GEO GROUP ON EARTH OBSERVATIONS

CEOS Committee on Earth Observation Satellites

UN HABITAT FOR A BETTER URBAN FUTURE

Earth Observations Toolkit for Sustainable Cities and Human Settlements

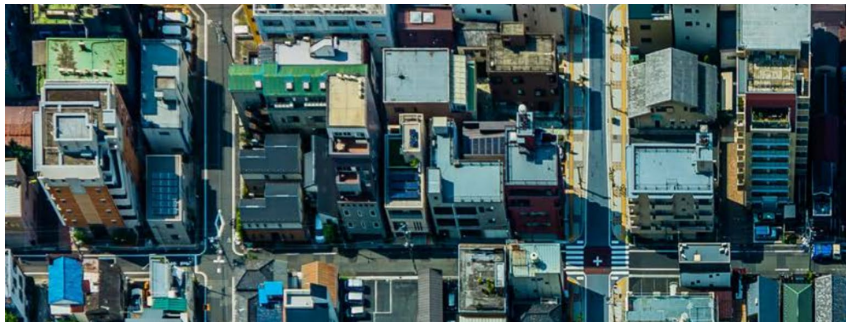
Part 2: Applications of the EO Toolkit to Measure and Analyze Sustainable Development Goals

February 3, 2022

Course Information and Prerequisites

- Three 90-minute sessions on January 27, February 3, and 10 from **10:00-11:30 EST (UTC-5)**
- Webinar recordings and PowerPoint presentations can be found on the training webpage: https://appliedsciences.nasa.gov/join-mission/training/english/arset-earth-observations-toolkit-sustainable-cities-and-human

- Fundamentals of Remote Sensing:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-fundamentals-remote-sensing



- Introduction to Population Grids and their Integration with Remote Sensing Data for Sustainable Development and Disaster Management:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-introduction-population-grids-and-their-integration-remote

Homework and Certificate

- One homework assignment:
  - Answers must be submitted via Google Form accessed from the ARSET website
  - Homework will be made available on February 10, 2022.
  - Due date for homework: February 24, 2022.

- A certificate of completion will be awarded to those who:
  - Attend all three live webinars and complete exercise
  - Complete the homework assignment by the deadline
  - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

Training Objectives

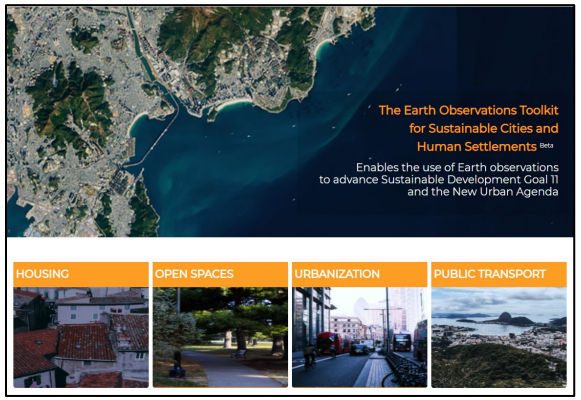
By the end of this training attendees will be able to:

- Understand the value and usefulness of Earth observations to monitor and report on urban Sustainable Development Goal (SDG) indicators and the New Urban Agenda.
- Learn from inspiring examples of cities using Earth observations for SDG 11 (sustainable cities and human settlements) and the New Urban Agenda.
- Understand how to apply Earth observation-based Toolkit resources to enhance urban resilience and improve decisions regarding planning, monitoring, and operational preparedness.

Training Outline

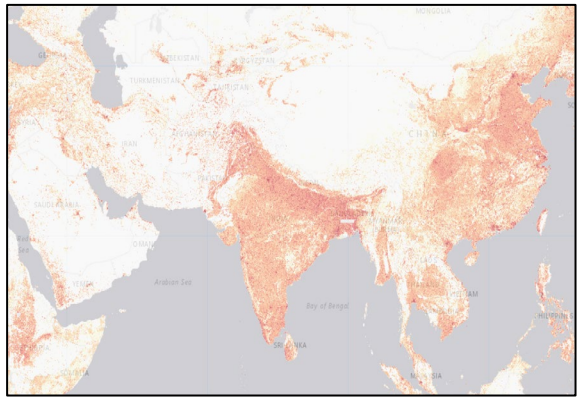
Three 90-minute sessions:

Part 1: January 27, 2022



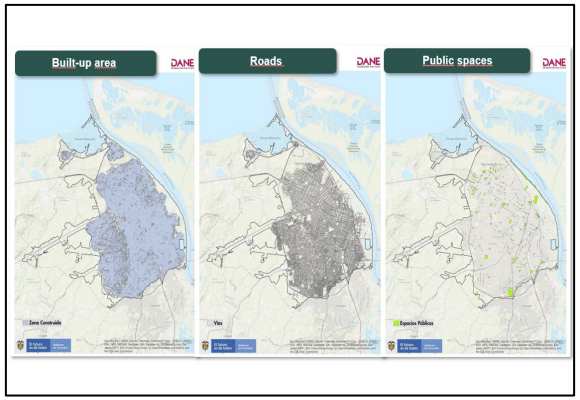
Introduction to Cities and the EO Toolkit for Sustainable Human Settlements

Part 2: February 3, 2022



Applications of the EO Toolkit to Measure and Analyze Sustainable Development Goals

Part 3: February 10, 2022



Use Cases from the National and City Level

SDG Reporting with the Degree of Urbanisation

Thomas Kemper, Project leader, European Commission, Joint Research Centre

Feb 3, 2022

European Commission

Presenter Bio

- Leader of the Global Human Settlement Layer (GHSL) project at the European Commission, Joint Research Centre
- Remote sensing for settlements detection, in particular informal settlements
- Ph.D. in geo-sciences
- Collaborated in the Centre for Satellite-Based Crisis Information (ZKI) of the German Aerospace Centre (DLR)

Thomas Kemper, PhD
Team Leader of the GHSL project
European Commission, JRC

Content of this Presentation

- Policy context
- Overview of the Degree of Urbanisation method
- Global online open data on human settlements provided by GHSL
- Tools to apply the Degree of Urbanisation to your own data
- Matching classified settlements with other data
- Focus on analyses for SDG 11 based on the Degree of Urbanisation
- Applications to other SDGs and to National datasets
- Support material

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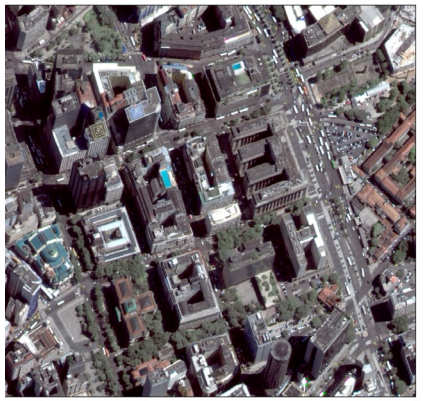
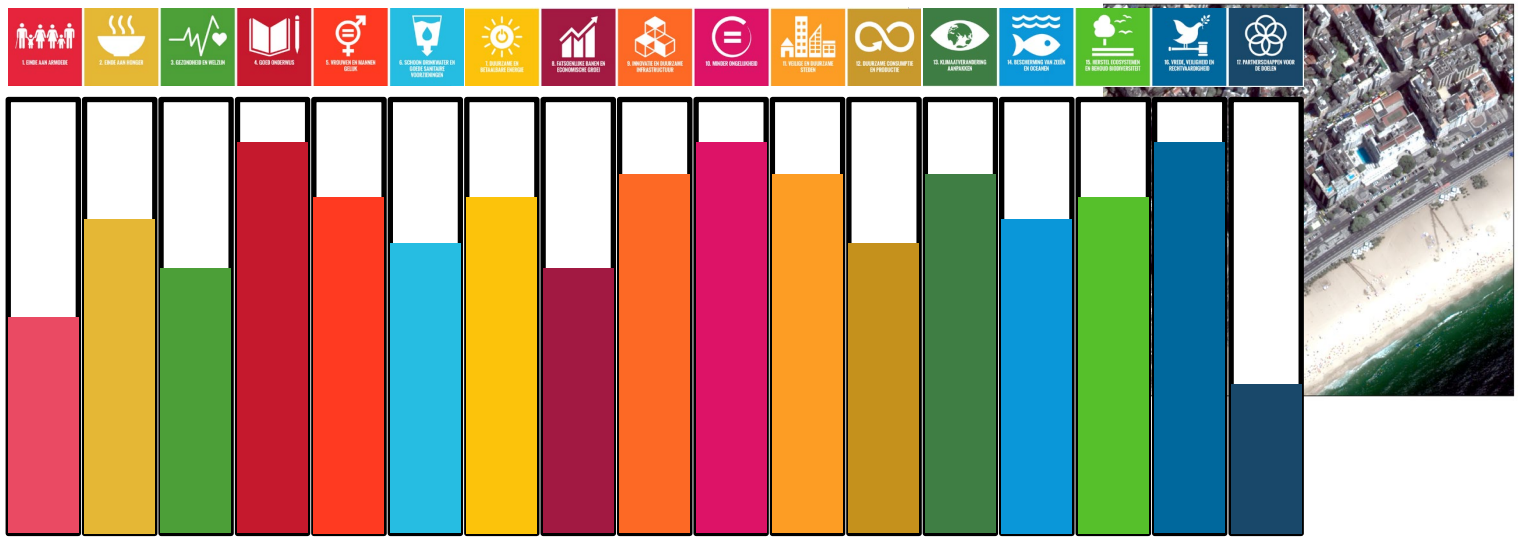
Policy Context

- 2030 Agenda for Sustainable Development
- Sendai Framework for Disaster Risk Reduction
- New Urban Agenda





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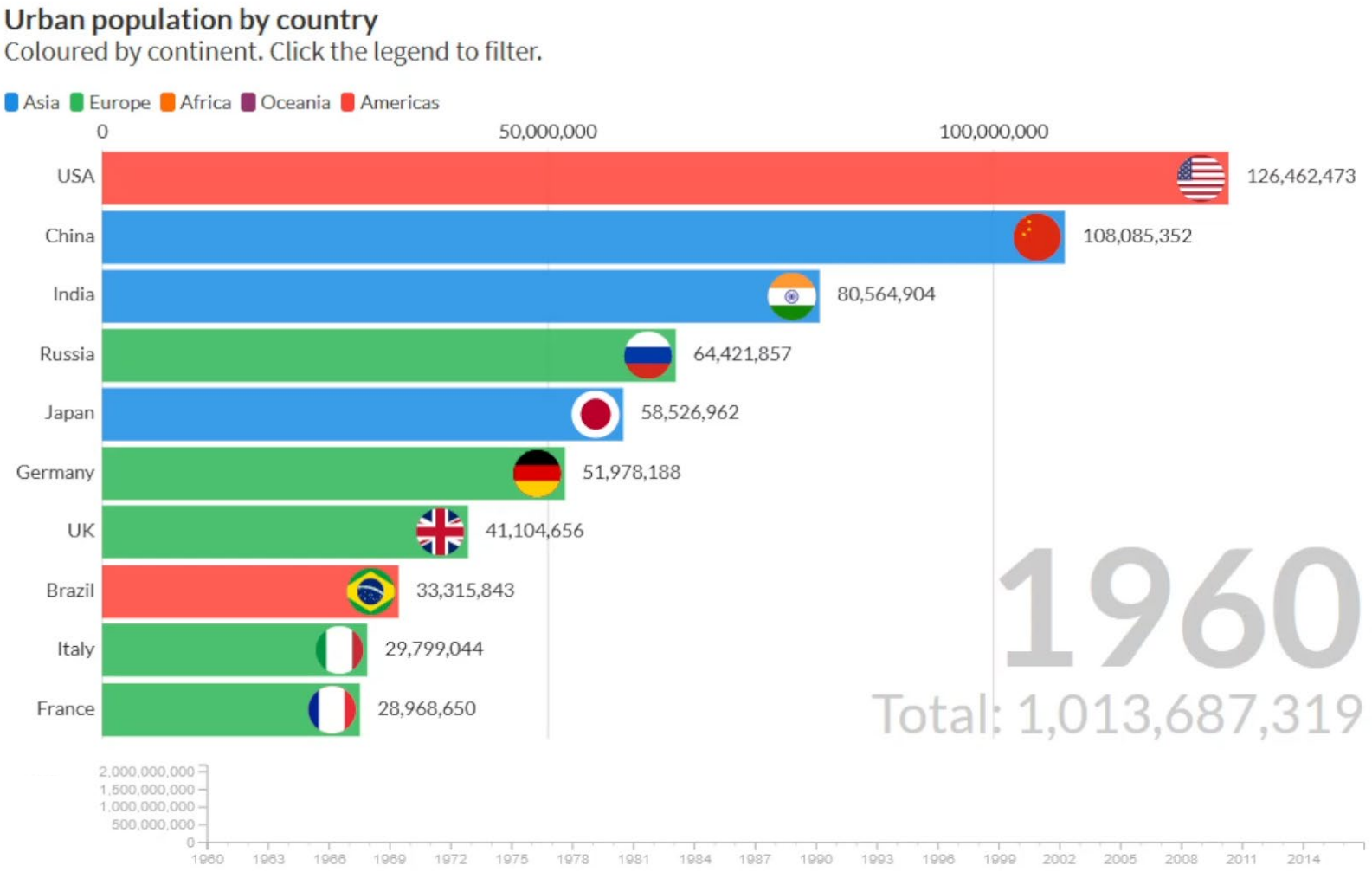
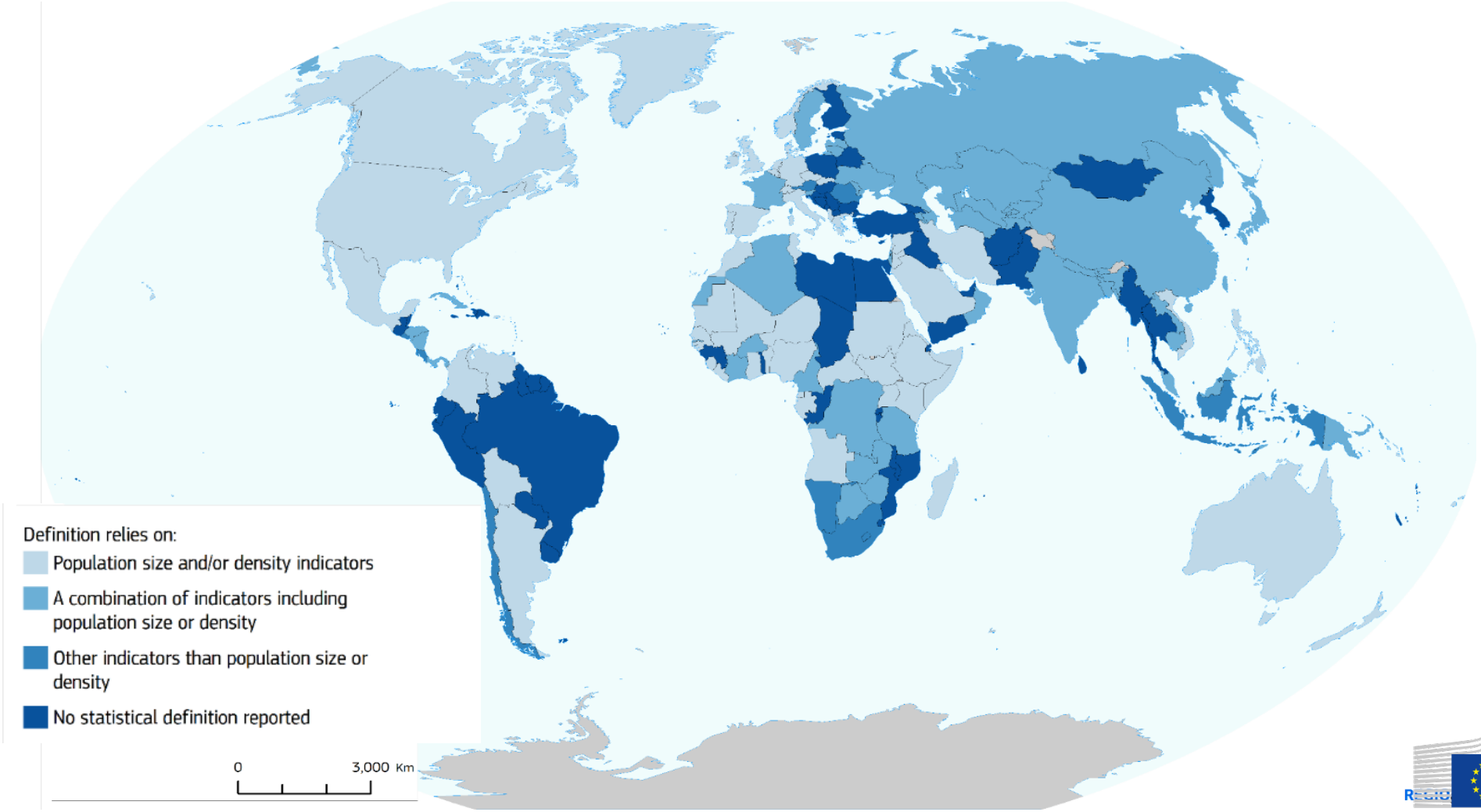
Urban Population Growth



Template: https://flourish.studio; Data: The World Bank

How are urban areas defined?



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The Degree of Urbanisation

1.1.1 Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural)

2.4.1 Proportion of agricultural area under productive and sustainable agriculture (and most other SDG 2 indicators)

3.3.1 Number of new HIV infections per 1,000 uninfected population, by sex, age and key populations

4.5.1 Parity indices (urban/rural) for all education indicators on this list that can be disaggregated

9.1.1 Proportion of the rural population who live within 2 km of an all-season road

11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing (and most other SDG 2 indicators)

- A **common definition of settlements** is needed for international comparisons.

European Commission

The Degree of Urbanisation

European Commission

OECD

UN-HABITAT

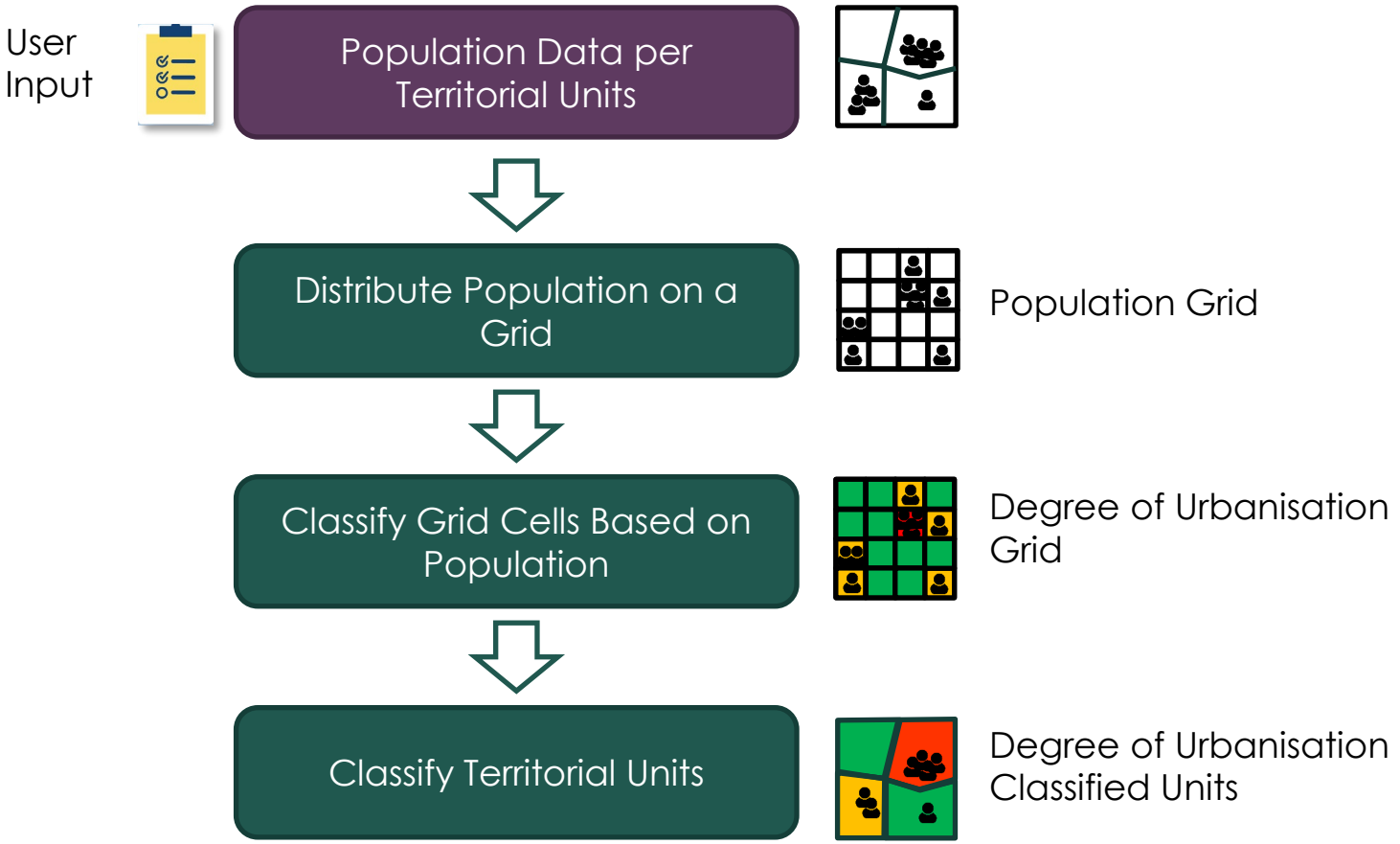
THE WORLD BANK

European Commission

Advantages of the Degree of Urbanisation

- Cost-effective, does not require expensive datasets
- Household surveys can be used as input
- Urban – rural types range is captured
- Independent from size of territorial units
- Focuses on population, universally reliable variable
- Used to monitor access to services and infrastructure

Method



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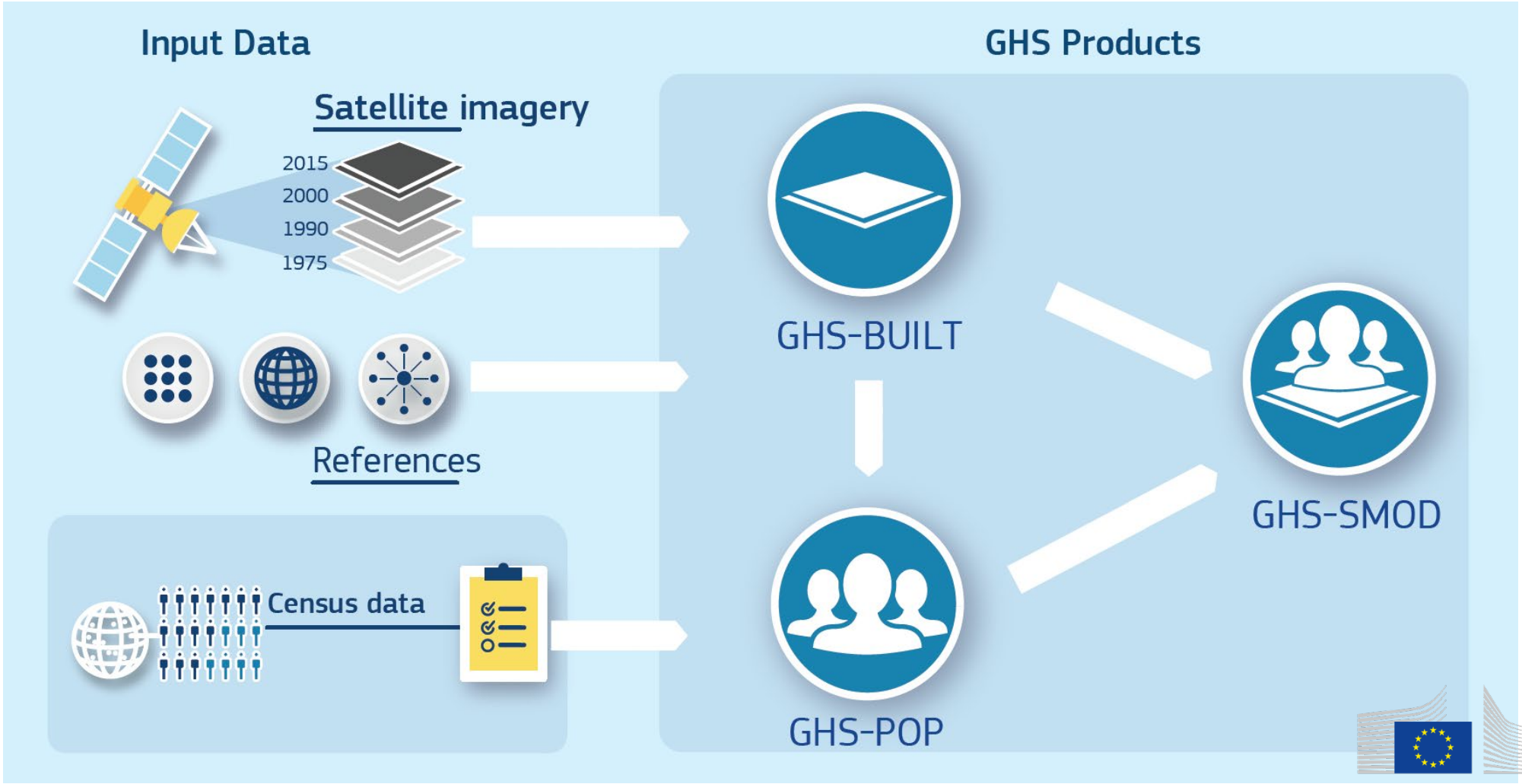
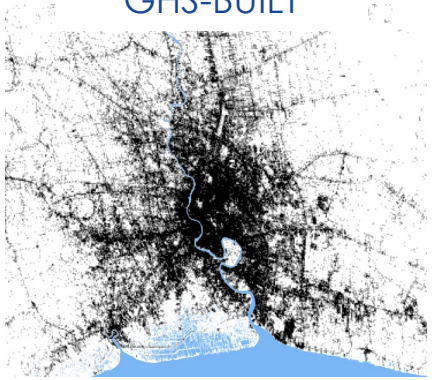
Global Human Settlement Layer (GHSL) Workflow

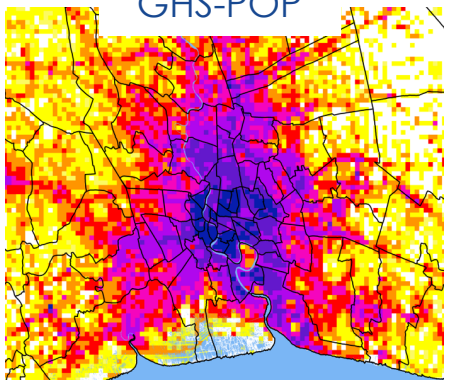


GHSL Open Online Data

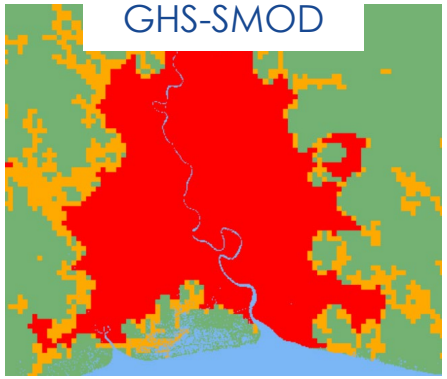
GHS-BUILT



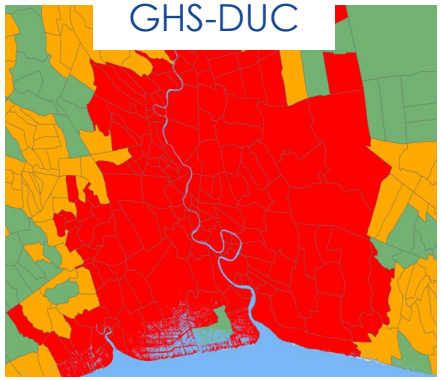
GHS-POP



GHS-SMOD



GHS-DUC



GHS-UCDB

GHS-FUA

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

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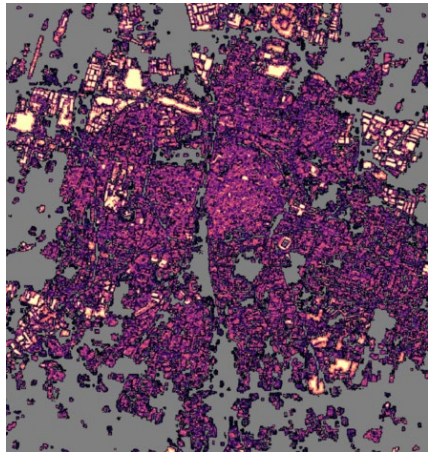
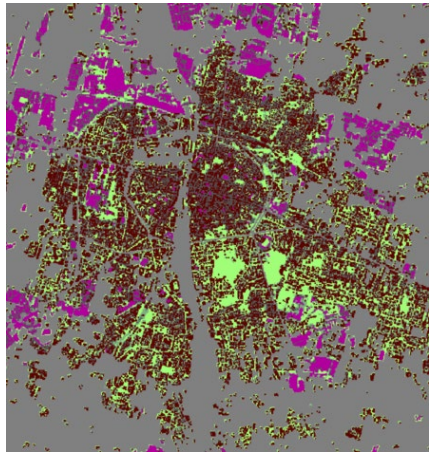
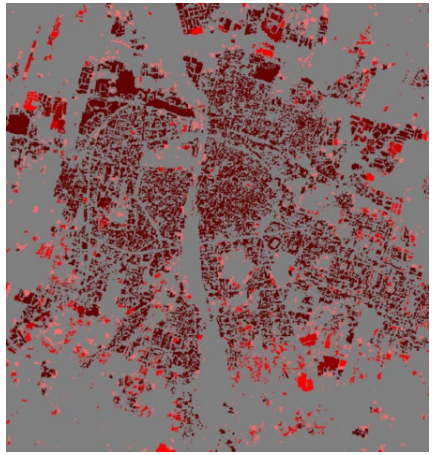
Types of GHSL Built-Up Data - Global

GHS-BUILT

Cell Size	Epochs	Coverage
10 m	2018, Multitemporal layer	Global
100 m	2018, 2014, 2000, 1990, 1975	
1 km	5 years interval 1975-2030	

aggregated

Fraction	Morphological	Multi-Temporal (MT)
		

Built-Up Fraction

Built-Up Type

- Residential Built-up
- Non-Residential Built-up
- Vegetation

Built-Up Epoch

- 2014 to 2018
- 2000 to 2014
- 1990 to 2000
- 1975 to 1990
- Before 1975

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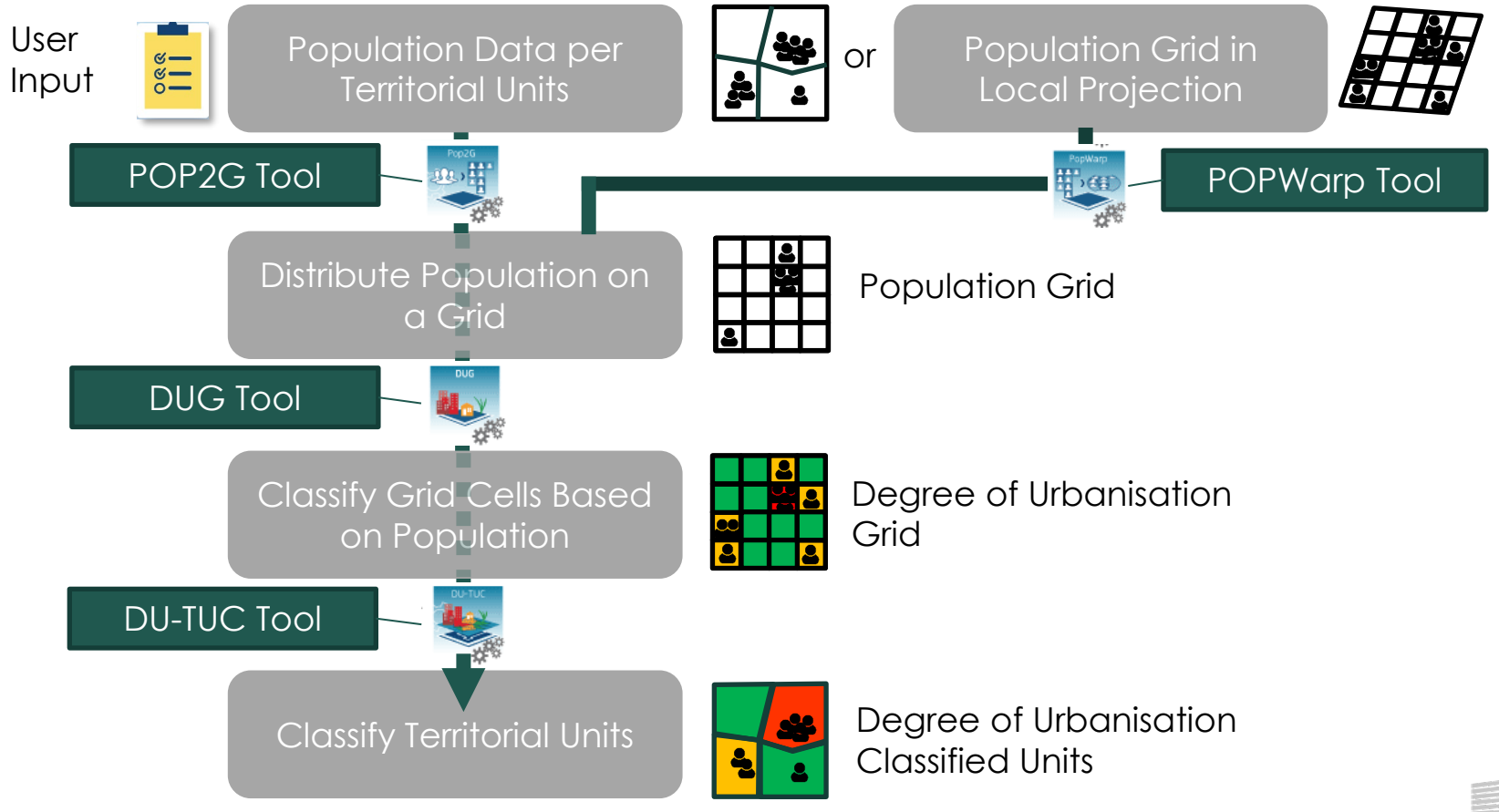
Tools



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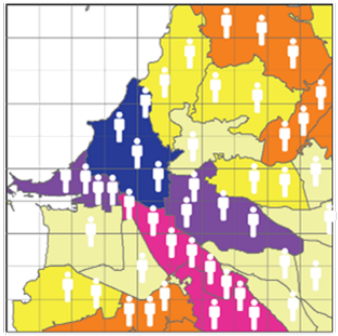
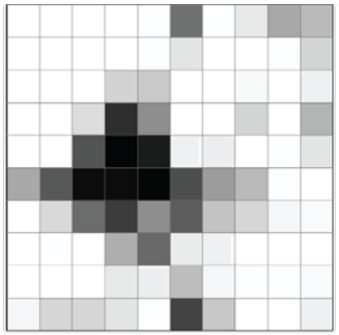
Input Data for the POP2G Tool

- Census vector map
- Built-up area raster



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

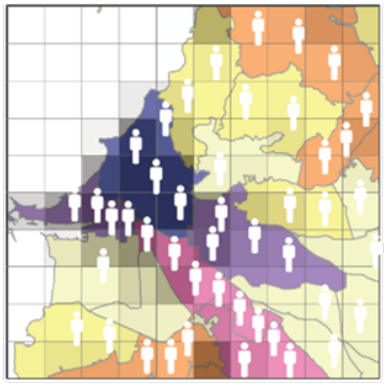
These data sets are typically available as a **total count for units varying widely in size and shape**, while frequently residents occupy only specific zones of these units, at different densities.



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

POP2G Tool Workflow

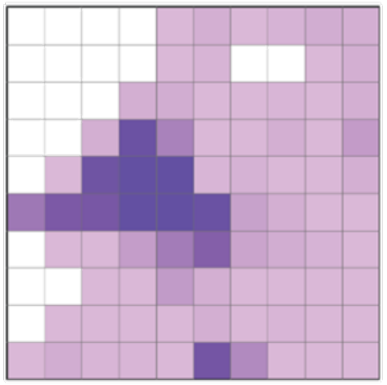
METHOD



The **GHSL method** is design to combine information from population censuses with built-up and to **downscale population** into a **grid of** 1 km 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 1 km)which disergards 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**.

The Degree of Urbanisation

1st Level

Urban Areas

- Urban Centres
- Urban Clusters

- Rural Grid Cells

2nd Level

- Dense Urban clusters
- Semi-dense Urban clusters
- Suburban, peri-urban grid cells

- Rural clusters
- Low density rural grid cells
- Very Low density rural grid cells

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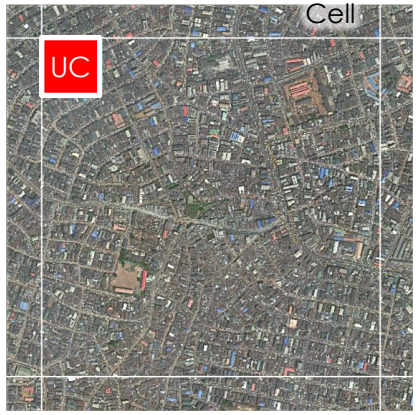
Icons credits: City by Muhajir ila Robbi from the Noun Project, Town by Alice Design from the Noun Project, Farm by Andi Nur Abdillah from the Noun Project

Satellite Images of Settlement Classes

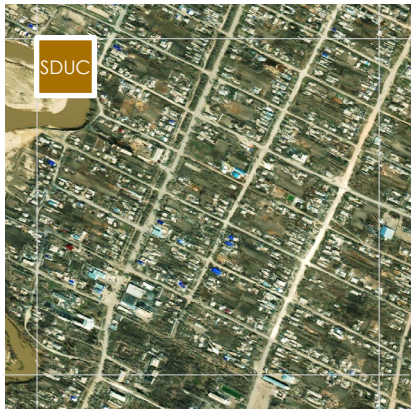
Urban

Urban Centre Grid Cell



Dense Urban Cluster Grid Cell

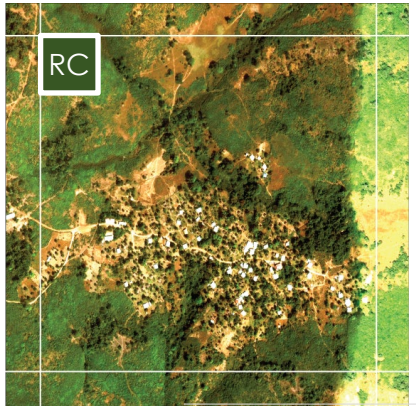
Semi-Dense Urban Cluster Grid Cell



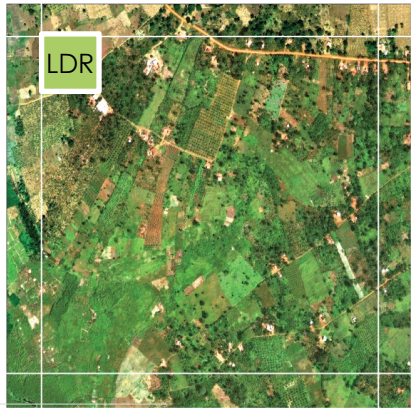
Suburban Grid Cell

Rural

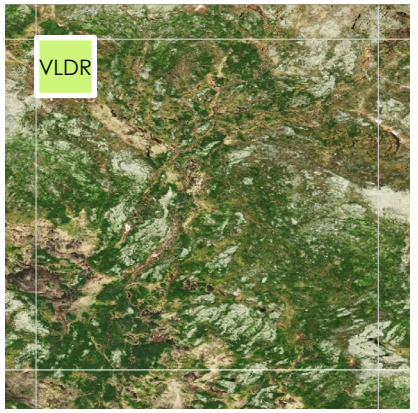
Rural Cluster Grid Cell

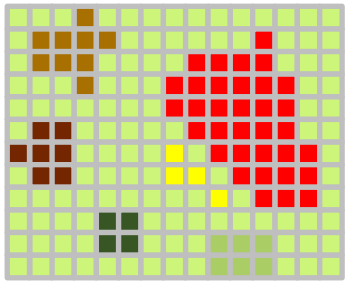


Low Density Rural Grid Cell



Very Low Density Rural Grid Cell





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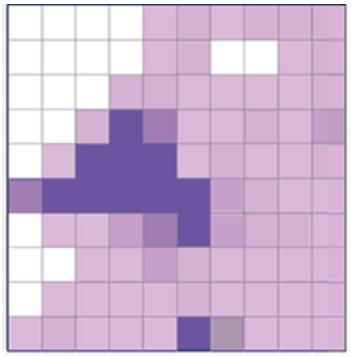
Input Data to the DUG Tool

- Pop raster
- (Built-Up Area raster)
- (Land raster)

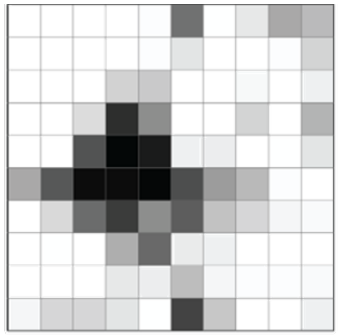
GHS-POP



layer (resolution 1km) which disergards 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**.

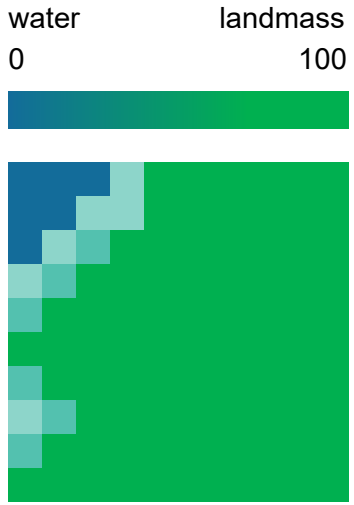
For the 50% BU option

GHS-BUILT

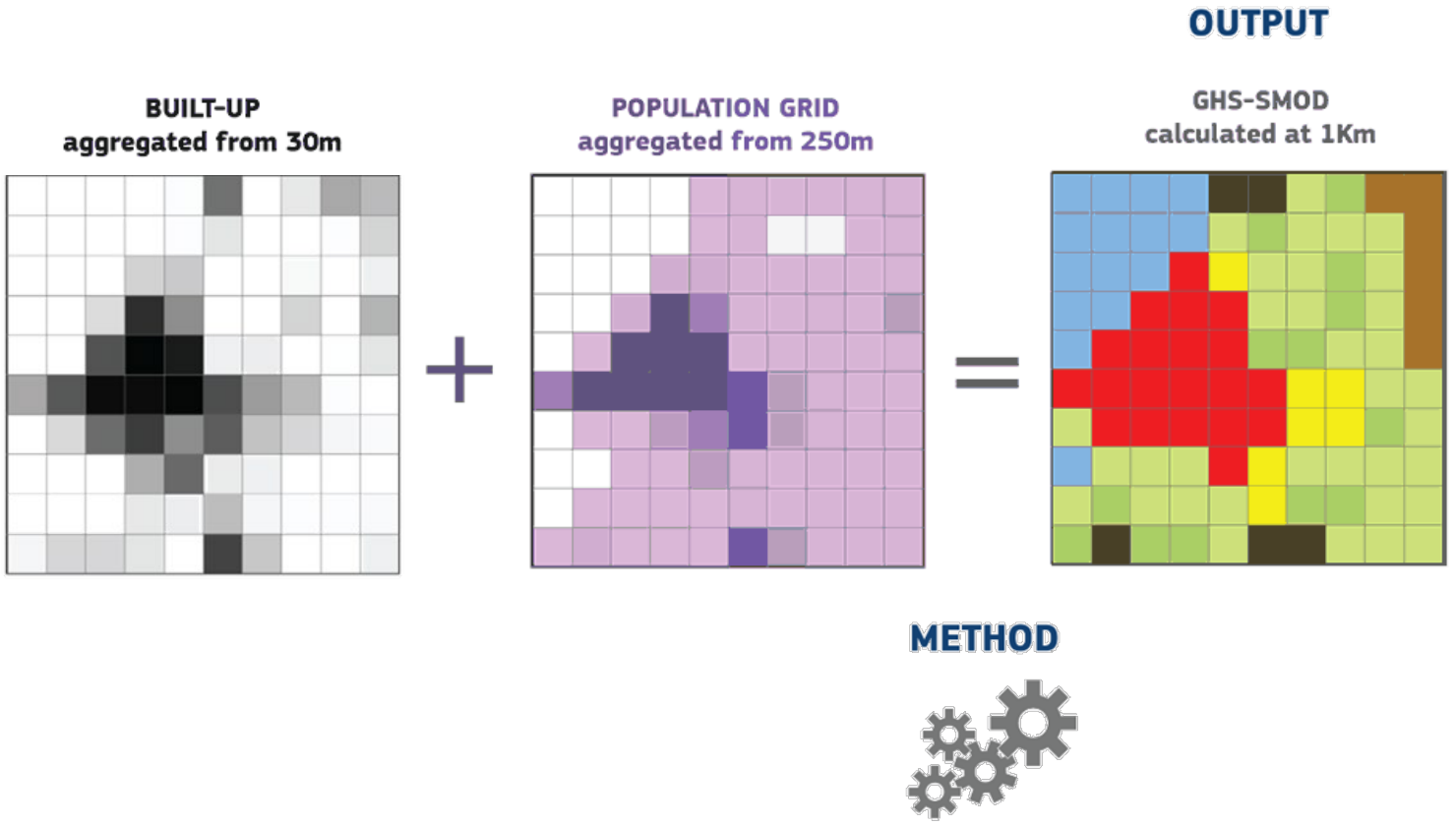


GHS BUILT uses **small grid cells** to measure human settlements **regardless of administrative boundaries**.

Land is a **continuous raster** indicating the landmass against water areas. It is pre-loaded in the GHS-DUG tool, but the user can introduce its own layer for a better performance.

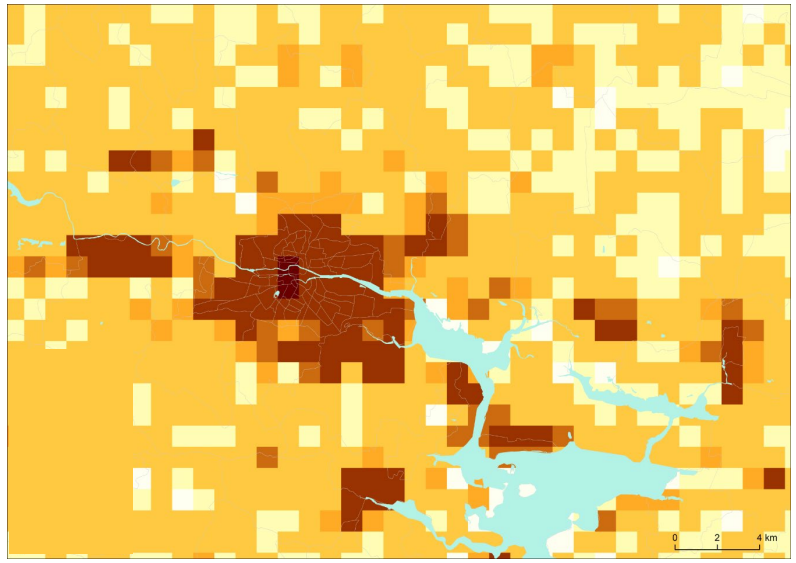


DUG Tool Workflow



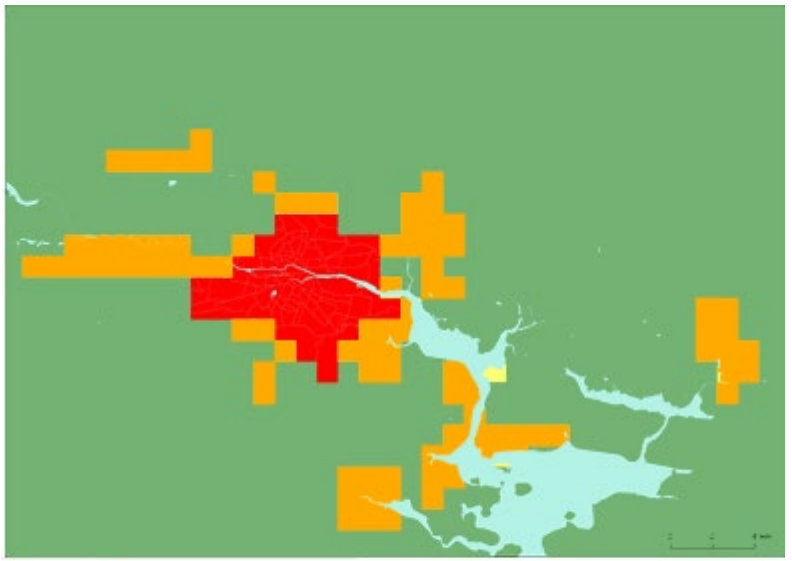
DUG Tool Workflow

Cork, Ireland



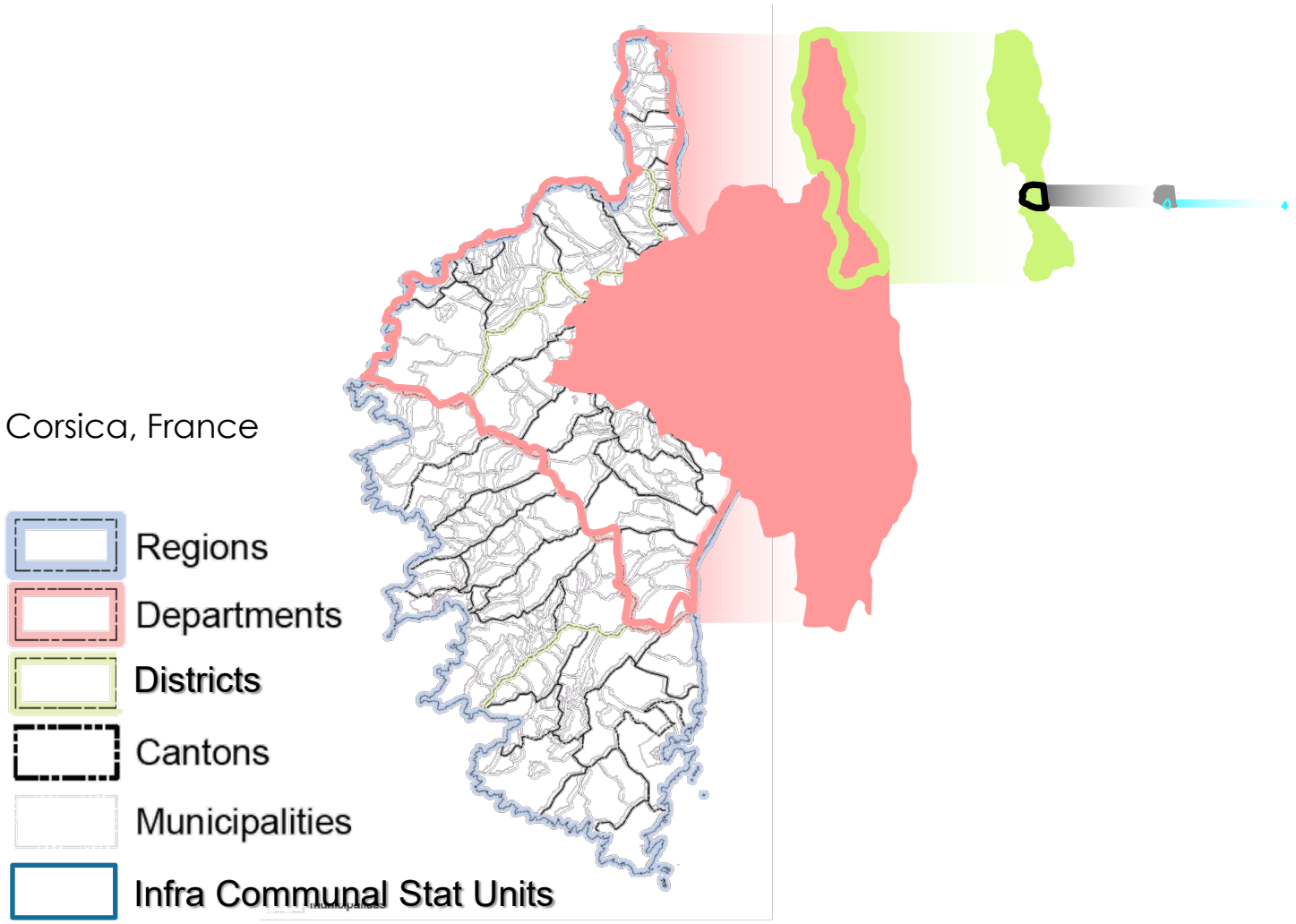
Inhabitants

- 0
- 1 - 20
- 21 - 200
- 201 - 500
- 501 - 1000
- 1001 - 5000
- > 5000



- Urban centre
- Urban cluster
- Rural grid cell

Territorial Units



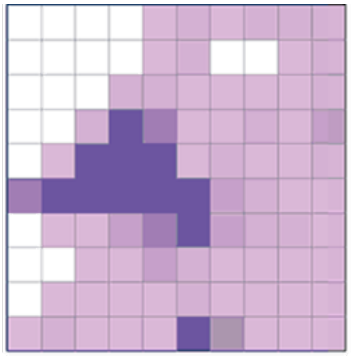
https://gadm.org/data.html

Input Data to the DU-TUC Tool

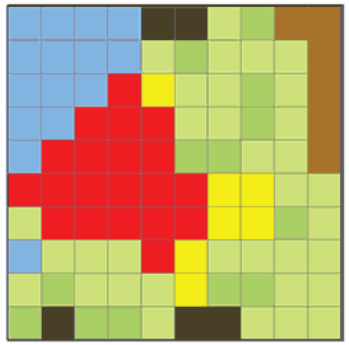
- Territorial Units polygons
- Pop grid raster
- Degree of Urbanisation grid raster

ADMIN SHAPE

GHS-POP



GHS-SMOD

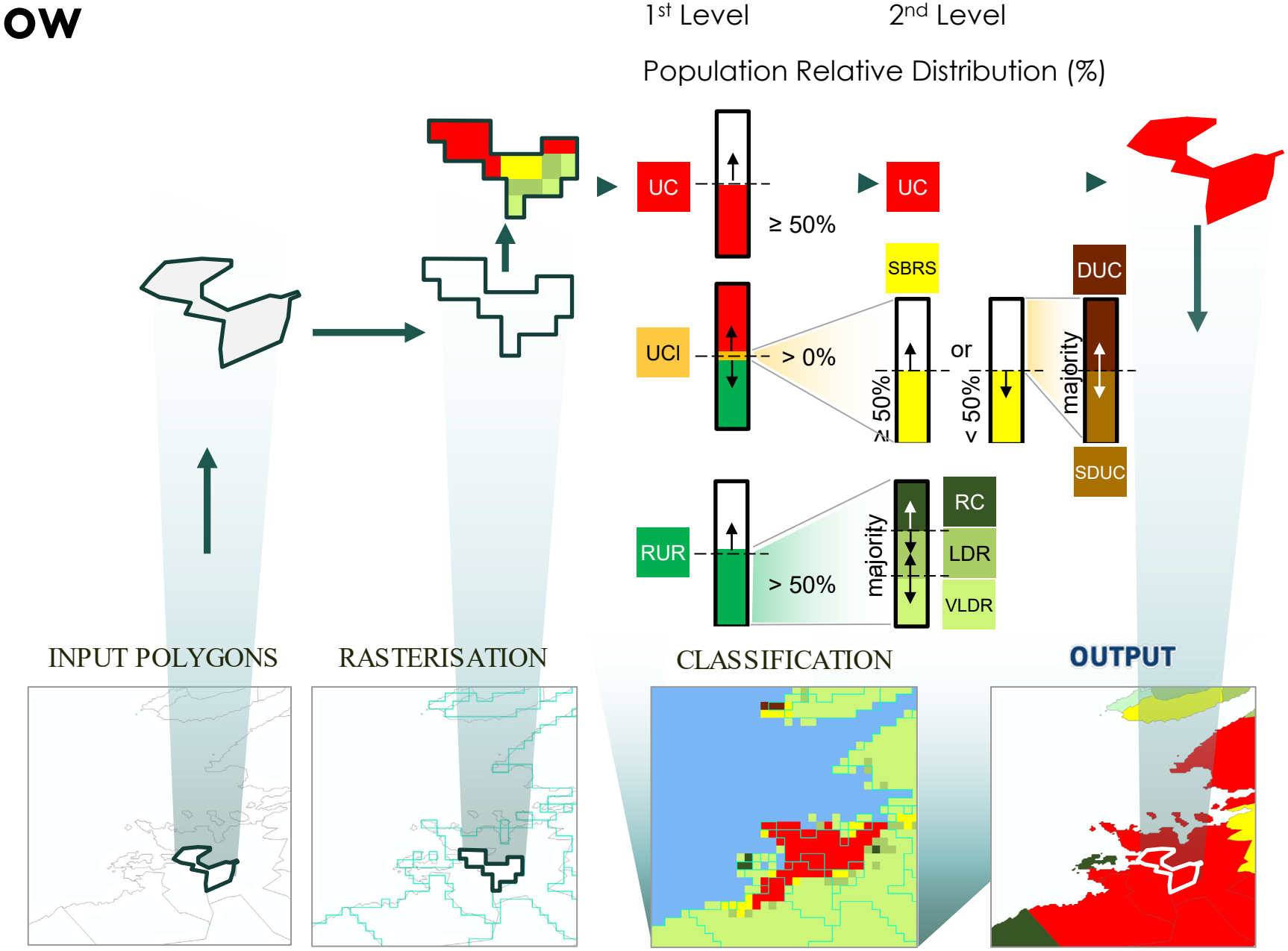


Settlement Model (resolution 1Km)

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

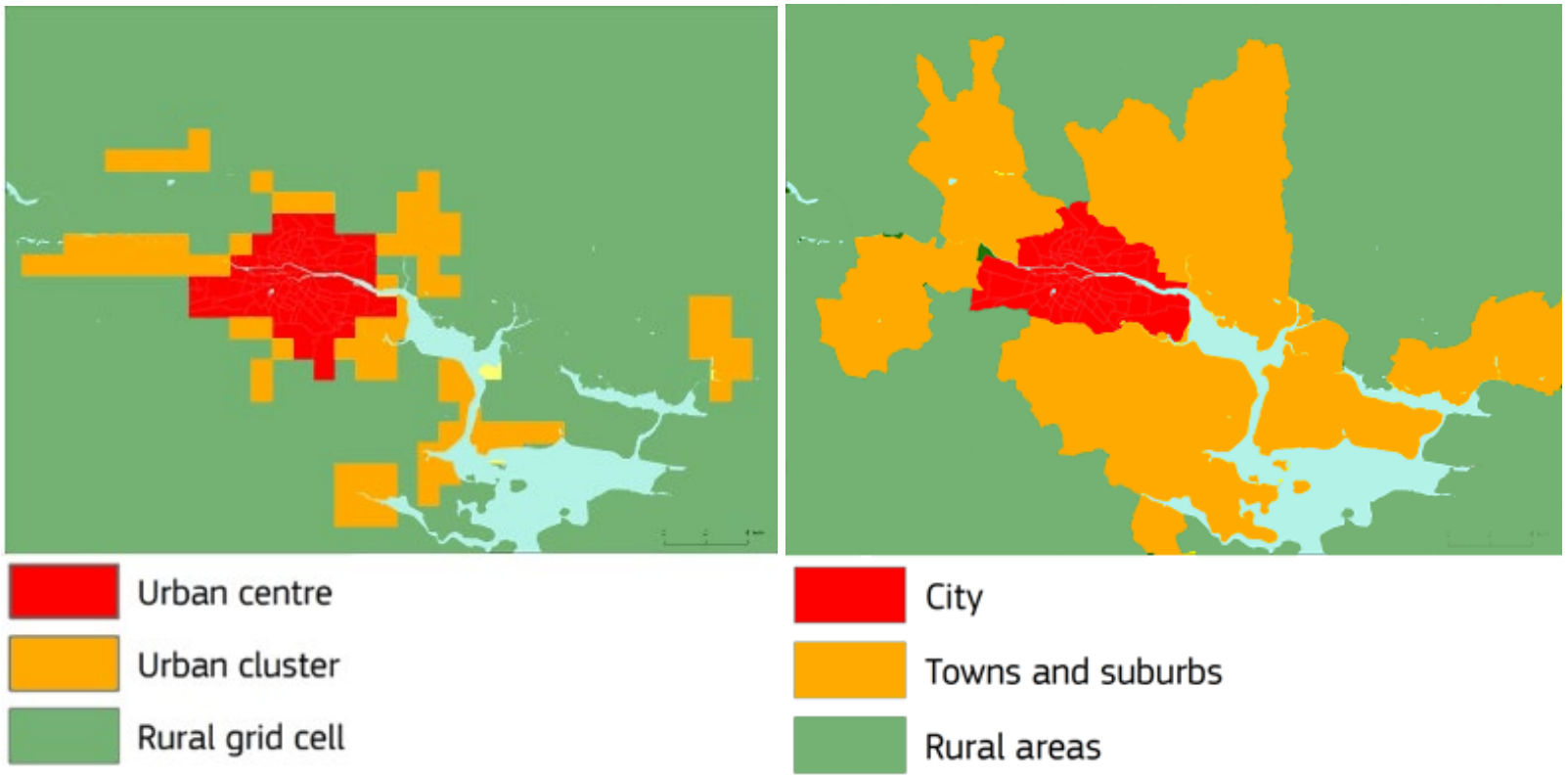
European Commission

Workflow


1st Level
2nd Level
Population Relative Distribution (%)
UC
≥ 50%
UC
SBRS
DUC
UCI
> 0%
≥ 50%
or
< 50%
majority
SDUC
RUR
> 50%
majority
RC
LDR
VLDR
INPUT POLYGONS
RASTERISATION
CLASSIFICATION
OUTPUT

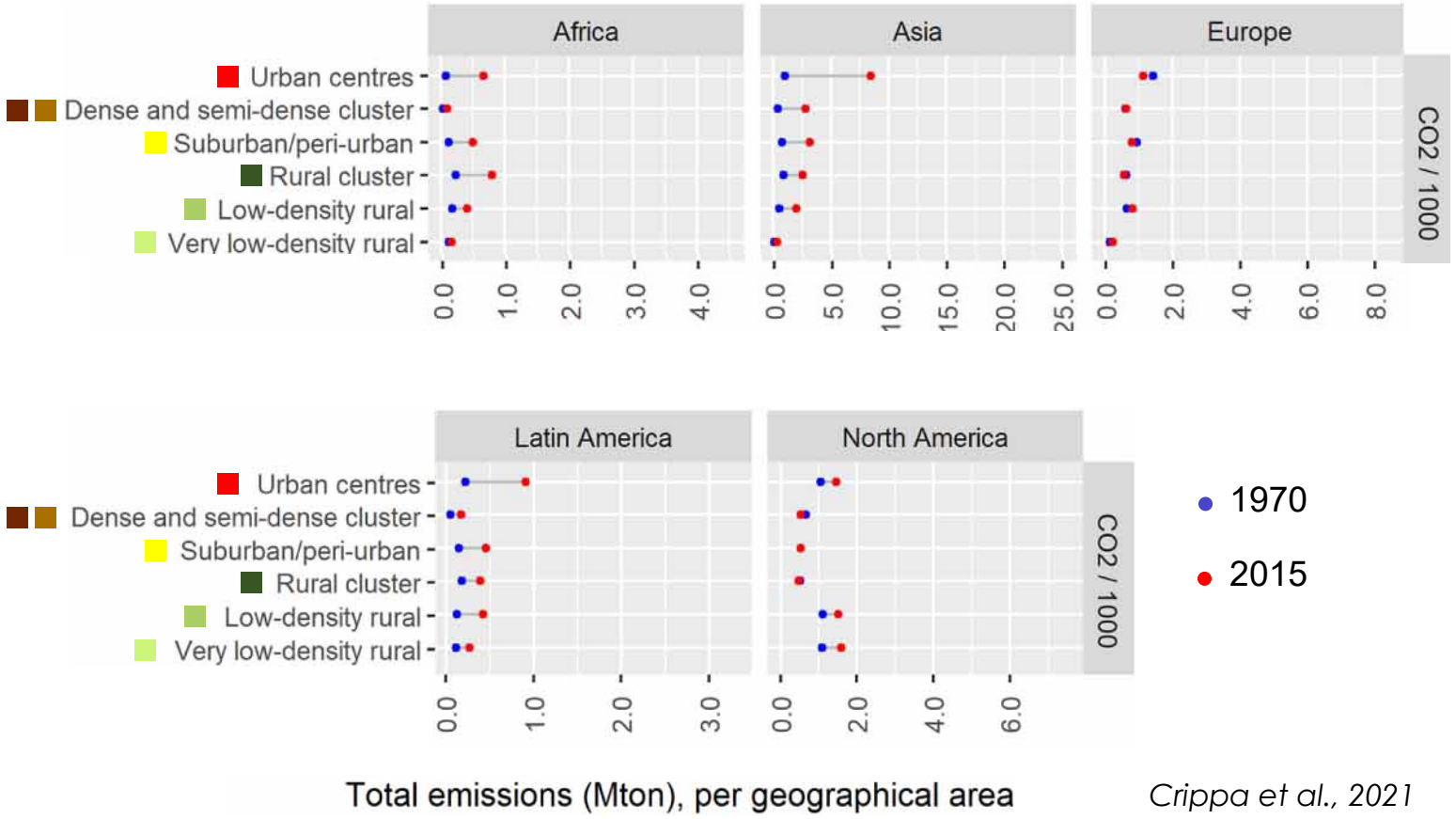
DU-TUC Tool Workflow

Cork, Ireland



Applications

- Statistics on air pollution per DoU class

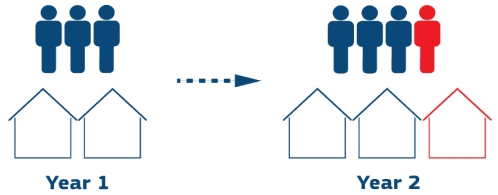


Crippa et al., 2021

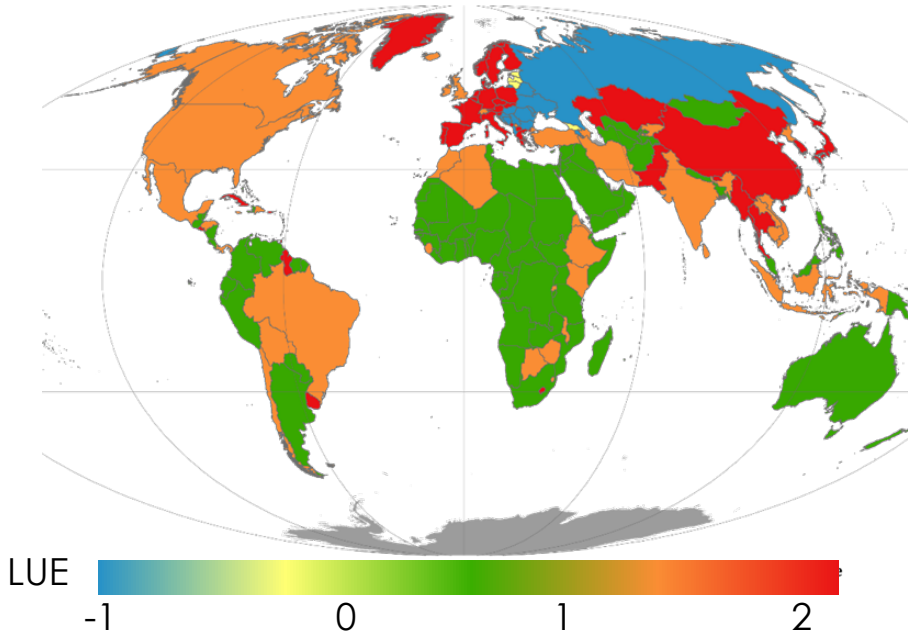
Icons credits: Air Pollution by Cuputo from the Noun Project

Land Use Efficiency (SDG 11.3.1)

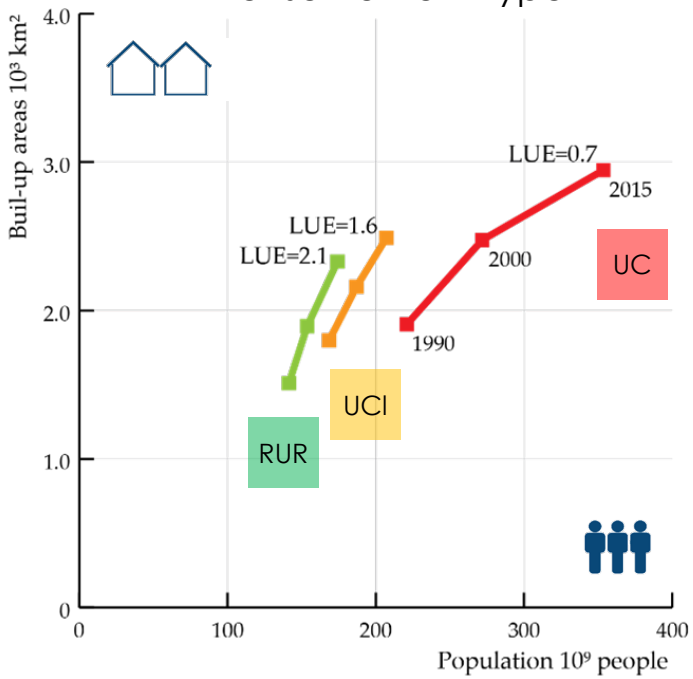
$$\frac{\ln\left(\frac{\text{built-up}}{\text{built-up}}\right)}{\ln\left(\frac{\text{population}}{\text{population}}\right)} = \text{LUE}$$



Per country



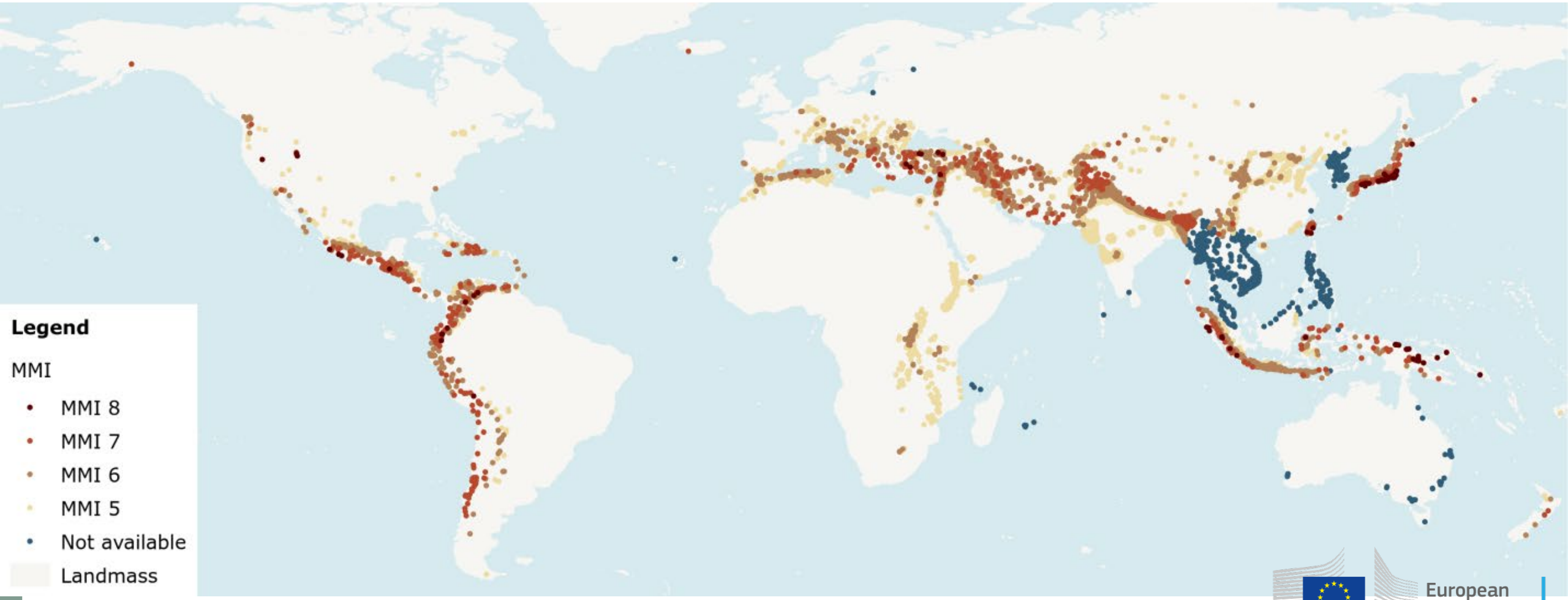
Per settlement type



M.Schiavina et al., 2019

Exposure to Earthquakes in Urban Centres

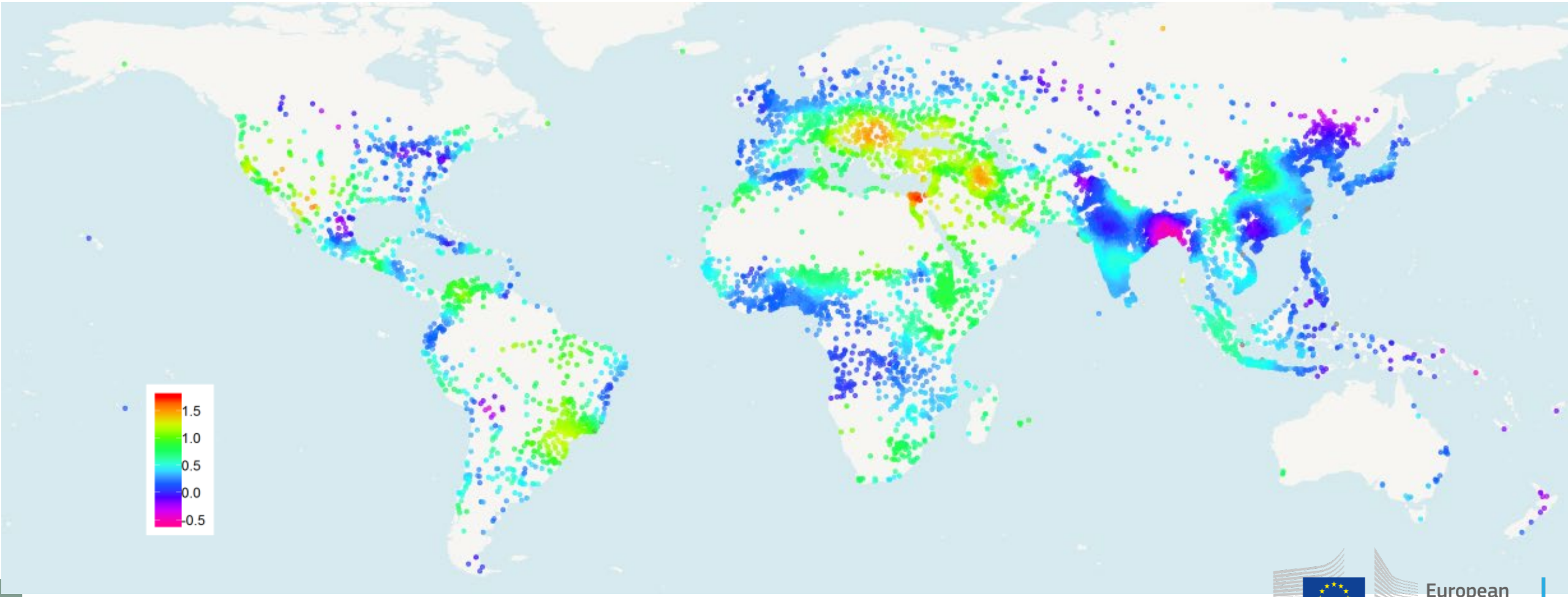
Exposure of urban centres to seismic hazard, considering MMI intensity equal or greater than five



European Commission

Temperature in Urban Centres

Changes in temperature (°C) in the period 1990-2015



European Commission

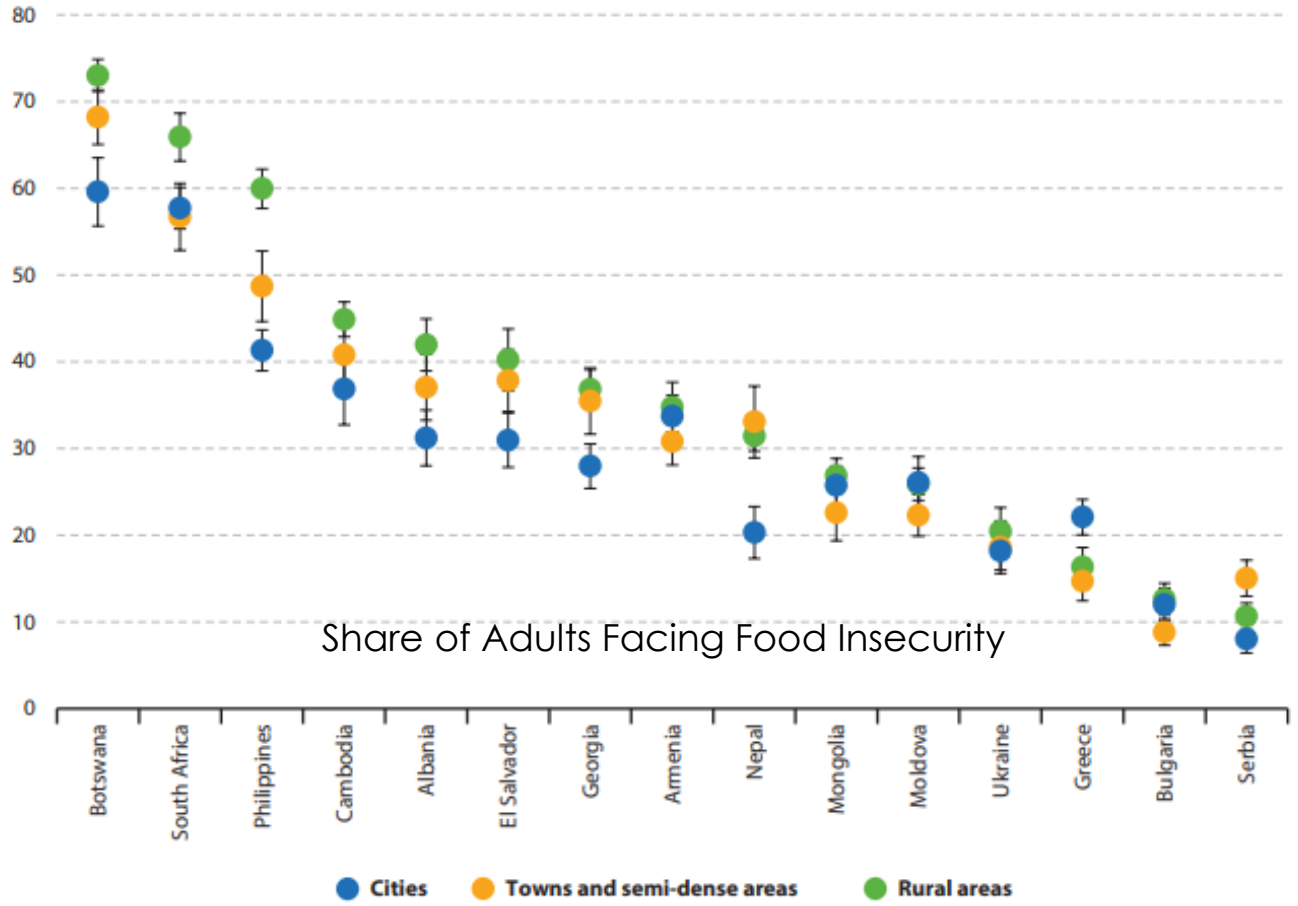
Access to Green in Urban Centres

Share of 2015 population with generalized access to green areas

European Commission

Applications

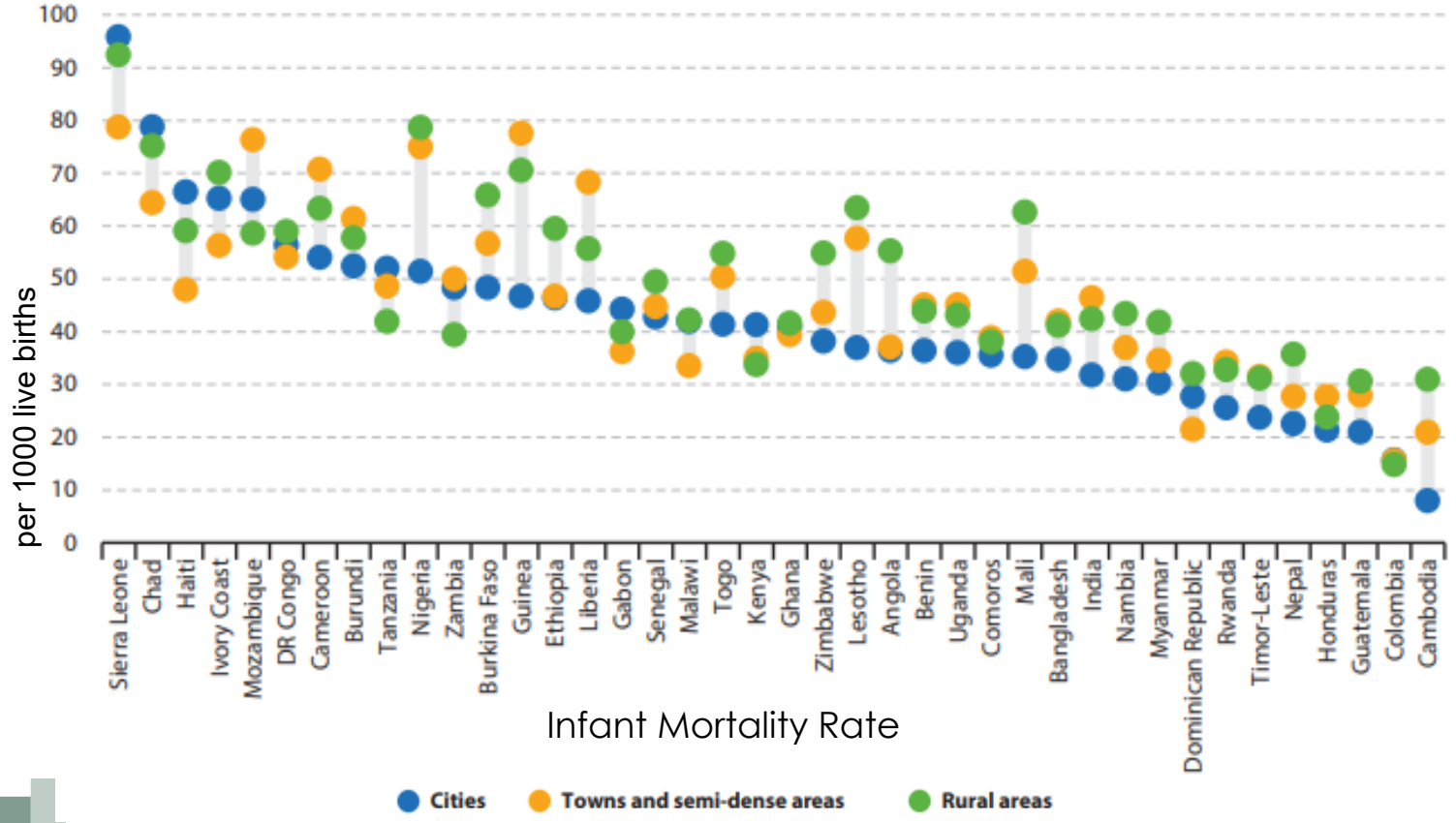
- Access to food



Share of Adults Facing Food Insecurity

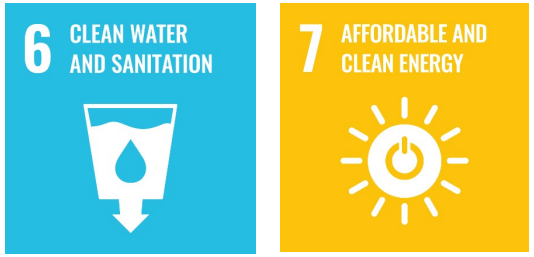
Applications

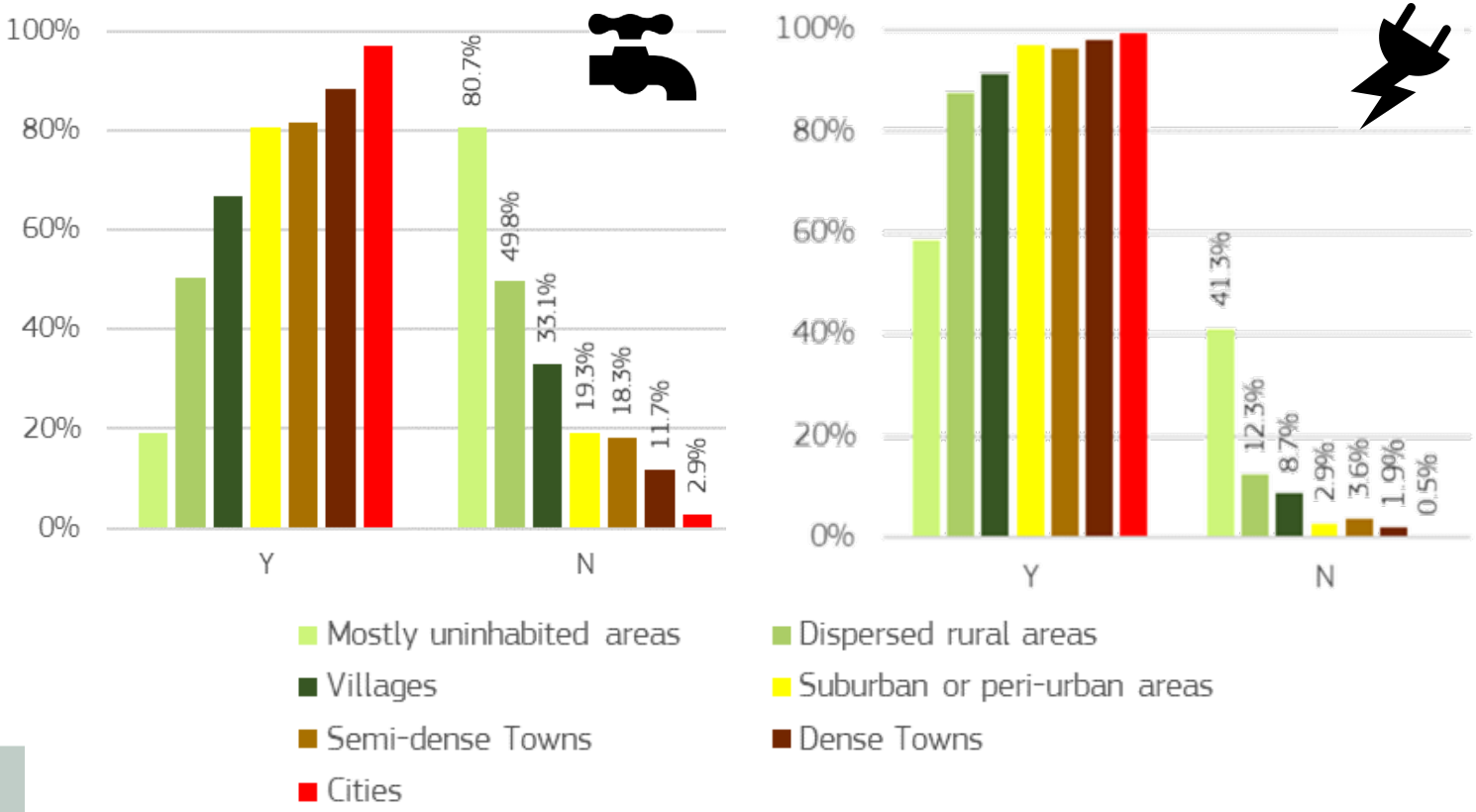
- Access to health services



Applications

- Colombian Census





Summary

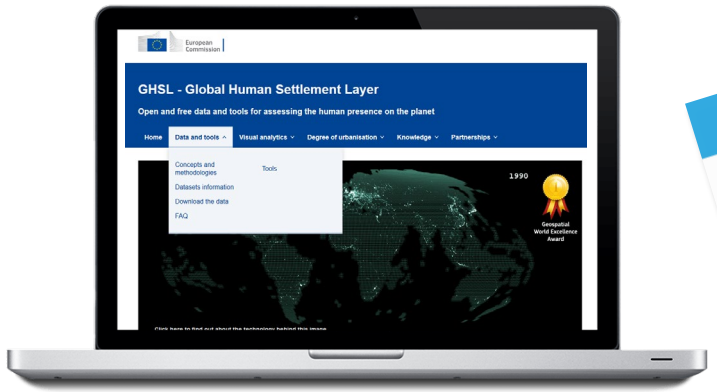
- A policy path towards sustainability
- Adapted strategies are based on the Degree of Urbanisation
- GHSL global datasets available online
- The methodology for computing the Degree of Urbanisation
  - Population grids (GHS-POP2G)
  - Degree of Urbanisation grids (GHS-DUG)
  - Territorial Units classification (GHS-DU-TUC)
- Applications to Sustainable Development Goals

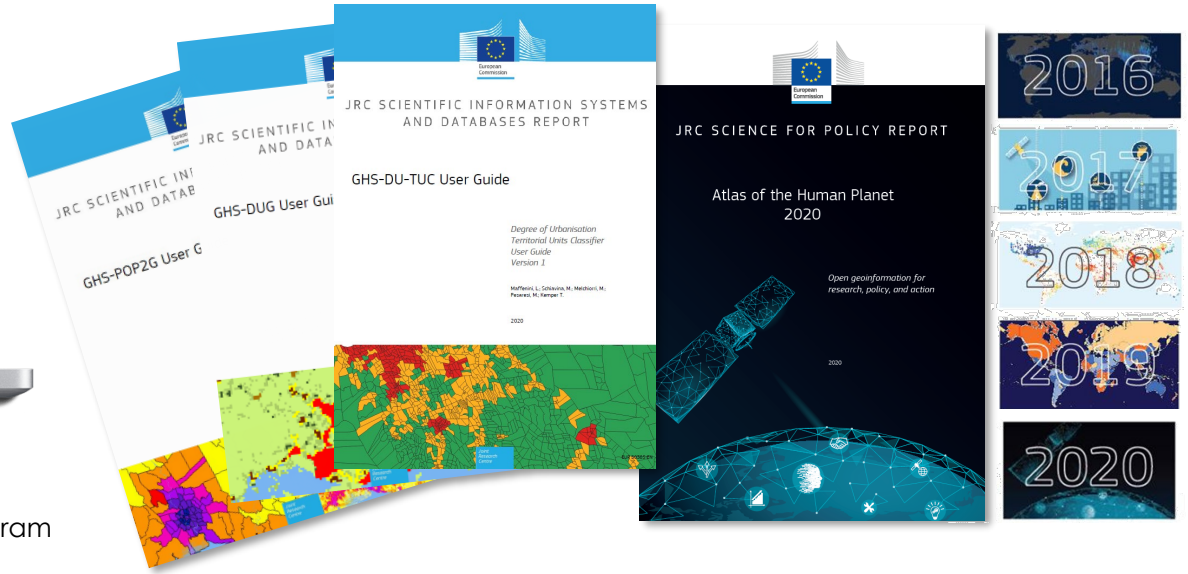
European Commission

Support Material

- Website: https://ghsl.jrc.ec.europa.eu/
- Tools instructions: https://ghsl.jrc.ec.europa.eu/tools.php
- Manual: https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-02-20-499

- Application Atlas: https://ghsl.jrc.ec.europa.eu/atlas2020Overview.php





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- *Crippa et al. (2021)*. Global Anthropogenic Emissions in Urban Areas. Environmental Research Letters 16 074033

Thank You

Contact: JRC GHSL JRC-GHSL@ec.europa.eu
GHSL TOOLS JRC-GHSL-TOOLS@ec.europa.eu

Slide 2: http://www.sdgnederland.nl/, Nederlands: Duurzaamheids Doelen totaal overzicht SDG, Wikimedia Commons.
Slide 3: Template: https://flourish.studio; Data: The World Bank
Slide 4: Lewis Dijkstra, RegioGIS
Slide 5: United Nations, Sustainable Development Goals.
Slide 6: European Commission, OECD, UN-Habitat, FAO, ILO, World Bank logos.
Slide 18: ESRI World Imagery from Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Slide 23: satellite images, source: © OpenStreetMap (and) contributors, CC-BY-SA 1:85.000ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Slide 30-36: Eurostat, Applying the Degree of Urbanisation A METHODOLOGICAL MANUAL TO DEFINE CITIES, TOWNS AND RURAL AREAS FOR INTERNATIONAL COMPARISONS, 2021 Edition
Slide 37: JRC Technical report, Applying the Degree of Urbanisation Method to National Population and Housing Census with GHSL Tools - The example of Colombia

Applications of the EO Toolkit to Measure and Analyze Sustainable Development Goals

Cascade Tuholske, Center for International Earth Science Information Network (CIESIN)
Columbia Climate School

February 3, 2021

Presenter Bio

I am a human-environment geographer working with CIESIN, a center at the new Columbia Climate School.

My current research focuses on the intersection of extreme heat exposure, climate change, and food security.

My goal is to inform adaptation strategies that reduce the harmful and inequitable impacts of extreme heat events.

I received my PhD in Geography from UC Santa Barbara in 2020.

Cascade Tuholske, PhD
Postdoctoral Research Scientist
Center for International
Earth Science Information Network
Columbia Climate School

Overview - Intro to POPGRID, Importance of Comparison of Gridded Population Datasets for SDG Indicators

- Overview of Gridded Population Datasets in the context of SDG 11.1
- Evaluating the accuracy of gridded population data sets for SDG 11.1.1 (adequate housing) and EO data for "slum" mapping
- Demonstration of POPGRID Website and Viewer
- Demonstration of POPGRID-Compare dataset for SDG 11.5.1 (people directly affected by disasters)

The UN Sustainable Development Goals

"Population distribution" and "Cities and Infrastructure Mapping" are important to indicators and decision making related to all 17 goals.

GEO GROUP ON EARTH OBSERVATIONS
GI-18 Initiative

THE GLOBAL GOALS For Sustainable Development

SDG 11

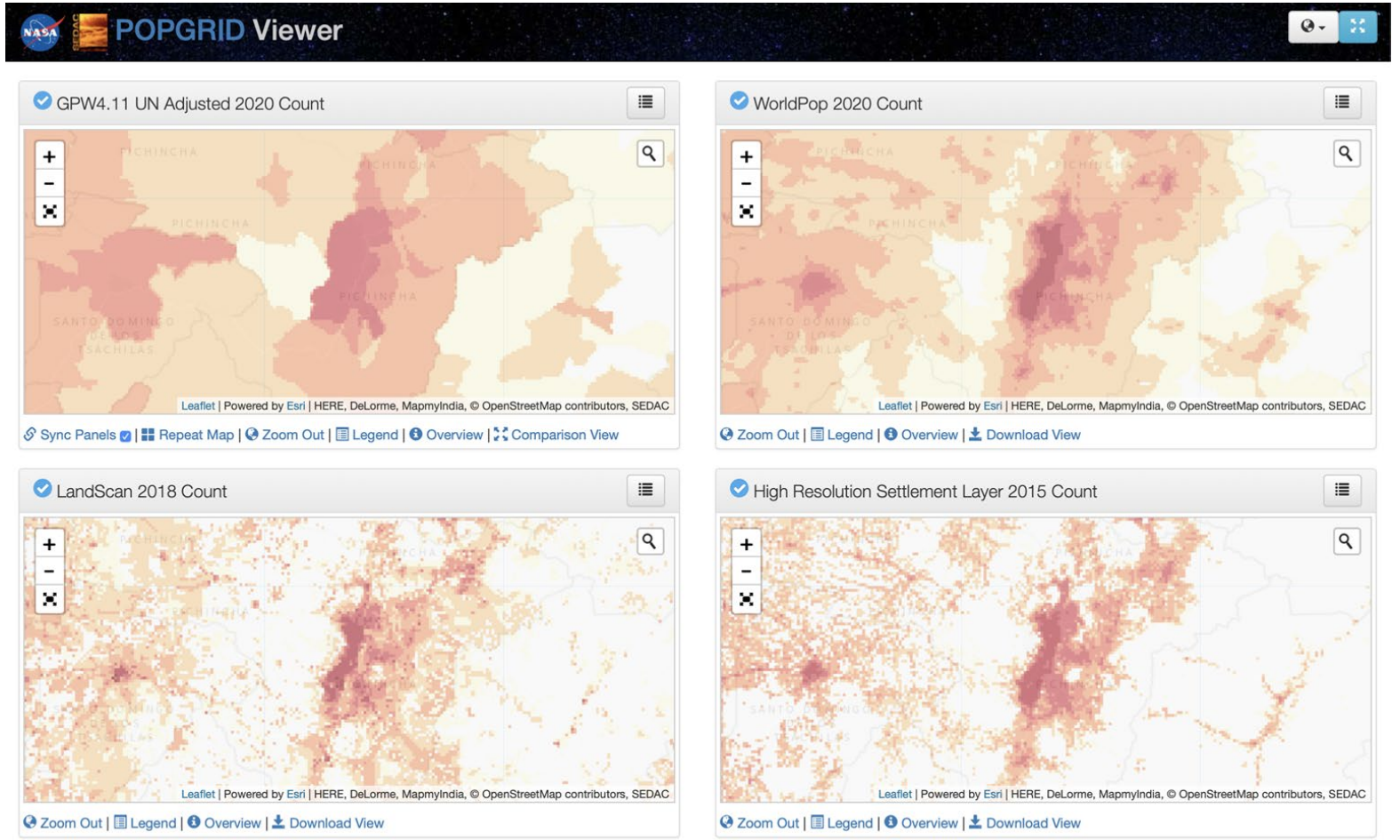
https://sdgs.un.org/goals/goal11

SDG 11 – Ten ”Targets”, each with “Indicators”

- **Target 11.1** - “By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums”
  - **11.1.1** “Proportion of urban population living in slums, informal settlements or inadequate housing”
- **Target 11.5** – “By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations”
  - **11.5.1** Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
  - **11.5.2** Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters

What is gridded population data?

- Population densities estimates allocated to grid-cells
- Many gridded population products exists
- Several products identify "urban" vs. "rural" settlement types.



https://sedac.ciesin.columbia.edu/mapping/popgrid/

What is gridded population data?

Each use different approaches to integrate fine-grained census data with Earth observation (EO) satellite data to allocate populations into grid cells.

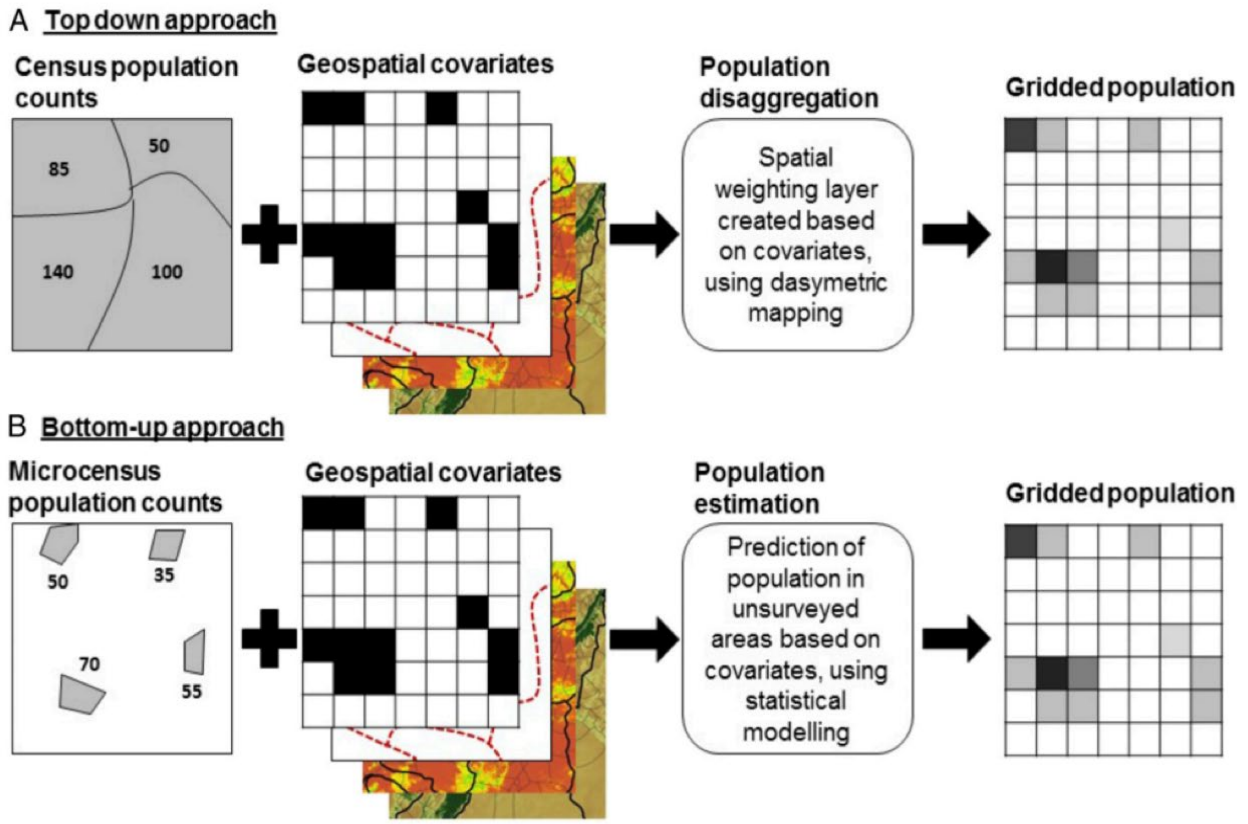


Fig. 2. Schematic of (*A*) top-down and (*B*) bottom-up mapping approaches. Populations are assumed to be restricted to areas containing residential buildings; population density within these areas is predicted based on ancillary datasets such as road networks, temperature, or green vegetation.

Wardrop et al.

PNAS | April 3, 2018 | vol. 115 | no. 14 | 3531

Wardop et al. 2018

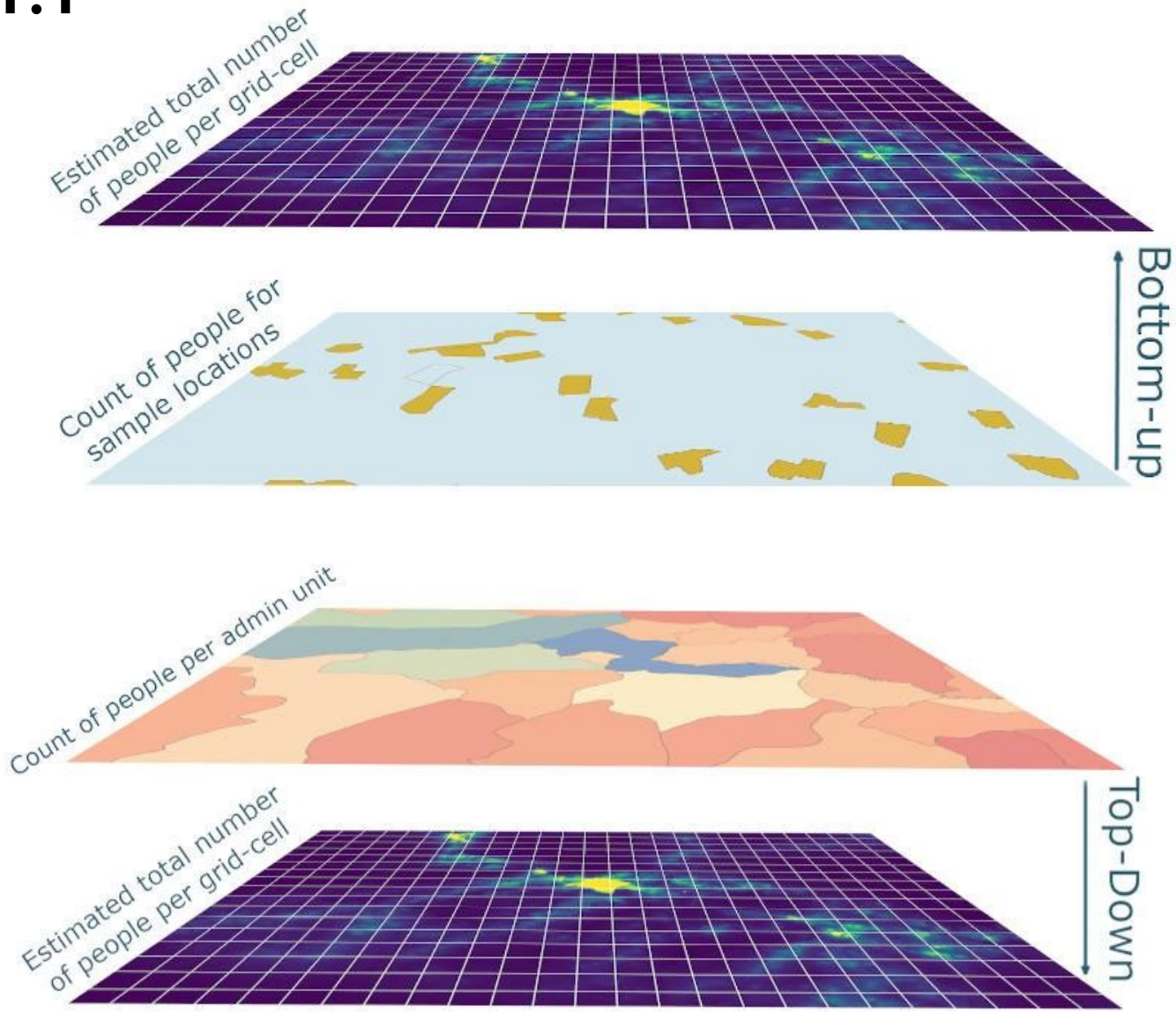
Measuring SDG Indicator 11.1.1

- SDG 11.1.1 "Proportion of urban population living in slums, informal settlements or inadequate housing".

Measuring SDG Indicator 11.1.1

- SDG 11.1.1 "Proportion of urban population living in slums, informal settlements or inadequate housing".

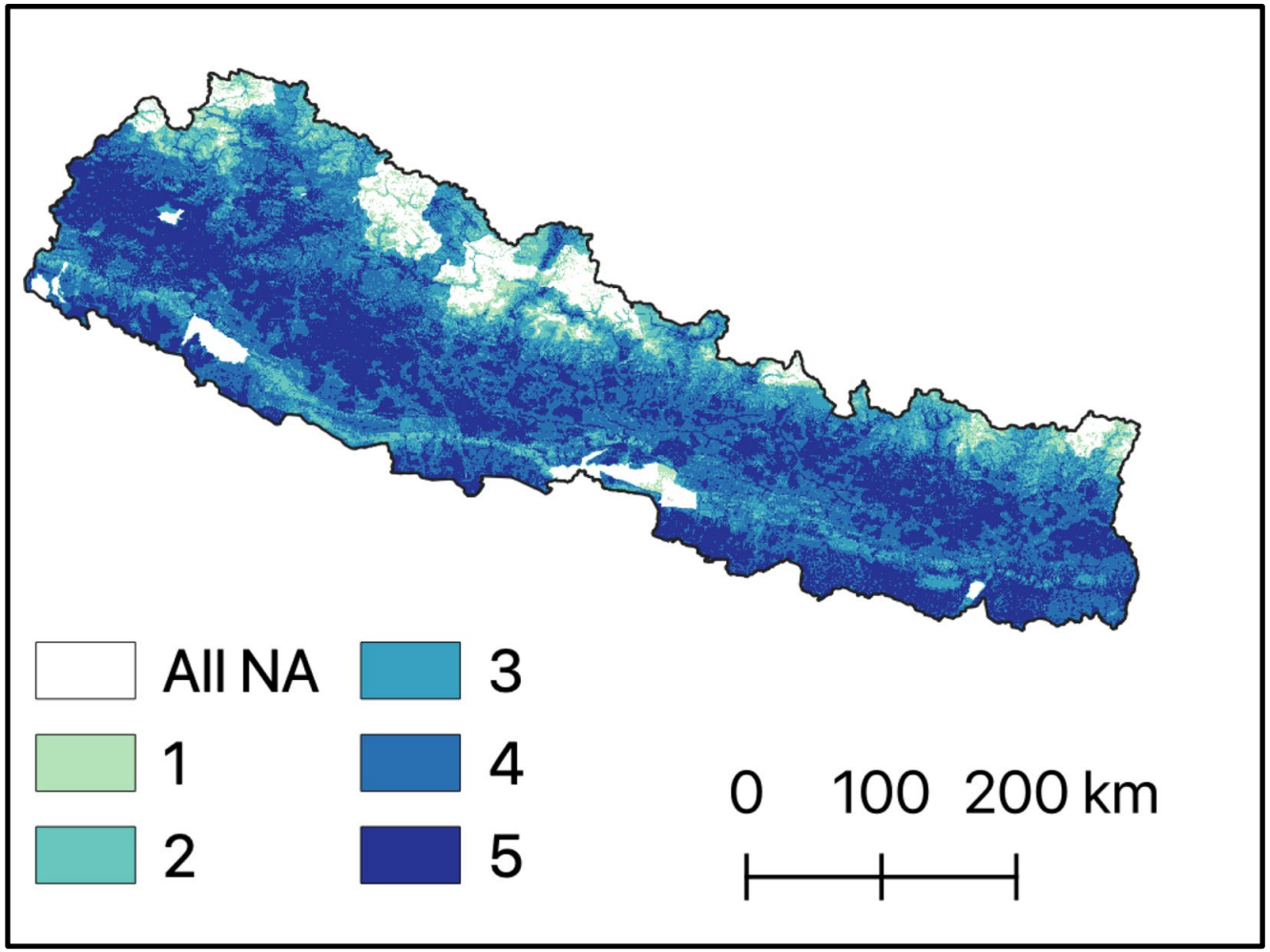
- "Bottom Up" vs. "Top Down"



www.worldpop.org

What is gridded population data?

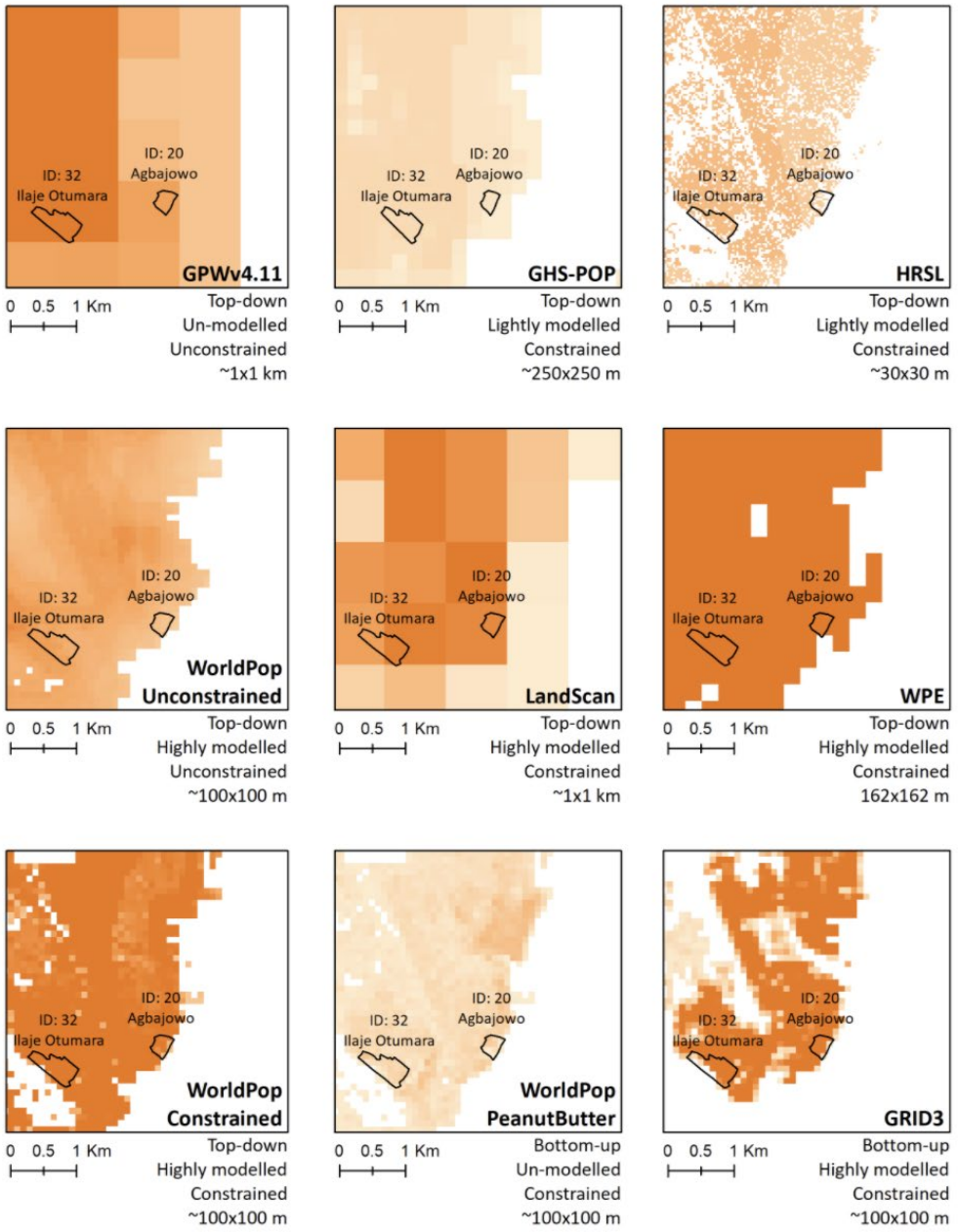
As such, they can provide different population estimates.



Agreement of if a pixel is inhabited or not across five gridded population products in Nepal (Tuholske et al. 2021).

Measuring SDG Indicator 11.1.1

- SDG 11.1.1 "Proportion of urban population living in slums, informal settlements or inadequate housing".
- "Bottom Up" vs. "Top Down"
- Gridded population data provide different estimates of high-density, small-area settlements (like slums).

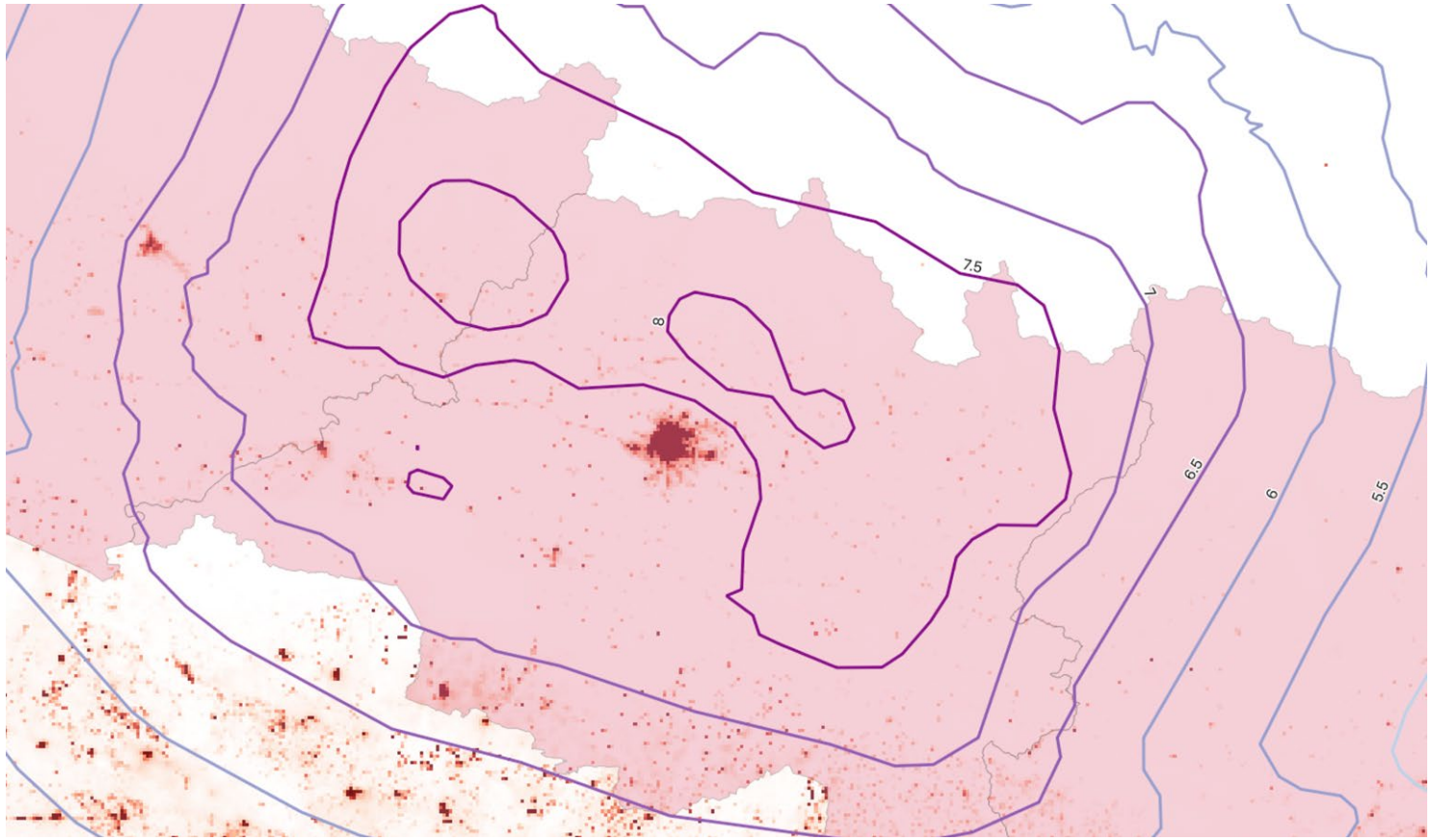


Thomson et al. 2021

Measuring SDG Indicator 11.5.1

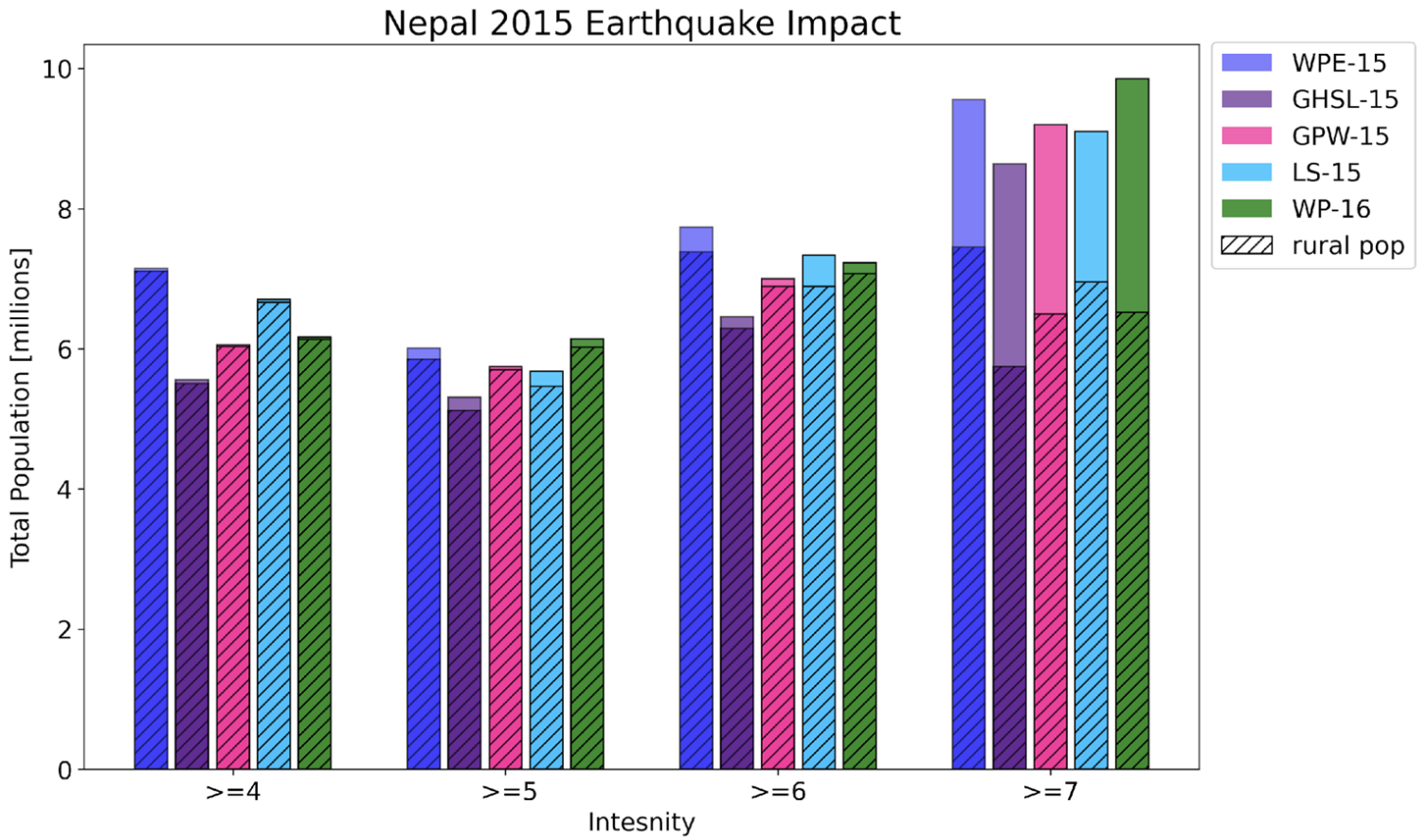
SDG 11.5.1 “Number of deaths missing persons and directly affected persons attributed to disasters per 100,000 population”.

7.8m Earthquake Nepal in 2015



Measuring SDG Indicator 11.5.1

The POPGRID-Compare dataset allows users to produce range estimates of exposure to hazards.



Tuholske et al. 2021

Data Access and Tutorials

- NASA Socioeconomic Data and Applications Center (SEDAC) provides resources, data, and tools to use gridded population data products to track SDG 11.
- The POPGRID Viewer and other mapping tools are available via the EO Toolkit.
- POPGRID-Compare will be formally released in the near future.

COLUMBIA CLIMATE SCHOOL
CENTER FOR INTERNATIONAL EARTH SCIENCE
INFORMATION NETWORK

NASA

SEDAC

TRENDS

BILL & MELINDA GATES foundation

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Contacts

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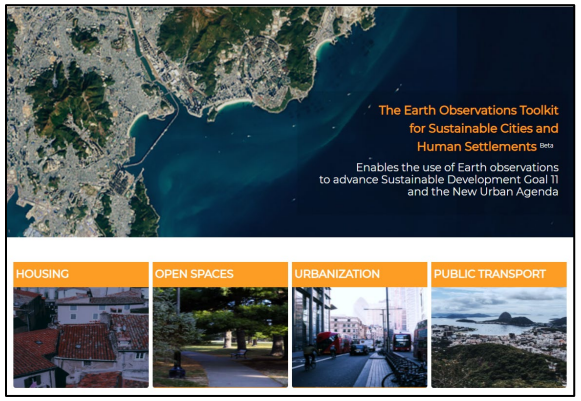
  - Cascade Tuholske: cascade@ciesin.columbia.edu

- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-earth-observations-toolkit-sustainable-cities-and-human
- ARSET Webpage:
  - https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

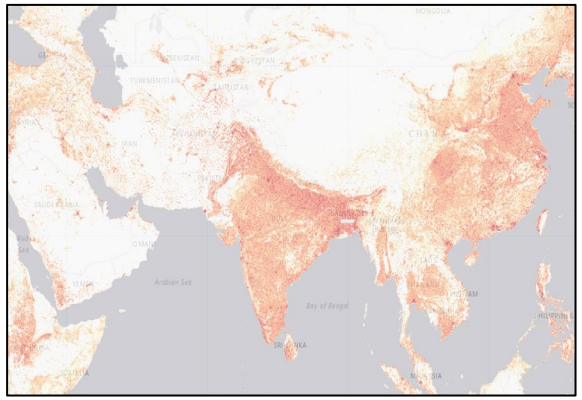
Next Week

Part 1: January 27, 2022



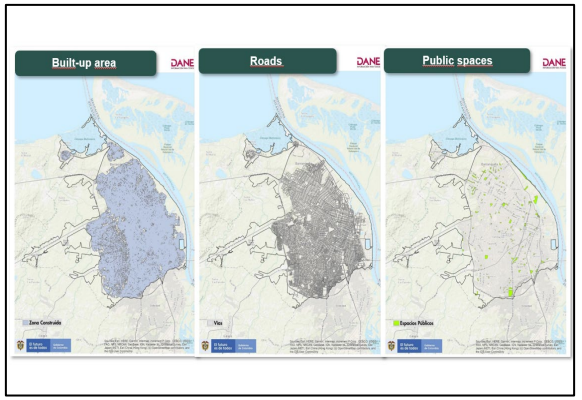
Introduction to Cities and the EO Toolkit for Sustainable Human Settlements

Part 2: February 3, 2022



Applications of the EO Toolkit to Measure and Analyze Sustainable Development Goals

Part 3: February 10, 2022



Use Cases from the National and City Level


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!