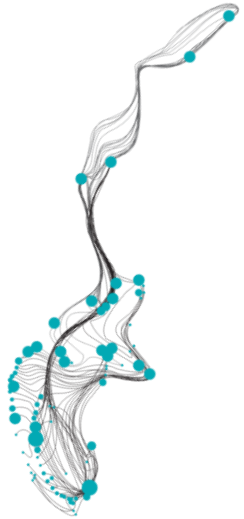


Understanding urban divide for environmental exposure *from* above

Jon Wang

Geo-Information Science and Earth Observation (ITC), University of Twente, 7514 AE Enschede, The Netherlands

About my research

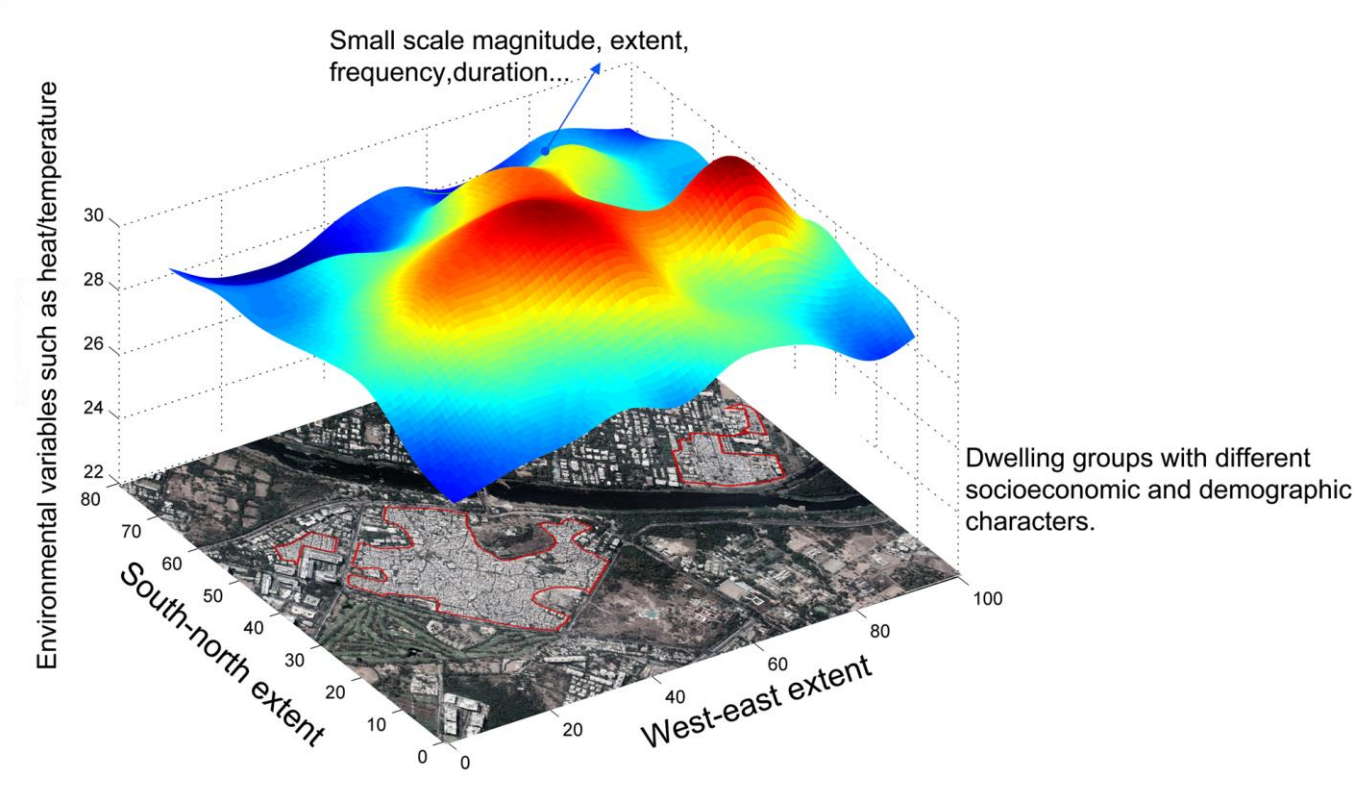
Urban climatic/atmospheric phenomenon and land surface specification (2012~, where Ph.D. started in Wuhan University):

- Statistical modelling of temperature/heat patterns in space and time;
- Characterizing land surface specification;
- Causes/factors.

Environmental exposure and settlement characterization (2017~, Postdoc):

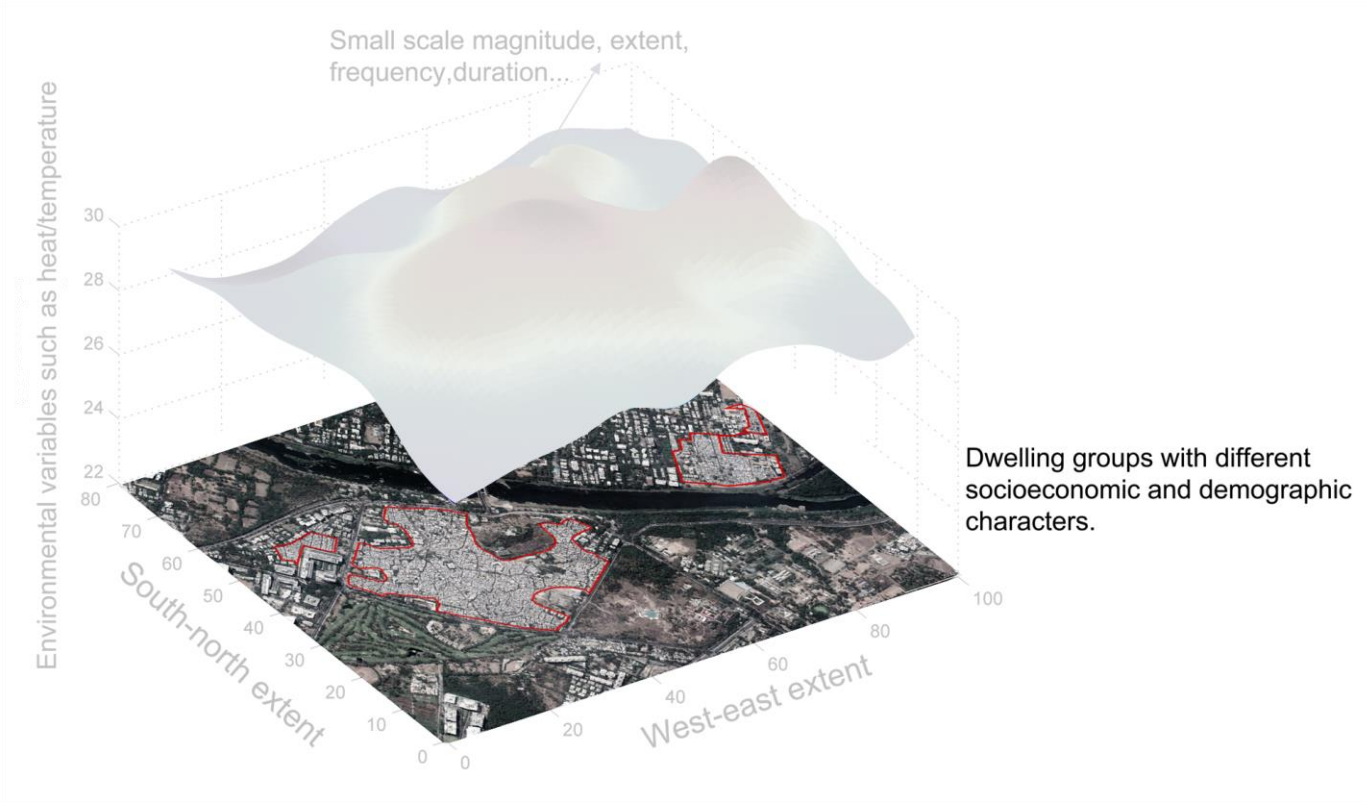
- Socioeconomic/demographic status;
- Vulnerable/deprived groups.

About my research



Wang, J., Kuffer, M., Sliuzas, R. and Kohli, D., 2019. The exposure of slums to high temperature: Morphology-based local scale thermal patterns. *Science of the total environment*, *650*, pp.1805-1817.

This talk: Urban divide from remote sensing imagery



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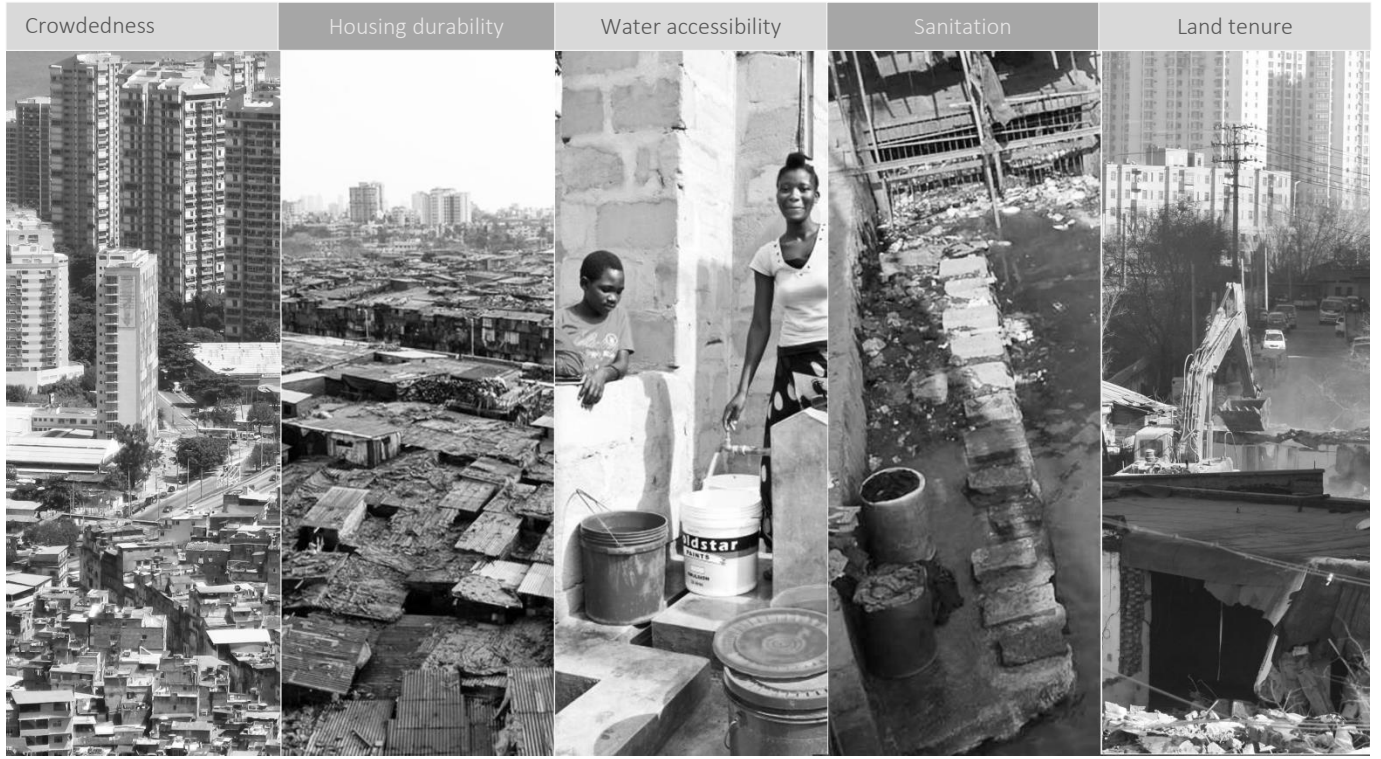
This talk: Urban divide from remote sensing imagery



This talk: Urban divide from remote sensing imagery

Assumption

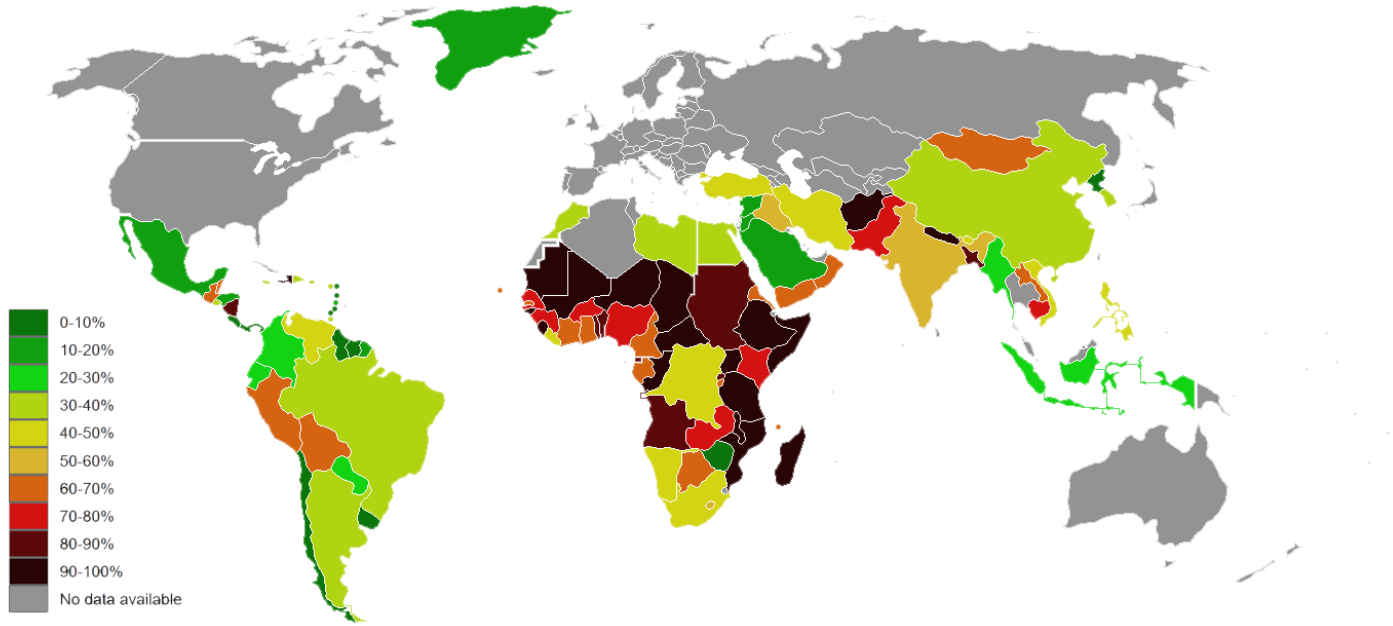
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



- More than **1.6** people now live in the deprivation (slums) of the world's cities, and by 2050 the slum population is expected to grow to more than **3** billion — that's more than **30%** of the projected population of 9.7 billion in 2050.
  (United Nation, https://unhabitat.org/up-for-slum-dwellers-transforming-a-billion-lives-campaign-unveiled-in-europe/)

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Fundamental assumption: From extreme cases

https://newatlas.com/unequal-scenes-drone-photograpy/55899/#gallery

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Fundamental assumption

- The characteristics of urbanization, such as demography, socioeconomic status, and ecology can be manifested by the physical appearance of urban forms.

Conventional practice as binary image classification

Assumption

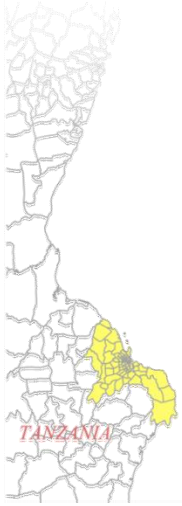
Conventional workflow

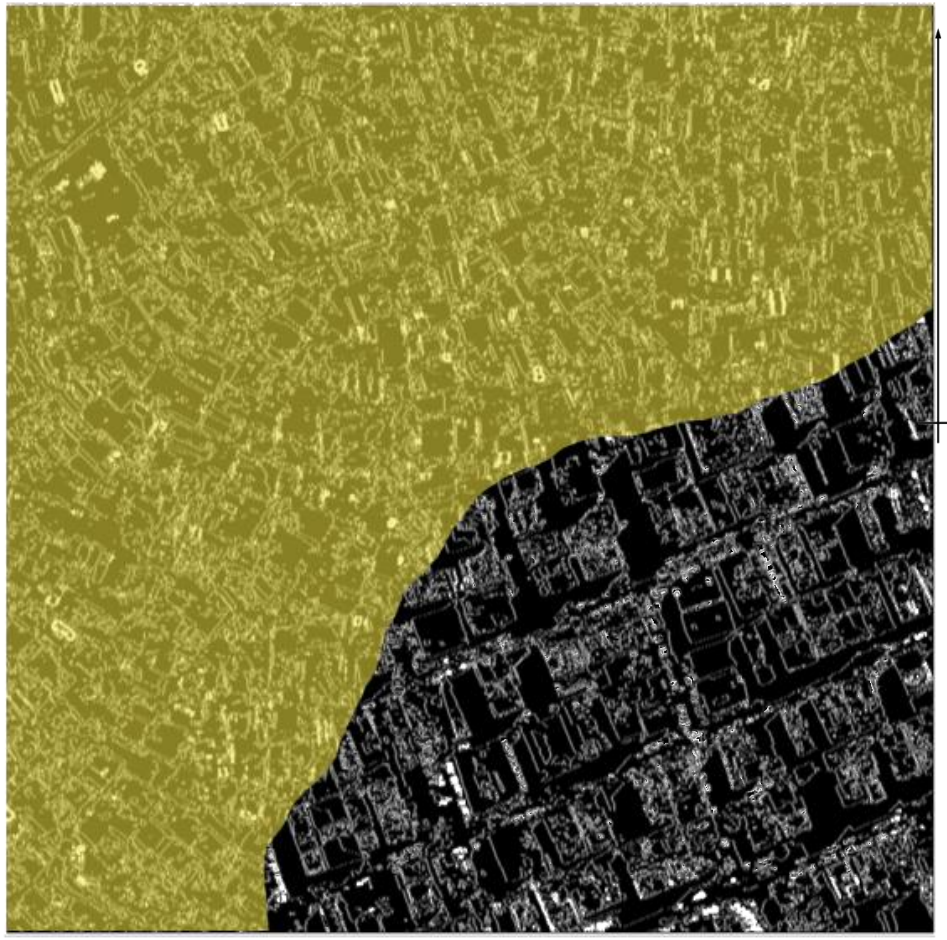
Scientific validity

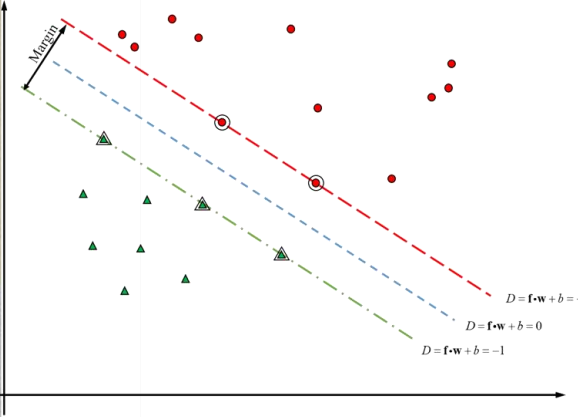
A shift in workflow

Study cases

Outlook







- Image data
- Features/
  Feature stats
- Classify:
  manually/automatically

Conventional practice as image classification

Assumption

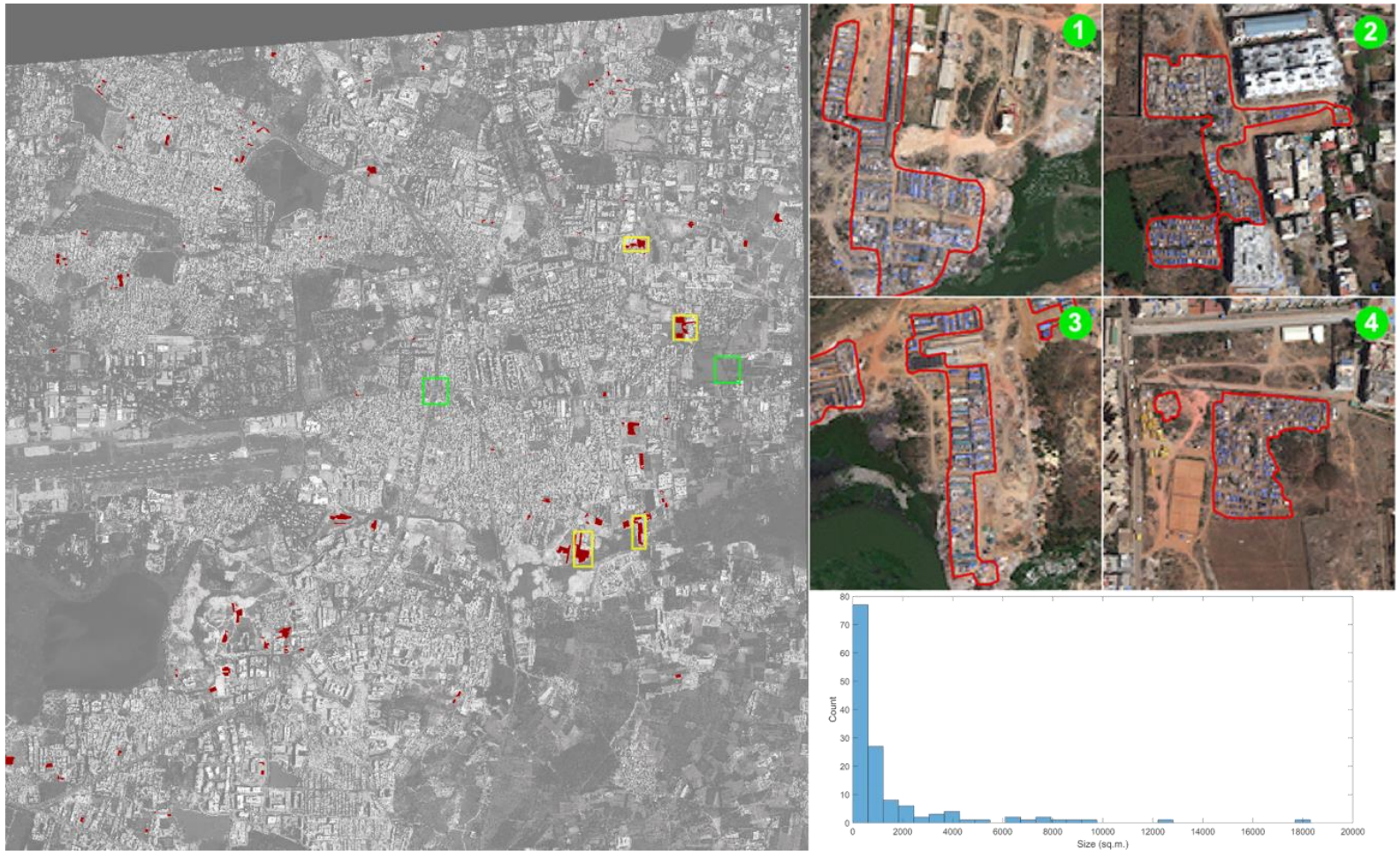
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



Wang, J., Kuffer, M., Roy, D. and Pfeffer, K., 2019. Deprivation pockets through the lens of convolutional neural networks. *Remote sensing of environment*, *234*, p.111448.

A generalized workflow

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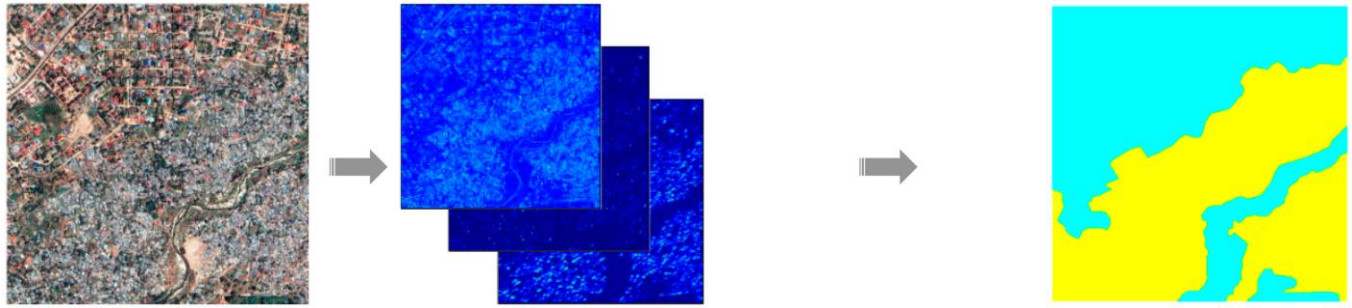
Conventional workflow

Scientific validity

A shift in workflow

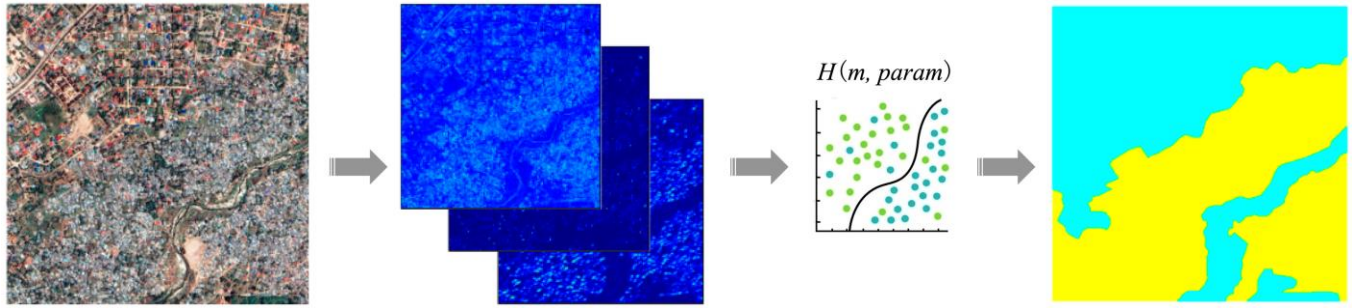
Study cases

Outlook



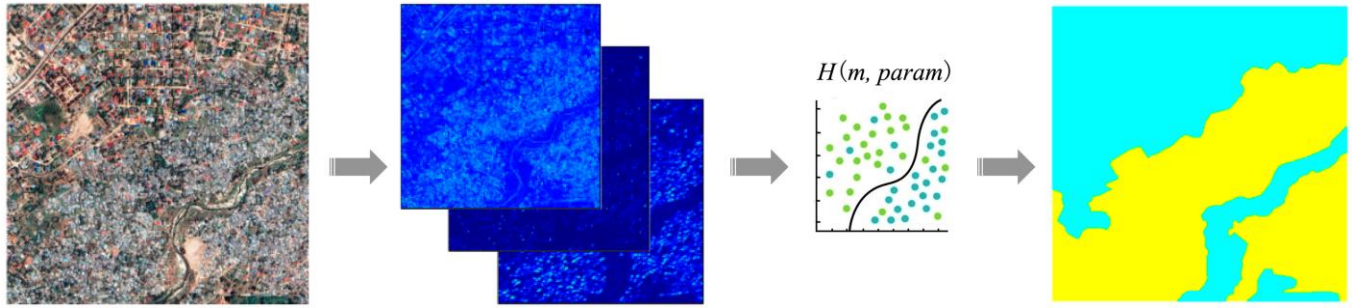
Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

A generalized workflow



Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Critical points in the workflow: Data and features



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Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

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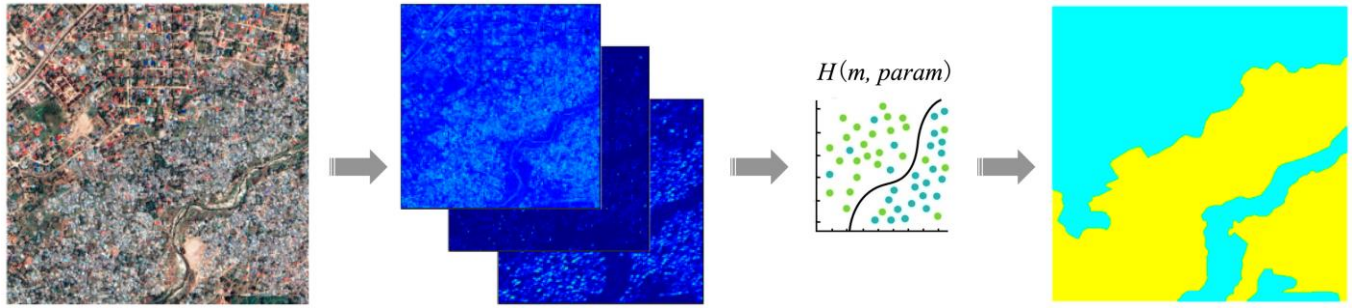

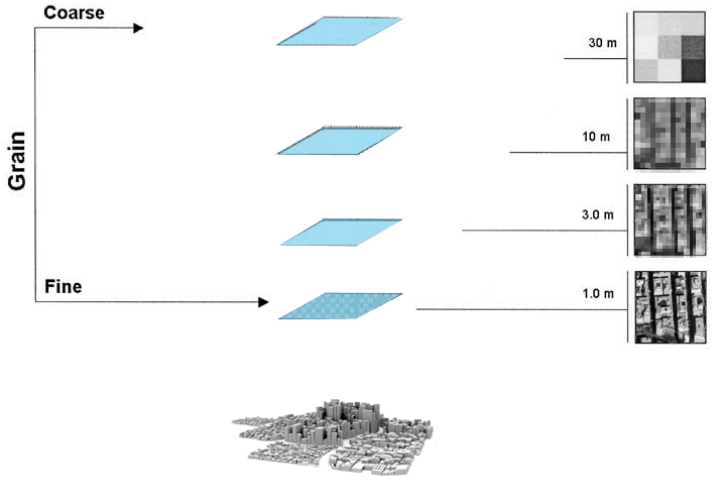

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Scientific validity
A shift in workflow
Study cases
Outlook

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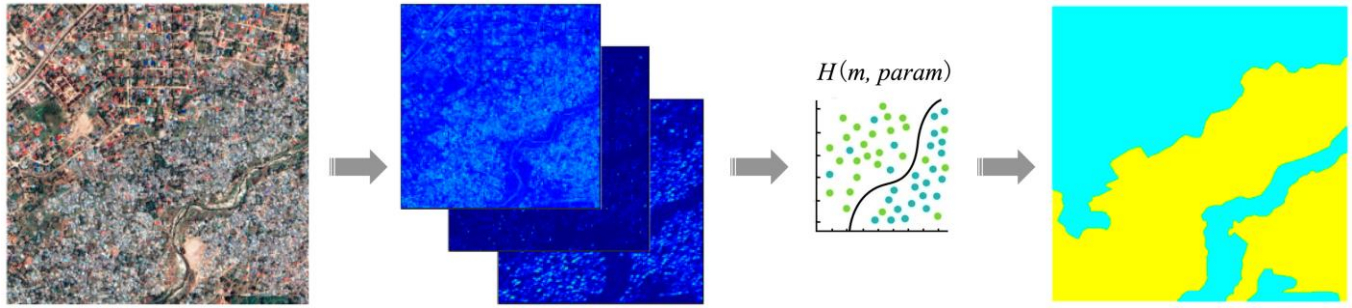

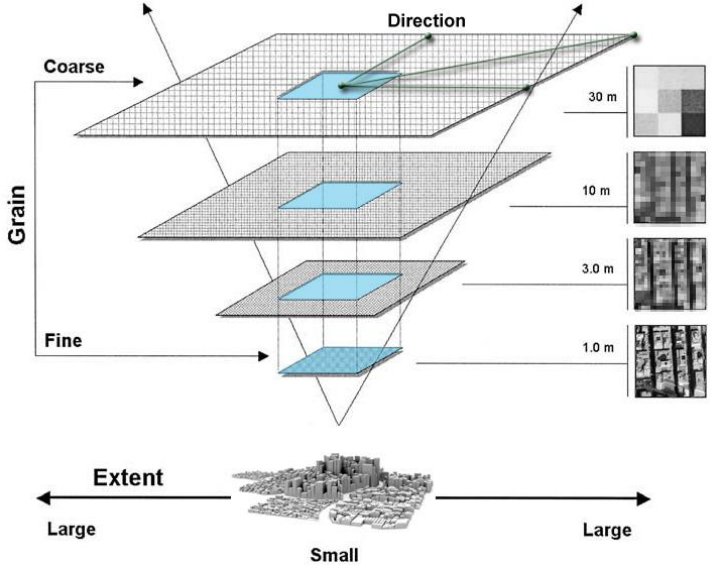

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Scientific validity
A shift in workflow
Study cases
Outlook

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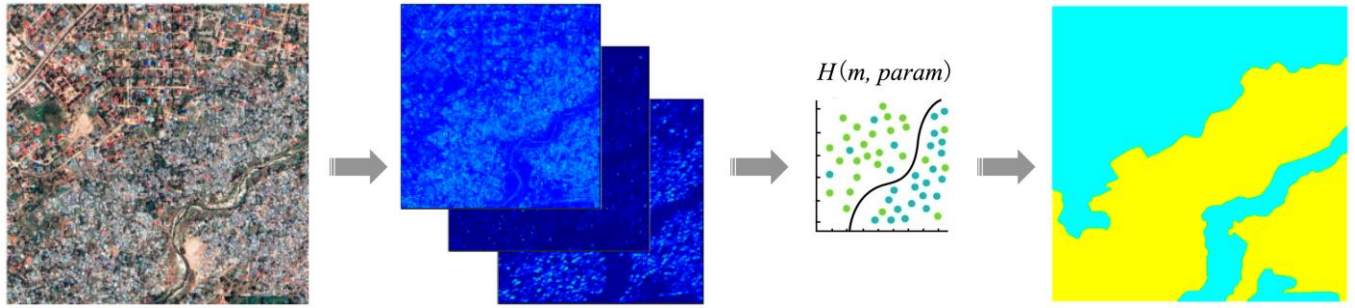

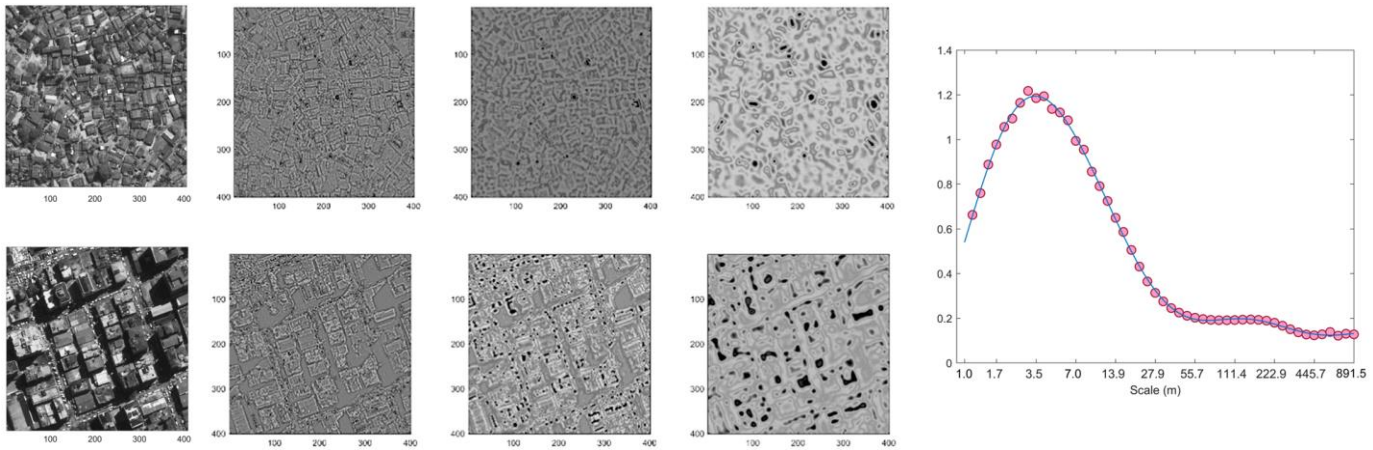

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Critical points in the workflow: Model advancement

Assumption

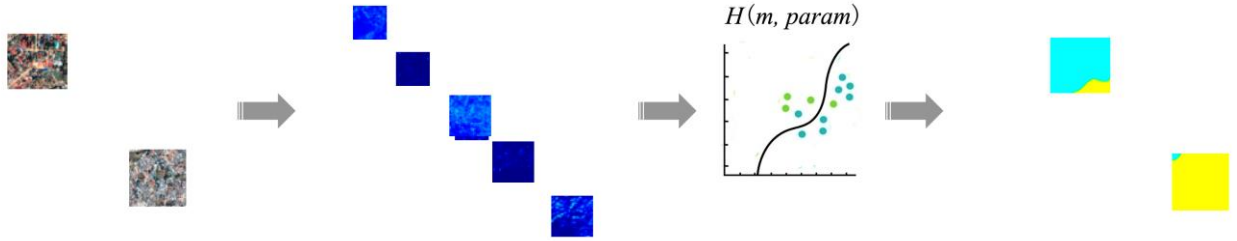
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



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Assumption

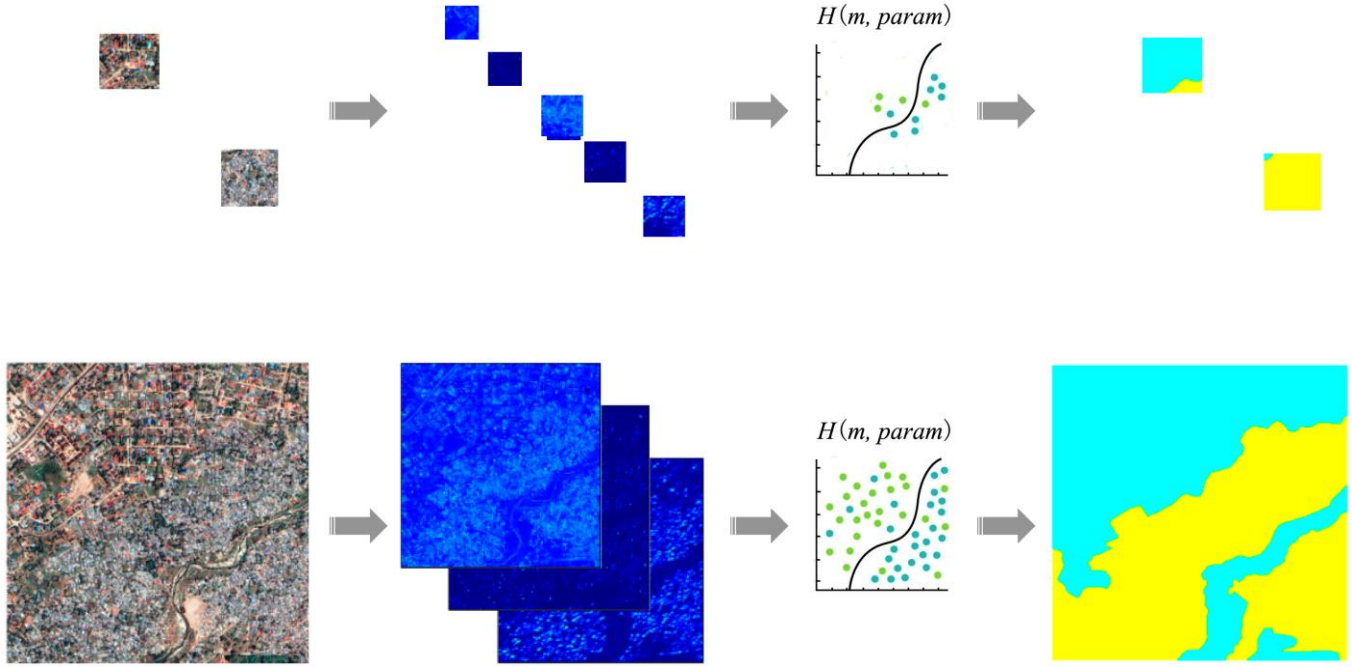
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



Critical points in the workflow: Model advancement

Assumption

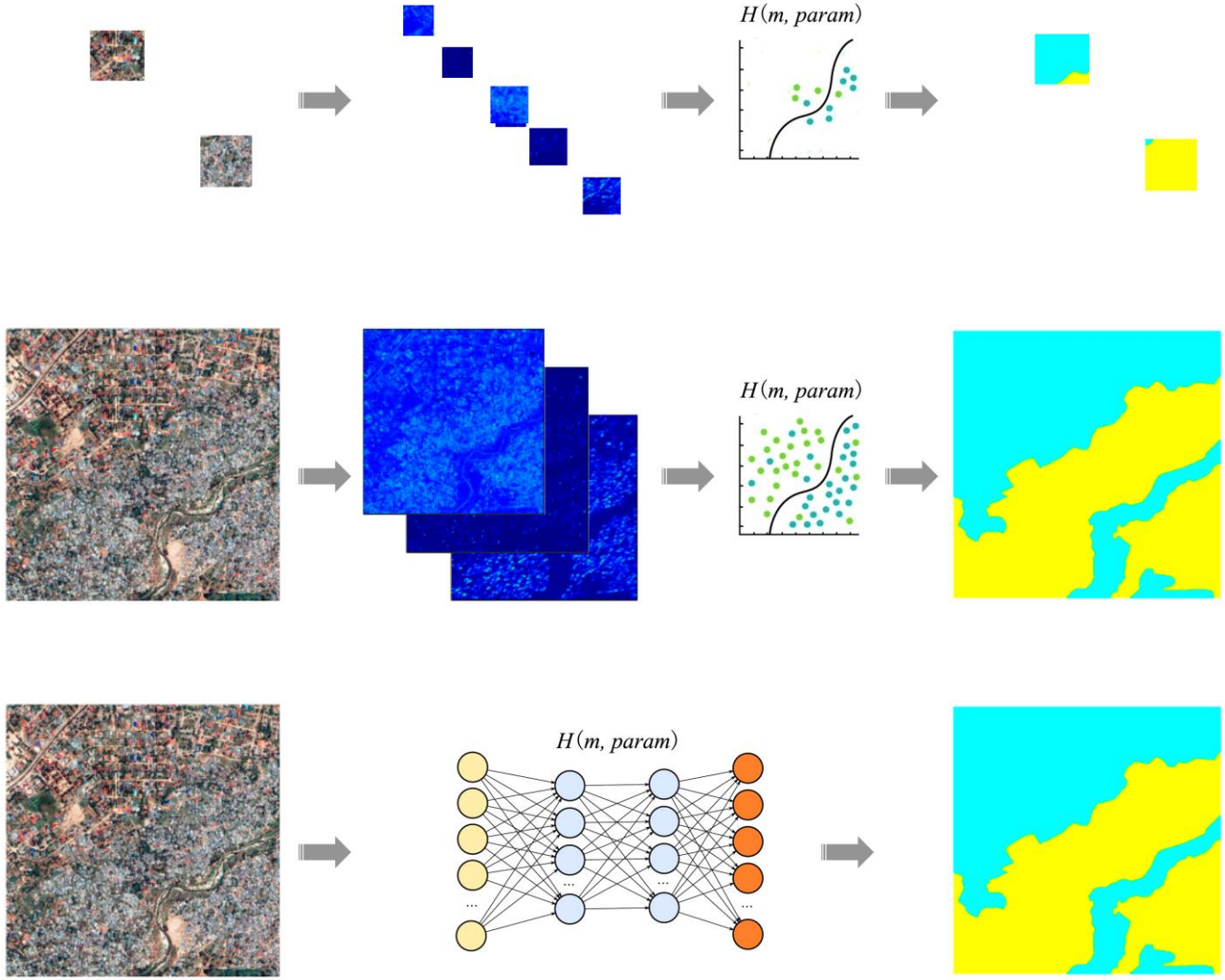
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



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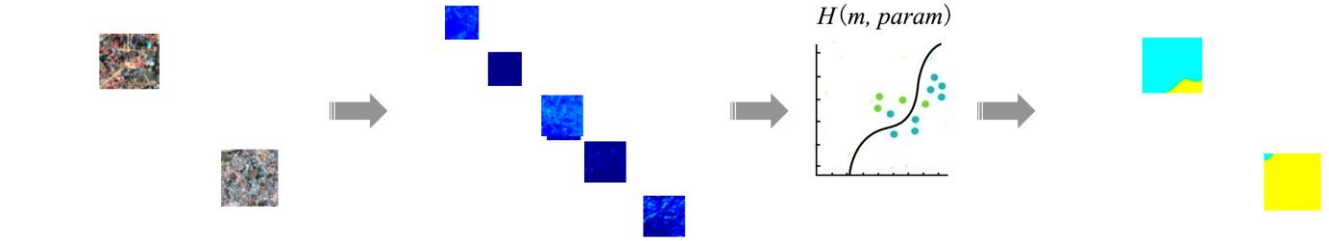
Conventional workflow

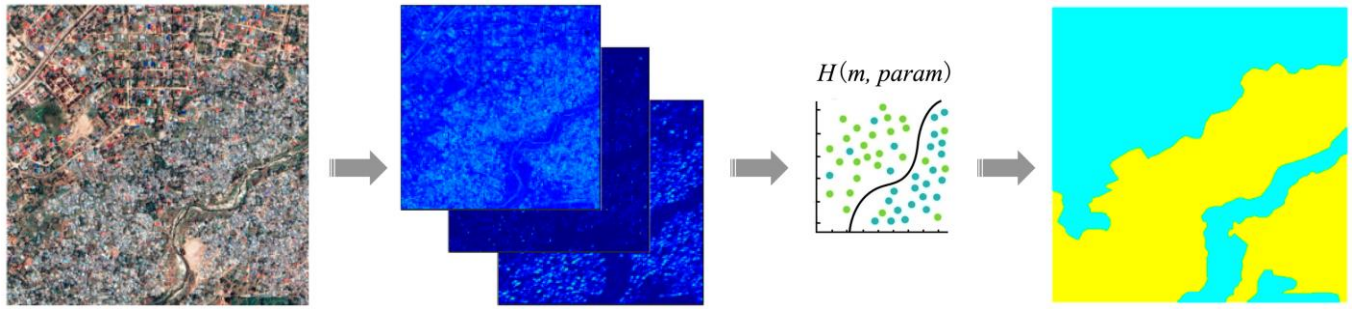
Scientific validity

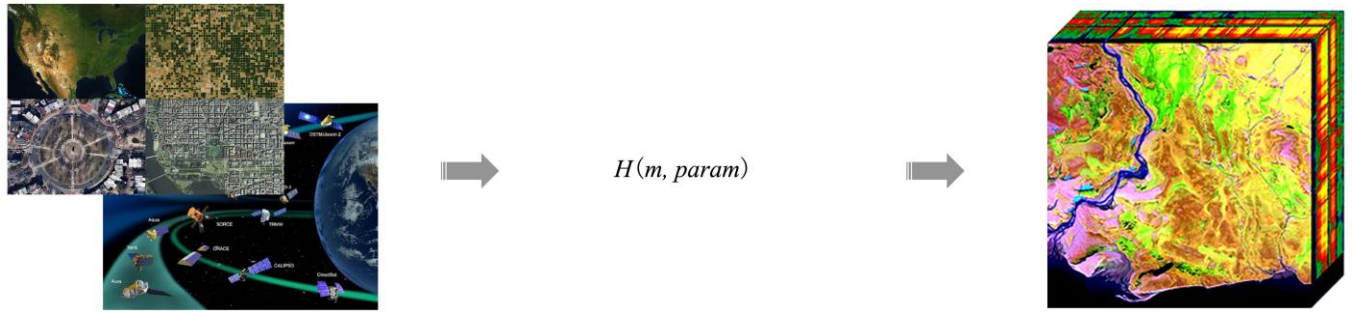
A shift in workflow

Study cases

Outlook







Deriving scientific knowledge from the workflow

Assumption

Conventional workflow

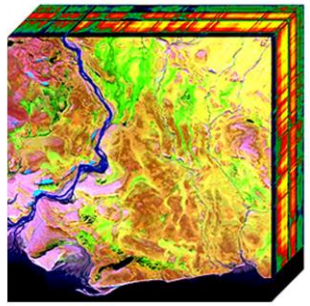
Scientific validity

A shift in workflow

Study cases

Outlook

$H(m, param)$



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Assumption

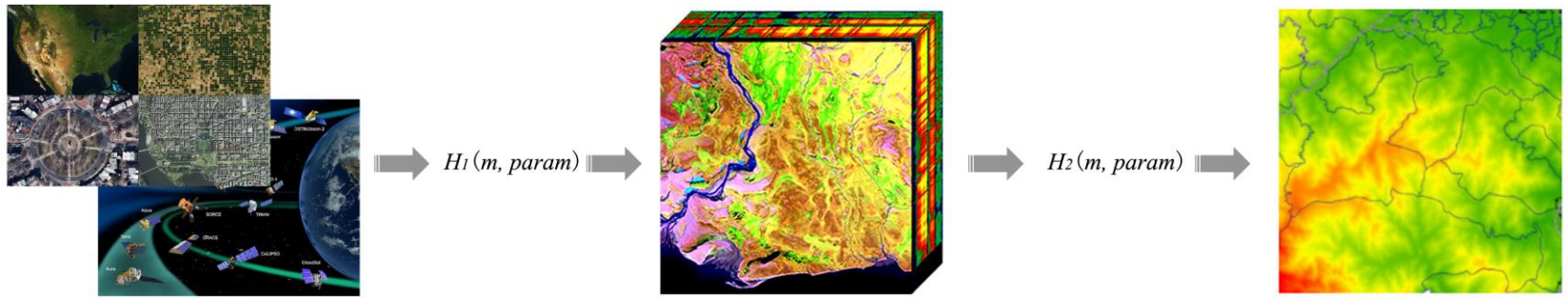
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



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Assumption

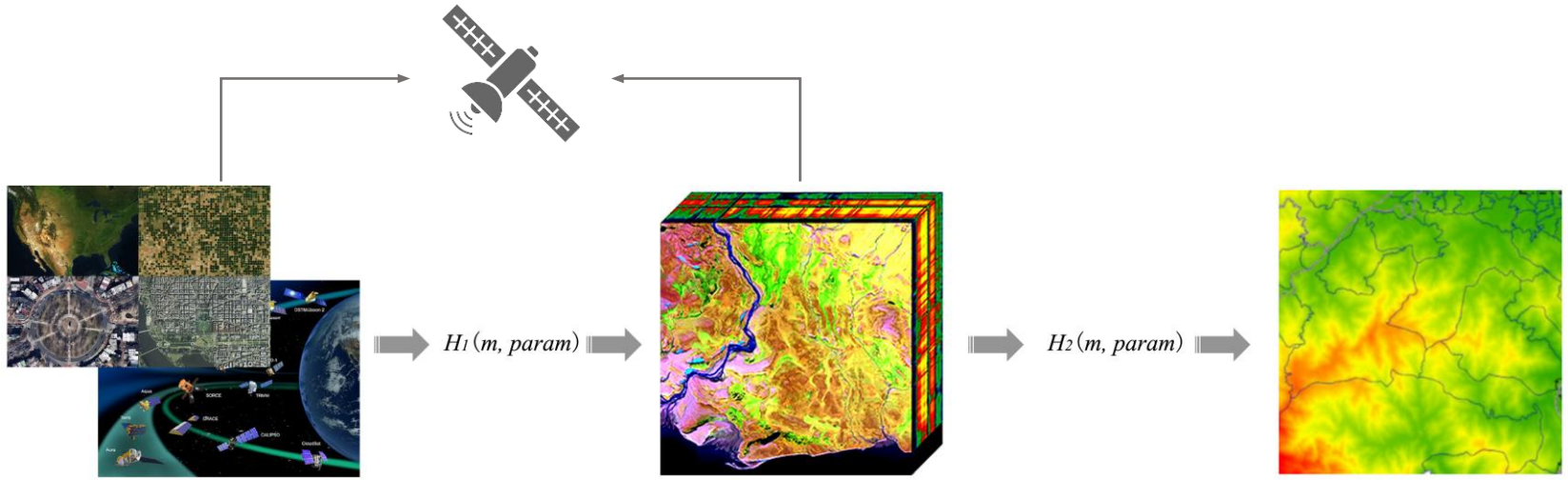
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



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Assumption

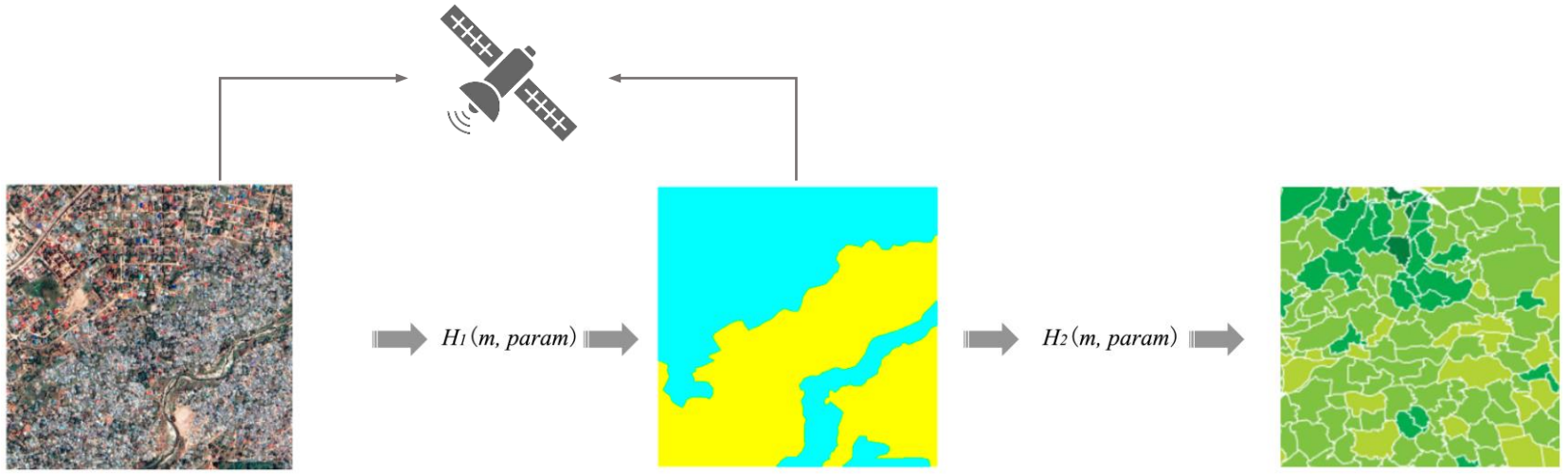
Conventional workflow

Scientific validity

A shift in workflow

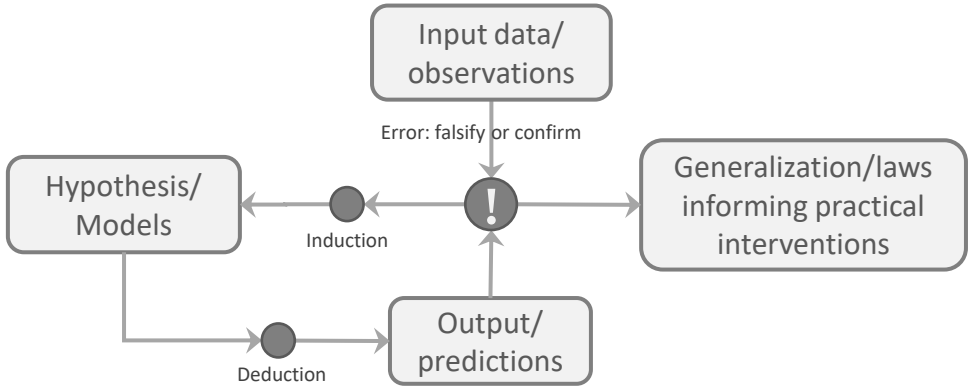
Study cases

Outlook

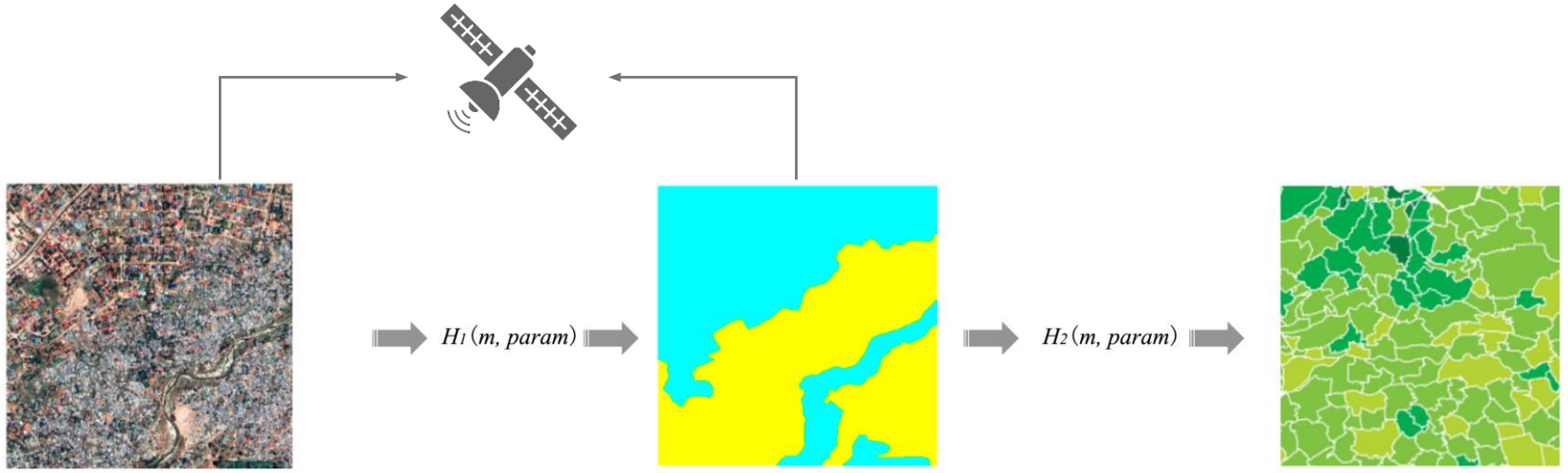


Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Deriving scientific knowledge from the workflow



Adapted from:
Box, G.E., 1976. Science and statistics. *Journal of the American Statistical Association*, *71*(356), pp.791-799.
Batty, M., 2017. Science in planning: theory, methods and models. *Planning Research and Knowledge*, pp.241-254.



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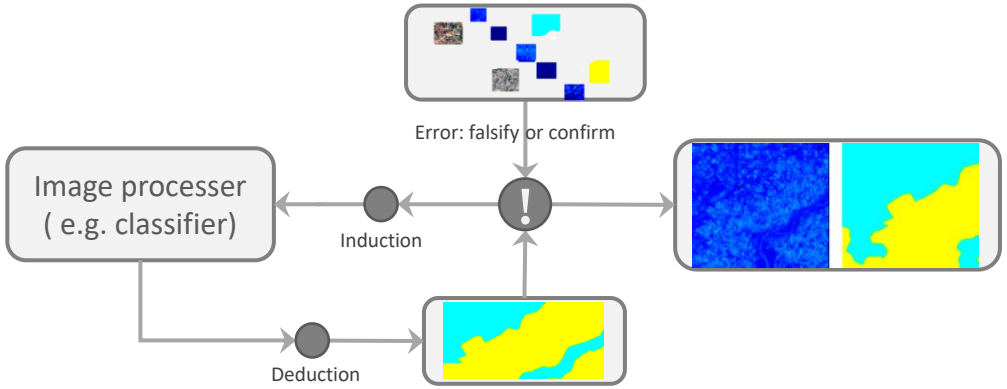
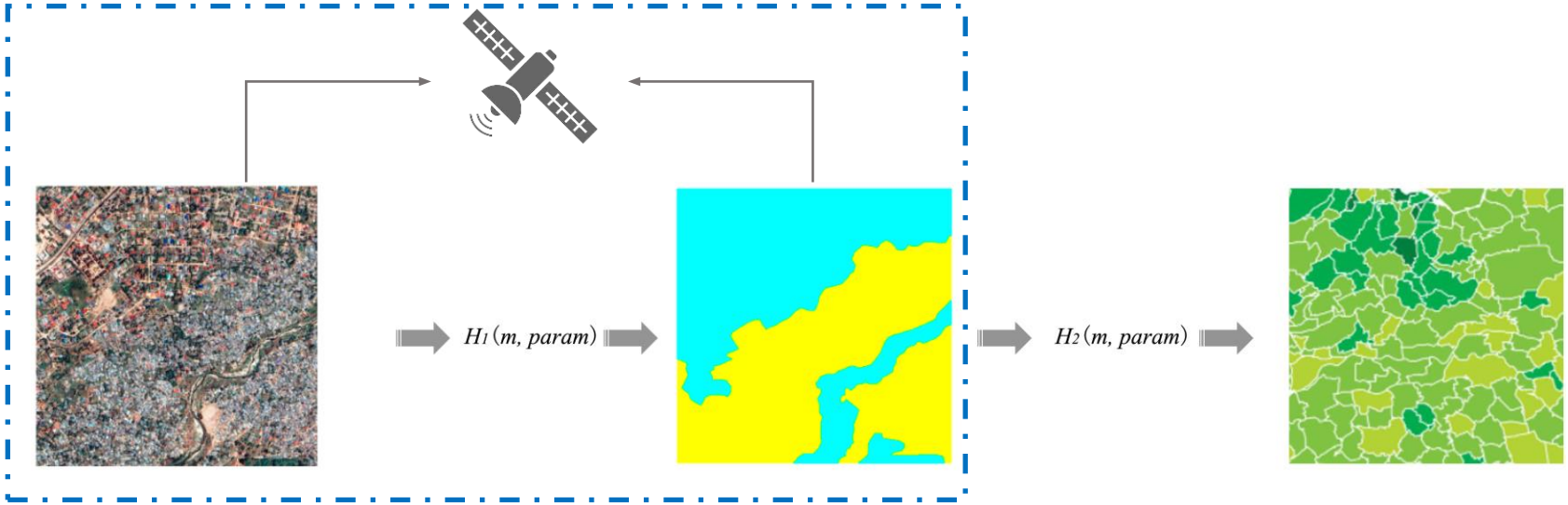
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Deriving scientific knowledge from the workflow

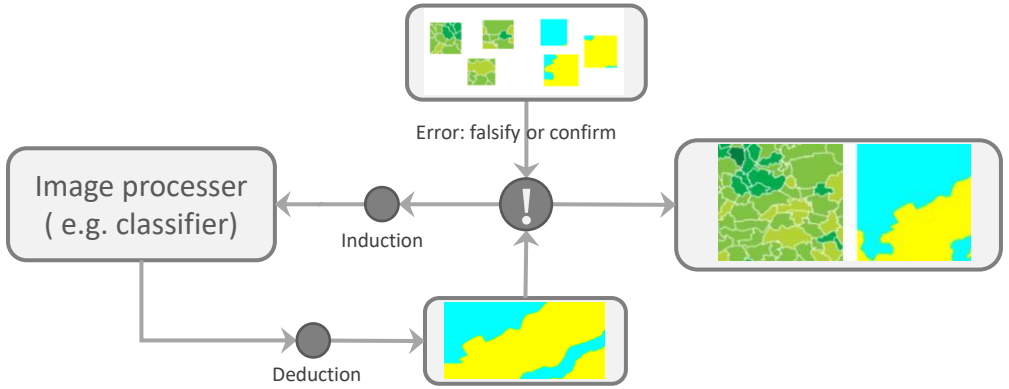


- Reduced interpretability.

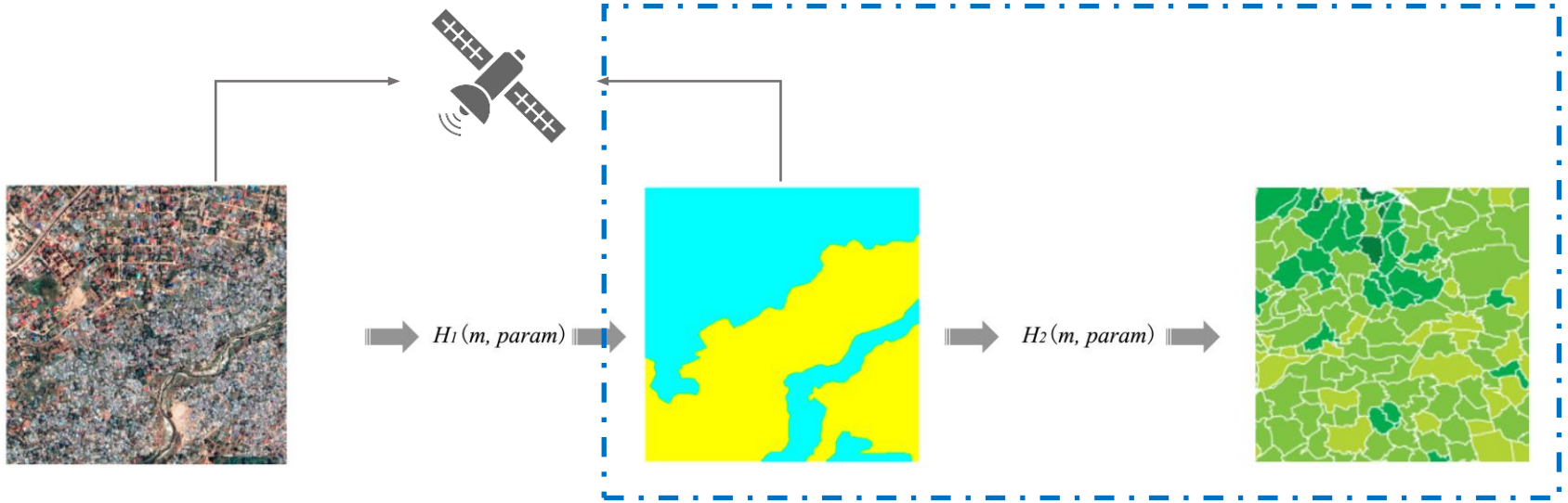


Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Deriving scientific knowledge from the workflow



- Interpretable knowledge about the real world.

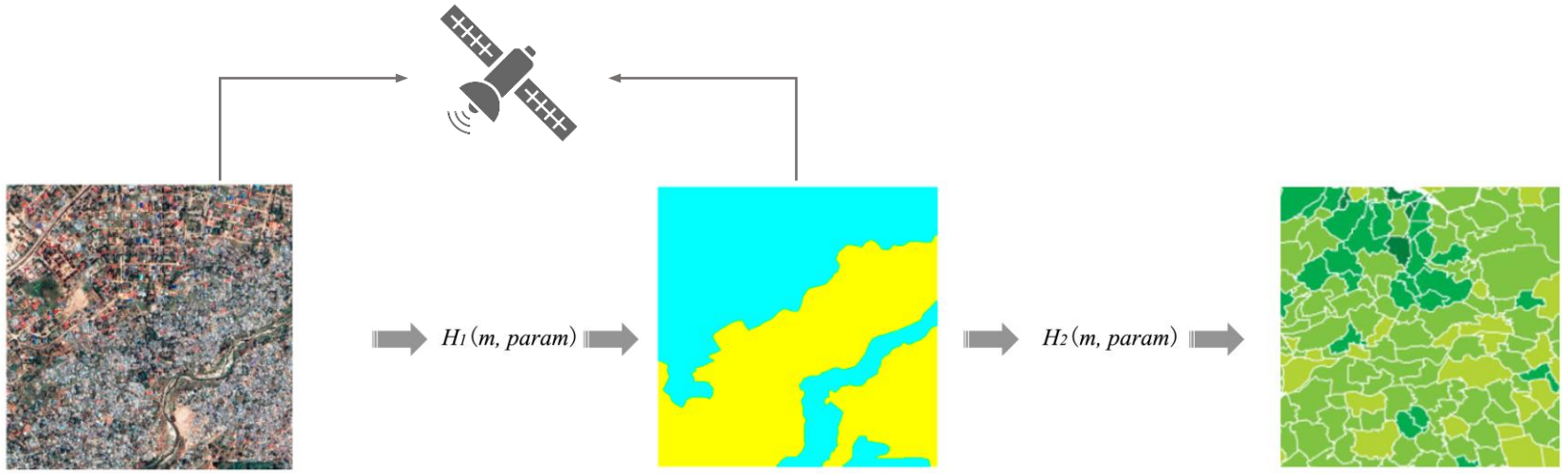


Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Deriving scientific knowledge from the workflow

Main causes:

- Ambition of directly mapping socioeconomic aspects of cities.
- Surge of data science/machine learning techniques.

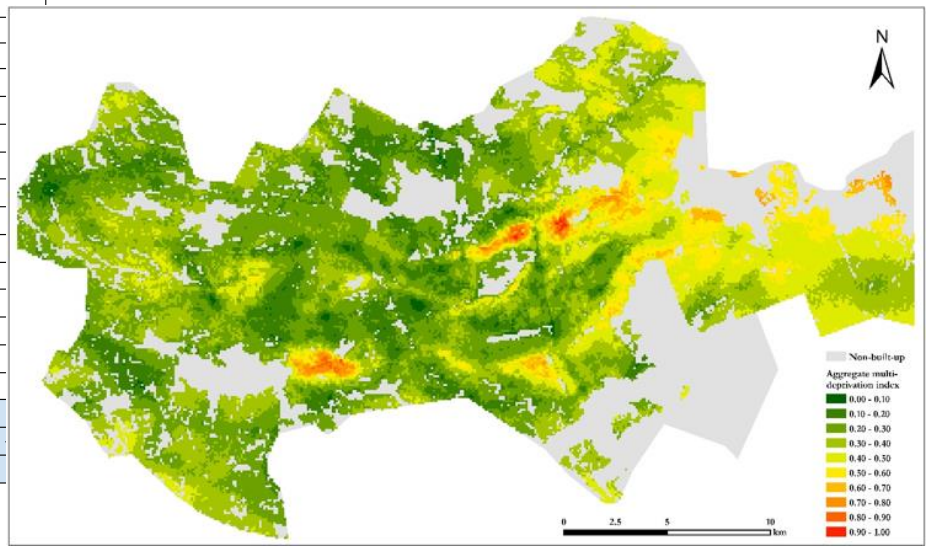


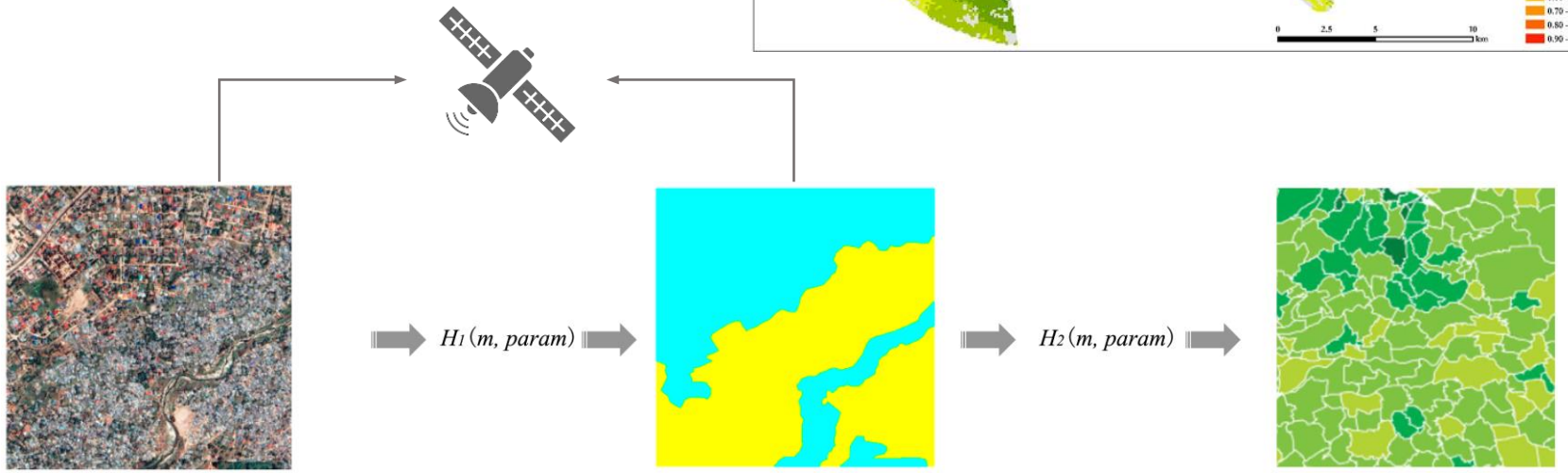
Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Deriving scientific knowledge from the workflow

- **Alternative:** Deprivation predicted/explained by interpretable indicators.

Component Name	Effect	Eigenvalue	% variance explained	Rotated Component Matrix			
				Dominant variables	Component loadings		
					PC1	PC2	PC3
Poverty, accessibility to facilities, and maternal health support	+	4.010	26.73	Estimated % of people living in poverty	**0.865**	-0.239	-0.064
				Distance to health facilities	**0.844**	-0.088	-0.277
				Distance to education facilities	**0.779**	-0.135	0.225
				Distance to financial facilities	**0.723**	-0.063	-0.399
				% of skilled birth attendance in delivery	**-0.709**	0.186	0.272
				Night-time light value	**-0.619**	0.346	0.309
Dense urbanization, absence of green space and waste management	+	2.651	17.67	Population density	-0.201	**0.800**	0.083
				Building density	-0.032	**0.794**	0.042
				Maximum NDVI value	0.118	**-0.653**	-0.396
				Density of illegal dumpsites	-0.192	**0.606**	0.145
Air and water contamination	+	1.599	10.66	Annual concentrations of pm 2.5	-0.165	0.160	**0.856**
				Density of waterways	-0.196	0.290	**0.466**
Transport infrastructure	+	1.311	8.74	Density of roads with poor quality	-0.231	0.348	-0.028
				Density of bus station	-0.385	0.336	-0.024
				Distance to OSM major roads	0.417	-0.030	-0.019





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Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

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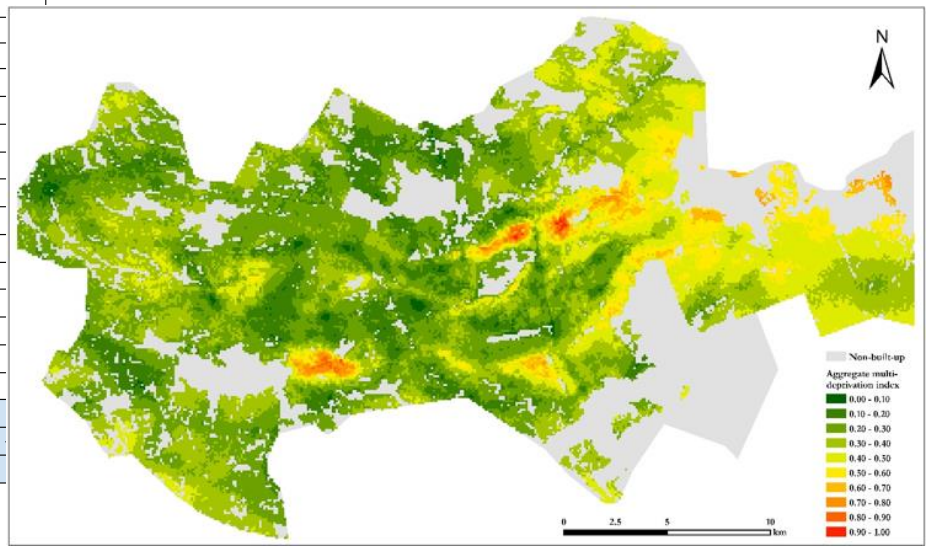
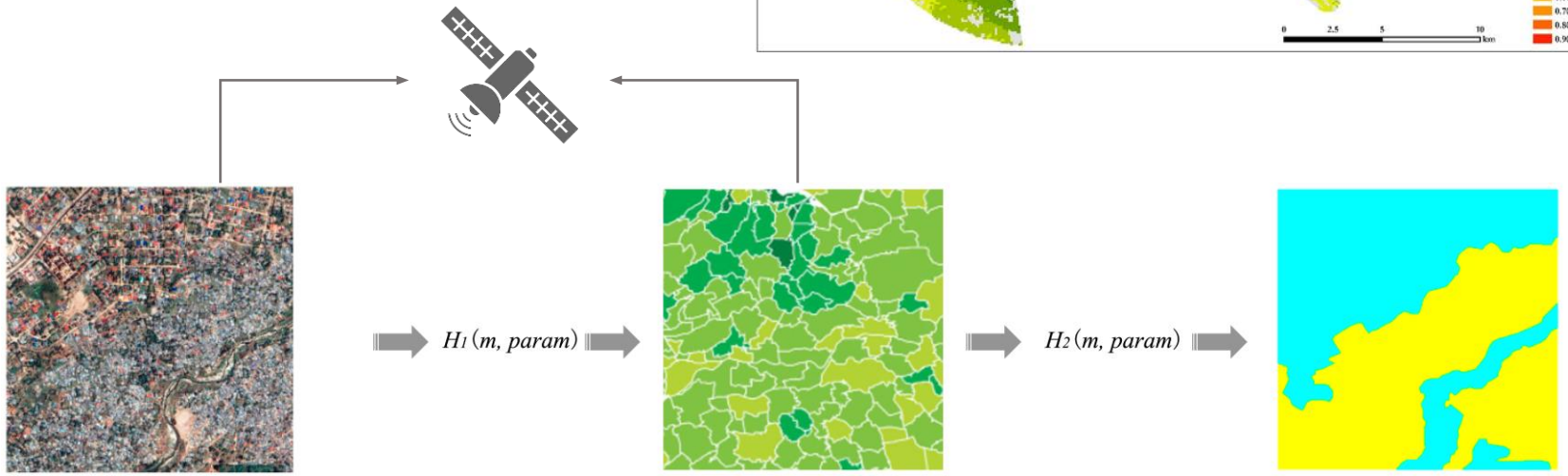
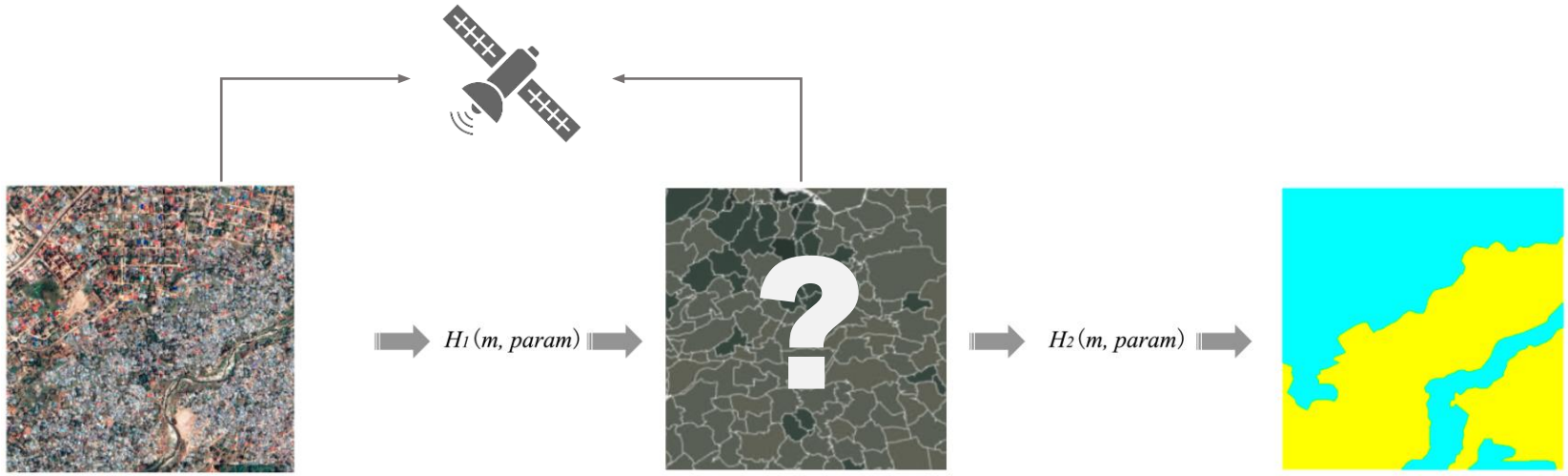




Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

A shift in the workflow

- Detection of interpretable indicators.



Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

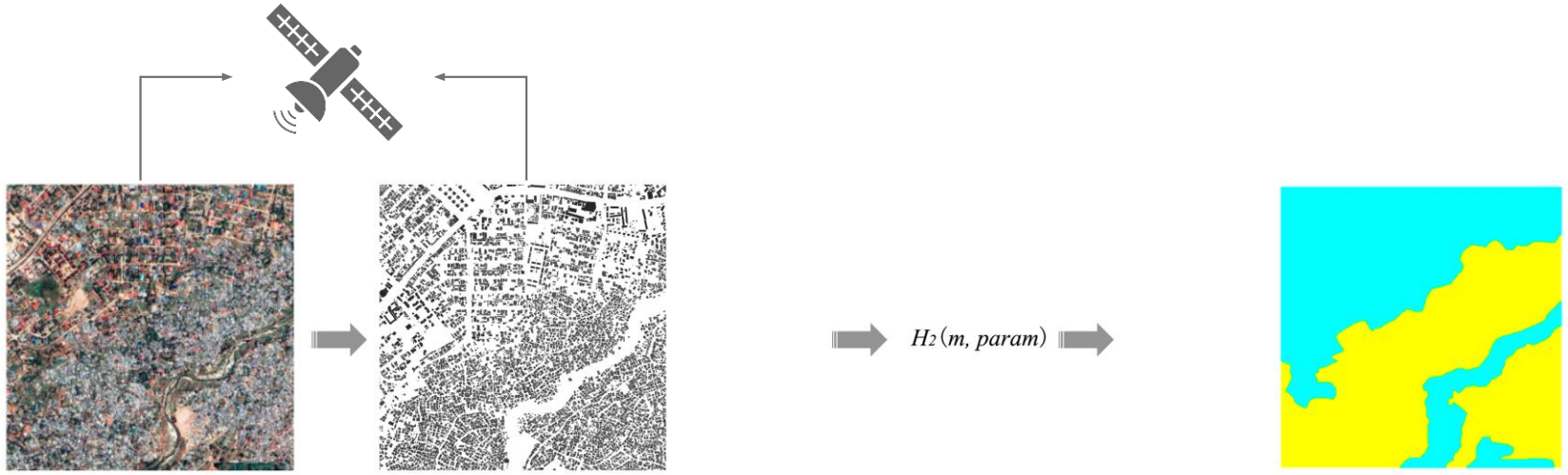
A shift in the workflow

- Detection of *interpretable* indicators.
- Minimize *un-interpretability*.

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

A shift in the workflow

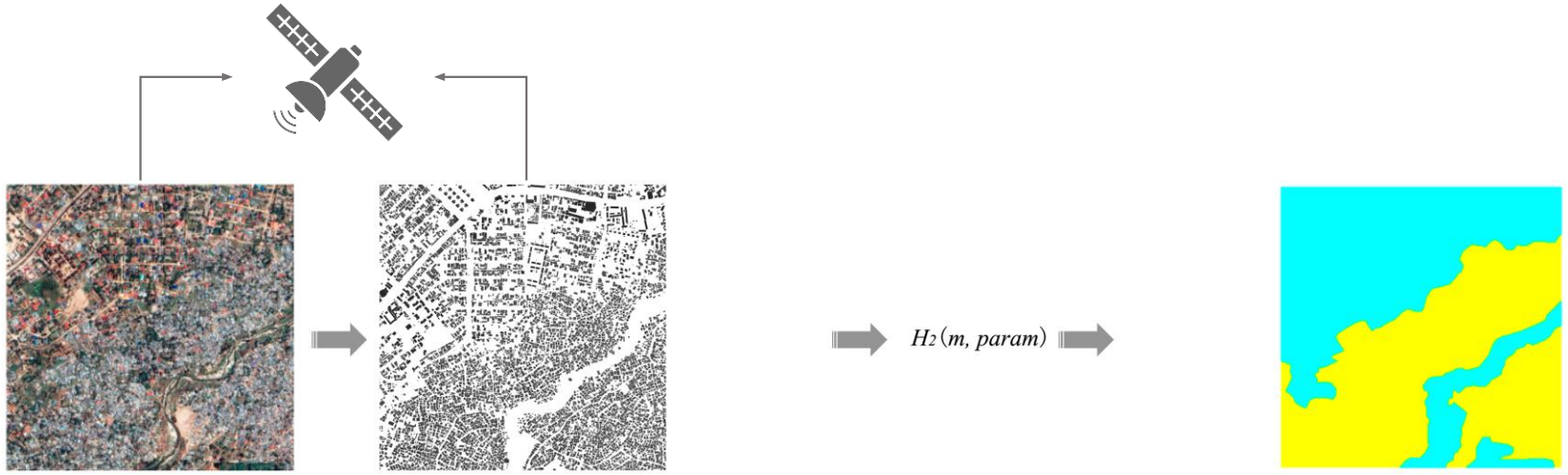
- Detection of basic physical elements.



Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

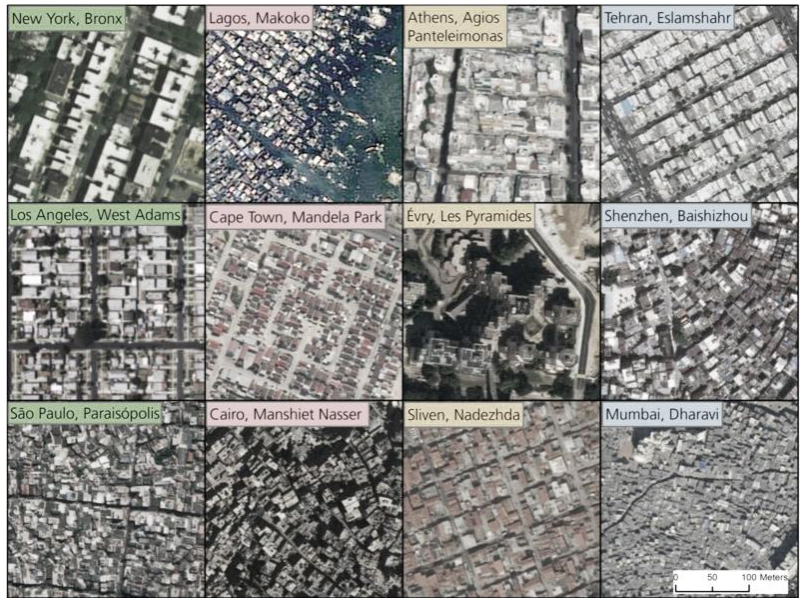
A link to morphological analysis: NOT new!

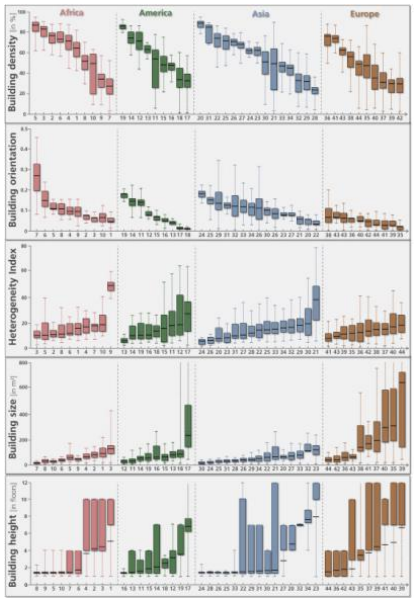
- Linking to existing theories: The study of ***urban morphology*** that is based on the analysis of space, traditionally mostly visual (Dibble et al., 2015). It explores the physical form of cities in space and the way it changes in time in relation to the agents of such change (Kropf, 2017). Its objects are the fundamental elements of urban form (building, plot, street) (Moudon, 1997).
- Less ambitious: Stick to the nature of remote sensing.



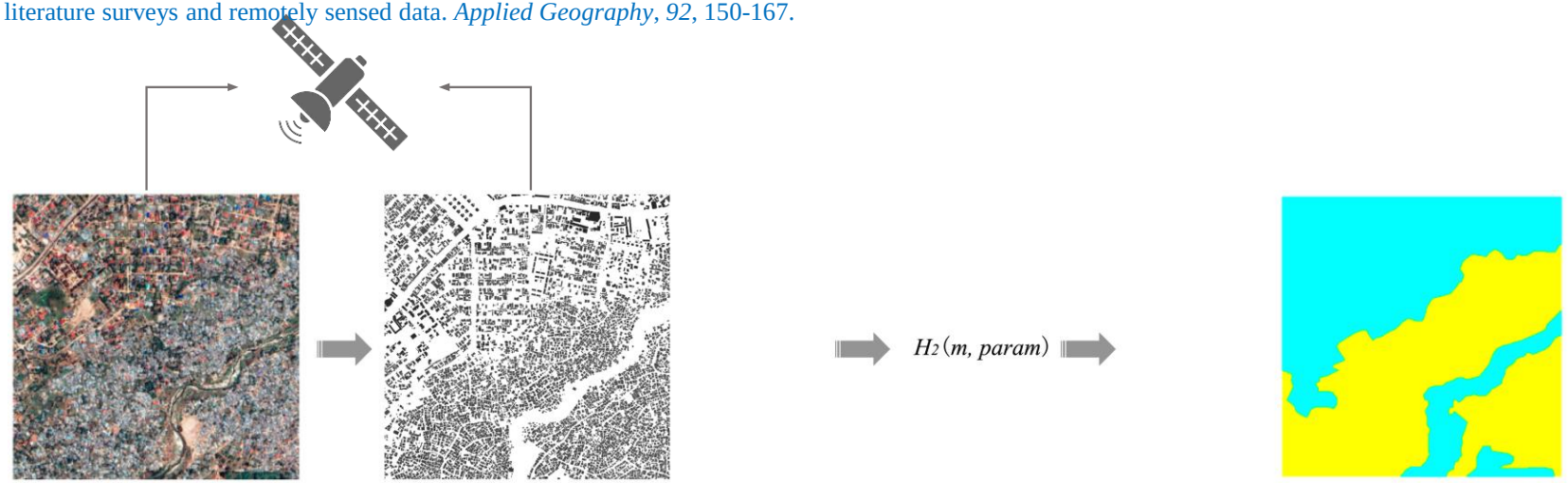
Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

A link to morphological analysis: NOT new!



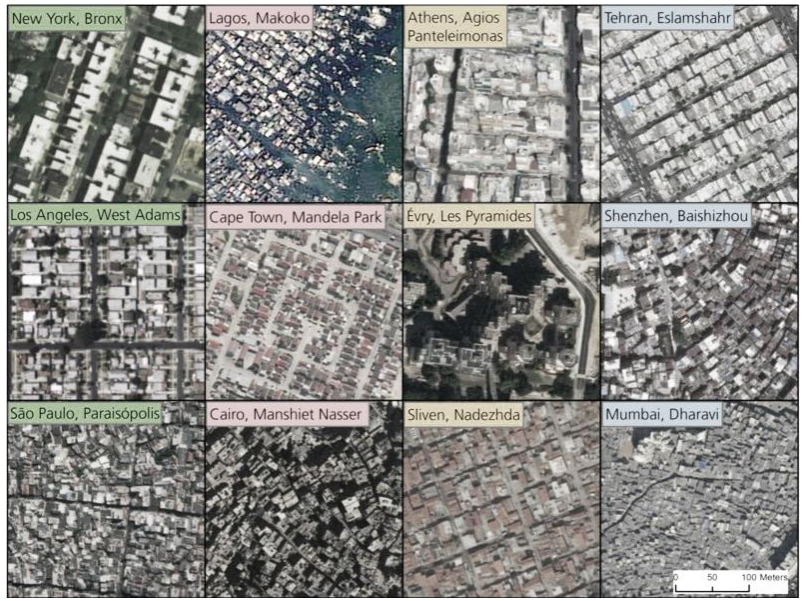


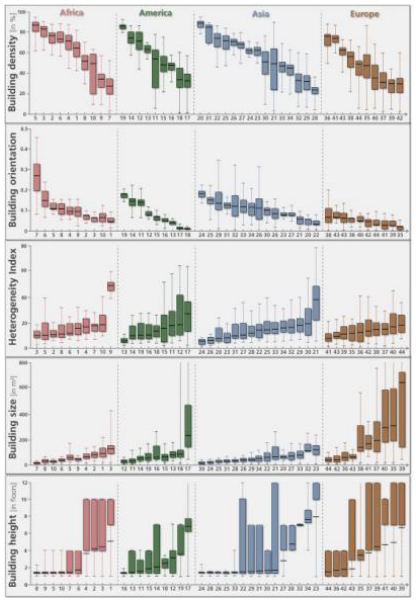
Taubenböck, H., Kraff, N. J., & Wurm, M. (2018). The morphology of the Arrival City-A global categorization based on literature surveys and remotely sensed data. *Applied Geography*, *92*, 150-167.



Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

A link to morphological analysis: NOT new!





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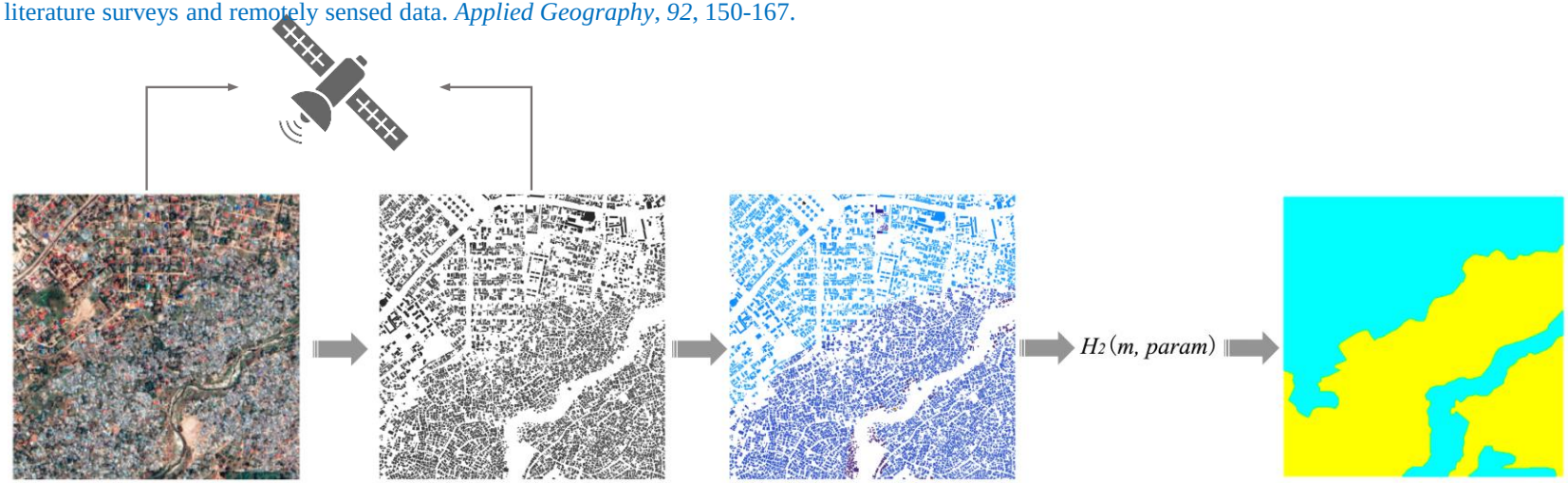
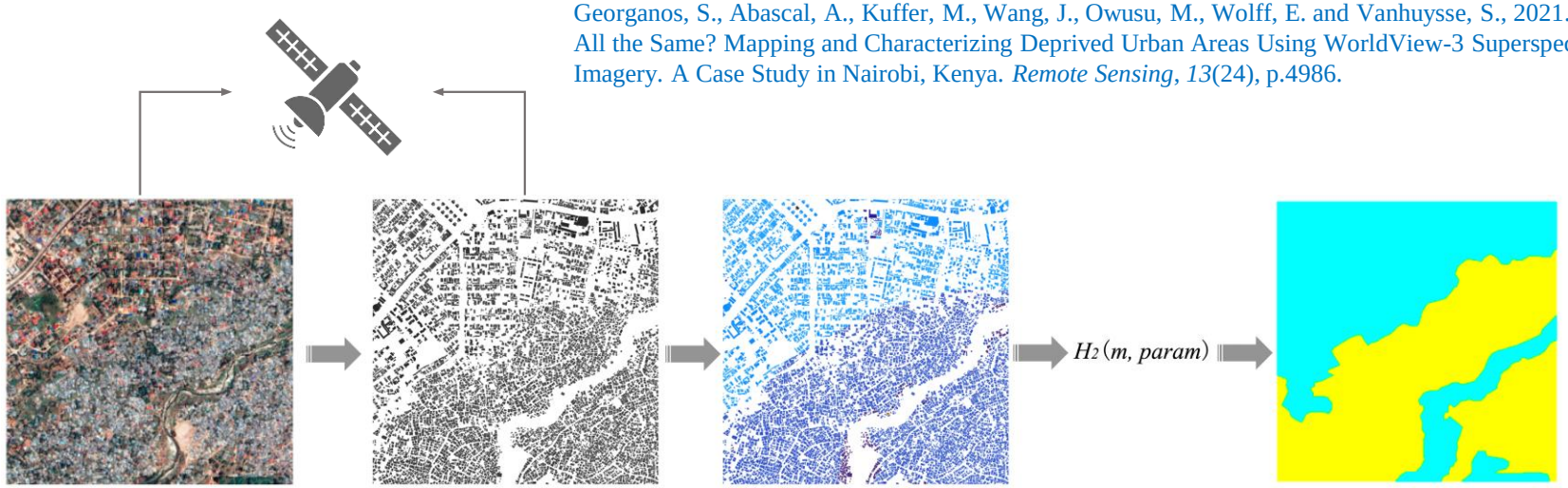


Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

A link to morphological analysis: NOT new!

Georganos, S., Abascal, A., Kuffer, M., Wang, J., Owusu, M., Wolff, E. and Vanhuysse, S., 2021. Is It All the Same? Mapping and Characterizing Deprived Urban Areas Using WorldView-3 Superspectral Imagery. A Case Study in Nairobi, Kenya. *Remote Sensing*, *13*(24), p.4986.



Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Challenges: Detection of basic urban elements

Challenges: Detection of basic urban elements

Assumption

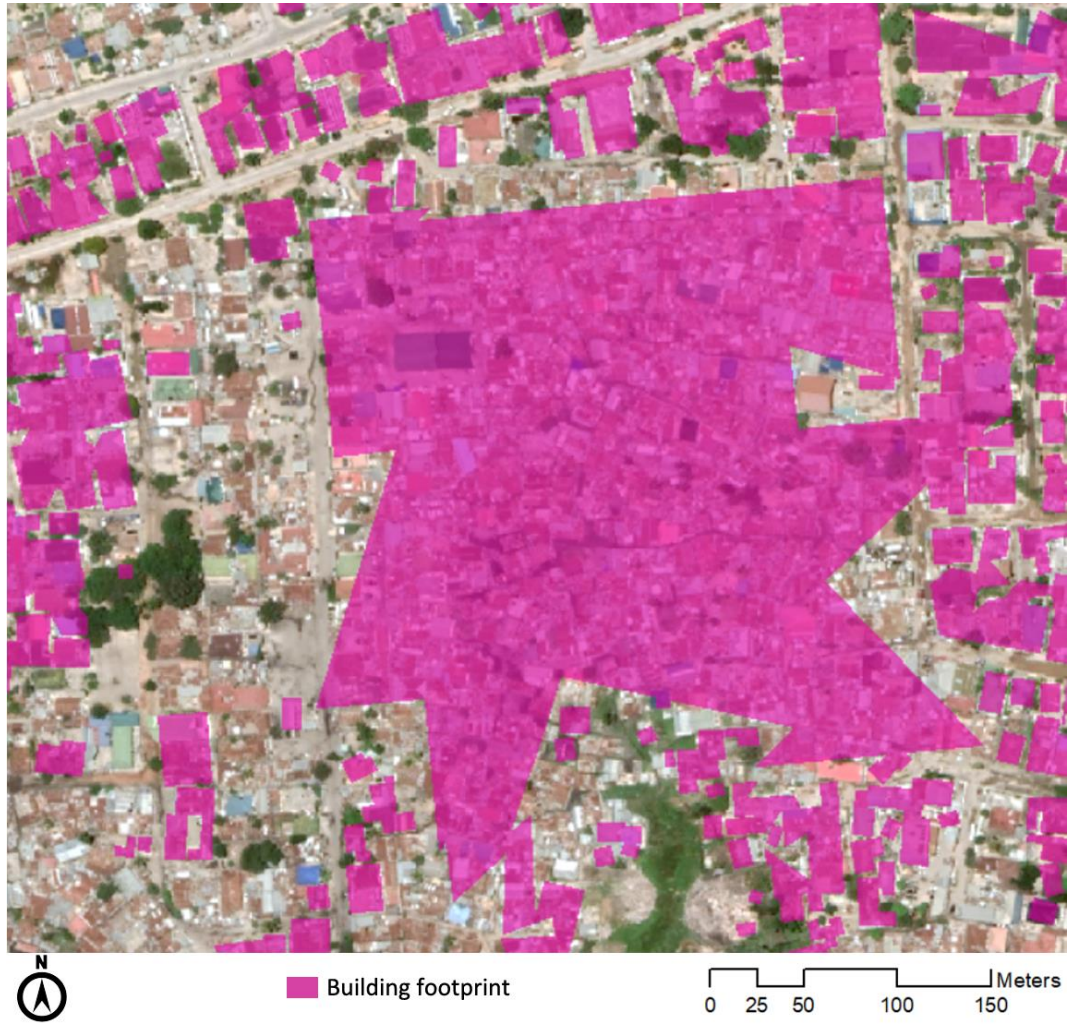
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



Challenges: Detection of basic urban elements

Assumption

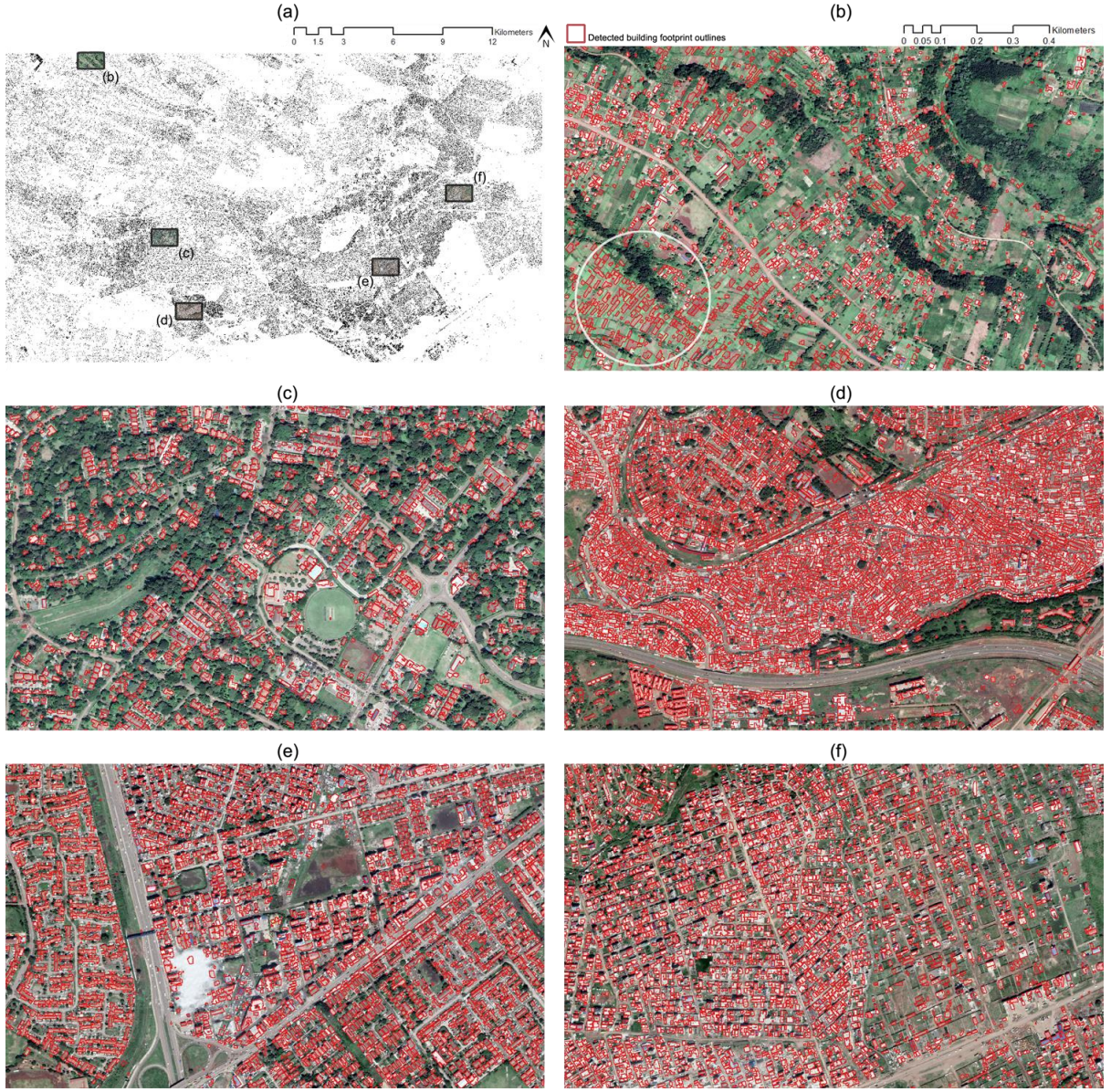
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



Challenges: Measuring of basic urban elements

Assumption

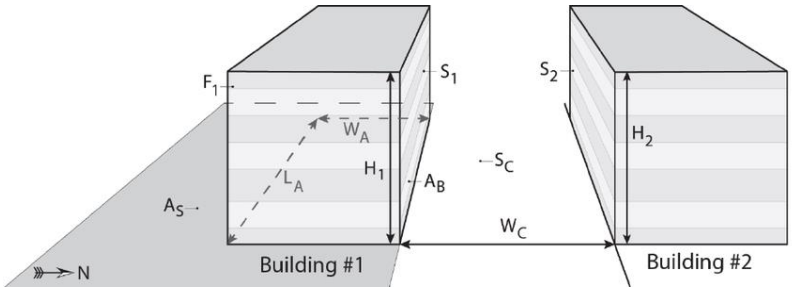
Conventional workflow

Scientific validity

A shift in workflow

Study cases

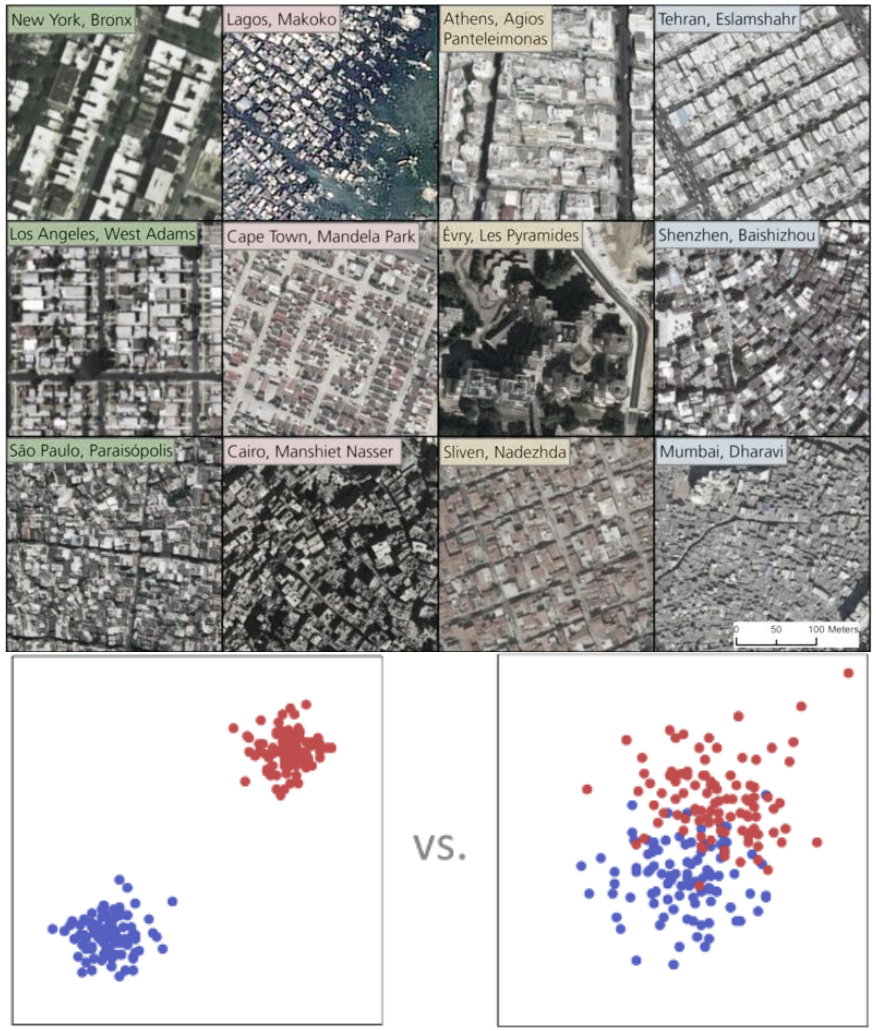
Outlook

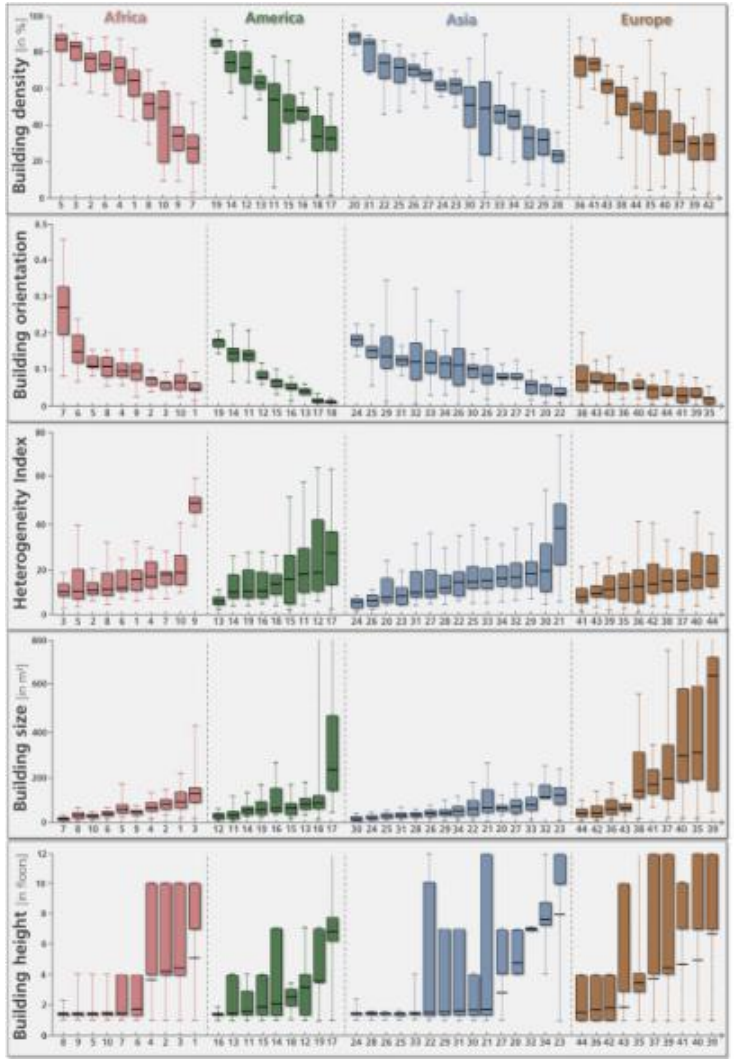


Category	Variable
Building Characteristics	Site Plan Area (A_S)
	Building Footprint Area (A_B)
	*Building Height (H_1)
	Building Plan Area Ratio (A_B/A_S)
	Frontal Area Index (S_1/A_S & F_1/A_S)
	Complete Aspect Ratio (L_A/W_A)
Street Canyon	*Building Height #2 (H_2)
	Height-to-Width Ratio
	*Street Canyon Width (W_C)
	*Street Canyon Orientation
	Surface Albedo (Paving[1])

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Challenges: Measuring of basic urban elements





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Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Study cases: Nairobi, Kenya

- 60-70% of urban population in the city lives in deprivation since 2014.

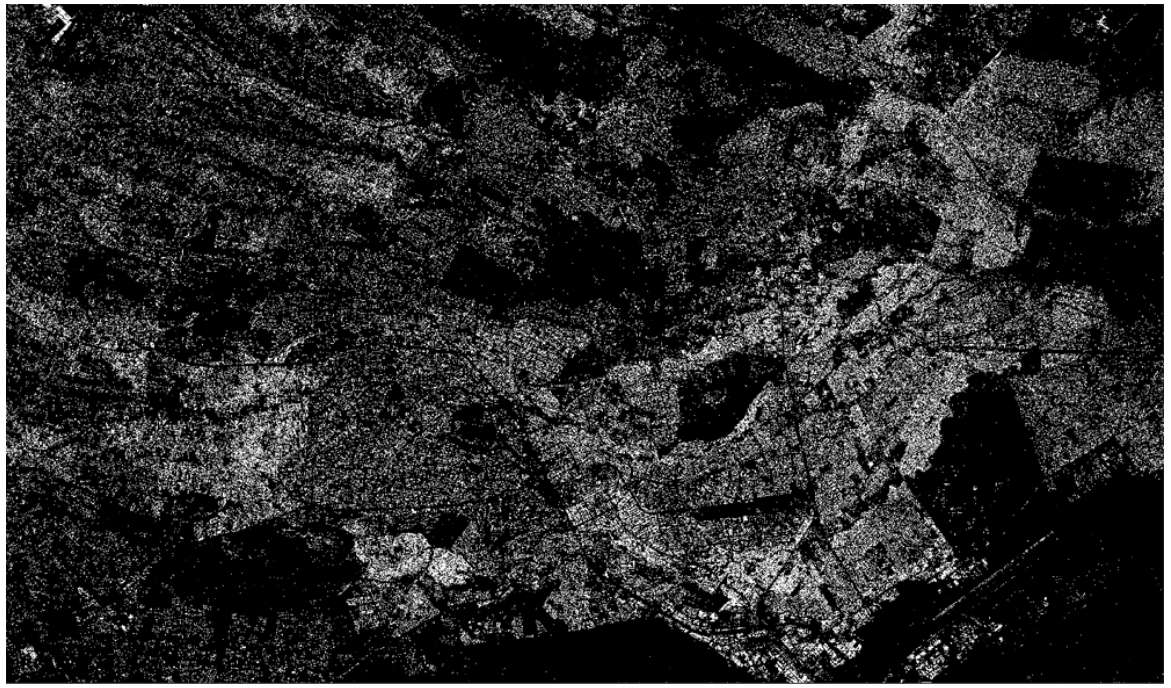
Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Study cases: Nairobi, Kenya

- 60-70% of urban population in the city lives in deprivation since 2014.

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

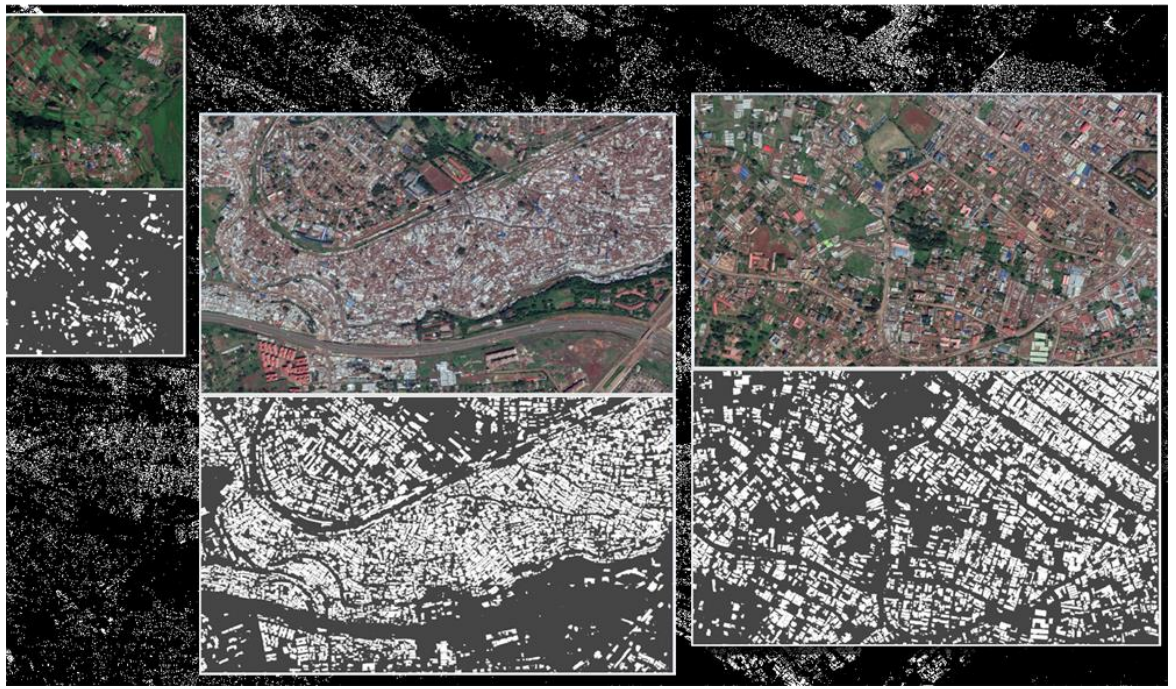
Study cases: Nairobi, Kenya



- 60-70% of urban population in the city lives in deprivation since 2014.

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Study cases: Nairobi, Kenya



Assumption
Conventional workflow
Scientific validity
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Study cases
Outlook

Study cases: Nairobi, Kenya

index	element	context
area	building	building
perimeter	building	building
circular compactness	building	building
corners	building	building
squareness	building	building
equivalent rectangular index	building	building
elongation	building	building
centroid - corner distance deviation	building	building
centroid - corner mean distance	building	building
solar orientation	building	building
cell alignment	building	building
longest axis length	tessellation cell	tessellation cell
area	tessellation cell	tessellation cell
circular compactness	tessellation cell	tessellation cell
equivalent rectangular index	tessellation cell	tessellation cell
solar orientation	tessellation cell	tessellation cell
coverage area ratio	tessellation cell	tessellation cell
alignment	neighbouring buildings	neighbouring cells
mean distance	neighbouring buildings	neighbouring cells
weighted neighbours	tessellation cell	neighbouring cells
area covered	neighbouring cells	neighbouring cells
mean inter-building distance	neighbouring buildings	cell queen neighbours 3
building adjacency	neighbouring buildings	cell queen neighbours 3

Study cases: Nairobi, Kenya

Assumption

Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook

- One of the measurements: Building orientation/alignment.

Assumption
Conventional workflow
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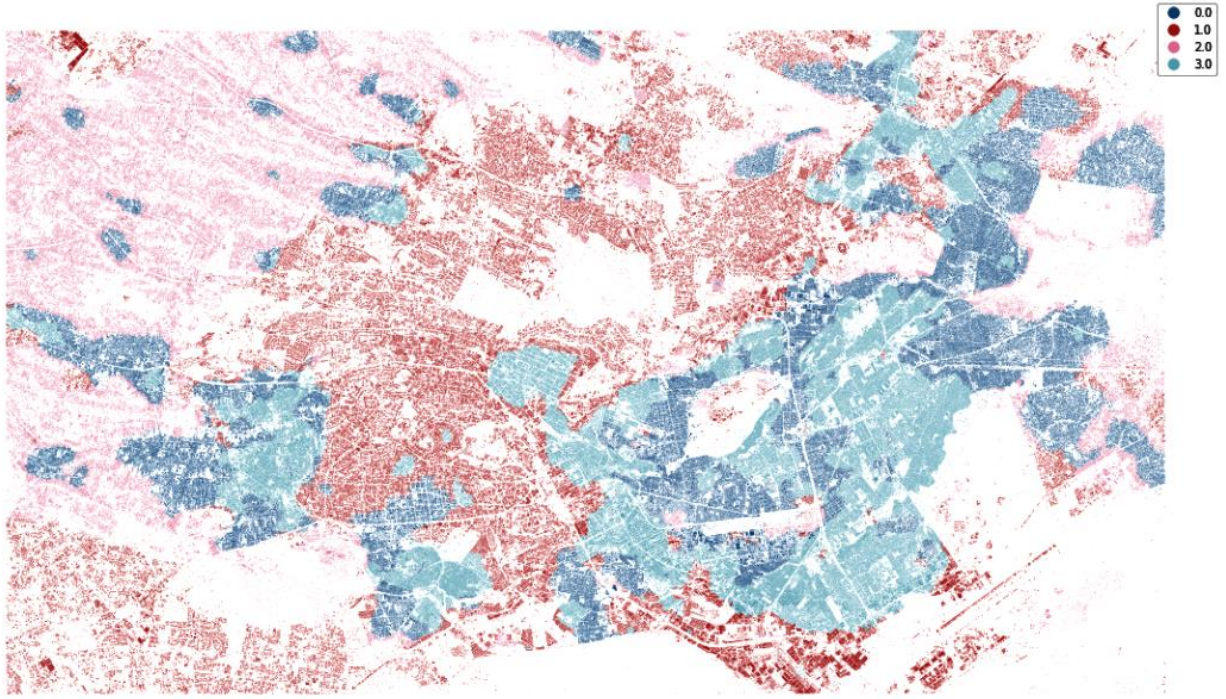
A shift in workflow
Study cases
Outlook

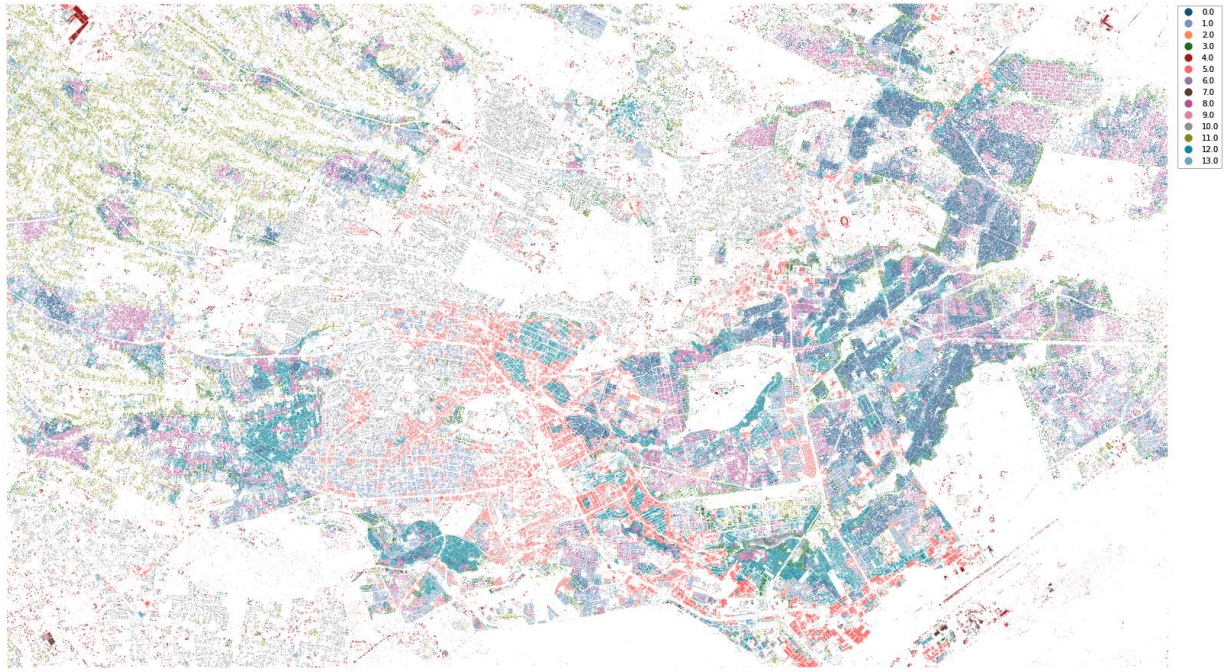
Study cases: Nairobi, Kenya



- Building clusters as morphological types.

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Study cases: Nairobi, Kenya



- Building clusters as morphological types.

Study cases: Nairobi, Kenya

Assumption
Conventional workflow
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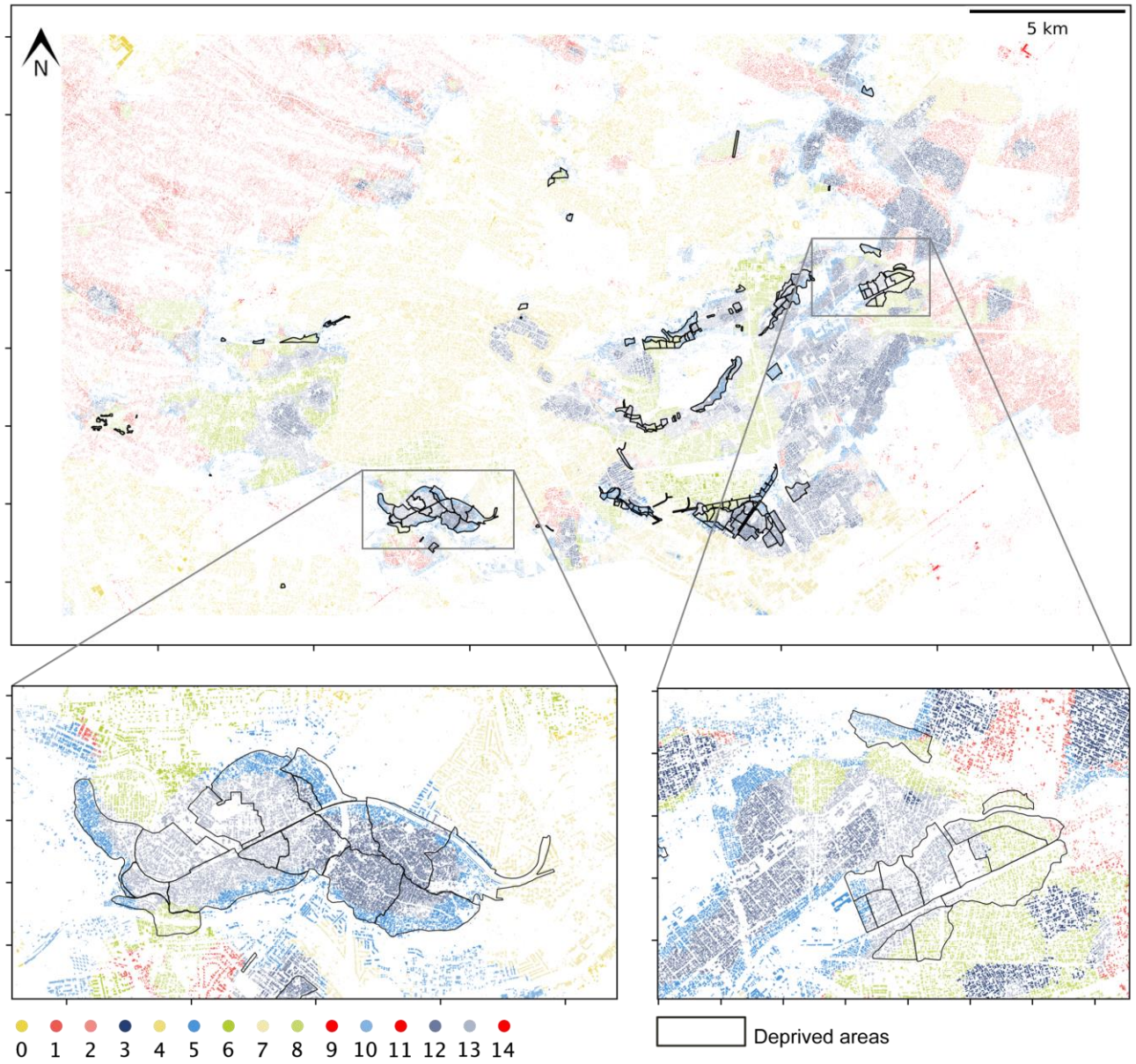
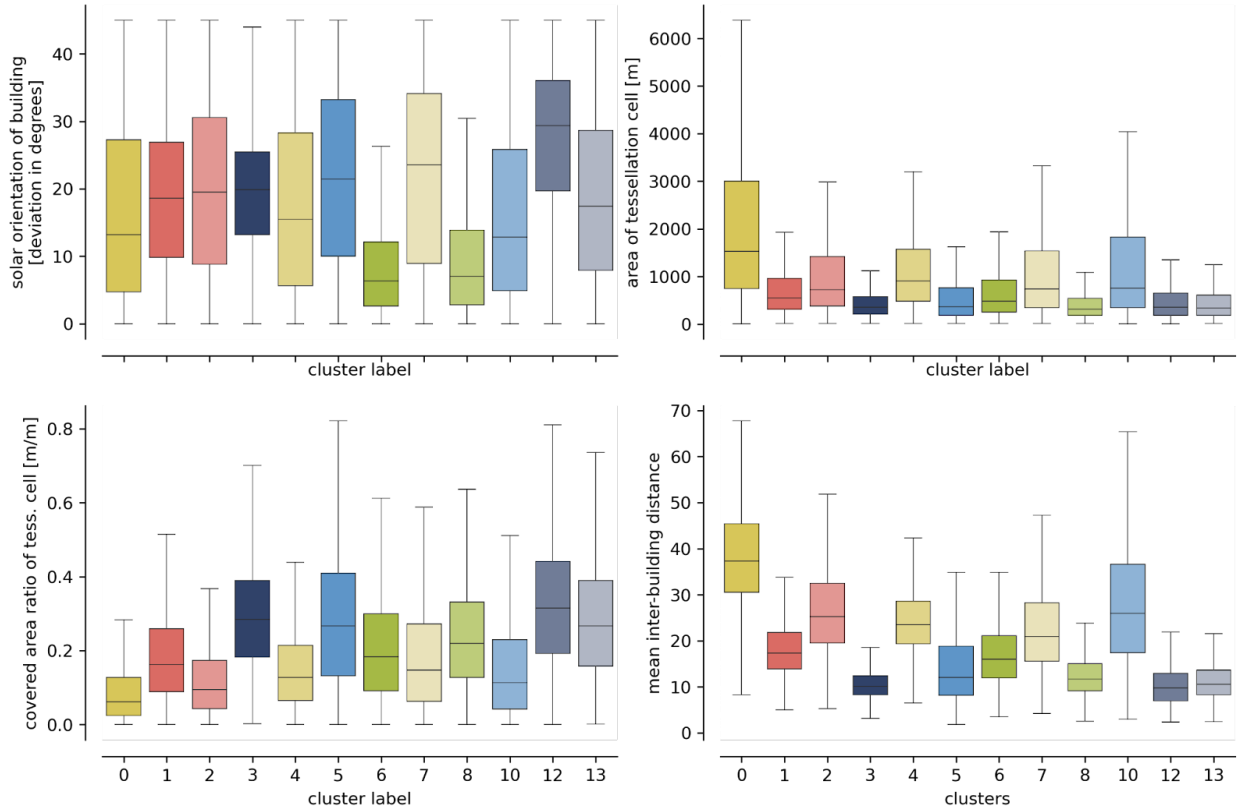
Study cases
Outlook



- How deprived/poor neighbourhoods are dominated by certain types of buildings? How similar types are also occupied by other neighbourhoods?

Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

Study cases: Nairobi, Kenya



- Detailed interpretation of morphological types.

Study cases: More African cities

Assumption

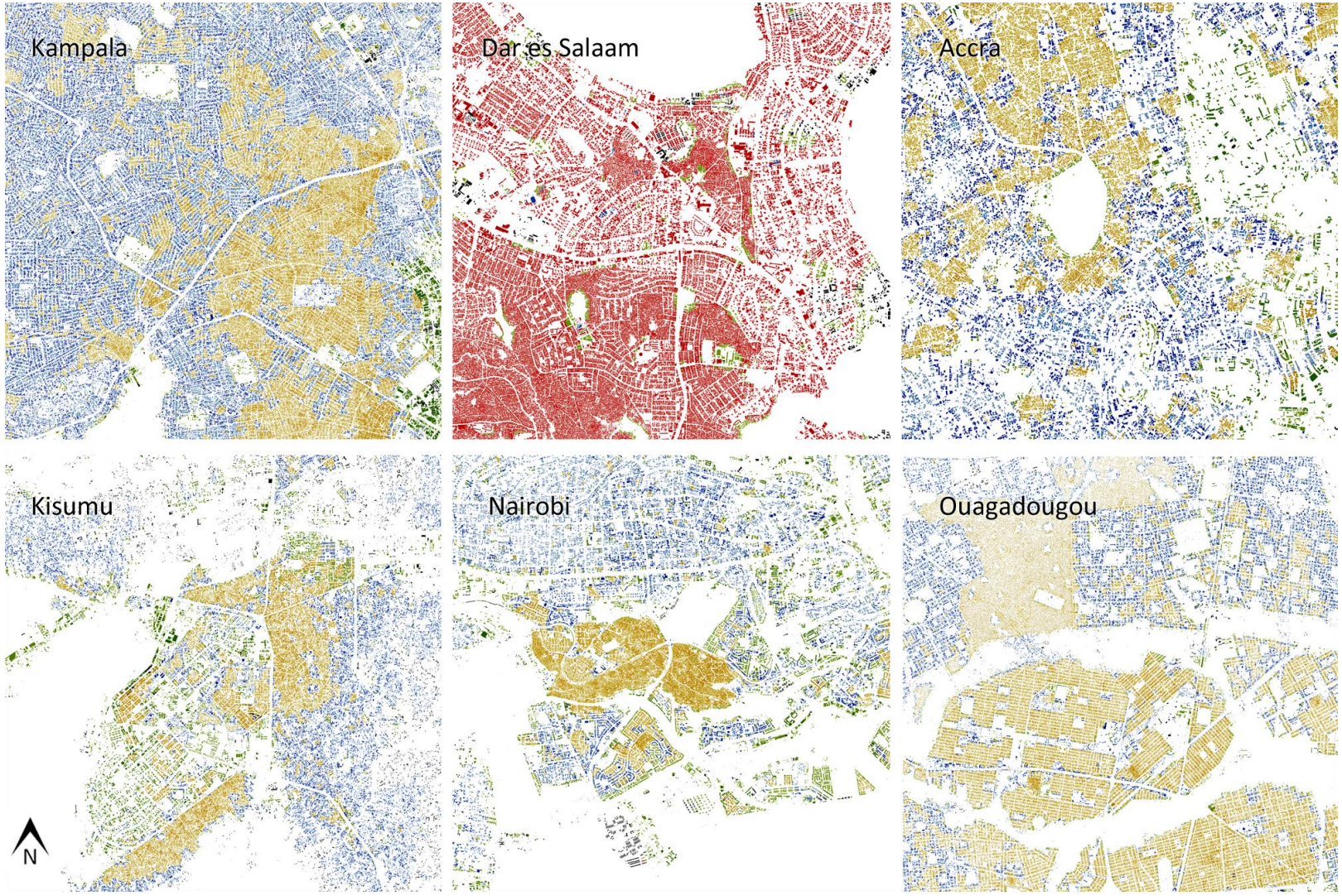
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



Assumption
Conventional workflow
Scientific validity
A shift in workflow
Study cases
Outlook

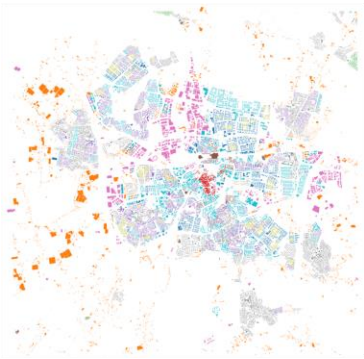
Study cases: Also cities from Global North

Amsterdam

Utrecht

Eindhoven

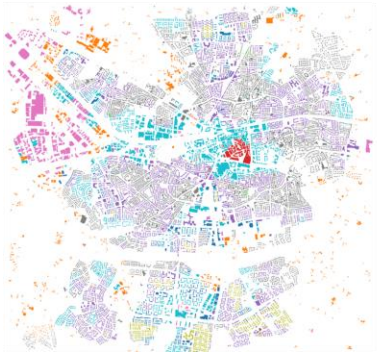
Breda



Rotterdam

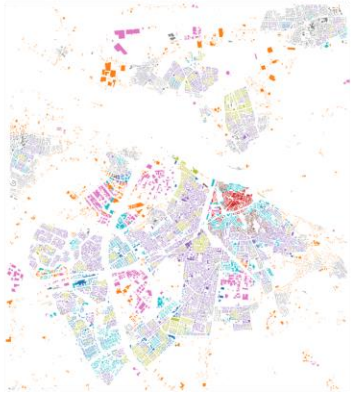
Den Haag

Enschede



Groningen

Nijmegen



Study cases: Other things to detect and measure?

Assumption

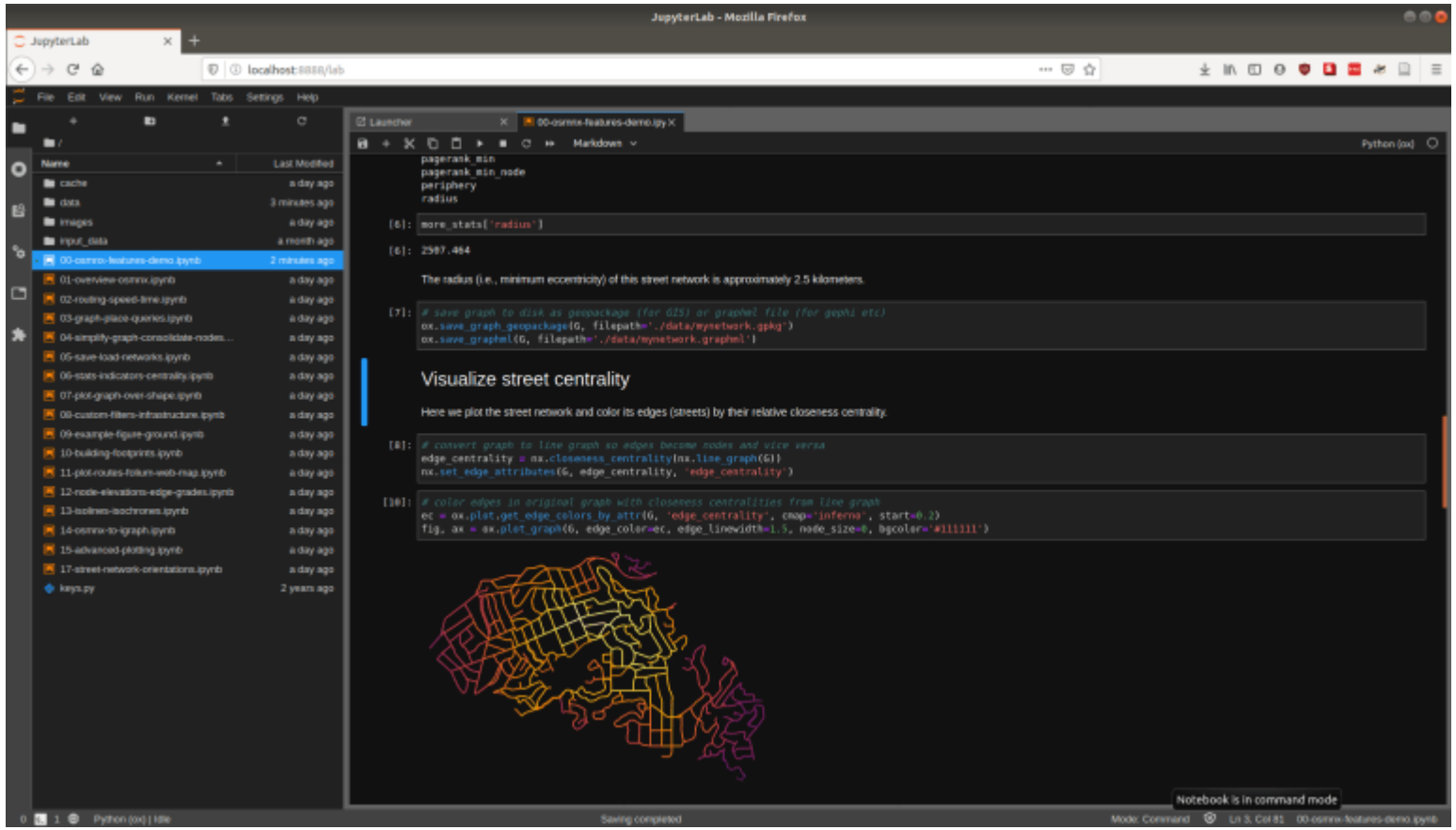
Conventional workflow

Scientific validity

A shift in workflow

Study cases

Outlook



https://geoffboeing.com/

Open science: Physical manifestation of urban dynamics

Assumption

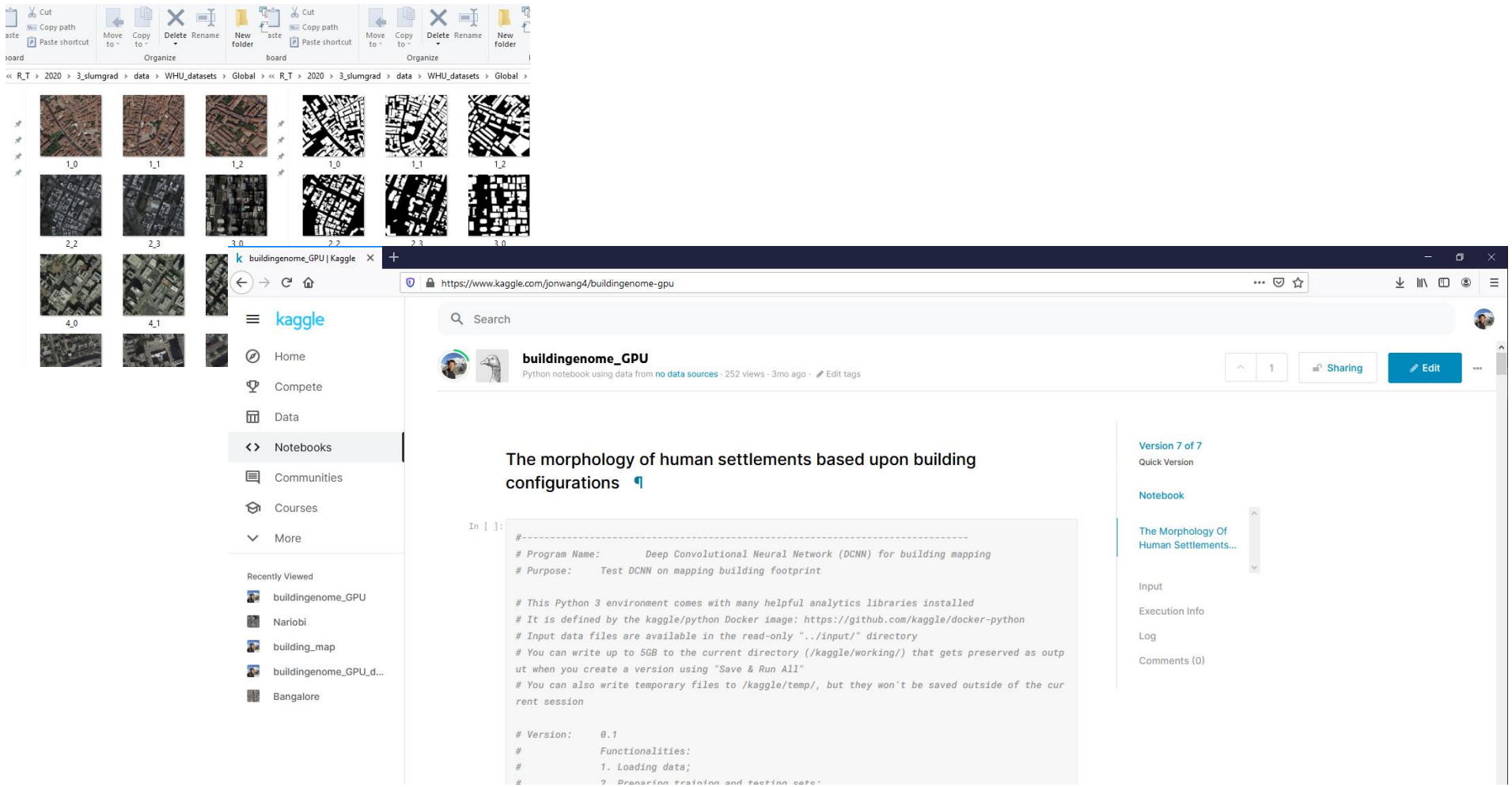
Conventional workflow

Scientific validity

A shift in workflow

Study cases

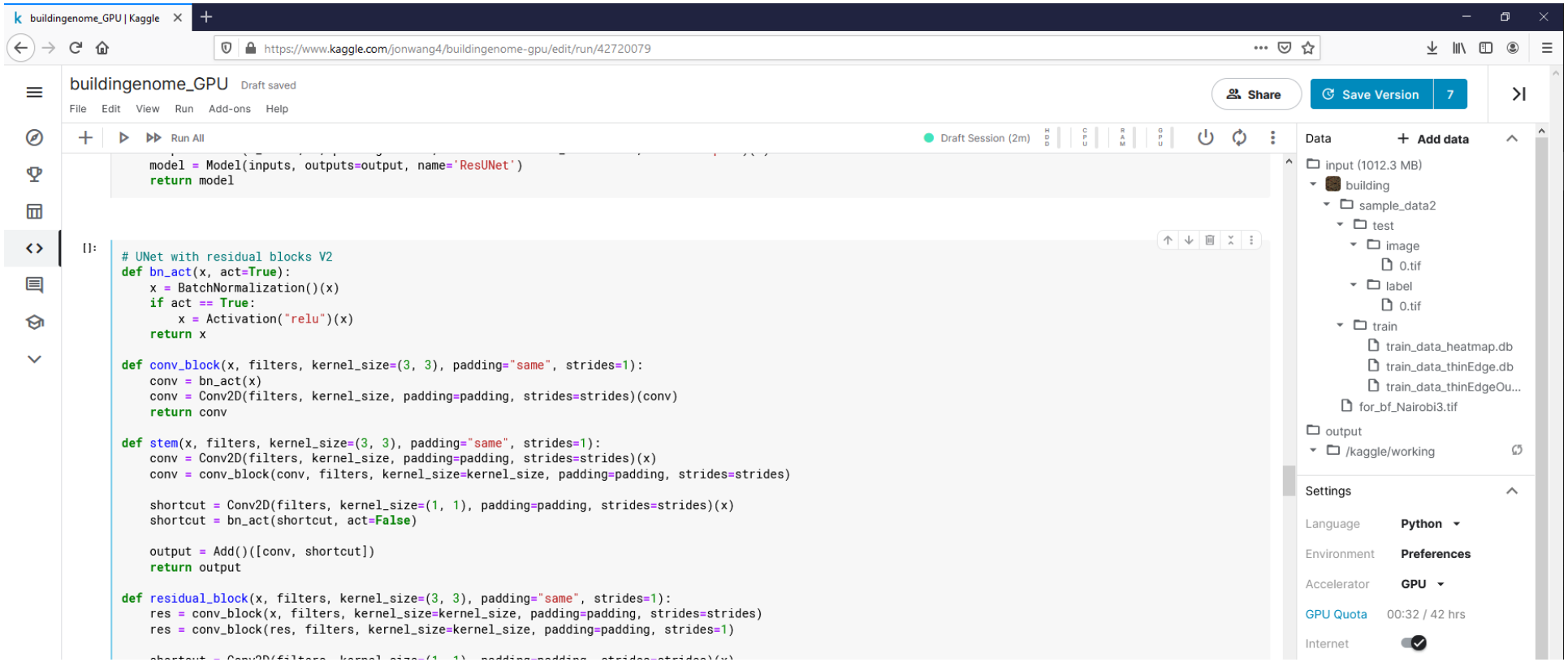
Outlook



https://www.kaggle.com/jonwang4/buildingenome

Open science: Physical manifestation of urban dynamics

- Assumption
- Conventional workflow
- Scientific validity
- A shift in workflow
- Study cases
- **Outlook**



https://www.kaggle.com/jonwang4/buildingenome

Open science: Physical manifestation of urban dynamics

Assumption

Conventional workflow

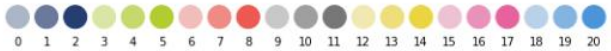
Scientific validity

A shift in workflow

Study cases

Outlook


```
    ax.set_axis_off()
    ax.set_aspect(1)
    ax.autoscale()
    plt.xlim(-1.25,43.25)
    plt.ylim(-1,1)
```



In [37]:

```
symbology = {0: cols[14],
             1: cols[8],
             2: cols[7],
             3: cols[2],
             4: cols[13],
             5: cols[20],
             6: cols[5],
             7: cols[12],
             8: cols[4],
             9: 'red',
             10: cols[19],
             11: 'red',
             12: cols[1],
             13: cols[0],
             14: 'red',}
```

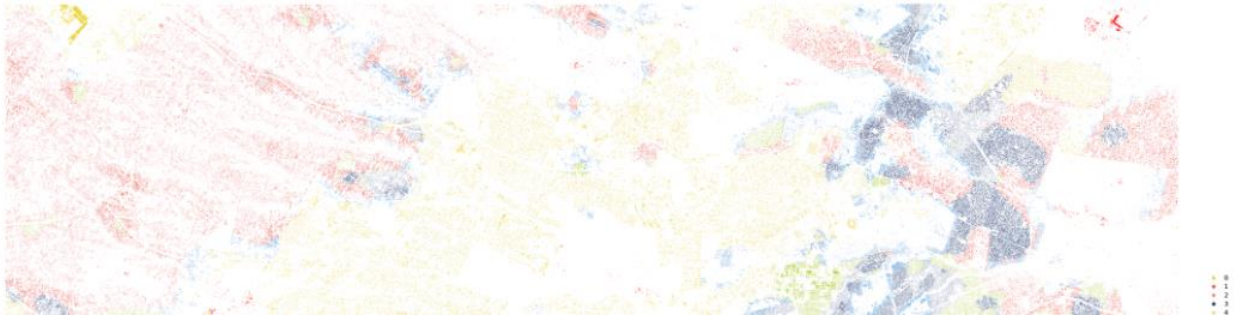
In [40]:

```
ax = gdf.dropna().plot(color=gdf.dropna()['clusters'].map(symbology), categorical=True, legend=True, figsize=(40, 40))
ax.set_axis_off()
# boundaries.boundary.plot(ax=ax, edgecolor='k')

from matplotlib.lines import Line2D
custom_points = [Line2D([0], [0], marker="o", linestyle="none", markersize=5, color=color) for color in symbology.values()]
leg_points = ax.legend(custom_points, symbology.keys(), loc='center right', frameon=False)
ax.add_artist(leg_points)
```

Out[40]:

```
<matplotlib.legend.Legend at 0x7f71348c6700>
```



Final remark

- The role/ambition of remote sensing in understanding settlements, vulnerability, urban socioeconomics.

- Analysis tools/techniques to be developed on top of remote sensing outputs.

Thank you!

- Questions and comments?