

UNIVERSITY OF TWENTE.

# SLUM MAPPING: TECHNOLOGIES, METHODS AND APPLICATIONS.

JUNE 2017 FOR SES PROJECT

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ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION



# CONTENT OF LECTURE

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- The nature of slums
- Scales of slum mapping
- Trends in geo-spatial technology
- Methods for slum mapping
  - City wide from EO data
  - Participatory mapping and drone imagery

# The nature of slum dwellers and slums

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)

UN-HABITAT 2002



# SLUMS: SPATIAL CONCENTRATION OF SLUM DWELLERS - DIVERSITY OF PHYSICAL FORMS AND SETTINGS



Rio de Janeiro  
Brazil



Cairo  
Egypt



Addis Ababa  
Ethiopia



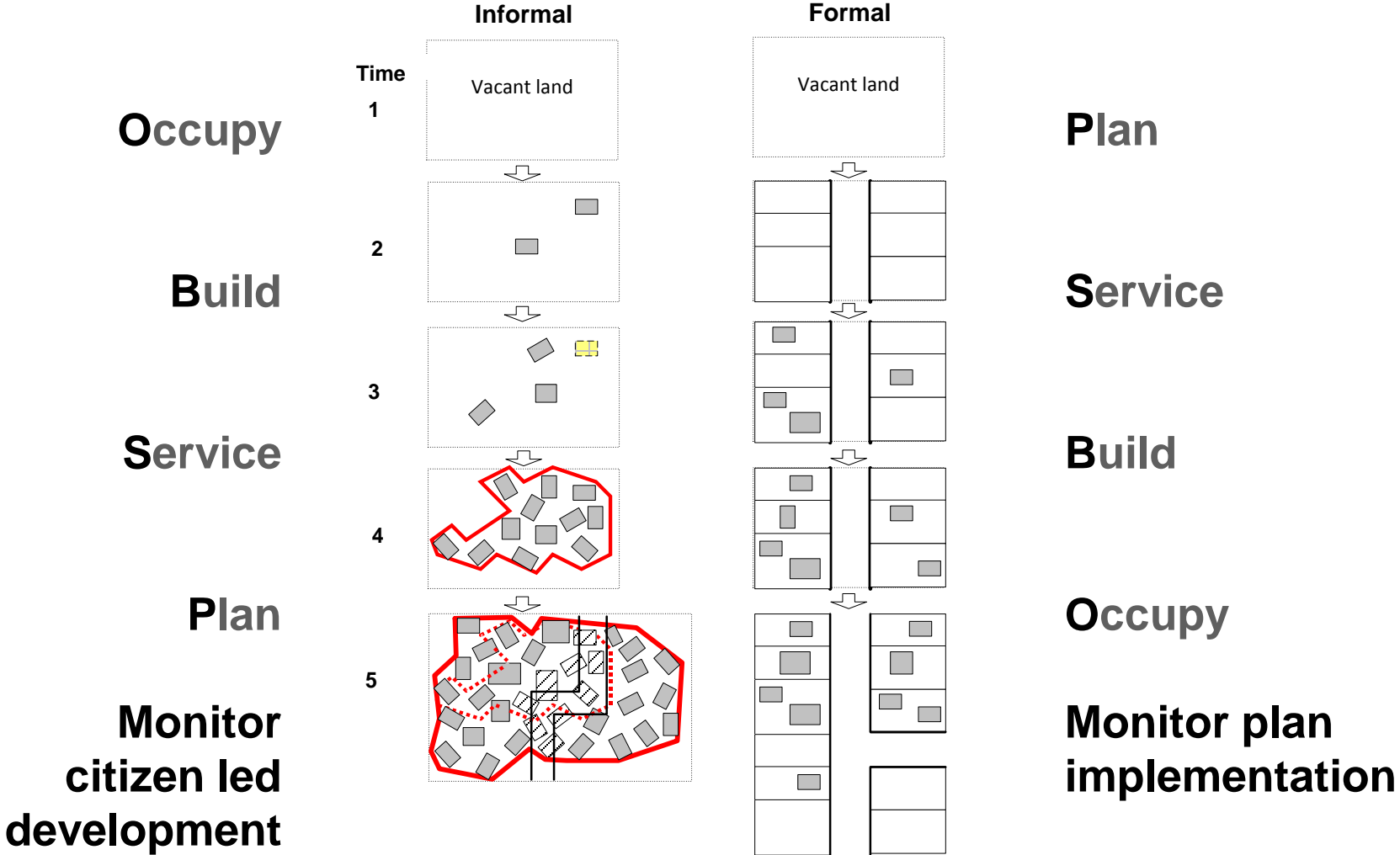
Ahmedabad  
India



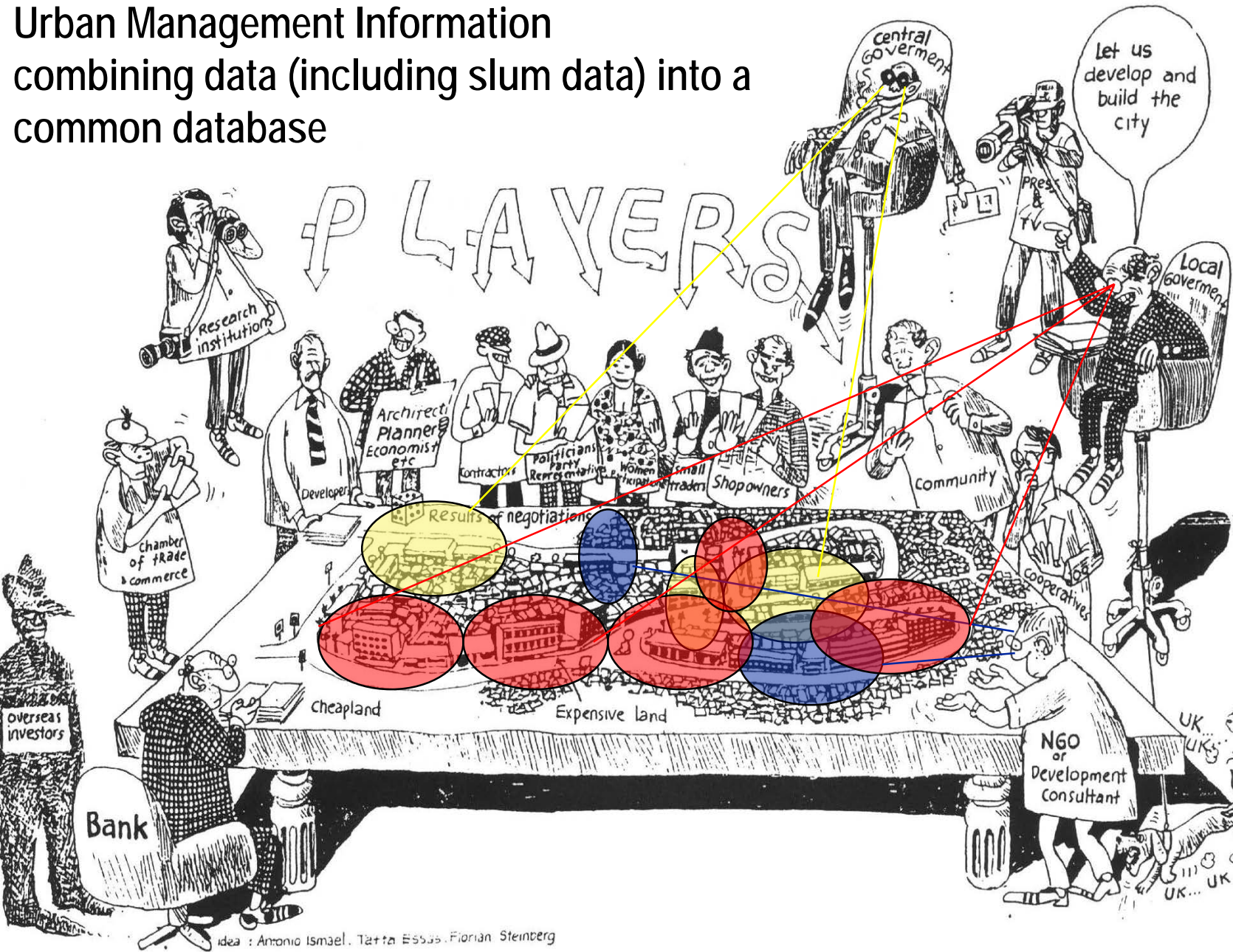
# The physical nature of slums: possible morphological characteristics of slum areas and planned areas

Morphological features	Slums /informal	Formal /planned
Size	<ul style="list-style-type: none"><li>• Small (substandard) building sizes</li></ul>	<ul style="list-style-type: none"><li>• Generally larger building sizes</li></ul>
Density	<ul style="list-style-type: none"><li>• High densities (high roof coverage)</li><li>• Lack of public spaces within or in the vicinity of residential areas</li></ul>	<ul style="list-style-type: none"><li>• Low – moderate density areas</li><li>• Provision of public spaces within or in vicinity of residential areas</li></ul>
Pattern	<ul style="list-style-type: none"><li>• Organic layout structure (disorderly road network and noncompliance with planning standards)</li></ul>	<ul style="list-style-type: none"><li>• Regular layout pattern (orderly road network and compliance with planning standards)</li></ul>

# INFORMAL VS FORMAL DEVELOPMENT PROCESS



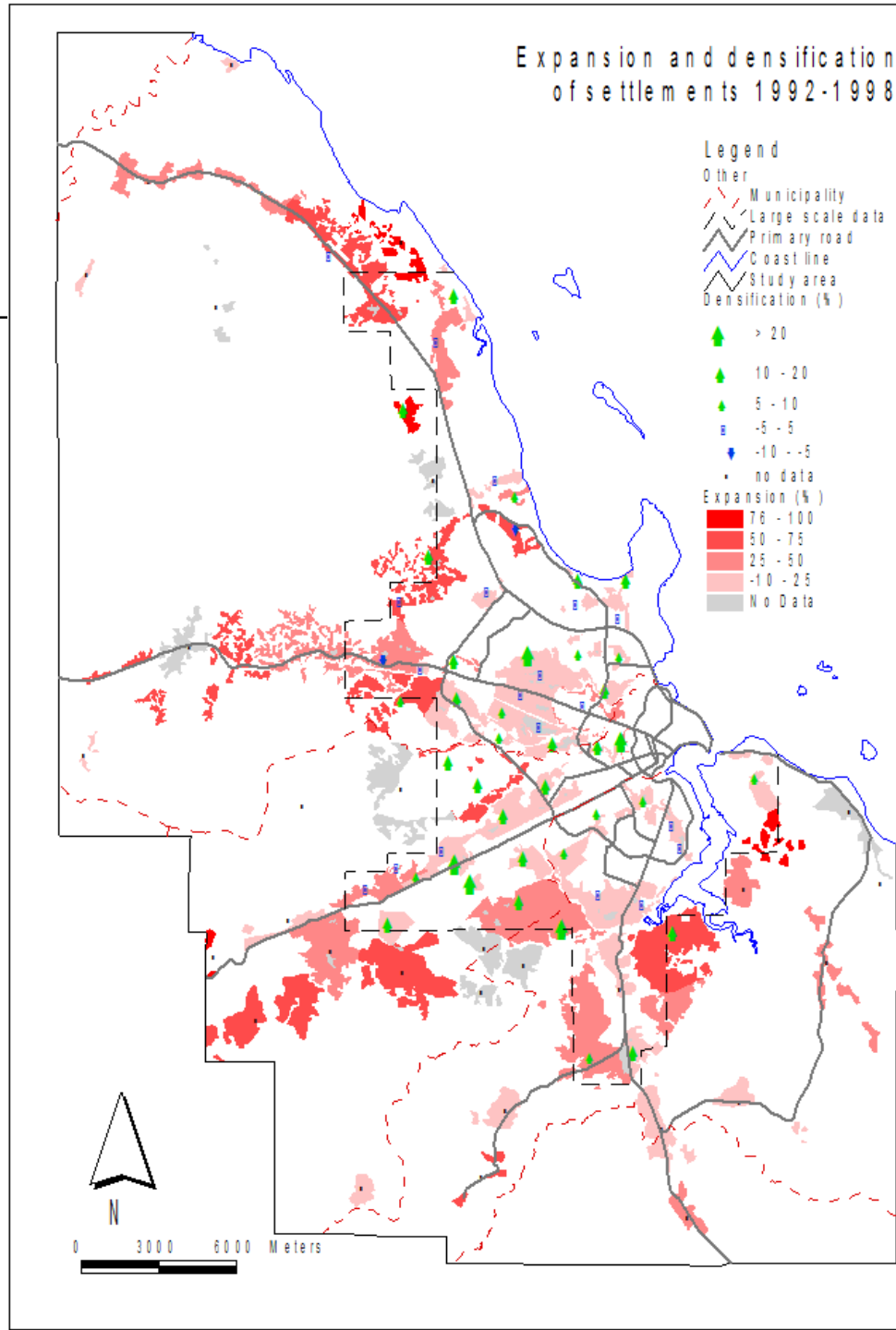
# Urban Management Information combining data (including slum data) into a common database



idea : Antonio Ismael, Tatta Essas, Florian Steinberg

# Scales of slum mapping: city wide

Location, expansion and densification  
Dar es Salaam, 1992-1998





# Modelling informal development in Dar es Salaam

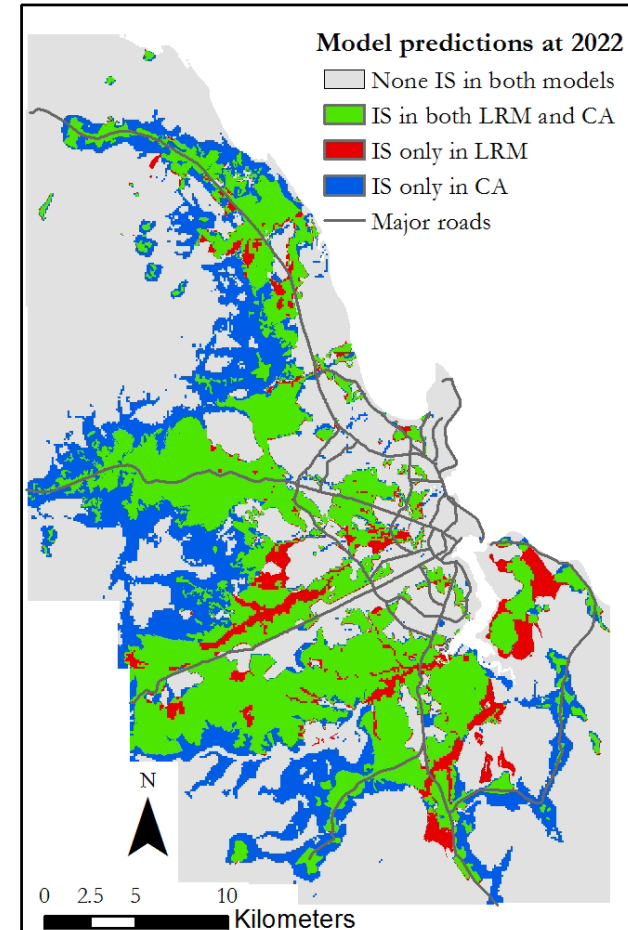
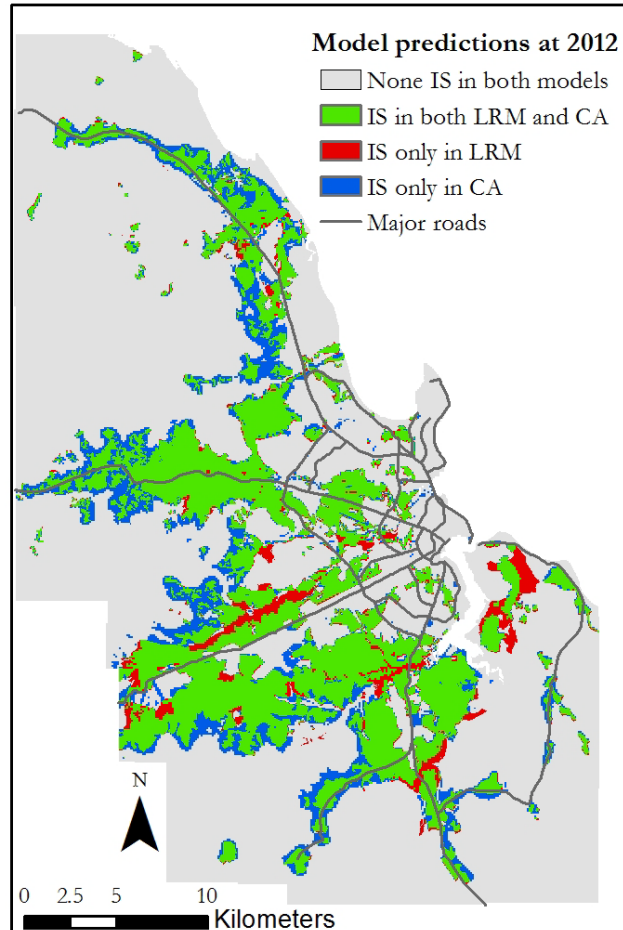
Source: Fikreselassie K. Abebe, 2011., MSc thesis.

## IS area at 2012

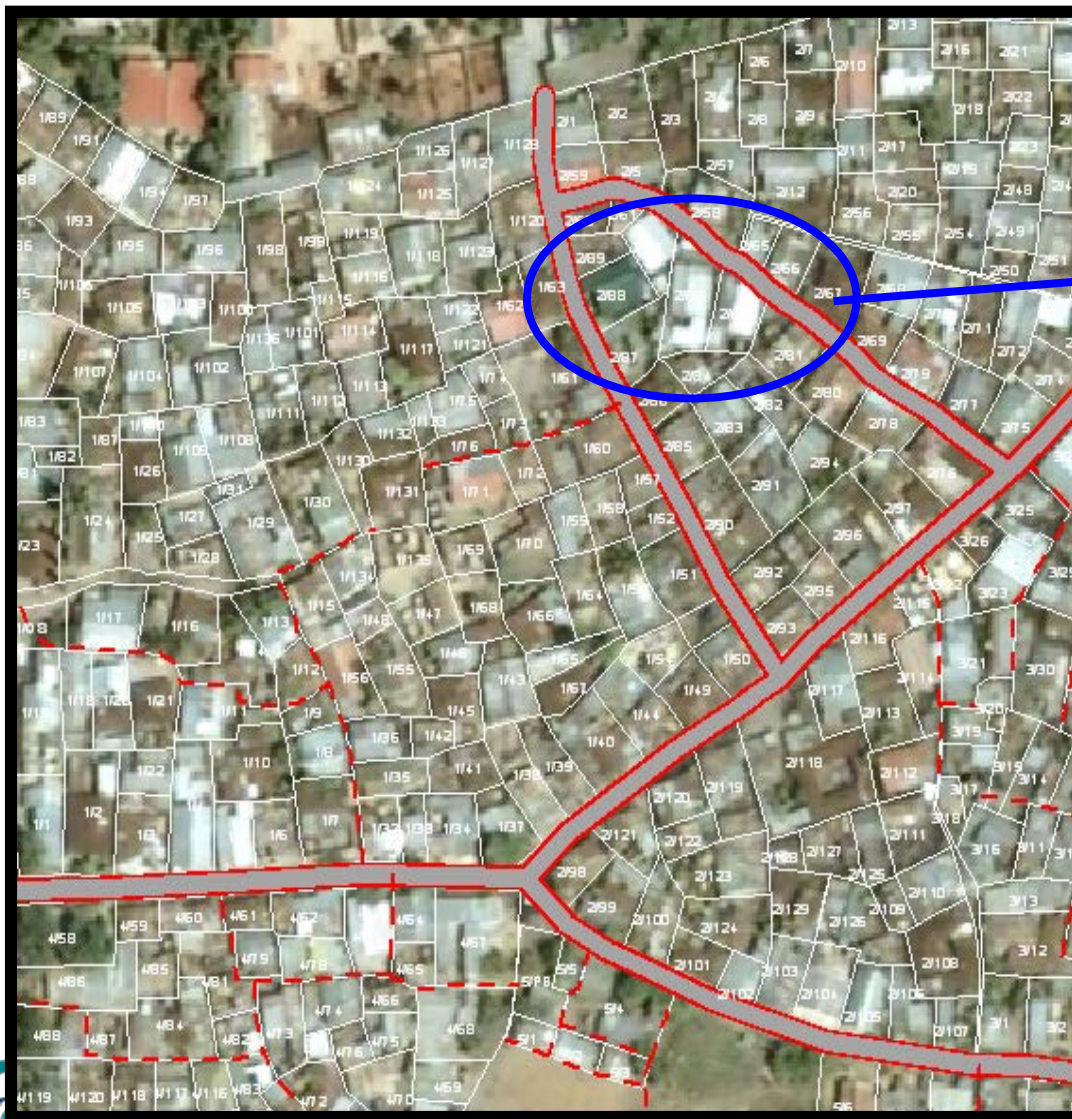
- Substantial agreement (Kappa = 0.74)
- New IS cluster around existing IS

## IS area at 2022

- Moderate agreement (Kappa = 0.56)
- Compact IS dev't by LRM
- Leapfrog IS dev't by CA



# Scales of slum mapping – settlement, plots



Shape	Polygon	
Pid	2/88	
PARCELID	KND/MNY/KKP2/88	
Wamiliki	Nicholaus Celestine Mtei	
Municipali	KINDONDONI	
Location	KWAKOPA	
Ward	MWANANYAMALA	
Street	KWAKOPA	
Proptaxno	MNY/KKP/20	
Houseno	20	
Plotdevelo	Jengo Kamilifu	
Families	1	
Occupants	8	
Bedrooms	3	
Incomeearn	1	
Polutantas	Hapana	
Residentst	Mwenye Nyumba	
Lrentpermo	0.000000	
Landuse	Biashara	
Development	Jengo Kamilifu	
Buildingsv	100000000.000000	
Access	Barabara Kuu	
Watersourc	Bomba Binafsi	
Telephone	Ndiyo	
Electricit	Ndiyo	
Wastetreat	Zinazolewa na kampuni binafsi	
Wastetreat	Zinazolewa na kampuni binafsi	
Wastecostp	500.000000	

# RESIDENTIAL LICENSE

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 la ukubwa wa Ardhi ni 340 m<sup>2</sup>

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 m/wili (2)  
kuanzia tarehe 9 mwezi Mei mwaka 2005  
hadhi 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 nja zilizo.
6. Muda wa leseni hii unaweza kuongezwa.

Imetolewa leo tarehe 9 mwezi Mei mwaka 2005 na Halmashauri ya  
MANISPAA YA KINONDONI.

Laini/Mfaloni

Jina kamili .....

Saini.....

Cheo.....

Tarehe.....



Mmiliki/Wamiliki

Jina/Majina

Saini au Dole gumba

(1) Bibi WEMBO SHABANI MARIJANI .....

(2).....

3).....



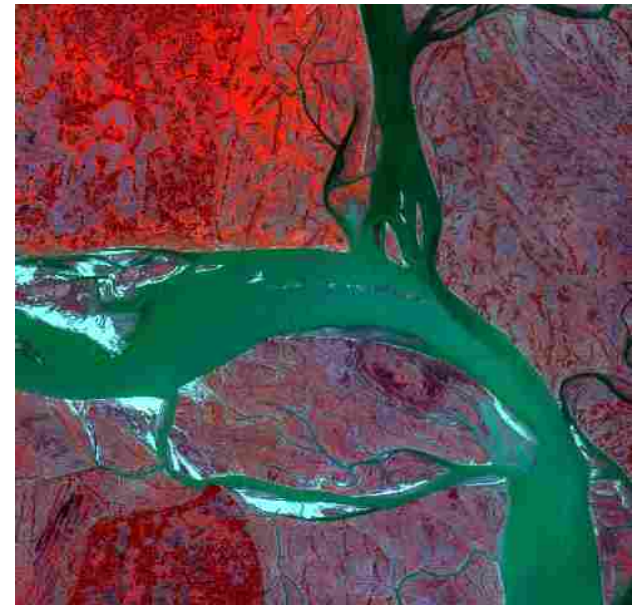
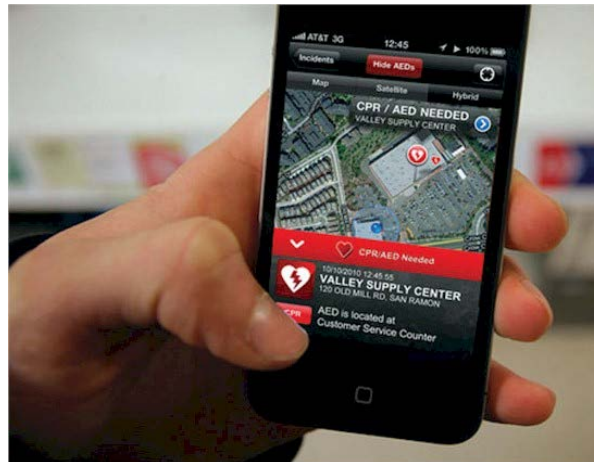
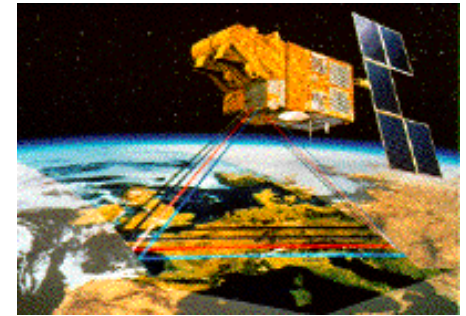
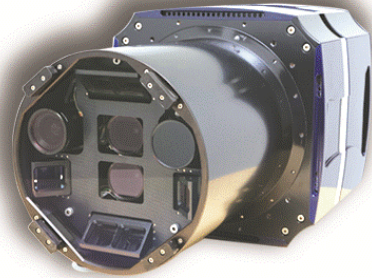
IMEAJILIWA TAREHE ..... SAA.....

MUHURI

Kuongeza Muda (Renewal) hadhi tarehe:-

1. ....
2. ....
3. ....

# Trends in geo-spatial technologies: from space to unmanned aerial vehicles & terrestrial systems





# Slum mapping

## 4 broad communities

**Professional  
public data &  
mapping services**

**Professional  
commercial data &  
mapping services**

**NGO/CBO  
participation  
& empowerment**

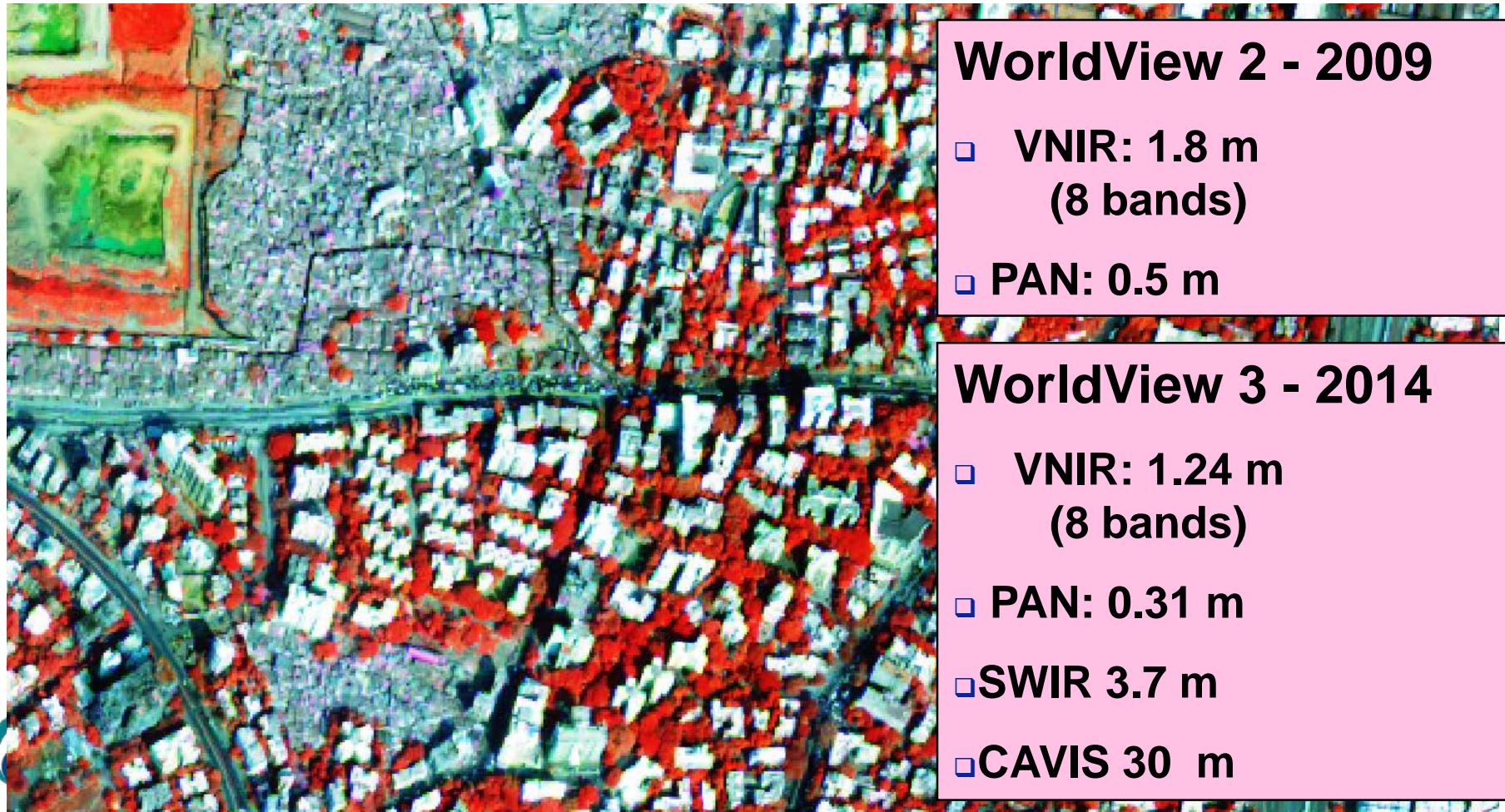
**Academic  
researchers  
new technologies  
& methods**



**How are slums being mapped?**  
UNIVERSITY OF TWENTE.

Trends in geo-spatial technologies

# Increasing spatial, spectral and temporal resolutions



## WorldView 2 - 2009

- ❑ VNIR: 1.8 m  
(8 bands)
- ❑ PAN: 0.5 m

## WorldView 3 - 2014

- ❑ VNIR: 1.24 m  
(8 bands)
- ❑ PAN: 0.31 m
- ❑ SWIR 3.7 m
- ❑ CAVIS 30 m

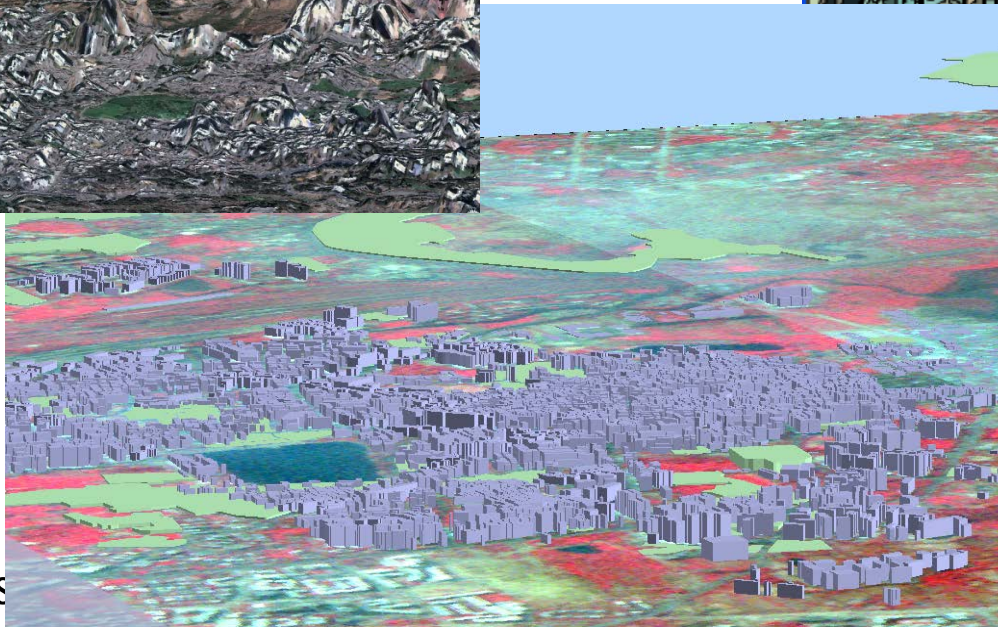
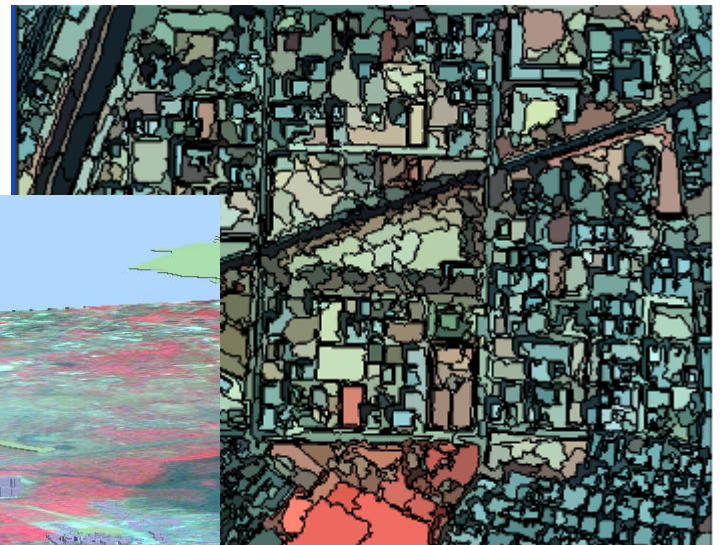
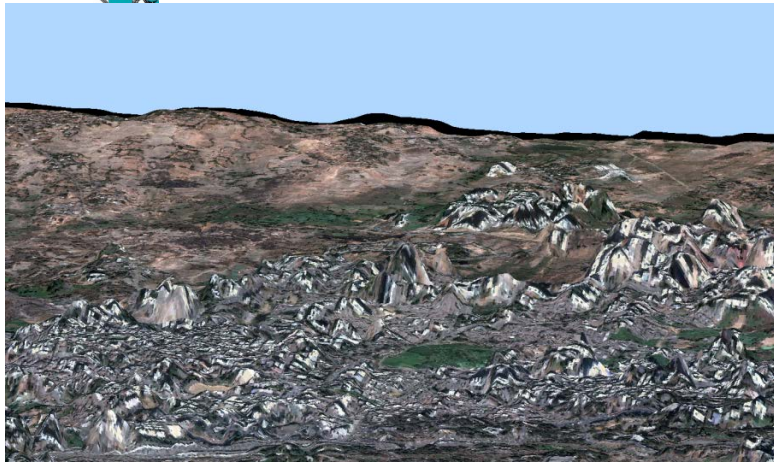
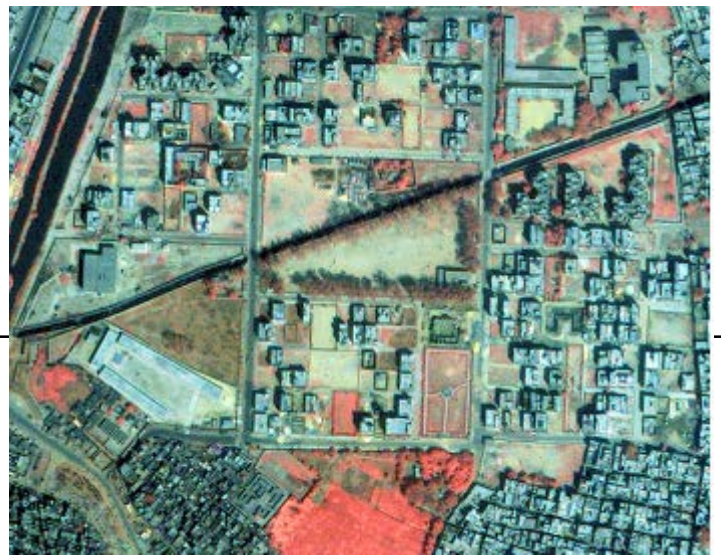
# SLUM AREA MAPPING

Slum areas are areas which are **physically deprived** in terms of the housing structure, availability of basic services and presence of open space. They share **morphological characteristics** (built-up densities, buildings sizes, organic layout patterns).



# OBIA - MUMBAI

- Image segmentation
- Rule based extraction of objects

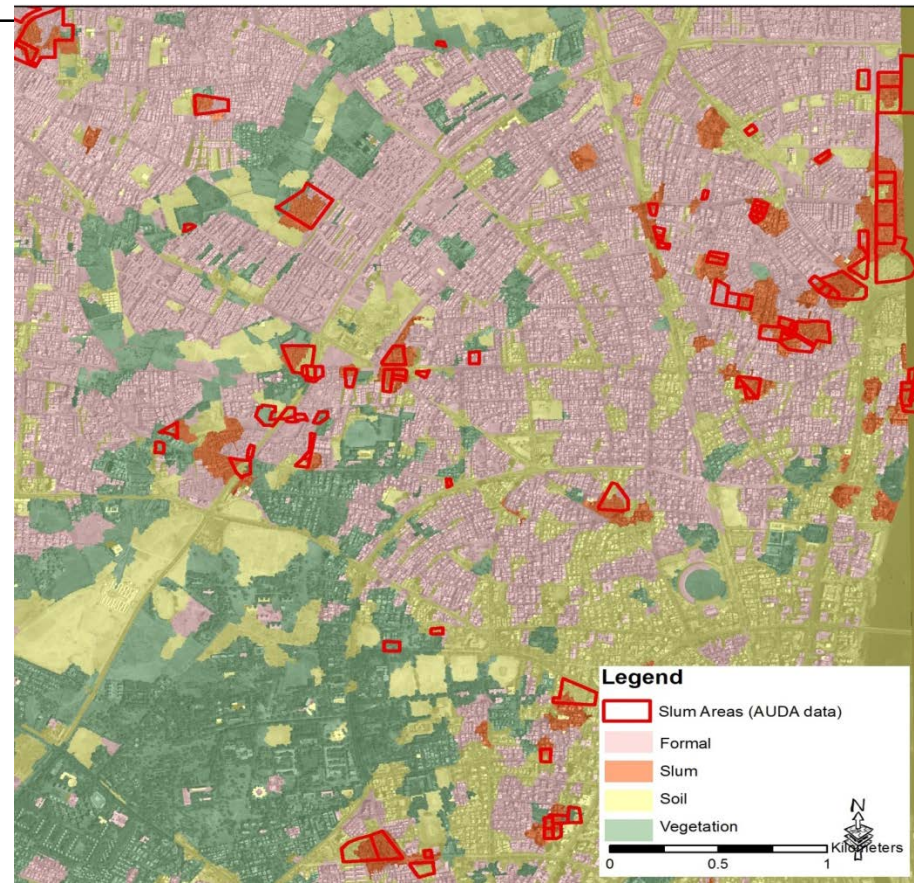
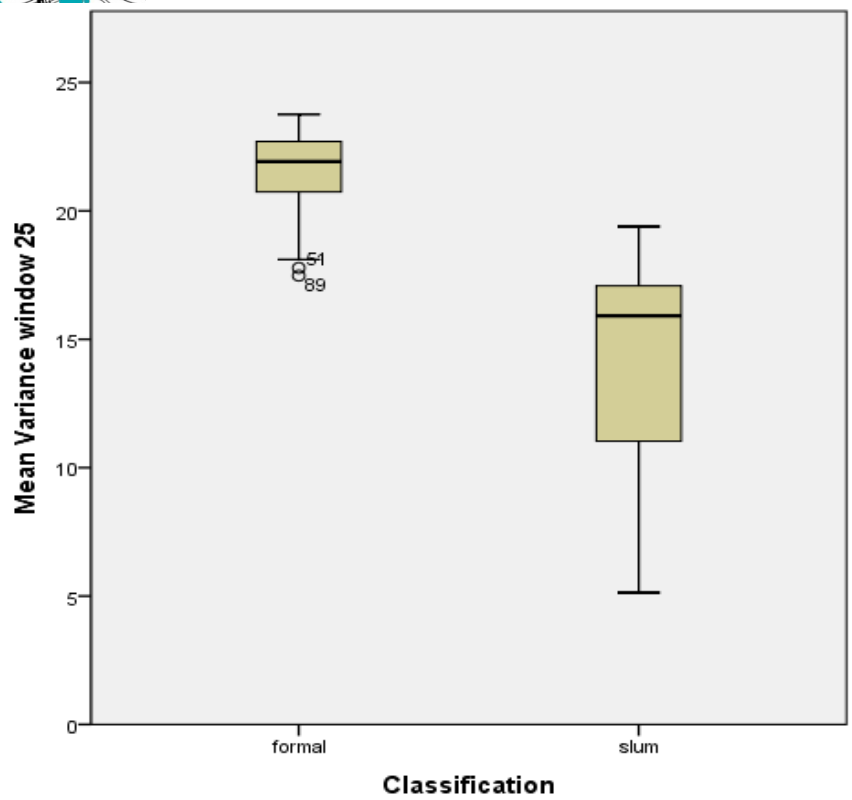






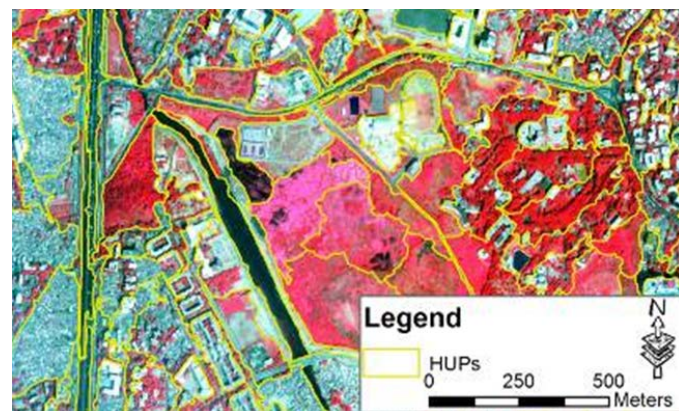
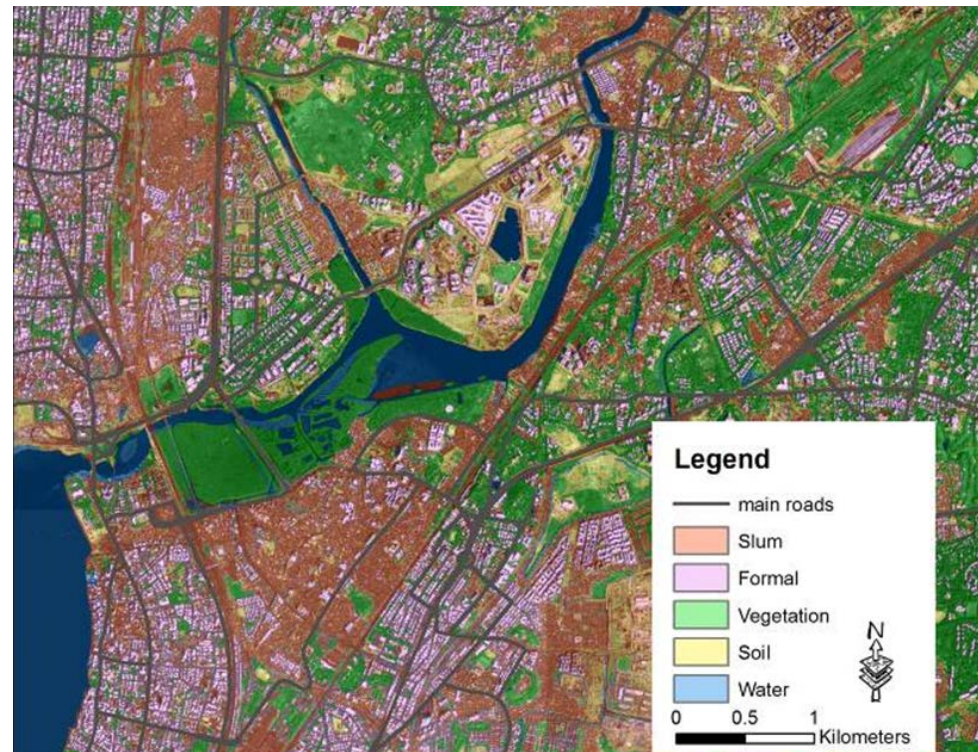
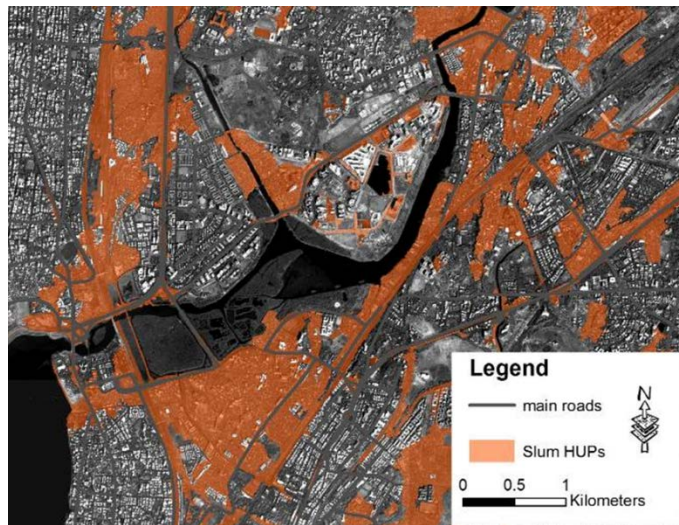
# SLUM AREA MAPPING BASED ON IMAGE TEXTURE

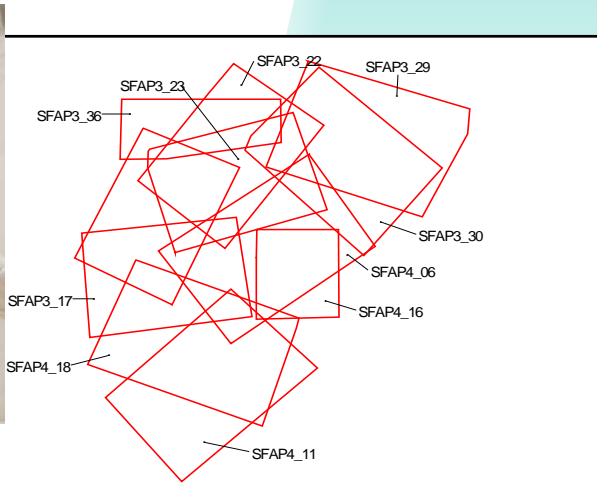
## EXAMPLE AHMEDABAD



# RANDOM FOREST CLASSIFICATION

## EXTRACTION OF SLUM AREAS (HOMOGENEOUS URBAN PATCHES) IN MUMBAI





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# OPPORTUNITIES FOR UAV MAPPING TO SUPPORT UNPLANNED SETTLEMENT UPGRADING

Caroline GEVAERT, Richard SLIUZAS, Claudio PERSELLO,  
George VOSSELMAN

UNIVERSITY OF TWENTE – FACULTY ITC  
GEOTECH CONFERENCE, RWANDA, NOV. 2015.



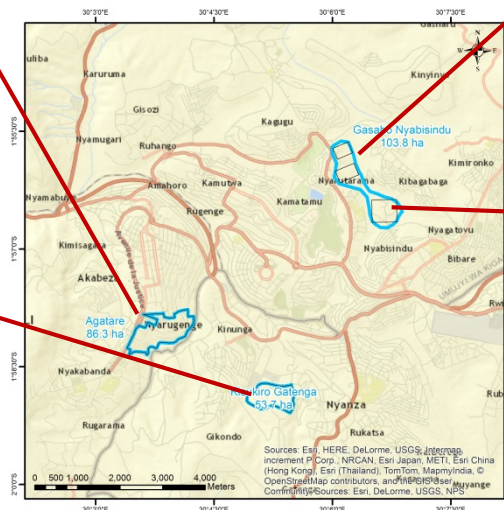
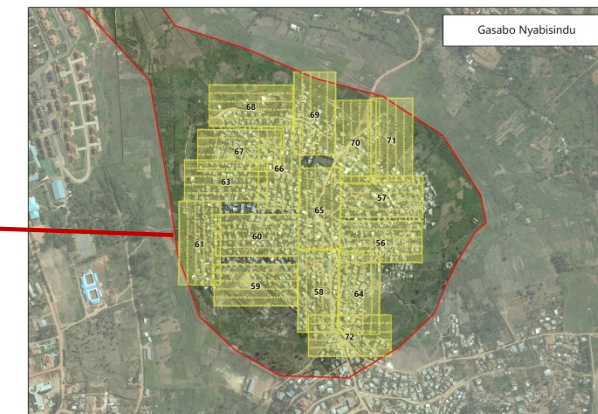
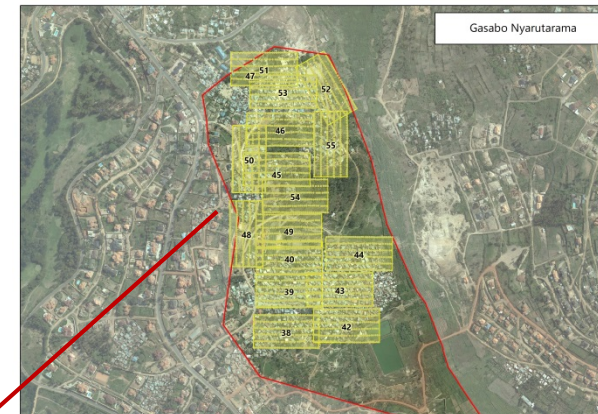
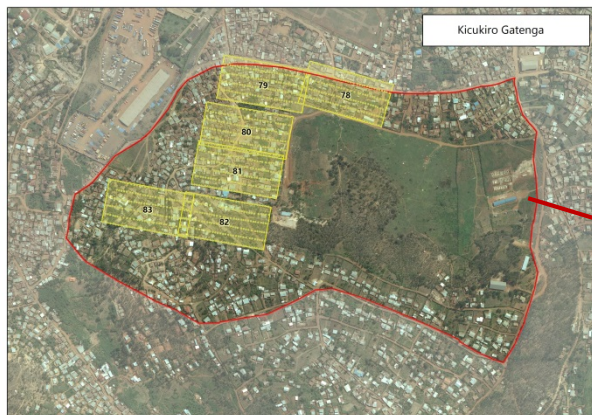
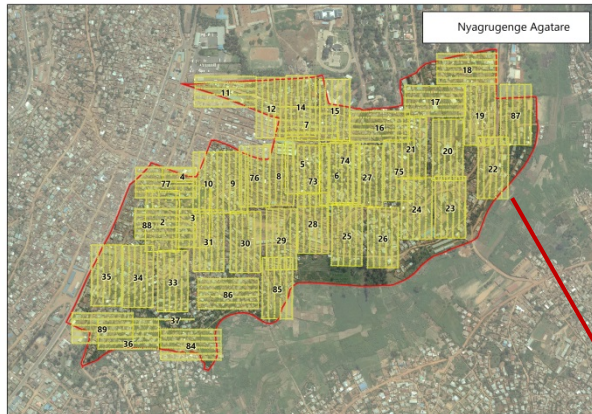
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# UAV FLIGHTS KIGALI MAY 2015

AGATARE: 86 HA – 4000 HOUSEHOLDS – 19000 PERSONS

11 days, 89 flights, 150 ha, 15 700 images

- DJI Phantom 2 Vision+, 1.2 kg., 14MP RGB camera, fish-eye lens,
- Flight planning with Pix4D app for smartphone



# SIGNIFICANCE FOR UPGRADING PROJECTS

DESCRIBE AREA AND PRIORITIZE INTERVENTIONS

Existing Orthophoto (2008, 20 cm pixels)



UAV Orthophoto (2015, 3 cm pixels)



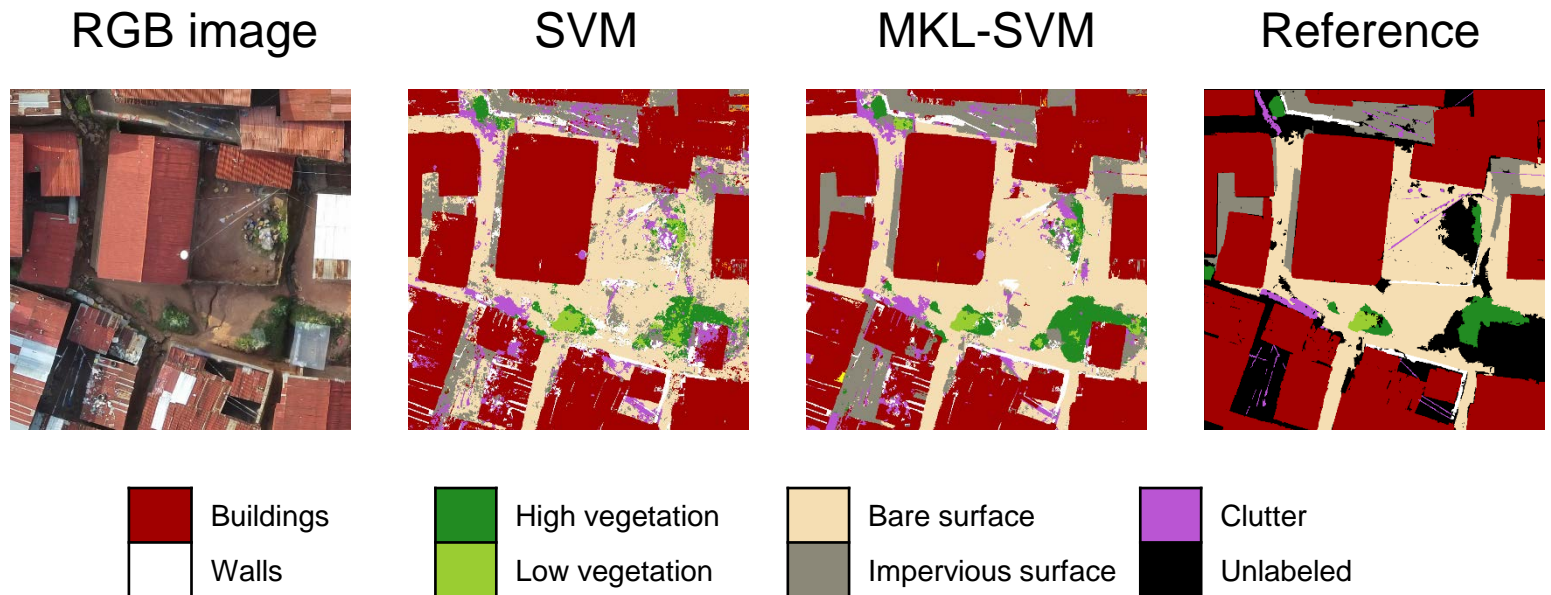






# APPROPRIATE CLASSIFICATION ALGORITHMS FOR SLUM MAPPING (GEVAERT ET AL)

- Multiple Kernel Learning (MKL) – Support Vector Machines (SVMs)
- 5.2% improvement over single-kernel SVM and 4.1% over random forests



# CLASSIFICATION RESULTS EXTENDED STUDY AREA

- Extended study area (Kigali, Rwanda)



# SIGNIFICANCE FOR UPGRADING PROJECTS

## CURRENT USAGE – PARTICIPATORY DESIGN OF UPGRADING

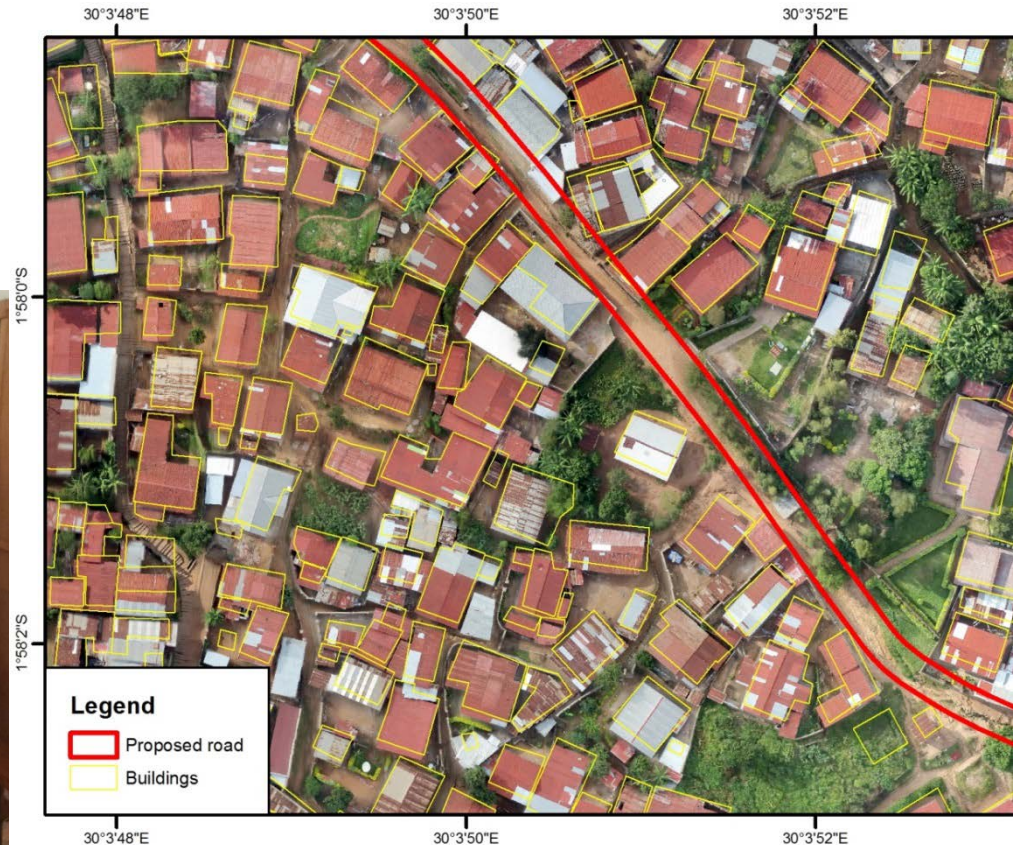
Feasibility

Prioritize

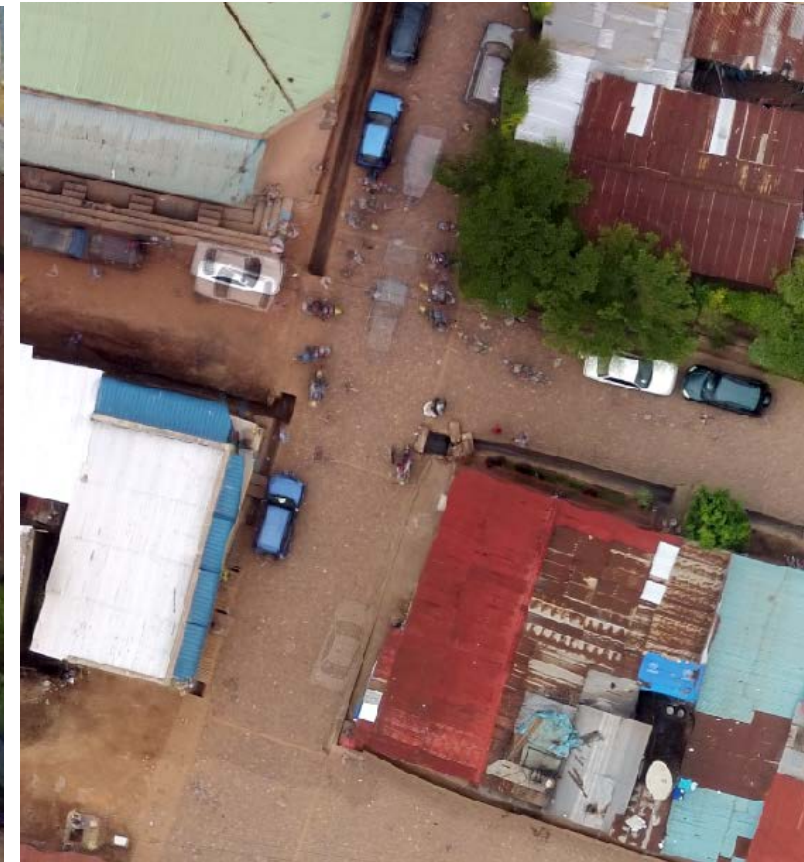
Design

Implement

- Design to mitigate expropriation
- Speed up field work
- Integrated overview of area
- Communication with residents



# DETAILS OF MOVING OBJECTS (INCLUDING MOST PEOPLE) ARE LOST IN FINAL PRODUCT (RIGHT)



But who controls access to the original images and derived products?

VERY HIGH RESOLUTION IMAGES CAN BE VERY INTRUSIVE  
PROBABLY NEED TO CONSIDER PRIVACY AND ACCESS



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# 2D & 3D MODELLING OF SLUMS USING TERRESTRIAL IMAGERY

LINUS KIHARA MWANGI

## SUPERVISORS

M. GERKE

F. NEX

C. PERSELLO

ADVISORS: C. GEVAERT, M. KOEVA, R. SLIUZAS



FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

# TERRESTRIAL DATA ACQUISITION WITH SIMPLE EQUIPMENT

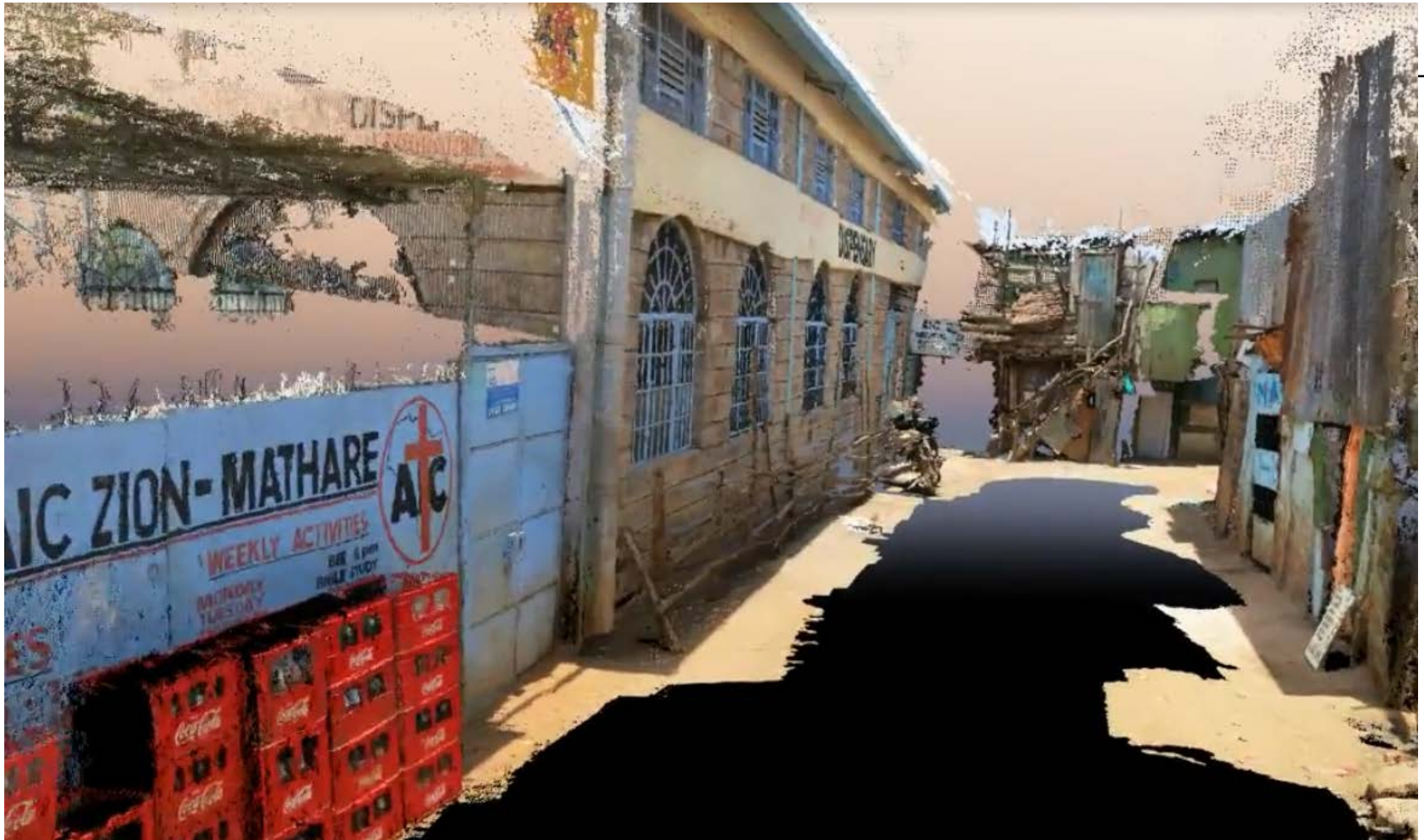


# Mapping of Mashimoni village, Mathare, Nairobi





# SNAPSHOT FROM POINTCLOUD



**FINAL PRODUCTS MAY ALSO REQUIRE SCREENING TO PROTECT PRIVACY.**



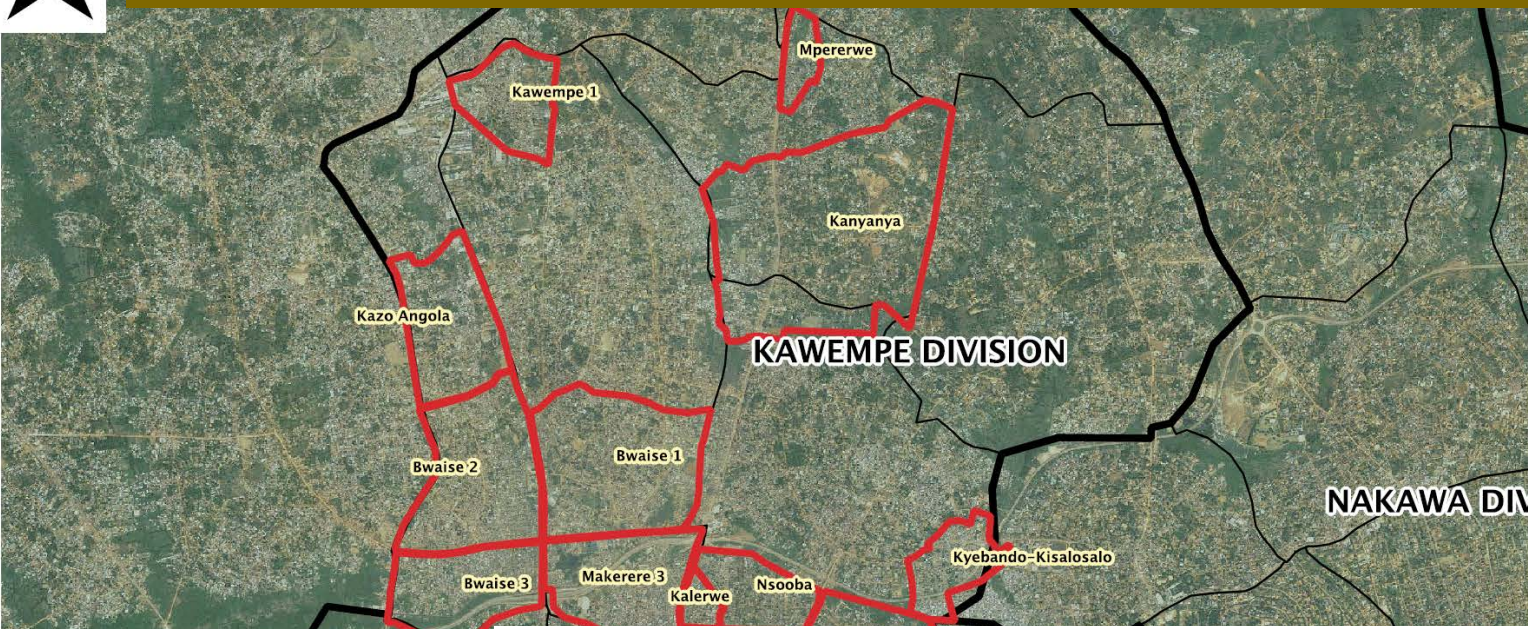
# SHOULD PEOPLE ON THE STREET BE PROTECTED?



# Participatory slum mapping NGO/CBO approaches

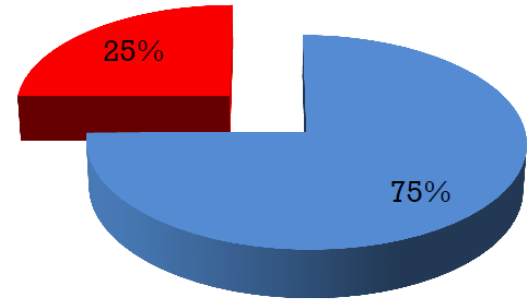


# Informal settlements in Kawempe Division Kampala



- Legend**
- Informal Settlement
  - Ward
  - Division

## KAWEMPE: SLUM COVERAGE



- Non-Slum Areas
- Slum Area



KAMPALA *SLUM*  
PROFILES 2014

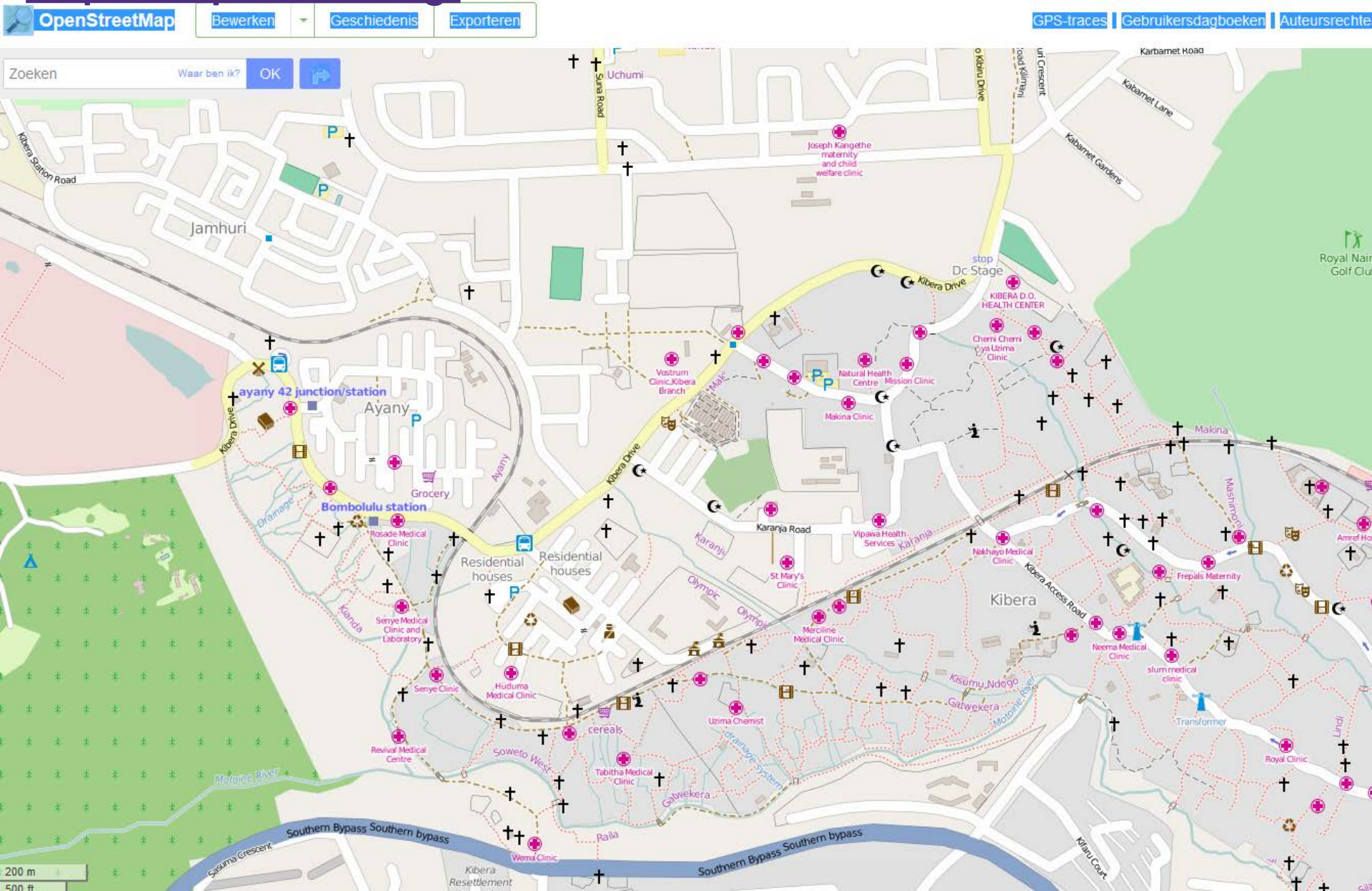


KAWEMPE DIVISION



# Participatory Voluntary Geo-Information (VGI)

<http://mapkibera.org/>



# Participatory Voluntary Geo-Information (VGI) using UAV images and open source mapping tools. [www.ramanihuria.org/](http://www.ramanihuria.org/)

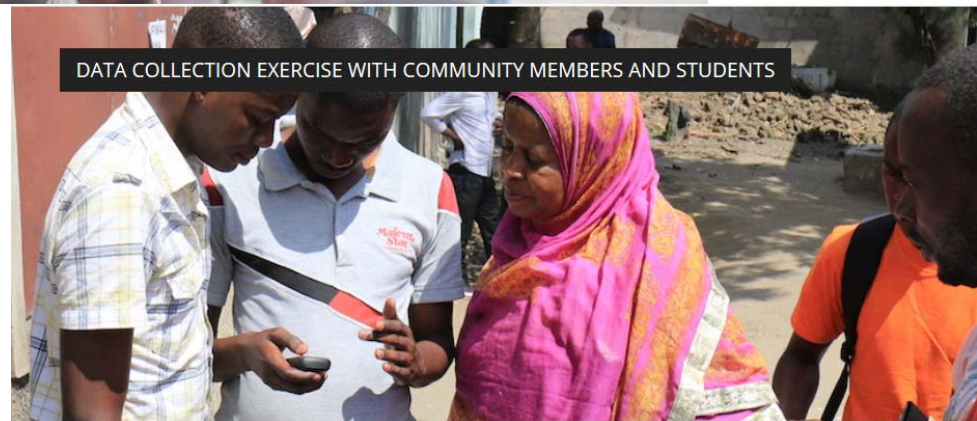


Home About Wards News Data Resources Events Language: 



Events Language: 

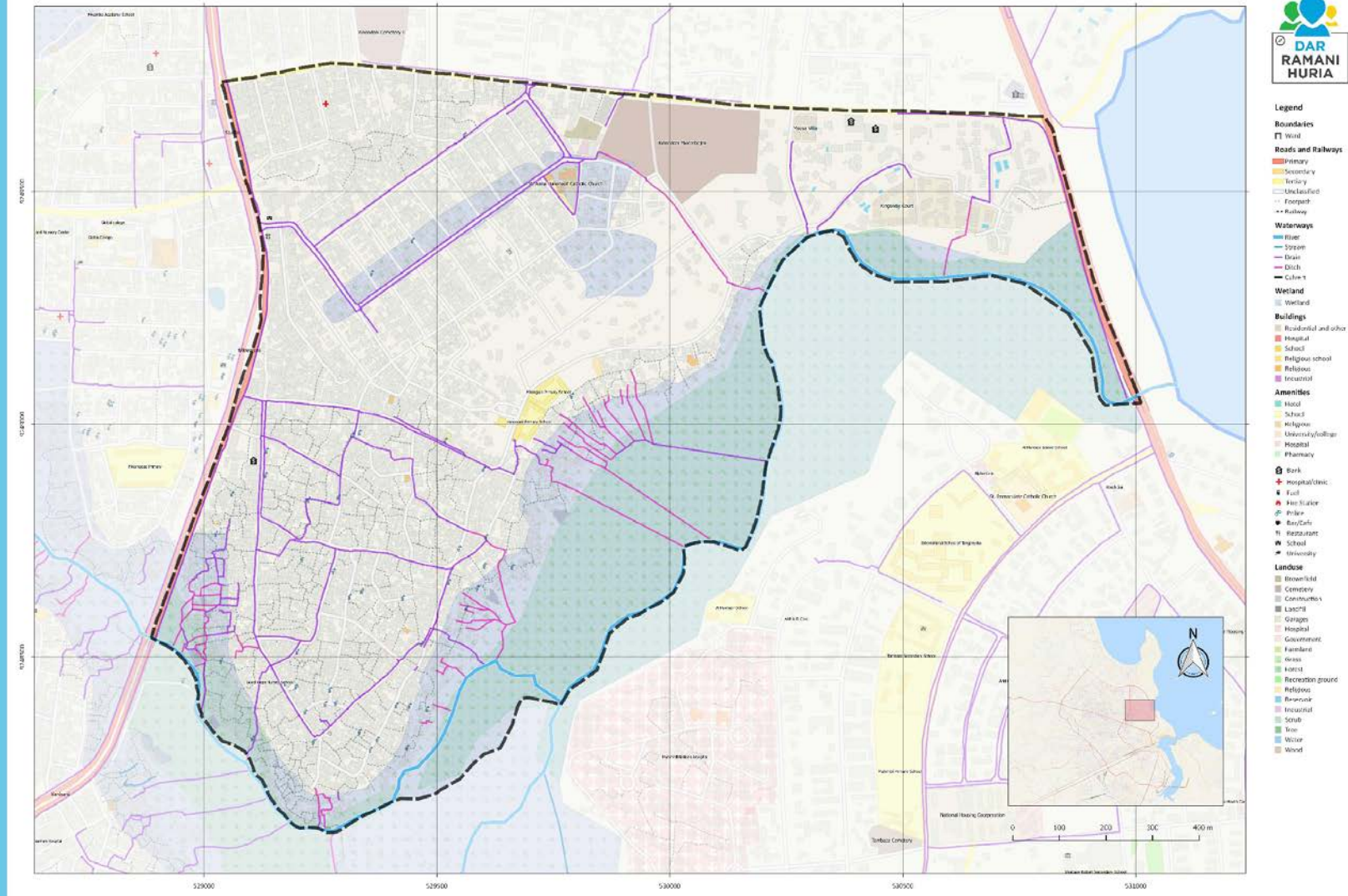
- > 90 sq.km. mapped
- Quality is variable
- How to update and maintain the database?
- Replication ongoing



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# HANA NASIF

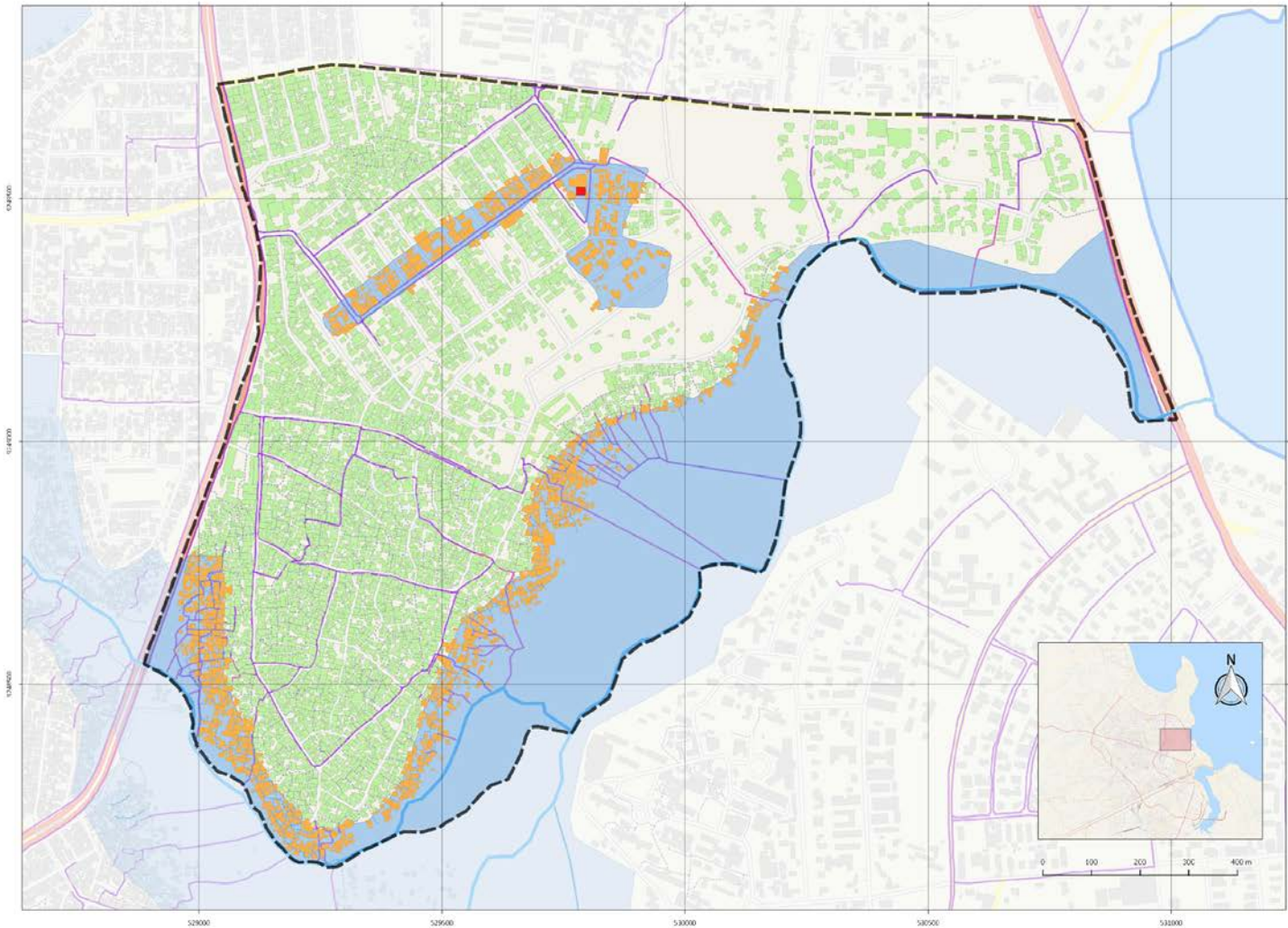
## Hananasif – Drainage Map





# HANA NASIF

## Hananasif – Inundation





# Trends in geo-spatial technologies open data and software

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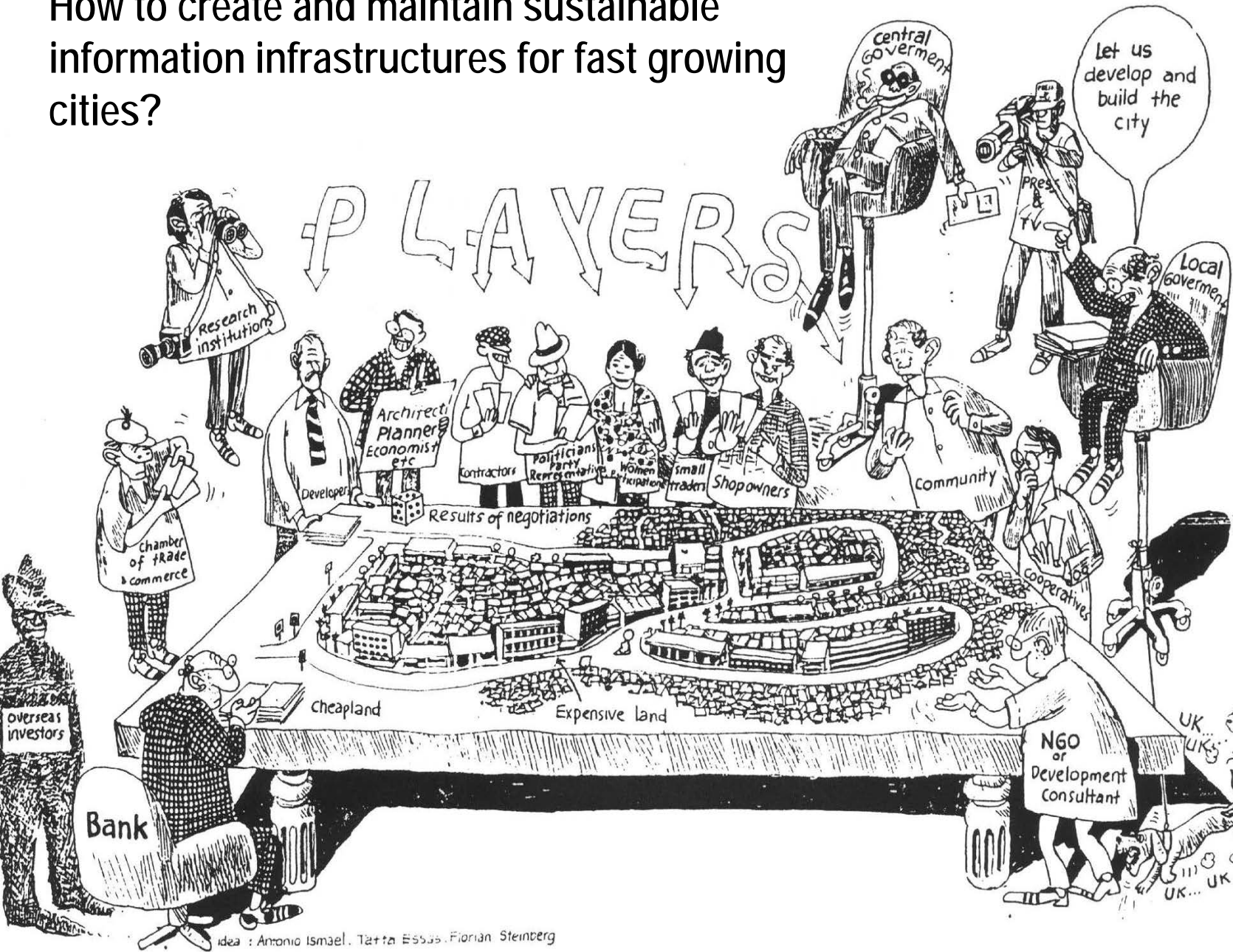
- Increasing availability of open data – e.g. promoted by Group on Earth Observation ([www.earthobservations.org](http://www.earthobservations.org)) – some images freely available
- Internet platforms for access to data and maps: OpenStreetMaps, Google Earth/Maps/Map maker, India's Buhvan server and Wikimapia etc.
- Many open source software packages (e.g. QGIS, ILWIS, GRASS, etc.)
- Advanced methods for data fusion, dense image matching, etc. to improve data extraction and quality

# Summing up

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- Developments in GIT create many opportunities for slum mapping
- Automatic slum identification, delineation and characterization is useful in certain contexts –rapidly developing research field but not yet operational.
- Social and institutional issues – governments have the power to recognize and legitimize community based slum mapping or reject it, and as well to open their spatial databases to their citizens. These choices are crucial to engage citizens as partners in urban planning and management
- Mapping is not a one off exercise: slums change rapidly so we need to create and maintain data on slums – think in terms of databases not maps.
- Building knowledge and capacity and actions more important than the geospatial technologies and the maps themselves.

# How to create and maintain sustainable information infrastructures for fast growing cities?



idea : Antonio Ismael, Tatta Essas, Florian Steinberg

# Other resources

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- Online video lecture: <http://uni.unhabitat.org/new-lecture-release-s03e06-richard-sliuzas-implications-of-developments-in-geo-spatial-technologies-for-slum-dwellers/>
- Kuffer, M., Pfeffer, K., & Sliuzas, R. (2016). Slums from space-15 years of slum mapping using remote sensing. *Remote Sensing*. <http://doi.org/10.3390/rs8060455>
- Sliuzas, R., Kuffer, M., Gevaert, C., & Pfeffer, K. (2017). Slum mapping From space to unmanned aerial vehicle based approaches. In *Proceedings of Joint urban remote sensing event (JURSE) 2017, 6-8 March 2017, Dubai, United Arab Emirates*. (pp. 1–4). Dubai: IEEE.
- Kohli, D. (2015). *Identifying and classifying slum areas using remote sensing*. University Twente. Retrieved from <http://purl.org/utwente/doi/10.3990/1.9789036540087>

# Other resources

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- Taubenbock, H., & Kraff, N. J. (2013). The physical face of slums: a structural comparison of slums in Mumbai, India, based on remotely sensed data. *Journal of Housing and the Built Environment*. <http://doi.org/DOI 10.1007/s10901-013-9333-x>
- Sliuzas, R. V, & Kuffer, M. (2008). Analysing the spatial heterogeneity of poverty using remote sensing : typology of poverty areas using selected RS based indicators. *In: Remote Sensing : New Challenges of High Resolution, EARSeL, Joint Workshop, 5-7 March 2008 Bochum, Germany / Ed. by C. Jürgens. Bochum : EARSeL, 2008. ISBN 978-3-925143-79-3. Pp. 158-167*. Retrieved from [http://intranet.itc.nl/papers/2008/conf/sliuzas\\_ana.pdf](http://intranet.itc.nl/papers/2008/conf/sliuzas_ana.pdf)
- Kuffer, M., Orina, F., & Sliuzas, R. (2017). Spatial Patterns of Slums : Comparing African and Asian Cities. In *JURSE 2017* (pp. 7–10). Dubai: IEEE.
- Kohli, D., Sliuzas, R., & Stein, A. (2016). Urban slum detection using texture and spatial metrics derived from satellite imagery. *Journal of Spatial Science*, 8596(May), 1–22. <http://doi.org/10.1080/14498596.2016.1138247>