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PROSPECTS FOR GLOBAL MONITORING OF THE SDG SLUM INDICATOR WITH EARTH OBSERVATION

SLIUZAS, R., KUFFER, M., WANG, J., NAGENBORG, M., PFEFFER, K., KOHLI, D., AND PERSELLO, C.

ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

CONTENTS

- Some basic parameters for slum mapping (with EO)
- Slum mapping research at ITC
- Prospects and issues for global slum mapping

The nature of slum dwellers and slums
UN-HABITAT 2002

Who are slums dwellers?

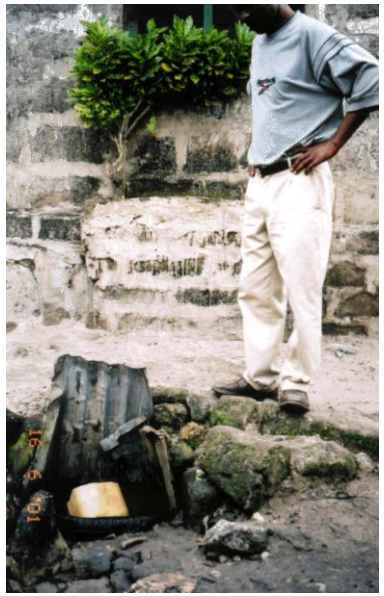
Urban households lacking at least 1 of the following:

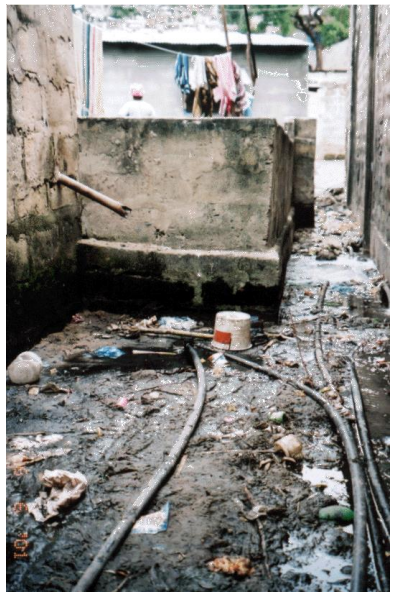
- Adequate water
- Adequate sanitation
- Sufficient living space
- Secure tenure
- Durable housing (quality of structures & environment – hazards)

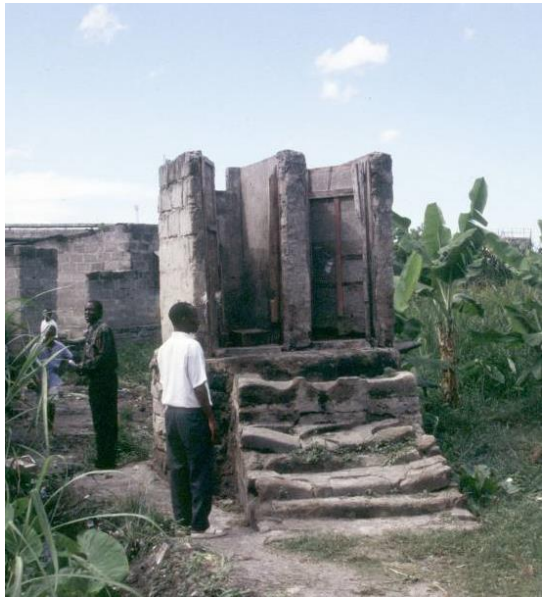
Large scale surveys:
Census, DHS

City and Settlement surveys

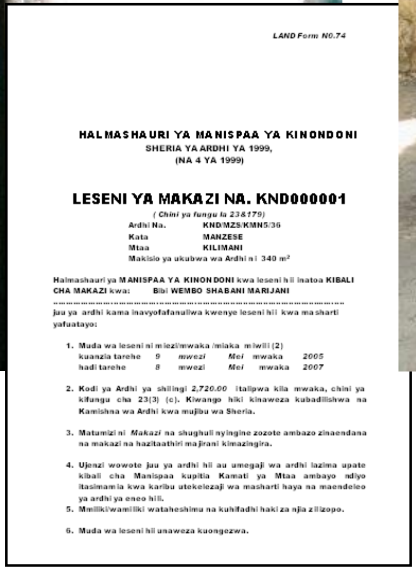
INDICATORS FOR SLUM DWELLERS
ADEQUATE WATER AND ADEQUATE SANITATION







TENURE SECURITY



LAND Form N0.74

HALMASHAURI YA MANISPAA YA KINONDONI
SHERIA YA ARDHI YA 1999,
(NA 4 YA 1999)

LESENI YA MAKAZI NA. KND000001
(Chini ya fungu la 23&179)

Ardhi Na.	KND/MZS/KMN5/36
Kata	MANZESE
Mtaa	KILIMANI

Makisio ya ukubwa wa Ardhi ni 340 m^2

Halmashauri ya **MANISPAA YA KINONDONI** kwa leseni hii inatoa **KIBALI CHA MAKAZI** kwa: Bibi **WEMBO SHABANI MARIJANI**
……………………………………………………………………………………
juu ya ardhi kama inavyofafanuliwa kwenye leseni hii kwa masharti yafuatayo:

1. Muda wa leseni ni miezi/mwaka /miaka miwili (2)
kuanzia tarehe *9* *mwezi* *Mei* mwaka *2005*
hadi tarehe *8* mwezi *Mei* mwaka *2007*
2. Kodi ya Ardhi ya shilingi *2,720.00* italipwa kila mwaka, chini ya kifungu cha 23(3) (c). Kiwango hiki kinaweza kubadilishwa na Kamishna wa Ardhi kwa mujibu wa Sheria.
3. Matumizi ni *Makazi* na shughuli nyingine zozote ambazo zinaendana na makazi na hazitaathiri majirani kimazingira.
4. Ujenzi wowote juu ya ardhi hii au umegaji wa ardhi lazima upate kibali cha Manispaa kupitia Kamati ya Mtaa ambayo ndiyo itasimamia kwa karibu utekelezaji wa masharti haya na maendeleo ya ardhi ya eneo hili.
5. Mmiliki/wamiliki wataheshimu na kuhifadhi haki za njia zilizopo.
6. Muda wa leseni hii unaweza kuongezwa.

OVERCROWDING

> 3 persons per room

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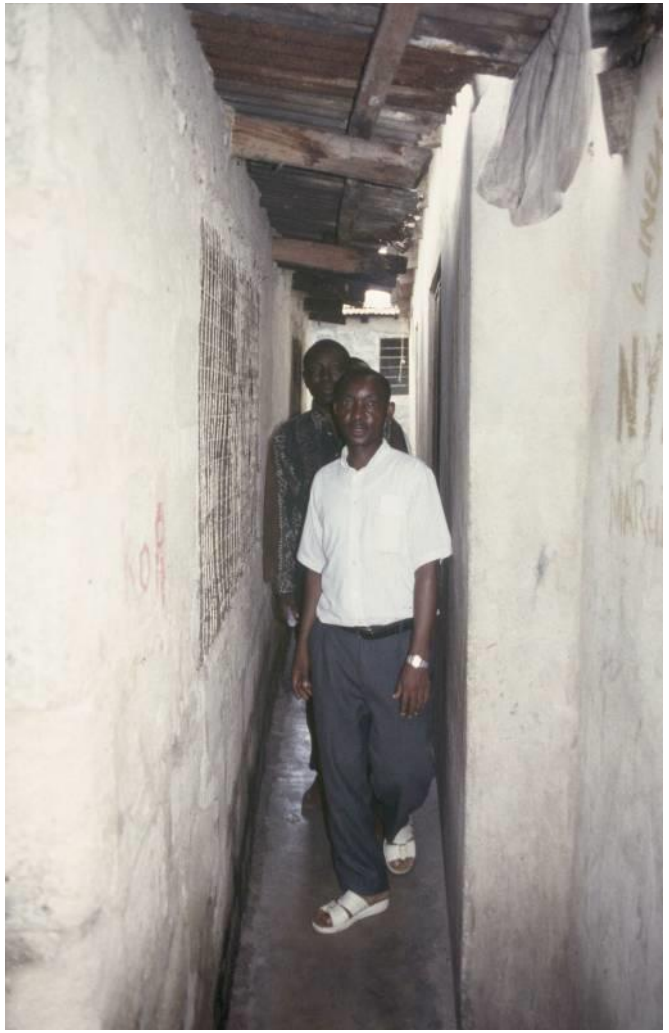
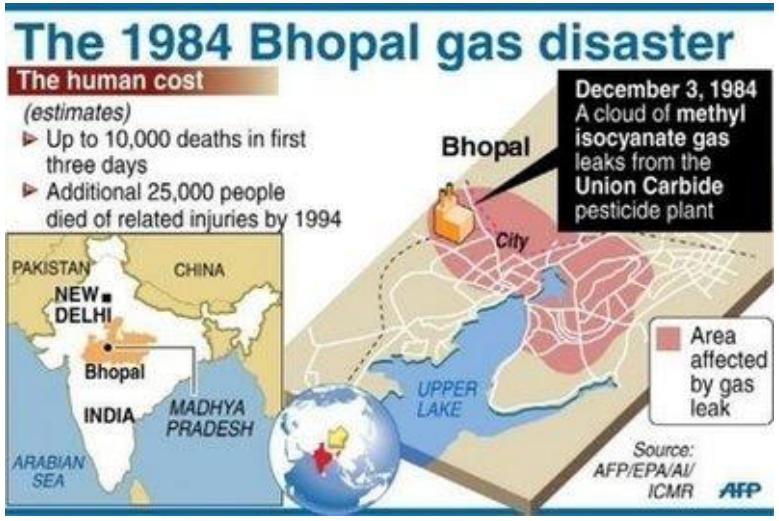
DURABLE HOUSING

PRIVATE VS PUBLIC SPACE, BUILDING AND PLANNING STANDARDS



DURABLE HOUSING:

SAFE FROM NATURAL AND TECHNOLOGICAL HAZARDS



HAZARDS AND SLUM FORMATION: DAR ES SALAAM

INFORMAL VS FORMAL URBAN DEVELOPMENT

Adapted from Baros

Occupation (land)

Building

Servicing

Planning
(regularization, eviction, resettlement)

Monitor (guide) citizen led development

Planning

Servicing

Building

Occupation

Monitor plan implementation

Sliuzas et al., 2017 https://ieeexplore.ieee.org/document/7924589

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SLUMS: spatial concentration of slum dwellers - diversity of physical forms and settings

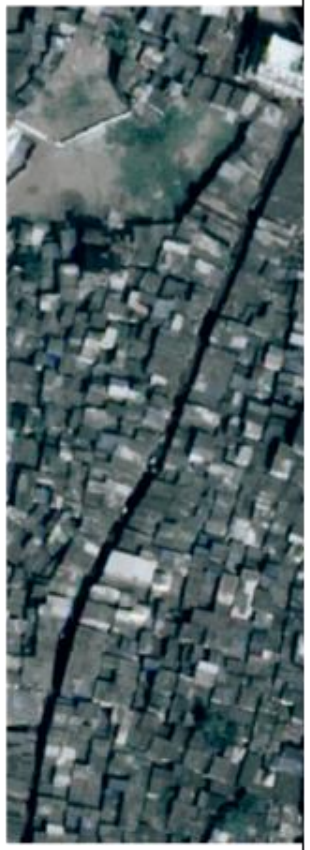
Kampala
Uganda

Cairo
Egypt

Kisumu
Kenya

Ahmedabad
India

THE URBAN DIVIDE – THE MORPHOLOGY

Dar es Salaam	Kigali	Ahmedabad	Delhi	Mumbai	Rio de Janeiro
					

MORPHOLOGY OF SLUMS – FROM SPACE

What is specific to slums?

Features	Slums	Planned areas
Size	• Small building sizes	• Generally larger building sizes
Density	• High densities (roof coverage) • Lack of public (green) spaces	• Low – moderate density areas • Provision of public (green spaces)
Pattern	• Organic layout structure	• Regular layout pattern
Site Aspects	• Hazardous locations • Access to livelihood opportunities • Etc…	• Formal development with services and infrastructure provision

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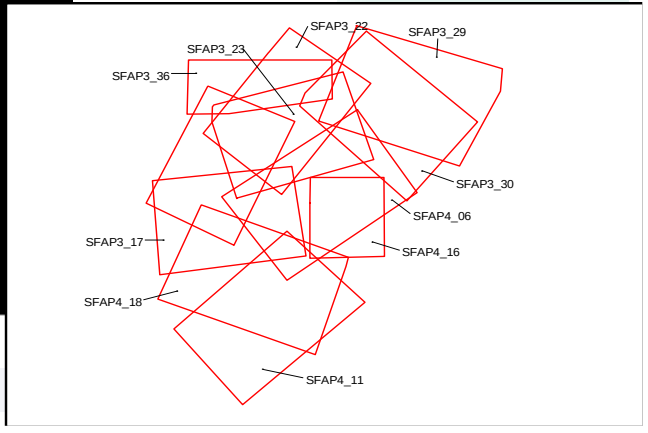
SLUM MAPPING FROM SMALL FORMAT AERIAL PHOTOS



(Source: Sliuzas, 2004)

POINT CLOUD FROM UAV IMAGES, KIGALI, RWANDA FOR 2D AND 3D ANALYSIS AND PLANNING

(IMAGE BY C. GEVAERT)

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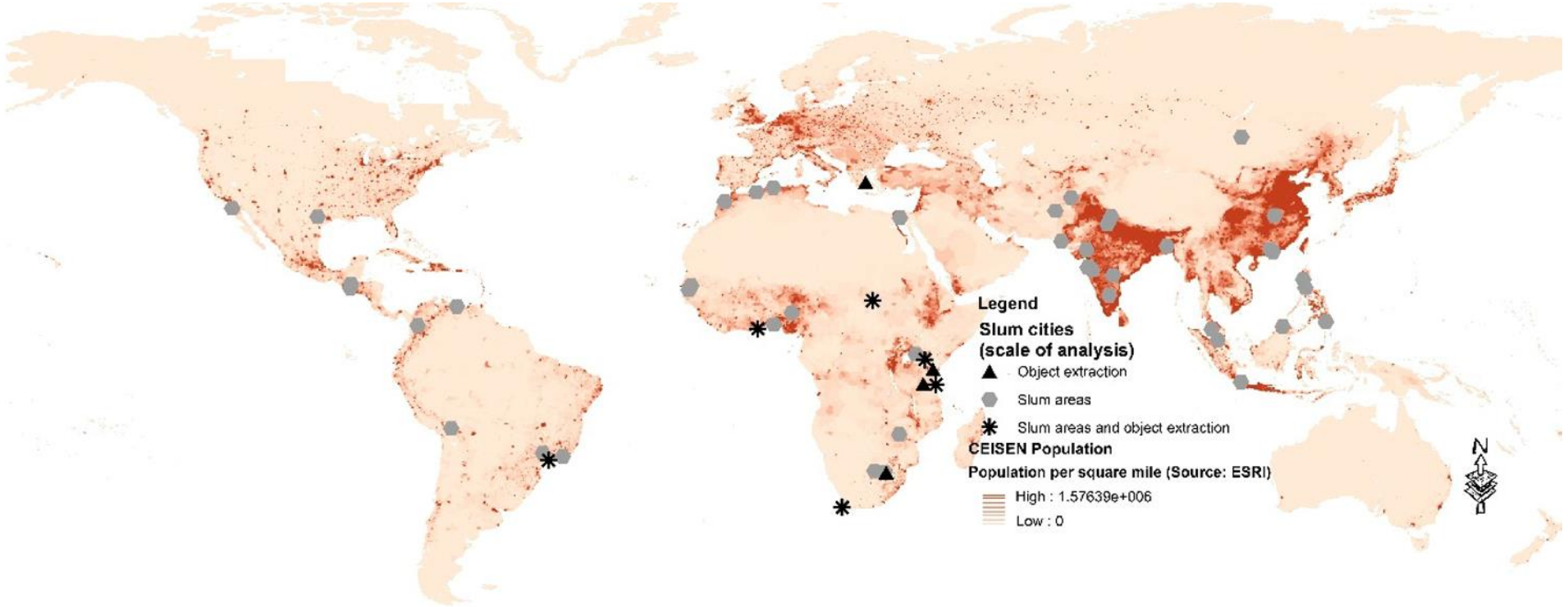
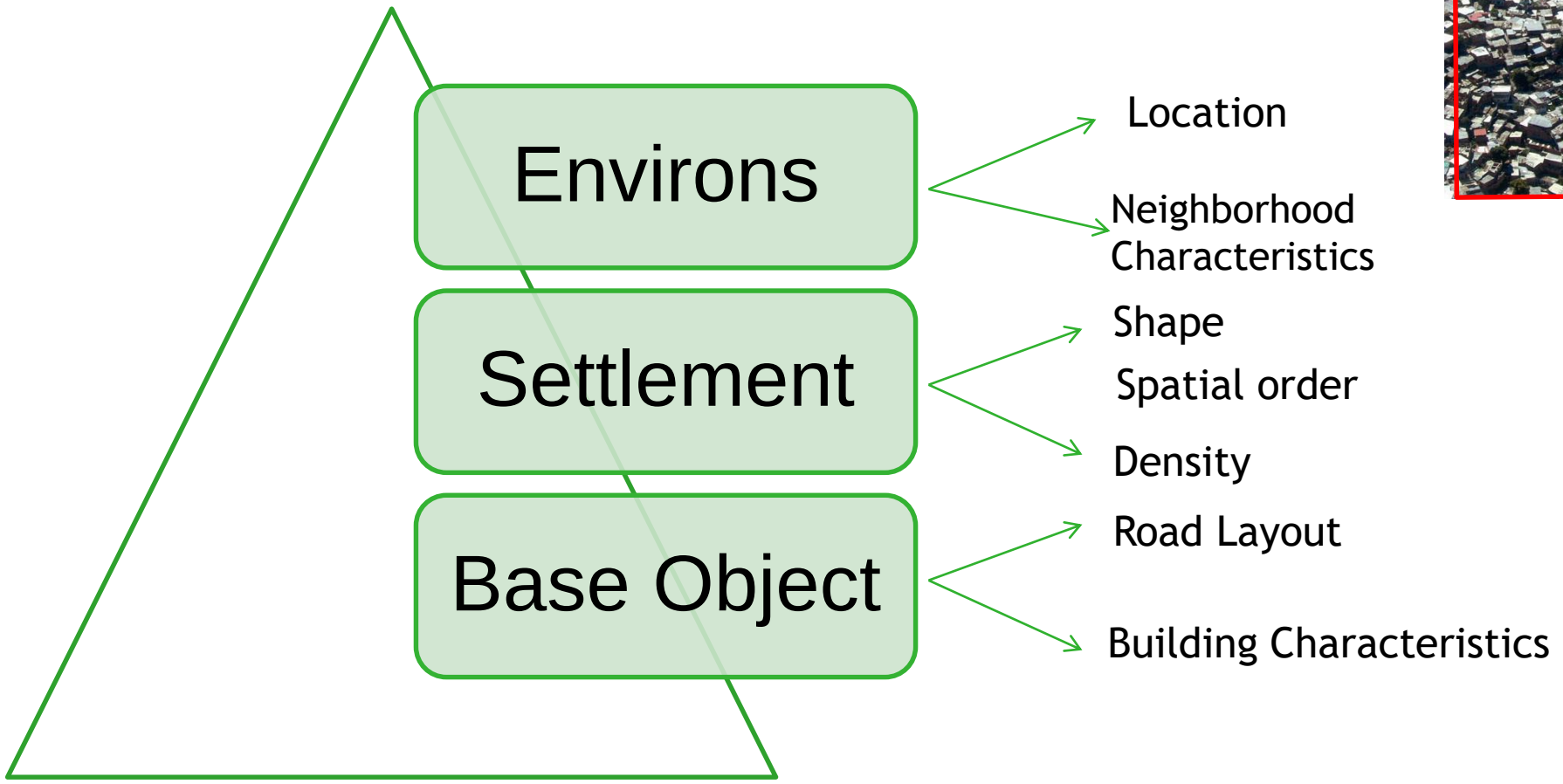
THE URBAN DIVIDE

What do we know about global slum developments



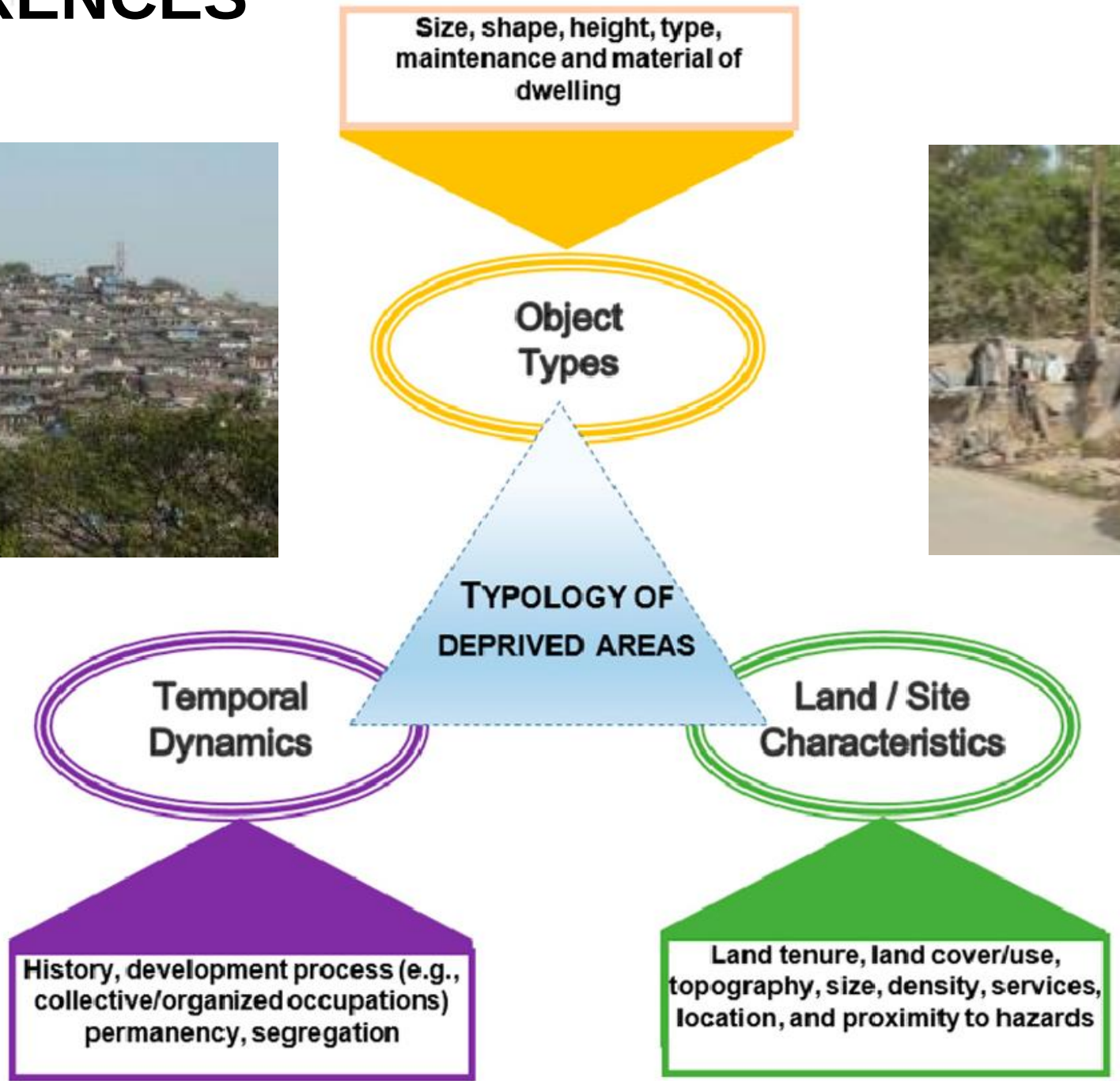
- 15 years of slum mapping using remote sensing
  (Kuffer, Pfeffer and Sliuzas, 2016)
- Based on 87 publications selected and reviewed

THE GENERIC SLUM ONTOLOGY



Kohli, D.; Sliuzas, R.V.; Kerle, N.; Stein, A. An ontology of slums for image-based classification. Comput. Environ. Urban Syst. ***2012****, 36, 154–163.*

DIFFERENCES



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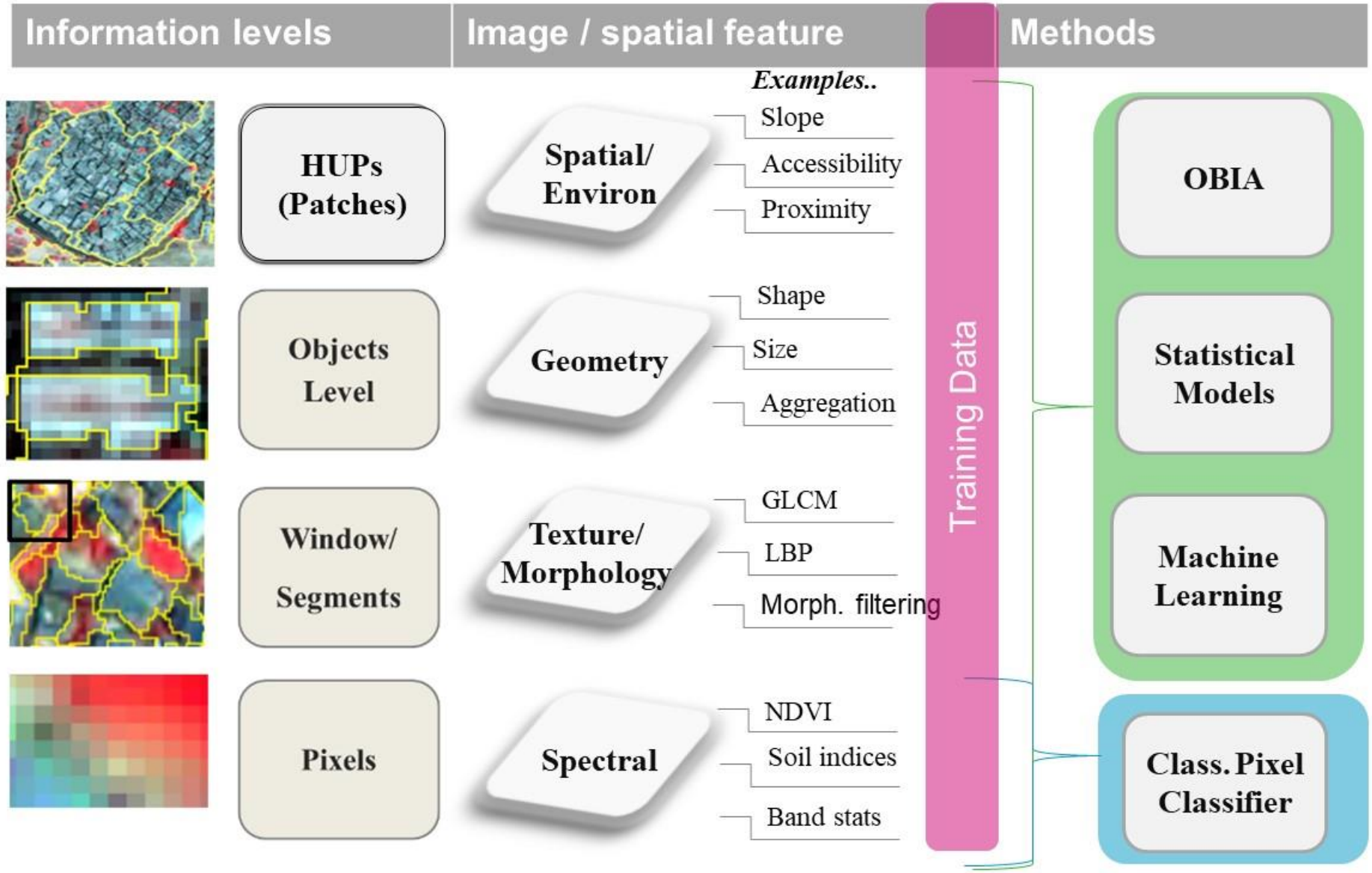
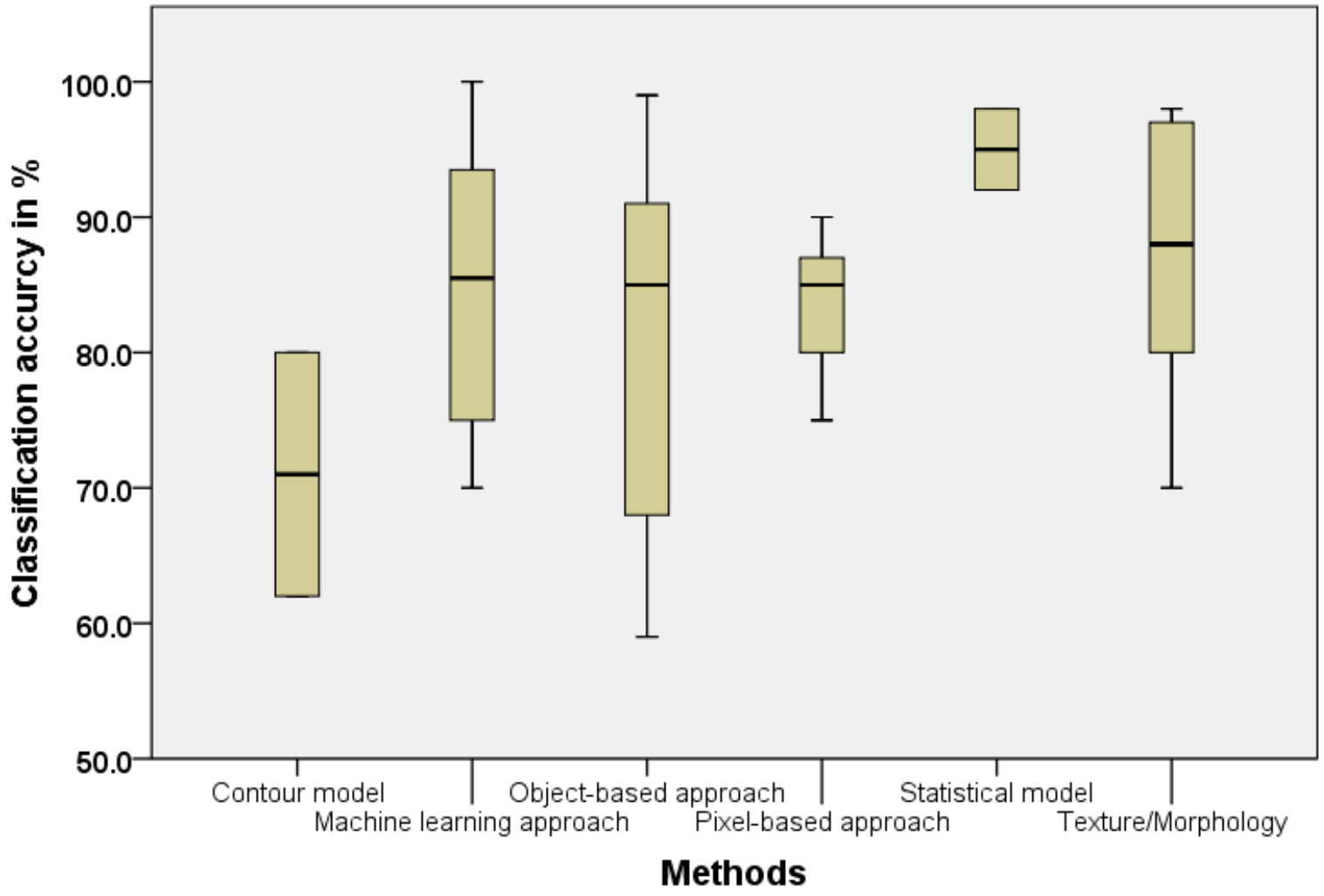
SLUM MAPPING



ACCURACIES OF METHODS TO MAP SLUMS



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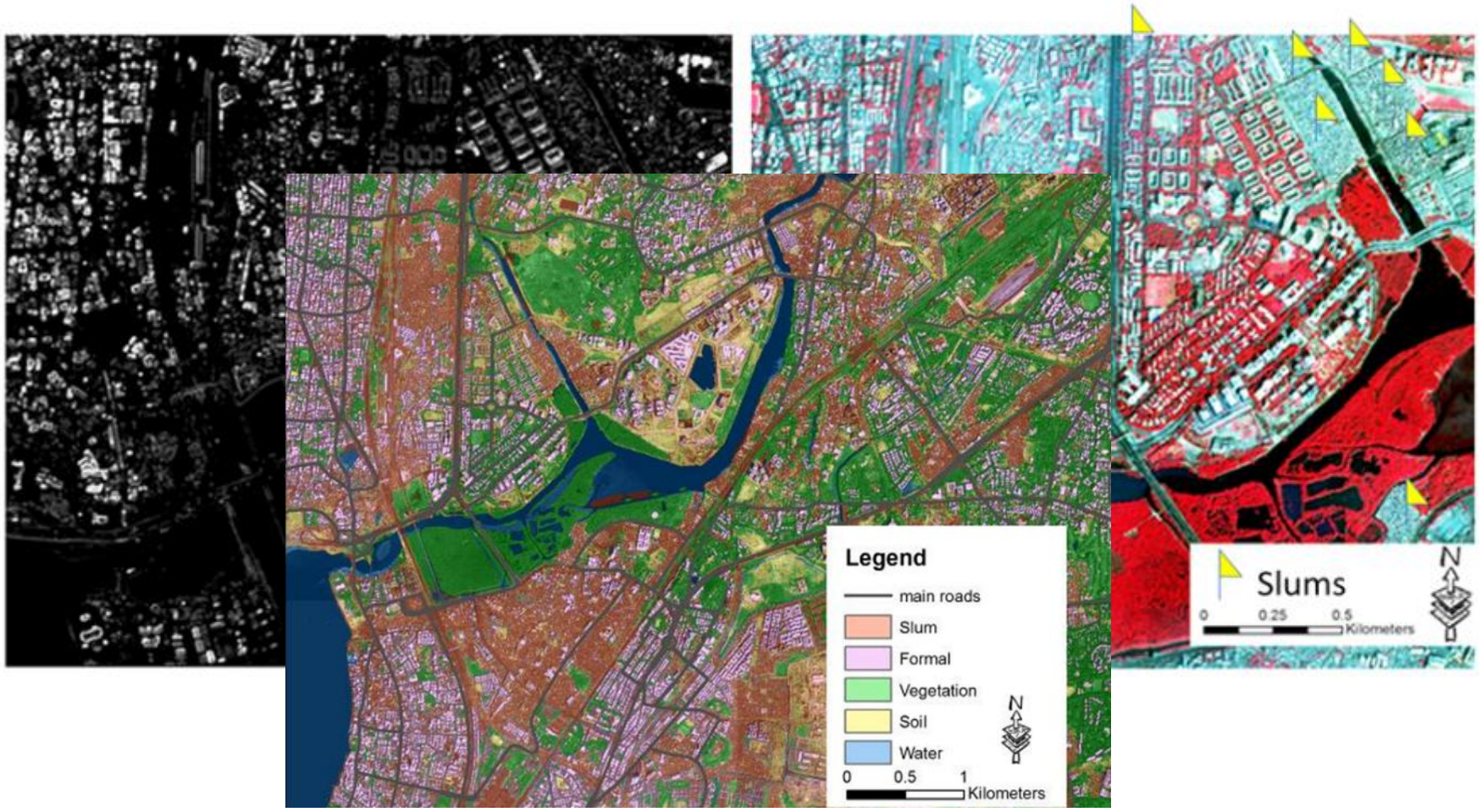
THE URBAN DIVIDE AND MACHINE LEARNING

GLCM (Gray Level Co-Occurrence Matrix) - Example Mumbai



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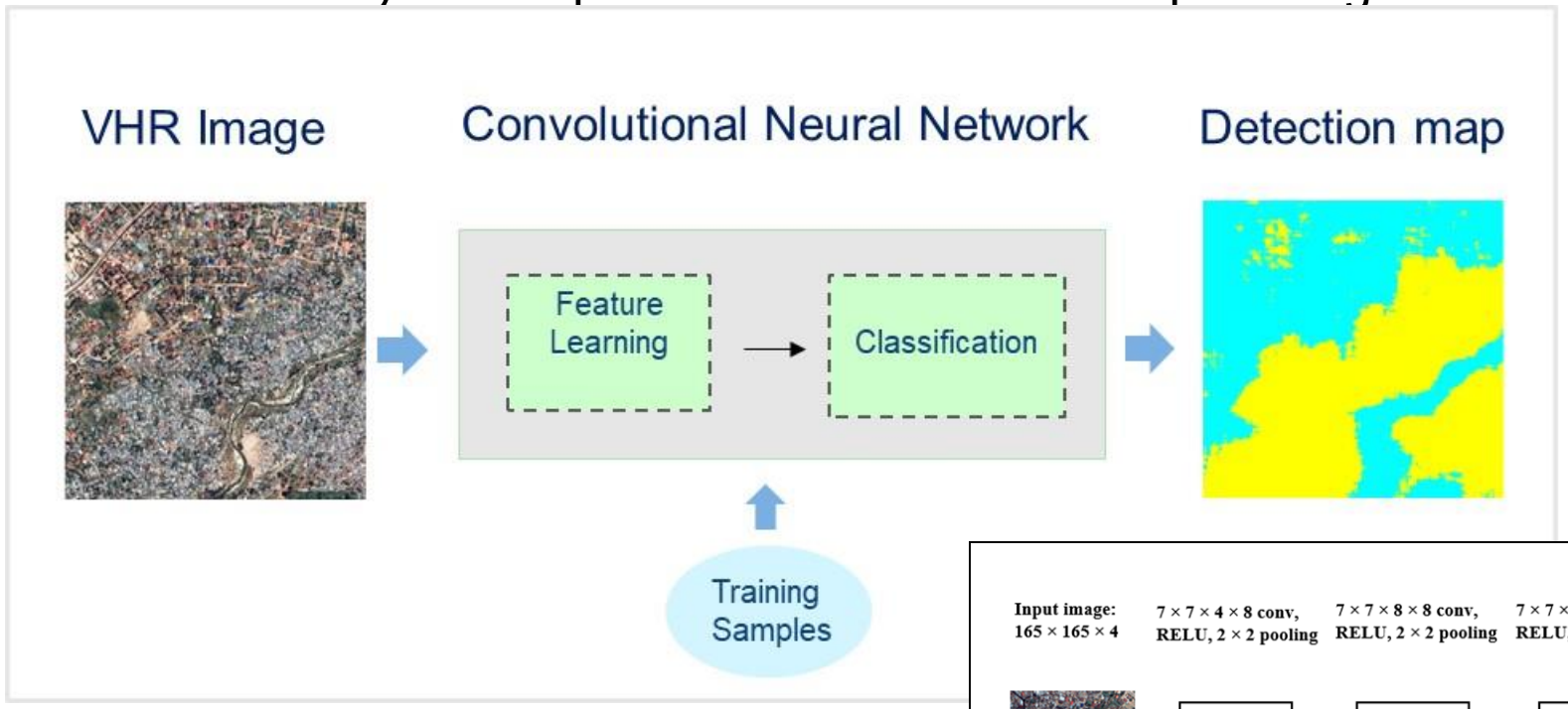
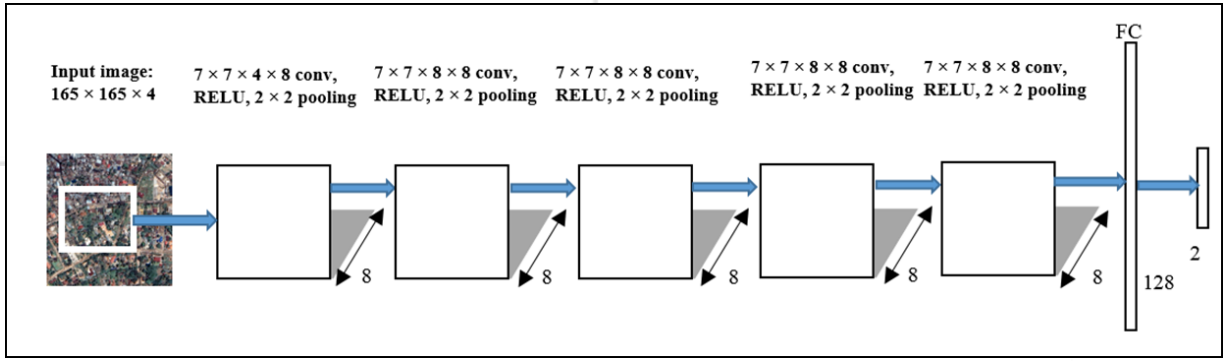
THE URBAN DIVIDE - DEEP LEARNING APPROACH

Deep learning methods such as **Convolutional Neural Networks** can automatically learn spatial features from the input image.





Mboga, Persello, Bergado, Stein, "Detection of Informal Settlements from VHR Satellite Images using Convolutional Neural Networks, *IGARSS 2017*.

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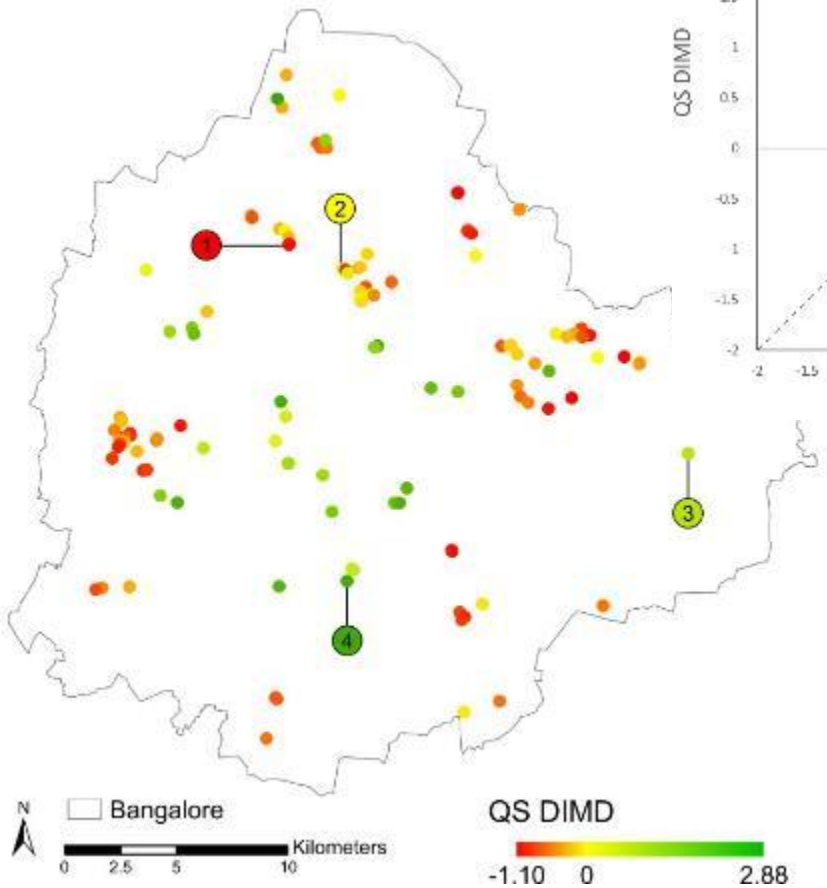
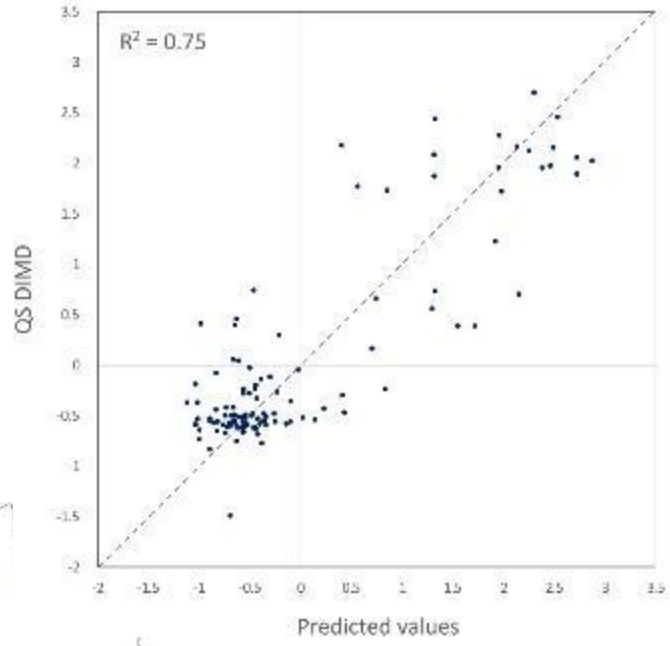
DEGREE OF DEPRIVATION USING CNNs





CNN-based model **Transfer learning**

Classification problem
Distinguishing slum from formal
2000 samples for training
→ Distinctive features

Regression problem
Predicting Deprivation indices
<121 samples for training
→ CNN model

Source: A. Ajami et al. forthcoming

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PROSPECTS FOR GLOBAL SLUM MAPPING?

- Producers, uses and users
- Incorporating different slum development stages, dynamics and typologies?

- Feature selection – training – assessment – which algorithms and reference data?
- Transferability of methodology (temporal – spatial)?
- How to upscale to global level?
- Suitable data (spatial resolution, cost…)

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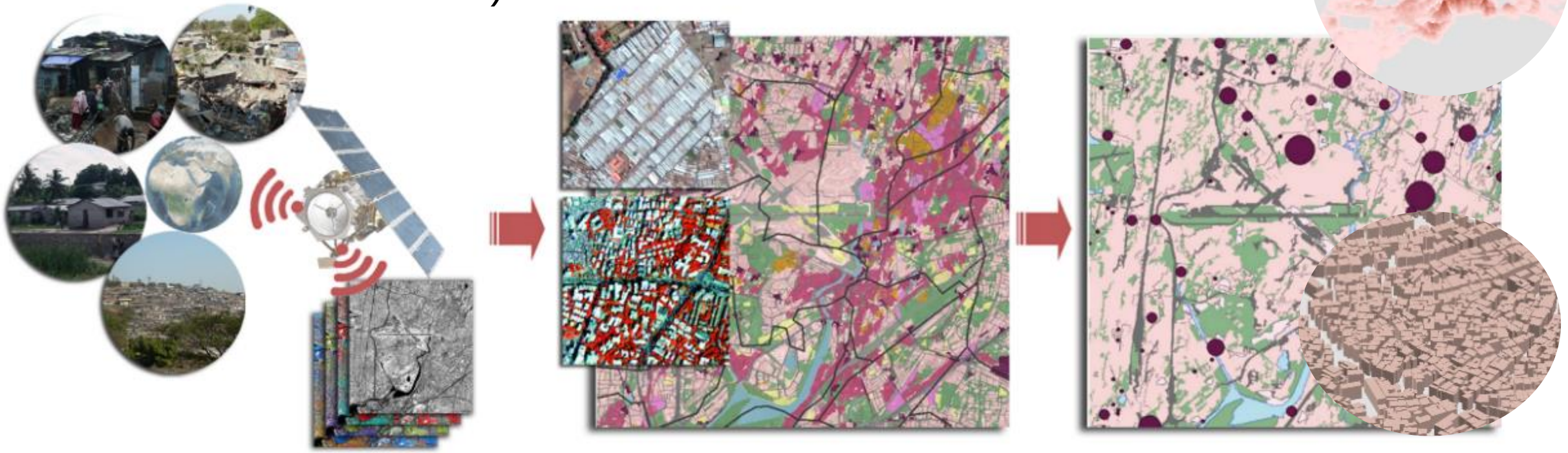
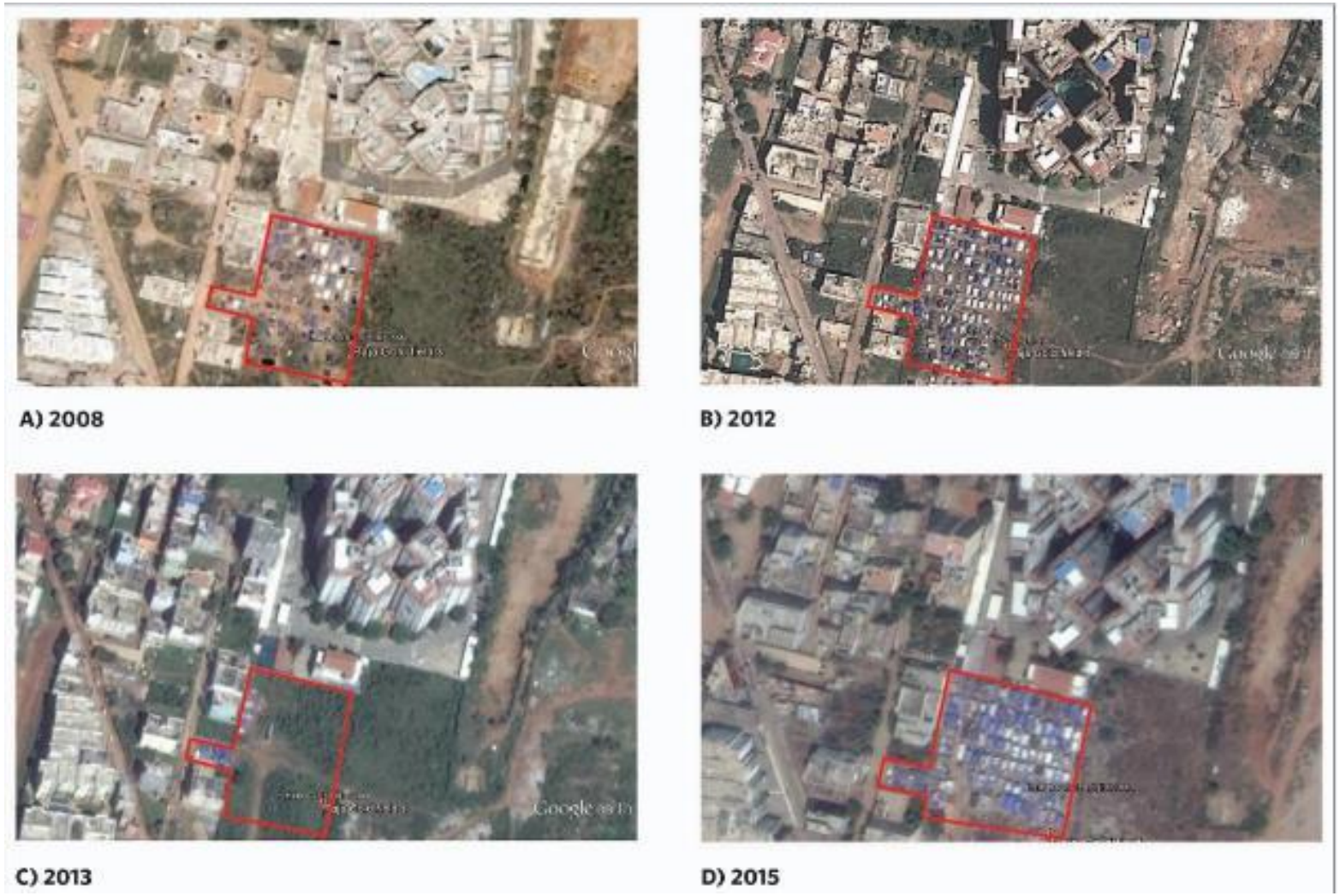
PRODUCERS, USES AND USER NEEDS

- Slum mappers: government, researchers, communities, NGOs
- Better understanding user requirements – bridge communication gap
- Making products relevant to support user needs
- Co-production of slum maps and data
- Data access, distribution and maintenance (slum mapping as a social-technical infrastructure)



TEMPORAL DYNAMICS



Ranguelova et al. 2017
https://www.tandfonline.com/doi/full/10.1080/22797254.2018.1535838

Emergence and Growth of a slum in Huidi, Bangalore (marked with a red polygon). a) Slums emerge near a construction Site in 2008. b) Slum grows near the same site. c) Slum disappear when construction is complete in 2013. d) A slum re-emerge at the same site in 2014 (Images– Google Earth) (Source: Dynaslum)

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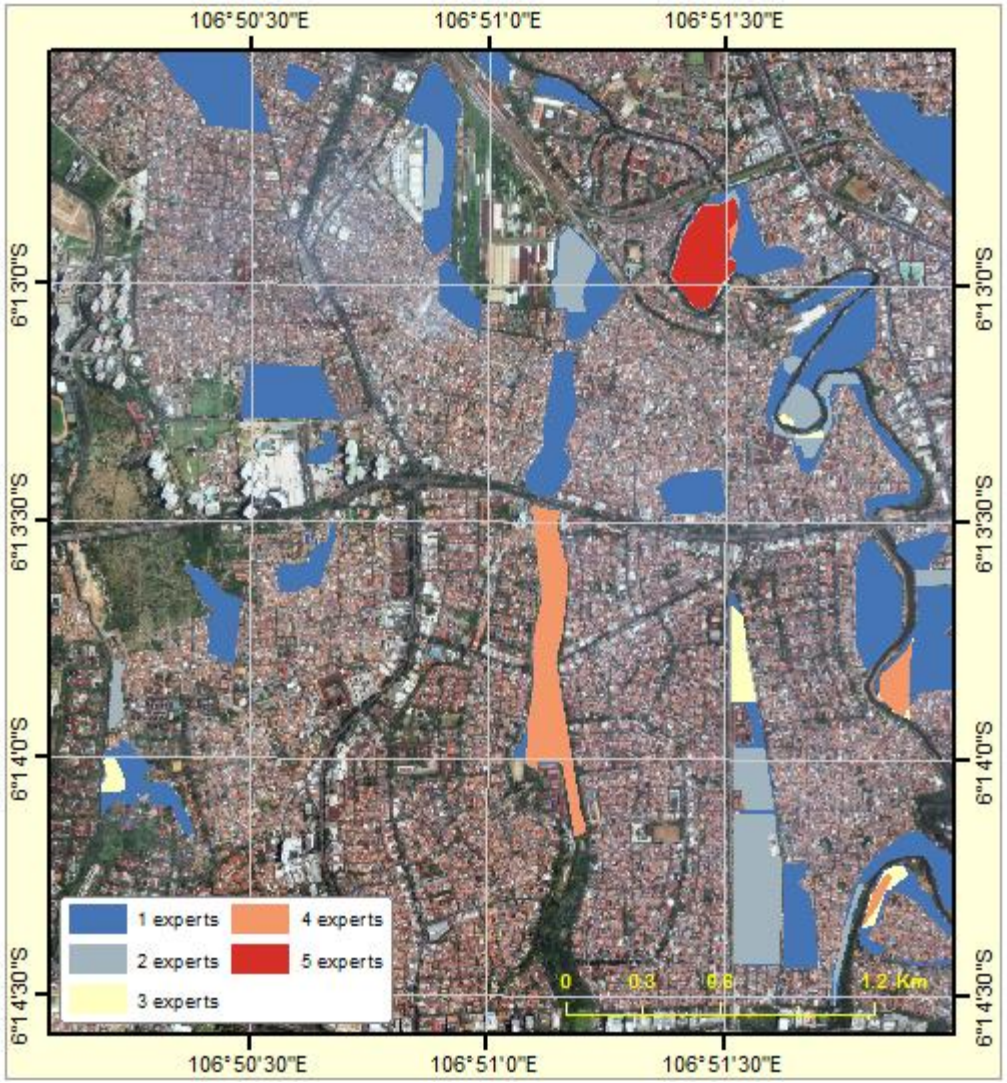
UNCERTAINTIES IN THE REFERENCE DATA



In area with higher agreement shows (on the ground): poor building materials, high density and

Misclassifications: high density and have a roof from asbestos, but not a slum

Opportunity to link to NGOs and communities slum dweller groups

Source: Pratomo et al., 2017: https://www.mdpi.com/2072-4292/9/11/1164

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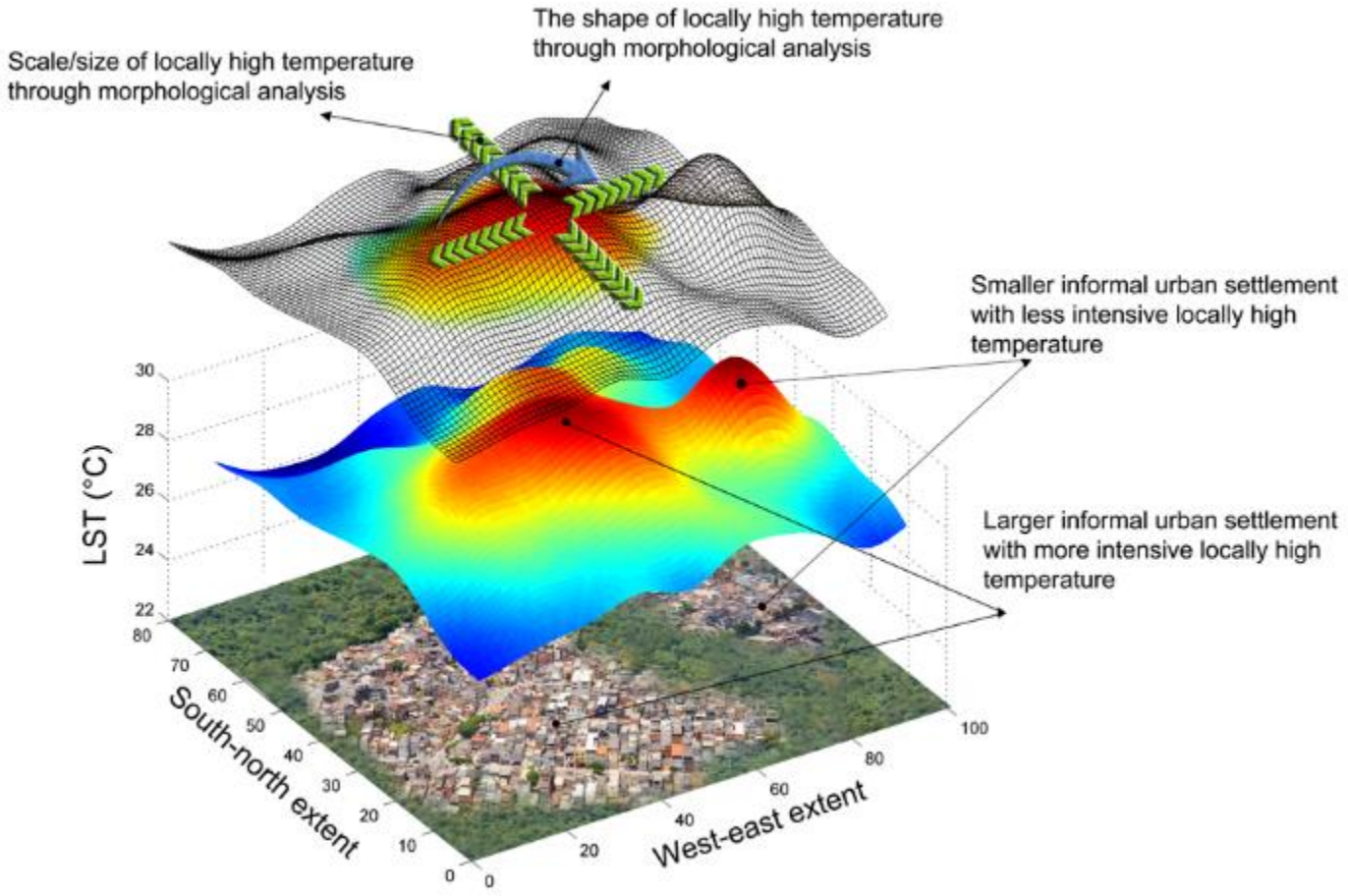
UNDERSTAND BETTER ENVIRONMENTAL CONDITIONS OF SLUMS: HAZARDS – CLIMATE



WANG, J., Sliuzas, R., Kuffer, M., Kohli, D.
https://www.sciencedirect.com/science/article/pii/S0048969718337811

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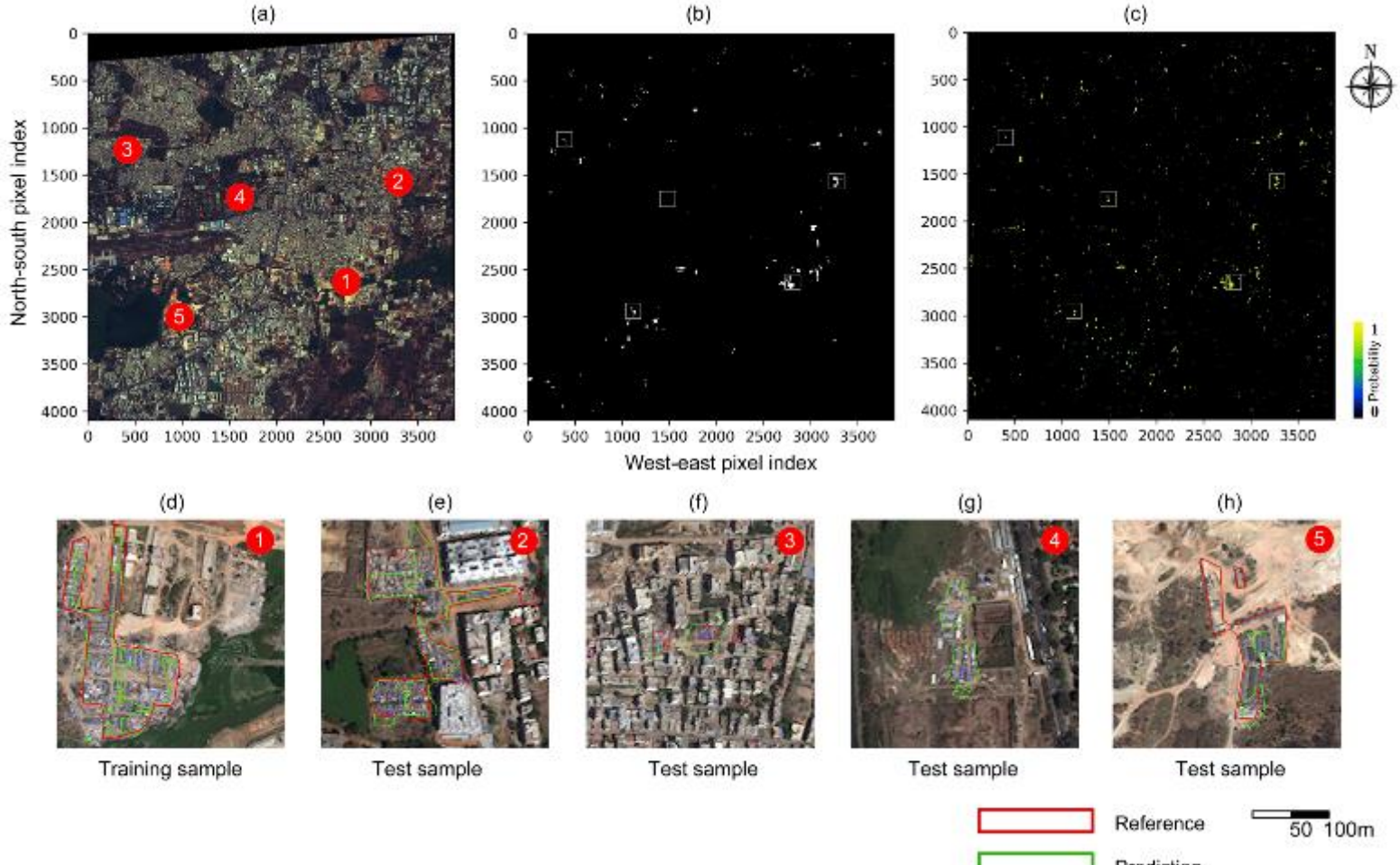
GOING AHEAD: CAN MAP SLUMS WITH CNNs BASED ON LIMITED TRAINING DATA

- Mapping small clusters of slums with training based on few large slums



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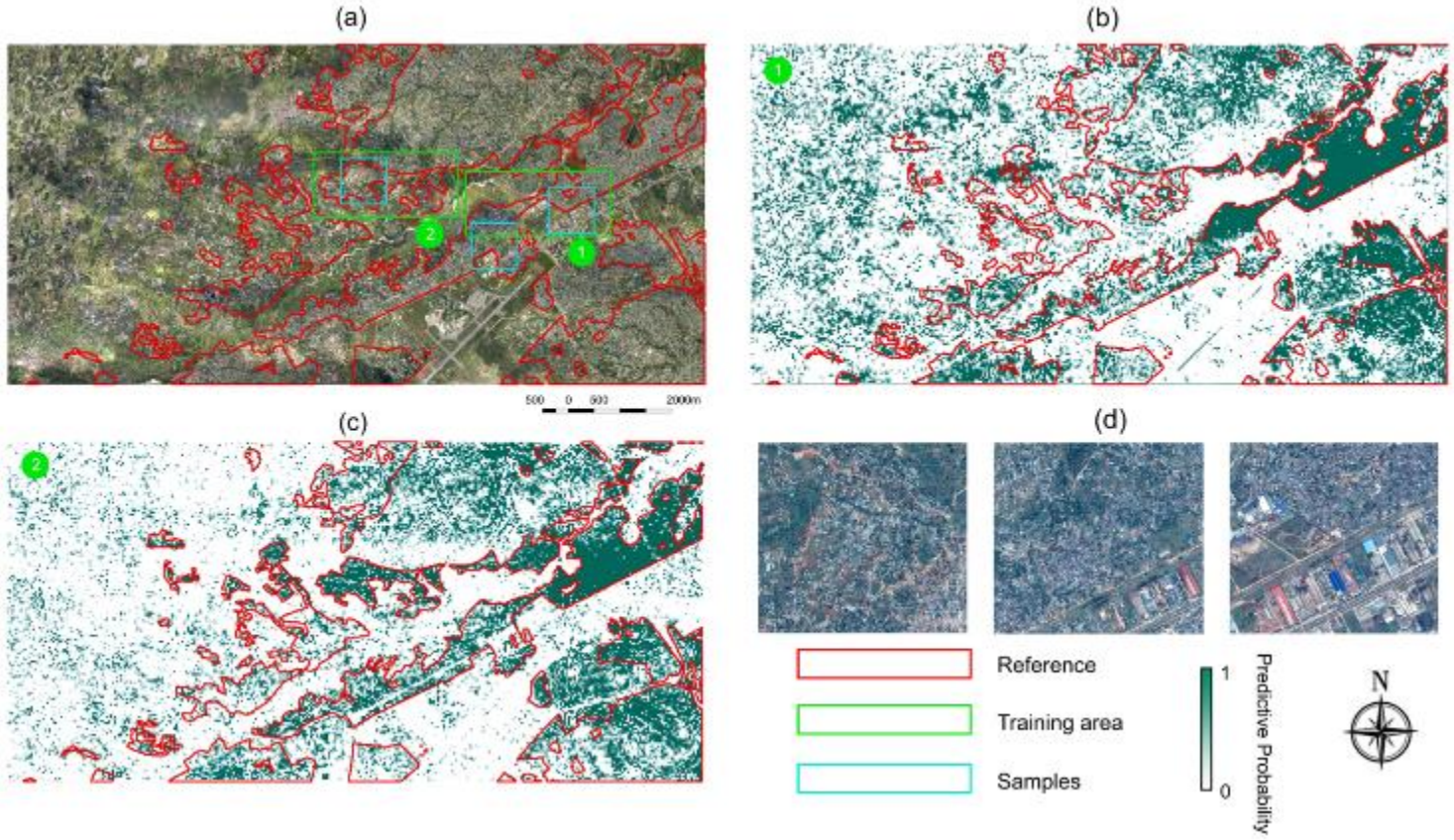
GOING AHEAD: CNNs NEED TO HAVE TRAINING DATA THAT INCLUDE THE VARIATIONS

- CNNs need to be trained based on the full variety of their morphologies



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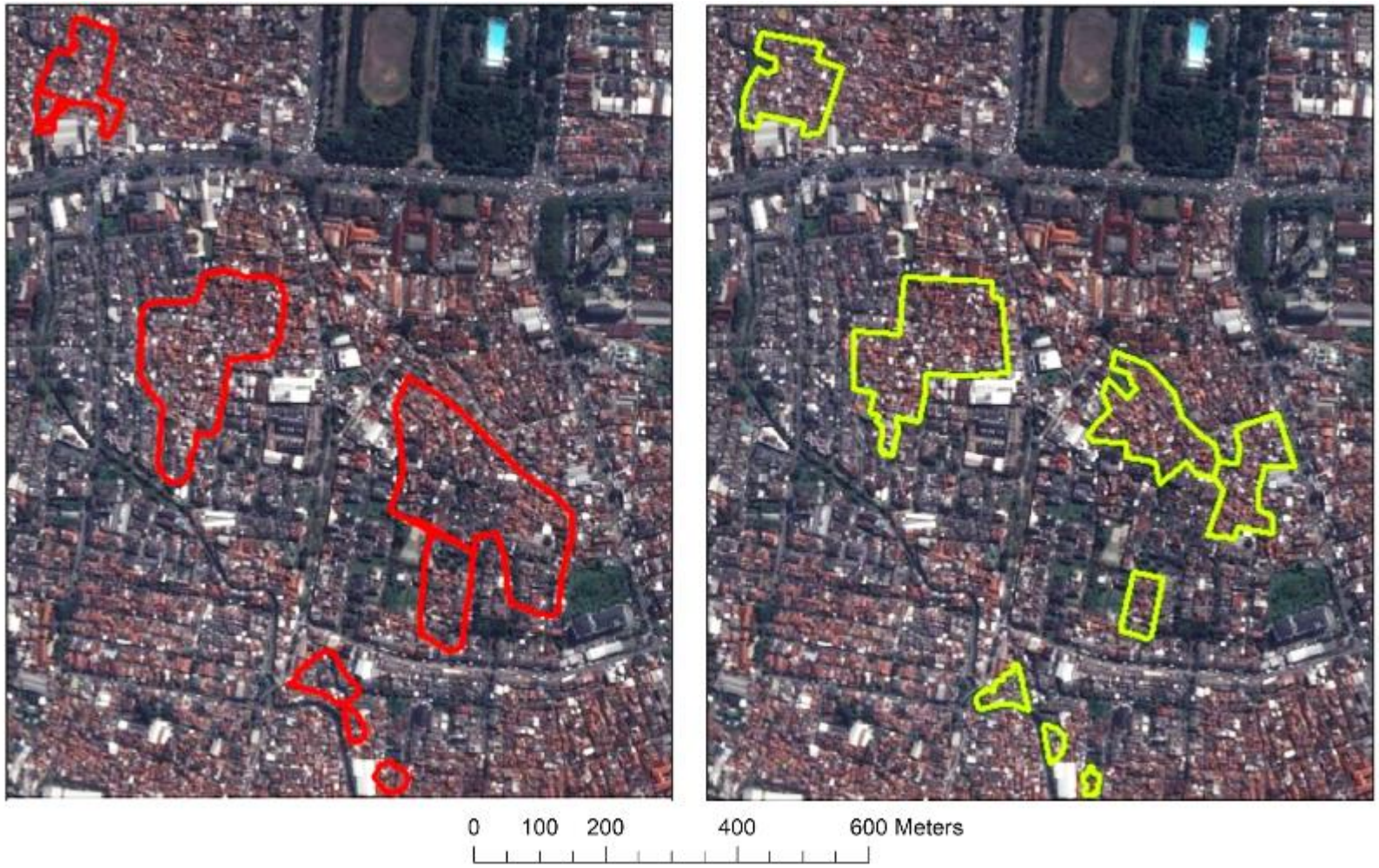
UNCERTAINTIES ON SLUM BOUNDARIES: BANDUNG, INDONESIA

Local authorities

Ground-truth delineation including image



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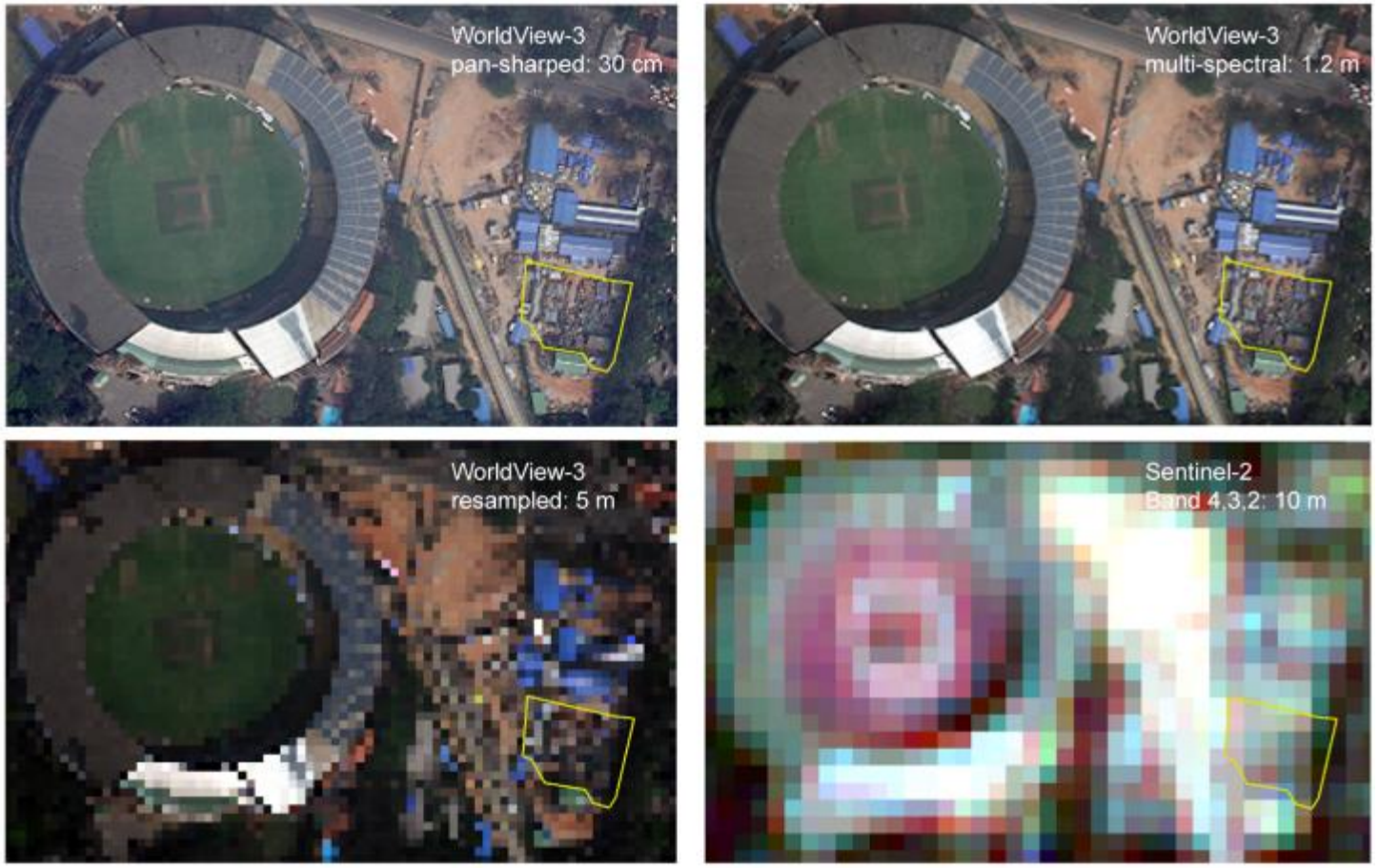
MOST SUITABLE SPATIAL RESOLUTION OF IMAGES

Benefits versus image and computational costs



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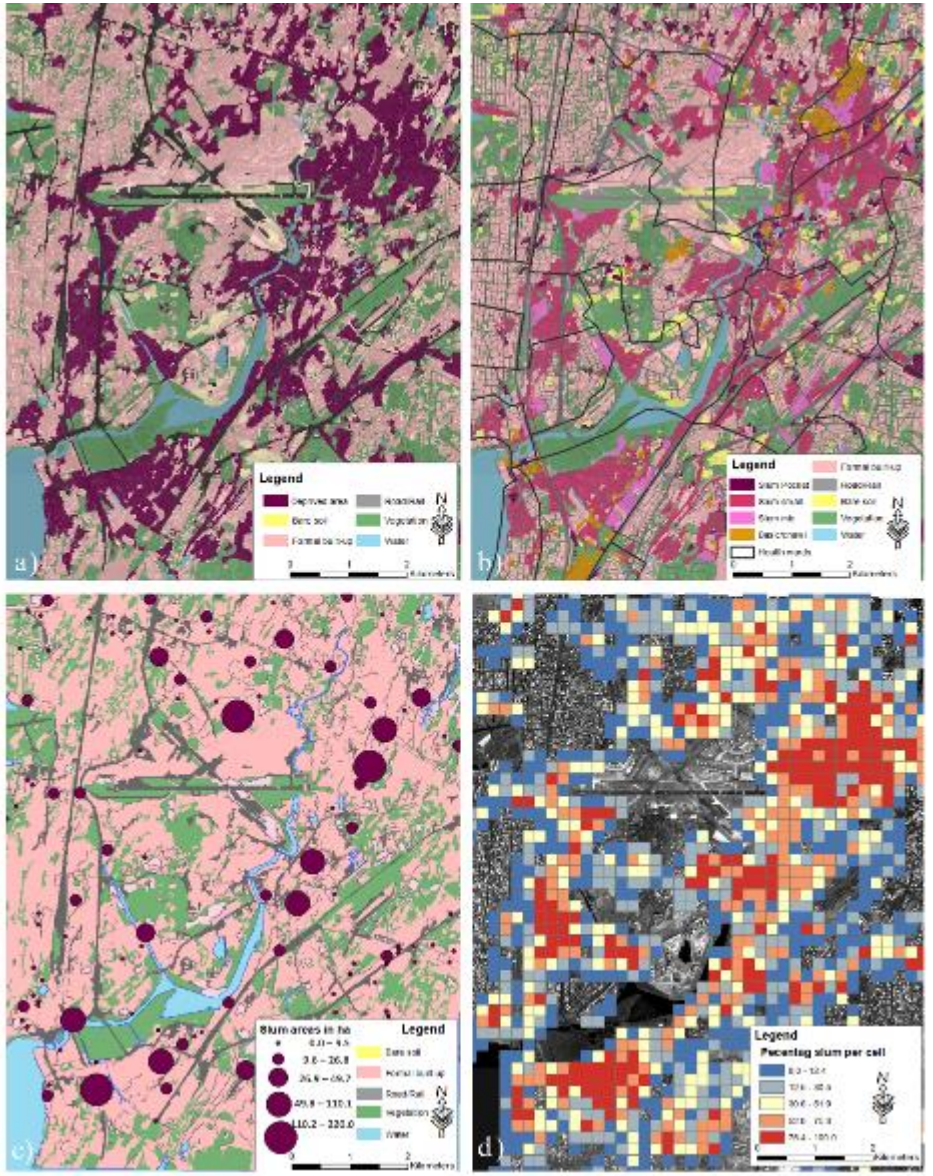
HOW CAN WE SHOW THE FUZZINESS IN MAPS

- Is the highest detail necessary?
- Ethical considerations (not) making data on slums publically available?

1 ***Kampungs*** **with basic facilities, amenities, durable housing materials, cars**

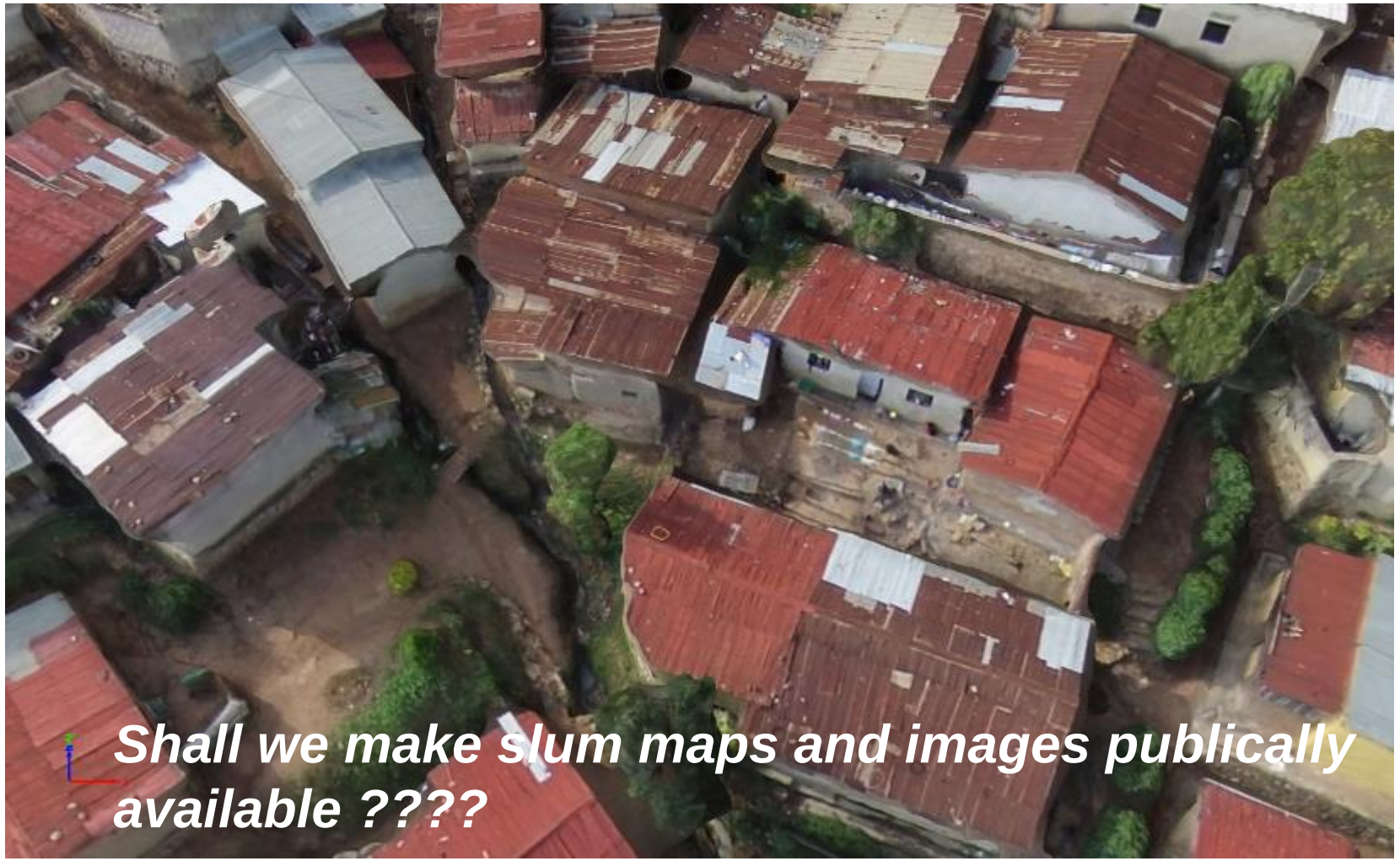
2 ***Kampungs*** **without basic facilities, poor housing materials, poor households**



SLUMS IN EUROPE?

Immigrants in France. (L) Eviction from Calais, (R) New settlements in Paris

INFORMATION NEEDS AND ETHIC CONSIDERATIONS



Source Gevaert et al. 2018: https://www.mdpi.com/2220-9964/7/3/91

https://www.sicherheitspolitik-blog.de/2018/07/11/the-digitalization-of-the-globe-machine-learning-about-population-in-need-of-support/

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POSSIBLE ETHICAL CONCERNS IN SLUM MAPPING

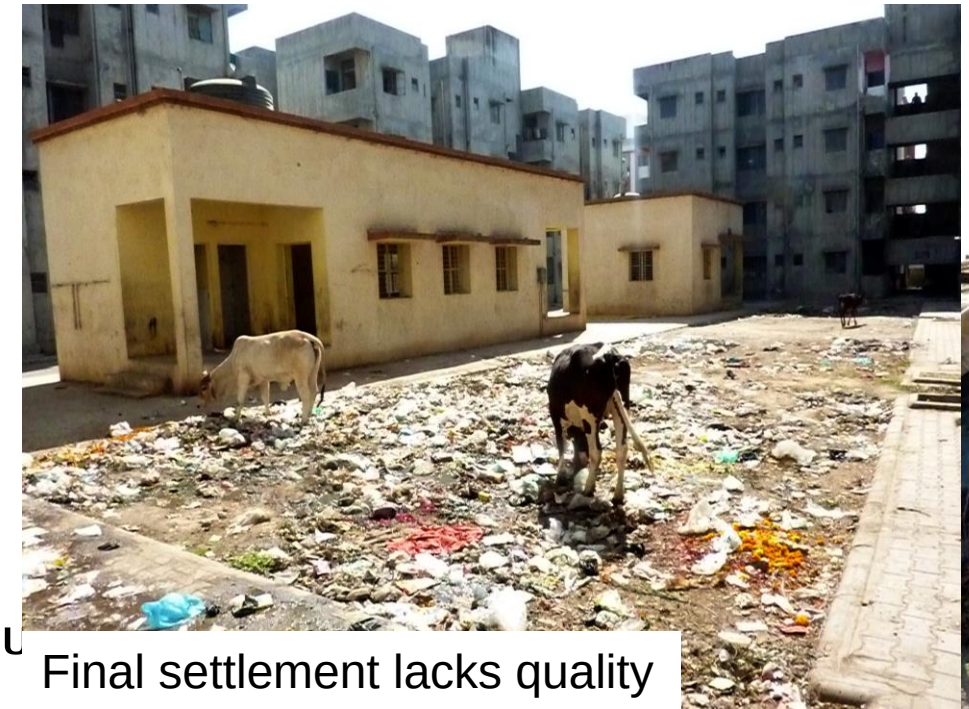
- Who decides and who owns the process?
- Who is eligible for compensation and resettlement?
- Who pays?
- Issues of possible eviction or economic displacement – gentrification?
- …..

SLUM EVICTION IN AHMEDABAD INDIA

LEADS TO FURTHER DEPRIVATION RELATED MOSTLY TO SERVICE LEVELS AND LOCATION OF NEW SITES

Patel, S., Sliuzas, R., & Mathur, N. (2015).
http://doi.org/10.1177/0956247815569128

Many residents do not qualify



Final settlement lacks quality

Very poor temporary resettlement

SOME KEY ISSUES AND QUESTIONS

- Definitions: do we really have a global definition?
  - Slums are often not binary (slum vs non-slum)
  - How do we bring in hazards in an effective manner (also non-binary, dynamic and related to
- Diversity
  - Should we differentiate at regional, country or city level?
  - At least we will need to include training sets that reflect diversity
  - What do slum development processes imply for training samples and processing?
  - *This is shown on the slides 4&5 – we need to include different development stages – but this makes the analysis complex!*
- How to connect local actors and communities (SDI etc.)?
  - In data collection efforts for sample generation?
  - In validation of slum classification maps?
  - As users of the data in daily management and upgrading, etc.?

SOME KEY ISSUES AND QUESTIONS

- Uses and users:
  - Which potential uses have priority and for whom?
  - Will political and other actors be prepared to accept and use such data sets derived from advanced image analysis?
  - What are the margins for error and will these be context dependent?
- Technical
  - Image availability and sensor types
  - Computational power – which processing facilities can support the level of computation required for this task and can these be accessed as and when needed?
  - How to best connect to socio-economic datasets (Census, DHS, MICS etc.)
- Ethical and privacy issues
- Social-technical: what would an inclusive global slum mapping infrastructure look like and how to build and maintain it?

NEW INITIATIVES

Opportunities

- SDG process
- MAUPP partners and follow-up projects
- Group on Earth Observation – Human Planet Initiative (https://www.earthobservations.org/index.php https://www.itc.nl/hpi-forum/)
- Global programmes related to hazards and climate change (UNISDR, UNFCC)
- UN-HABITAT - GUO, Slum Upgrading Programme, Climate Change Unit: Building the Climate Resilience of the Urban Poor Initiative for UN Summit 2019

Source: Ralf Graf. RxAxLxF Informal City

SOME USEFUL REFERENCES

- Gevaert, C. M., Sliuzas, R., Persello, C., & Vosselman, G. (2018). Evaluating the societal impact of using drones to support urban upgrading projects. *ISPRS International Journal of Geo-Information*, *7*(3). https://doi.org/10.3390/ijgi7030091
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- Mahabir, R., Croitoru, A., Crooks, A. T., Agouris, P., & Stefanidis, A. (2018). A Critical Review of High and Very High-Resolution Remote Sensing Approaches for Detecting and Mapping Slums: Trends, Challenges and Emerging Opportunities. *Urban Science*, *2*(8), 1–38. https://doi.org/10.3390/urbansci2010008