The European Settlement Map

Matina **HALKIA** and the GHSL team
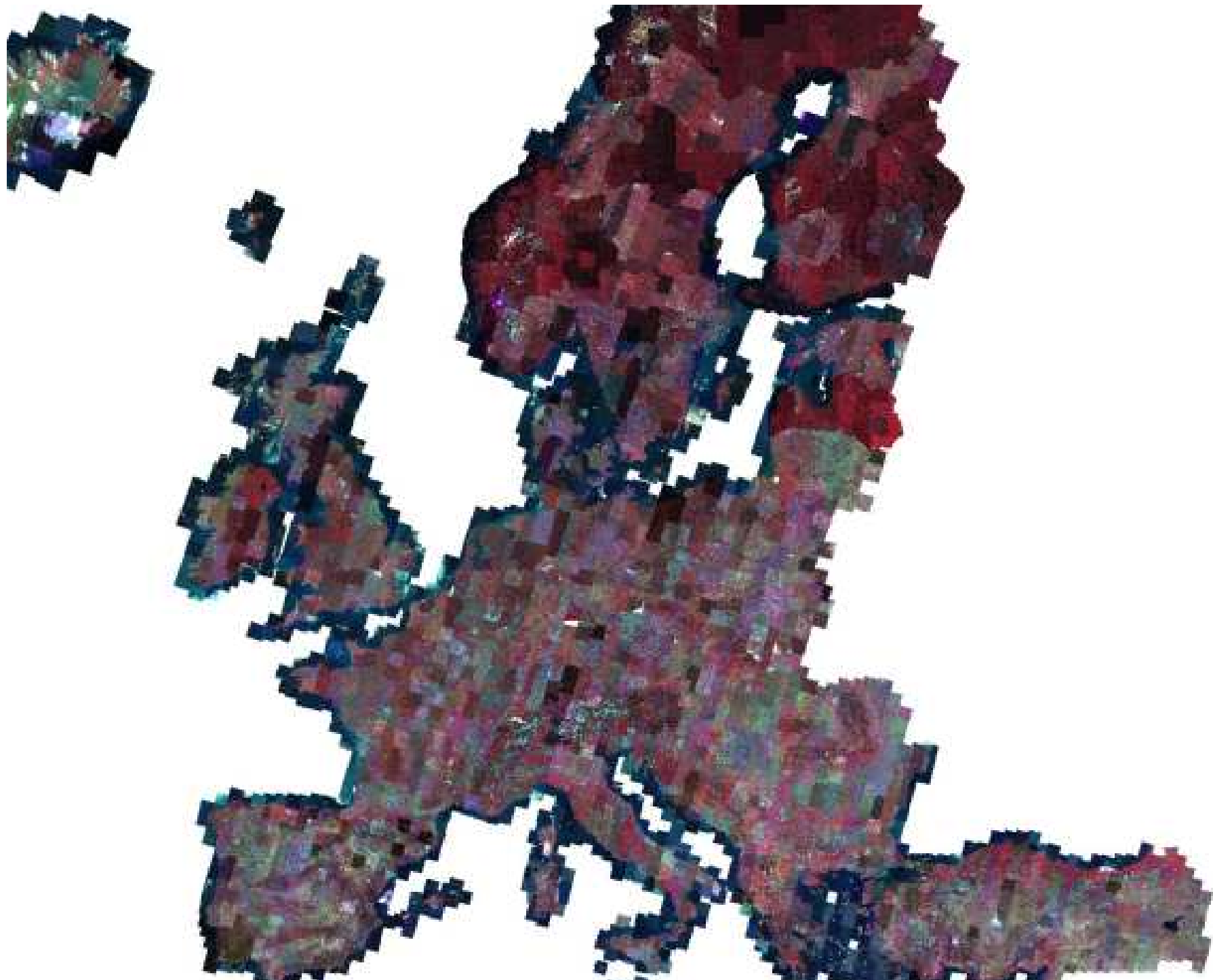
**JRC/EXPO2015 Urbanization in Europe and the World
Ispra 27th May 2015**

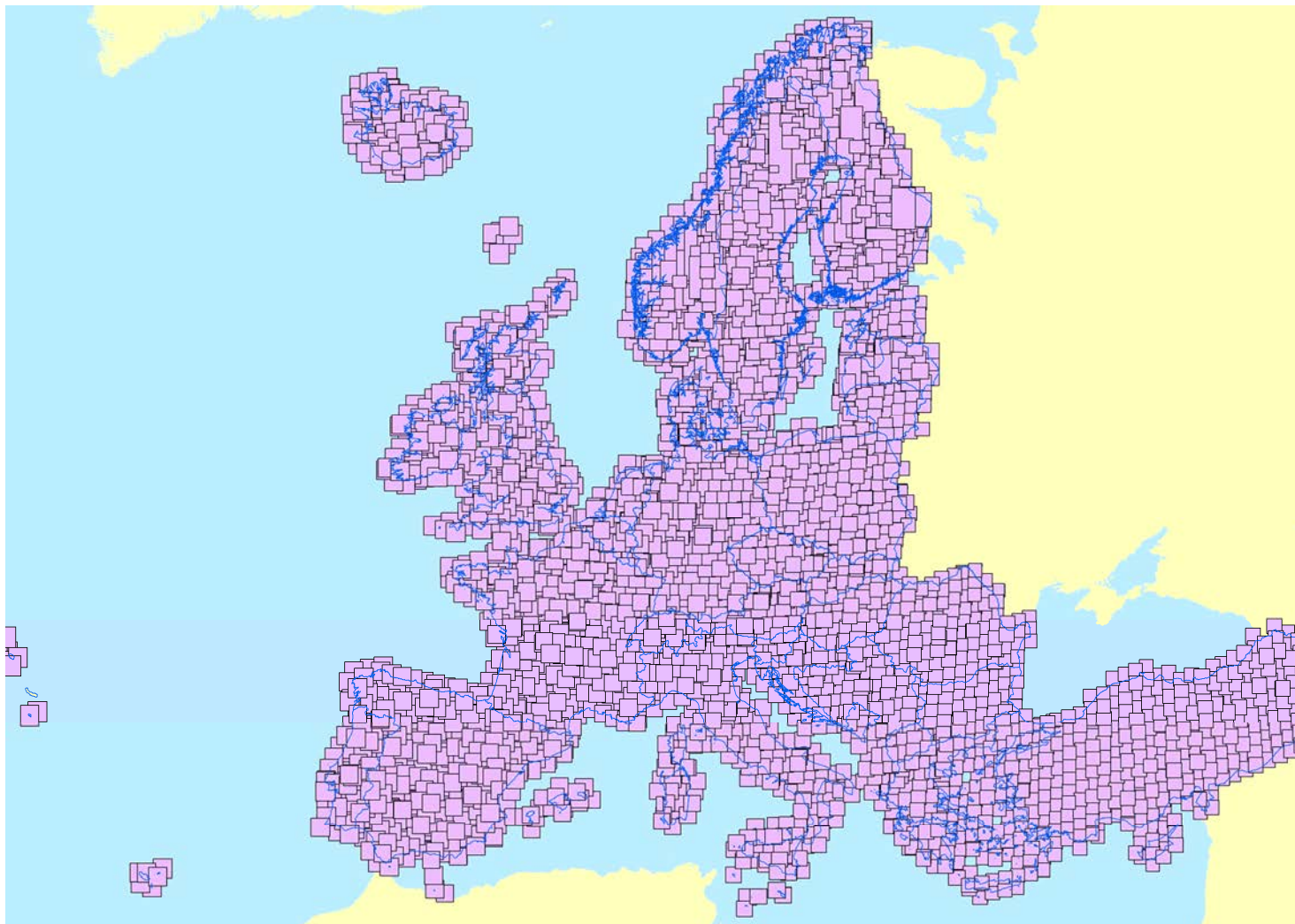**www.jrc.ec.europa.eu**

*Serving society
Stimulating innovation
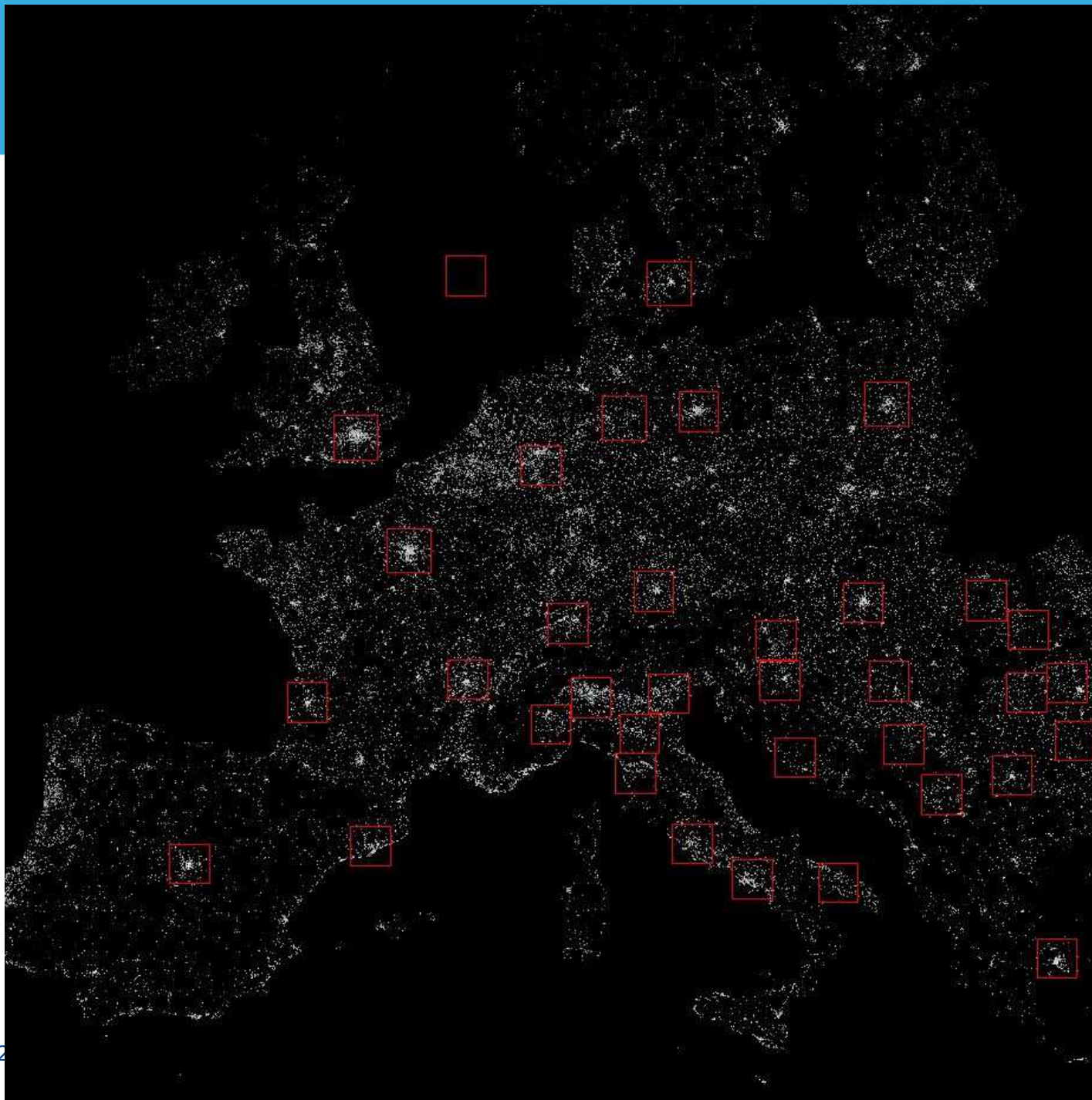Supporting legislation*

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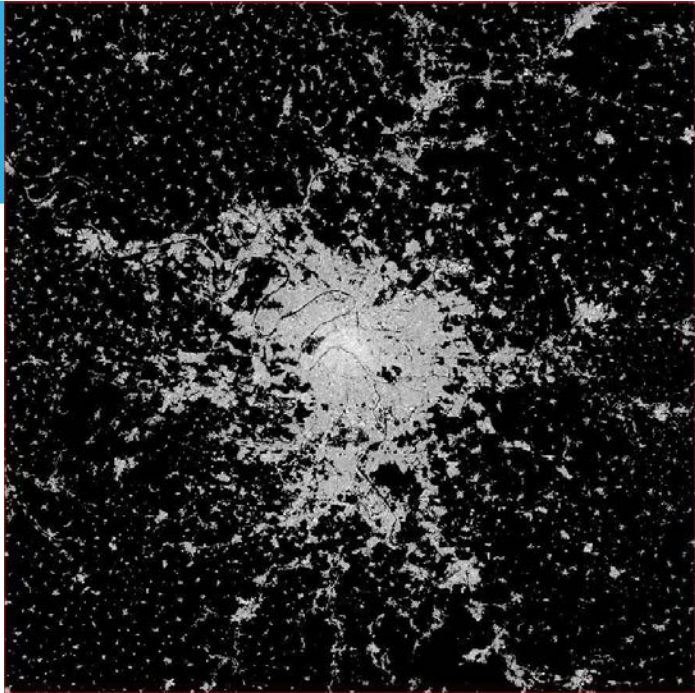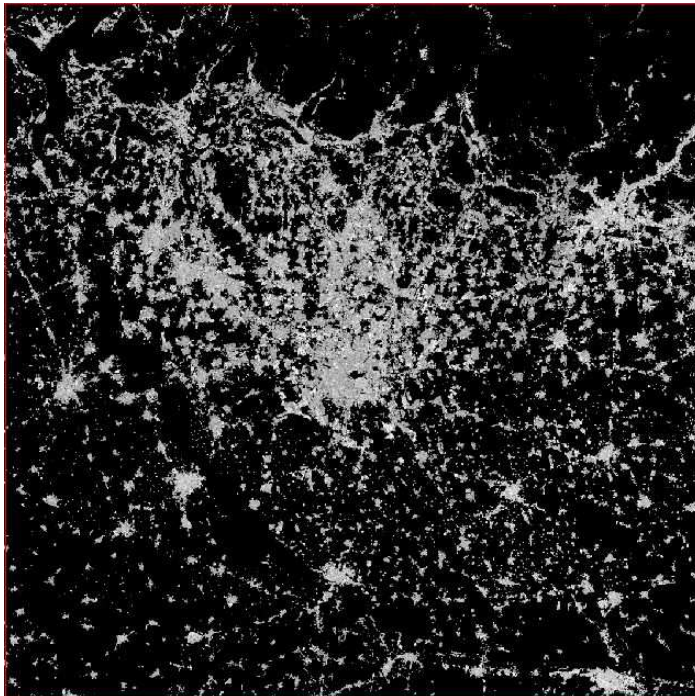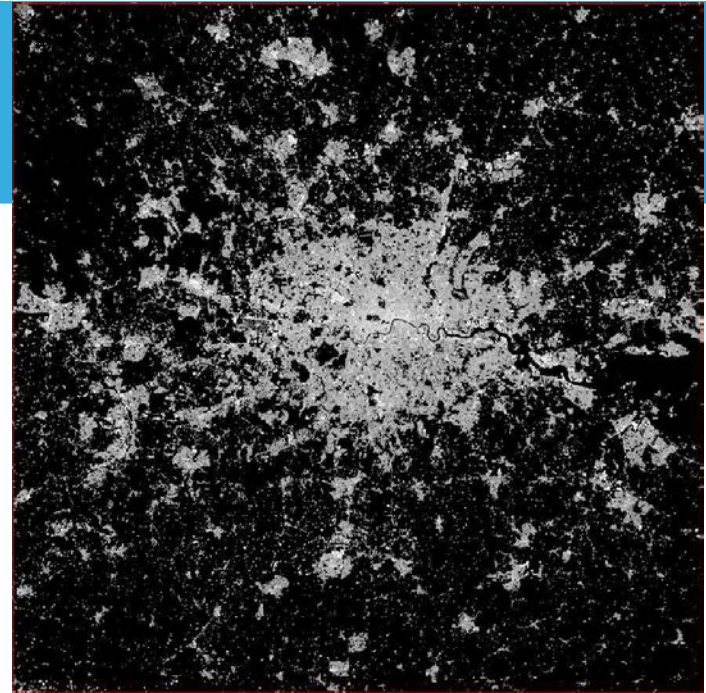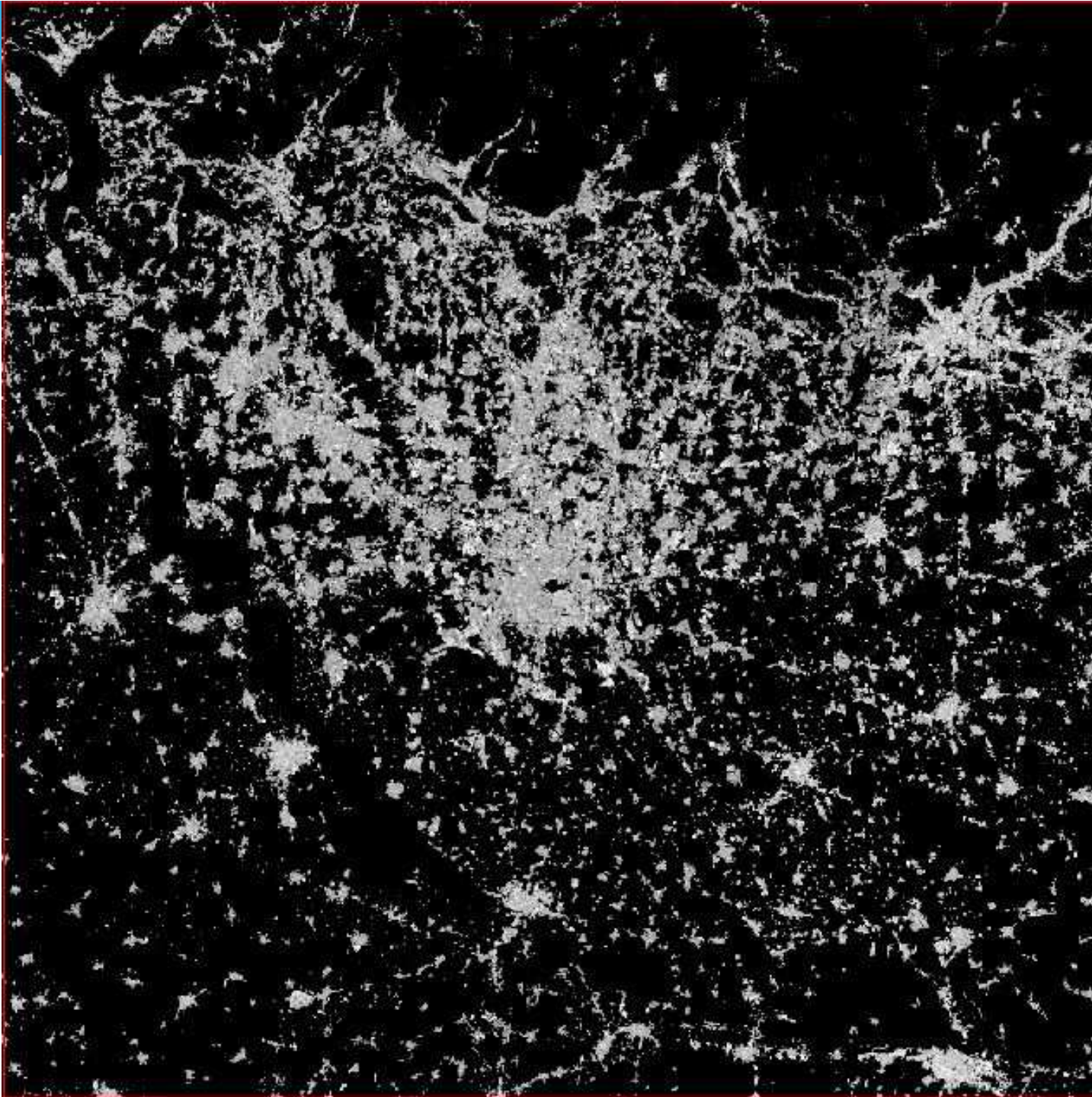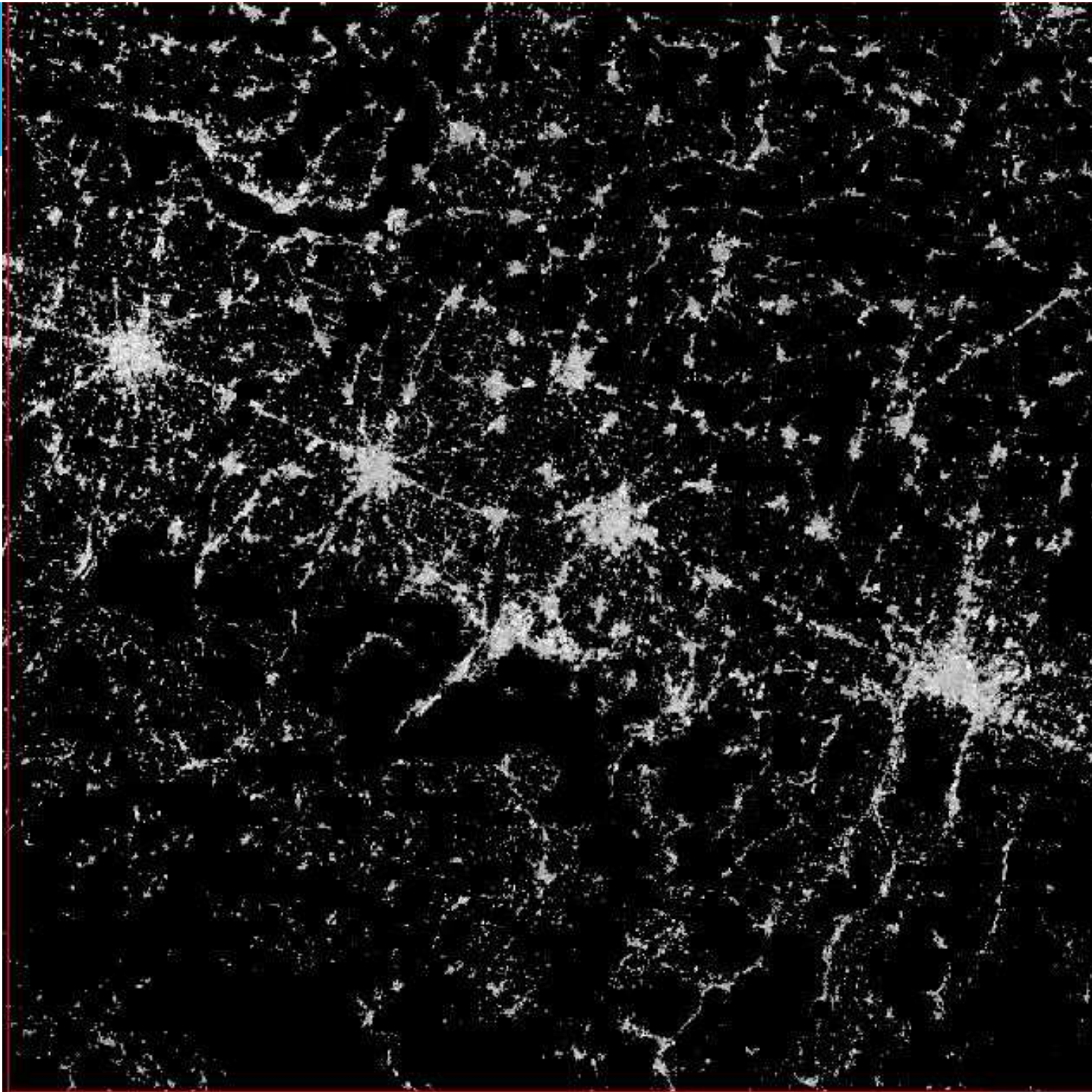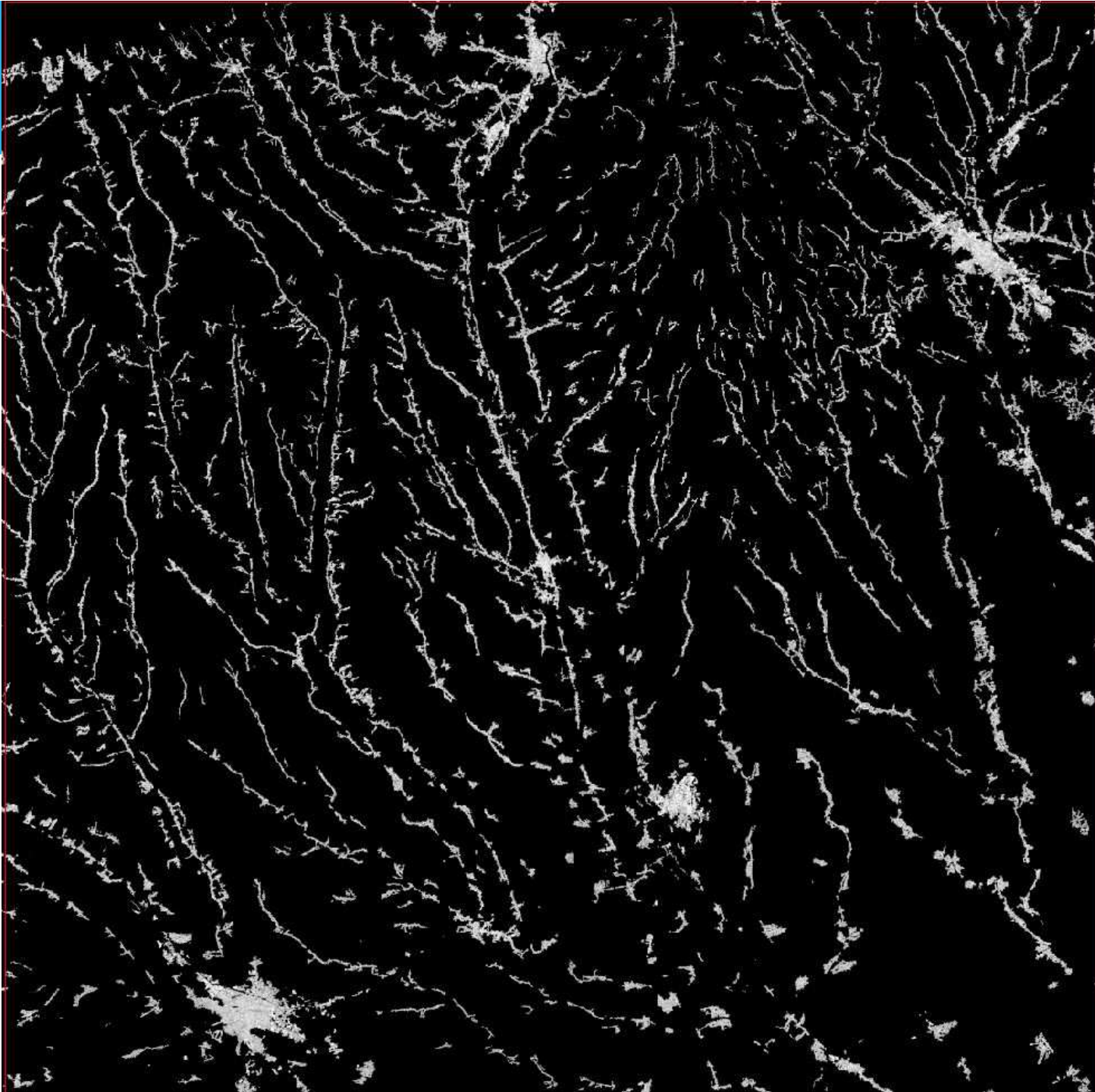
The GHSL team

Two architect/planners, three geographers, three environmental/ electrical engineers, two computer scientists, three technical assistants.

The Global Security and Crisis Management Unit

Specializes in data mining, image processing, text analysis, crisis management technologies, antifraud, conflict and natural disaster modeling in a global context.

Topics

European Settlement Map (ESM)

EU_Global Human Settlement Layer (GHSL) concept, method and technology

ESM for
    settlement classification
    suburb definition
    and the Urban Atlas
    urban green detection
    population disaggregation
    disaster modeling
    as input to policy makers

THE GHSL CONCEPT

Global and data-driven

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The GHSL concept

- **Multi-scale vision**
  - Global ↔ Regional ↔ Local

- **Multi-sensor approach**
  - Any optical airborne/satellite data better than 10 m (EU_GHSL)

- **Automatic image information retrieval**
  - Quantitative information: built-up area, size, density, urban green

- **Inclusive concept of human settlements**
  - refugee/IDP camps, slums, rural hamlets

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Opportunities and challenges

- **Amount of data**
  - Processing and storage

- **Image acquisition**
  - Scene availability and quality (cloud coverage, etc)

- **Objective and independent information**
  - Data-driven approach, global concept

- **High resolution data**
  - Population disaggregation

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Available information today

- Global:
  - MODIS urban layer (500 m spatial resolution)
  - Night-light images (Suomi-NPP/DMSP, 750 m)
  - Landscan population layer (1 km spatial resolution)
- Regional/local:
  - land use/land cover at different scales (SSL, CLC, UA)

Gaps between the needs of the users and the information layers:

- **Inconsistency** and **incompatibility** of data sets
- Very high **semantic abstraction**
- Globally consistent **data sets are too coarse** for many applications

SPOT-5

27 May,
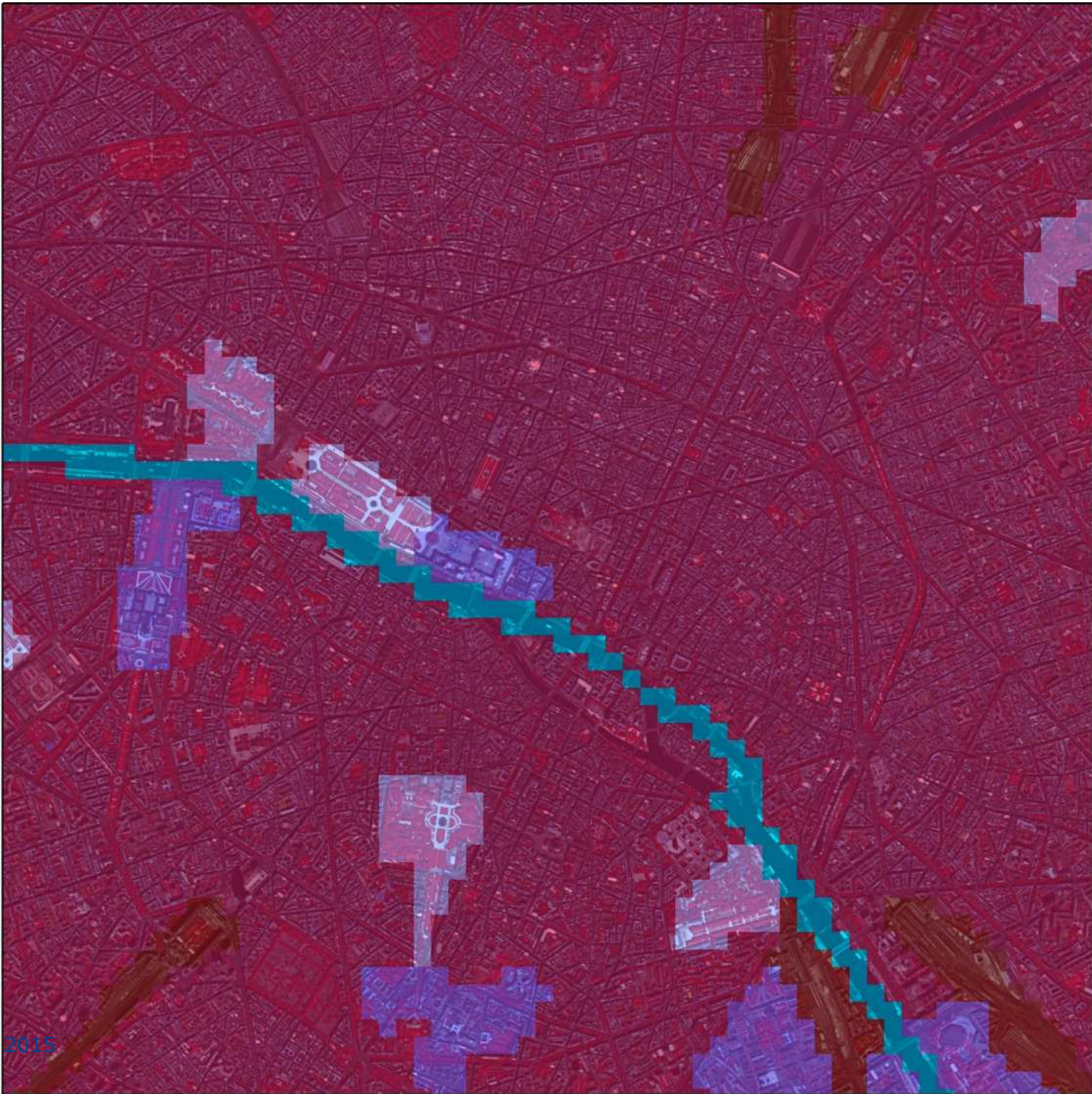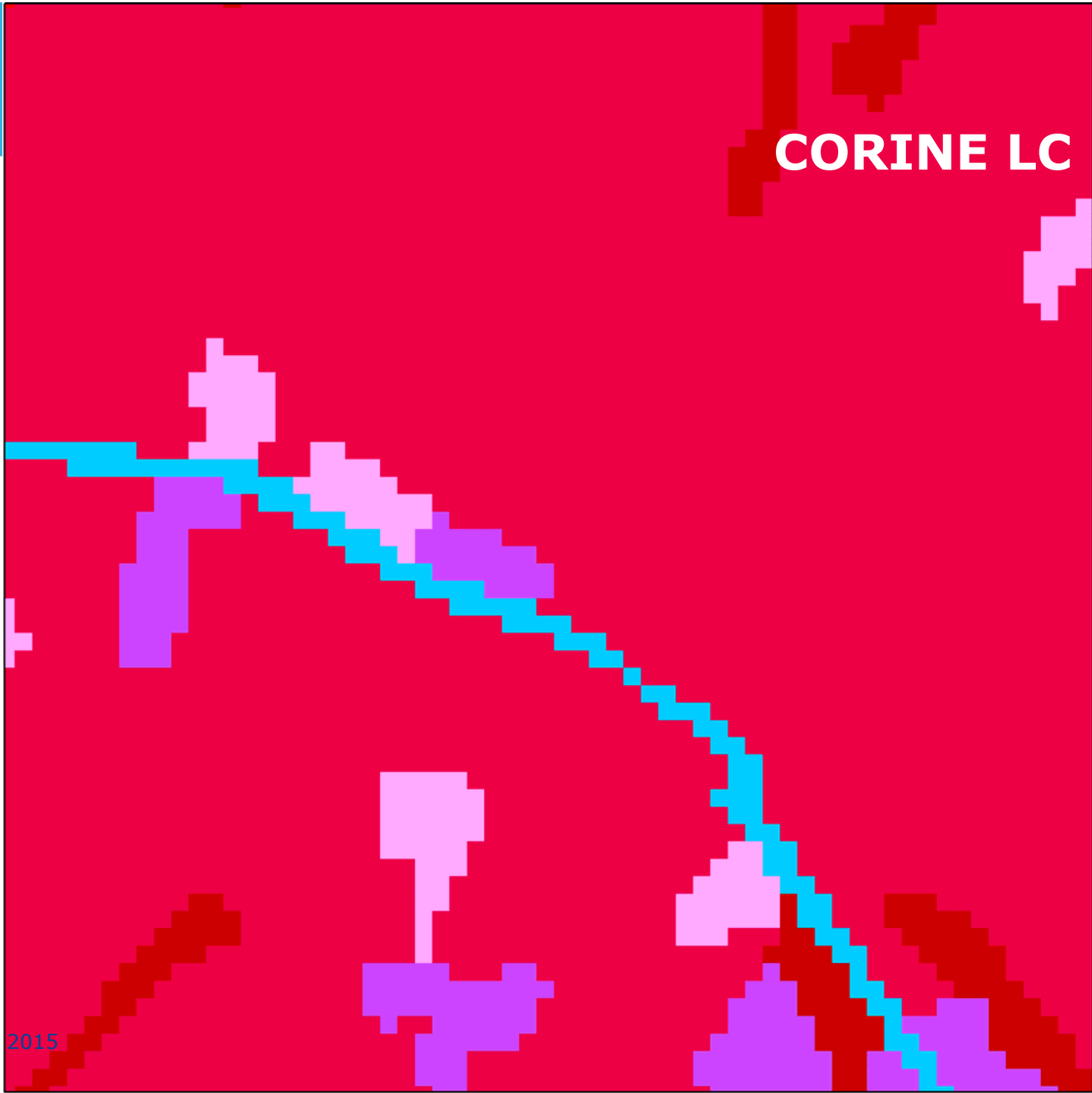
CORINE LC
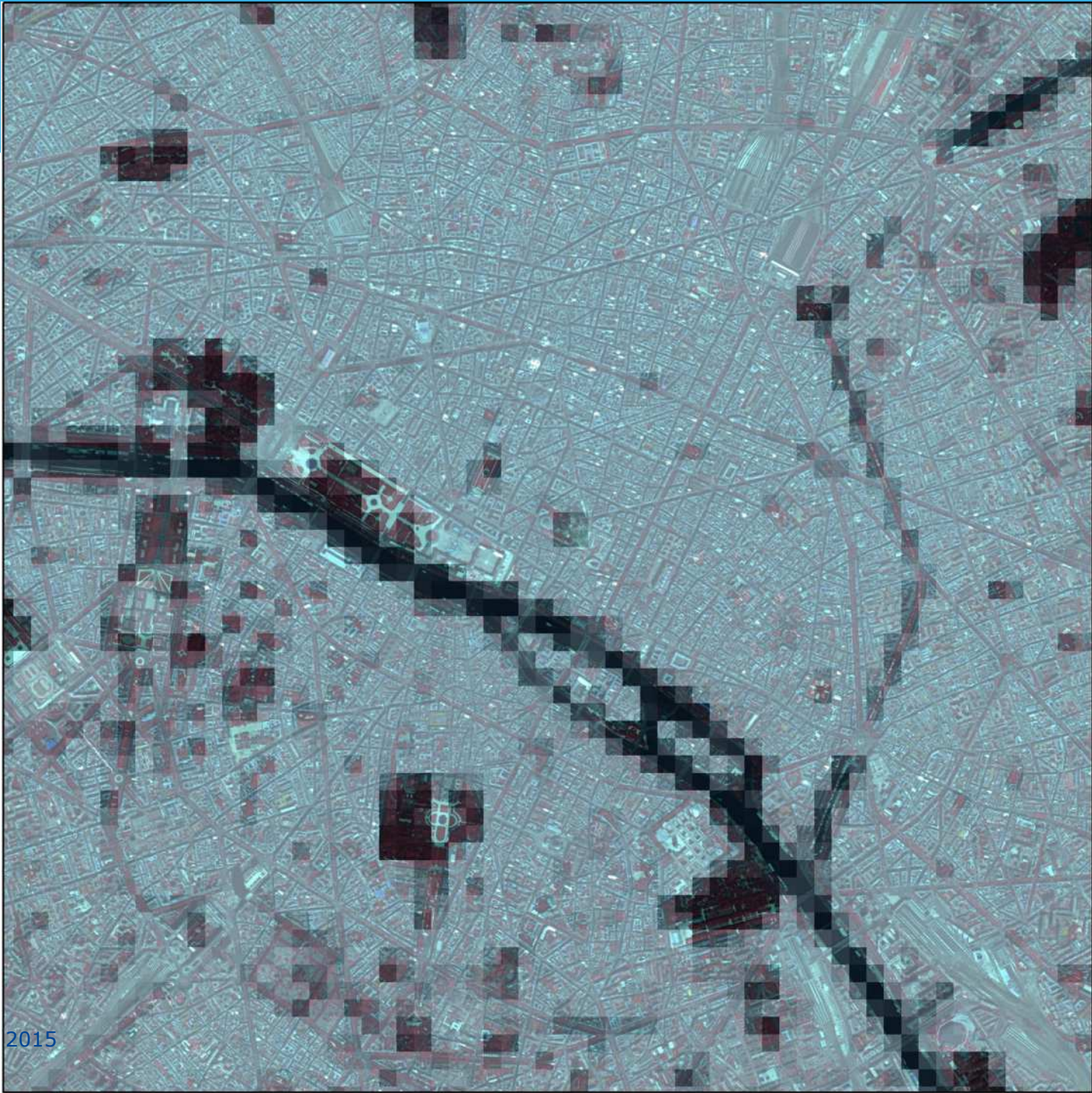
SPOT-5

27 May,

Sealed Surface Layer
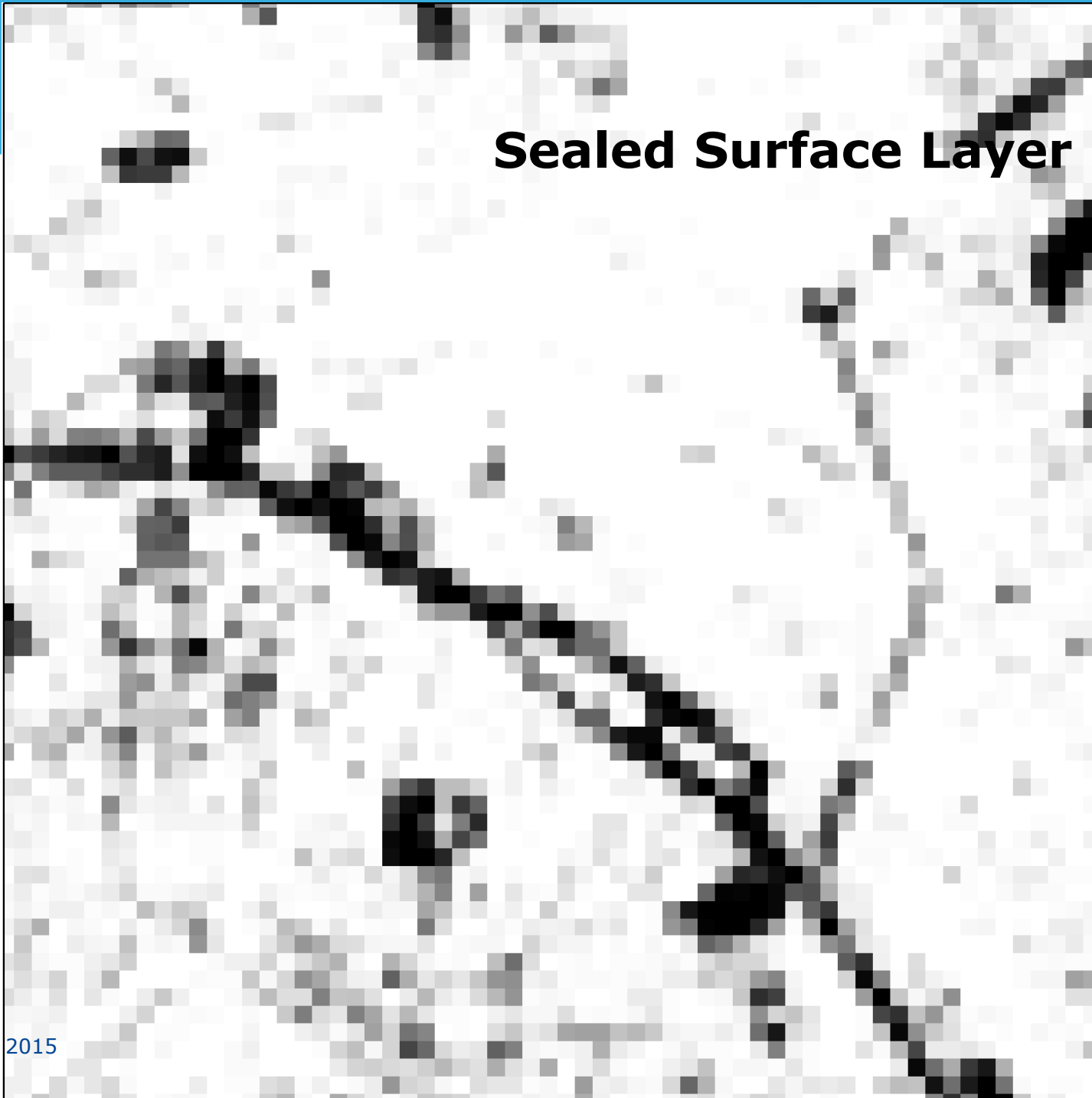
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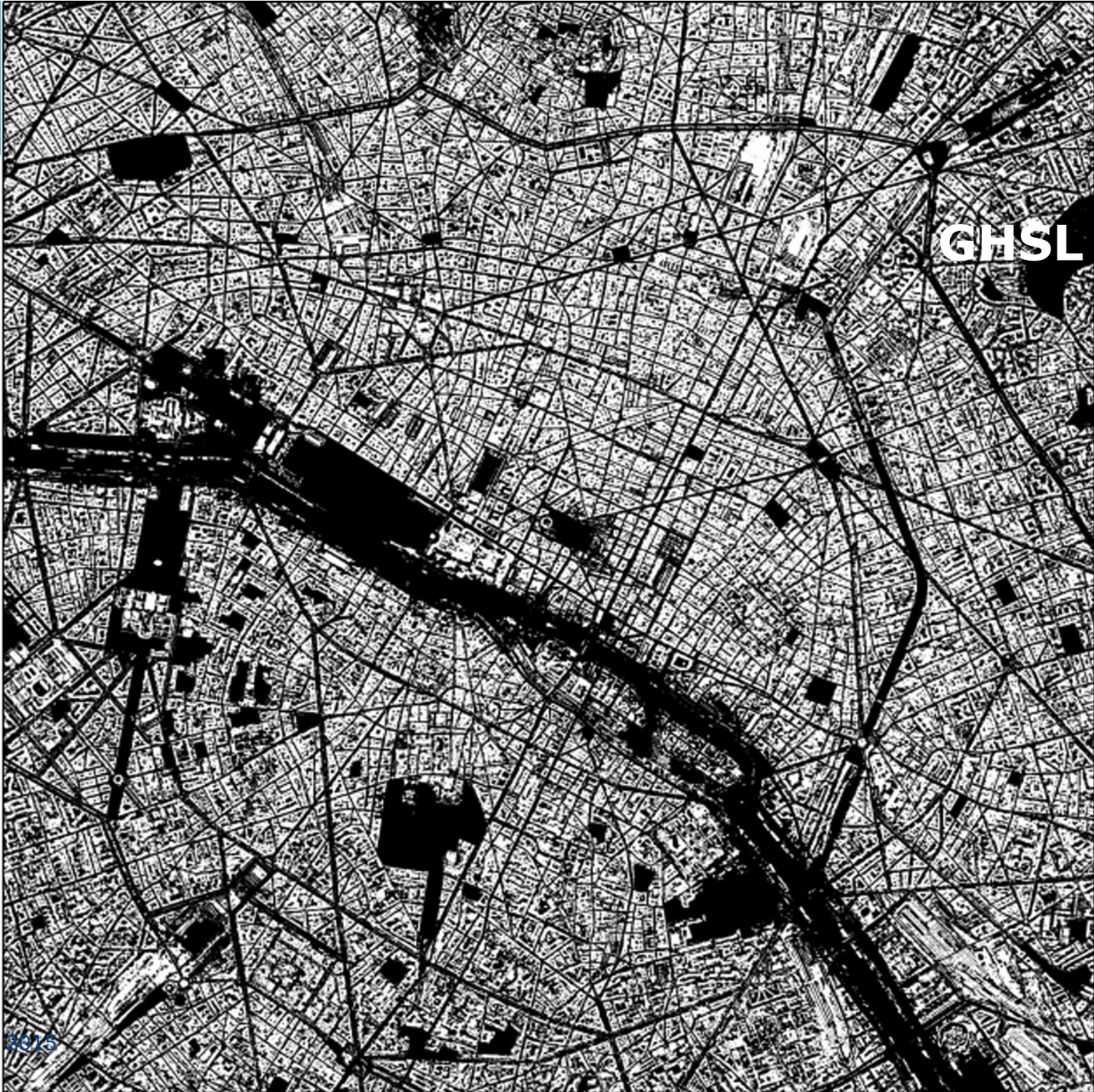
27 May,

GHSL

Human settlement characterization
Image multiscale morphological decomposition (DMP)

European
Commission

Input SPOT5/6

Data mining 1

Data mining 2

Data mining 3

Post processing

Out ESM 10m

Ancillary data

3800 input scene (2.5m)
size of 75km x 75km
3,445,707,437,702 pixels
3 bands (NIR, RED, GREEN)

Processing at original resolution 2.5m
3,445,707,437,702 pixels in data mining 1
3,445,707,437,702 pixels in data mining 2
3,445,707,437,702 pixels in data mining 3
10,337,122,313,105 pixels Total

Aggregation and fusion at 10m
215,356,714,856 pixels

Mosaic of 270 GeoTiff Tile
55 Countries covered
5,947,006 sq km
85,000 sq km of built-up

Global Human Settlements Layer

Athens – GHSL settlement classification

**Athens – GHSL classes
With Administrative Units**

Settlement classification model

pop per sqkm	pop x cell 100m	Classes		XL	L	M	S	XS
				Metro	City	Town	Village	Hamlet
				9	8	7	6	5
pop = 0	Uninhabited	Uninhabite	0	90	80	70	60	50
0<pop<10	LowDens	Periphery	5	95	86	76	66	
10<pop<100	MediumDens	2nd ring	6	96				
100<pop<1000	HighDens	1st ring	7	97				55
1000<pop<10000	VeryHighDens	Core	8	98	88	78	67	
pop > 10000	HyperHighDens	Hypercore	9	99				
				>500000 po	50000<pop<50000(	5000<pop<5000(	500<pop<500(	pop<500

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GHSL SETTLEMENT MAP OF EUROPE

Legend:
- XS
- S
- M
- L
- XL

Scale 1:25.000.000

N

GHSL SETTLEMENT TYPE SEGMENTS
(WESTERN EUROPE)

European Commission

Amsterdam
The Hague
London
Dusseldorf
Lille
Brussels
Cologne
Frankfurt
Paris
Strasbourg

	50 XS uninhabited
	55 XS centre
	60 S uninhabited
	66 S ring
	67 S centre
	70 M uninhabited
	76 M ring
	78 M core
	80 L uninhabited
	86 L ring
	88 L core
	89 L hypercore
	90 XL uninhabited
	95 XL periphery
	96 XL outer ring
	97 XL ring
	98 XL core
	99 XL hypercore

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Scale   1:4.000.000

N

GHSL SETTLEMENT TYPE SEGMENTS
(RUHR/RHEIN)

50 XS uninhabited
55 XS centre
60 S uninhabited
66 S ring
67 S centre
70 M uninhabited
76 M ring
78 M core
80 L uninhabited
86 L ring
88 L core
89 L hypercore
90 XL uninhabited
95 XL periphery
96 XL outer ring
97 XL ring
98 XL core
99 XL hypercore

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Scale   1:1.000.000

GHSL SETTLEMENT TYPE SEGMENTS
(BALKANS)

Beograd
Belgrade

	50 XS uninhabited
	55 XS centre
	60 S uninhabited
	66 S ring
	67 S centre
	70 M uninhabited
	76 M ring
	78 M core
	80 L uninhabited
	86 L ring
	88 L core
	89 L hypercore
	90 XL uninhabited
	95 XL periphery
	96 XL outer ring
	97 XL ring
	98 XL core
	99 XL hypercore

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Scale   1:600.000

N

GHSL SETTLEMENT TYPE SEGMENTS
(CENTRAL EAST EUROPE)

Legend:
- 50 XS uninhabited
- 55 XS centre
- 60 S uninhabited
- 66 S ring
- 67 S centre
- 70 M uninhabited
- 76 M ring
- 78 M core
- 80 L uninhabited
- 86 L ring
- 88 L core
- 89 L hypercore
- 90 XL uninhabited
- 95 XL periphery
- 96 XL outer ring
- 97 XL ring
- 98 XL core
- 99 XL hypercore

Map labels: Katowice, Krakow, Ostrava, Presov, Zilina, Kosice, Banska Bystrica

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Scale 1:1.500.000

N

GHSL SETTLEMENT TYPE SEGMENTS
(SOUTHERN IBERIA)

Madrid

Córdoba

50 XS uninhabited
55 XS centre
60 S uninhabited
66 S ring
67 S centre
70 M uninhabited
76 M ring
78 M core
80 L uninhabited
86 L ring
88 L core
89 L hypercore
90 XL uninhabited
95 XL periphery
96 XL outer ring
97 XL ring
98 XL core
99 XL hypercore

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Scale   1:2.000.000

N

GHSL SETTLEMENT TYPE SEGMENTS
(NORTHEAST EUROPE)

Kaunas

Vilnius

Alytus

Bialystok

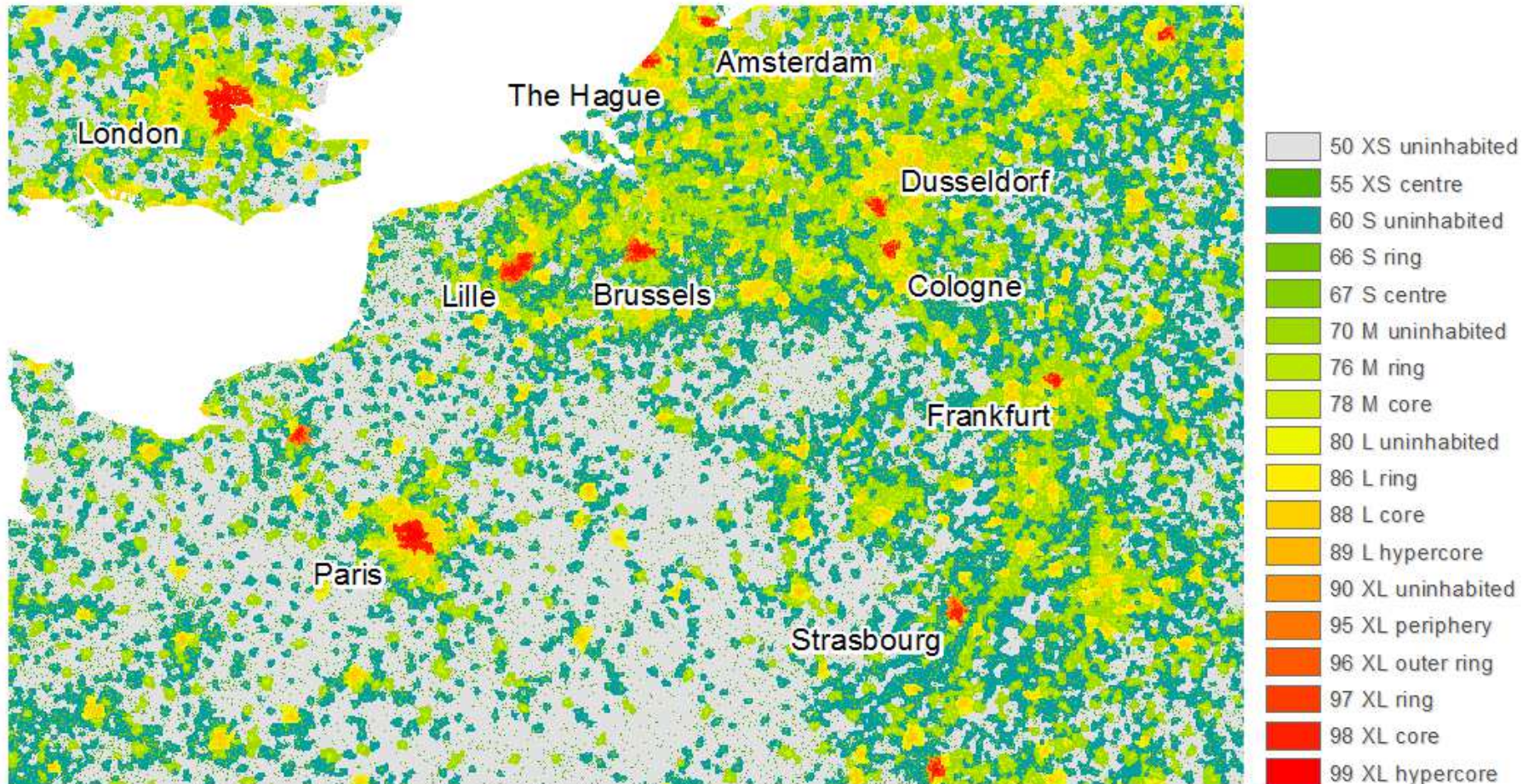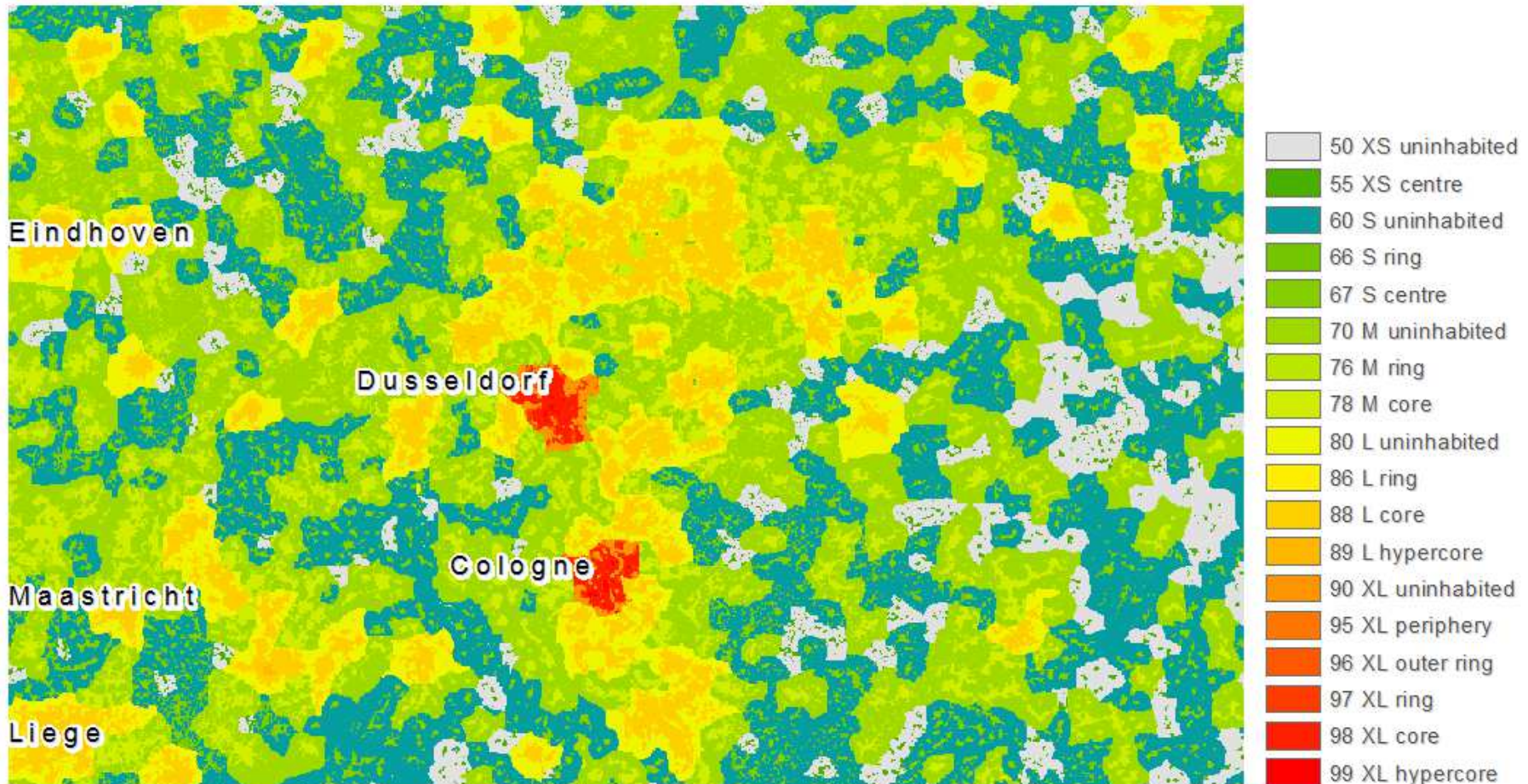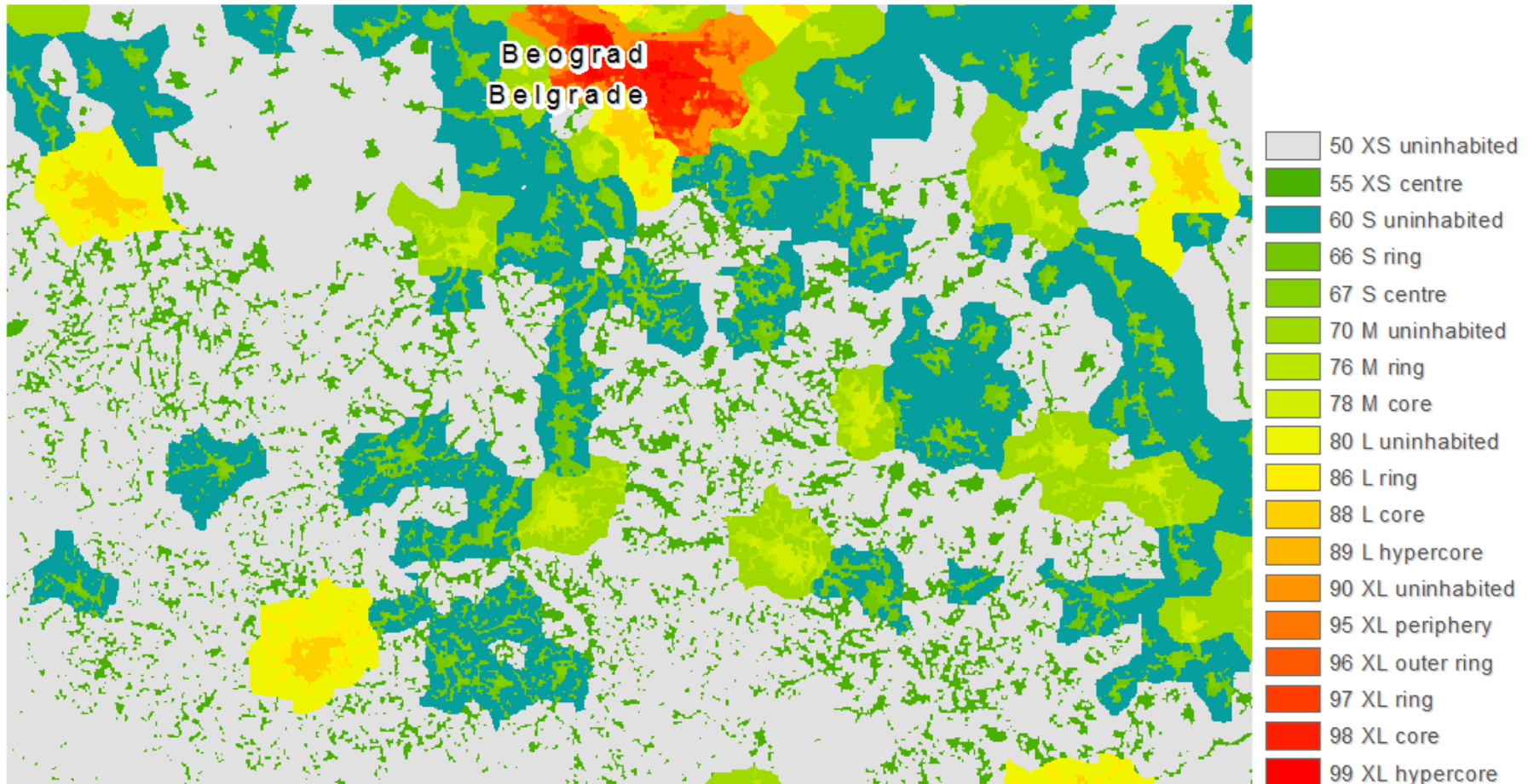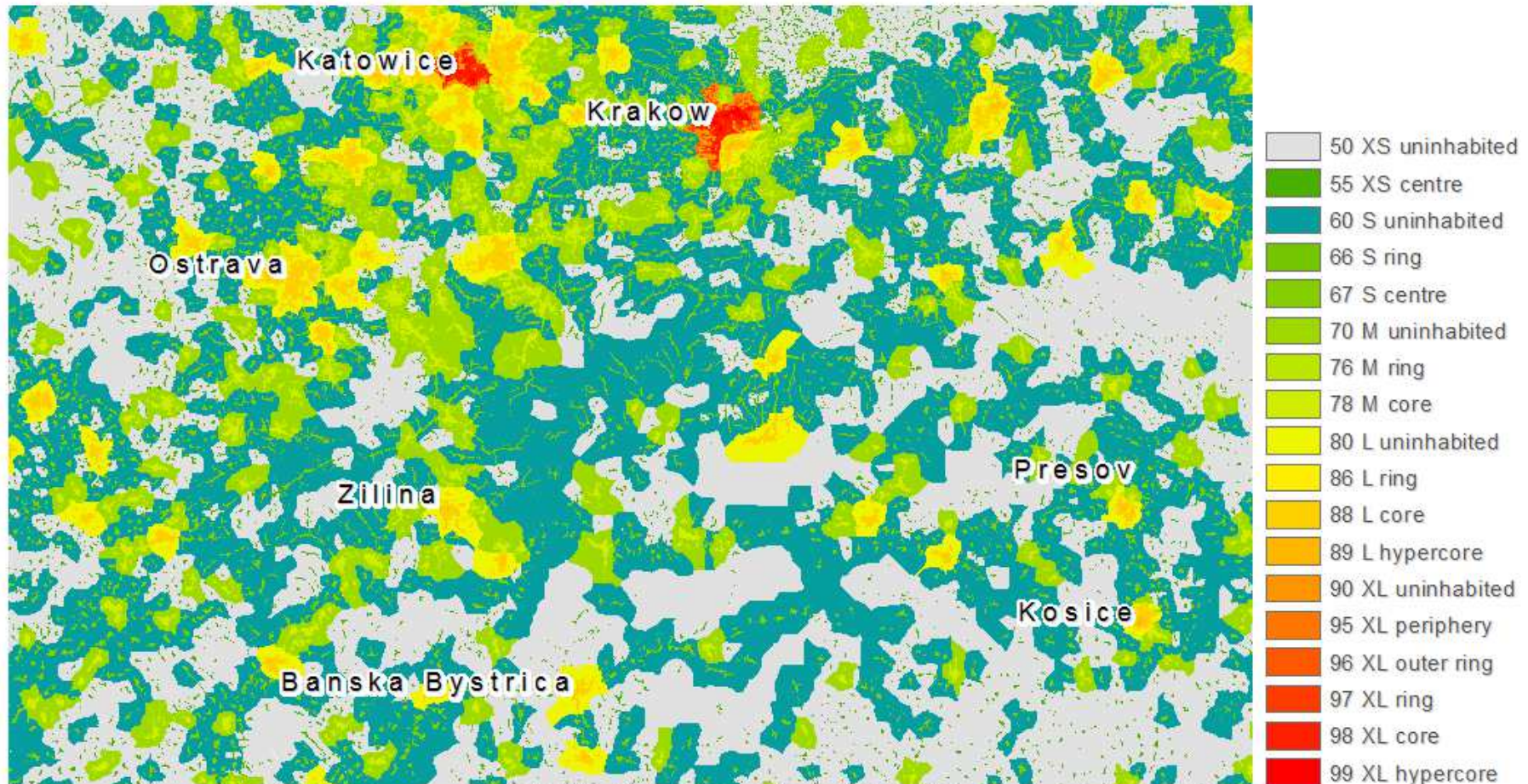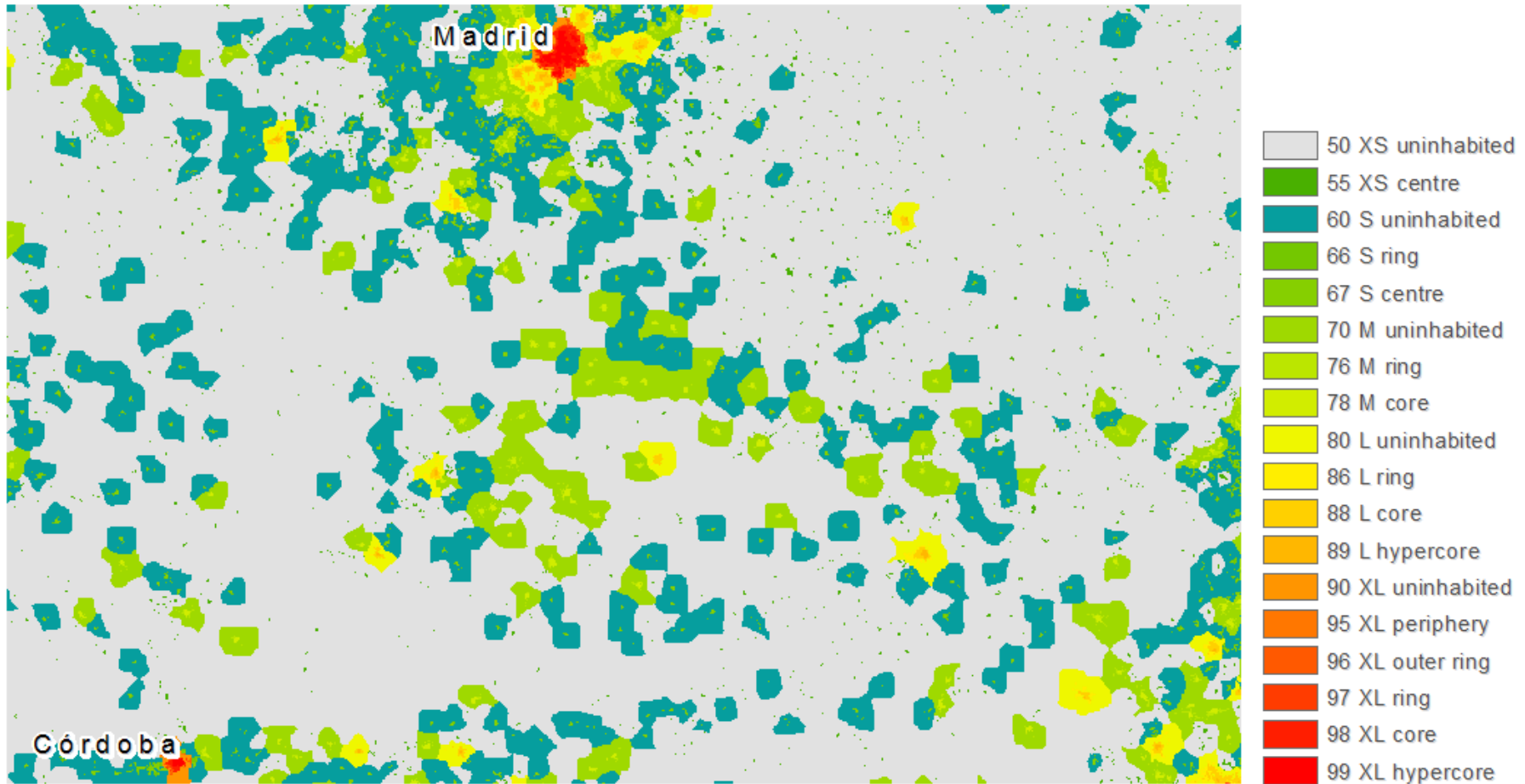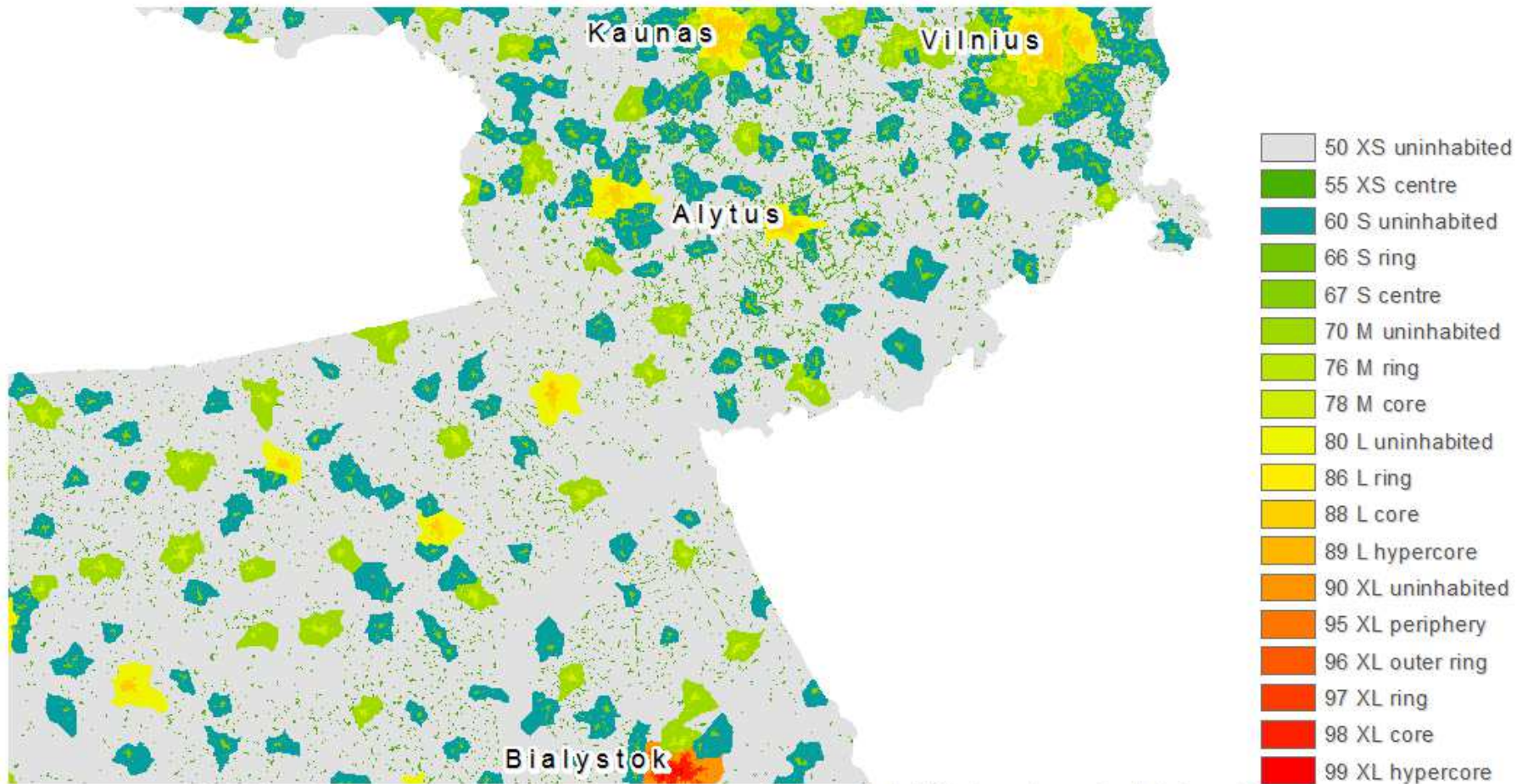|	Legend
	50 XS uninhabited
	55 XS centre
	60 S uninhabited
	66 S ring
	67 S centre
	70 M uninhabited
	76 M ring
	78 M core
	80 L uninhabited
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	88 L core
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	90 XL uninhabited
	95 XL periphery
	96 XL outer ring
	97 XL ring
	98 XL core
	99 XL hypercore

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Scale   1:1.500.000

N

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6	0	46162	4198	51002	6697	4093	7226	1280	2658	0	0	0	0	0	0	0	0	0	0	123316
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11	0	291	7	1527	88	62	2065	296	642	4606	1353	7027	208	5608	219	693	2462	8971	4983	41108
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23	0	96529	8269	117186	11275	4916	21949	2787	3541	0	0	0	0	1	0	0	0	0	0	266453
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42	0	3934	1100	20794	4405	4256	14661	2434	6731	2585	900	1497	0	0	0	0	0	0	0	63297
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45	0	5188	783	11927	2264	1129	7095	1978	3319	0	0	0	0	0	0	0	0	0	0	33683
46	0	1386	539	26588	7034	5764	19916	5627	11467	6743	1544	8278	28	0	0	0	0	0	0	94914
47	0	5051	1536	9092	2681	1627	15017	4083	3630	0	0	0	0	0	0	0	0	0	0	42717

"Suburb" EU_GHSL definiton

- Built-up density 8 - 25% of the 100m GHSL pixel
- Geographic extent > 1 sqkm and > 5 sqkm
- Contiguity in 8 directions (possibly also in 2 to catch suburban belt development) in a given spatial unit

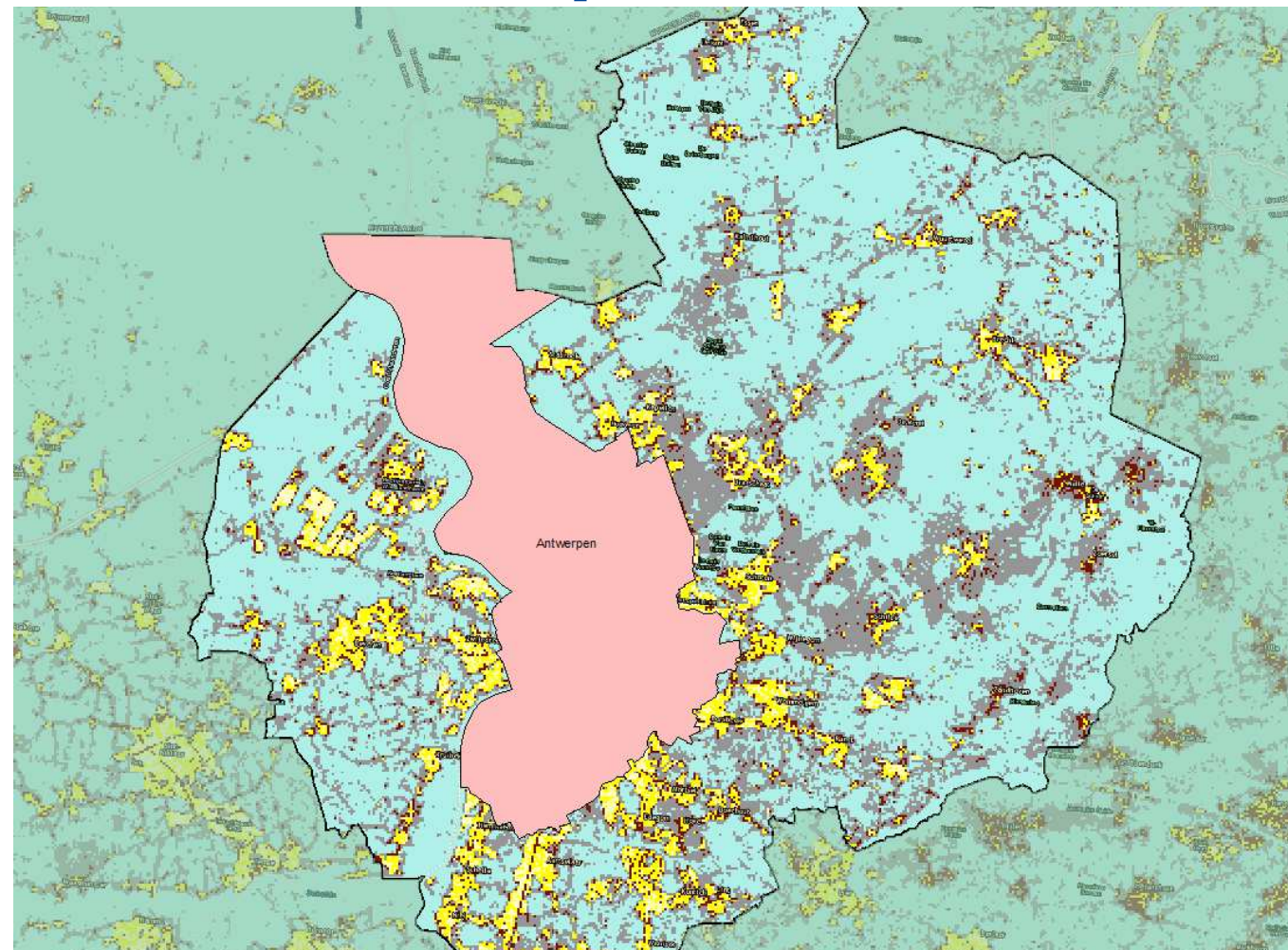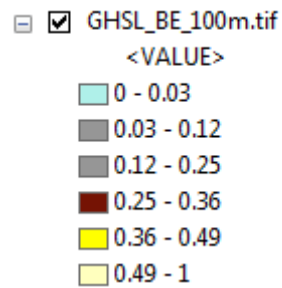- Low population density areas excluded with high resolution population data

Suburban development GHSL detection Brussels
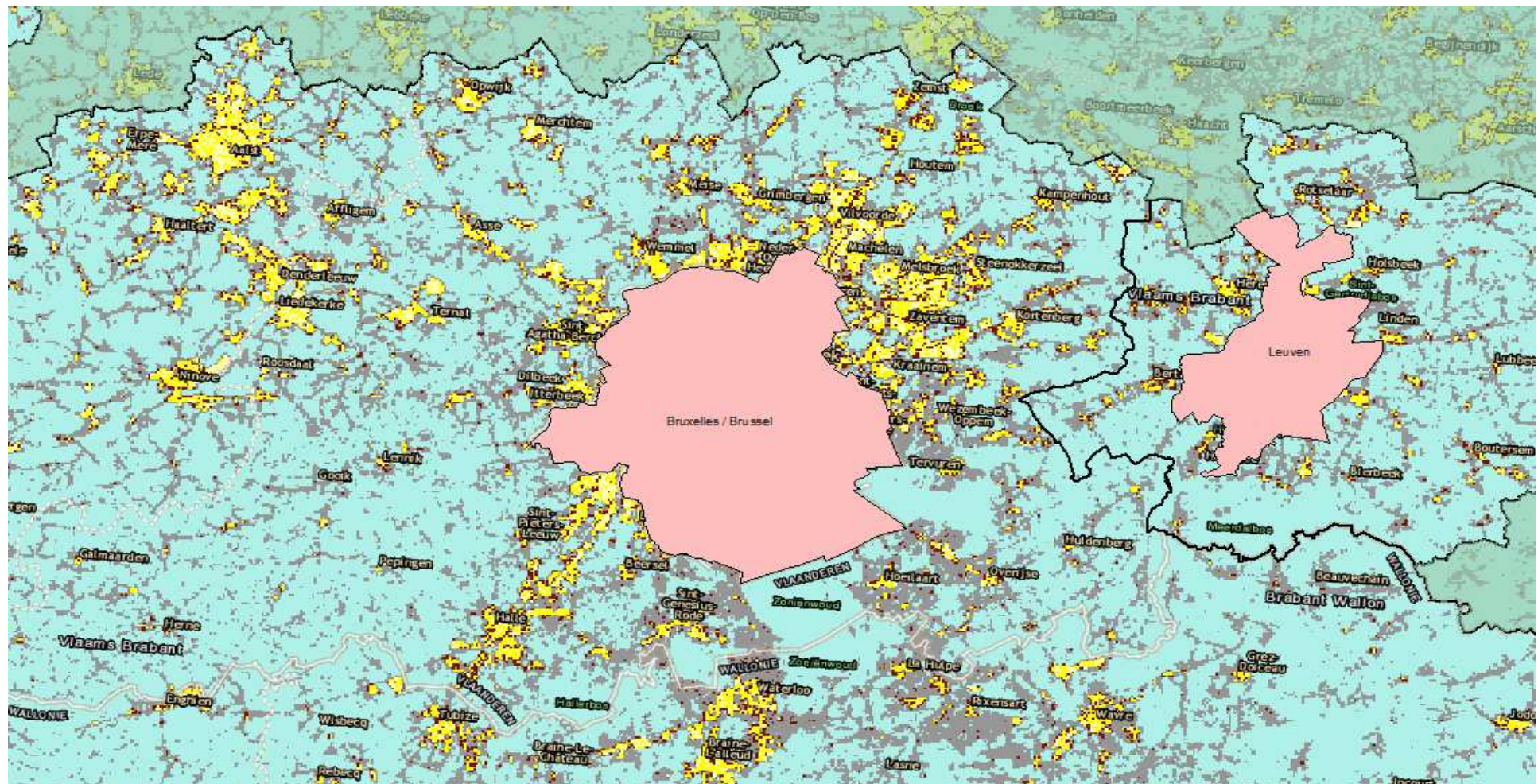
Aerial snapshot of the suburban area
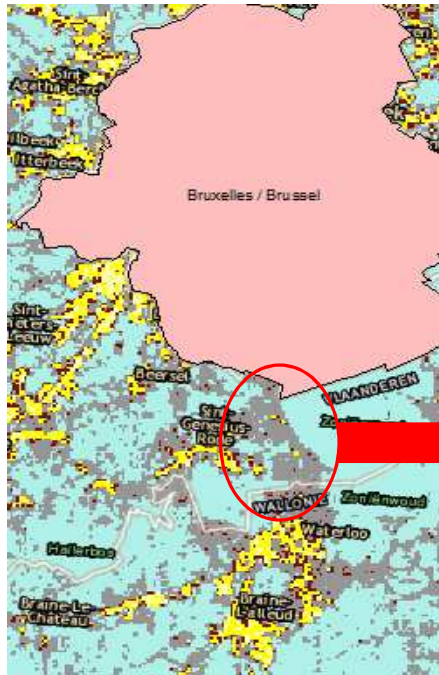
Suburban development GHSL detection: Antwerp

27 May 2015

Aerial snapshot of the suburban area

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Wien 10m GHSL - UA

Wien 10m GHSL Green - UA
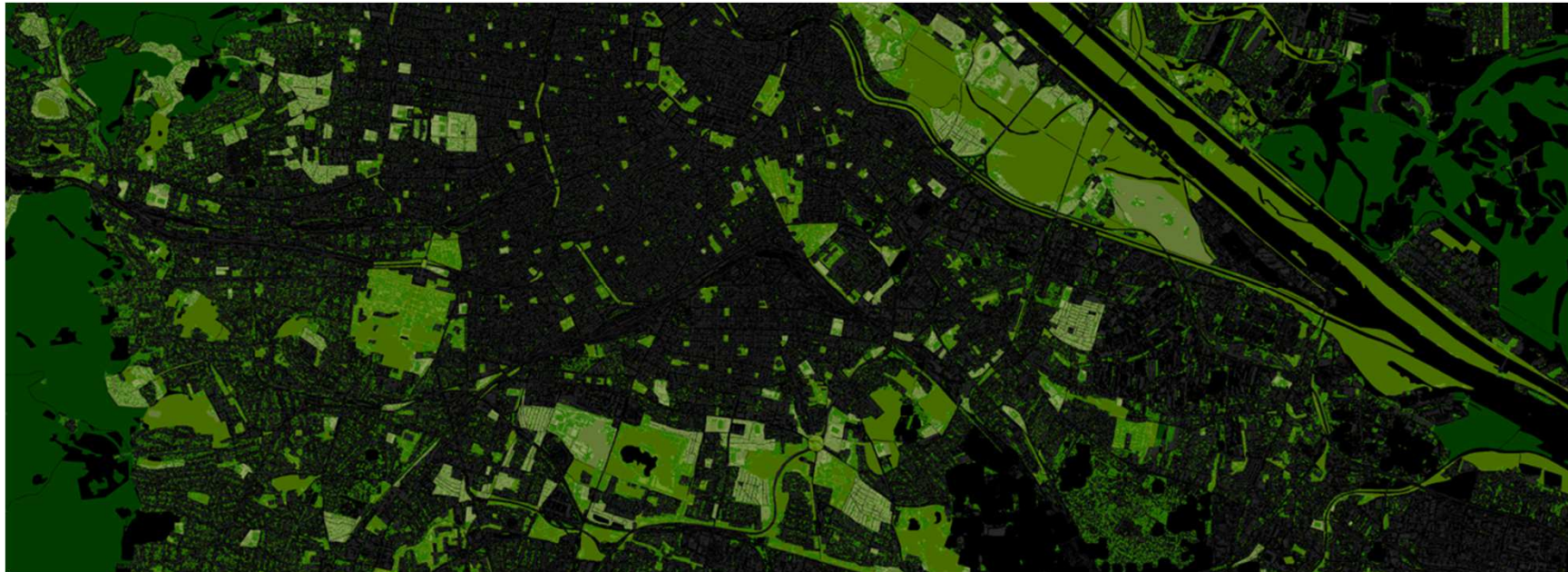
Wien GHSL 10m + Green - UA

Urban green definition EU_GHSL:

- Min MU 2,5x2,5m = 6,25sqm
- Any chlorophyl emitting urban object (tree, grass, green roof etc)
- Inlcusive definition of public or private green space, including interstitial green, tree-lined avenues, internal green to the built-up area
- Patches of natural vegetation or agricultural areas in proximity to built-up areas are included.

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In this application, the optical bands are only two: RED and GREEN. Then, a *pseudo-vegetation index* (veg_x) is calculated as follows:

$$veg_x = \frac{NIR - lum_p}{NIR + lum_p} \qquad (4)$$

It can be easily noticed that the formula 4 is a modified NDVI where the RED band is replaced with a feature extracted in 3. The fact is that the NDVI is created for purpose of environmental studies in order to distinguishing soils and vegetation. Here, the goal is to shift the focus from soil to the potential built-up structures. The veg_x plays important role in the final classification for creation of the vegetation classes. The lum_x is used as an input for the textural and morphological processing, which are performed simultaneously.

GHSL
Built-up with urban green

27 May, 2015

Continuous Urban Fabric (S.L. > 80%)
Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)
Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)
Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%)
Discontinuous Very Low Density Urban Fabric (S.L. < 10%)
Green urban areas
Water bodies
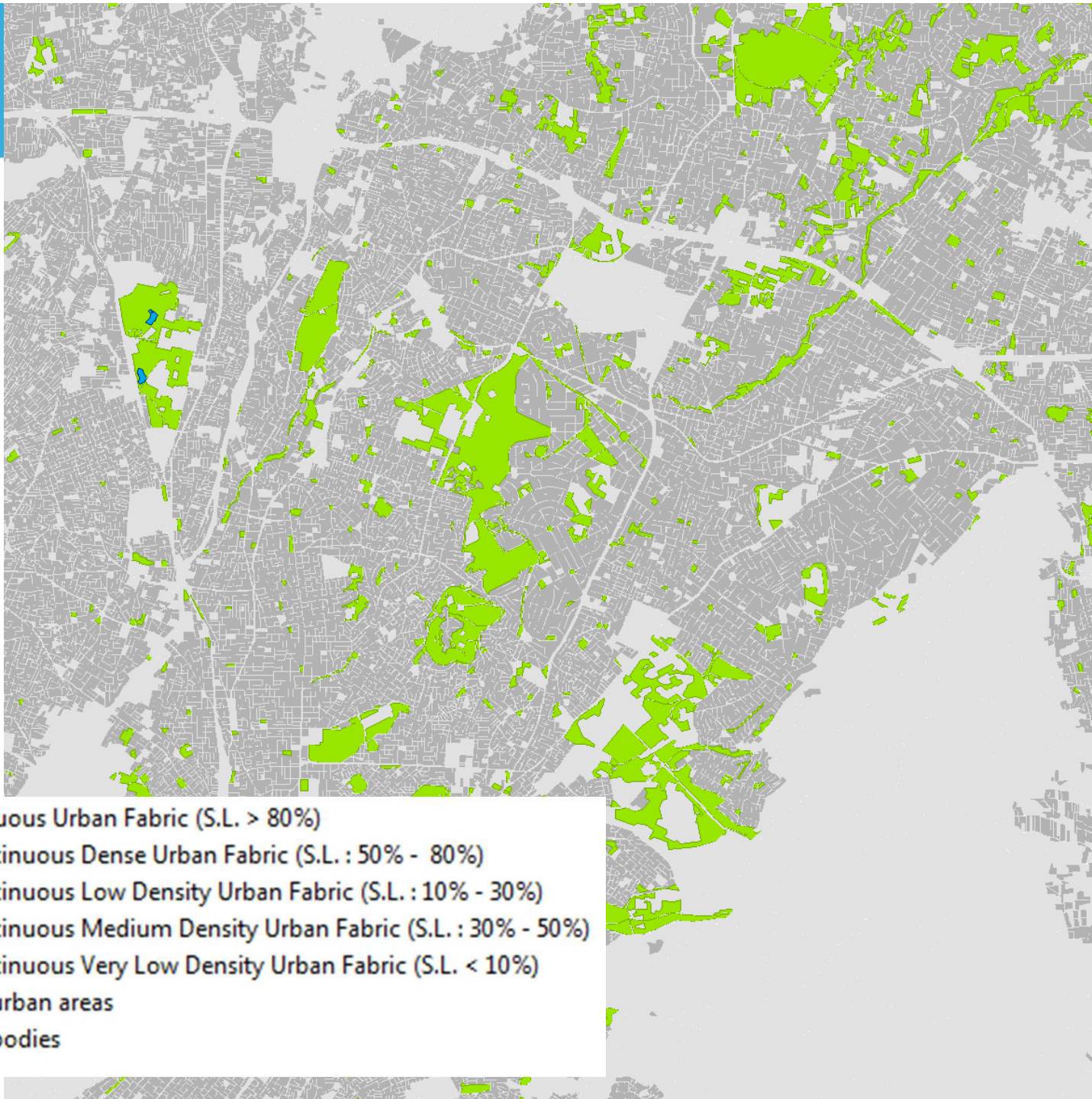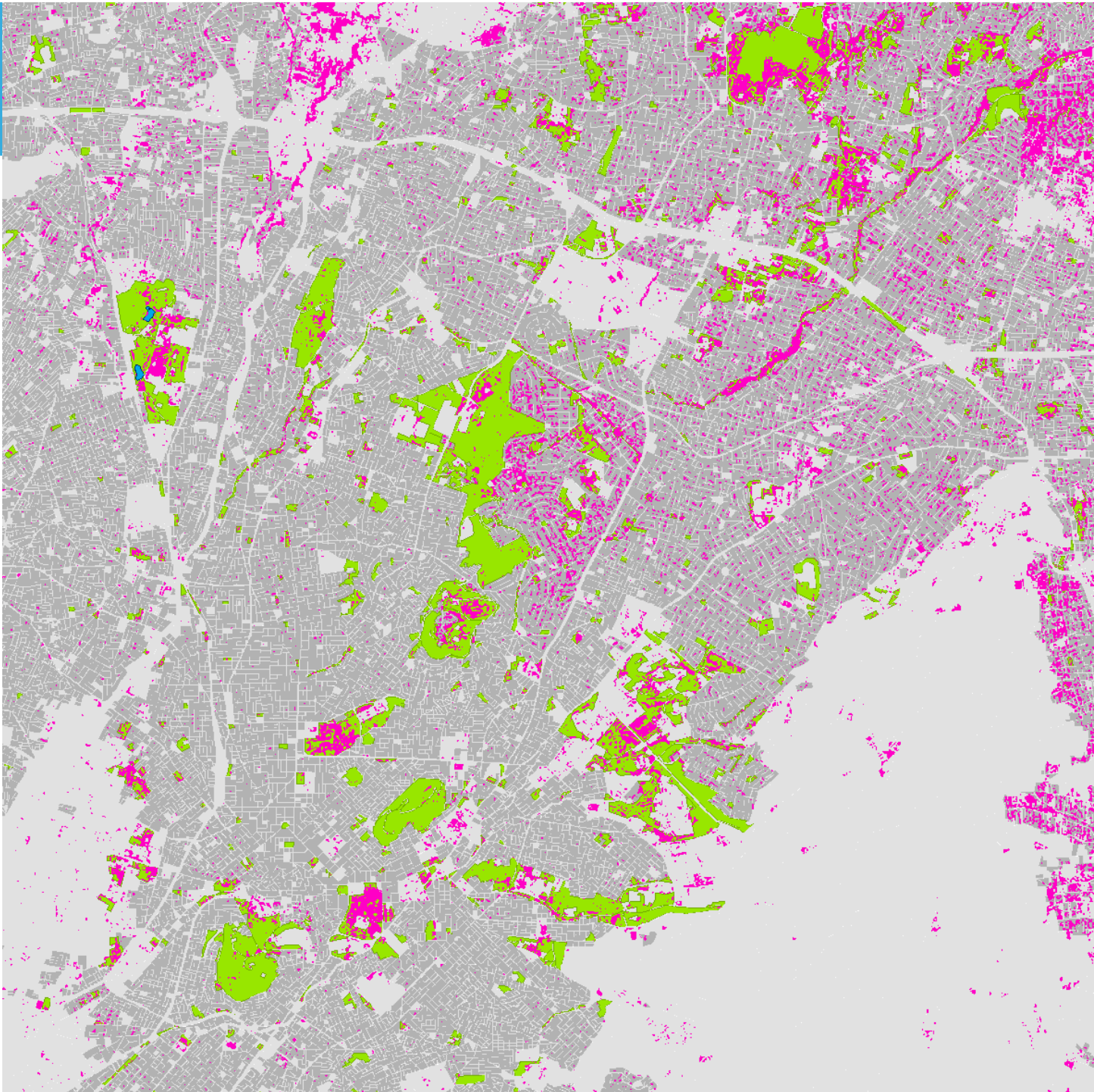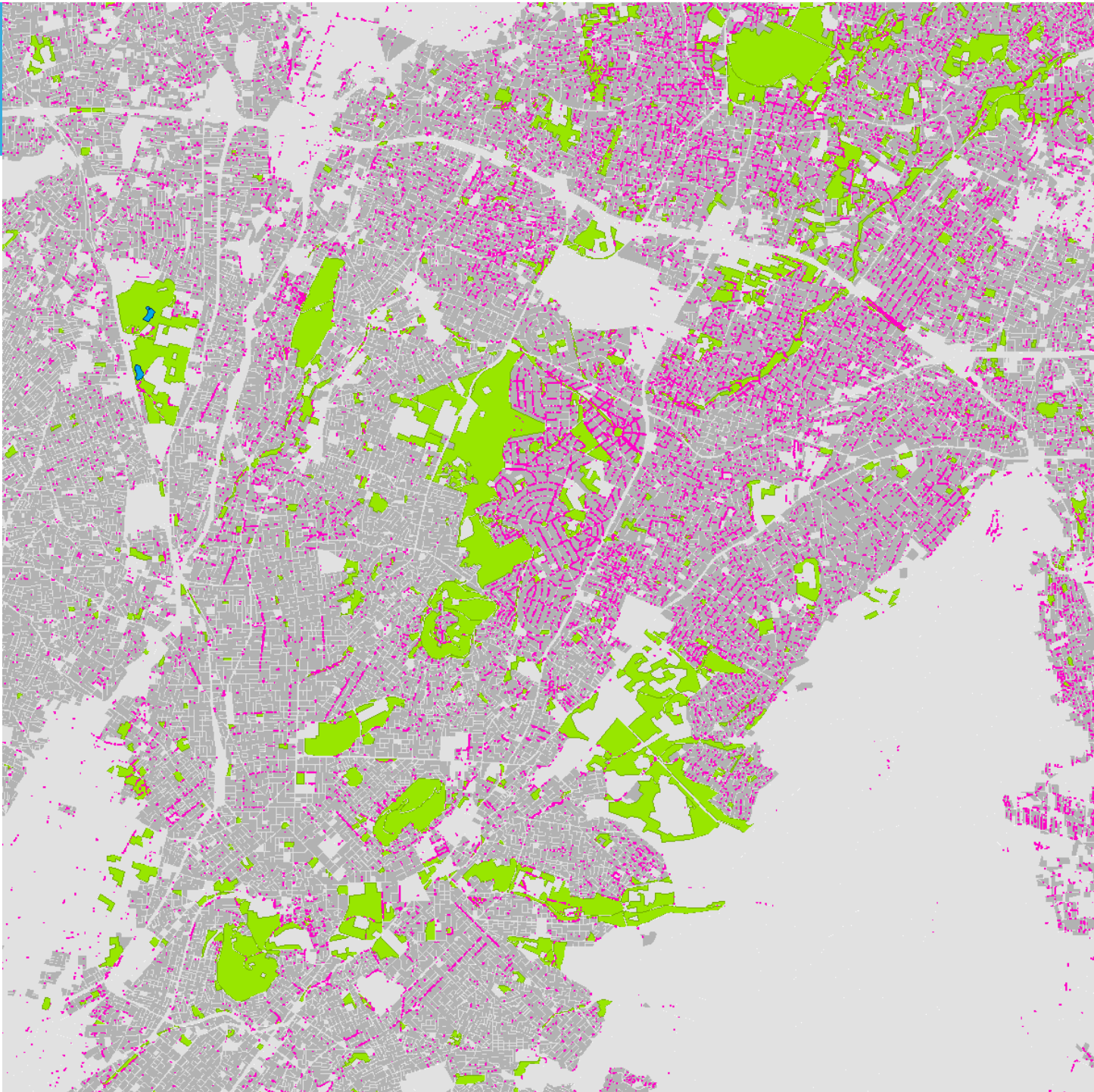
Athens – GHSL (10m)

Athens - GHSL (100m)

Athens – Geostat (1km)
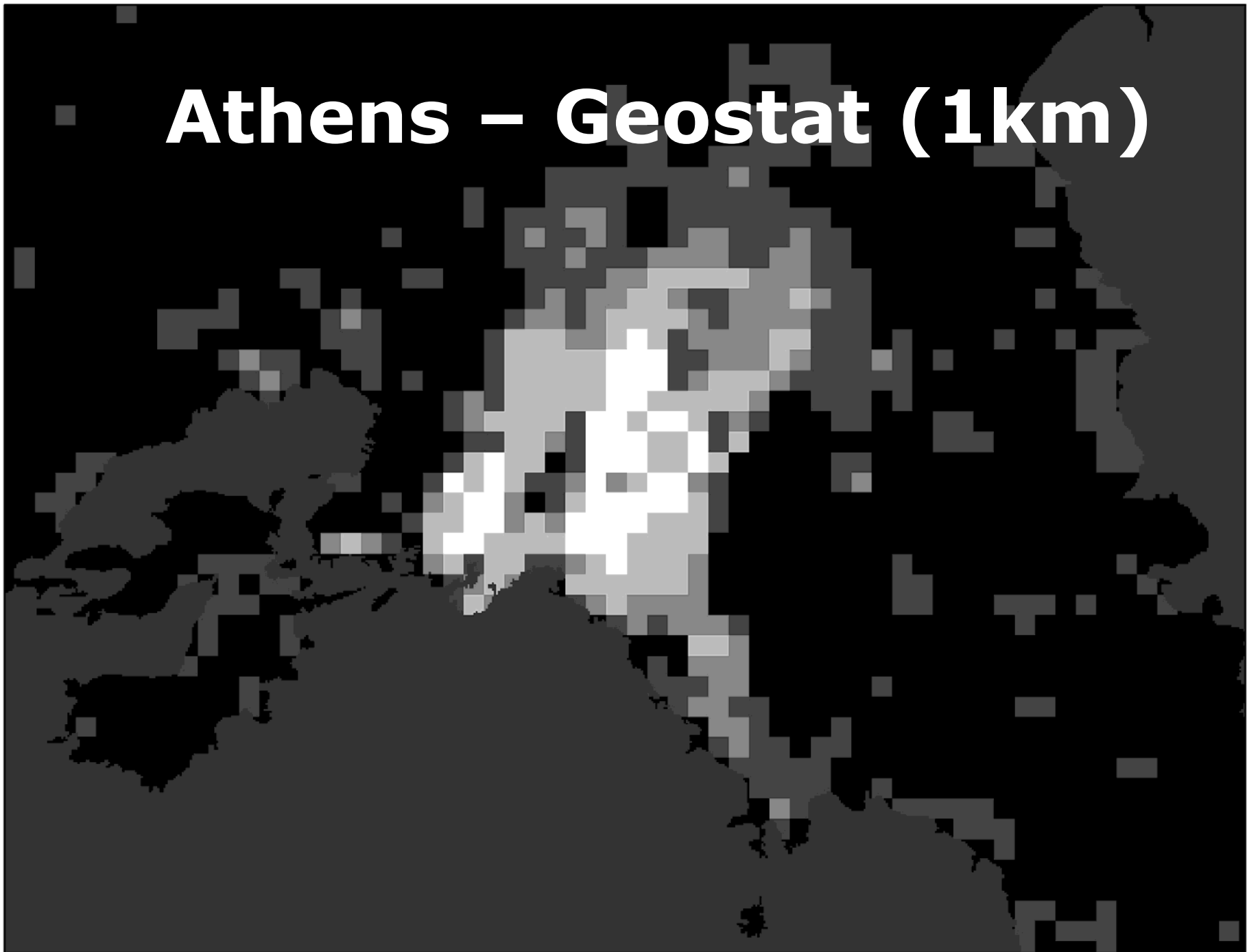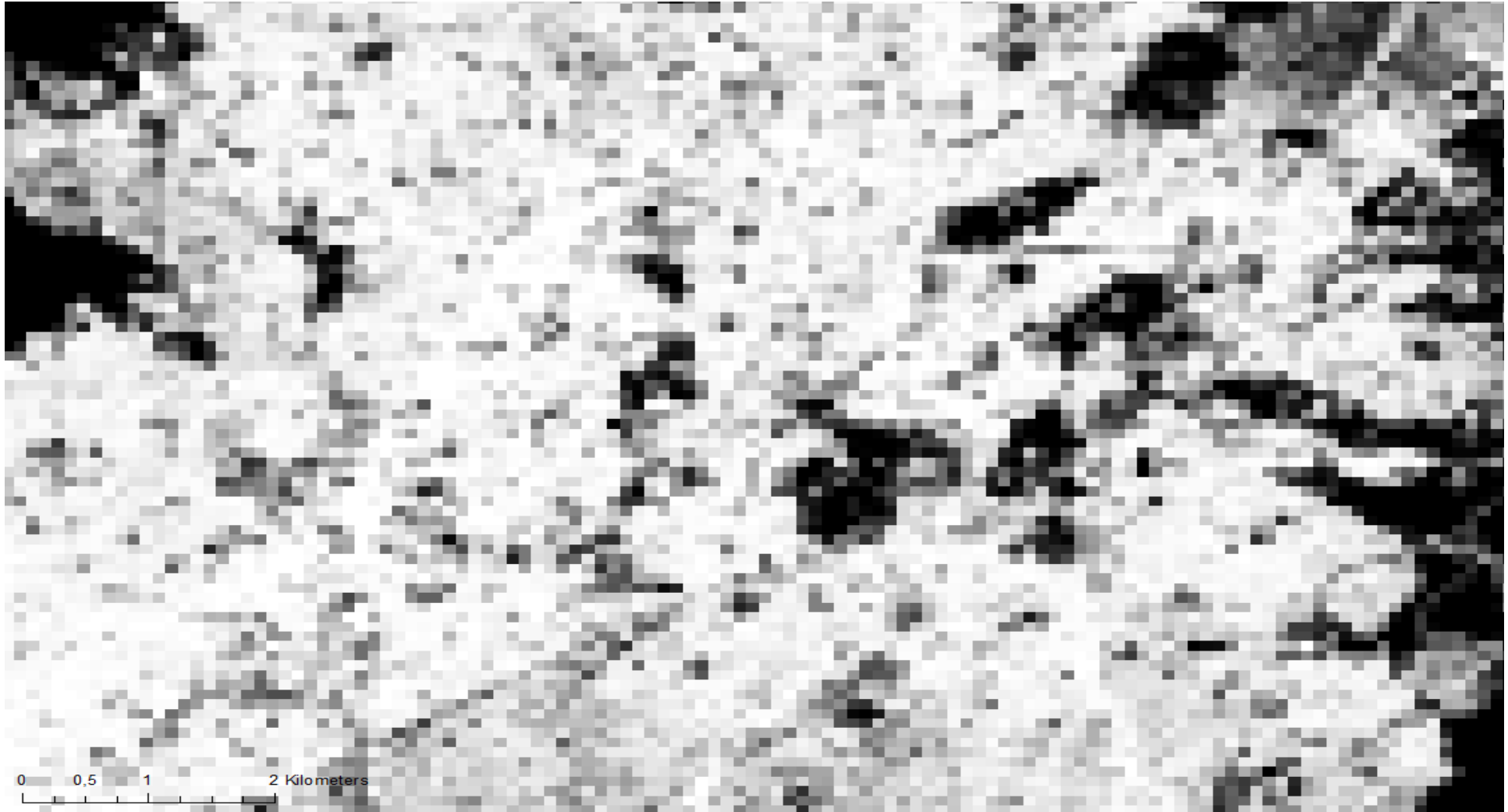
kilometers

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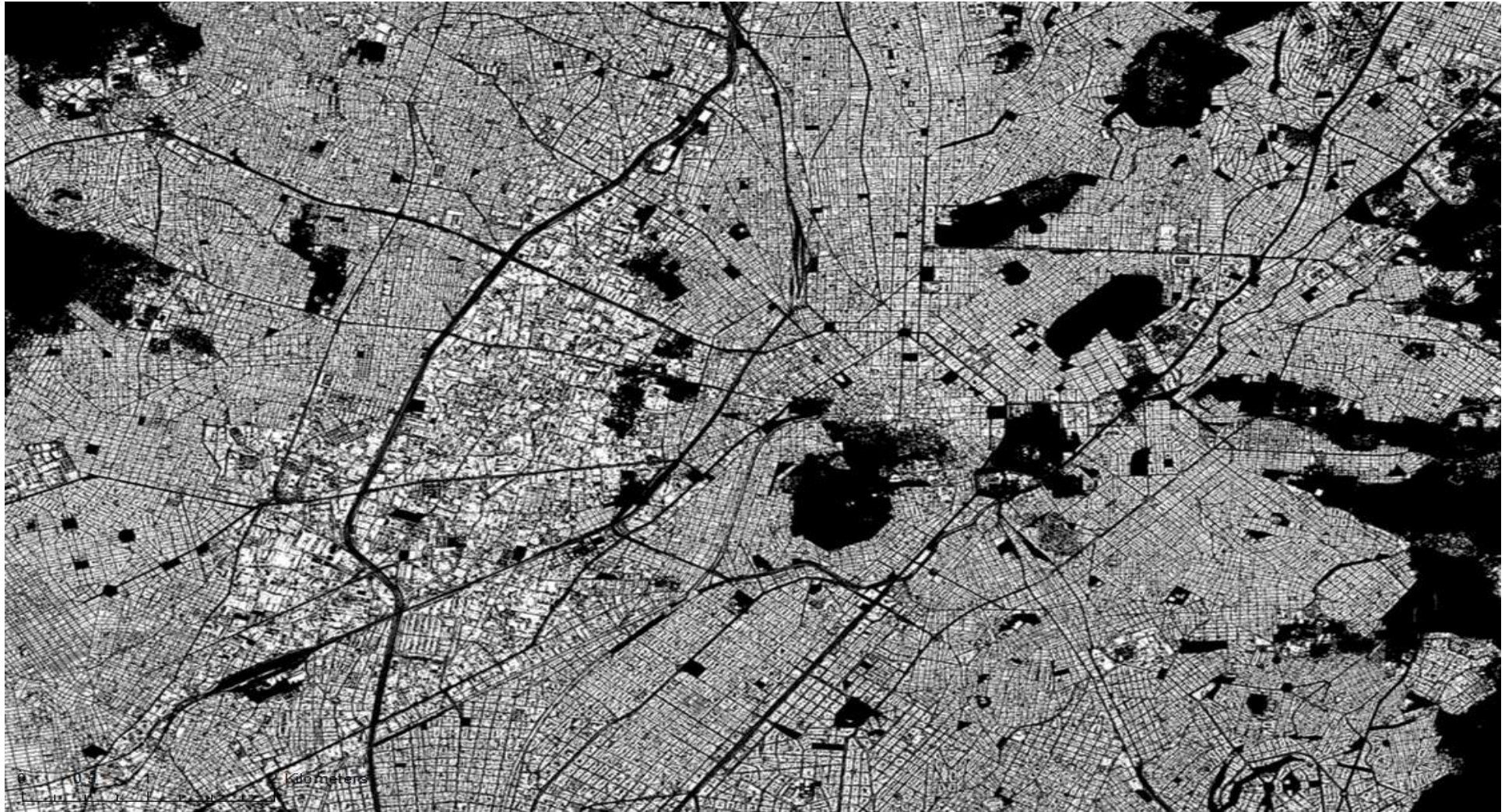
GHSL population disaggregation
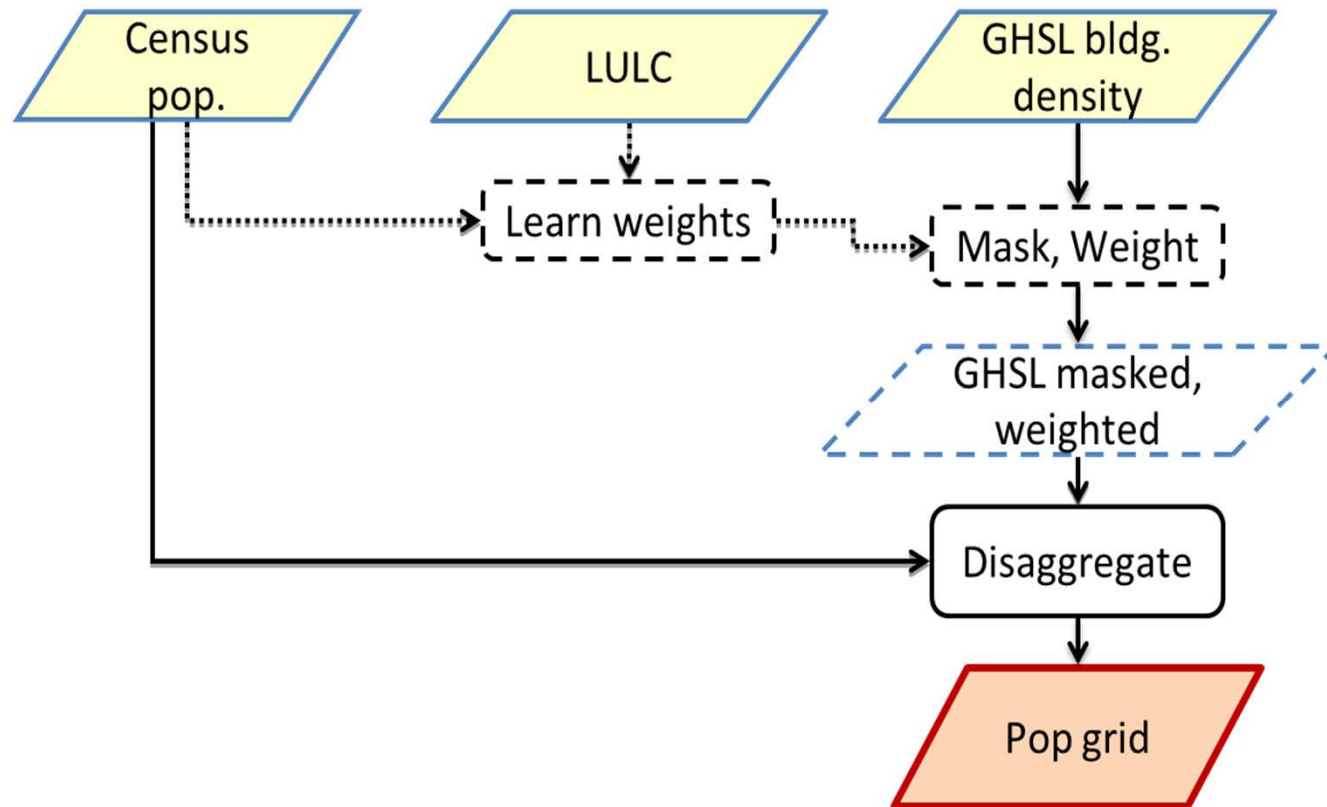
Weights:

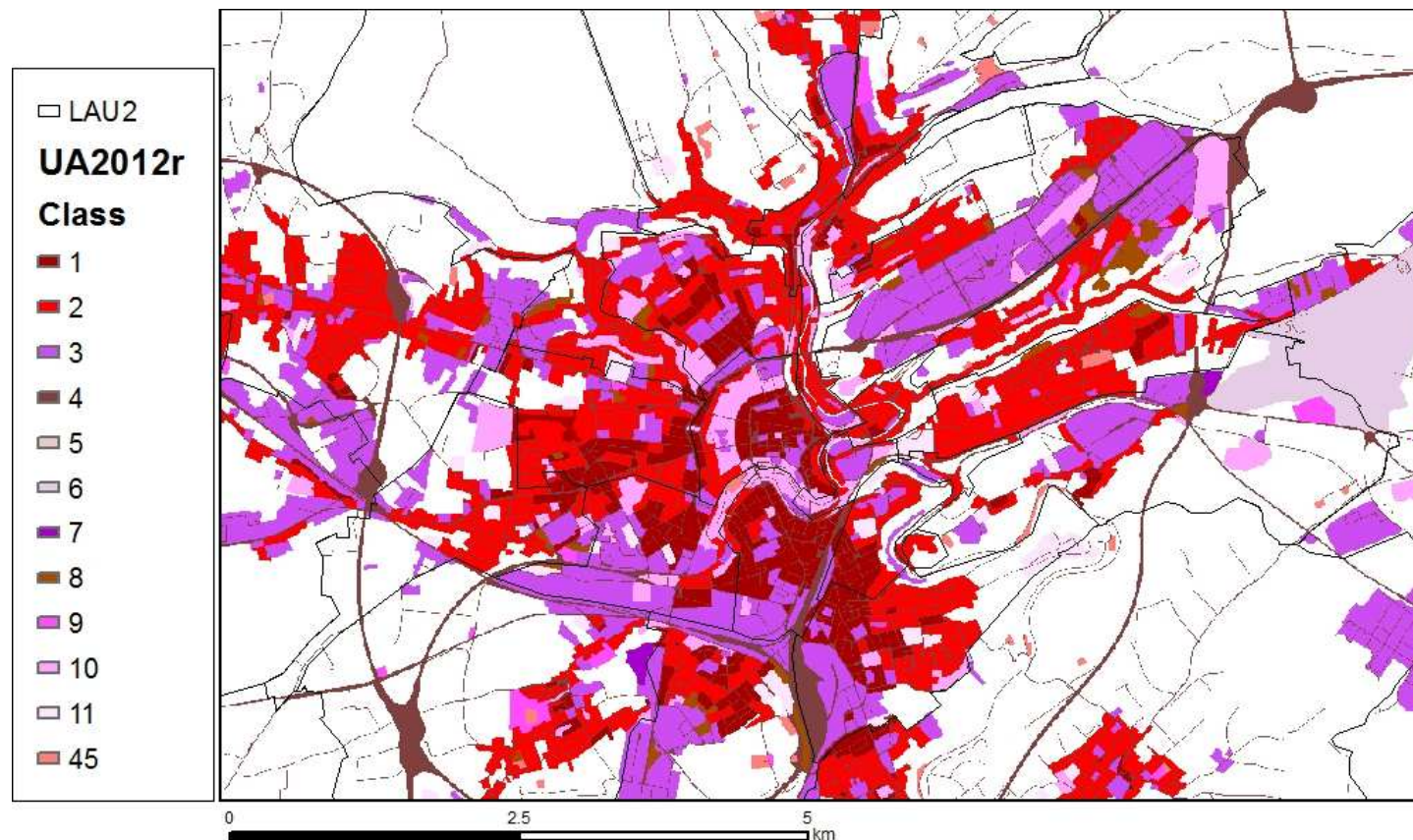| CODE	CLC_C3	CLC06_R	12 BLDGS	8 RESID.	23 MASK	23 C. GLOBAL POP_HA	WG1H	23 C. 3C SOUTH POP_HA	WS1H	6 C. 2C NORTH POP_HA	WN1H
0	0	NODATA			Y						
1	111	High-density urban fabric	Y	Y		180.0	57.58	200.0	58.65	120.0	52.2
2	112	Medium-density urban fabric	Y	Y		60.0	19.19	70.0	20.53	60.0	26.1
45	113	Low-density urban fabric	Y	Y		30.0	9.60	30.0	8.80	40.0	17.4
3	121	Industrial or commercial units	Y	Y		10.0	3.20	10.0	2.93	5.0	2.2
4	122	Road and rail networks and associated land	Y		Y						
5	123	Port areas	Y		Y						
6	124	Airports	Y		Y						
7	131	Mineral extraction sites			Y						
8	132	Dump sites			Y						
9	133	Construction sites	Y	Y		10.0	3.20	4.0	1.17		
10	141	Green urban areas	Y		Y						
11	142	Sport and leisure facilities	Y	Y		4.0	1.28	3.0	0.88		
12	211	Non-irrigated arable land		Y		2.0	0.64	1.0	0.29	3.0	1.3
13	212	Permanently irrigated land				1.0	0.32	0.5	0.15		
14	213	Rice fields				1.0	0.32	0.5	0.15		
15	221	Vineyards				1.0	0.32	1.0	0.29		
16	222	Fruit trees and berry plantations				1.0	0.32	1.0	0.29		
17	223	Olive groves				1.0	0.32	1.0	0.29		
18	231	Pastures				1.0	0.32	3.0	0.88	2.0	0.9
19	241	Annual crops associated with permanent crops		Y		3.0	0.96	4.0	1.17		
20	242	Complex cultivation patterns	Y	Y		3.0	0.96	5.0	1.47		
21	243	Land principally occupied by agriculture, with significant area		Y		3.0	0.96	5.0	1.47		
22	244	Agro-forestry areas				1.0	0.32	1.0	0.29		
23	311	Broad-leaved forest				0.1	0.03	0.1	0.03		
24	312	Coniferous forest				0.1	0.03	0.1	0.03		
25	313	Mixed forest				0.1	0.03	0.3	0.09		
26	321	Natural grasslands				0.1	0.03	0.1	0.03		
27	322	Moors and heathland			Y						
28	323	Sclerophyllous vegetation				0.1	0.03	0.1	0.03		
29	324	Transitional woodland-shrub				0.1	0.03	0.3	0.09		

CORINE LCv2 Ljubljana, Croatia
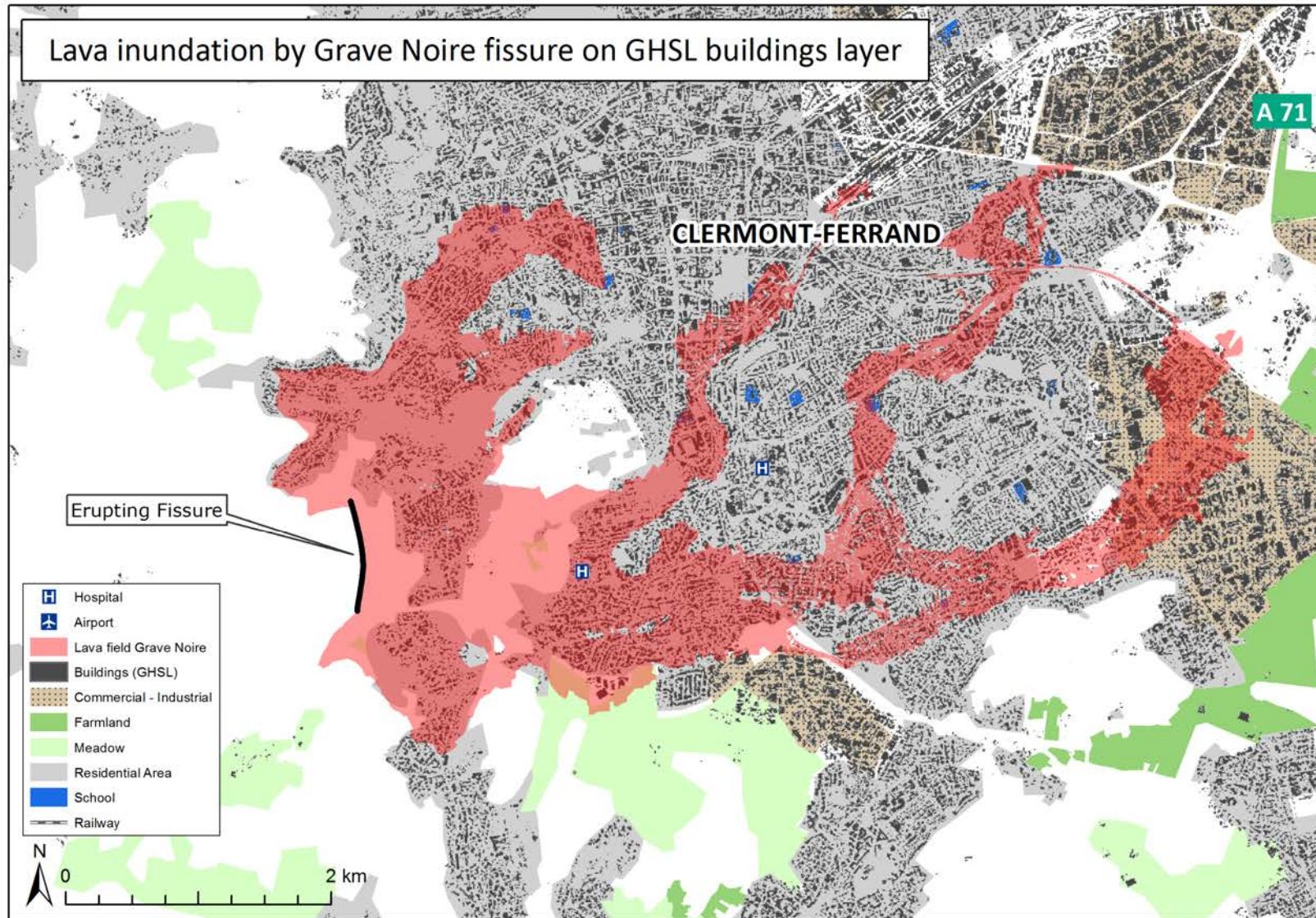
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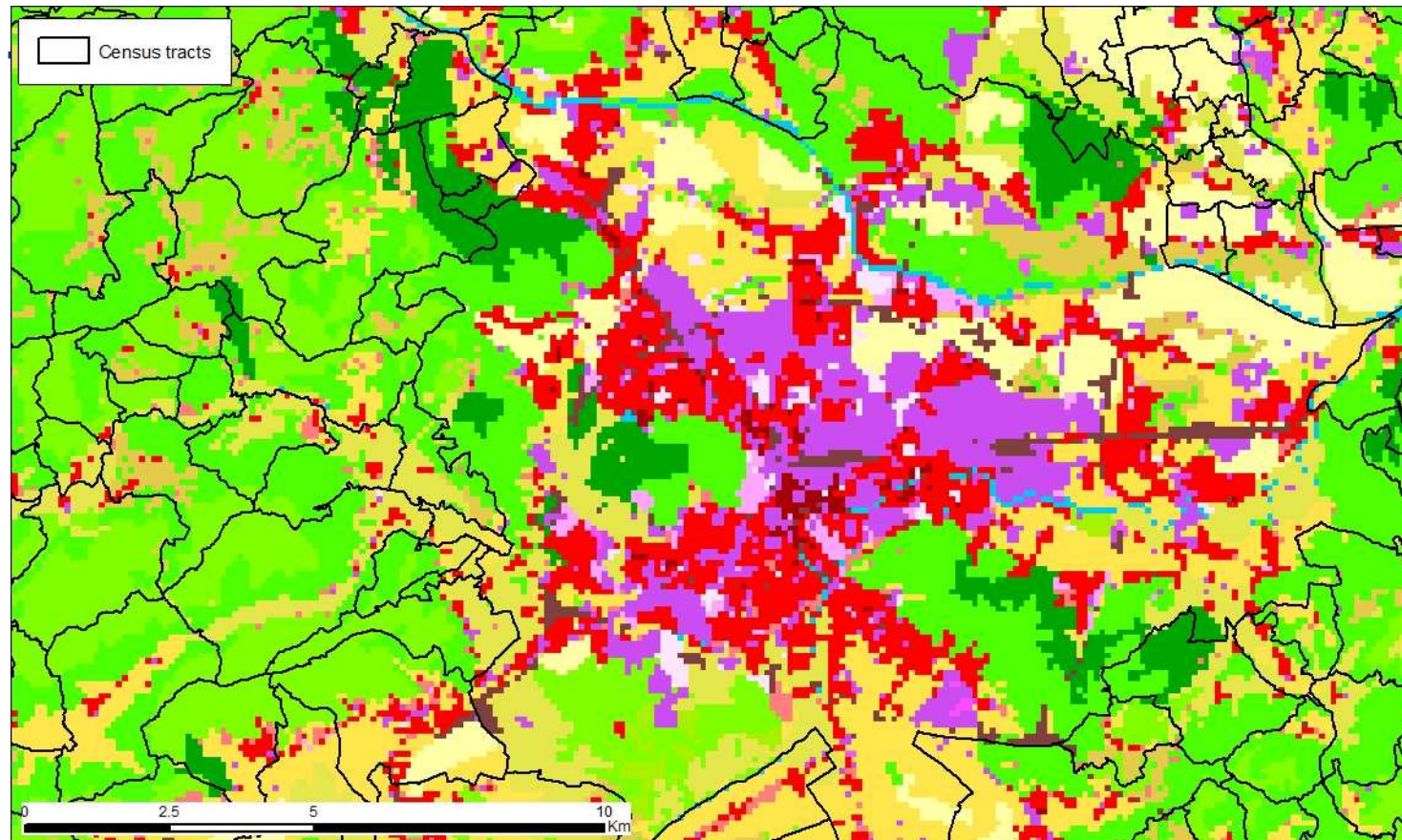
Improving population disaggregation by weighting land use:
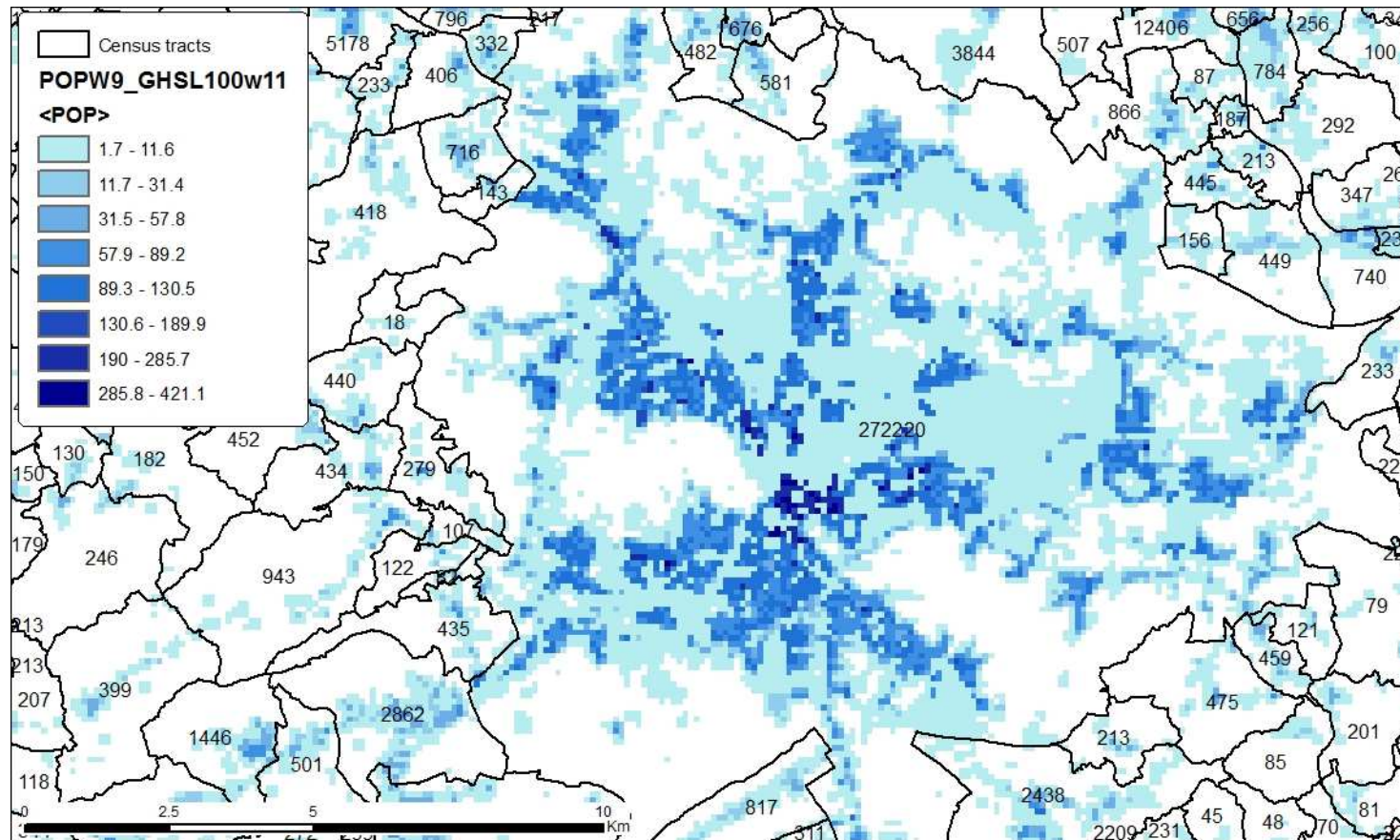
Reclassifying urban atlas by CLCv2 land use in Luxembourg

Lava inundation by Grave Noire fissure on GHSL buildings layer

CLERMONT-FERRAND

A 71

Erupting Fissure

Legend:
- H Hospital
- ✈ Airport
- Lava field Grave Noire
- Buildings (GHSL)
- Commercial - Industrial
- Farmland
- Meadow
- Residential Area
- School
- Railway

N

0   2 km

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30 JUL 2014

JRC analyses and modelling support the 6th Cohesion Report

JRC analysis of EU human settlements, land-use and resource efficiency, as well as modelling work addressing options for urban and regional development have fed into the 6th Report on Economic, Social and Territorial Cohesion, released on 23 July by the European Commission. The report examines the state of cohesion of the Union and highlights challenges faced by national, regional and local authorities in overcoming the impact of the financial and economic crises.

The work carried out by the JRC on human settlements shows that cities are more efficient in terms of land and resource consumption compared to rural areas. According to the report, the amount of built-up land (i.e. land with a building on it) per person in urban areas is four times lower than that in rural or peripheral areas. This analysis is backed by the first ever map of European settlements from satellite imagery, which offers a comprehensive overview of all built-up areas at an unprecedented detailed scale, reporting on the location and surface area of buildings across urban and rural agglomerations.

The map was produced using an innovative technology and method developed by the JRC – the Global Human Settlements Layer (GHSL) – which is able to automatically analyse a huge amount of data coming from different satellite sensors, at different resolutions, from anywhere in the world and taken at different moments in time. A land-use efficiency analysis was also carried out through the JRC's Land Use based Integrated Sustainability Assessment (LUISA) modelling platform, coupled with another JRC tool, the Regional Economic Model (RHOMOLO). A particular focus was given to urban growth since the

Investment for jobs and growth
Promoting development and good governance in EU regions and cities

Sixth report on economic, social and territorial cohesion

Preliminary version   July 2014

The Cohesion report looks into development and governance of EU regions and cities

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Related Content

Commission press release

Sixth report on economic, social and territorial cohesion

Global Human Settlements Layer

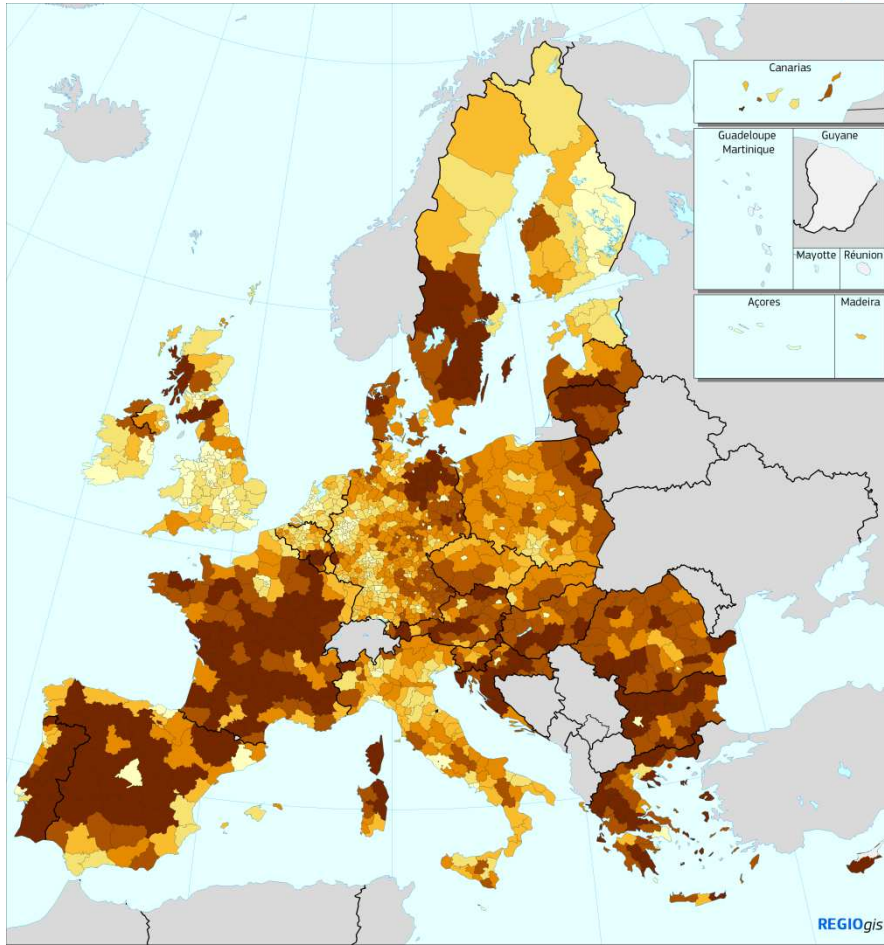Land-Use-based Integrated Sustainability Assessment Modelling

Related Topics

Crisis management

Disaster risk management

Integrated sustainability assessments

Natural and man-made hazards

Regional economic analysis and modelling
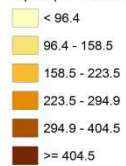
JRC Institutes

IES
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IPTS

Built up area per head by region, 2012

sq.km per million inhabitants

- ▢ < 96.4
- ▢ 96.4 - 158.5
- ▢ 158.5 - 223.5
- ▢ 223.5 - 294.9
- ▢ 294.9 - 404.5
- ▢ >= 404.5
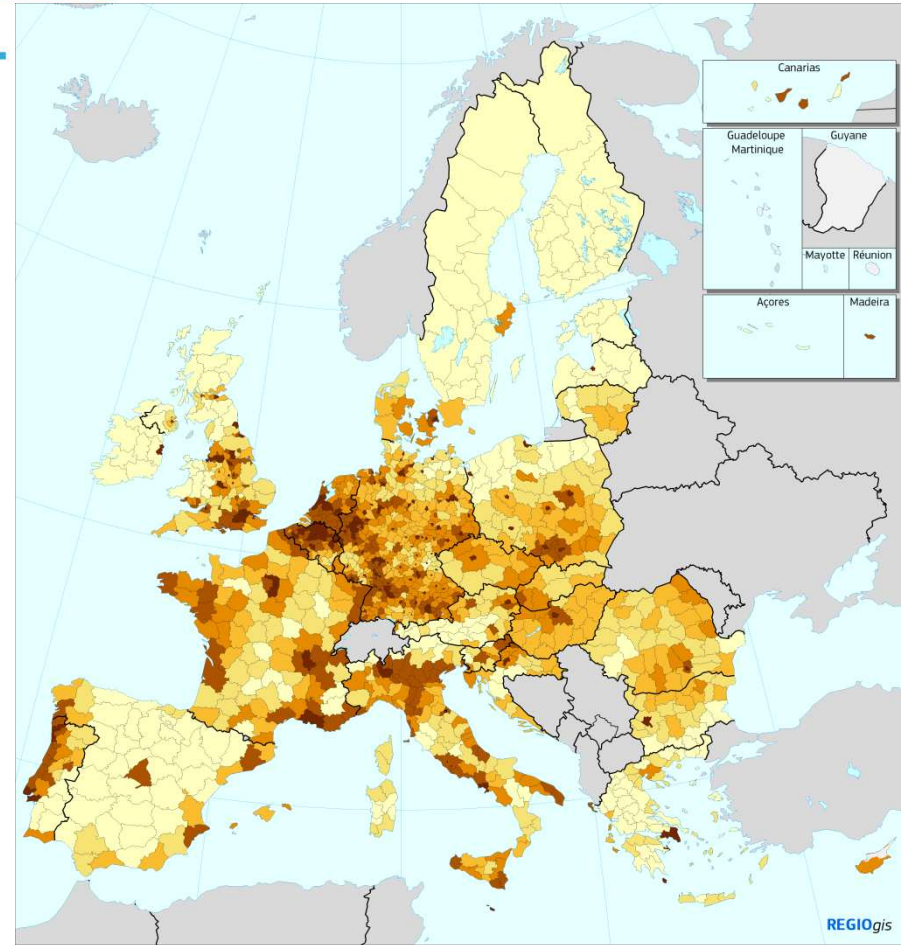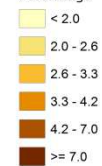
Source: JRC

0   500 Km

© EuroGeographics Association for the administrative boundaries

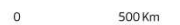**Share of built up area in total area by region, 2012**

Percentage

- ▢ < 2.0
- ▢ 2.0 - 2.6
- ▢ 2.6 - 3.3
- ▢ 3.3 - 4.2
- ▢ 4.2 - 7.0
- ▢ >= 7.0

Source: JRC

0   500 Km

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REGIOgis

Land-use efficiency of cities

Built-up area per inhabitant, EU regions, 2012

sq. km per mn inhabitants	Urban regions	Inter-mediate regions	Rural regions
EU-28	97	230	368
EU-15	94	221	372
EU-13	126	260	362

Source: JRC European Human Settlement Map and DG REGIO calculations

Dwellings in cities are smaller and more vertical

Offices are more vertical

Energy use for transport, heating and cooling also lower in cities

Joint Research Centre

European Settlement Map 2014

Spatial data set

Metadata Language	Resource Language	Metadata Date
English	English	2014-11-25

Metadata Point Of Contact

Global Security and Crisis Management Unit, *E-mail*:
matina.halkia@jrc.ec.europa.eu

Responsible Party

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GlobSec, *E-mail*: globesec-secretariat@ec.europa.eu

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Resource Title

European Settlement Map 2014

Spatial Data Theme

Buildings (Buildings)

Topic Category

Imagery / BaseMaps / EarthCover

Resource Abstract

European Settlement Map 2014 (also referred as 'EUGHSL2014') is raster data that represents percentage of built-up per spatial unit.
This product is released in 100m resolution (i.e. the unit is a pixel of 100x100 m). It originates from average aggregation of raster data outputs at 10m
resolution produced by automatic information extraction processes using SPOT-5 and SPOT-6 satellite images input at 2.5m resolution

Lineage

The method uses machine learning techniques in order to understand systematic relations between morphological and textural (pantex) features,
extracted from the multispectral and panchromatic bands, describing the human settlement. For the machine learning the following two data sets are
used as training sets Corine Land Cover 2000 and Sealed Surface Layer (v2)

Conformity

Specification: Commission Regulation (EU) No 1089/2010 of 23 November
2010 implementing Directive 2007/2/EC of the European Parliament and of the
Council as regards interoperability of spatial data sets and services, *Date of
publication*: 2010-12-08

Degree: Not evaluated

Unique Resource Identifier

Code: ESM-EUGHSL-2014-100

Conclusions

- The European Settlement Map (ESM) is publicly available at 100m of resolution (native data at 10m)
- It is based on multi-scale, multi-sensor automatic extraction of information mapping built-up in an inclusive way, the EU_GHSL
- It more refined, more thematically consistent than any other reference dataset in Europe and globally, and provides a powerful tool for settlement analysis.
- ESM can be used for population disaggregation, for settlement classification and for urban green detection.
- ESM data have been used to derive policy recommendations about land-use efficiency

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2014 – first tests on automat. assessment of global built-up areas using Landsat data
GLS1975,GLS1990,GLS2000, and L8 JRC collection 15,30,75-m-res input

Thank you

M. Halkia
matina.halkia@jrc.ec.europa.eu

The European Settlement Map 2014
http://land.copernicus.eu/pan-european
view service, WMS, download and a feedback form

More info:
http://ghslsys.jrc.ec.europa.eu/