南京信息工程大学

Mapping Local Climate Zone in China’s Major Cities

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Outline

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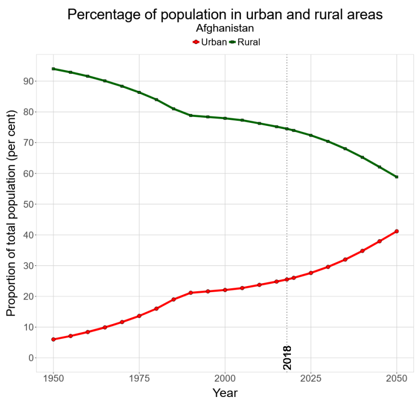
Introduction



Urban and rural population in the current country or area as a percentage of the total population, 1950 to 2050.

World Urbanization

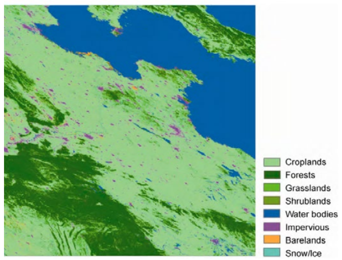
On a global scale，urbanisation proceeding rapidly （UN,2015） However, due to this rapid urbanization, Cities are especially at risk from the ensuing effects, which include poor air quality, flooding and heat waves.（Demuzere et al.,2019)

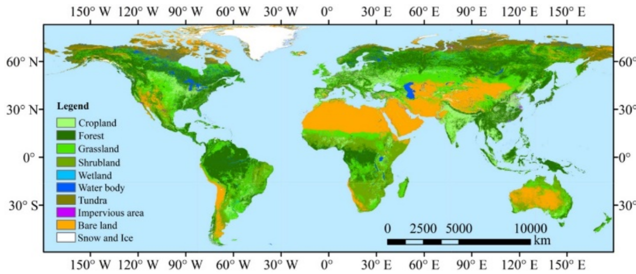
Motivation

advanced urban models
Great progress in mapping urban areas

BUT ...

Lacking the detailed information about the urban surface （Bechtel et al.,2015)
The problem of urban morphological data harmonization, quality, and availability are well-known(Xu et al.,2017)





land cover map

(YU et al.,2014)

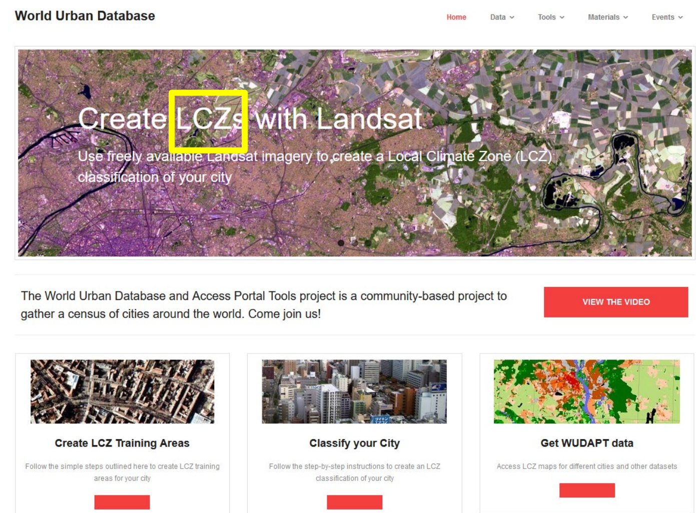
Global land cover map

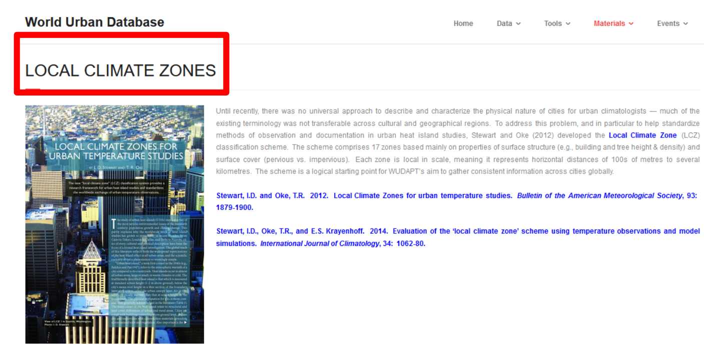
(Gong et al.,2019)

Why using WUDAPT to get urban morphological data?

WUDAPT

- World Urban Database and Access Portal Tools
- international collaborative project for the **acquisition, storage and dissemination of climate relevant data** on physical geographies of cities
- Aim:
  - to acquire and make accessible coherent and consistent descriptions and information on form and function of urban morphology relevant to climate, weather, and environment studies on a worldwide basis;
  - to provide a portal with tools that extract relevant urban parameters and properties for models and for model applications at appropriate scales for various climate, weather, environment, and urban planning purposes.





(Ching et al.,2017； Stewart and Oke,2012)

Introduction

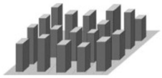
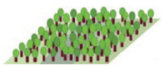
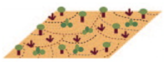
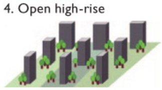
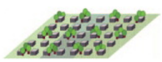
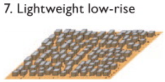
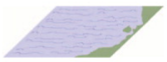
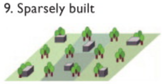
The landscape universe

Local Climate Zones (LCZ)

- 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

(Stewart and Oke,2012)

Abridged definitions for local climate zones

Built types	Definition	Land cover types	Definition
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.	**VARIABLE LAND COVER PROPERTIES**	Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles.
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.
		s. snow cover	Snow cover >10 cm in depth. Low admittance. High 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.	*d. dry ground*	Parched soil. Low admittance. Large Bowen ratio. Increased albedo.
		w. wet ground	Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.

Introduction

Some of the parameter values associated with LCZ types.

Local climate zone (LCZ)	Sky view factor[a]	Aspect ratio[b]	Building surface fraction[c]	Impervious surface fraction[d]	Pervious surface fraction[e]	Height of roughness elements[f]	Terrain roughness class[g]
LCZ 1 *Compact high-rise*	0.2–0.4	> 2	40–60	40–60	< 10	> 25	8
LCZ 2 *Compact midrise*	0.3–0.6	0.75–2	40–70	30–50	< 20	10–25	6–7
LCZ 3 *Compact low-rise*	0.2–0.6	0.75–1.5	40–70	20–50	< 30	3–10	6
LCZ 4 *Open high-rise*	0.5–0.7	0.75–1.25	20–40	30–40	30–40	>25	7–8
LCZ 5 *Open midrise*	0.5–0.8	0.3–0.75	20–40	30–50	20–40	10–25	5–6
LCZ 6 *Open low-rise*	0.6–0.9	0.3–0.75	20–40	20–50	30–60	3–10	5–6
LCZ 7 *Lightweight low-rise*	0.2–0.5	1–2	60–90	< 20	<30	2–4	4–5
LCZ 8 *Large low-rise*	>0.7	0.1–0.3	30–50	40–50	<20	3–10	5
LCZ 9 *Sparsely built*	> 0.8	0.1–0.25	10–20	< 20	60–80	3–10	5–6
LCZ 10 *Heavy industry*	0.6–0.9	0.2–0.5	20–30	20–40	40–50	5–15	5–6
LCZ A *Dense trees*	<0.4	>1	<10	<10	>90	3–30	8
LCZ B *Scattered trees*	0.5–0.8	0.25–0.75	<10	<10	>90	3–15	5–6
LCZ C *Bush, scrub*	0.7–0.9	0.25–1.0	<10	<10	>90	<2	4–5
LCZ D *Low plants*	>0.9	<0.1	<10	<10	>90	<1	3–4
LCZ E *Bare rock or paved*	>0.9	<0.1	<10	>90	<10	<0.25	1–2
LCZ F *Bare soil or sand*	>0.9	<0.1	<10	<10	>90	< 0.25	1–2
LCZ G *Water*	>0.9	<0.1	<10	<10	>90	–	1

[a] Ratio of the amount of sky hemisphere visible from ground level to that of an unobstructed hemisphere
[b] Mean height-to-width ratio of street canyons (LCZs 1–7), building spacing (LCZs 8–10), and tree spacing (LCZs A–G)
[c] Ratio of building plan area to total plan area (%)
[d] Ratio of impervious plan area (paved, rock) to total plan area (%)
[e] Ratio of pervious plan area (bare soil, vegetation, water) to total plan area (%)
[f] Geometric average of building heights (LCZs 1–10) and tree/plant heights (LCZs A–F) (m)
[g] Davenport et al.'s (2000) classification of effective terrain roughness (z_0) for city and country landscapes. See Table 5 for class descriptions

Local climate zone (LCZ)	Surface admittance[a]	Surface albedo[b]	Anthropogenic heat output[c]
LCZ 1 *Compact high-rise*	1,500–1,800	0.10–0.20	50–300
LCZ 2 *Compact midrise*	1,500–2,200	0.10–0.20	<75
LCZ 3 *Compact low-rise*	1,200–1,800	0.10–0.20	<75
LCZ 4 *Open high-rise*	1,400–1,800	0.12–0.25	<50
LCZ 5 *Open midrise*	1,400–2,000	0.12–0.25	<25
LCZ 6 *Open low-rise*	1,200–1,800	0.12–0.25	<25
LCZ 7 *Lightweight low-rise*	800–1,500	0.15–0.35	<35
LCZ 8 *Large low-rise*	1,200–1,800	0.15–0.25	<50
LCZ 9 *Sparsely built*	1,000–1,800	0.12–0.25	<10
LCZ 10 *Heavy industry*	1,000–2,500	0.12–0.20	>300
LCZ A *Dense trees*	unknown	0.10–0.20	0
LCZ B *Scattered trees*	1,000–1,800	0.15–0.25	0
LCZ C *Bush, scrub*	700–1,500	0.15–0.30	0
LCZ D *Low plants*	1,200–1,600	0.15–0.25	0
LCZ E *Bare rock or paved*	1,200–2,500	0.15–0.30	0
LCZ F *Bare soil or sand*	600–1,400	0.20–0.35	0
LCZ G *Water*	1,500	0.02–0.10	0

[a] Ability of surface to accept or release heat (J m^{-2} $s^{-1/2}$ K^{-1}). Varies with soil wetness and material density. Few estimates of local-scale admittance exist in the literature; values given here are therefore subjective and should be used cautiously. Note that the "surface" in LCZ A is undefined and its admittance unknown.

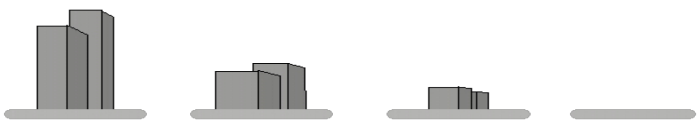
[b] Ratio of the amount of solar radiation reflected by a surface to the amount received by it. Varies with surface color, wetness, and roughness.

[c] Mean annual heat flux density (W m^{-2}) from fuel combustion and human activity (transportation, space cooling/heating, industrial processing, human metabolism). Varies significantly with latitude, season, and population density.

(Stewart and Oke,2012）

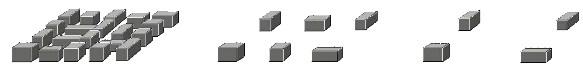
How to construct the LCZ Framework?

- **Height of roughness features**
  Buildings



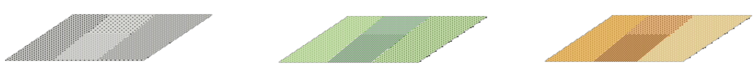
highrise > 10 stories | midrise 3-9 stories | lowrise 1-3 stories | no rise 0 stories

- **Packing of roughness features**
  Buildings



compact H/W > 1 | open H/W < 1 | sparse H/W < 0.25

- **Surface cover around roughness features**



impervious concrete/rock | pervious low plants | pervious soils

- **Thermal admittance of materials**

heavy concrete, stone | lightweight sheet metal, wood

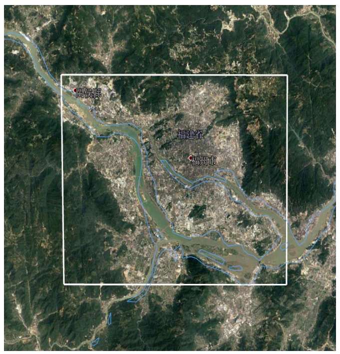
Datasets and Method

How to **make** the data sets?

- **Create the ROI** (Region of Interest) in Google Earth

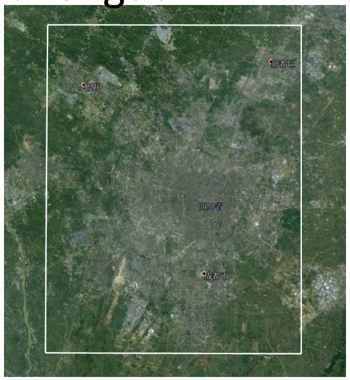
ROI in part of cities

Fuzhou



Haikou

Chengdu



Dalian

- Download and preprocess Landsat Data

Seamless mosaic and atmospheric correctionwere.

Resample the image resolution from 30 metersto 120 meters. ROI must be projected to UTM(the projection of the Landsat data)

Part of satellite images acquired in the present paper

city	Landsat Entity ID	Acquisition date
	LC81230412018082LGN00	2018/03/23
Changsha	LC81230412019277LGN00	2019/10/04
	LC81230412019309LGN00	2019/11/05
Qingdao	LC81200352018285LGN00	2018/10/08
	LC81200352019272LGN00	2019/09/29
	LC81260352019074LGN00	2019/03/15
Linfen	LC81250352019227LGN00	2019/08/15
	LC81250352019323LGN00	2019/11/19
	LC81190332019105LGN00	2019/04/15
Dalian	LC81190332019265LGN00	2019/09/22
	LC81200332019304LGN00	2019/10/31
	LC81190382017355LGN00	2017/12/21
Wuxi	LC81190382018054LGN00	2018/02/23
	LC81190382018118LGN00	2018/04/28
Huizhou	LC81210442019071LGN00	2019/03/12
	LC81210442019263LGN00	2019/09/20
	LC81300352017192LGN00	2017/07/11
Lanzhou	LC81300352017272LGN00	2017/09/27
	LC81310352017359LGN00	2017/12/25
	LC81190382017355LGN00	2017/12/21
Suzhou	LC81190382018054LGN00	2018/02/23
	LC81190382018118LGN00	2018/04/28

How to make the data sets?

Sampling is crucial!

- **Digitize training areas**

Large 'homogenous' areas (the optimal size and shape of training areas is > 1 km^2 and >200 m wide at the narrowest point)

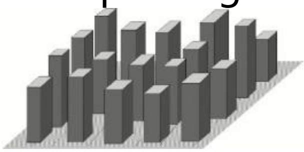
Leave a buffer of about 100 m between LCZs

There should be several examples (5-15) of each LCZ to help in the automatic classification

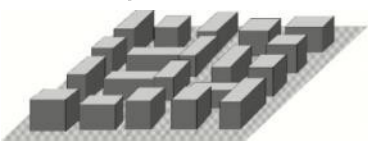
Avoid construction sites and harvested fields

Snapshots of different LCZ classes from Google Earth

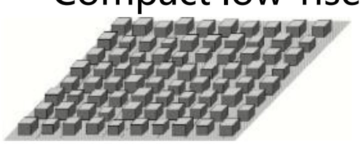
LCZ 1
Compact high-rise



LCZ 2
Compact mid-rise

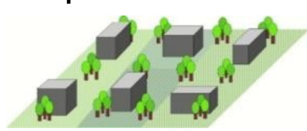


LCZ 3
Compact low-rise



LCZ 4
Open high-rise

LCZ 5
Open mid-rise



LCZ 6
Open mid-rise

Datasets and Method

How to make the data sets?

- **Digitize training areas**

Screenshots of Training samples of some cities from Google Earth.

Fuzhou

Haikou

Chengdu

Dalian

Wuxi

Suzhou

Haerbin

Nantong

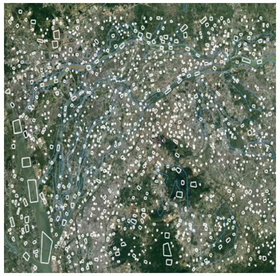
Changchun

Wuhan

Zhongshan

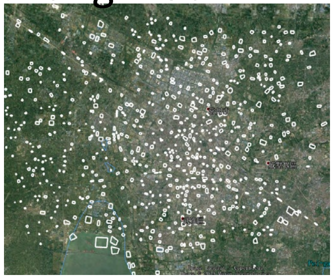
Xiamen

Dongguan



Yinchuan

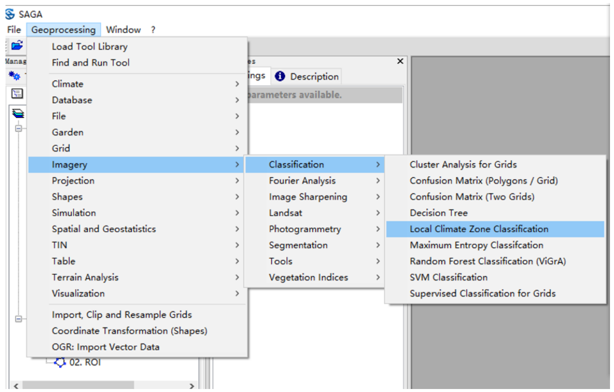
Changzhou

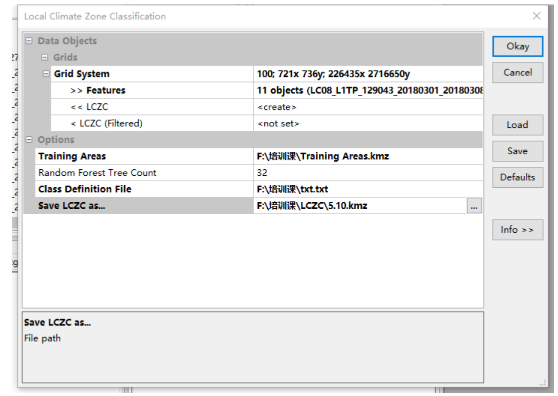


Datasets and Method

How to make the data sets?

- **Generate the LCZ classification using SAGA GIS**





- **Export data from SAGA GIS.**

ID	X	Y	LCZC
1	330093.765566	3428526.857326	107.000000
2	330213.765566	3428526.857326	3.000000
3	330333.765566	3428526.857326	7.000000
4	330453.765566	3428526.857326	104.000000
5	330573.765566	3428526.857326	104.000000
6	330693.765566	3428526.857326	104.000000
7	330813.765566	3428526.857326	104.000000

→

lat	lon	lu
30.97795	121.2208	107.0000
30.97797	121.2221	3.000000
30.97799	121.2233	7.000000
30.97800	121.2246	104.0000
30.97802	121.2258	104.0000
30.97804	121.2271	104.0000
30.97805	121.2283	104.0000

How to Validate the accuracy of data sets?

- **Validate the accuracy of the classification.**

  - Using 50% of the training polygons for training (stratified by class) and the remaining **50% for testing.** (Bechtel et al.,2019)
  - Set 0.5% of the number of each LCZ class previously developed. Compare the developed LCZ classes with the reference data. (Ren et al.,2017)
  - Comparison with survey data.

- Overall accuracy = Cell area corresponding to random points consistent with the actual underlying surface/0.5% pixel area
- Acceptable accuracy = (Correct cell area + Confused pixel area)/Total pixel area

Results

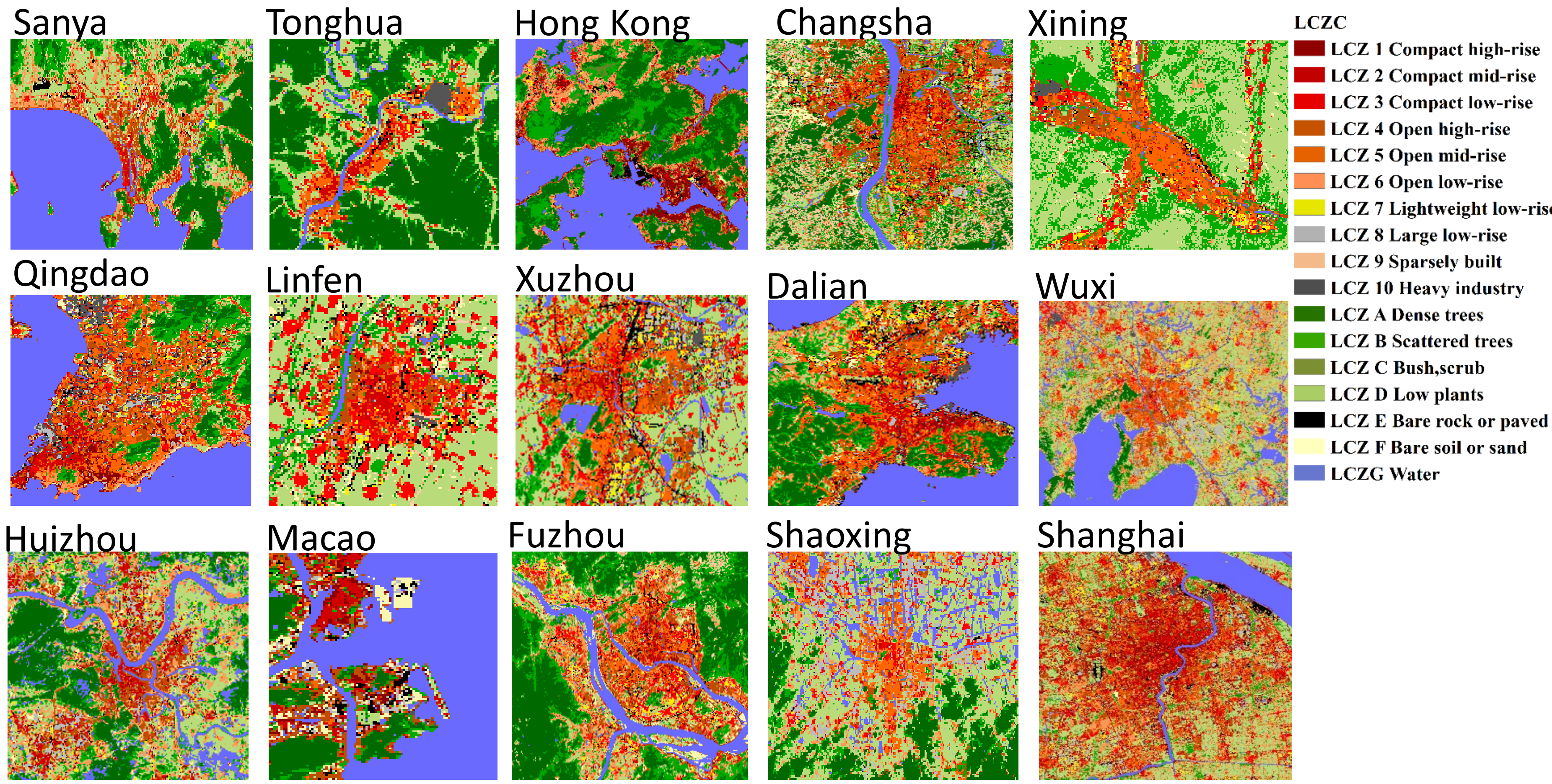
What data sets have we done for cities?

63 Chinese cities

Sanya	Tonghua	**Hong Kong**	**Changsha**	**Xining**	Qingdao	Linfen	Xuzhou
Dalian	Wuxi	Huizhou	**Macao**	**Fuzhou**	Shaoxing	**Shanghai**	**Lanzhou**
Suzhou	Wenzhou	Jiaxing	**Harbi**	Wuhu	Shantou	Taizhou	Shenzhen
Nanchang	Quanzhou	**Shenyang**	**Chongqing**	**Tianjin**	Luoyang	Zhongshan	Baoding
Lhasa	Nantong	**Changchun**	Xiamen	Dongguan	**Wuhan**	**Taiyuan**	**Yinchuan**
Chengdu	Changzhou	Foshan	Ningbo	**Hangzhou**	**Haikou**	**Hefei**	**Jinan**
Zhuhai	Yangzhou	Ordos	**Nanjing**	**Shijiazhuang**	**Guangzhou**	Jinhua	Tangshan
Kunming	**Beijing**	**Guiyang**	**Zhengzhou**	**Xi'an**	**Nanning**	**Huhehaote**	

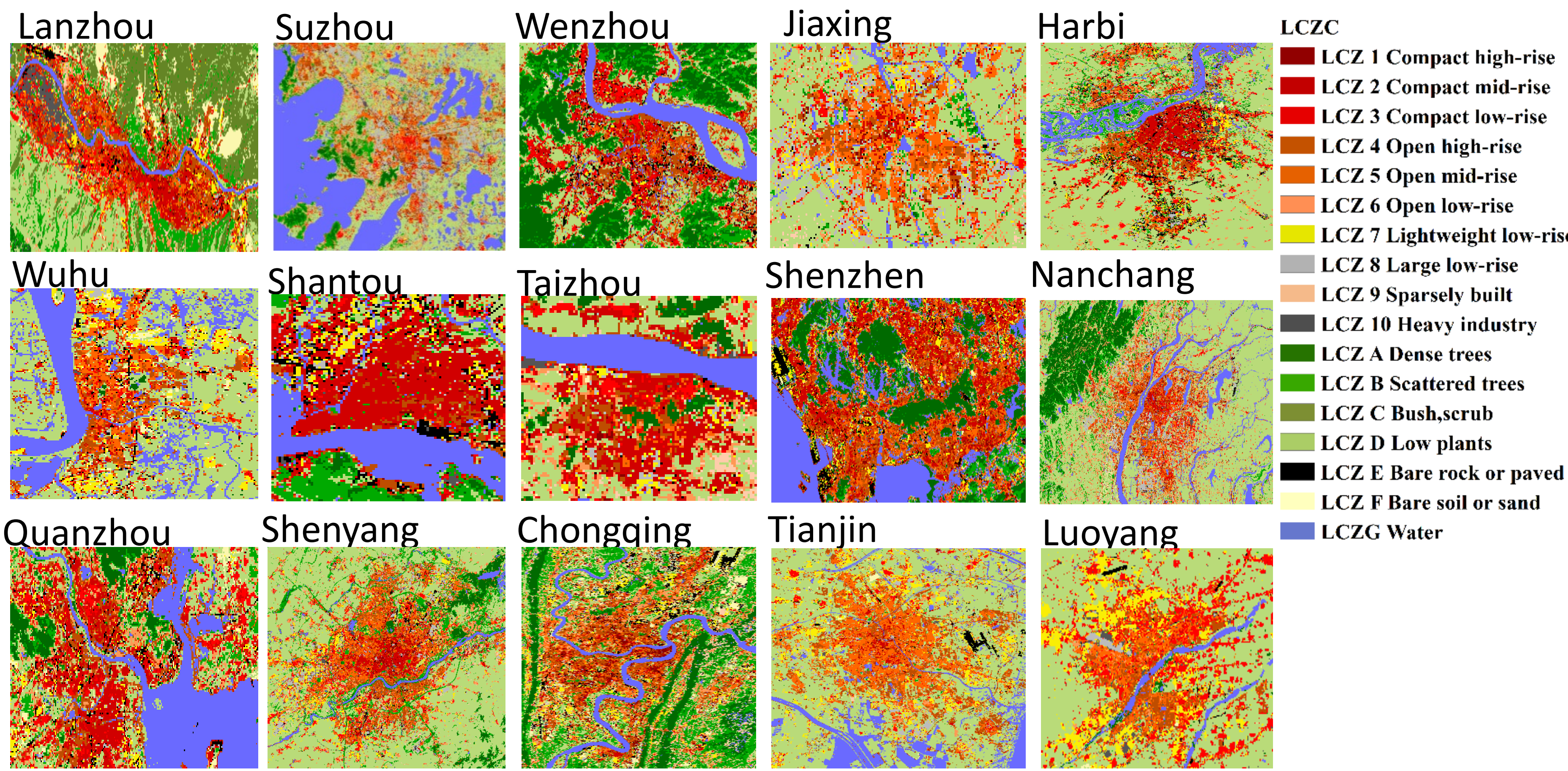
Results

Local climate zones for 30 Chinese cities.



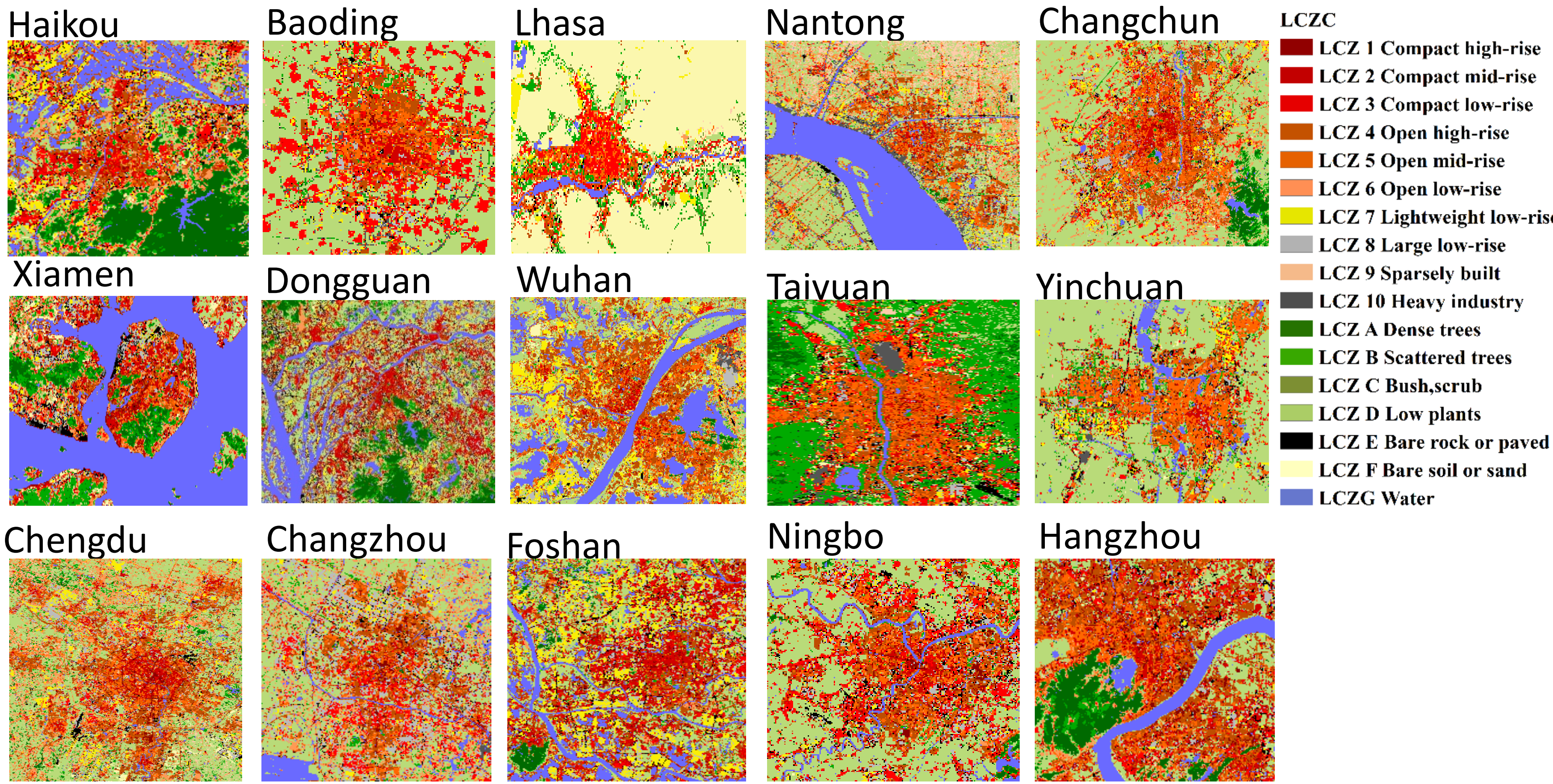
Results

Local climate zones for 30 Chinese cities.



Results

Local climate zones for 30 Chinese cities.



Results

Classification accuracy assessment

ID	City	accuracy rate	acceptable accuracy rate
1	Sanya	0.9188	0.9250
2	Tonghua	0.8967	0.9239
3	Hong Kong	0.8927	0.9099
4	Changsha	0.8678	0.9017
5	Xining	0.8643	0.8786
6	Qingdao	0.8587	0.8891
7	Linfen	0.8573	0.8573
8	Xuzhou	0.8563	0.8965
9	Dalian	0.8480	0.8717
10	Wuxi	0.8454	0.8880
11	Huizhou	0.8423	0.8694
12	Macao	0.8416	0.9010
13	Fuzhou	0.8415	0.8778
14	Shaoxing	0.8377	0.8896
15	Shanghai	0.8339	0.8767
16	Lanzhou	0.8314	0.8953
17	Suzhou	0.8299	0.8815
18	Wenzhou	0.8285	0.8866
19	Jiaxing	0.8259	0.8795
20	Harbin	0.8244	0.8798
21	Wuhu	0.8224	0.8547
22	Shantou	0.8218	0.8515
23	Taizhou	0.8214	0.8452
24	Shenzhen	0.8209	0.8919
25	Nanchang	0.8249	0.8572
26	Quanzhou	0.8176	0.8494
27	Shenyang	0.8131	0.8575
28	Chongqing	0.8125	0.8832
29	Tianjin	0.8111	0.8241
30	Luoyang	0.7105	0.8235
31	Zhongshan	0.8101	0.8418

ID	City	accuracy rate	acceptable accuracy rate
32	Baoding	0.8080	0.8800
33	Lhasa	0.8065	0.8172
34	Nantong	0.8045	0.8508
35	Changchun	0.7999	0.8561
36	Xiamen	0.7949	0.8540
37	Dongguan	0.7904	0.8519
38	Wuhan	0.7859	0.8207
39	Taiyuan	0.7841	0.8415
40	Yinchuan	0.7797	0.8267
41	Chengdu	0.7780	0.8240
42	Changzhou	0.7771	0.8257
43	Foshan	0.7708	0.8063
44	Ningbo	0.7716	0.8148
45	Hangzhou	0.7700	0.8000
46	Haikou	0.7693	0.8615
47	Hefei	0.7602	0.8556
48	Jinan	0.7602	0.8462
49	Zhuhai	0.7525	0.8218
50	Yangzhou	0.7500	0.8077
51	Ordos	0.7475	0.8429
52	Nanjing	0.7448	0.8202
53	Shijiazhuang	0.7438	0.8468
54	Guangzhou	0.7388	0.8060
55	Jinhua	0.7387	0.8468
56	Tangshan	0.7349	0.8166
57	Kunming	0.7260	0.8168
58	Beijing	0.7133	0.7727
59	Guiyang	0.7110	0.7919
60	Zhengzhou	0.7106	0.8277
61	Xian	0.7009	0.8023
62	Nanning	0.6908	0.8027
63	Hohhot	0.7390	0.8239

Results

Comparison of OA from this study to the results from other studies.

literature	City	Source	Division scale	classification method	Overall Accuracy
Bechtel et al. (2016)	Khartoum	Landsat ,Google Earth	＞100×100m	WUDAPT	0.97
Bechtel et al. (2015)	Hamburg, Houston,Dublin	Landsat ,Google Earth	＞100×100m	WUDAPT	0.96
Thomas et al. (2014)	Kochi	physical measurements and google images	100×100m；500×500m	Divide according to the reference range of index value	
Hu et al. (2018)	Shanghai	Landsat ,Google Earth	＞100×100m	WUDAPT	0.89
Zheng et al. (2017)	Hong Kong	buildings, streets, topography and land use in GIS format	300m	GIS-based	
Xu et al. (2017)	Guangzhou	Landsat ,Google Earth	＞150×150m	WUDAPT	0.62
Cai et al. (2017)	YRD megaregion	Landsat ,Google Earth Aster	＞100×100m	WUDAPT	0.67
Lin et al. (2017)	Fuzhou	Landsat ,Google Earth	＞100×100m	Select basic training samples based on Google Earth, Classify according to spectral index	
Cai et al. (2016)	Guangzhou	Landsat ,Google Earth	＞100×100m	WUDAPT	

Discussion

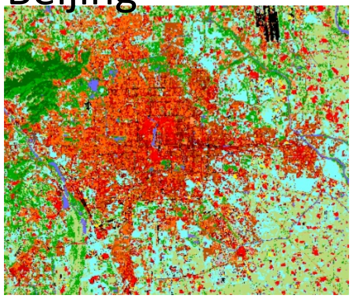
LCZ as a as a new standard for mapping Chinese urban areas?

The screen shot of Construction area of Chinese cities from Google Earth

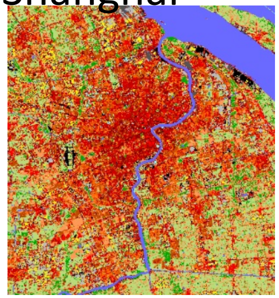
Discussion

Local climate zones for 7 Chinese cities(after adding LCZ H)

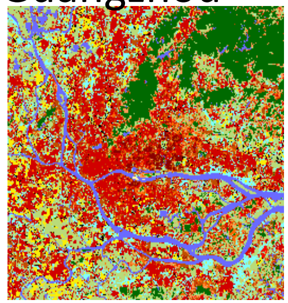
Beijing



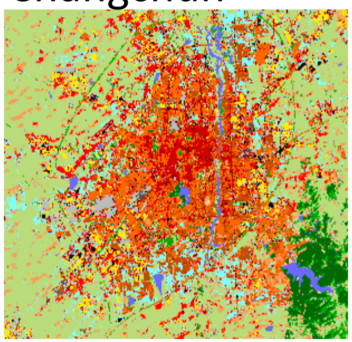
Shanghai



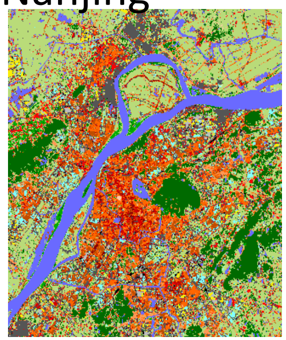
Guangzhou



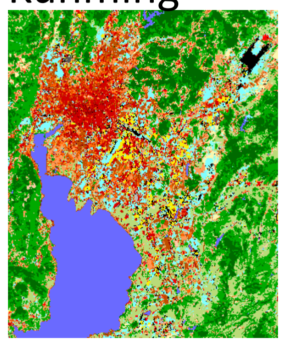
Changchun



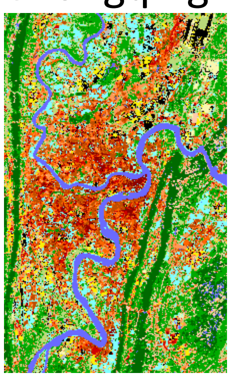
Nanjing



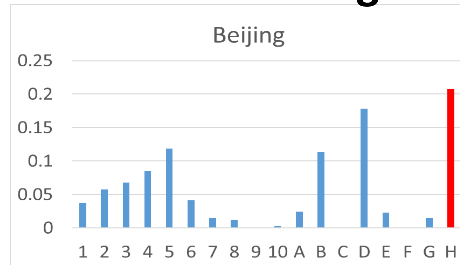
Kunming

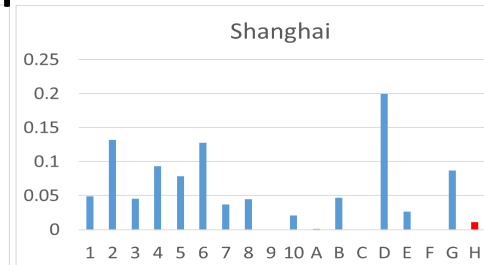


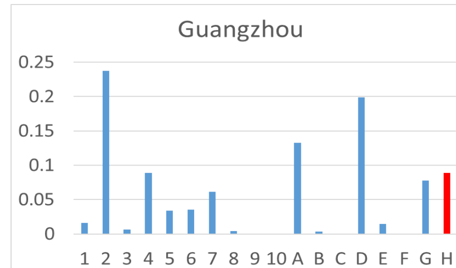
Chongqing

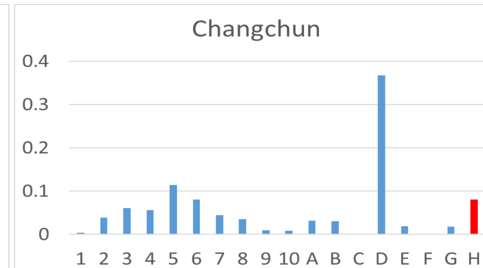


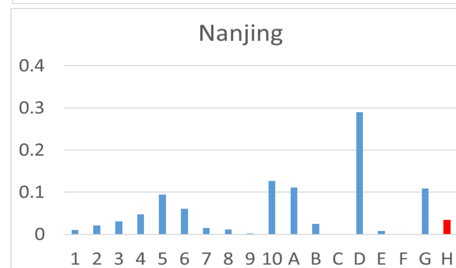
Percentage of per LCZ in cities

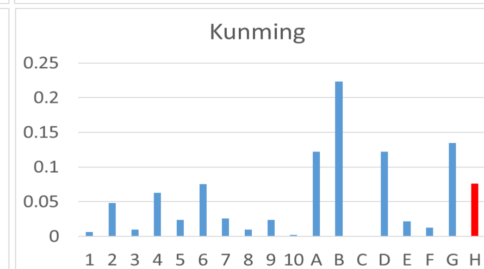


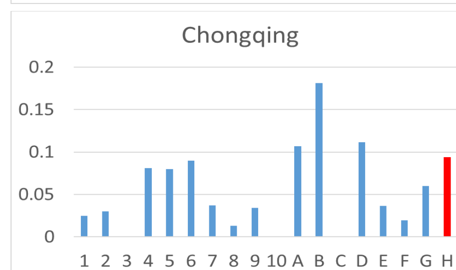










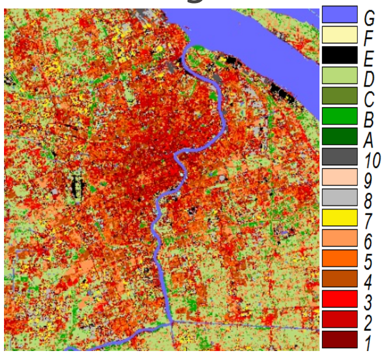


Discussion

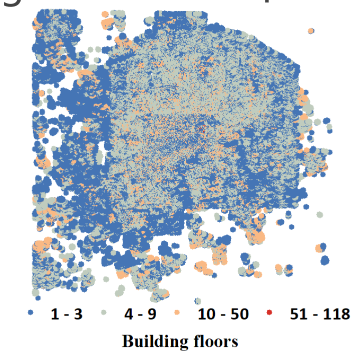
Urban canopy parameters

- **Building height**

Take Shanghai and Qingdao for example

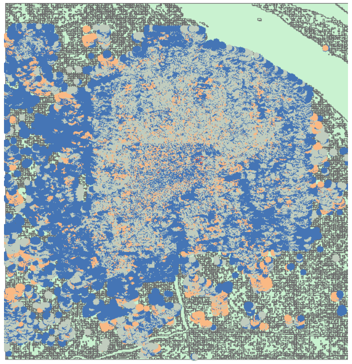


LCZ map of Shanghai



building height of Shanghai

intersect



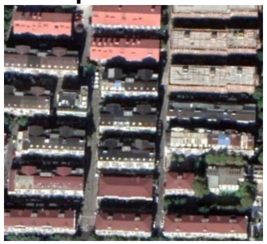
The map after intersection

Accuracy of building height

	Low-rise (1-2)	Low-rise or midrise (3)	Midrise (4-9)	High-rise (≥10)	Overall
Shanghai	0.4861	0.8405	0.6186	0.6371	0.5991
Qingdao	0.4643	0.8781	0.7267	0.6858	0.6213

LCZ 2
LCZ 5
? → **Low-rise**

LCZ 2
Compact mid-rise



LCZ 3
Compact low-rise

LCZ 5
Open mid-rise

LCZ 6
Open mid-rise

Accuracy of building height (LCZ 2 & 5 → Low-rise)

	Low-rise (1-2)	Overall
Shanghai	0.8141	0.7113
Qingdao	0.8224	0.7832

Discussion

Urban canopy parameters

- **Building height**

Take Shanghai and Qingdao for example

Mean building stories per built LCZ class for the Urban cities.

	LCZ 1	LCZ 2	LCZ 3	LCZ 4	LCZ 5	LCZ 6	LCZ 7	LCZ 8
Reference range (Stewart and Oke,2012)	≥10	3-9	1-3	≥10	3-9	1-3	1-3	1-3
Shanghai	18.82	5.69	2.21	15.50	5.82	2.26	2.01	**3.29**
Qingdao	20.21	5.20	1.81	17.34	4.97	2.12	1.74	2.60

- **Impervious surface fraction**
- **Anthropogenic heat flux**
- **Sky view factor**

…

Discussion

summary

- The research classifies 63 cities' LCZs in total, which fills the gaps in the spatial information of Chinese cities in a comprehensive manner and provides a better reference for future Chinese urban planning.

- This study shows that given a sufficient number of training samples, the accuracy of the LCZ data remains essentially stable. It was concluded that the overall accuracy rate of the city was between 0.69 and 0.92, which met the requirement of an average minimum accuracy of 50% in the WUDAPT protocol.

- From this datasets, the parameter set such as building height, impervious water percentage, man-made heat flux and sky visibility factor are further extracted. In future research, we will further discuss the application of parameter sets in various cities.

谢谢

恳请各位老师批评指正！