



## Data and tool training

### Built-up Area extraction with the Massive Automatic Spatial Data Analytics (MASADA) tool

**Date:** 12 September 2017

**Trainer:** Dr. Christina Corbane, European Commission, Joint Research Centre (JRC)

**Venue:** University of Twente, Faculty ITC

#### Program

##### Morning session

9.00 - 12.30 hrs.

- The Global Human Settlement Layer (GHSL) concept: data analytics, knowledge extraction and global products
- The Symbolic Machine Learning (SML) classifier for mapping human settlements from remote sensing data
- Operationalizing scientific information into indicators in support for post-international frameworks: key findings from Atlas 2016 and Atlas 2017
- How to access to GHSL data

##### Afternoon session

13.30 - 17.00 hrs.

- Hands-on computer lab on Built-up extraction with the MASADA tool

Participants must bring their own laptop computer (see requirements below)

Basic knowledge of GIS, remote sensing and data analysis

Software: Quantum GIS or ArcGIS, Matlab runtime 2016b

Minimum Hardware requirements for running MASADA: 16 GB of RAM - Any Intel or AMD x86-64 processor, 100 Mb (+ 700 Mb for Matlab Runtime) disk space for installation and the Matlab Runtime version 2016b. The supported OS are 64-bit Win7-Win10.



# Global Human Settlements Layer

<http://ghsl.jrc.ec.europa.eu>

Pesaresi M., Corbane C., Syrris V., Kemper T., Politis P., Soille P., Florczyk A., Sabo F.,  
Rodriguez Aseretto R., Maffenini L., Ferri S., Freire S., Ehlich D. Siragusa A.,  
Zanchetta L., Airaghi D.

# CONCEPTS AND DEFINITIONS



## New open and free high resolution information layer

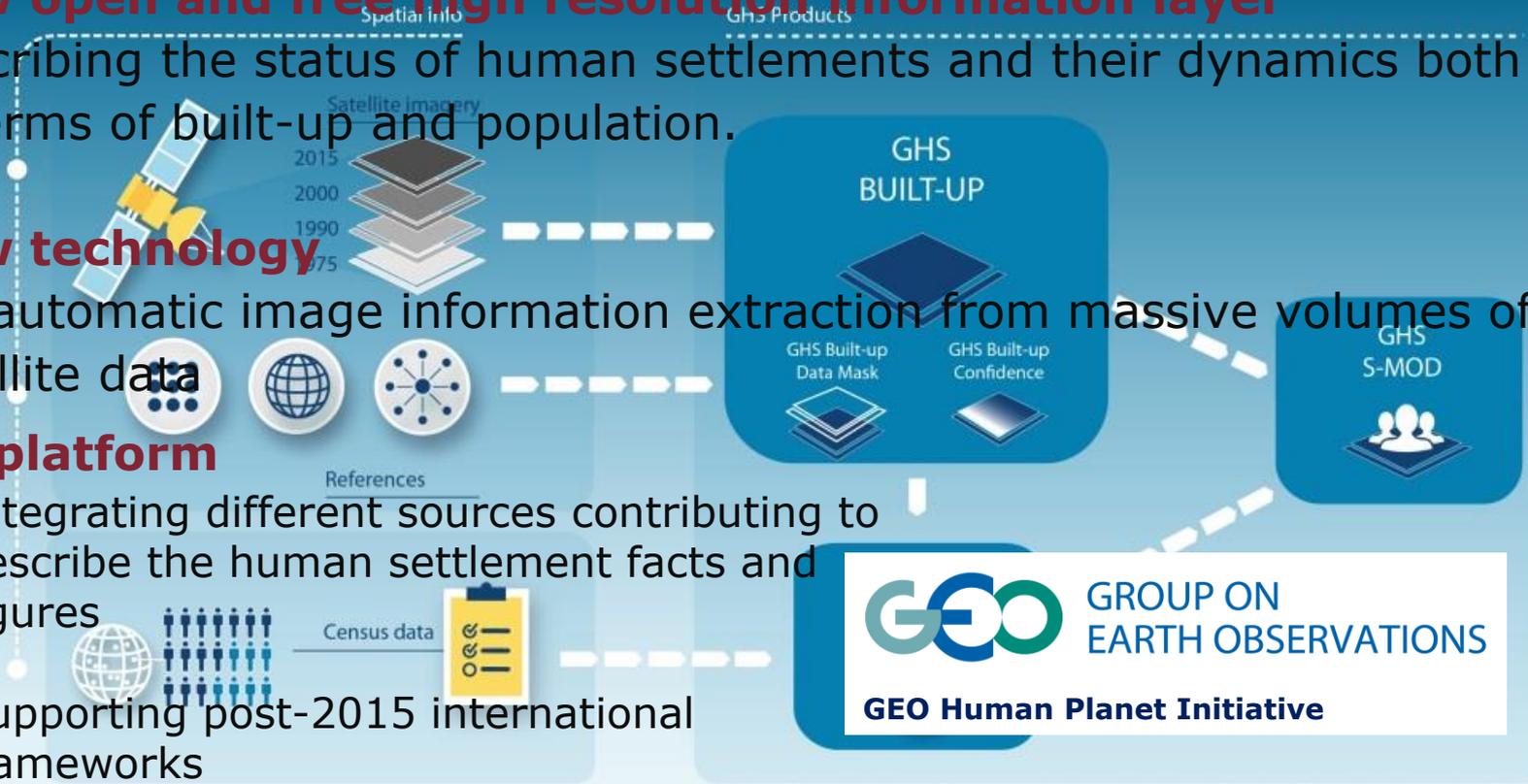
Describing the status of human settlements and their dynamics both in terms of built-up and population.

## New technology

For automatic image information extraction from massive volumes of satellite data

## A platform

- Integrating different sources contributing to describe the human settlement facts and figures
- Supporting post-2015 international frameworks



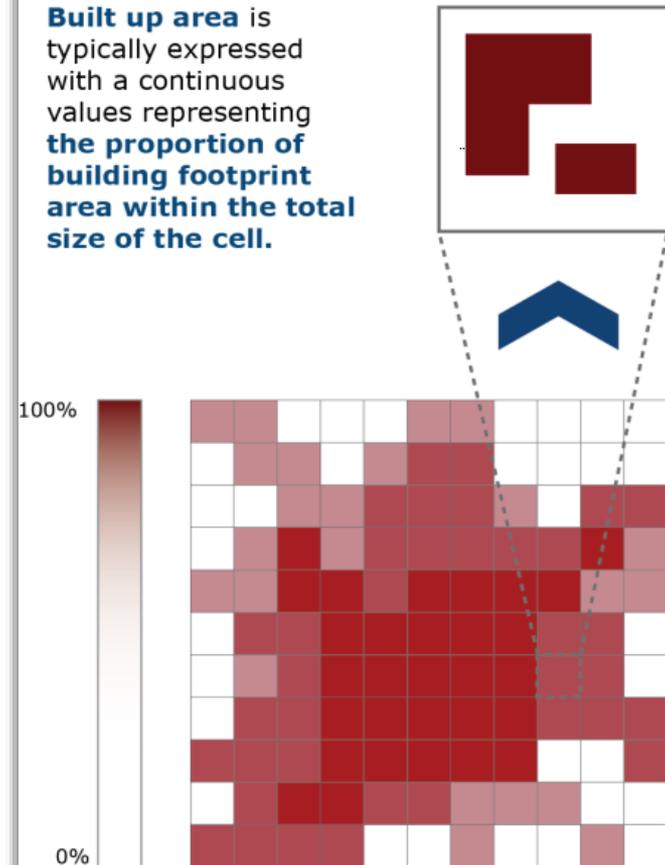
## Artificial built-up surface :

- Areas (spatial units) where buildings can be found
- Subset of “artificial surfaces”

## Epistemology of settlement:

- Physical description focused on the presence of dwellings
- Made of parts: building/dwelling, roads, open spaces
- Any dwelling included – tents to skyscraper
- Any size included – from hamlet to megacity

**Built up area** is typically expressed with a continuous values representing **the proportion of building footprint area within the total size of the cell.**

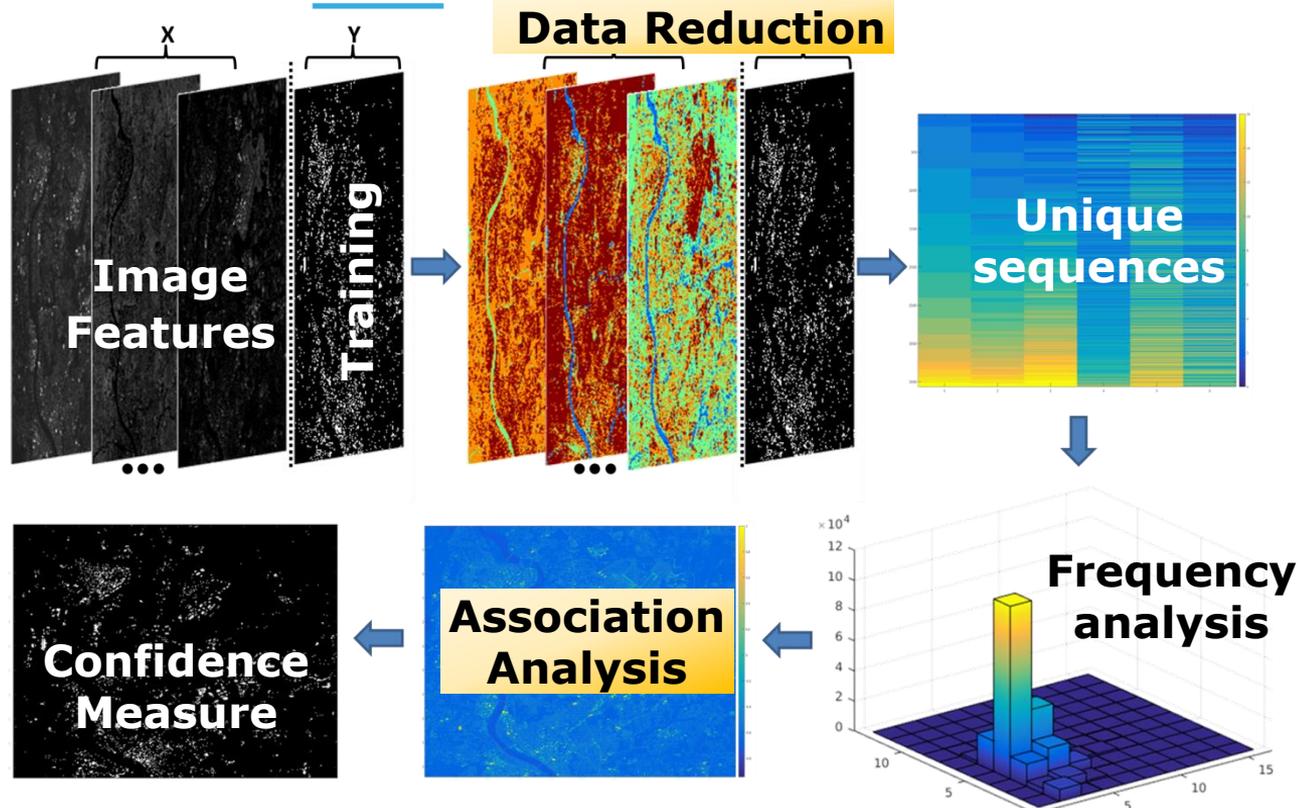




Built-up area" = all spatial units (e.g. 30x30m /sensor dependent) where a building or part of a building can be recognized



## Symbolic Machine Learning (SML)





**Input data in “false color” composite at 2.5 m spatial resolution**

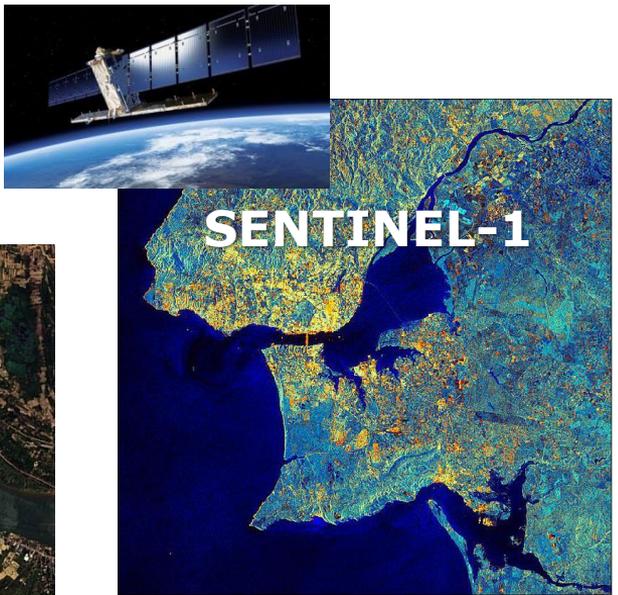
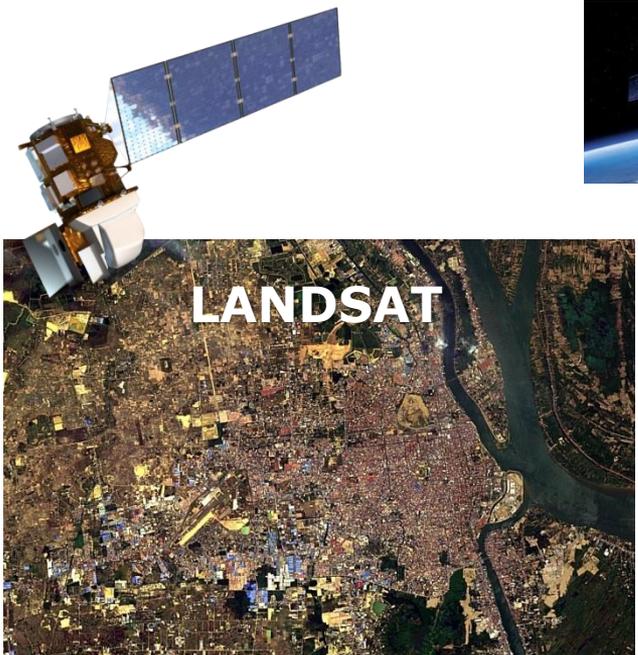


**Classes of the reference set extracted from the Land Cover at 100 m resolution**

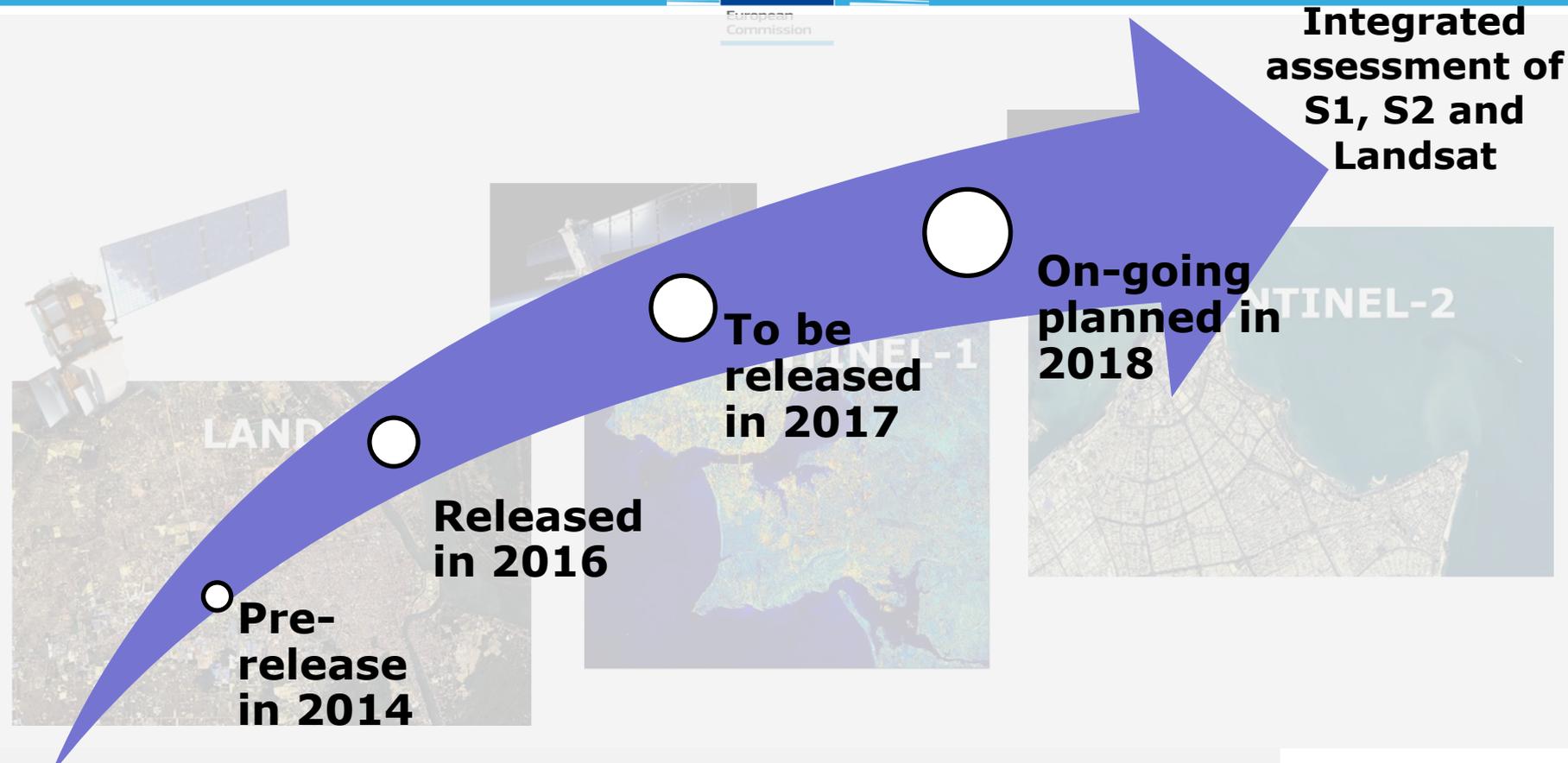


**Result of SML classification at 2.5 m spatial resolution.**

# BUILT-UP INFORMATION FROM MULTIPLE SENSORS



# BUILT-UP INFORMATION FROM MULTIPLE SENSORS



LANDSAT

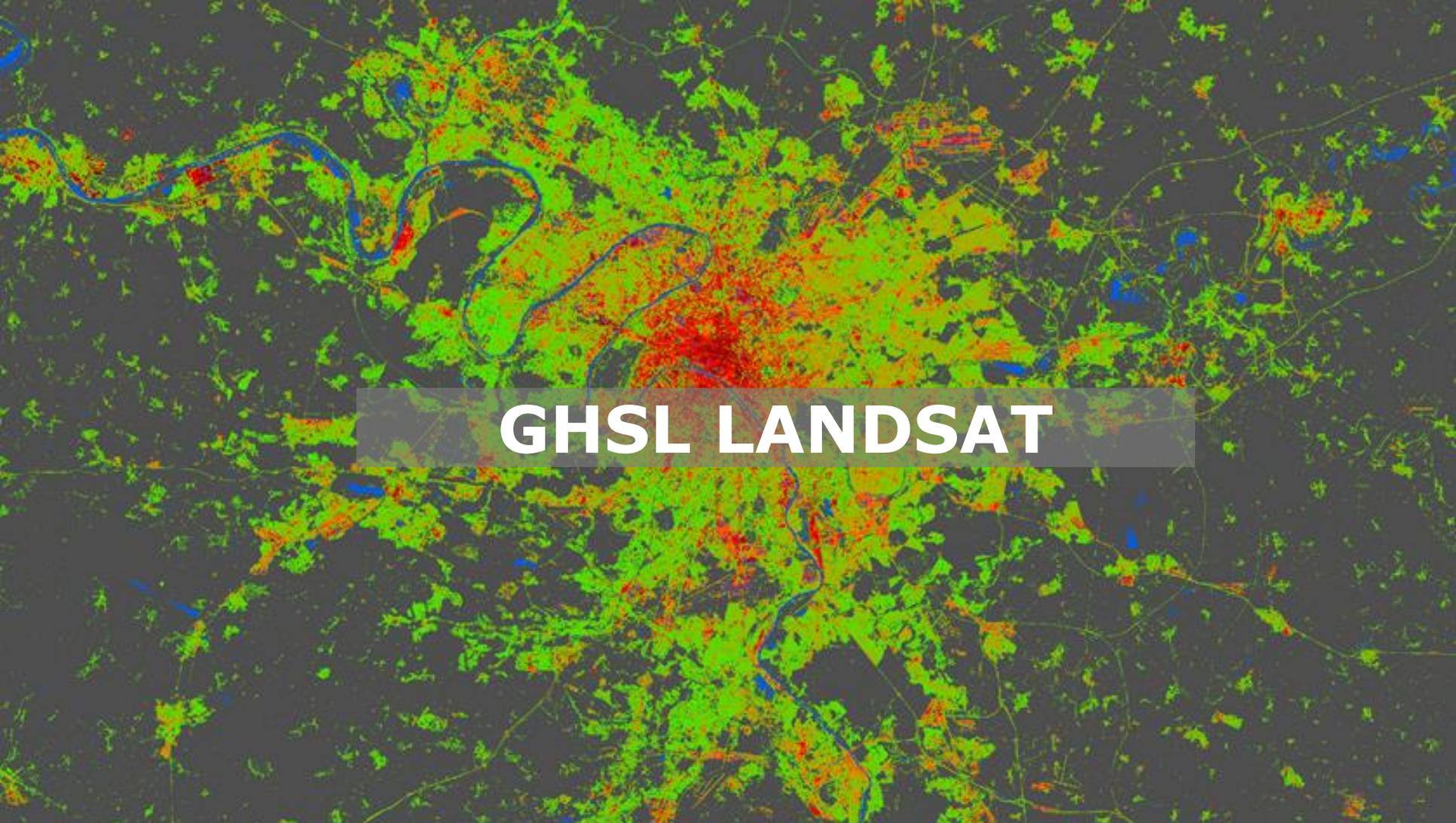
Pre-release in 2014

Released in 2016

To be released in 2017

On-going planned in 2018

Integrated assessment of S1, S2 and Landsat

An aerial satellite image of a landscape. A winding river, colored in shades of blue and cyan, flows through a dense forest. The forest is depicted in various shades of green and yellow, indicating different vegetation types or health. The background is a dark, almost black, color, which makes the green and blue features stand out. The overall image has a high-contrast, somewhat grainy appearance, characteristic of satellite imagery.

# **GHSL LANDSAT**

1979-1990-2000-2014

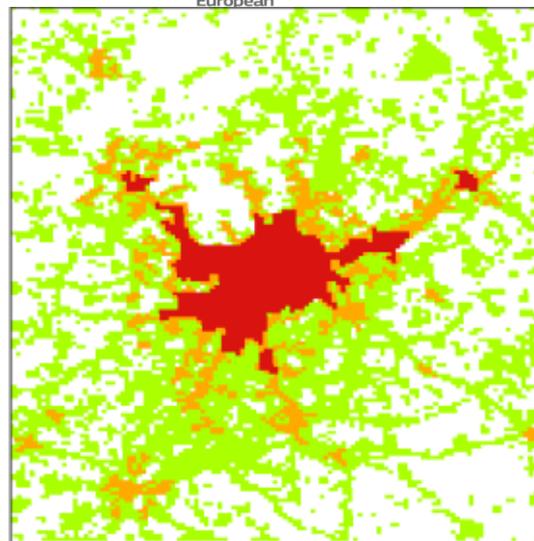


First available multi-temporal assessment of human settlements

# GHSL LANDSAT-DERIVED GLOBAL PRODUCTS



European



Settlement classification

-  Rural
-  Urban Cluster
-  Urban Centre

	<b>GHS_BUILT-UP</b>	<b>GHS_POP</b>	<b>GHS_SMOD</b>
Definition	Global built-up grids	Global population grids	Global human settlement model
Epoch	1975, 1990, 2000, 2015	1975, 1990, 2000, 2015	1975, 1990, 2000, 2015
Resolution	38 m, 250 m, 1 km	250 m, 1 km	1km

# GHSL – Baseline data anatomy



Fine-scale built-up areas  
1975,1990,2000,2014  
Landsat 75,30,15m



Population grids  
1975,1990,2000,2015  
250m

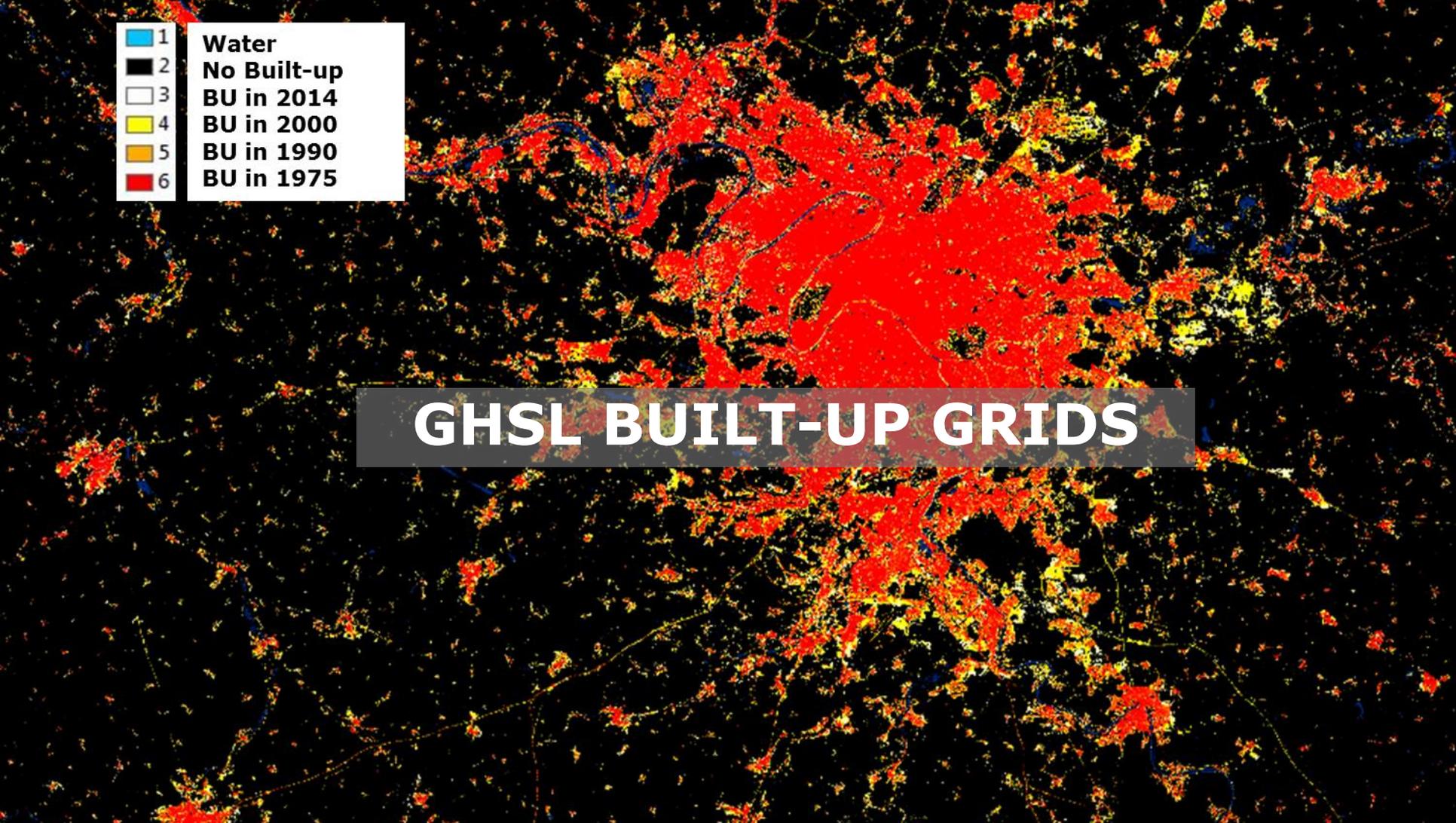


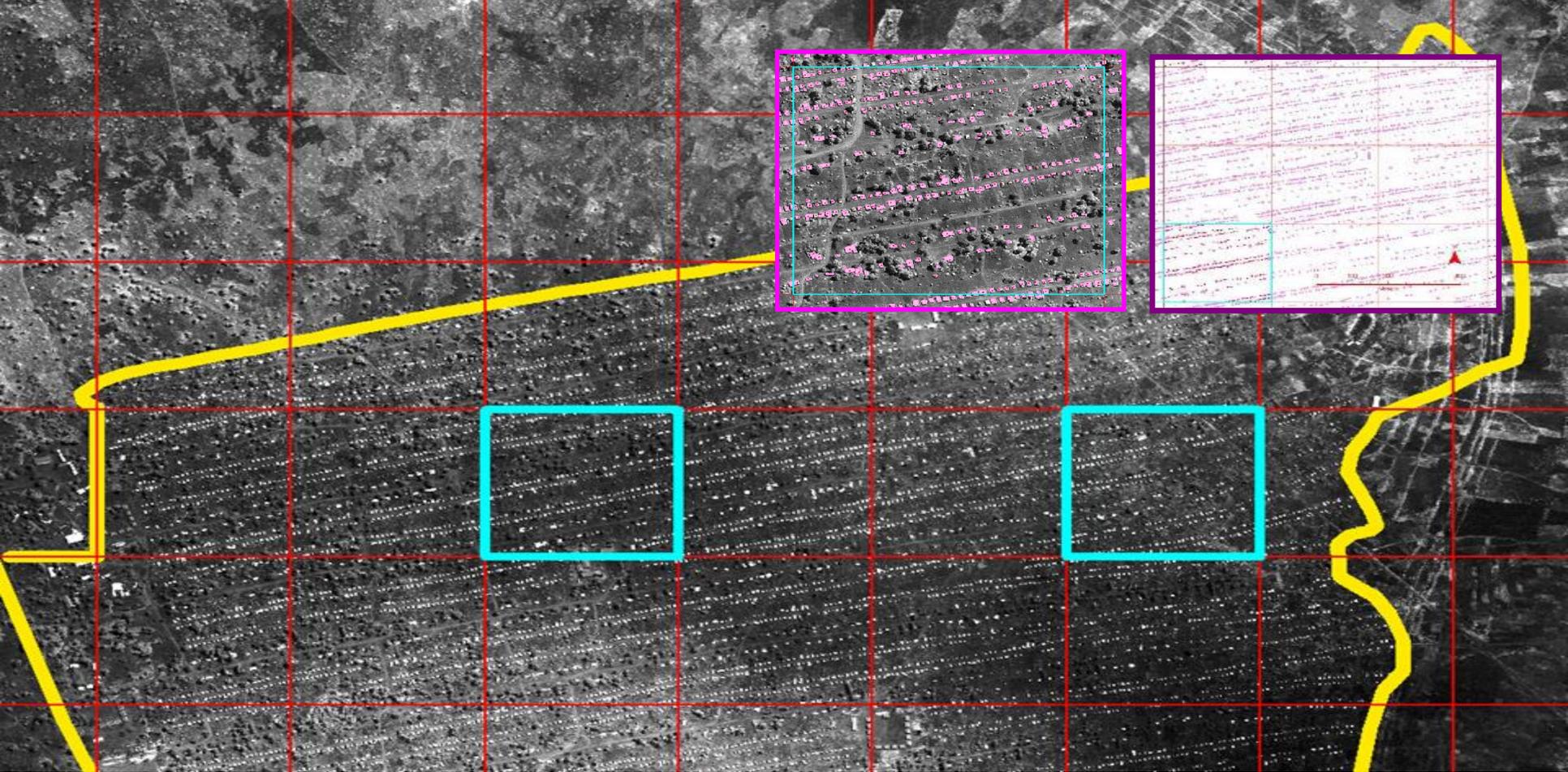
Settlement model  
1975,1990,2000,2015  
250m , 1000m  
Harmonized city spatial footprint  
“from the hamlet to the megacity”





# GHSL BUILT-UP GRIDS



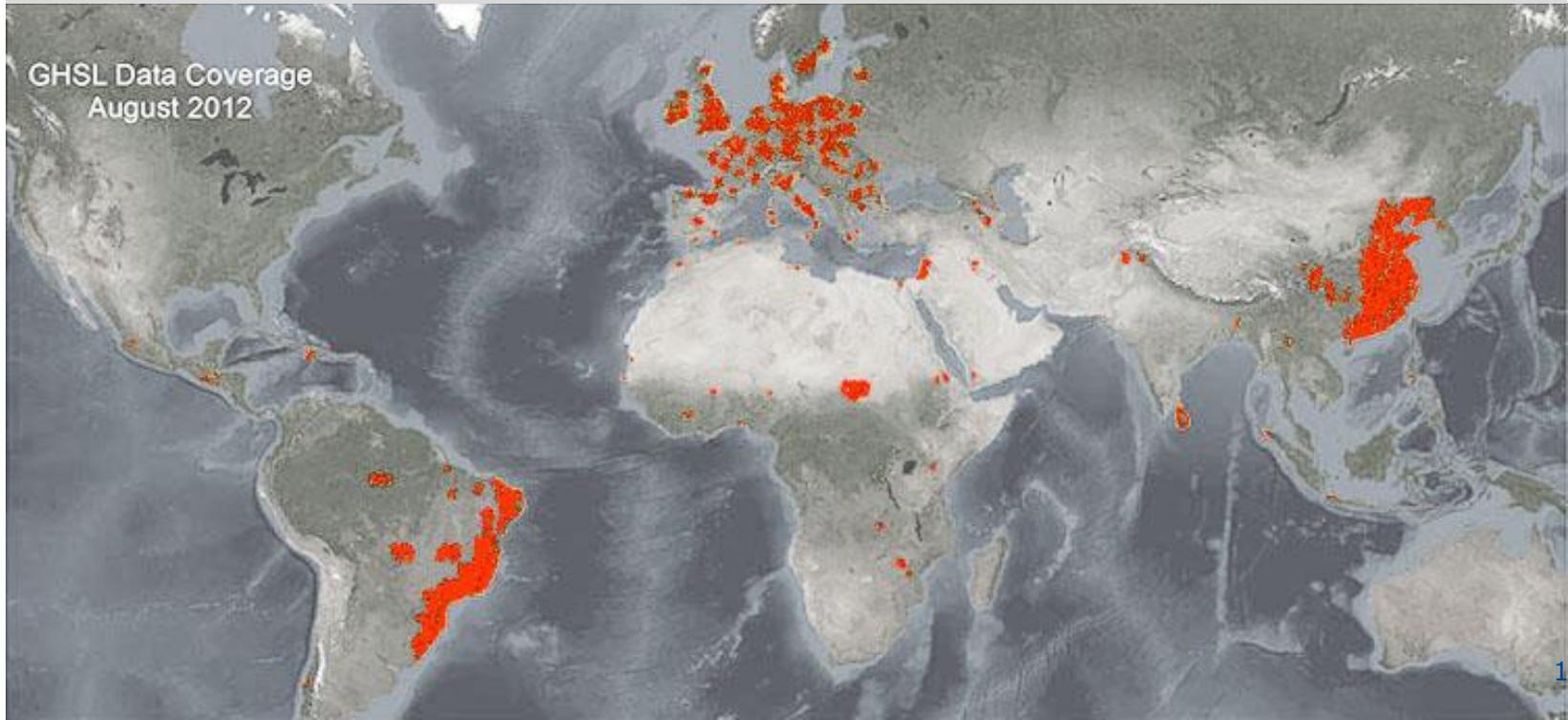


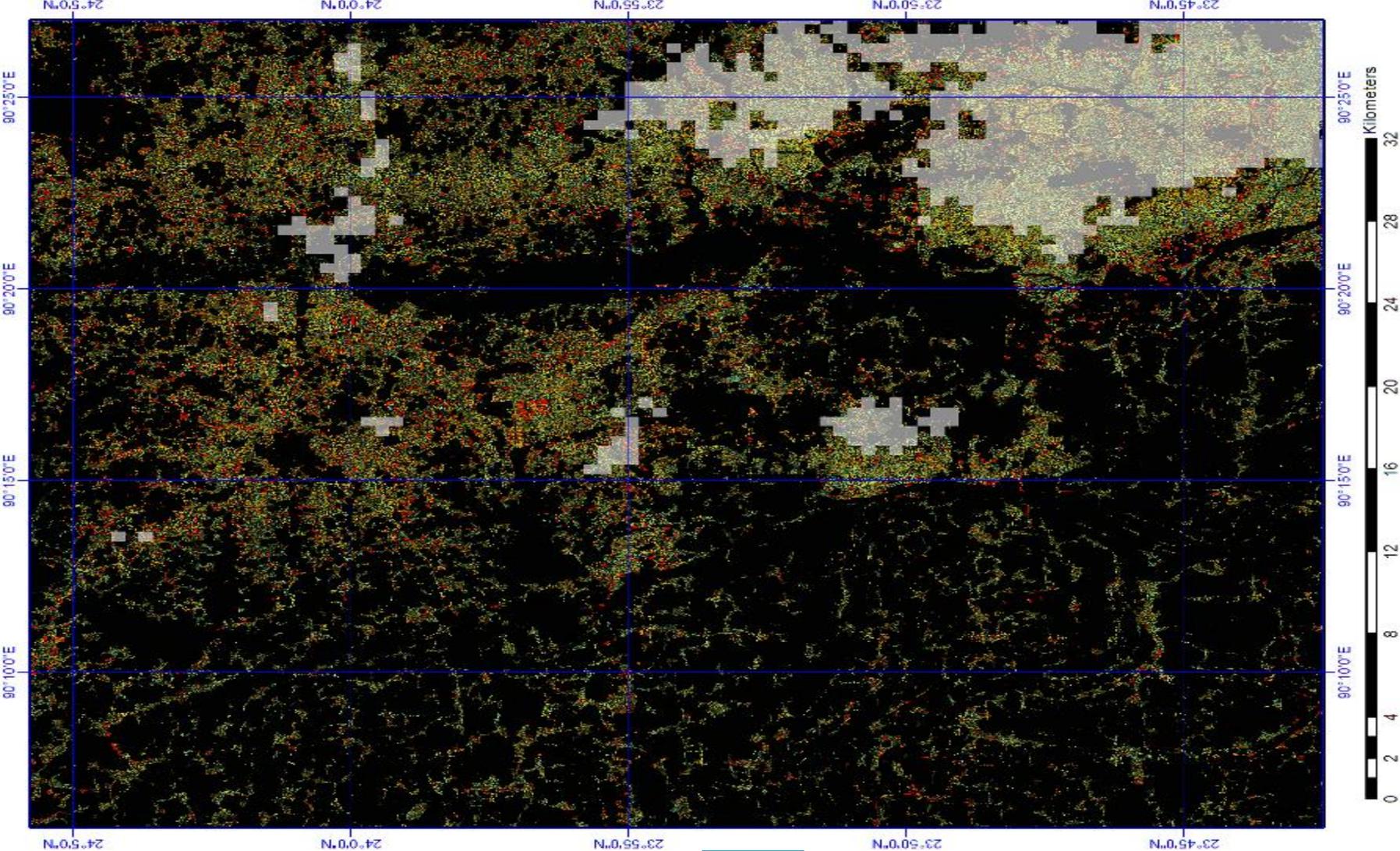
**2003 – first tests on automat. enumeration of tents  
Lukole refugee camp, Tanzania. Input Ikonos data 1,4-m-res**



# HR Global Human Settlement Layer

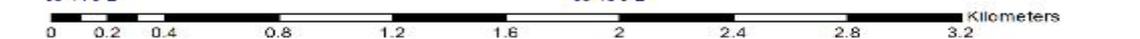
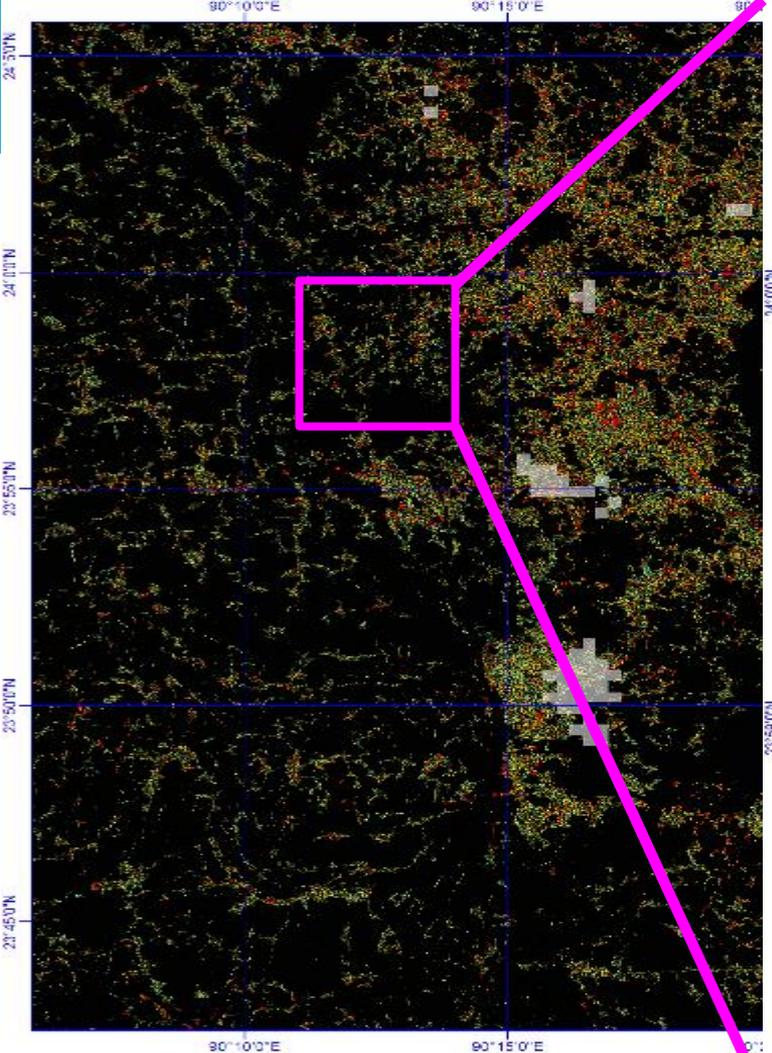
## Proof of concept 1<sup>st</sup> operational test 2012

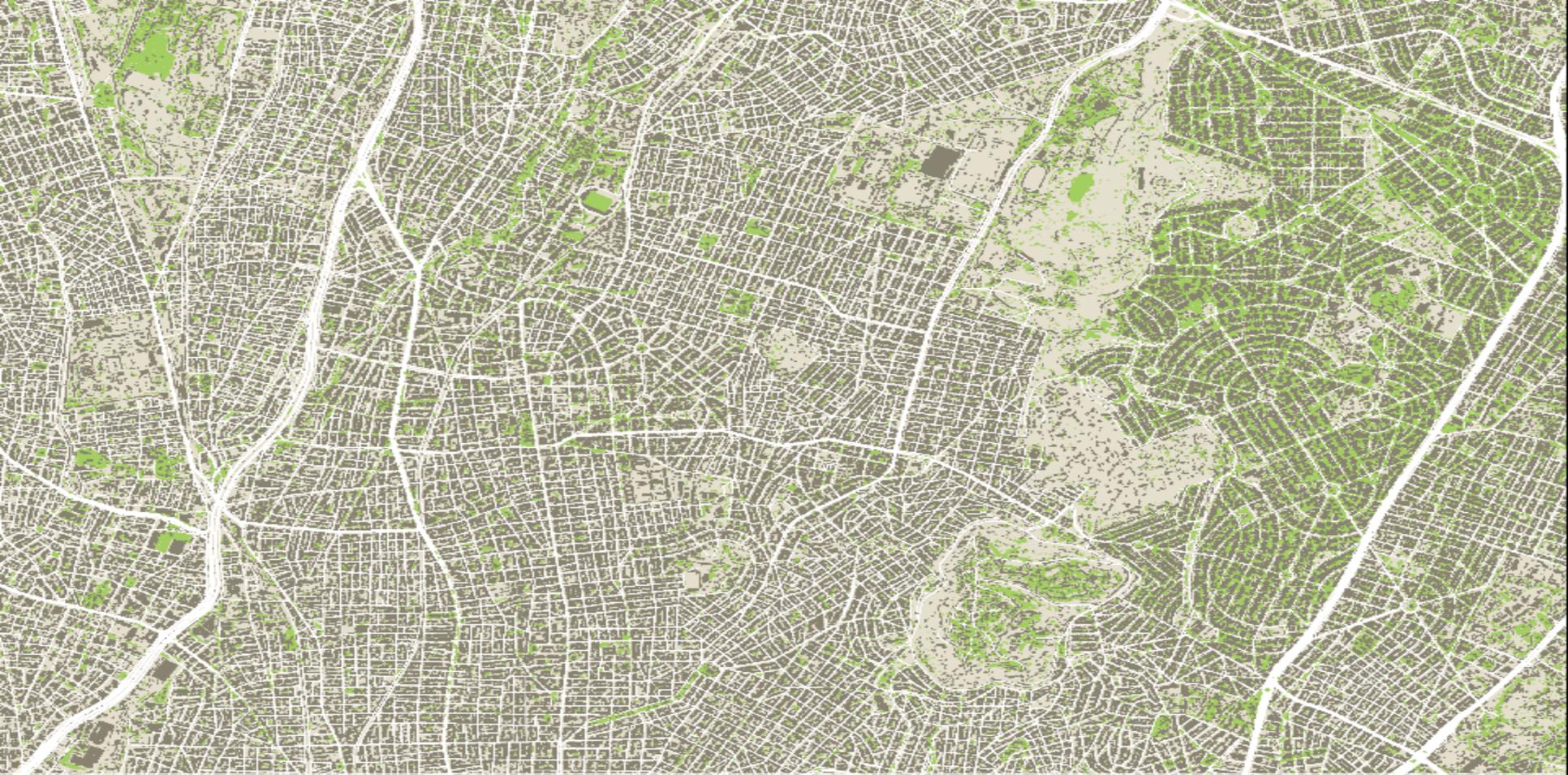




# Dhaka, HR GHSL

*(white: LR MODIS Urban layer, color: HR GHSL)*





**2012: Fine scale analysis of the whole European settlements using 2.5-m-res input image data  
(GMES/Copernicus CORE003 2012)**

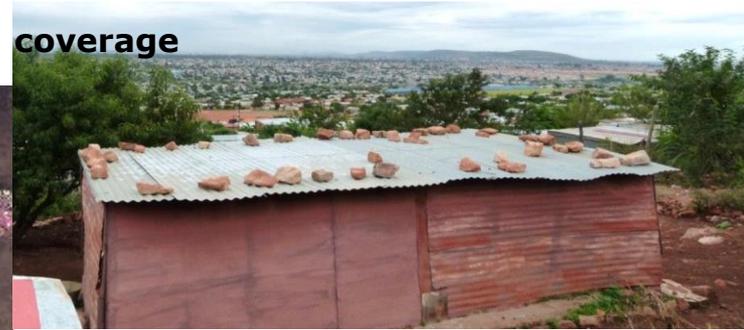
**Credits: European Commission, DG Regional Development /Joint Research Centre**

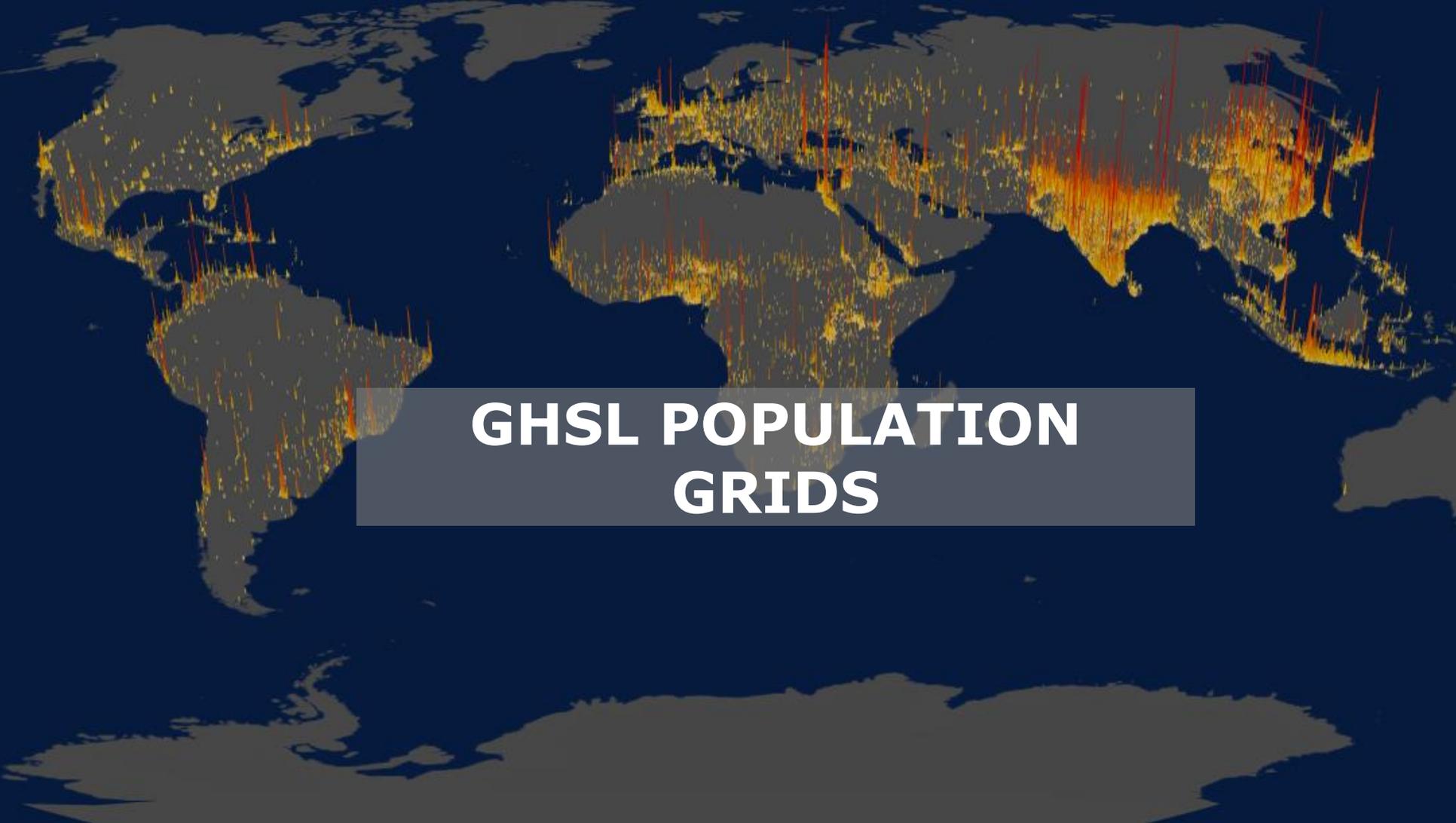
2 000 Meters



**Development of an advanced GHSL workflow for poor settlement monitoring and characterization**  
**processing of approx. 500 SPOT-5 scenes national multi-temporal coverage**

## **2014: GHSL - South Africa pilot study**

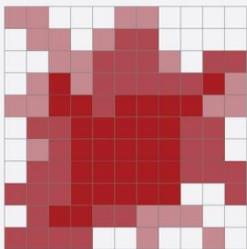


A world map with a dark blue background. Overlaid on the map is a grid of small, vertical, golden-yellow and red spikes, representing population density. The spikes are most prominent in the Eastern Hemisphere, particularly in East Asia and South Asia. A semi-transparent grey rectangular box is centered over the map, containing the text "GHSL POPULATION GRIDS" in white, bold, uppercase letters.

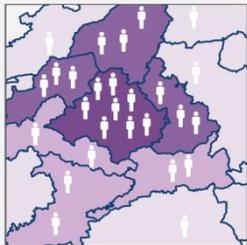
# GHSL POPULATION GRIDS

INPUT

GHS  
BUILT-UP



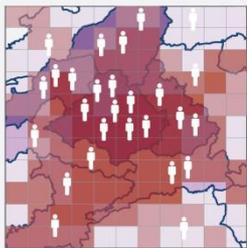
Census data



GSH built-up uses **small grid cells** to measure human settlements **regardless of administrative boundaries**.

**Population censuses** provide accurate information on the characteristics and **number of residents** for administrative or finer numeration areas (census tracts).

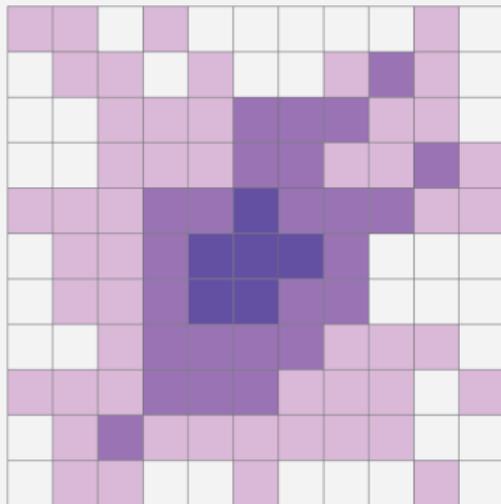
METHOD



The **GHSL method** is design to combine information from population censuses with built-up and to **downscale population** into a **grid of 1Km** of resolution, according to the presence or absence of built-up in the grid cell.

## OUTPUT

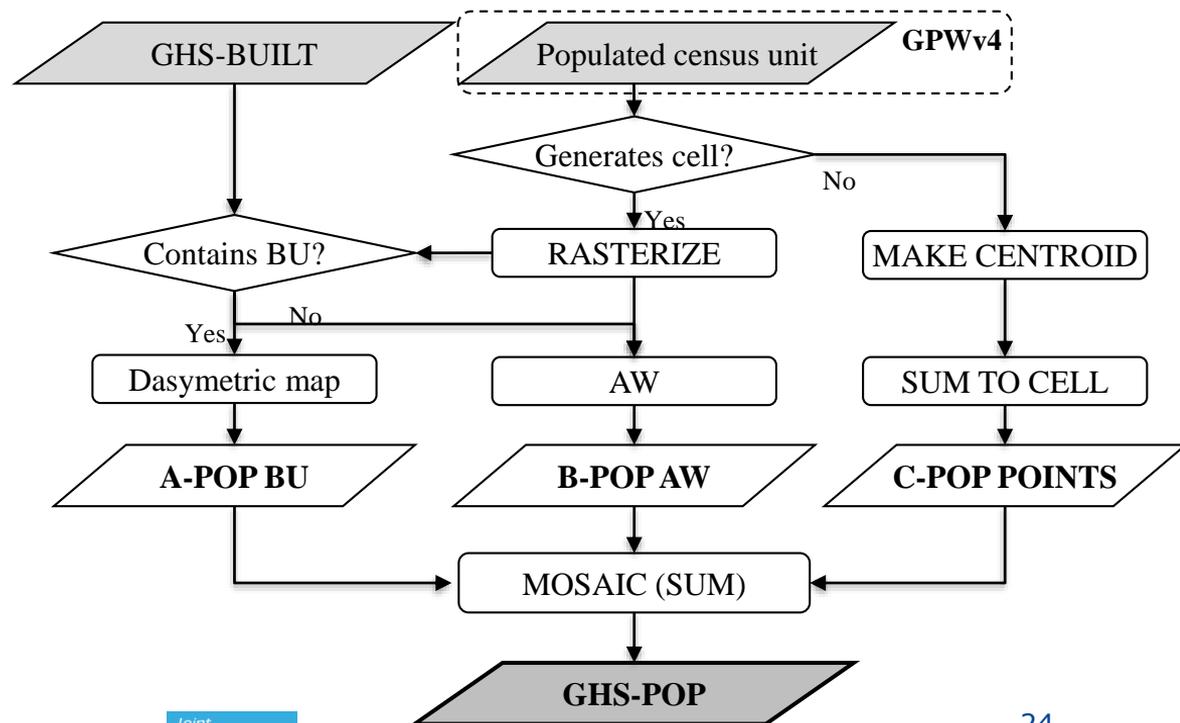
GHS  
POP



The combined information result into a new layer (resolution 1Km) which disregards administrative boundaries, and represents the **presence and density of population**. In the GHS pop grid, the grid cell value represents the absolute **number of inhabitants**.

## Methodology for Pop. disaggregation

- **Dasymetric mapping:**
- Volume-preserving
- Mollweide projection



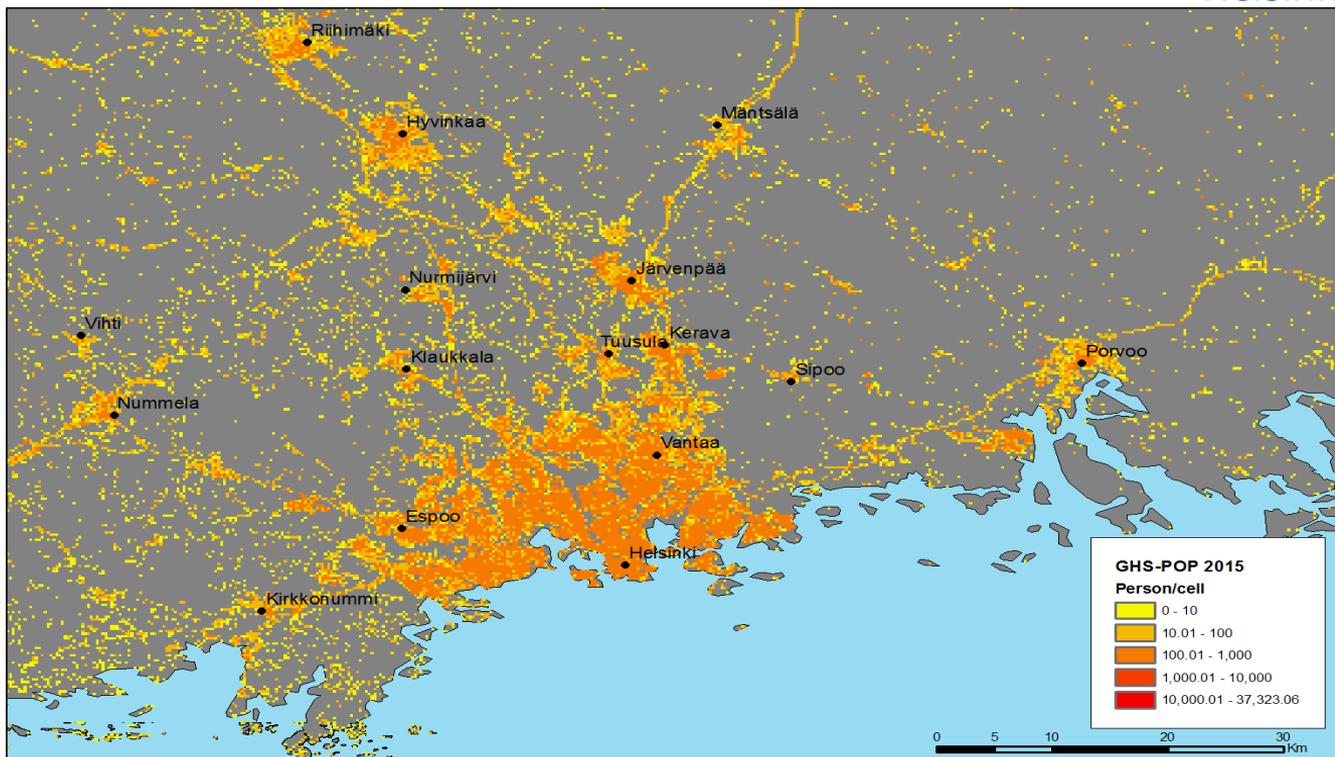
# GHSL-BASED GLOBAL POPULATION GRIDS



European  
Commission

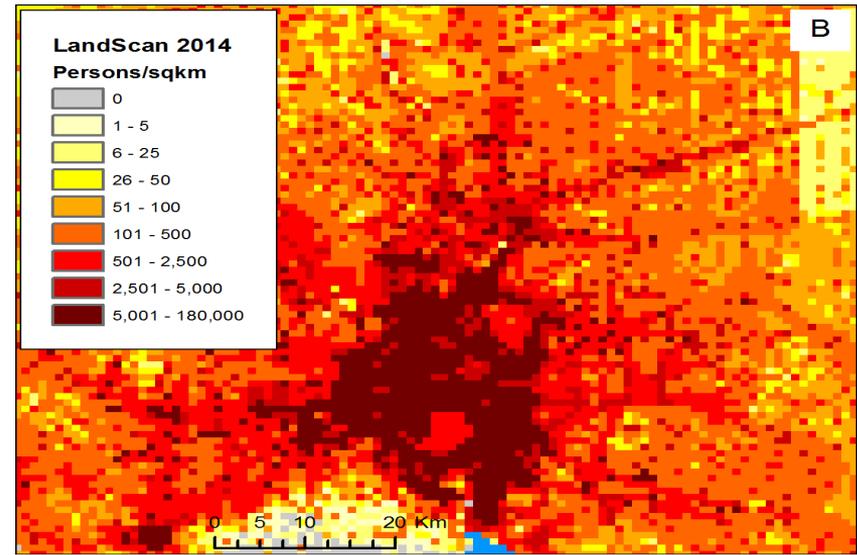
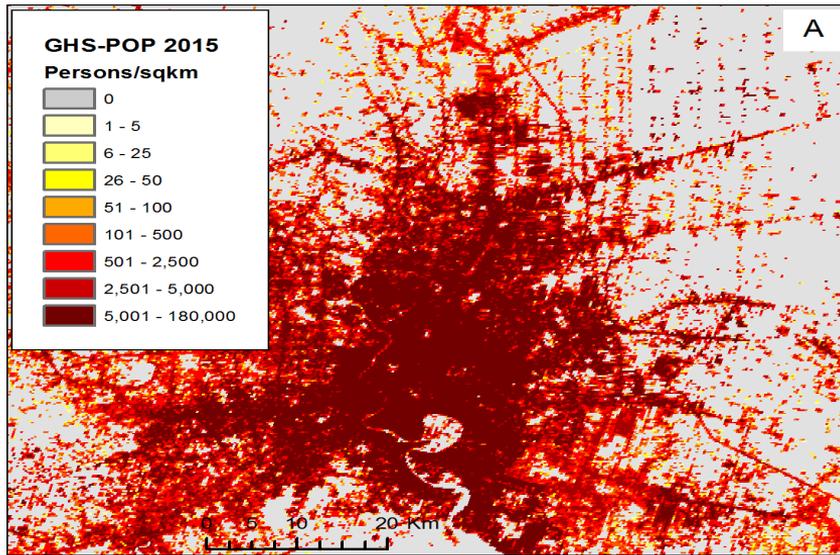
## Pop. density 1975-1990-2000-2015 @ 250m

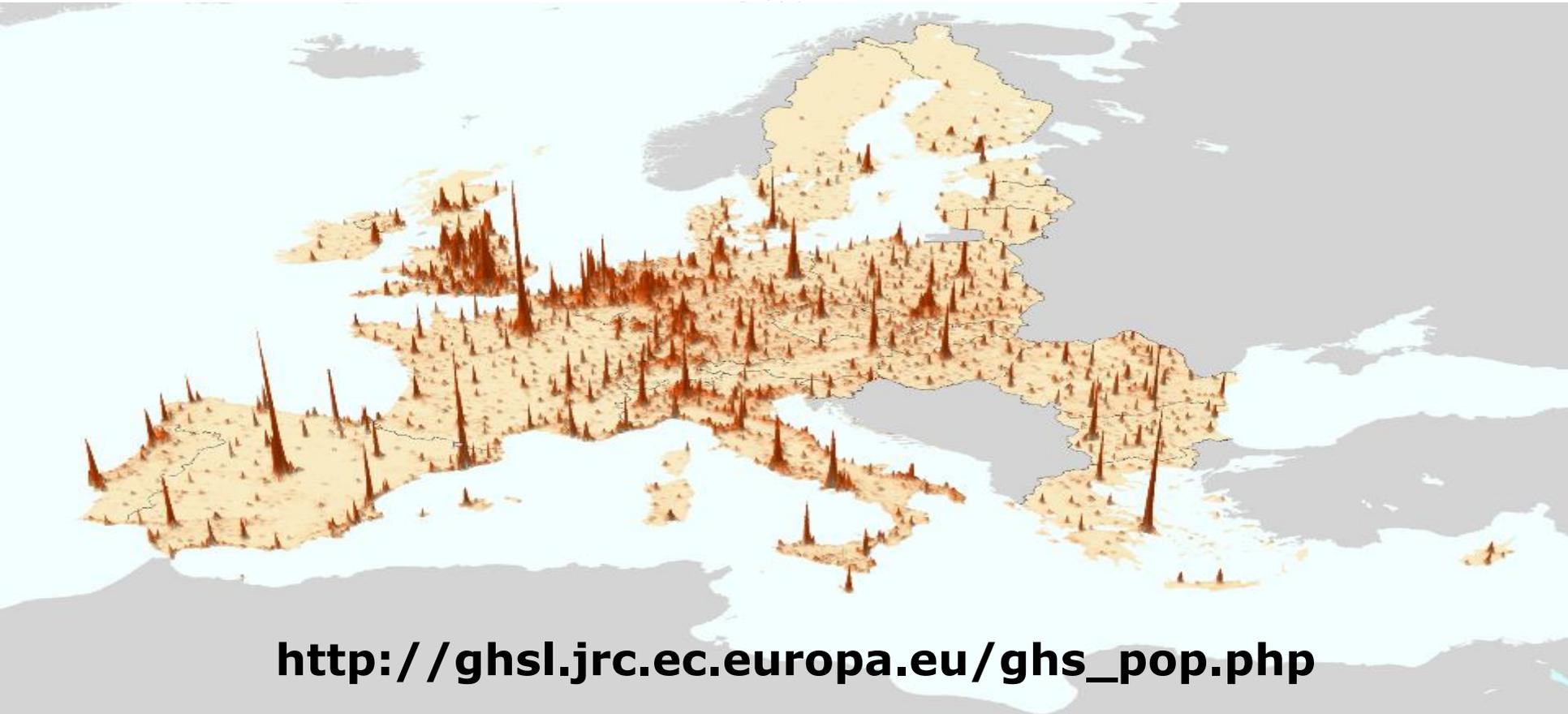
### Helsinki, FI



## Comparison with LandScan Global

### Bangkok, Thailand





[http://ghsl.jrc.ec.europa.eu/ghs\\_pop.php](http://ghsl.jrc.ec.europa.eu/ghs_pop.php)

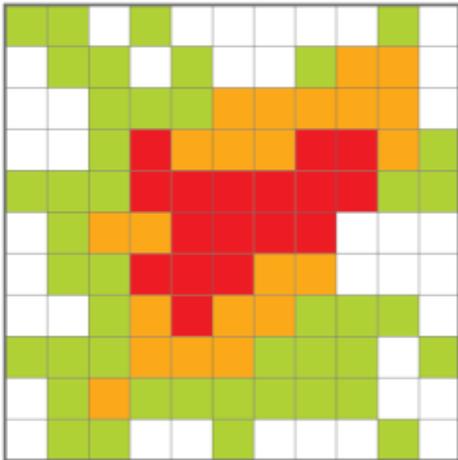


# GHSL SETTLEMENT MODEL

# GHSL-BASED SETTLEMENT MODEL

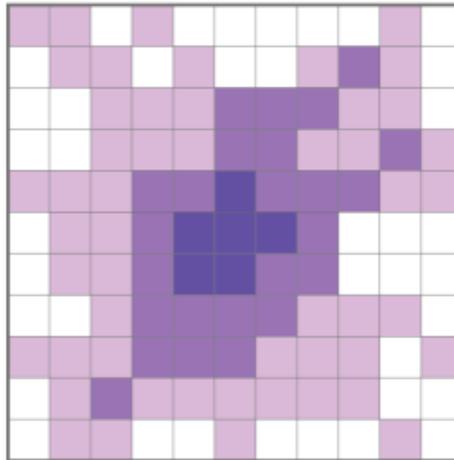


**S-MOD**  
calculated at 1Km



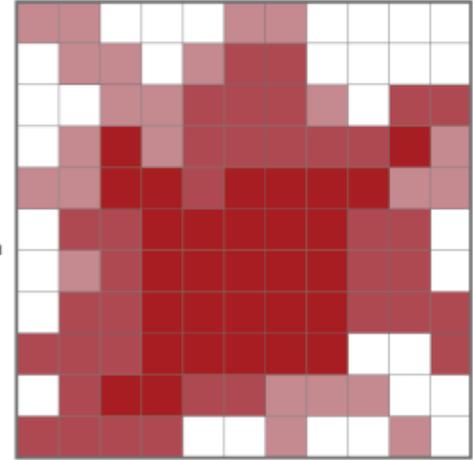
=

**POPULATION GRID**  
aggregated from 250m



+

**BUILT-UP**  
aggregated from 38m

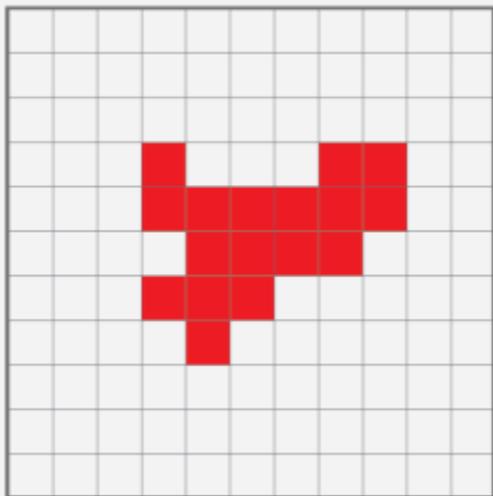


[http://ghsl.jrc.ec.europa.eu/ghs\\_smod.php](http://ghsl.jrc.ec.europa.eu/ghs_smod.php)

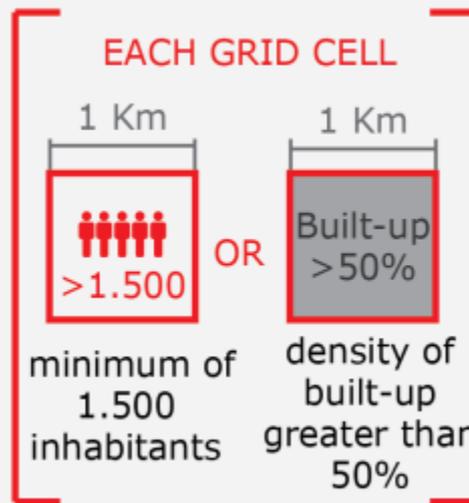
# GHSL-BASED SETTLEMENT MODEL



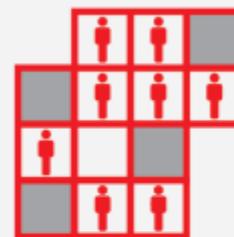
## URBAN CENTRE



## Required conditions



AND



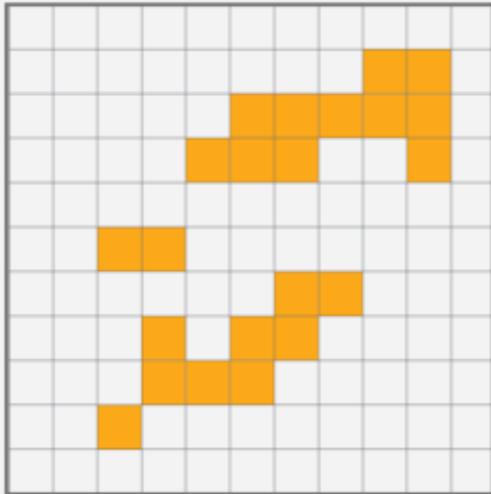
**TOTAL POPULATION > 50.000 INHABITANTS**

contiguous grid cells (4-connectivity, gap filling) with minimum population of 50.000 inhabitants

# GHSL-BASED SETTLEMENT MODEL



## URBAN CLUSTER



## Required conditions

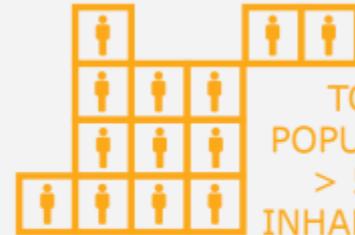
EACH GRID CELL

1 Km



minimum  
of 300  
inhabitants

AND



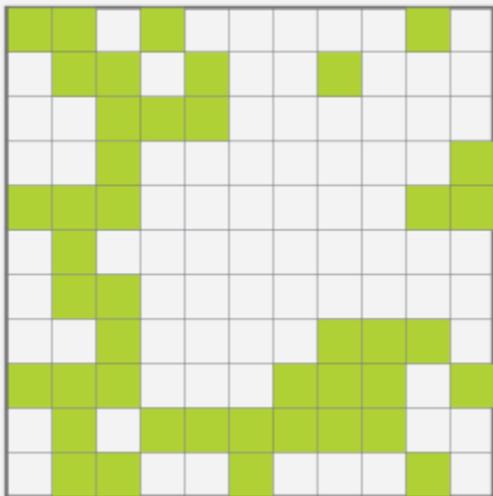
TOTAL  
POPULATION  
> 5.000  
INHABITANTS

contiguous grid cells  
(8-connectivity)  
with minimum population of  
5.000 inhabitants

# GHSL-BASED SETTLEMENT MODEL



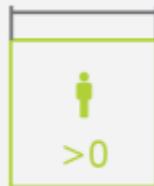
## RURAL



## Required conditions

EACH GRID CELL

1 Km



cell with  
inhabitants



AND

single or contiguous grid  
cells with total population  
of less than 5.000  
inhabitants

# GHSL-BASED SETTLEMENT MODEL: MADRID



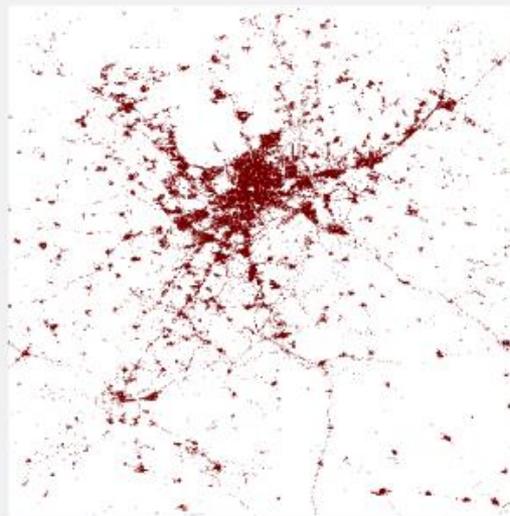
Satellite imagery



Legend

-  Administrative boundaries (Gadm level 3)

The image on the left is a satellite image of the city of **Madrid, Spain in 2015**. The overlapped administrative boundaries (in blue) show their differences in size and unevenness of borders.



Built-up area

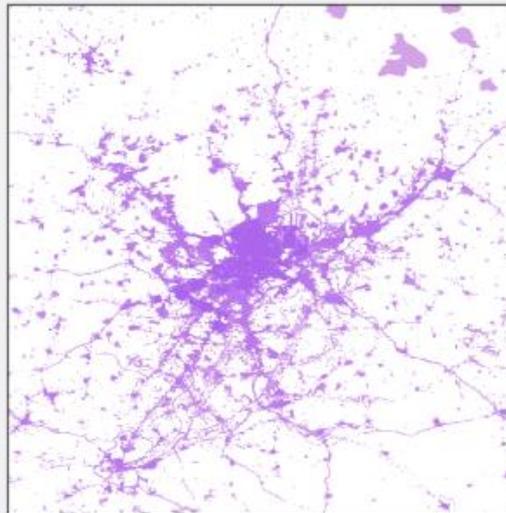


## Built-up (resolution 38m)

**Built up area** is typically expressed with a continuous values representing **the proportion of building footprint area within the total size of the cell.**

The value of the cells in this area are significantly different, from 0 to 98.

GHSL  
POP



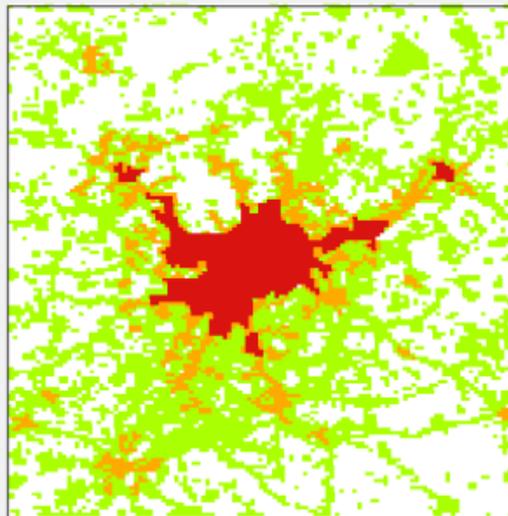
Number of inhabitants



## Population grids (resolution 250m)

In the population grid, grid cell value represents the number of inhabitants.

In this specific area, the number of inhabitants varies from 3 to about 12.000 per sqKm.



Settlement classification

-  No data
-  Rural
-  Urban Cluster
-  Urban Centre

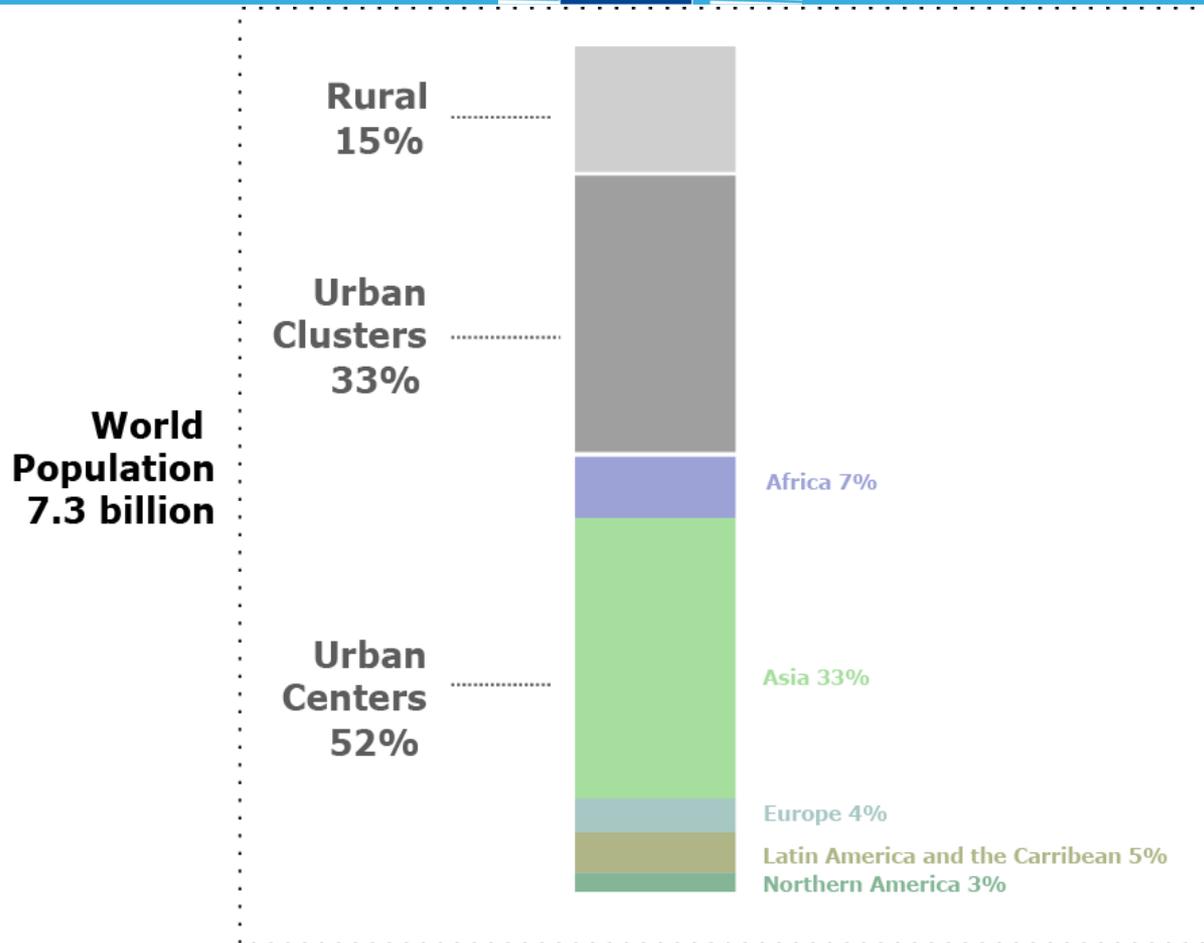
## Settlement Model (resolution 1Km)

The GHS S-MOD aims at classifying human settlements according to certain rules of population and built-up density and contiguity of grid cells.

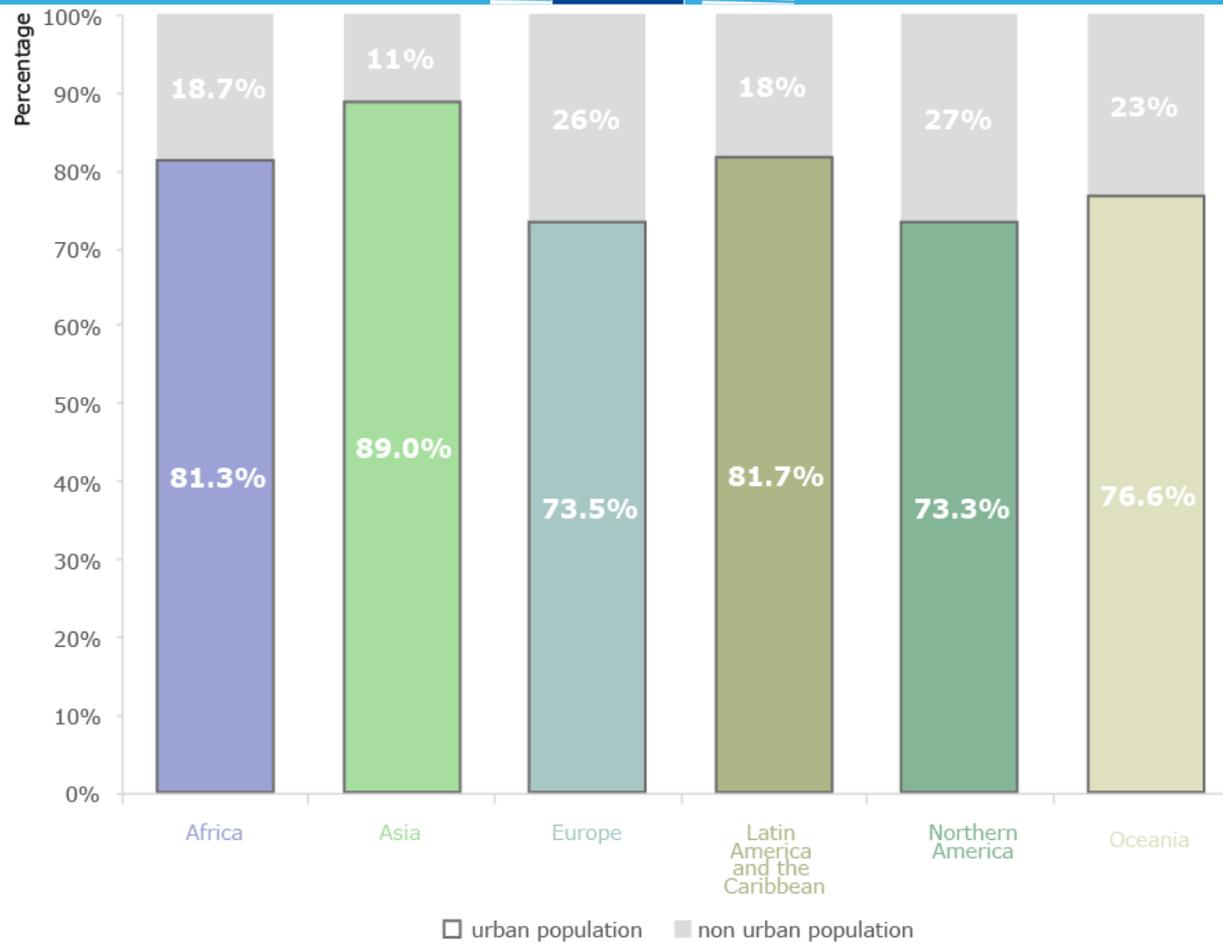
In the example on the left, the urban centre of Madrid, with relative urban clusters and rural settlements.

Dijkstra L., Poelman, H. 2014. A harmonized definition of cities and rural areas: the new degree of Urbanization. Working Paper, WP 01/2014, DGRegio, Brussels.

# DISTRIBUTION OF GLOBAL POPULATION ACCORDING TO GHSL SMOD



# DEGREE OF URBANISATION IN 2015 PER CONTINENT



An aerial satellite image of a coastal region, likely in the Gulf of Mexico. The image shows a mix of green vegetation, brownish terrain, and dark water bodies. A semi-transparent grey rectangular box is overlaid in the center, containing the text "GHSL SENTINEL- 1" in white, bold, sans-serif font. The text is centered horizontally and vertically within the box. The background image shows a coastline with several large, dark, irregularly shaped water bodies, possibly lagoons or bays, and a network of roads and fields. The overall color palette is dominated by greens, browns, and blacks.

# GHSL SENTINEL- 1



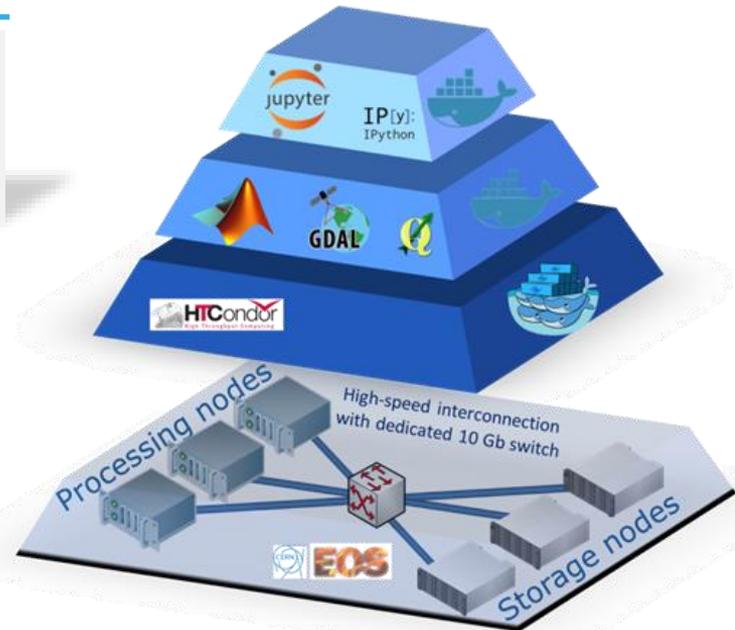
## Sentinel-1 Ground Range Detected (GRD) – Dual polarization

**5000 scenes**  
Dec 2015 – June 2016



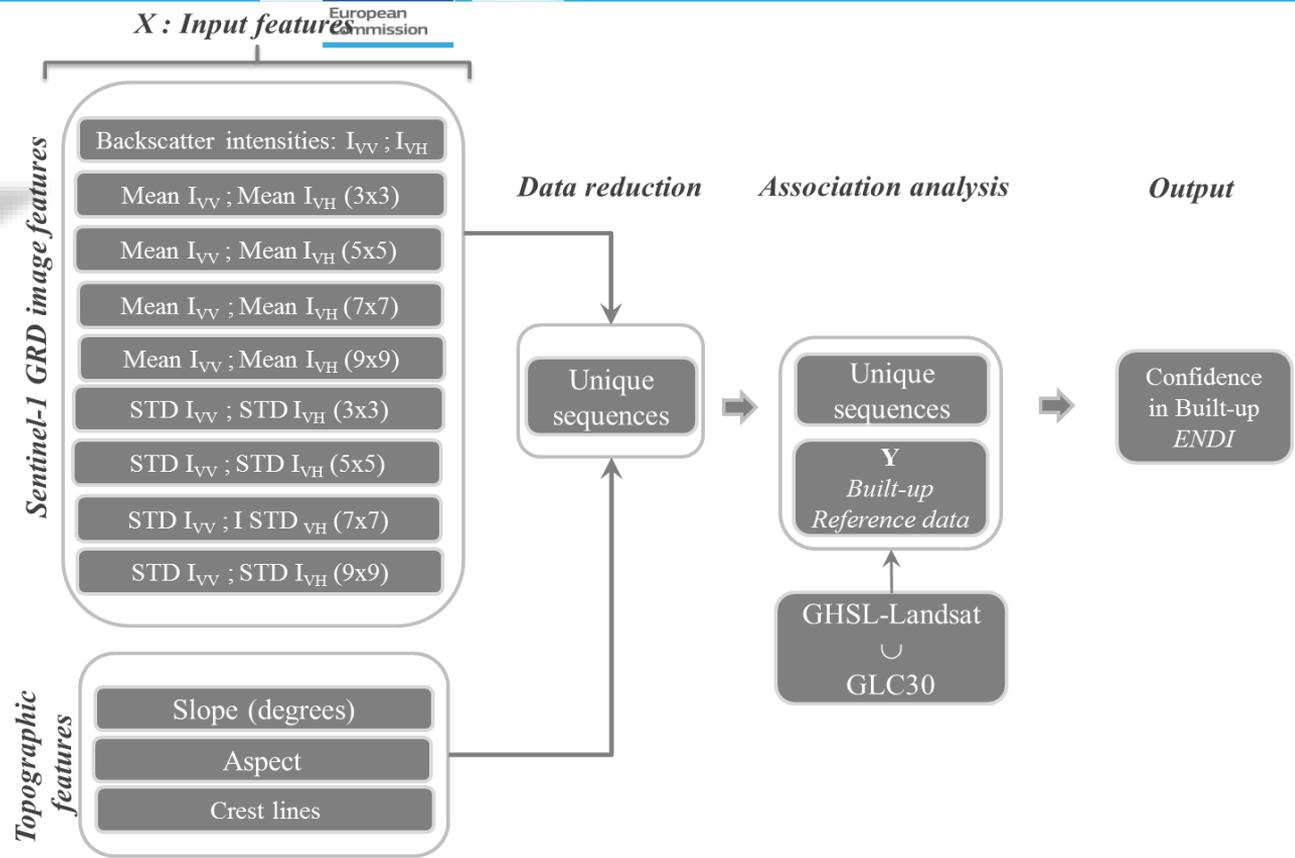
## JRC Earth Observation Data and Processing Platform (JEODPP)

Cutting-edge storage technology thanks to a collaboration between the European Organization for Nuclear Research ([CERN](http://cern.ch)) and JRC





## Adaptation of SML workflow to SENTINEL-1



# GHSL SENTINEL-1: ENHANCED BUILT-UP DETECTION

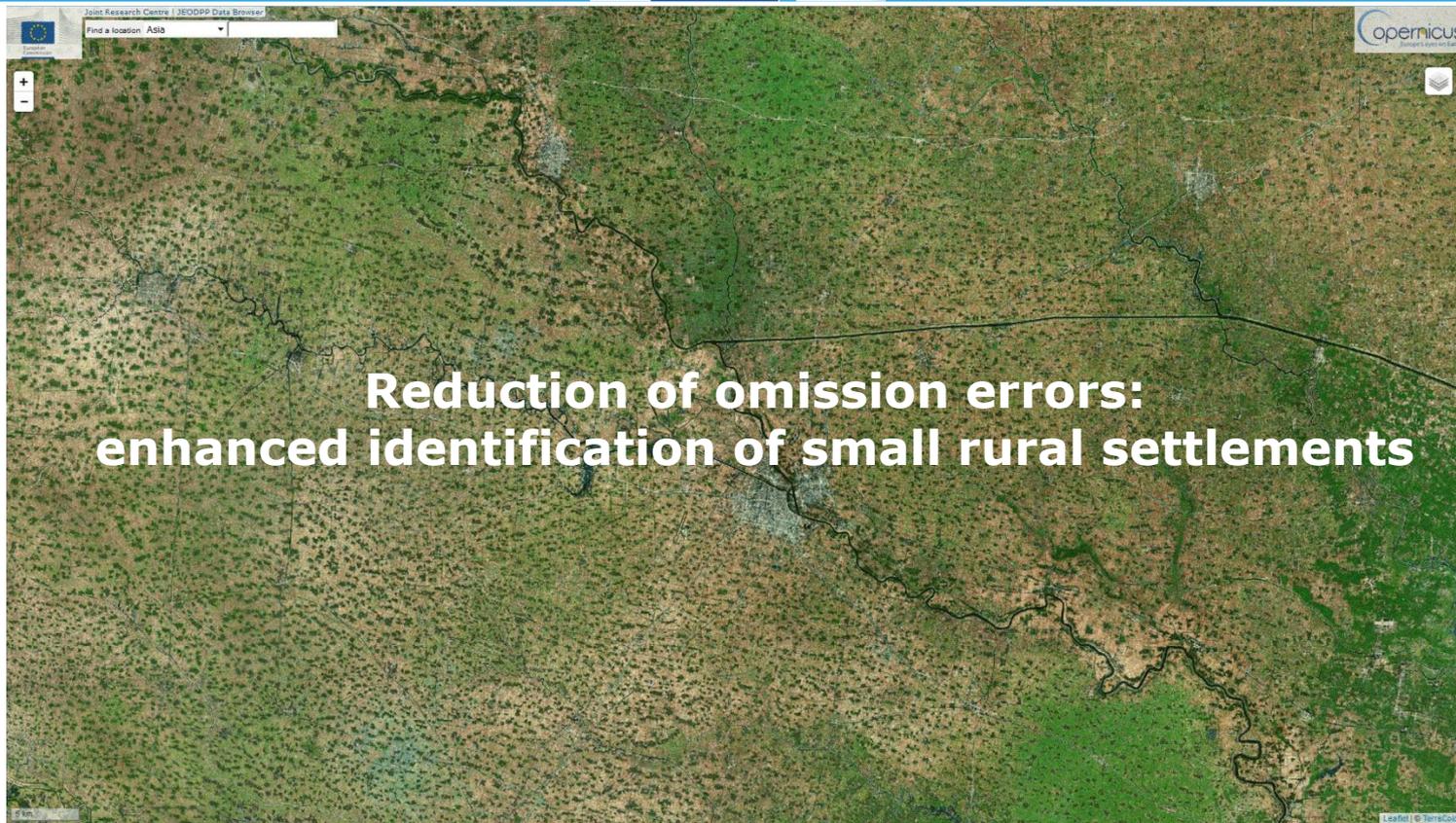


## AMSTERDAM

Note: the images above have been generated using the ([JEODPP platform](#))



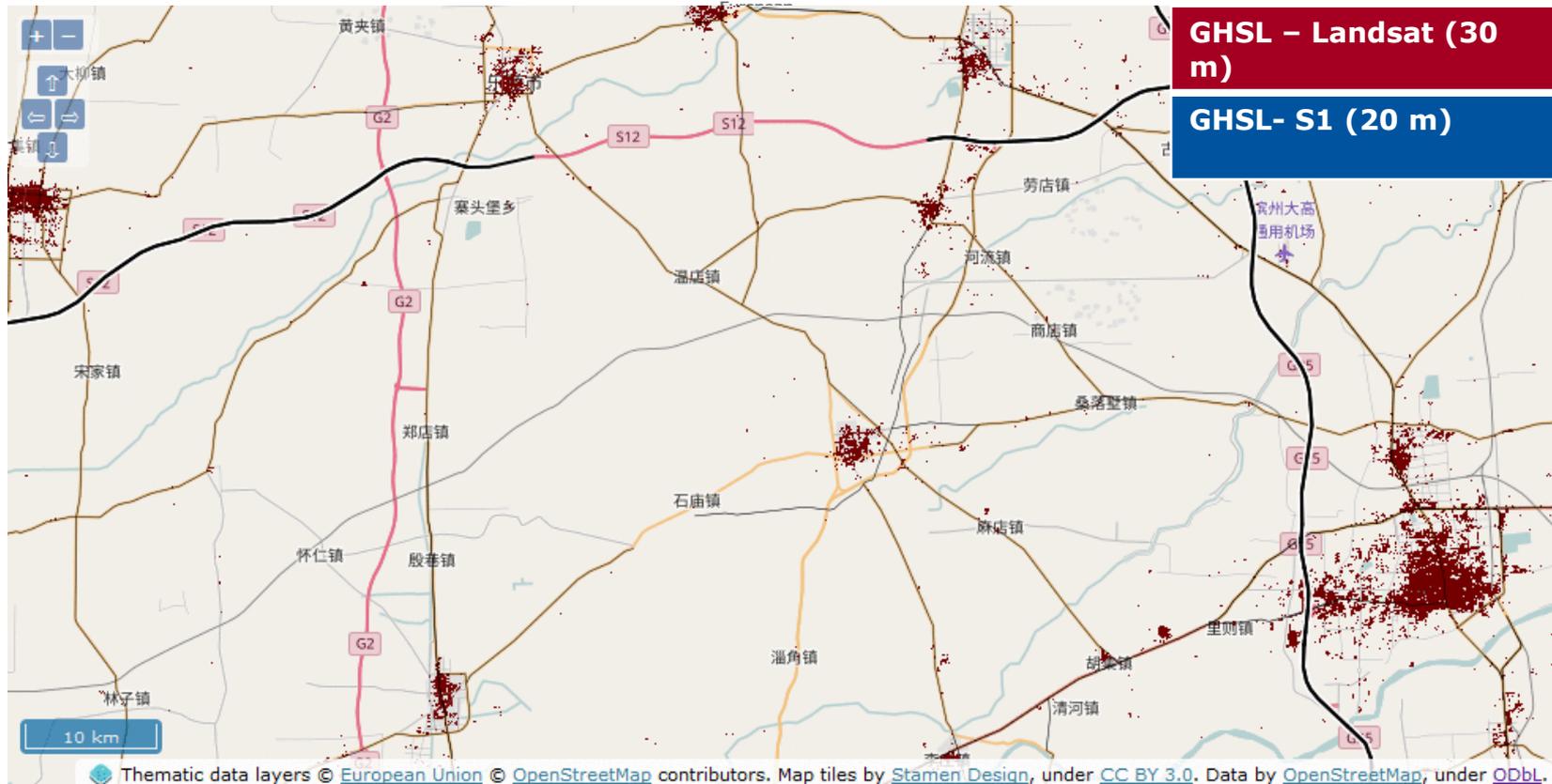
# GHSL SENTINEL-1: ENHANCED BUILT-UP DETECTION



DENZHOU

Note: the images above have been generated using the ([JEODPP platform](#))

# GHSL SENTINEL-1: ENHANCED BUILT-UP DETECTION



## DENZHOU

Note: the images above have been generated using the ([JEODPP platform](#))

# NEXT STEPS AND CHALLENGES



New global built-up layer derived from Sentinel-2



Integrated GHSL product: Landsat, Sentinel-1 and Sentinel-2



GHSL based indicators for Sustainable Development Goals and Sendai Framework for Disaster Risk Reduction



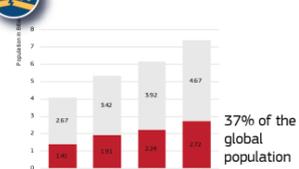
GEO Human Planet Initiative

Joint Research Centre

## KEY FINDINGS FROM THE ATLAS OF THE HUMAN PLANET 2017 Global Exposure to Natural Hazards



### EARTHQUAKE

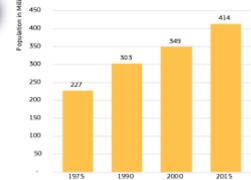


Population potentially exposed to earthquakes increased from 1.4 to 2.7 billion between 1975 and 2015

37% of the global population



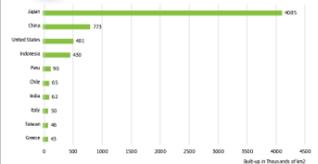
### VOLCANO



In 2015, 414 million people (6% of the global population) live near one of the 220 most dangerous volcanoes and can be affected by the consequences of eruptions



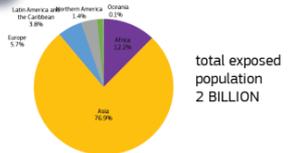
### TSUNAMI



The built-up area potentially exposed to tsunamis in Japan is 2 times the sum of built-up in the other 9 most exposed countries.



### FLOOD

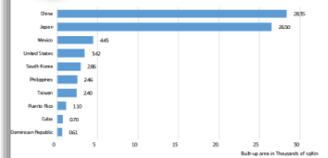


Flood, the most frequent natural disaster, potentially affect people in Asia and Africa more than in other regions

total exposed population 2 BILLION



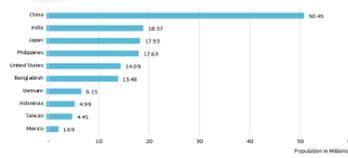
### CYCLONE WIND



China and Japan are by far the countries with the most built-up area exposed to strong cyclone winds



### CYCLONE SEA LEVEL SURGE



Population exposed to cyclone sea level surge in China approximates the sum of the exposed population of

Global Human Settlement... X +

ghsl.jrc.ec.europa.eu/index.php

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EUROPEAN COMMISSION  
Global Human Settlement

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### GHSL - Global Human Settlement Layer

**A new open and free tool for assessing the human presence on the planet**

- Produces new global spatial information, evidence-based analytics and knowledge describing the human presence on the planet
- Operates in an open and free data and methods access policy (open input, open method, open output)
- Supported by the Joint Research Centre (JRC) and the DG for Regional Development (DG REGIO) of the European Commission, together with the international partnership [GEO Human Planet Initiative](#)  GROUP ON EARTH OBSERVATIONS



1975

<http://ghsl.jrc.ec.europa.eu>

Click here to find out about the technology behind this image

1 2 3 4 5 6

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# Thank you for your attention

## Joint Research Centre

[christina.corban@ec.europa.eu](mailto:christina.corban@ec.europa.eu)