ACC DAR Adapting to Climate Change in Coastal Dar es Salaam

International Workshop

TOWARDS SCENARIOS FOR URBAN ADAPTATION PLANNING

Assessing seawater intrusion under climate and land cover changes in Dar es Salaam, Tanzania

Investigating the Relationship between Land Cover and Vulnerability to Climate Change in Dar es Salaam

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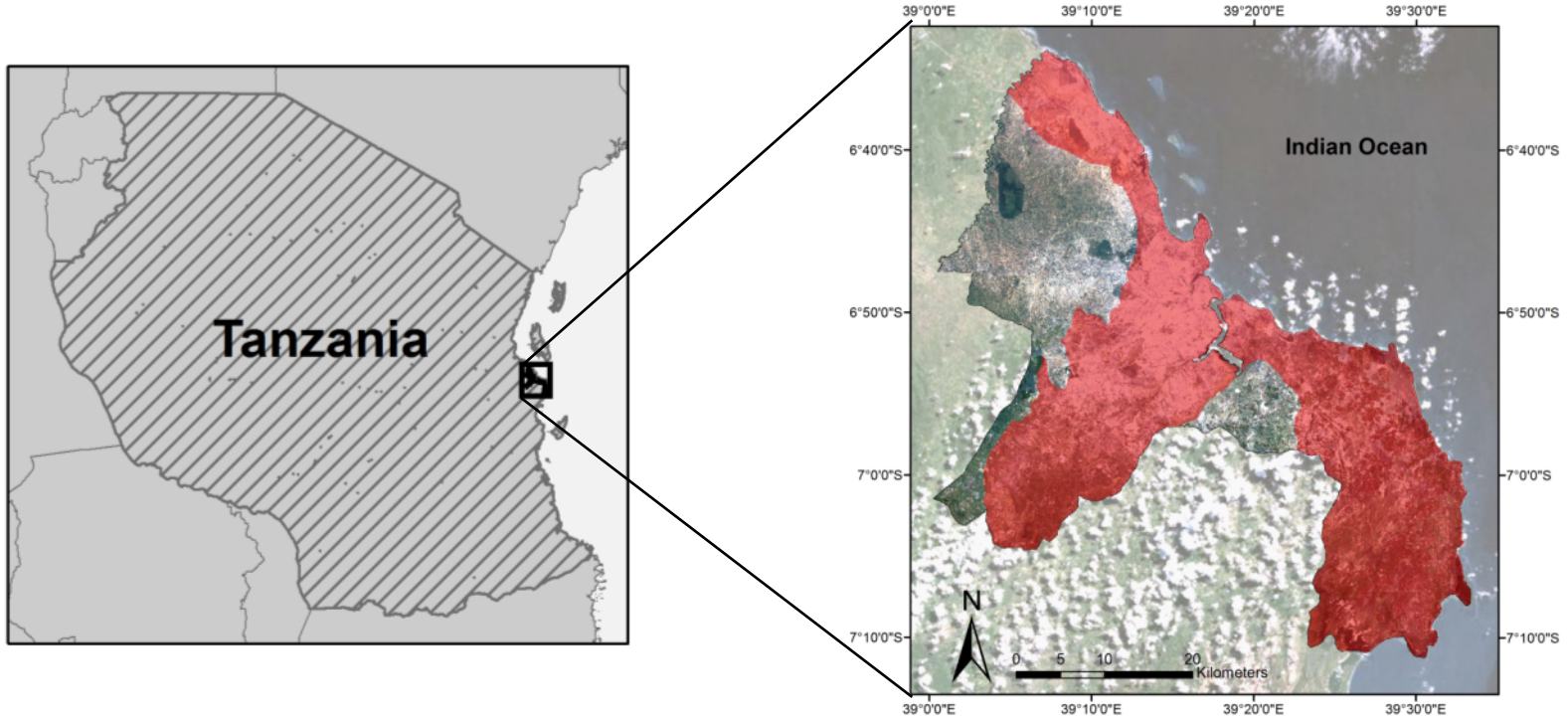
Activity 2.1

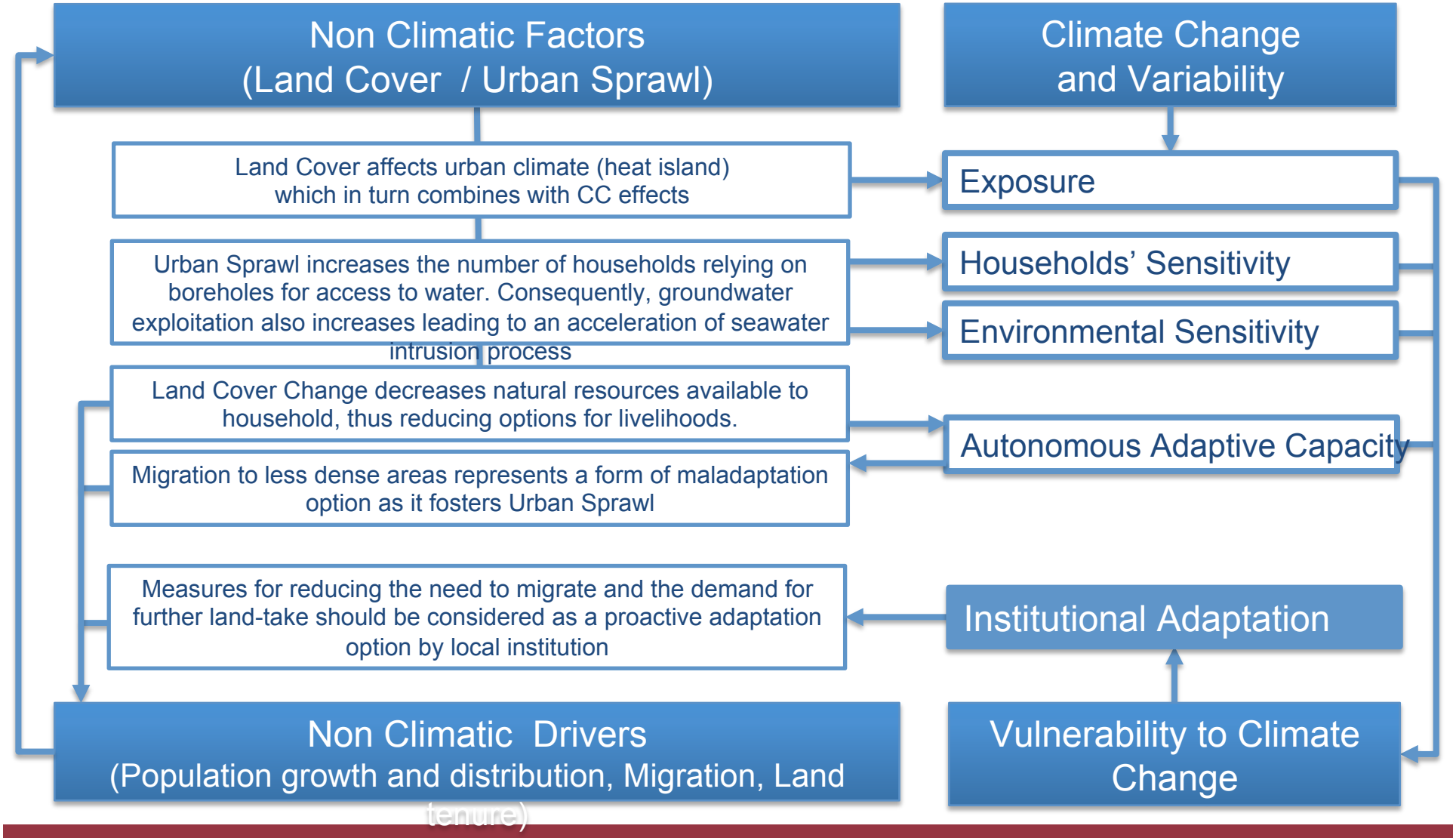
- Activity aim: develop methodologies for **monitoring changes** in **peri-urban settlements** using **remote sensing**



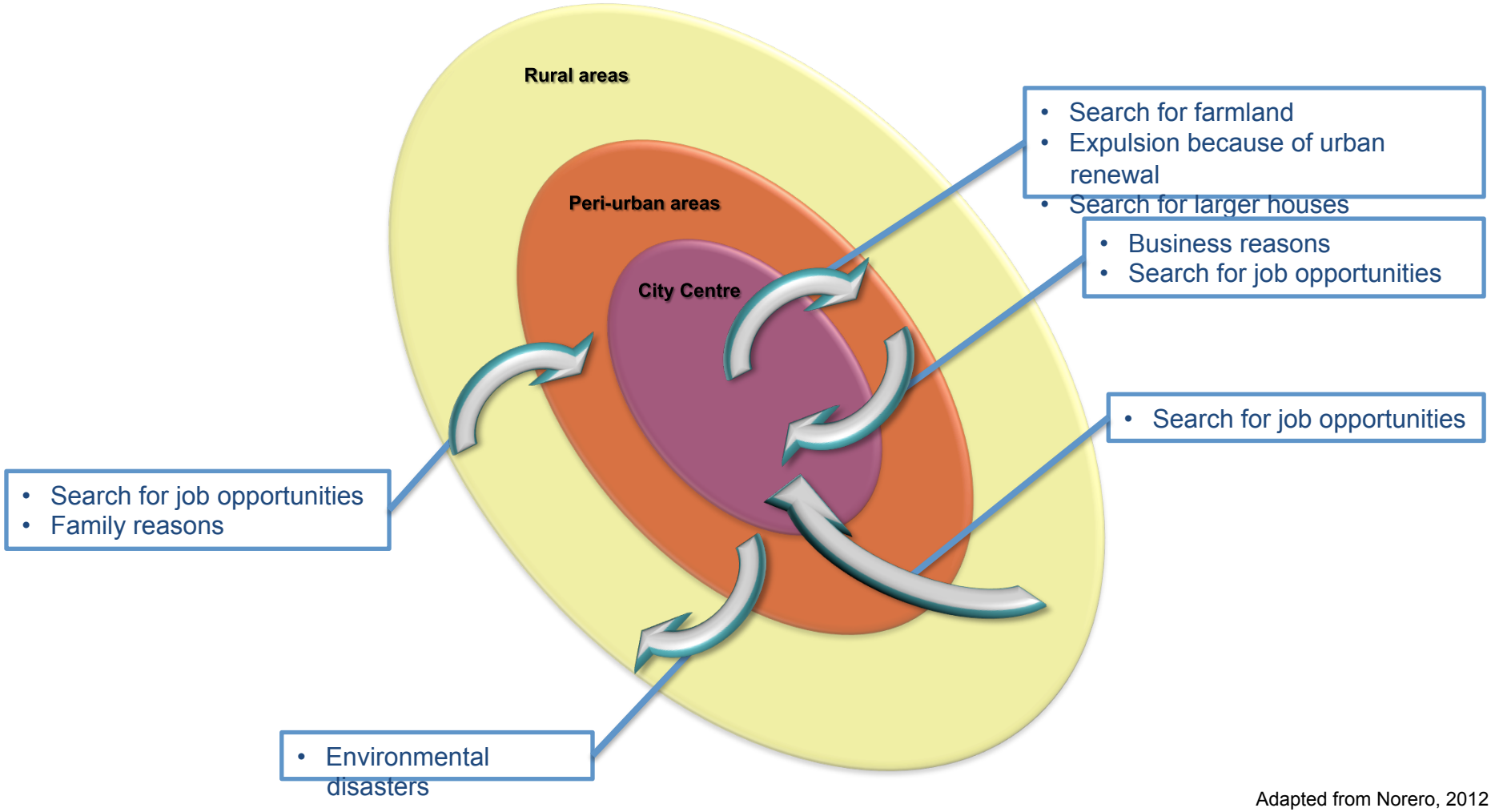
Goals of the study

- Methodology for **Land Cover (LC) monitoring**
- Analysis of **Land Cover Change** (LCC) and urban dynamics
- Investigation of the relationships between **urban sprawl and population growth**, as a first step towards the development of future urban expansion scenarios

Land Cover Change and Vulnerability to CC

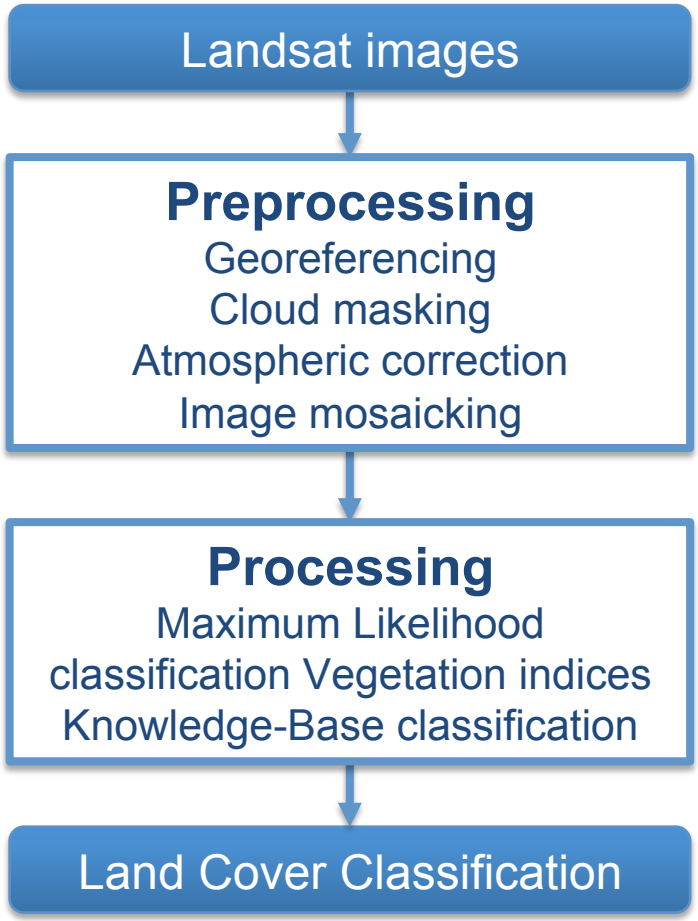


Scheme of Migration within Dar es Salaam Region



Adapted from Norero, 2012

Land Cover Classification Methodology: Workflow



Land Cover Classification Methodology: Landsat Data

- **Available for free** at the USGS Landsat archive (http://landsat.usgs.gov/):
  - Images have **6 multispectral bands** with a **spatial resolution of 30m**
  - About 60 images acquired from 1984 to 2011 were downloaded
- Imagery issues :
  - Landsat 7 images acquired after 2003 have SLC-off gaps
  - Cloud cover is often present in most of Landsat images
- New satellite (Landsat 8) already in orbit (public release of data beginning in late May 2013)

Land Cover Classification Methodology: Preprocessing

- Main steps
  - Convert **DN to reflectance**, applying atmospheric correction (DOS1 image based model)
  - Image **georeferencing**
  - Create **clouds mask** and shadows mask
  - Apply clouds and shadows masks
  - Combine multiple images in a **mosaic** in order to obtain a cloud -free image

Land Cover Classification Methodology: Processing

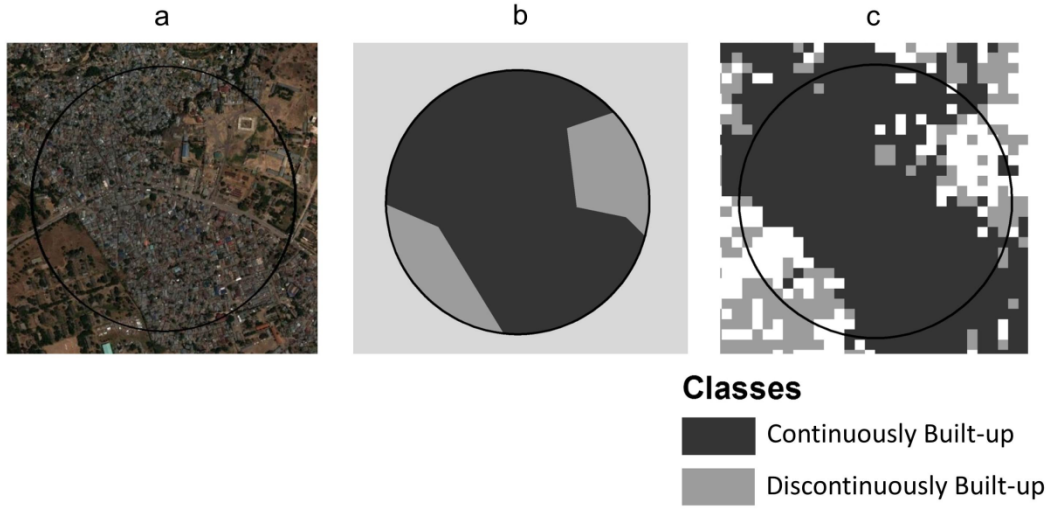
- Definition of the **training areas** identifying the classes
- Classification using the **Maximum Likelihood** (ML) algorithm
- Calculation of **vegetation indices** (NDVI)
- Refinement of ML classification using **Knowledge-base classification** with ancillary data and vegetation indices

Land Cover Classification

- Spatial resolution: 30m
- Identified LC classes:
  - "**Continuously Built-up**", a densely developed class
  - "**Discontinuously Built-up**", an urbanized class with low-density development
  - "Soil", bare soil or sparse vegetation
  - "Full Vegetation", very green and abundant vegetation (mainly trees)
  - "Mostly Vegetation", a less green class of vegetation (typically grass and brush)
  - "Water"

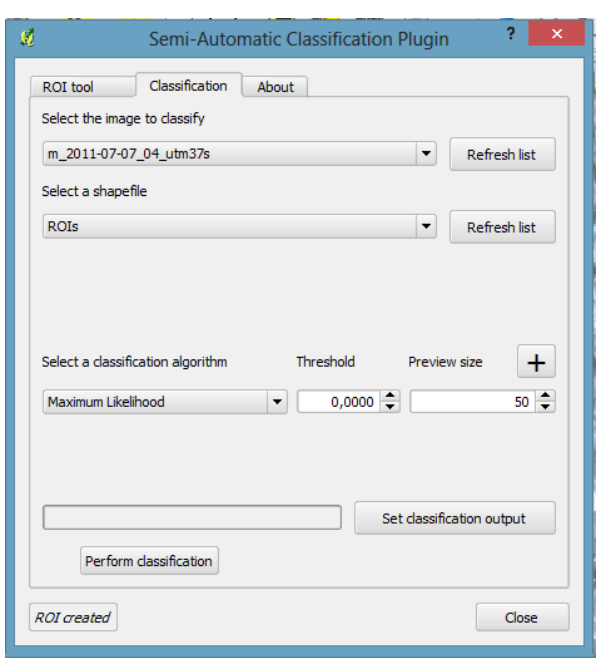
Land Cover Classification: Validation Methodology

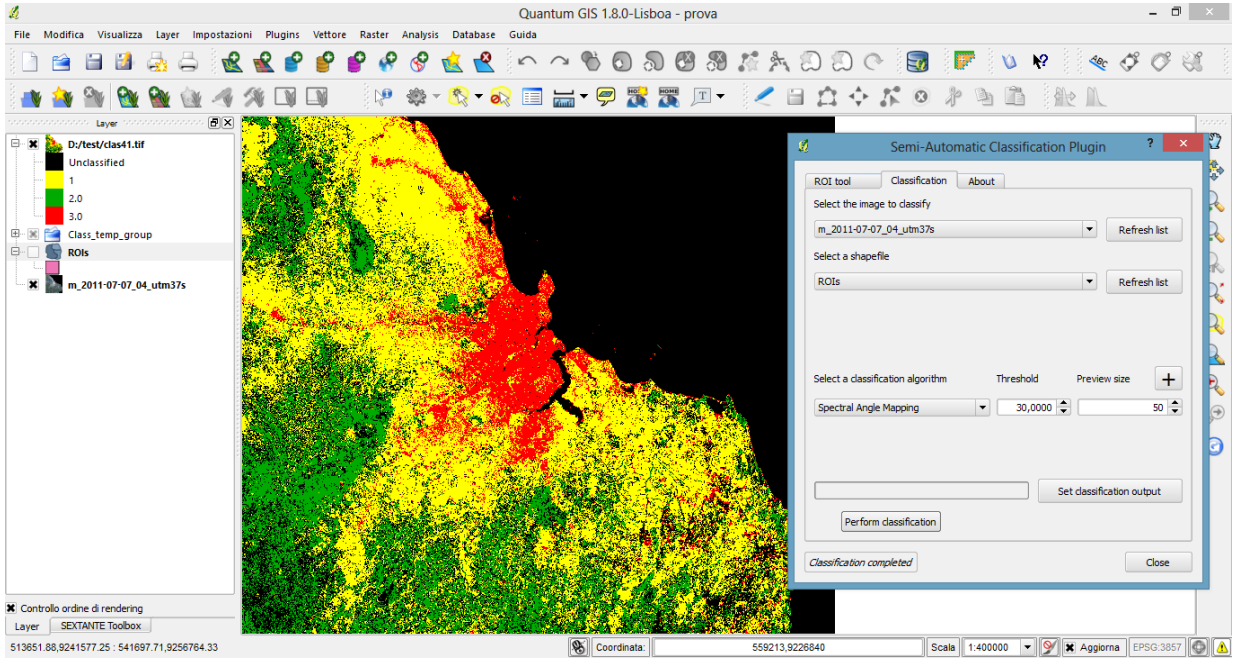
- **Accuracy assessment**: comparison of LC classification to **ground truth data**
- **Photo interpretation** of reference images (high resolution)
- Calculation of fuzzy **error matrices**
- **Field survey** for the validation of the photo interpretation



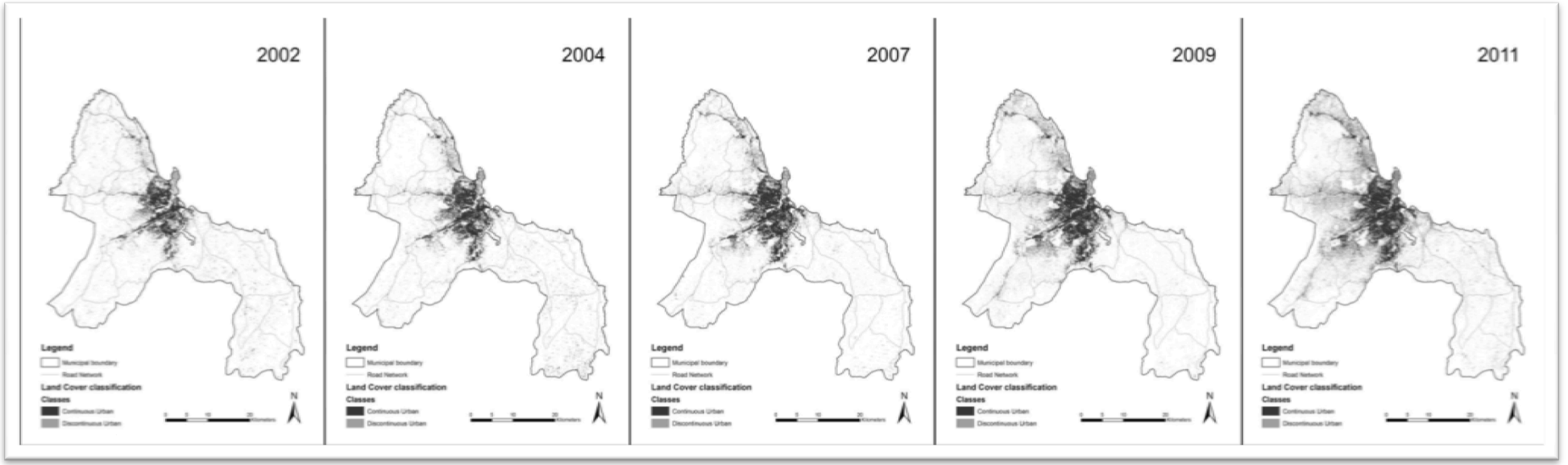
Land Cover Classification:
Semi-Automatic classification plugin for QGIS

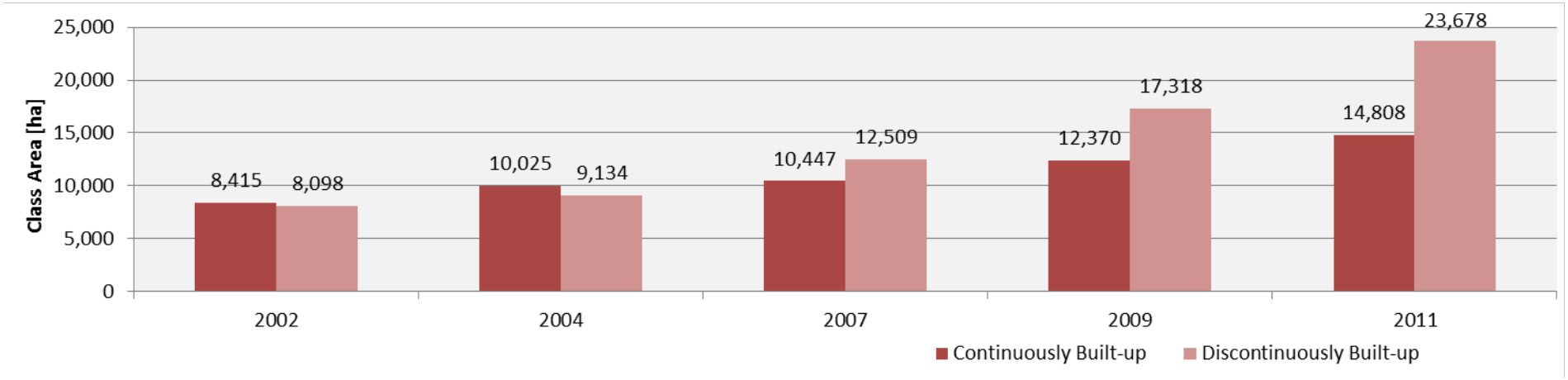
- **Free open source** (based on SEXTANTE, Orfeo Toolbox and SAGA)
- Allows for the training area collection through the **region growing**
- Allows for the LC classification using **several algorithms**





Land Cover Classification: Results





Land Cover Change

- Increase of built-up LC classes

	Area 2002 [ha]	**Area 2011** [ha]	**Growth** (%)
Continuously Built-up	8,415	14,808	+76
Discontinuously Built-up	8,098	23,678	+192

- LCC from 2002 to 2011

Land Cover Change Class	**Area [ha]**
Continuously Built-up in 2002	6,402
Discontinuously Built-up converted to Continuously Built-up (2002-2011)	2,856
Non-urban converted to Continuously Built-up (2002-2011)	5,550
Non-urban converted to Discontinuously Built-up (2002-2011)	15,580

- Urban Sprawl Indicator

$$Urban\ Sprawl\ Indicator = \frac{Discontinuously\ Built-up\ area}{Total\ Urban\ area} * 100$$

Year	2002	2004	2007	2009	2011
Urban Sprawl Indicator [%]	49.0	47.7	54.5	58.3	61.5

Land Cover Classification: Limits

- Sources of classification errors:
  - The **high cloud cover**, and the need to mosaic different images adds spectral variability to Land Cover classes
  - **Spectral similarity** between soil and white roofs
  - In low density built-up the **pixel is mixed** (because of **spatial resolution**) causing spectral confusion with soils, especially during the dry season
- Fuzzy accuracy for the 2011 classification:
  - Overall Accuracy = 72.0%
  - User's and Producer's accuracies

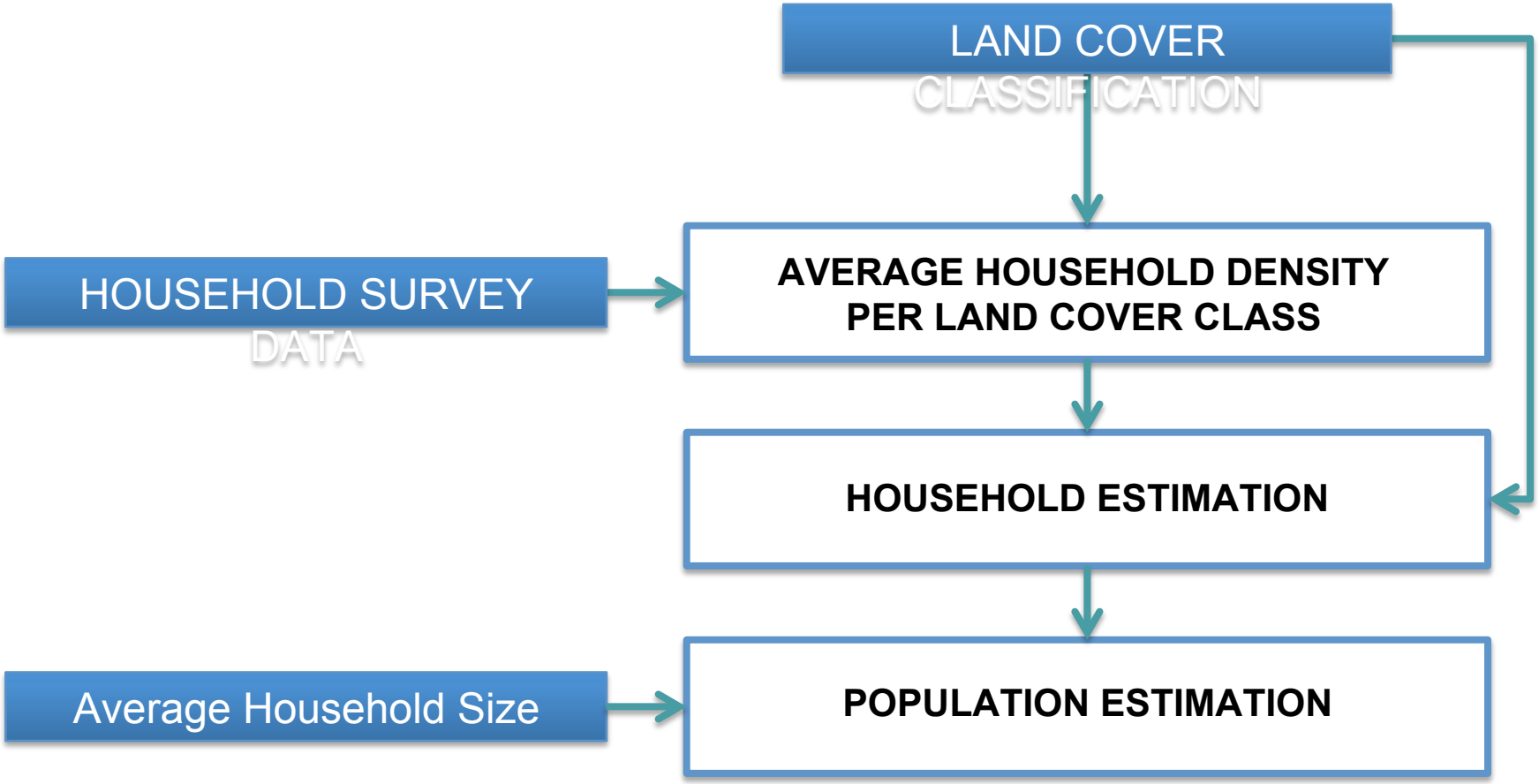
Class	User's accuracy [%]	Producer's accuracy [%]
Continuous Urban	98.0	93.1
Discontinuous Urban	97.5	70.8

Land Cover Classification: Advantages

- **Affordable methodology** for LC monitoring:
  - Free images
  - Low computer requirements
  - Free open source alternative for processing

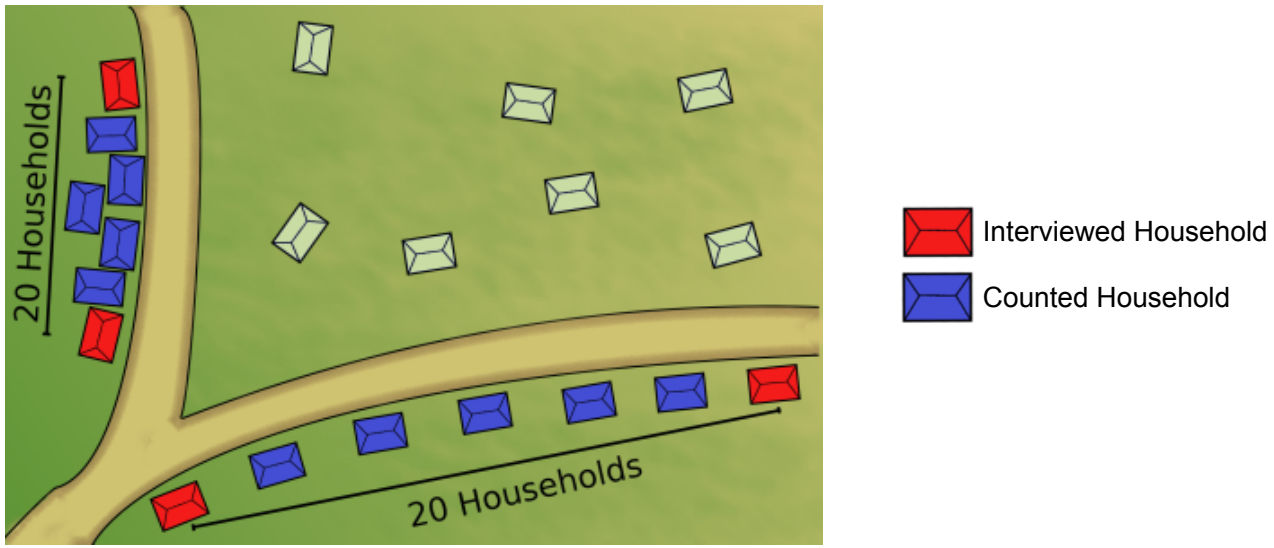
- **Assessment of LCC** over the years:
  - Monitoring urban sprawl
  - Institutions can integrate LCC assessment in planning processes

Population Estimation Workflow



Household data

- 2011 **Household Survey**, under Activity 1.1 of the project
- **5860 households** interviewed and **georeferenced with GPS**
- 20 households counted between each interviewed household
- The **distance** between two interviewed households varies with **household density**



Household Estimation

- Assumption: the **household density** around a given interviewed household is **inversely proportional to the distance** between that interviewed household and the next one in the sample
- It is then possible to calculate the **average household density per LC class** ($\bar{\rho}_i$) in relation to the **distance** (GIS spatial analysis)
- Estimation of households in Dar es Salaam =

Average Household Density x LC Class Area

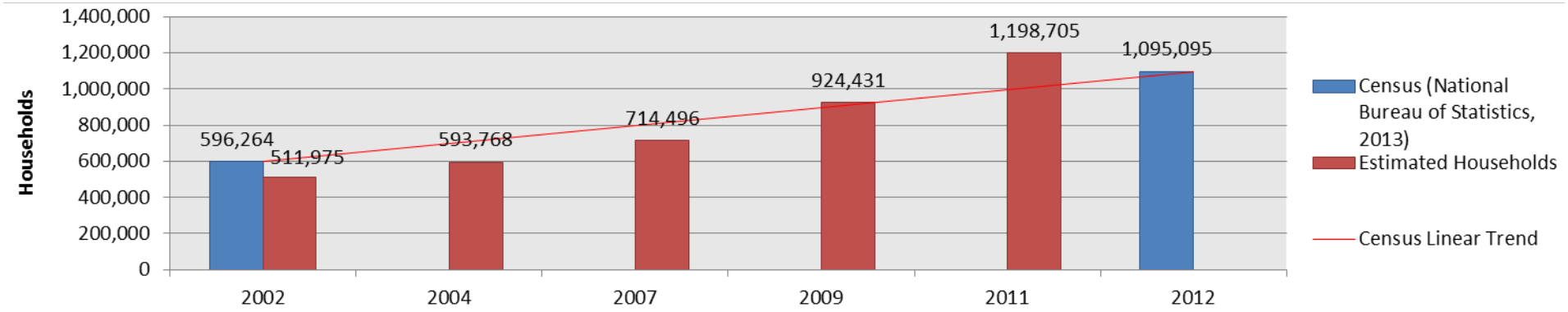
Land Cover Class	Household Estimate
Continuously Built-up	$\bar{\rho}_{\text{Continuously Built-up}} * Area_{\text{Continuously Built-up}}$
Discontinuously Built-up	$\bar{\rho}_{\text{Discontinuously Built-up}} * Area_{\text{Discontinuously Built-up}}$
Soil	$\bar{\rho}_{\text{Soil}} * Area_{\text{Discontinuously Built-up}}$
Full Vegetation	
Mostly Vegetation	
Water	

Household Estimation: Results

- Assumption: average household densities did not change over the years considered
- Household estimation in Dar es Salaam for 2002 and following years

Land Cover Class	Area [ha]	Average Household Density [household/ha]	Estimated Households
Continuously Built-up	8,365.5	31.11	260,251
Discontinuously Built-up	8,032.0	17.56	141,043
Soil	8,032.0	13.78	110,682
			Total 511,975

- Comparison between estimates and census data: **±15%**



Population Estimation

- Estimation of population in Dar es Salaam =
  Estimated Households x Average Household Size

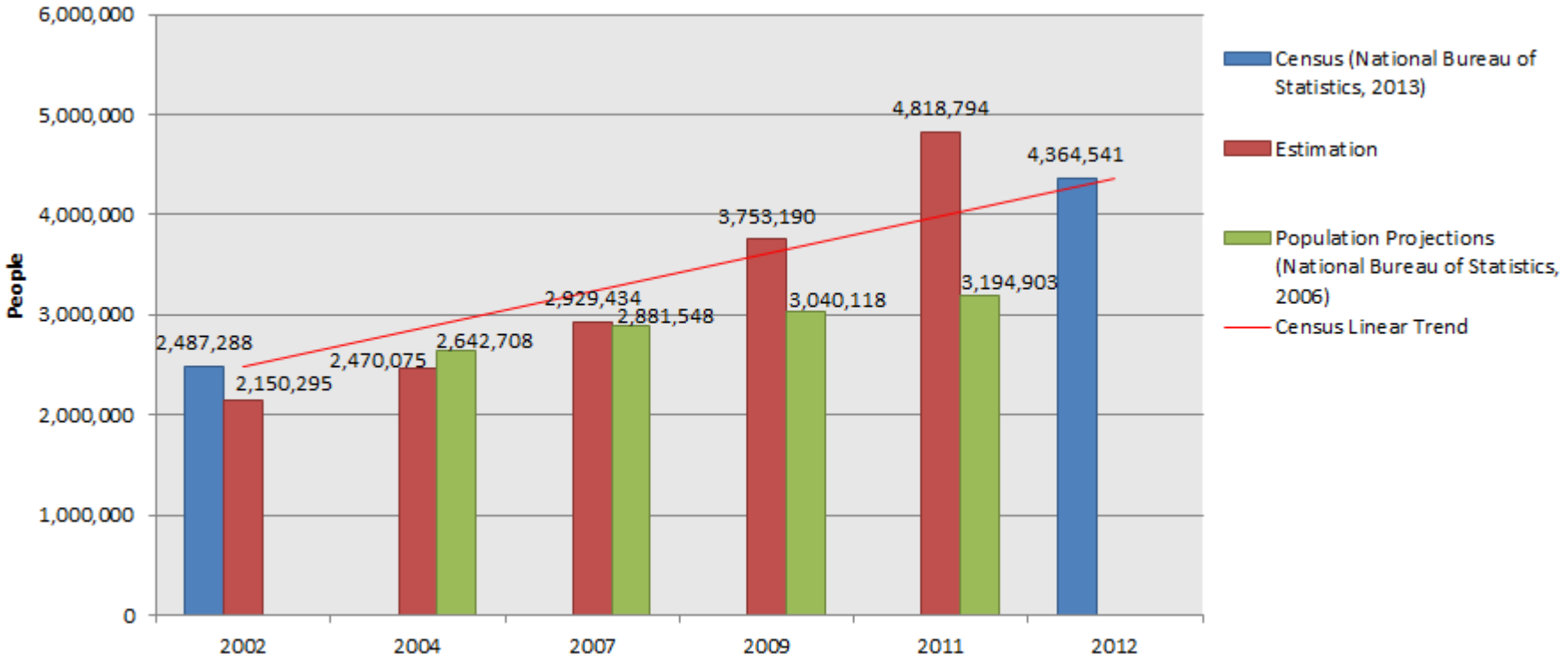
- Average Household Size (National Bureau of Statistics, 2013)
  - Dar es Salaam 2002 = 4.2
  - Dar es Salaam 2012 = 4.0

- Average Household Size calculated per year

Year	Average Household Size
2002	4.20
2004	4.16
2007	4.10
2009	4.06
2011	4.02

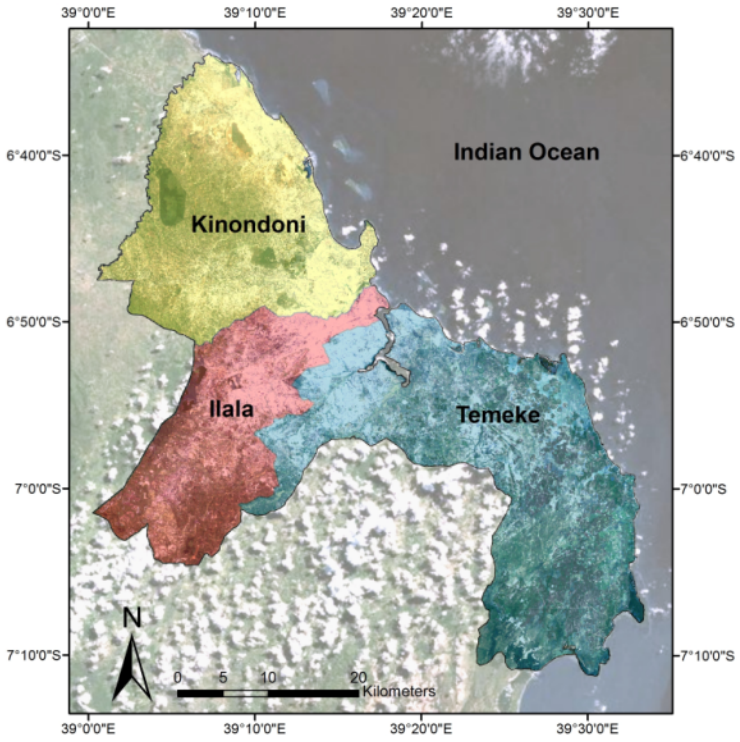
Population Estimation: Results

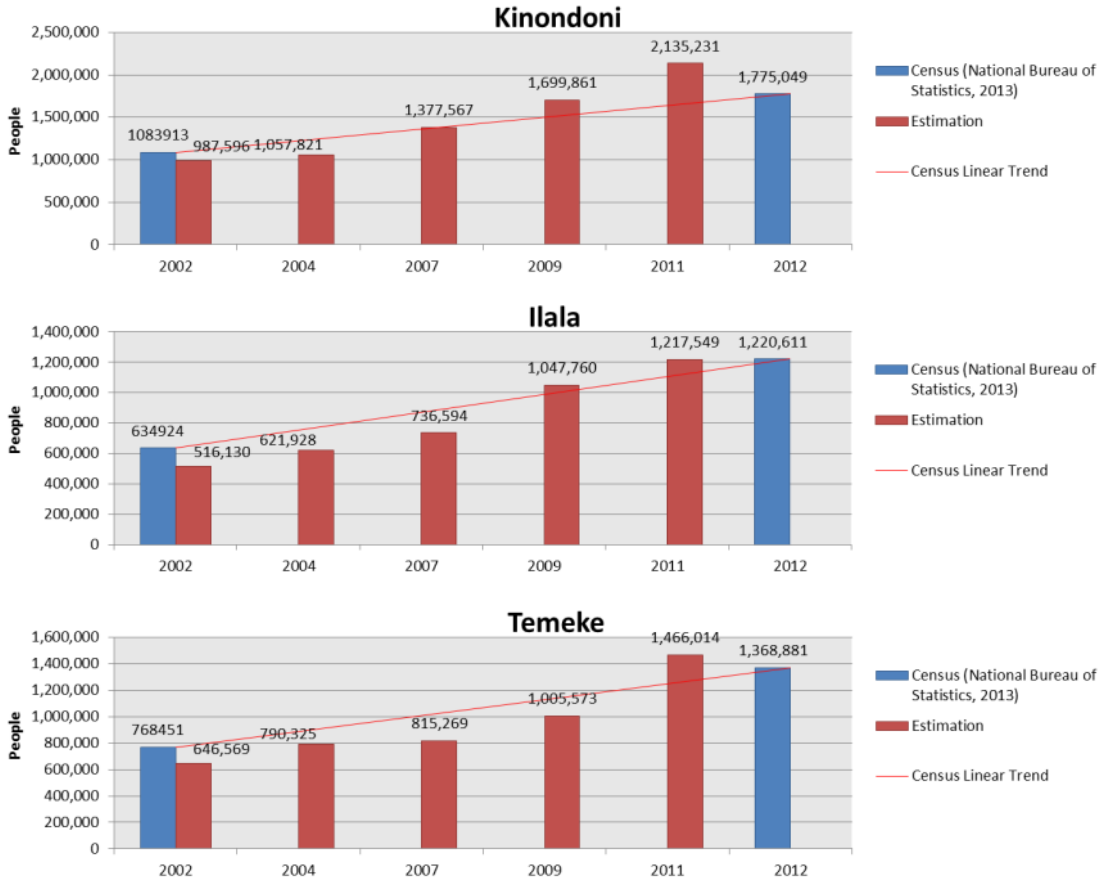
- Population estimates in Dar es Salaam from 2002 to 2011
- Comparison between estimates and census: margin of error **±15%**
- Comparison between estimates and projections



Population Estimation: Results at Municipal Level

- Comparison between estimate and census: margin of error **±25%**





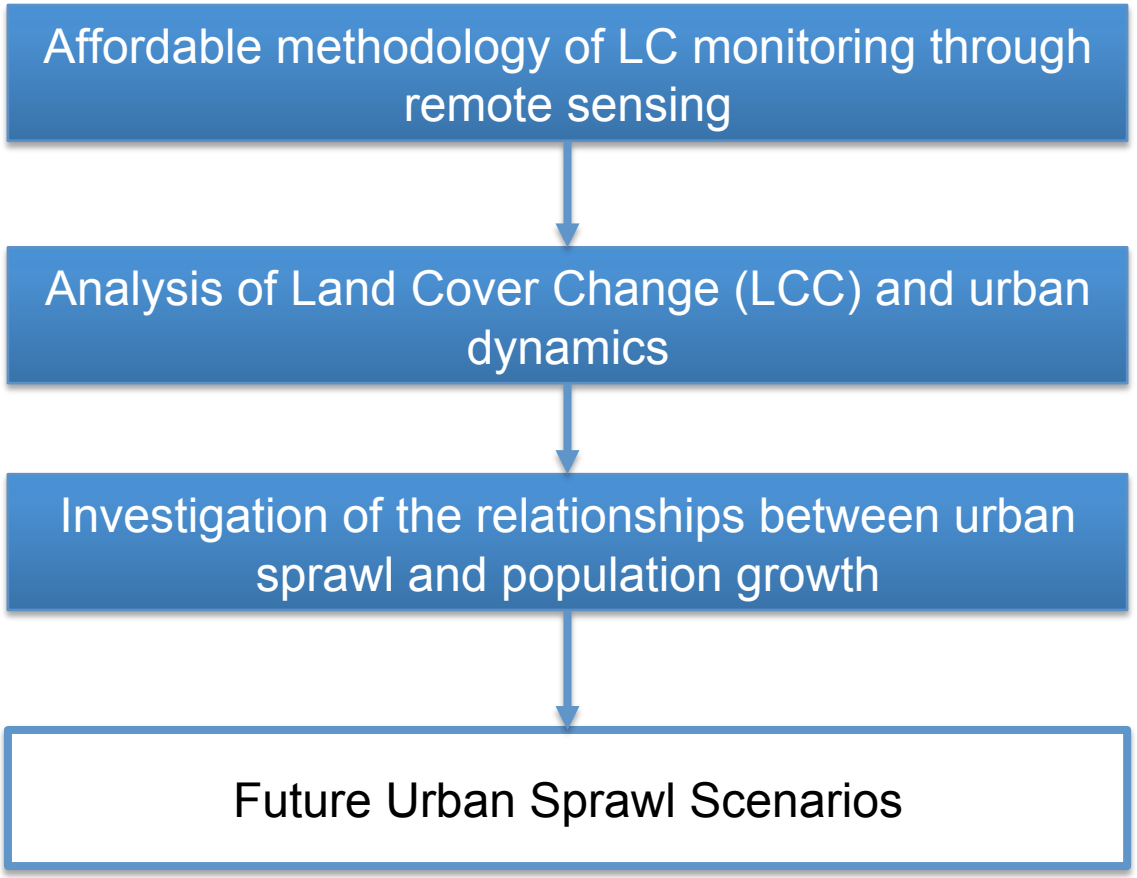
Limits of This Method

- **Margin of error ±15%** at city level and **±25%** at municipal level
- **Spatial resolution** and **accuracy of LC classifications**
  - LC classifications do not distinguish land uses, which can have different population densities
- The **relationship between LC and population** depends on the specific **development of the city**
- Influenced by variations over time of:
  - Average Household Density
  - Average Household Size

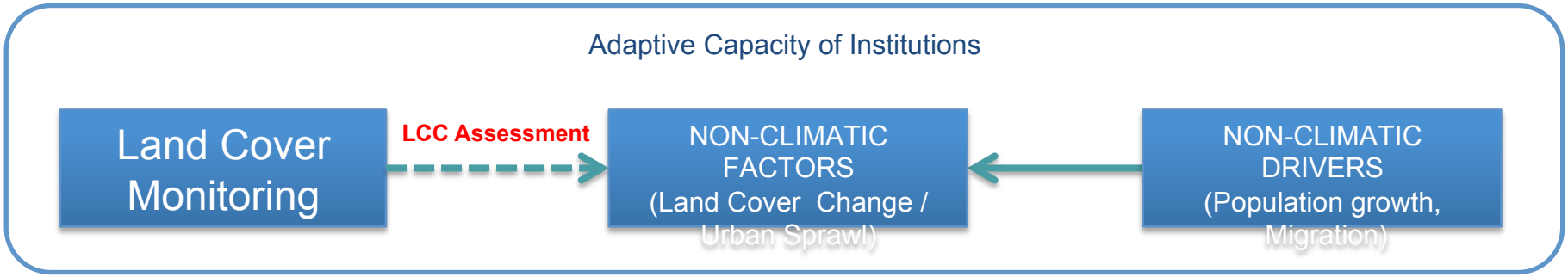
Advantages of This Method

- **Rapid and affordable** demographic estimation
- Valuable **alternative to traditional census**, which has low frequency given the growth rate of Dar es Salaam
- Valuable **alternative to projections**, especially when growth is rapid or unexpected, or when census data is outdated

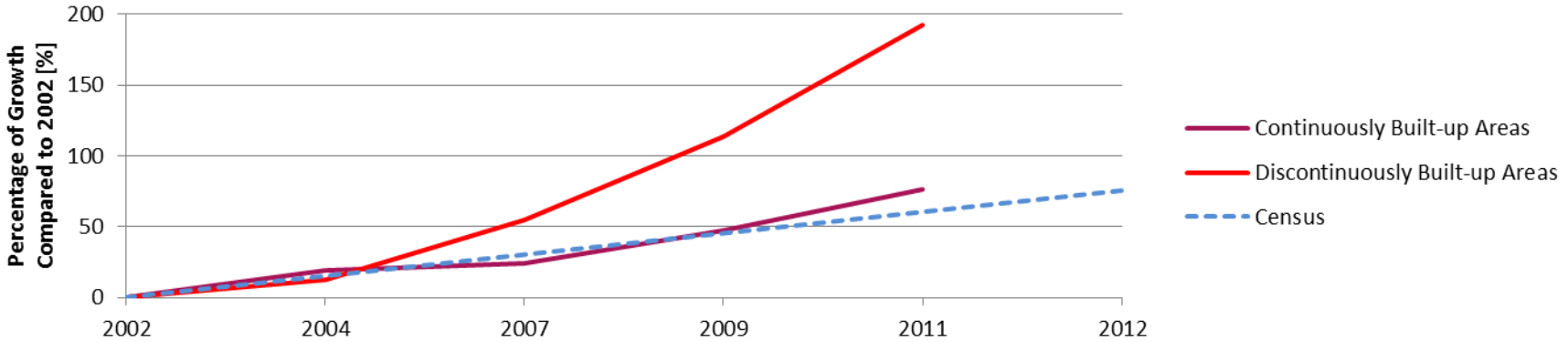
Conclusions



Conclusions



- **Urban Sprawl "happens when population growth and the physical expansion of a city are misaligned"** (UN-Habitat, 2010, p.10)



- Other drivers also cause urban sprawl in Dar es Salaam, and this affects the reliability of the population estimation method

Thank you

References:

- Norero, Carlo, 2012. Sprawl urbano e cambiamento climatico: il caso di Dar es Salaam, Tanzania. Master's Degree. Sapienza University. Rome.
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