land cover types inside each LCZ type is close to expectation. For example, compact midrise and large low-rise LCZs has much higher fraction of buildings than open midrise LCZ. Open high-rise and open midrise classes are very close to each other. They are further distinguished by building height, as is shown in Table 3. Scattered trees class has the same fraction of tall vegetation as sparsely built, but also has an additional area of low vegetation. Paved area included 14% of buildings, which is because the airports and railway hubs were classified as this LCZ type. It can be said that OSM-derived land cover is in general correspondence with LCZs derived from space imagery. Thus the next possible step is to derive some additional geometric characteristics that can facilitate the computation of LCZs directly from OpenStreetMap data, because it provides the direct vector-based access to urban geometry.

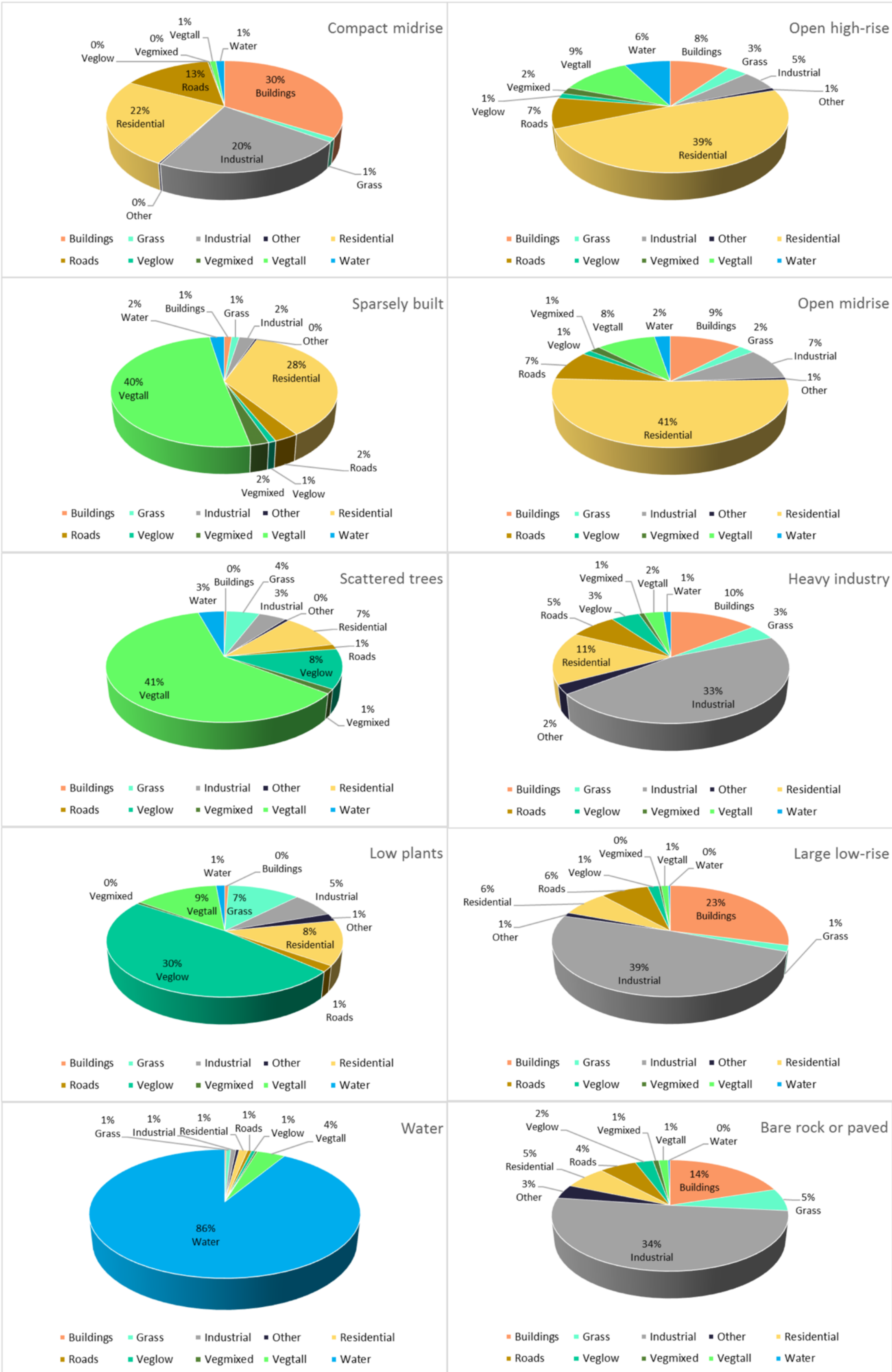

Figure 5: Moscow LCZ structure according to OSM land cover. The empty OSM areas are excluded from diagrams, so the digits show a real area fraction inside the LCZ type, while the sectors show land cover distribution inside areas that are non-empty in OSM dataset

LCZ	Average number of floors	Reference interval
Compact midrise	4,08	4—9
Compact low-rise	3,93	1—3
Open high-rise	7,10	> 10
Open midrise	3,69	4—9
Open low-rise	3,02	1—3
Lightweight low-rise	2,00	1—3
Large low-rise	4,00	1—3

Table 3: Actual derived average building levels and their reference intervals indicated by Stewart & Oke (2012)

3. Computing LCZ parameters directly from OSM data

OSM data contains much of the information needed for derivation of LCZs. We calculated some of geometric characteristics that differentiate LCZ types and aggregated them over the spatial grid of 1 km resolution (Figure 6). High building surface fraction (Figure 6) correlate in distribution with previously obtained compact LCZs. Urban canyon height/width ratio (HWR) was computed using TIN-based method presented in (Samsonov et al., 2015). As can be seen, Moscow is open city and is rather uniform in terms of HWR, and central district is characterized by higher building fraction but smaller building height in comparison with residential suburban districts. Most of the area is characterized by HWR smaller than 1. As expected, OSM-derived land cover failed to represent the fraction of pervious surfaces (Figure 6e) that include all vegetation, water and bare soil/sand areas. This is because most of the areas between buildings are usually simply attributed as residential or industrial in OSM, without information about the type of the surface. Moscow is rather green city and much of the spaces between buildings is occupied by vegetation. Hopefully, this shortcoming can be easily compensated by adding the vegetation mask quickly extracted from Landsat composite. Resulting image is shown in Figure 6f and represents the more realistic pervious surface fraction. Note that these images were obtained using the regular grid tessellation, while the natural LCZ boundaries should be extracted from OSM in the future using GIS-based approach.

4. Conclusion

The paper presents preliminary results in extracting land cover from OpenStreetMap data and using it both to assess the quality of local climate zones derived from space imagery and to obtain characteristics needed to direct computation of LCZs. Our experience shows that OSM has both advantages (direct computation of geometric properties) and disadvantages (weak derivation of pervious surfaces) in comparison with image-based methods. We plan to develop a methodology that combines the best properties of both approaches to facilitate more detailed and precise urban area descriptions suitable for geocomputational tasks.

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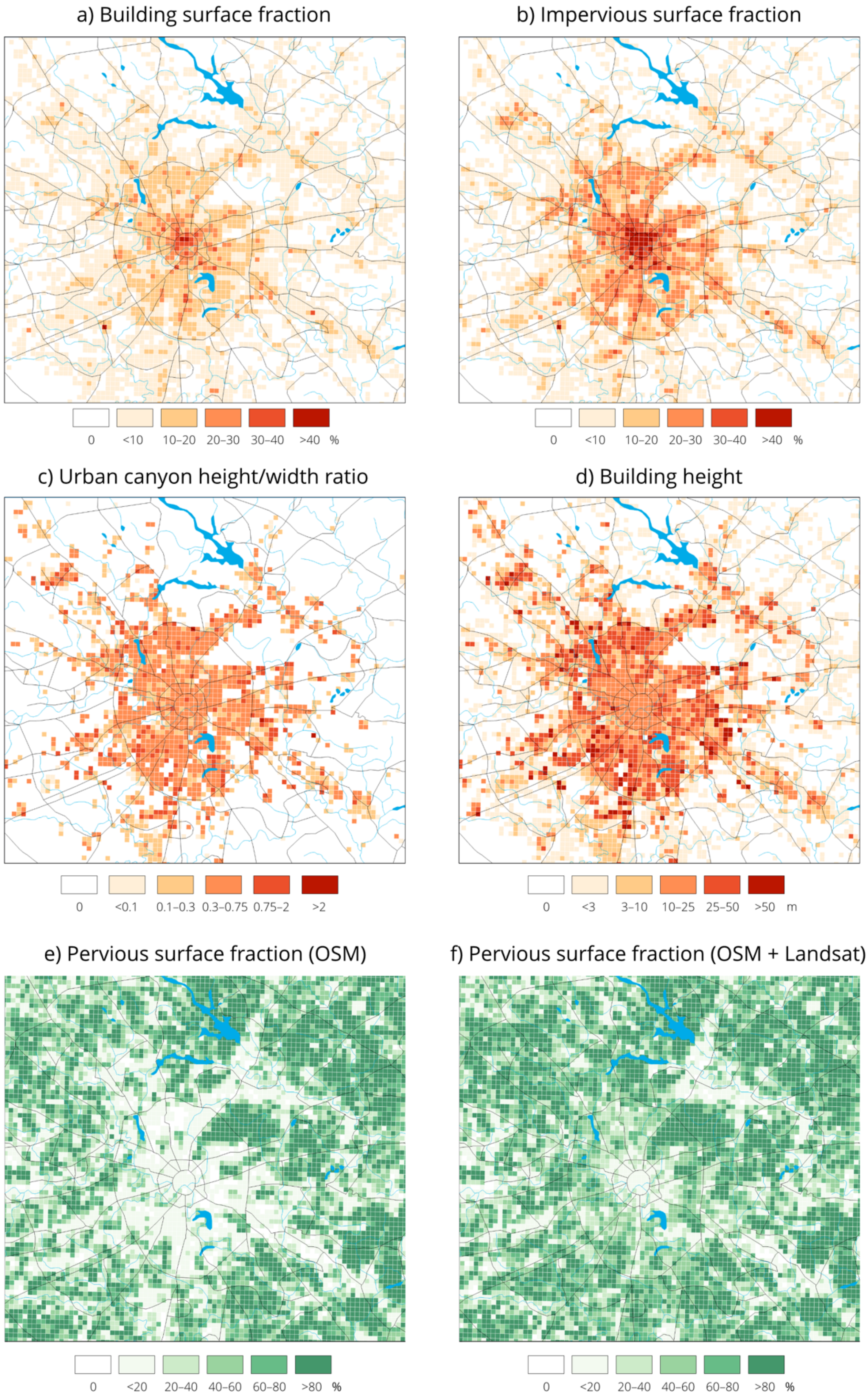

Figure 6: LCZ characteristics calculated from OpenStreetMap data (a-e) and OpenStreetMap/Landsat data (f).

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