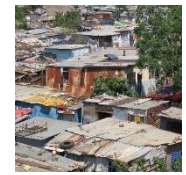
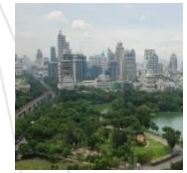




Earth Observation for Sustainable Development to Support Land Use Planning in Urban Areas

Thomas Häusler, Sharon Gomez, Fabian Enssle GAF AG

Land and Poverty Conference 2018: Using Satellite Imagery for Urban Change Detection
March 19-23, 2018
Washington, DC

Lead:

Partners:

Financed by:

The project "Earth Observation for Sustainable Development-Urban" (EO4SD-Urban) was initiated in May 2016 and is supported by the European Space Agency (ESA).

The main objectives are:

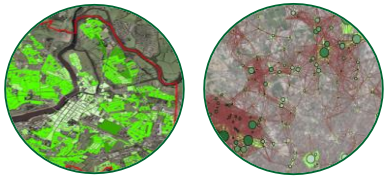
- To improve understanding of EO applications for urban development with the Multi-Lateral Development Banks and developing countries.
- To mainstream EO applications in an operational manner into development programmes.

Phase 1 was completed successfully by end of 2017.

Phase 2 now continues with new Cities and Stakeholders.

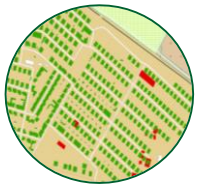
EO Products for Urban Development

Green Areas/Networks

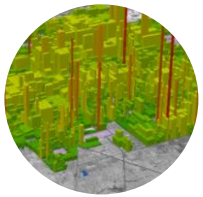


Urban Extent and Change

Building Footprint

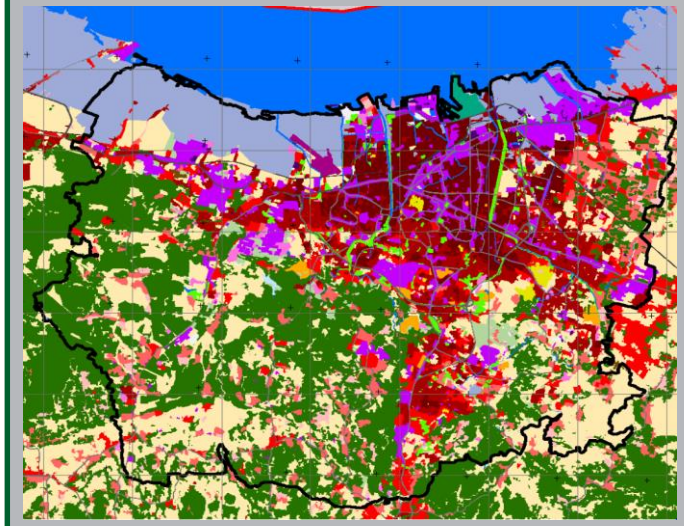


Population Density



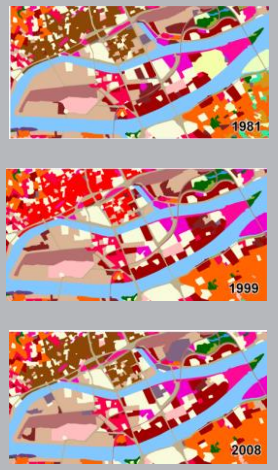
Waste Sites

Baseline Products
Urban and Peri-Urban LU /LC



Detailed

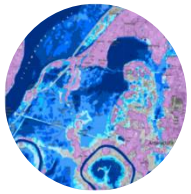
Change



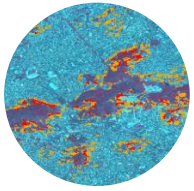
Transport Infrastructure

Informal Settlements

Flood Risk



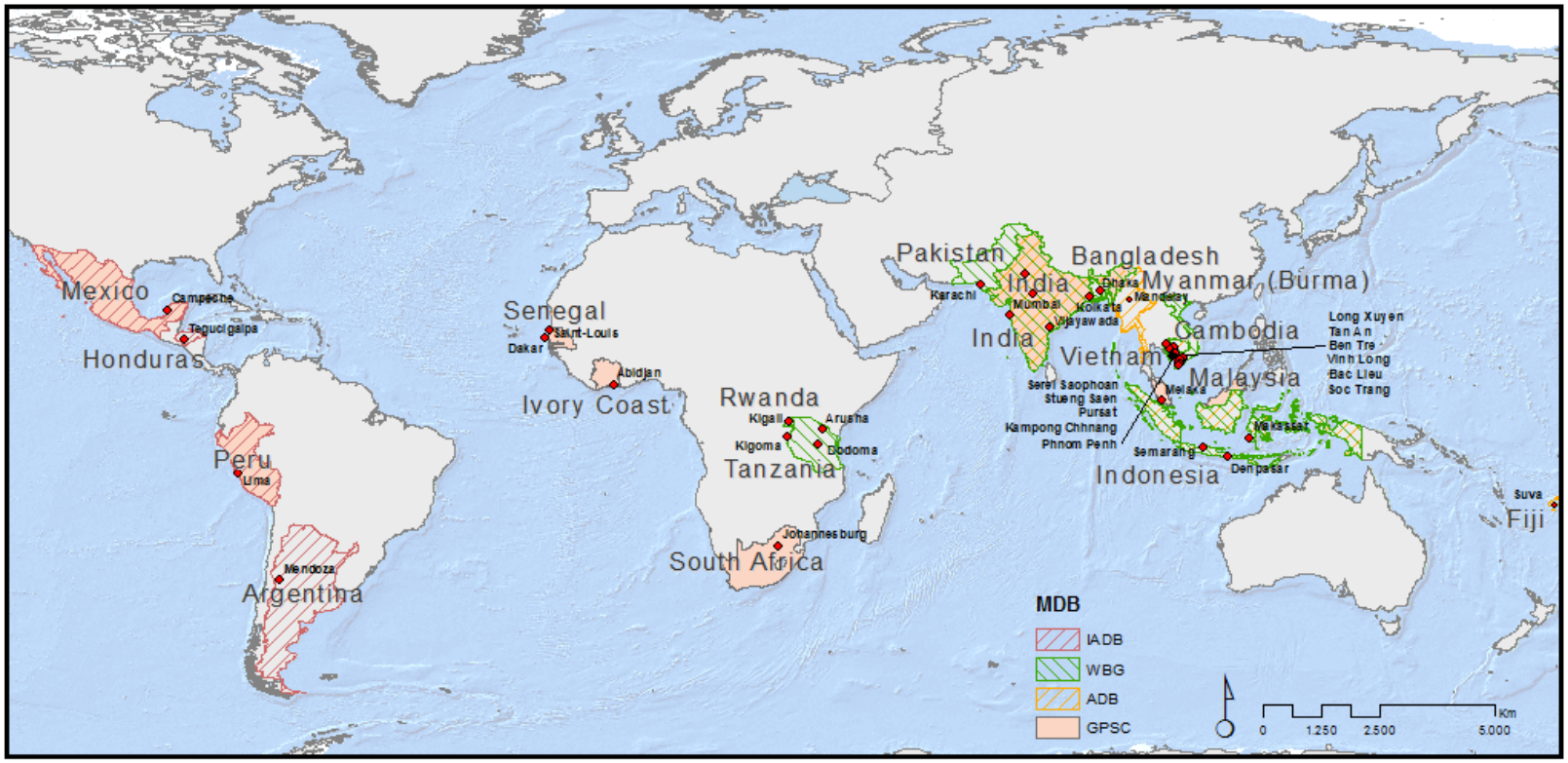
Landslide Risk



Terrain Motion

Geographic Spread of EO4SD-Urban Cities

About 40 cities have been identified and stakeholder engagement initiated.



- Distributed globally.
- Include mega-cities and small to medium sized cities.
- Cover a multitude of urban planning/development issues.

Phase 1 Cities

- 16 cities in 9 countries and 3 continents recieved 204 EO4SD-Urban products; (57 Baseline Products, 147 Special Products)
- 3 MDBs: Worldbank, Inter-American Development Bank, Asian Development Bank

Geographic Spread of EO4SD-Urban Cities

Rwanda:
Kigali

Cambodia:
Phnom Phen
Kampong Chhnang
Stueng Saen
Pursat
Serei Saophoan

India:
Kolkata

Indonesia:
Denpasar
Semarang

Myanmar:
Mandalay

Pakistan:
Karachi

Tanzania:
Arusha
Kigoma
Dodoma

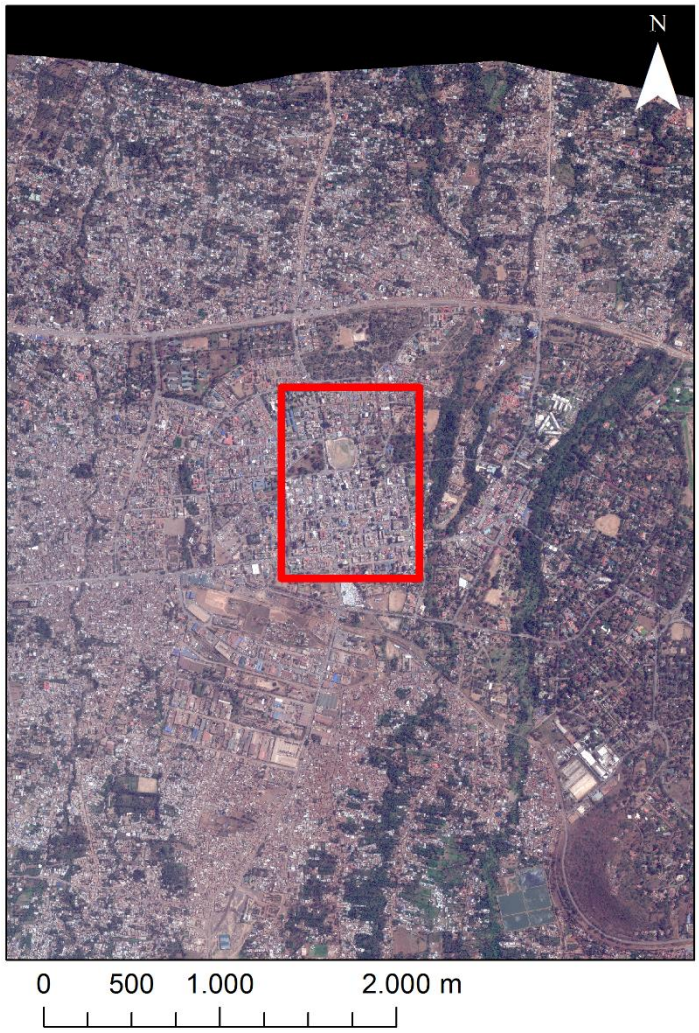
Argentinia:
Mendoza

Bangladesh:
Dhaka

Achievements of EO4SD-Urban Phase 1

- Baseline LU/LC and Derived Products Products for 2 points in time: 15 Cities
- LU/LC data for 4 points in time: 2 Cities
- Flood Risk Products: 6 Cities,
- Terrain Motion Product: 1 City (Semarang),
- Building Height data: 1 City (Kigali),
- Urban Extent/Imperviousness products: 16 Cities for 2 points in time, 6 Cities for 4 points in time.

EO Data: VHR Example – Worldview 2 & GeoEye 1

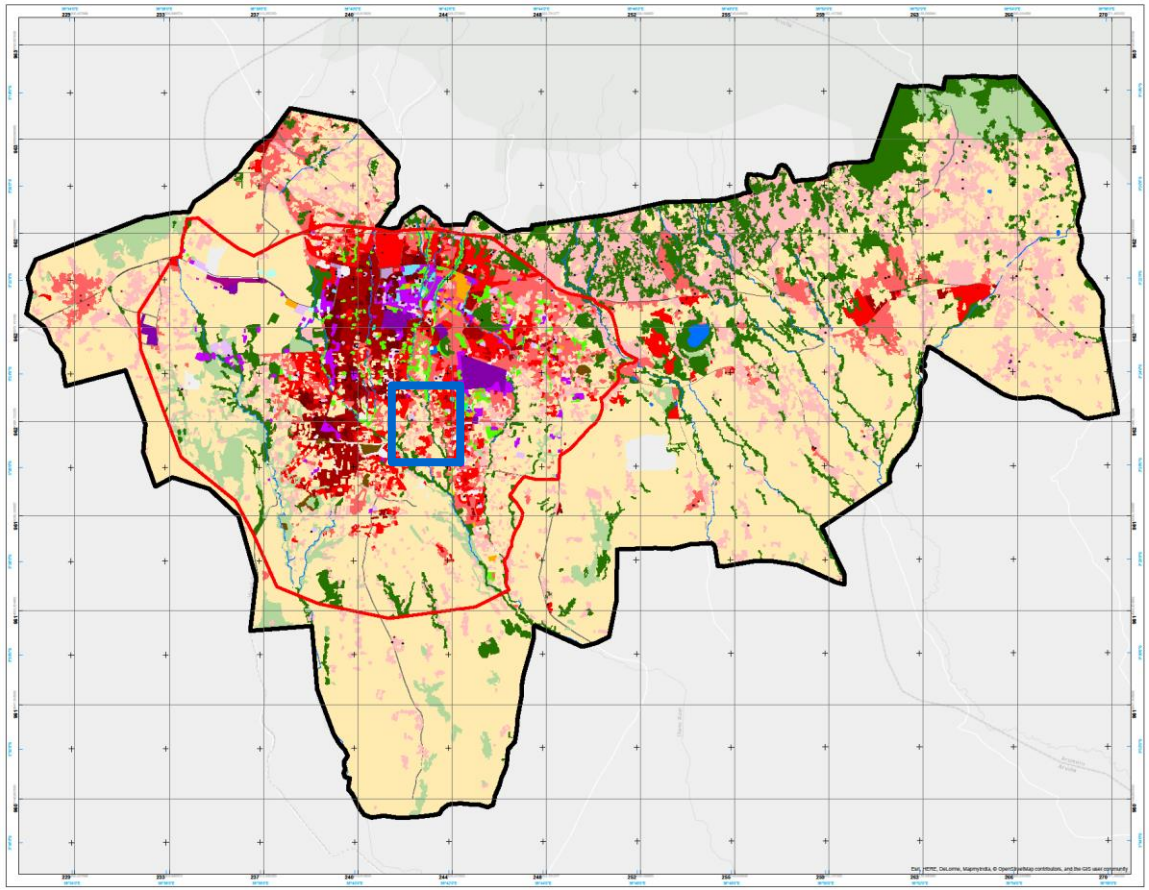


- Images from:
  17.09.2016
  30.12.2015
  04.01.2015
- Spatial Resolution:
  0.5 m
- Natural Composite Band Combination:
  Red, Green, Blue
  (3, 2, 1)

EO Data: HR Example – Sentinel 2

- Images from: 04.02.2016
- Spatial Resolution: 10 m
- Natural Composite Band Combination: Red, Green, Blue (4, 3, 2)

Arusha – Tanzania: Land Use/Land Cover 2015



Coordinate System: WGS 1984 UTM Zone 37S
Projection: Transverse Mercator
Datum: WGS 1984
False Easting: 500000.0
False Northing: 10000000.0
Central Meridian: 39.000
Scale Factor: 0.9996
Latitude of Origin: 0.00
Units: Meter

Printed on: 11.09.2017
Version: 1.0

LAND USE MAP OF ARUSHA, TANZANIA

Status 2015

N

0 0,5 1 2 3 4 5 km

urban development eo4sd

EO4SD-Urban:
Earth Observation for Sustainable Development - Urban Project

Map Producer: GAF AG

Interpretation:
The map displays precise Land Use / Land Cover (LULC) information (delivered in vector format) over Arusha (Tanzania). This product contains spatial explicit information about the different LULC categories for the year 2005.

The LULC information within the core urban area was derived from Very High Resolution (VHR) EO data and has a detailed nomenclature whereas the peri-urban area was mapped with High Resolution (HR) EO data with an aggregated nomenclature.

Image Data:
Worldview 2 © Digital Globe, Inc. (2016), (acquired on 17/09/2016, GSD 0.5 m);
Sentinel-2A (2016) (acquired on 04/02/2016, GSD 10 m) provided by the European Space Agency.

Vector Data: © OSM (2015), Toponyms © GoogleMaps (2015).

Background Map: © 2017 Esri

Land Use / Land Cover

Artificial Areas
- Very High Density Discontinuous Urban Fabric (IMD > 80%)
- High Density Discontinuous Urban Fabric (IMD 80% - 80%)
- Medium Density Discontinuous Urban Fabric (IMD 30% - 50%)
- Low Density Discontinuous Urban Fabric (IMD 10% - 30%)
- Very Low Density Discontinuous Urban Fabric (IMD < 10%)
- Commercial and Industrial Area, Public Buildings
- Arterial Line
- Collector Line
- Airport and Associated Area
- Mining Area
- Landfill
- Construction Site
- Open Space (Non-Green Open Space Areas)
- Urban Parks
- Cemeteries
- Sport Facilities
- Agricultural Area

Other Types
- Forest
- Grassland and Shrubs/ Natural Areas
- Peat/ Wetlands/ Swamps
- Water

Overview Map
- Core City Area
- Peri Urban Area of Interest for Mapping

Third Party Data
- Health Facilities
- Schools

Third Party Data was used to assist classification process only and did not undergo a Quality Assurance procedures. Completeness and spatial accuracy are unknown.

EO4SD-Urban is an ESA project aimed at deriving key geo-information products from Earth Observation data in support of urban development programmes.

More information available under: http://www.eo4sd-urban.info/

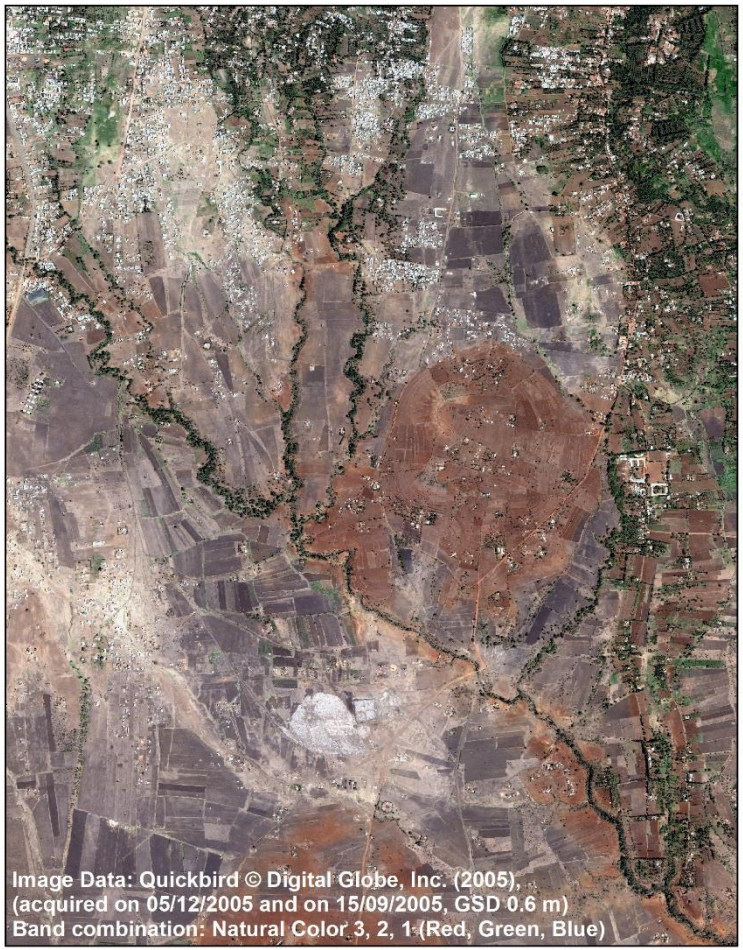
Map produced by: GAF AG

Map produced for: WORLD BANK GROUP

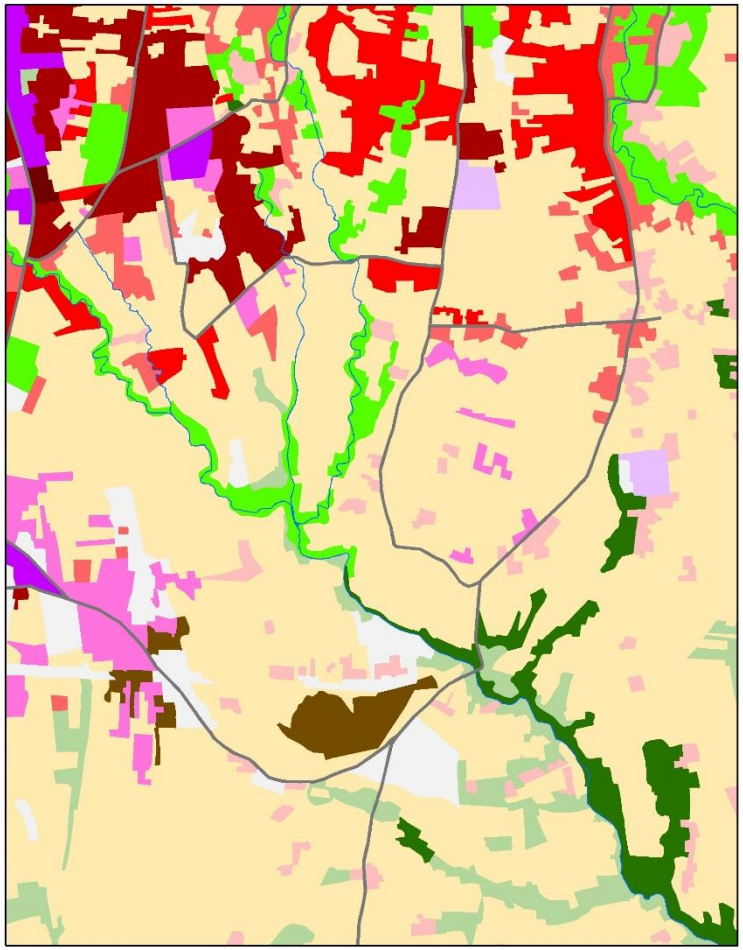
Project implemented by a Consortium lead by: GAF AG

Project funded by: esa

Arusha – Tanzania: Land Use/Land Cover 2005 Subset



N
0 0,75 1,5 km



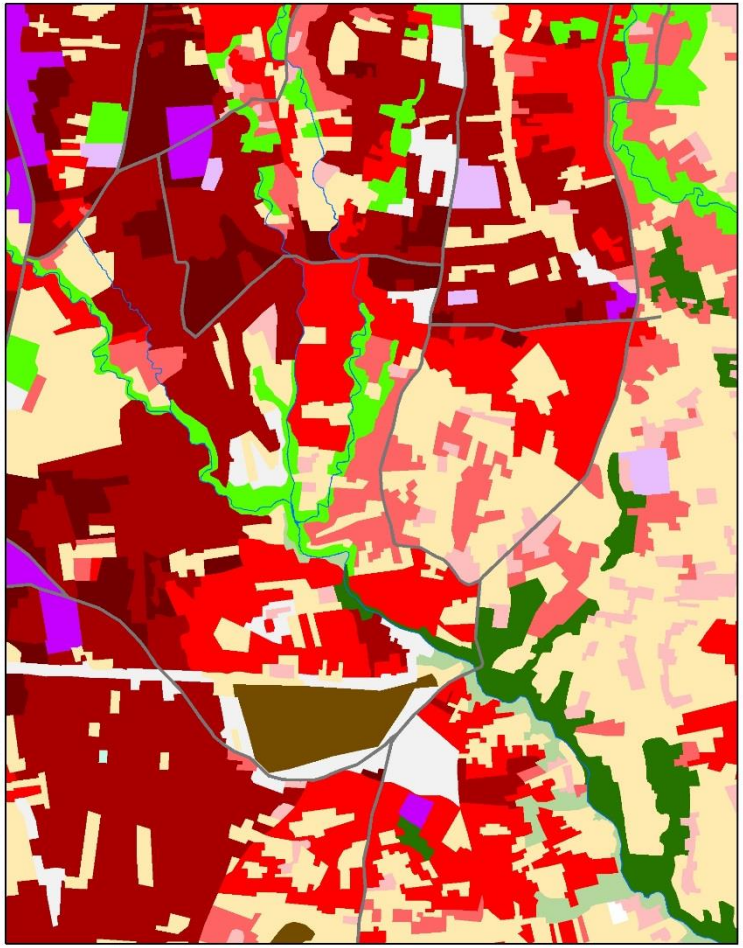
N
0 0,75 1,5 km

- Agricultural Area
- Airport
- Arterial Line
- Bare Soil
- Cemeteries
- Collector Line
- Commercial Area,
- Construction Site
- Forest and Shrublands
- Government
- Hospitals
- Industrial Area
- Land Without Current Use
- Military
- Mining/Quarry Areas/DumpSites
- Natural areas (non-forested)
- Public Buildings
- Railway
- Recreation Facilities
- Residential, 0 - 10% Sealed
- Residential, 10 - 30% Sealed
- Residential, 30 - 50% Sealed
- Residential, 50 - 80% Sealed
- Residential, 80 - 100% Sealed
- Schools
- University
- Urban Parks
- Water
- Wetlands

Arusha – Tanzania: Land Use/Land Cover 2015 Subset

N

0 0,75 1,5 km



N

0 0,75 1,5 km

- Agricultural Area
- Airport
- Arterial Line
- Bare Soil
- Cemeteries
- Collector Line
- Commercial Area,
- Construction Site
- Forest and Shrublands
- Government
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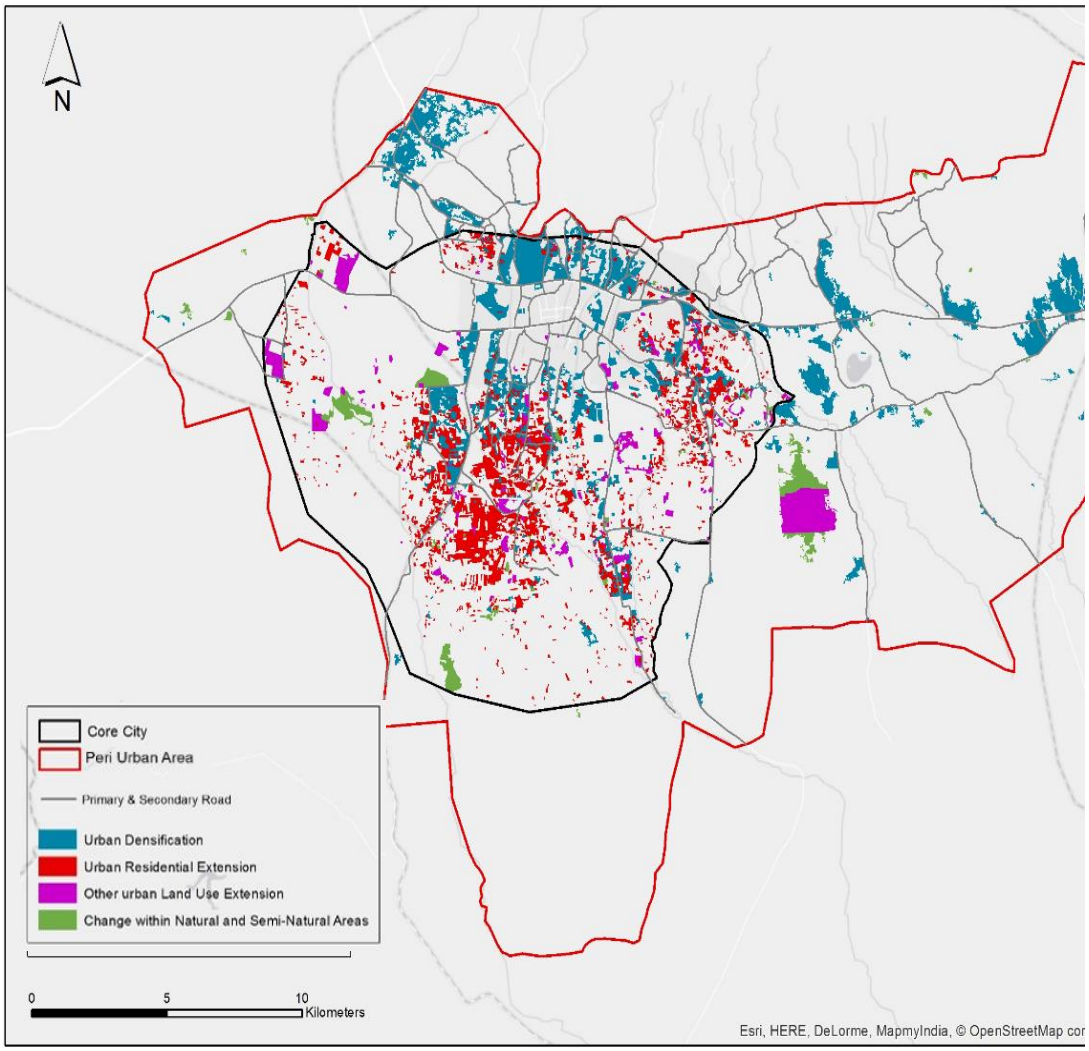
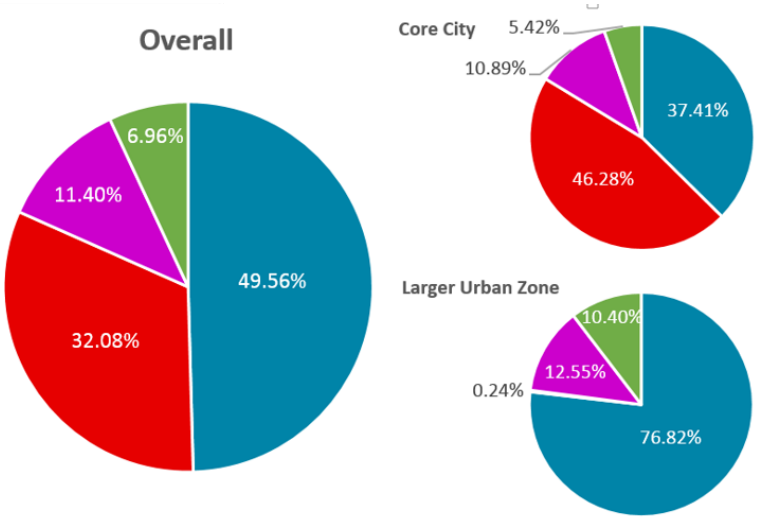
- Residential, 30 - 50% Sealed
- Residential, 50 - 80% Sealed
- Residential, 80 - 100% Sealed
- Schools
- University
- Urban Parks
- Water
- Wetlands

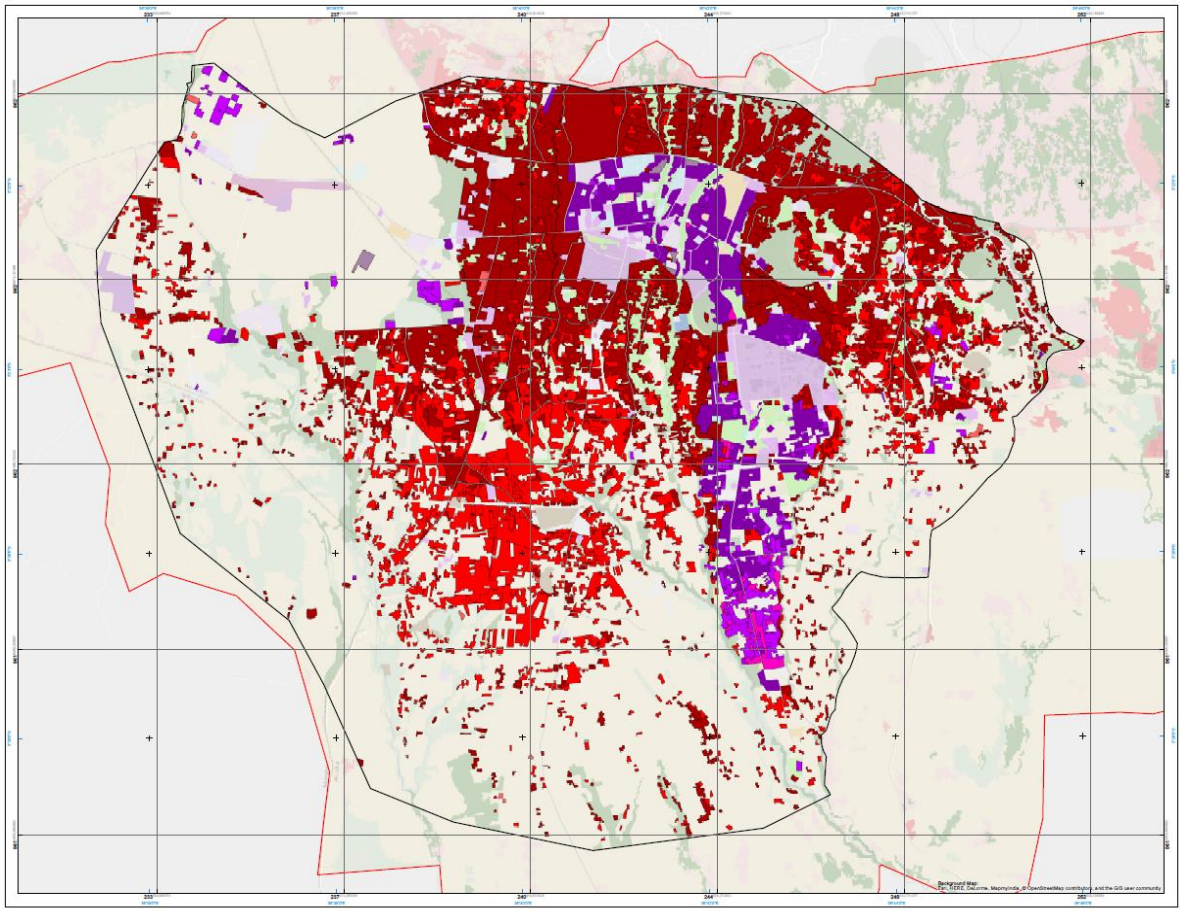
Arusha - Land Use Land Cover Change





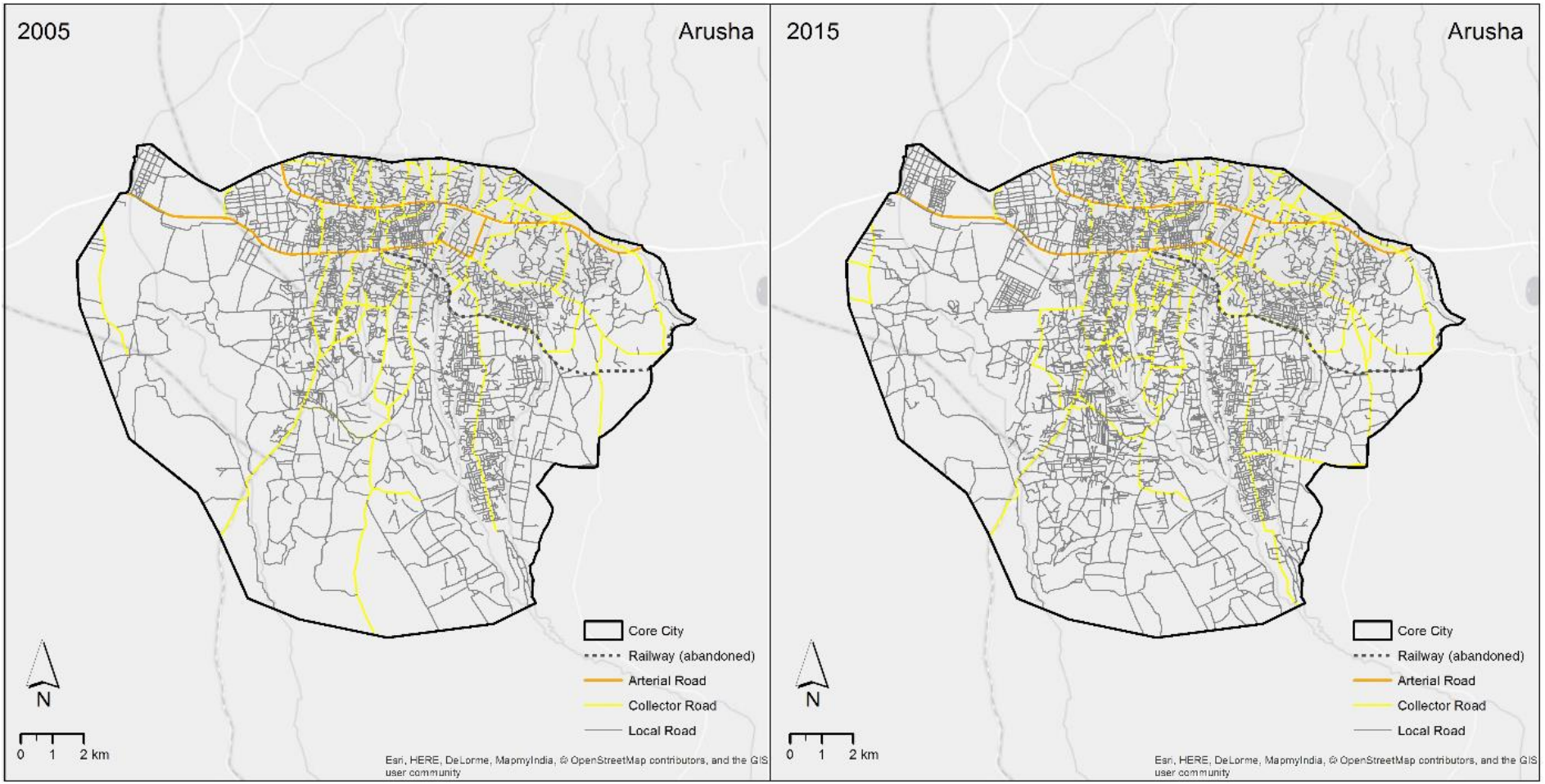
- **Residential densification is more dominant in Peri-urban zone**
- **Residential extension is more dominant in Core Urban zone**

Arusha – Unplanned vs planned Settlements 2005 - 2015

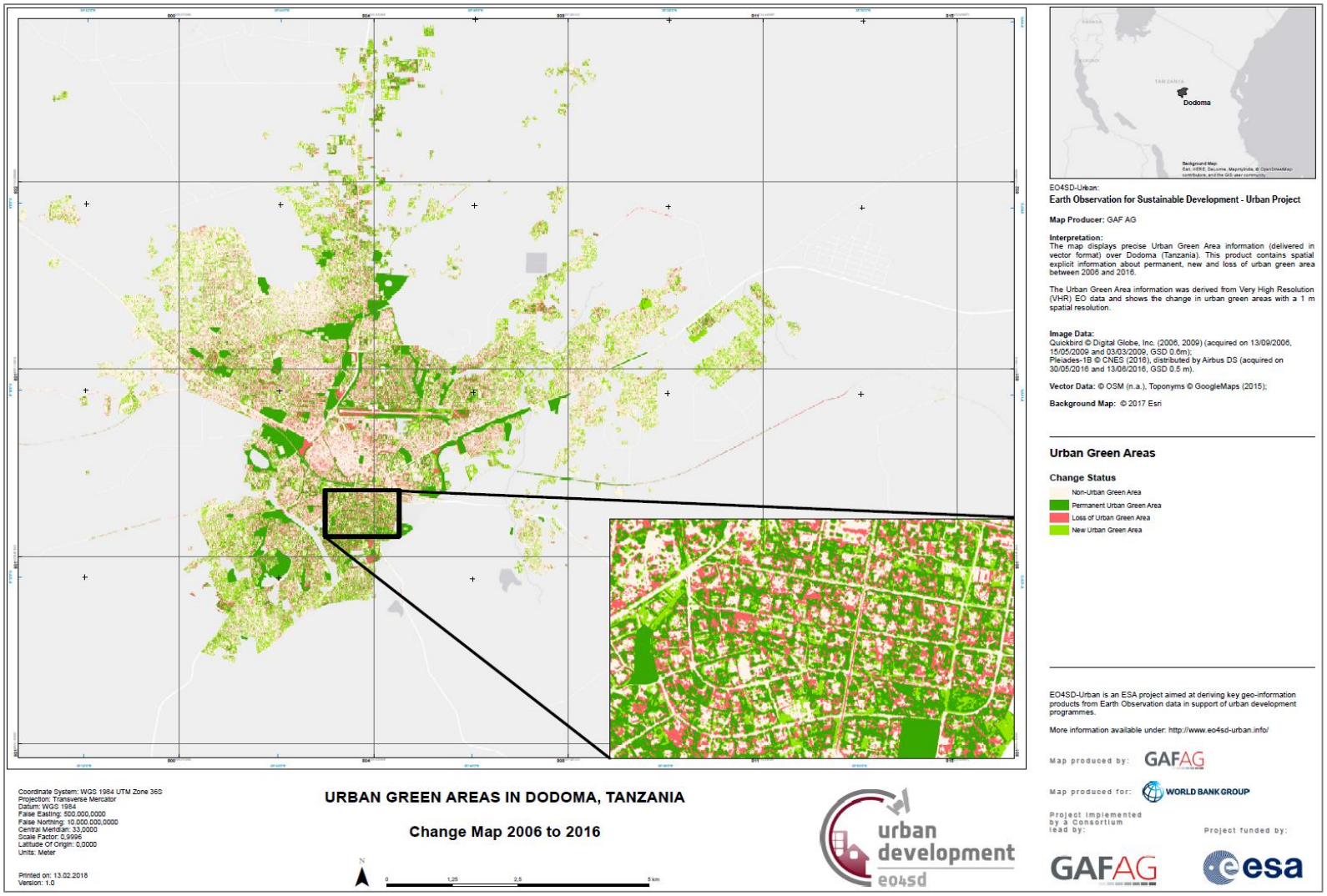


Unplanned areas continue to expand (more than planned areas) in Core Area

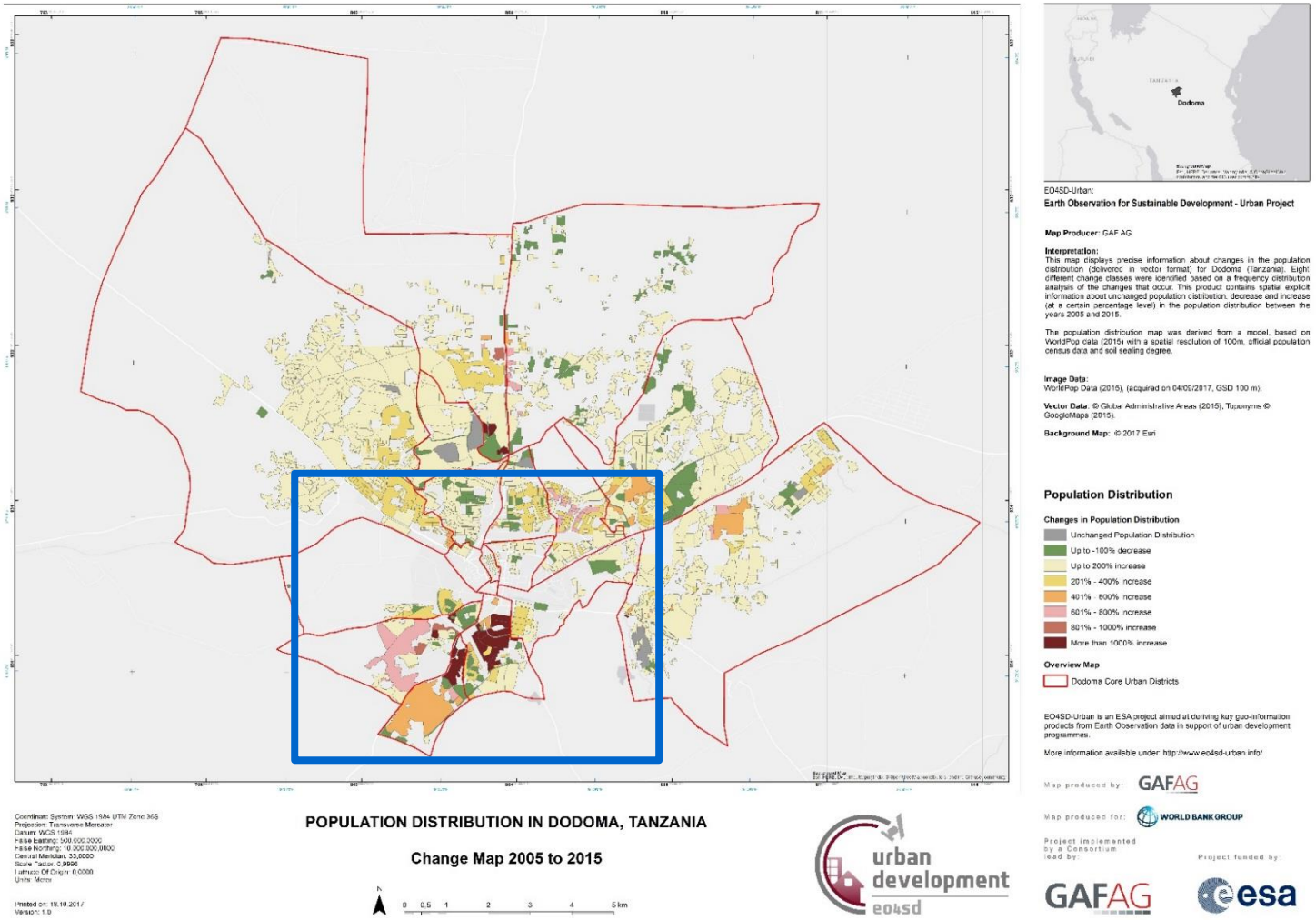
Transport Network of Arusha in 2005 and 2015



Changes of Urban Green Areas - Dodoma

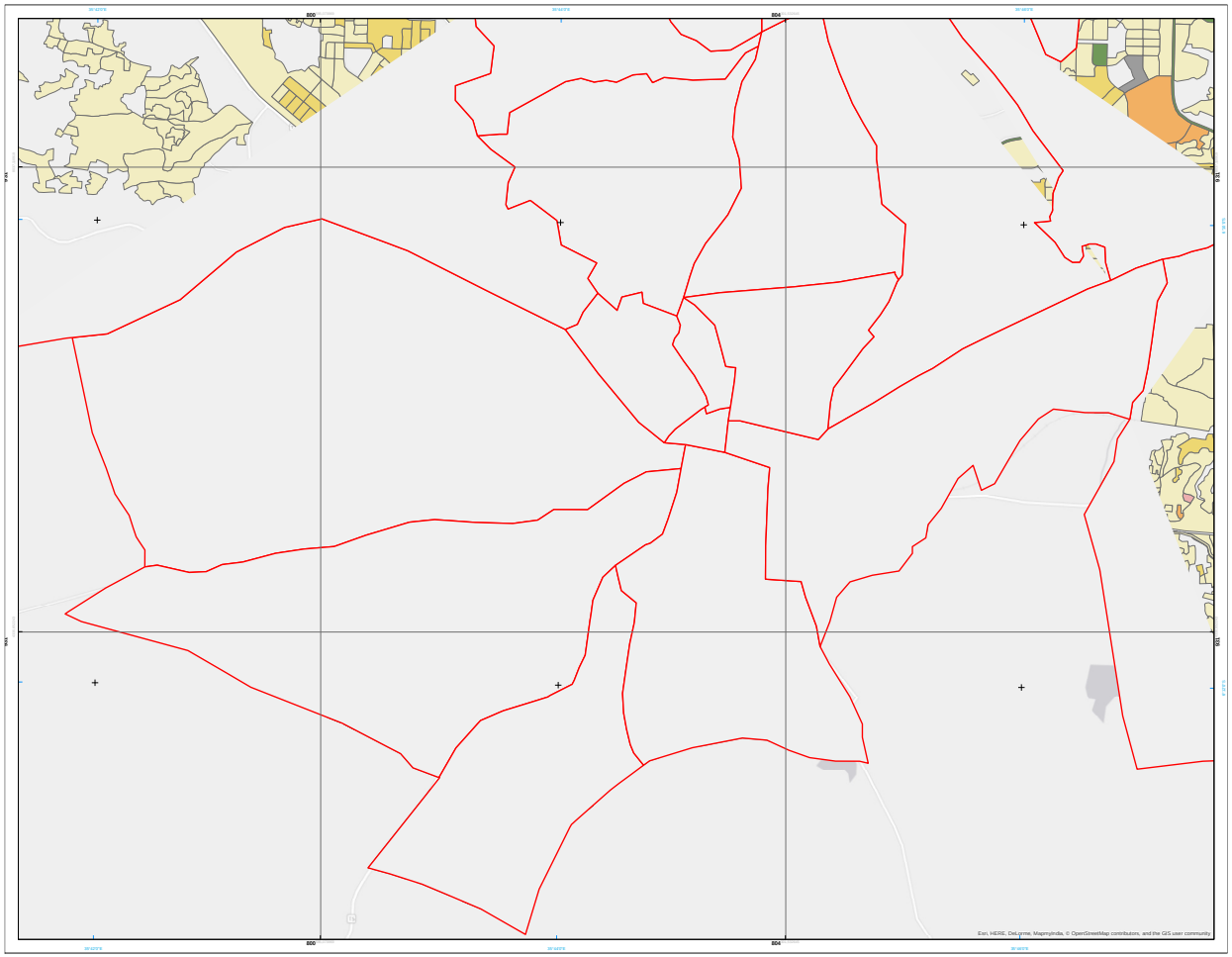


Dodoma – Tanzania: Population Distribution Change Map



Dodoma – Tanzania: Population Distribution Change Map

Subset



Changes in Population Distribution

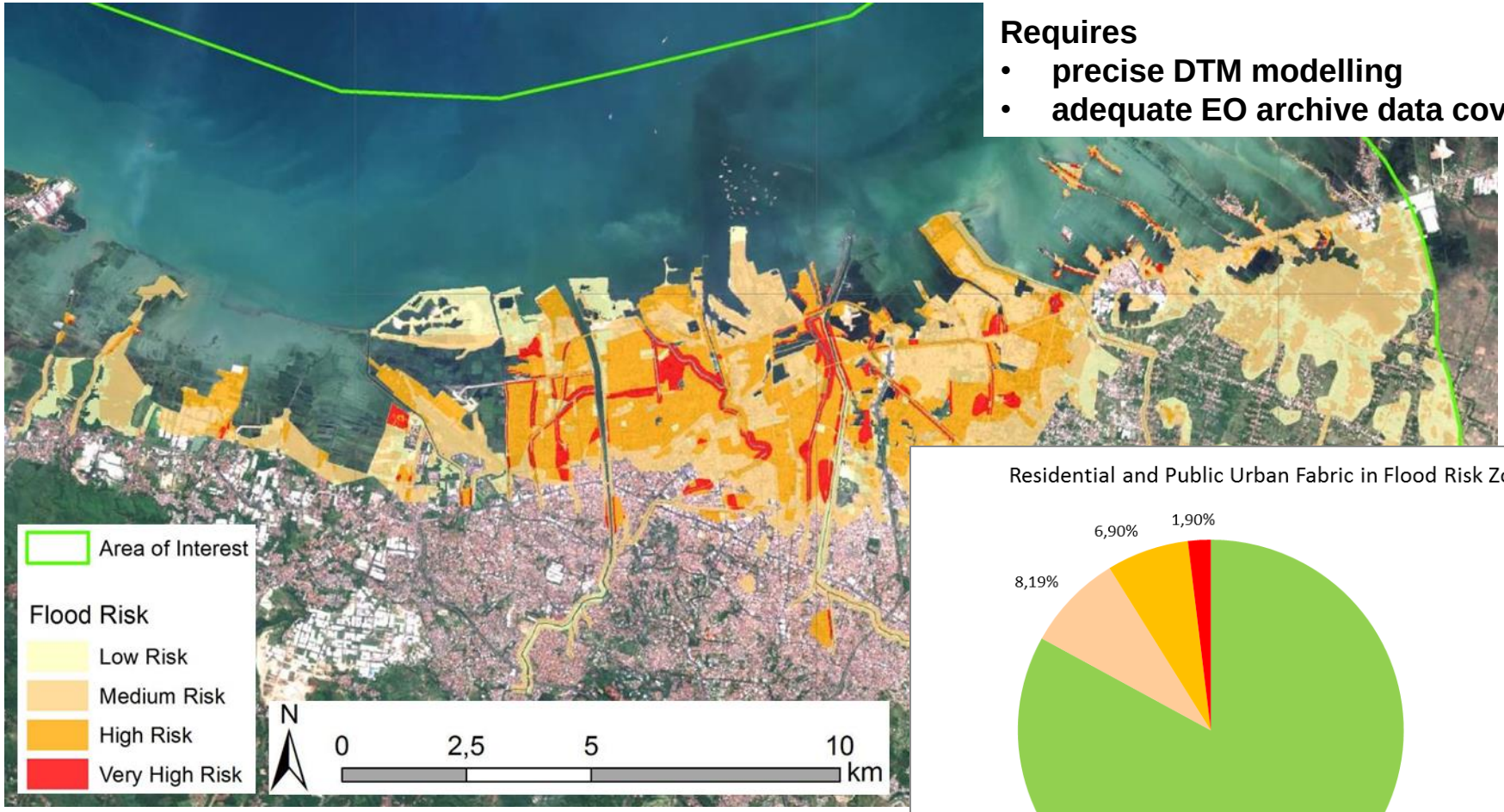
- Unchanged Population Distributior
- Up to -100% decrease
- Up to 200% increase
- 201% - 400% increase
- 401% - 600% increase
- 601% - 800% increase
- 801% - 1000% increase
- More than 1000% increase

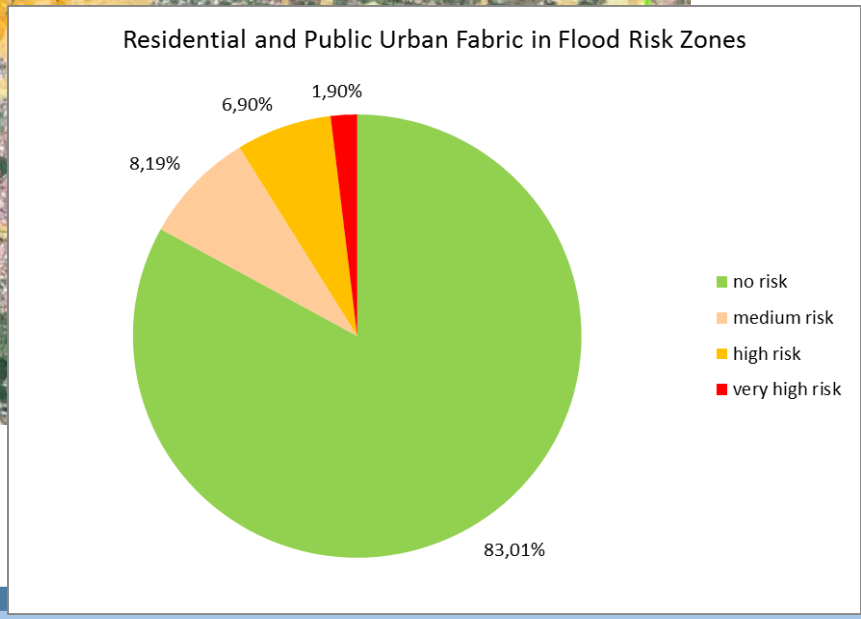
Overview Map

- Dodoma Core Urban Districts

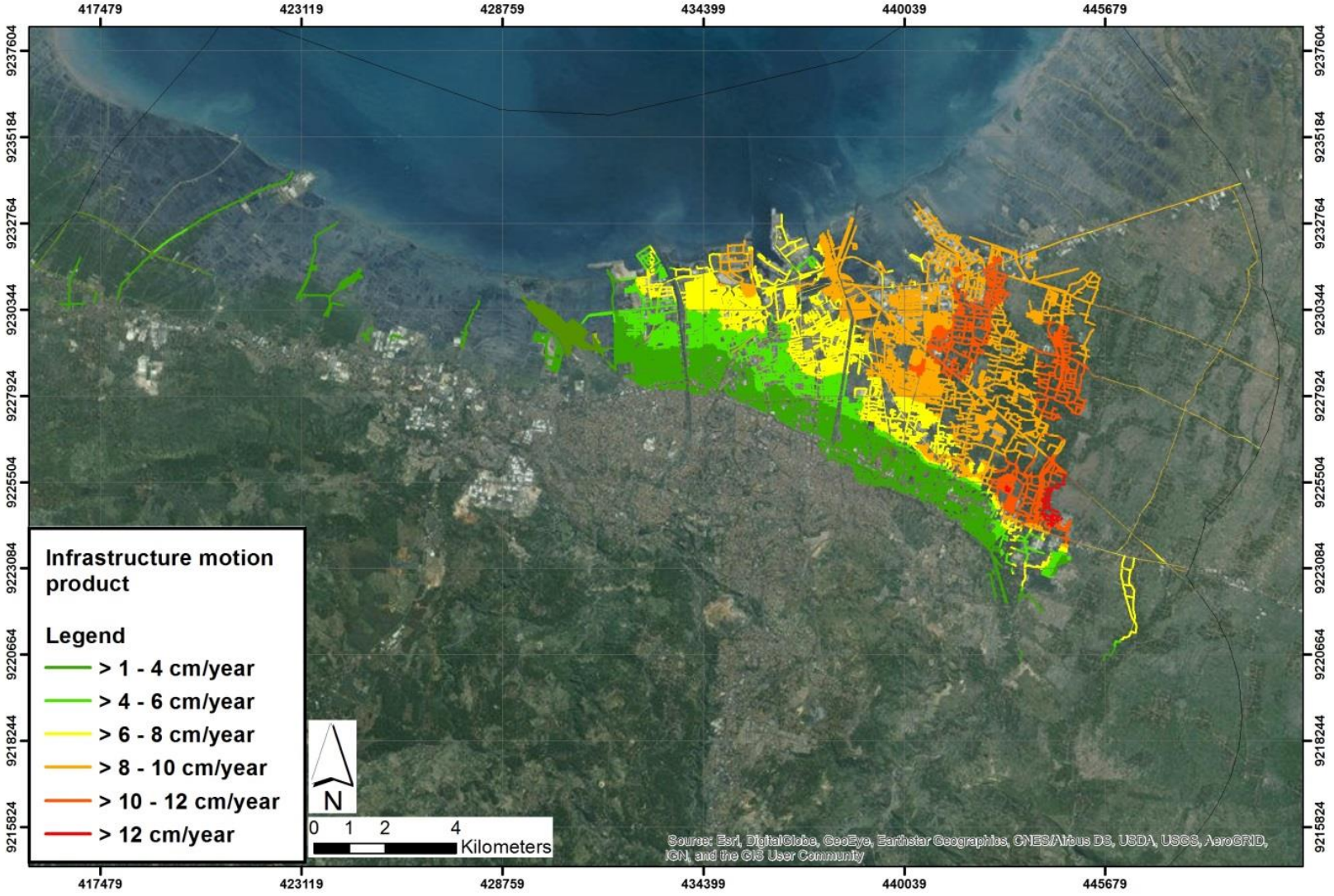
Semarang – Indonesia: Flood Risk Map

Requires
- **precise DTM modelling**
- **adequate EO archive data coverage**





Semarang – Indonesia: Terrain and Infrastructure Motion

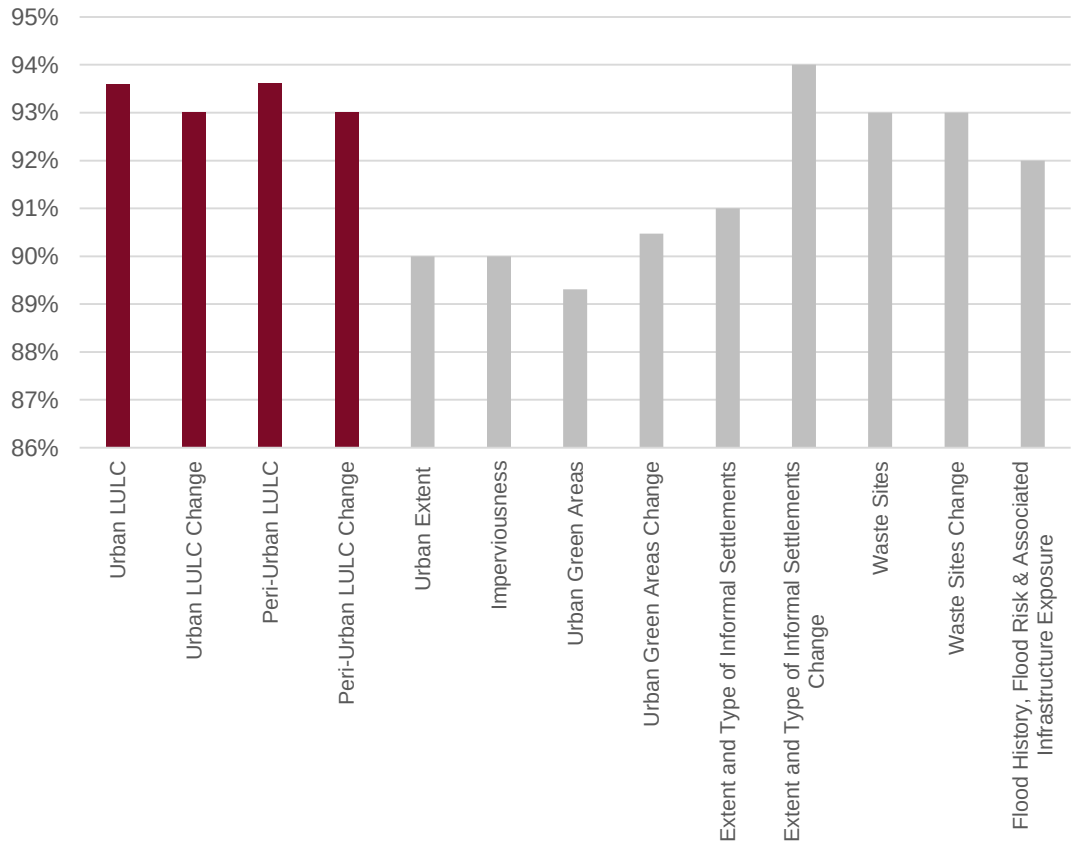


Accuracy Assessment

Statistically & Scientifically Sound Sampling Design

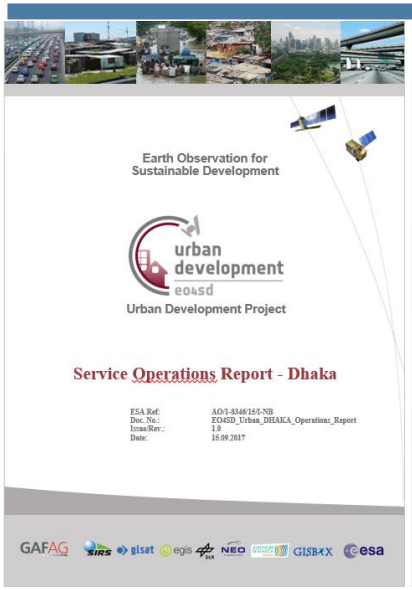
- **Stratified Random Sampling**
  - Number of samples per strata
  - Expected accuracy, acceptable error, 95% C.L.
- **Response Design**
  - Independent re-interpretation
- **Analysis Design**
  - Error matrix
  - Metrics (overall, user‘s, producer‘s acc.)

LULC, Green Areas, Planned and Un-planned Settlements

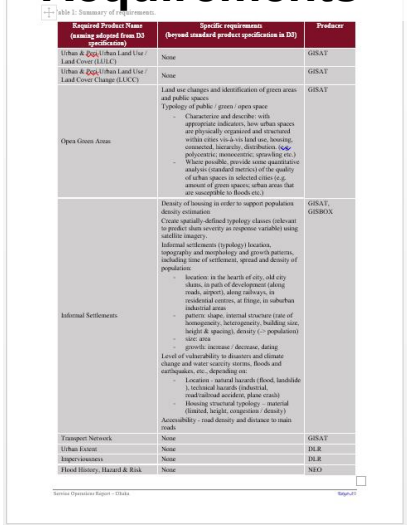


Transparent Methods - Quality - Accuracy

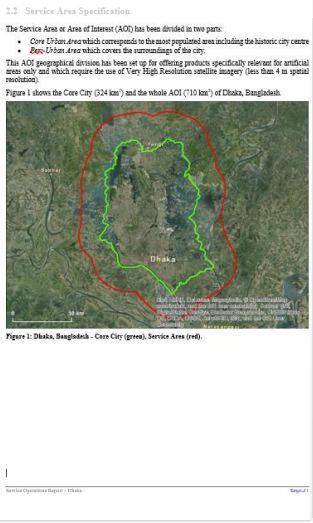
Service Operations Report for each City



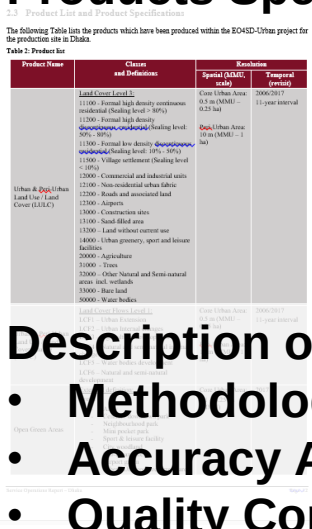
Requirements



Area of Interest

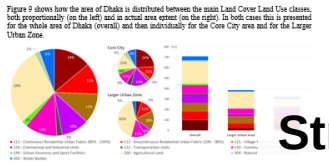


Products Specifications

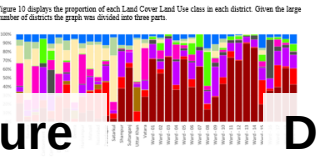


Description of:

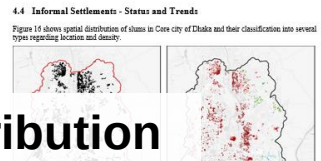
- Methodology
- Accuracy Assessment
- Quality Control Sheets



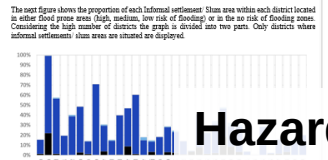
Structure



Distribution

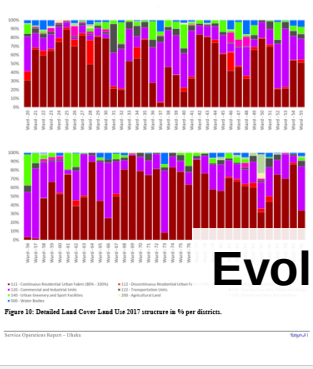


Hazard & Risk

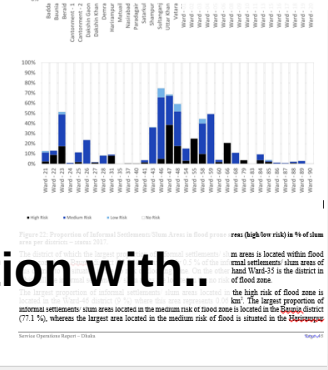


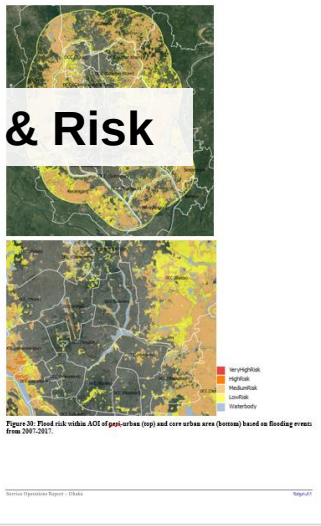
Statistics

Evolution



Integration with..





Quality Control and Assurance

- **Documentation of QC checks**
  - EO & ancillary data, interim & final products
  - Accuracy, consistency, completeness
- **Formalisation and consolidation into QC Sheets**

Earth Observation for Sustainable Development – Urban Project — QA/QC Sheets developed by GAF AG

Earth Observation for Sustainable Development - Urban

Quality Assurance and Quality Control Sheets

These QA/QC Templates were prepared by GAF AG compliant with ISO 9001:2008 Quality Management System standards and can only be used by Partners in the current EO4SD-Urban Project.

Project Title:	EO4SD-Urban
Project Leader:	GAF AG
Service Provider:	GAF AG
Client:	WB
Editor:	AB; DK; LV; FE
Date:	27.07.2017

Overview of QC-Sheets and Processing Steps	Sheet used	Sheet filled in
Requirements		
0.1 Requirements	Yes	Yes
Expected Specifications of Input Data		
1.1 List of EO Data	Yes	Yes
1.2 List of In-situ Data	Yes	Yes
1.3 List of Ancillary Data	Yes	Yes
Data Quality Checks		
2.1 EO Data Quality	Yes	Yes
2.2 In-situ Data Quality	Yes	Yes
2.3 Ancillary Data Quality	Yes	Yes
Pre-Processing of EO Data		
3.1 Geometric Correction	Yes	Yes
3.1.1 Data Fusion	Yes	Yes
3.2 Data Processing	Yes	Yes
Thematic Processing		
4.1 Classification	Yes	Yes
4.2 Intermediate Quality Control of Land Use Data	Yes	Yes
Accuracy Assessment		
5.1 Thematic Accuracy	Yes	Yes
5.2 Error Matrix and Accuracy Statistics	Yes	Yes
Delivery Checks / Delivery		
7.1 Completeness	Yes	Yes
7.2 Compliancy	Yes	Yes

Glossary (Index numbers in the QA/QC tables refer to the glossary at the end of this document)

Further QC relevant Documents:

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2.3 Ancillary Data Quality

Dataset 1 (1a) LU Map File Name (e.g. yymmdd, tbd…)	Readability (4)	Check Header / Metadata (5)	Data Coverage Matches Service Area (%)	Projection / Spheroid / EPSG (6a)	Spatial Resolution and unit (e.g. m, km)	Data Format (7)	Bit Depth (8)	Completeness (Vector: Attribute Table; Raster: Thematic Values)	Geom. Misalignment	Dropped Lines / Artefacts (EO data only) (9)	Utility for Current Project
Landuse_Map_Of_2014	☒ Yes ☐ No	☐ Complete (INSPIRE/ISO19115) ☐ Incomplete ☒ not available	☒ Yes ☐ No ☐ Unknown If no: xx%	☒ Correct ☐ Incorrect ☐ Unknown EPSG: 32749	n.a.	* sh p	n.a.	☐ Complete ☒ Incomplete	☐ No ☐ Yes ☒ Unknown If yes: XX m	☐ No ☐ Yes ☒ n.a. If yes: xx %	☐ None ☒ Partial ☐ Full
Comments:	41 unclassified classes, Map has gaps and overlaps, Definition of residential area 1 and 2 is unknown, class definitions are missing, especially for difficult classes like mixed garden.										

3.1 Geometric Correction

No.	Sensoren (9) Sentinel 2, Landsat 5, QB 2, Pl X File Name (e.g yymmdd; tbd…)	Processing Date	Aerial Extent, City / Region / Country	Projection / Spheroid (10)	No. & RMS (m) of GCPs (17)	No. & RMS (m) of TPs (18)	No. & RMS (m) of CPs (19)	Digital Elevation Model (DEM)	Model / Algorithm (13)	Resampling Method (20)	Validation Reports	Acceptance Status	Output File Name (e.g yymmdd; tbd…)
Sentinel-2													
1.	S2A_OPER_MSI_L1C_TL_SGS__20160328T115331_A003947_T49MDN	10.04.2017	Semarang IDN	UTM49S / WGS84	N/A	N/A	N/A						S2A_OPER_MSI_L1C_TL_SGS__20160325T115331_A003947_T49MDN
2.	S2A_OPER_MSI_L1C_TL_SGS__20160524T080330_A004805_T49MDN	10.04.2017	Semarang IDN	UTM49S / WGS84	N/A	N/A	N/A						S2A_OPER_MSI_L1C_TL_SGS__20160524T080330_A004805_T49MDN
Landsat-5													
3.	LT51200652007239BKT00	10.04.2017	Semarang IDN	UTM49N / WGS84	N/A	N/A	N/A						LT51200652007239BKT00_MTL_tba
Pleiades 1B													
4.	DIM_PHR1B_MS_201509080304179_SEN_2226855101-002_tba_PSH	10.04.2017	Semarang IDN	UTM49S / WGS84	N/A	17; RMSE x0,1.0; y 0.46	N/A	SRTM 30	Affin. 1st order polynom	CC	Yes	Yes	dDIM_PHR1B_MS_201509080304179_SEN_2226855101-002_tba_PSH
5.	DIM_PHR1B_MS_201509080304533_SEN_2226854101-002_tba_PSH	10.04.2017	Semarang IDN	UTM49S / WGS84	N/A	17; RMSE x0,1.0; y 0.46	N/A	SRTM 30	Affin. 1st order polynom	CC	Yes	Yes	dDIM_PHR1B_MS_201509080304533_SEN_2226854101-002_tba_PSH

Value of EO4SD-Urban Services

Product generation is based on:

- Verified user requirements
- Harmonised and standardised state-of-the-art methodologies
- Comprehensive and transparent documentation
- Application of statistically sound accuracy assessment
- Stringent Quality Control and transparent documentation
- User feedback to improve the services

Geospatial products can be used to monitor SDG 11 Indicators

SDG Indicators which can use EO

	Indicators:
Target 11.1: Housing and slums	**11.1.1:** Proportion of urban population living in slums, informal settlements or inadequate housing
Target 11.2: Transport	**11.2.1:** Proportion of the population that has convenient access to public transport by sex, age and persons with disabilities
Target 11.3: Planning	**11.3.1:** Ratio of land consumption rate to population growth rate
Target 11.7: Public space	**11.7.1:** Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities

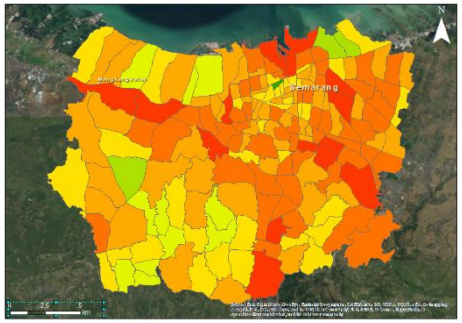
Spatial Data for Monitoring SDG 11 – Indicator 11.2.1

Target 11.2: Transport	**11.2.1:** Proportion of the population that has convenient access to public transport by sex, age and persons with disabilities

% with access to Public transport
=100x (population with convenient access to Public transport
(City Population)

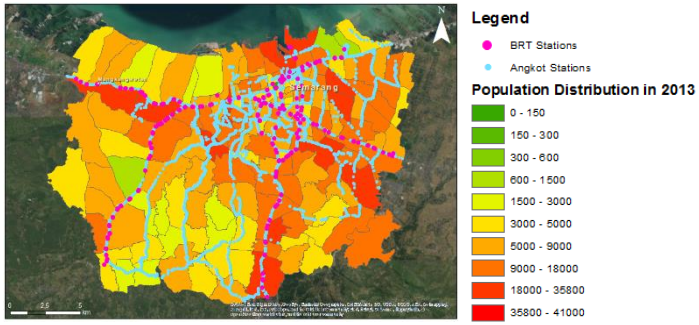
Input Data:

EO4SD-Urban Population Product
Census Data per Ward Level for 2013

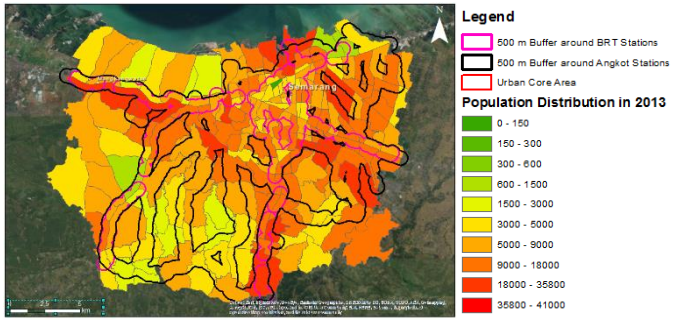


Other Spatial Data:

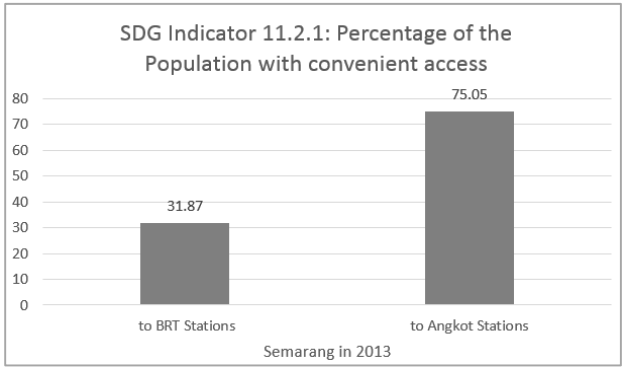
Public Transport Stations (BRT, Angkot)
Census Data per Ward Level for 2013



Buffer Analysis:



Results:



Spatial Data for Monitoring SDG 11 – Indicator 11.3.1

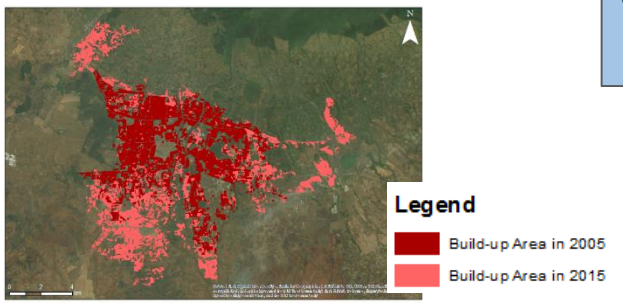
Target 11.3: Planning	**11.3.1:** Ratio of land consumption rate to population growth rate

Ratio of land consumption rate to population growth rate (LCRPGR)

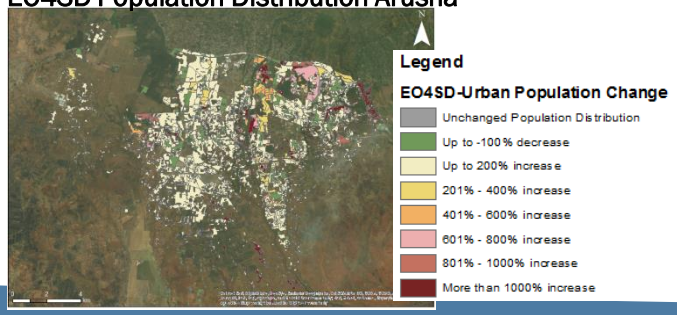
$$= \frac{\text{Land consumption rate}}{\text{Annual population growth rate}}$$

Input Data:

EO4SD Build-up Area Arusha



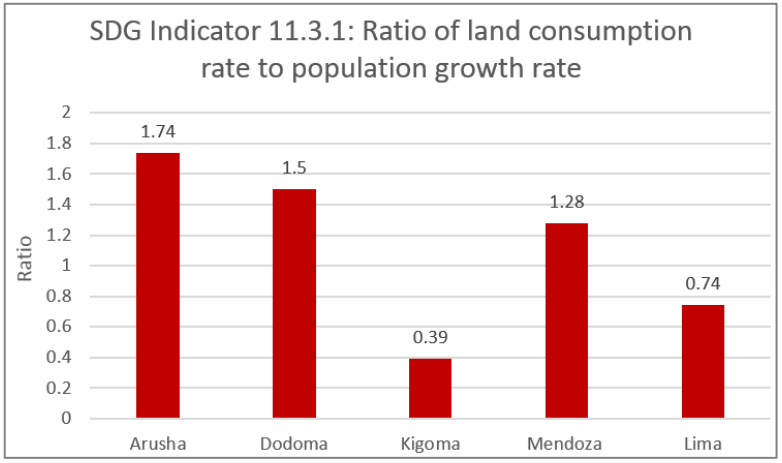
EO4SD Population Distribution Arusha



Other Spatial Data:

World Population Grid from the Global Human Settlements Layer (GHSL)

Results:



Conclusions

- **Positive feedback from the different stakeholders of the MDB programmes.**
- **The importance of rigorous QC, documentation of methods and results cannot be overstated as it has a direct impact on issues of**
  - transparency,
  - repeatability,
  - completeness and
  - validity of the products.
- **Phase 2: processing of geo-spatial products for additional Urban Projects in the different geographical regions will continue.**
- **Emphasis will be given on spatial analytics for urban planning.**
- **Stakeholder feedback at the end of the Project will provide an overview of the of the utility of the geo-spatial products for urban planning.**

This should support mainstreaming EO into urban programmes.

Thank you for your attention

www.eo4sd-urban.info

GAF AG
Dr. Thomas Haeusler (Co-ordinator)
Dr. Sharon Gomez
Arnulfstr.199, 80609 Munich - GERMANY

www.gaf.de
thomas.haeusler@gaf.de
sharon.gomez@gaf.de

Lead: GAFAG

Partners: SIRS, gisat, egis, DLR, NEO, JOANNEUM RESEARCH DIGITAL, GISBOX

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