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living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

EO data driven workflows for calculating SDG 11 indicators at an intra-urban scale

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Institute of Atmospheric Pollution Research of National Research Council of Italy

May 25th, 2022

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National Research Council of Italy

Introduction to our organization

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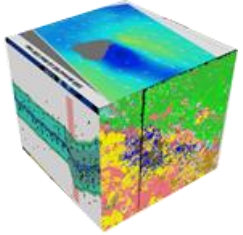


CNR-IIA Earth Observation team

Our skills range from calibration, analysis, and publication of data, products, and models (algorithms) in the GEO and EuroGEOSS international frameworks to facing the upcoming Sustainable Development Goals (SDGs) challenges.

GEO ITALY
http://geoitaly.iia.cnr.it/

2 Societal Benefit Areas (SBAs) framed by the «UN 2030 Agenda for Sustainable Development»

GEO engagement priority strategy:

Sustainable Urban Development

Biodiversity and Ecosystem Sustainability

BIO_SOS

GEOSSENTIAL ERA-PLANET

Welcome to

GEO ITALY

The Italian Group on Earth Observations

SMURBS ERA-PLANET

e-shape
EuroGEOSS Showcases: Applications Powered by Europe

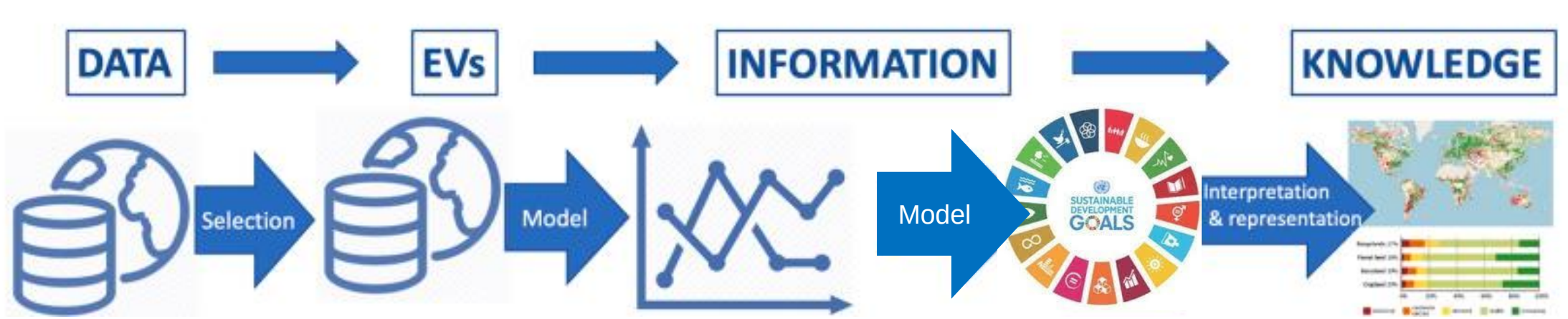
eLTER plus

eLTER PPP

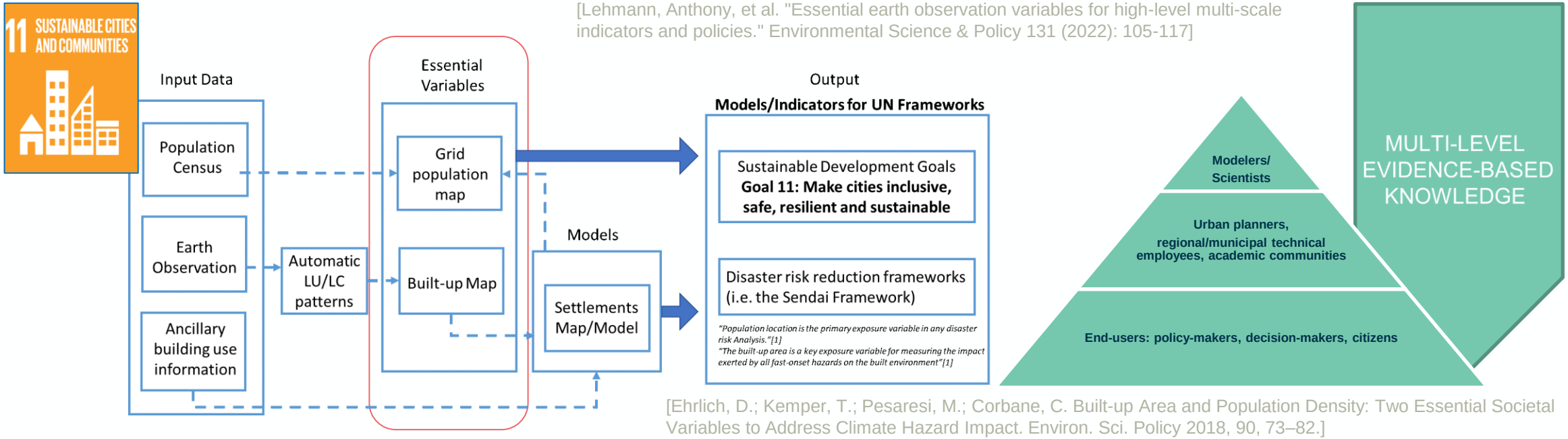
EOP

NewLife4Drylands

Generating a multi-level knowledge



[Lehmann, Anthony, et al. "Essential earth observation variables for high-level multi-scale indicators and policies." Environmental Science & Policy 131 (2022): 105-117]



[Ehrlich, D.; Kemper, T.; Pesaresi, M.; Corbane, C. Built-up Area and Population Density: Two Essential Societal Variables to Address Climate Hazard Impact. Environ. Sci. Policy 2018, 90, 73–82.]

Scientific workflows in support of SDG 11 indicators

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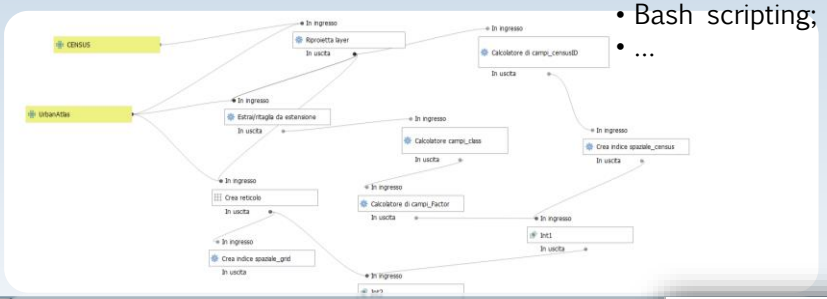
Potential stake-holders

Expertise level in EO domain

- **Modelers/ Scientists**
- **Urban planners, regional/municipal technical employees, academic communities**
- **End-users: policy-makers, decision-makers, citizens**

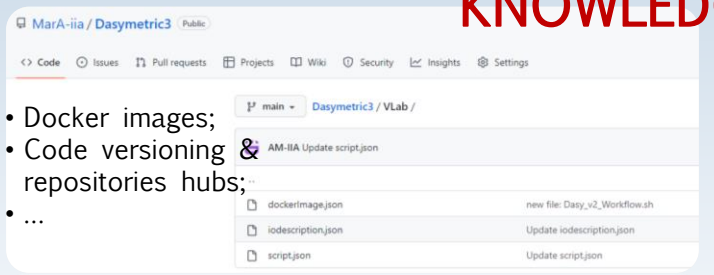
Developer/Modelers ENVIRONMENT

- Graph processing modeler;
- Python scripts;
- Bash scripting;
- ...



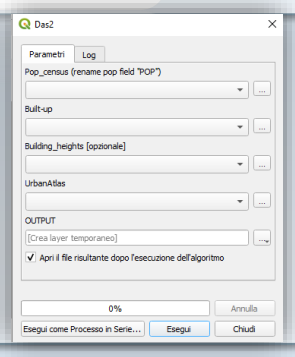
Platforms/Interfaces to share WORKFLOWS and generate KNOWLEDGE

- Docker images;
- Code versioning & repositories hubs;
- ...



pyQGIS

https://plugins.qgis.org/plugins/dasy/



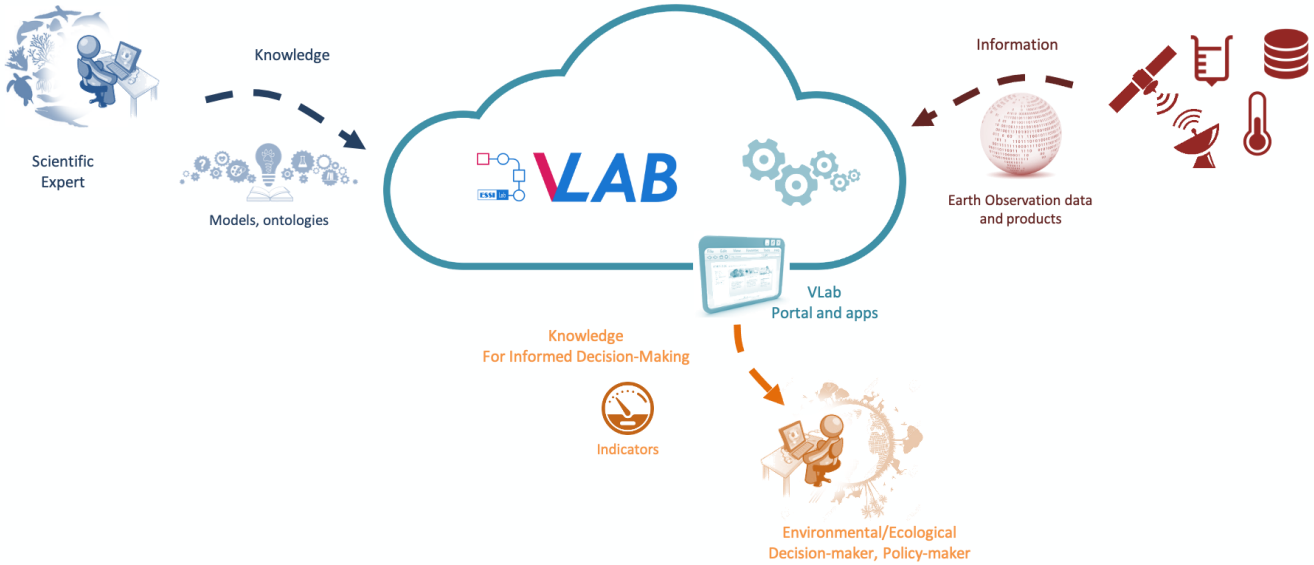
https://vlab.geodab.org/

Web Application Interfaces

.....

Virtual Earth Laboratory (VLab)

VLab is a software framework for the orchestration of data access and model invocation services that leverages the capabilities of existing cloud platforms to face important Big Earth data challenges. In particular, the framework addresses scientific model interoperability making them more usable with minimal agreements.



VLab was successfully experimented on different cloud platforms

VLab functionalities are published as RESTful APIs which can be used to build applications exploiting available models, e.g.:

- **Dashboards**
- **Web Apps**
- **Etc.**

VLab APIs are documented according to Open API specification and can be tested online at

https://vlabapi.geodab.org/

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From global to local implementation of SDG 11 indicators: open questions

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GAPS

Indicators

- In the framework of the United Nations (UN) 2030 Agenda for Sustainable Development and the New Urban Agenda (Habitat III), **local and regional authorities require indicators at the intra-urban scale to design adequate policies in support of the Sustainable Development Goal (SDG) 11**. However, the current literature provides mainly national, regional and city scale indicators.

EO data

- Earth Observations (EO) data have been recently recognized as an essential source of information to achieve the SDG 11 targets and progress measurements with respect the SDG 11 indicators. However, the **complexity of EO data handling and processing in SDGs monitoring and reporting mechanisms** makes difficult a direct integration in evidence-based decision-making processes.

Statistics and ancillary data providers

- Lack of population data at sub-city scale from National Institutes of Statistics. In Italy, the last official national census collection occurred in 2011.
- Lack of standardization in the aggregation levels, geometries, and definitions of input data for indicators.

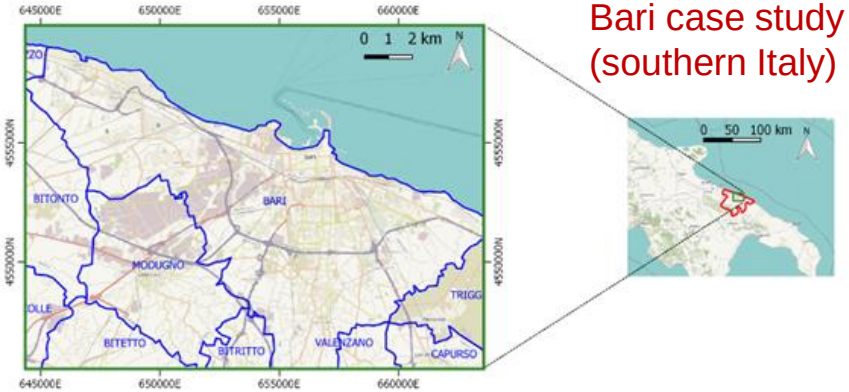
PROPOSED SOLUTIONS

- ✓ **INTRA-URBAN** scale indicators' implementation.
- ✓ **DISAGGREGATION** per population groups.
- ✓ **AUTOMATIC** workflows for those not-expert users in EO field domain.
- ✓ **FLEXIBILITY IN INPUT**: ingestion of data in a wide variety of resolutions and formats
- ✓ **OPEN DATA** demo usage

Population-weighted SDG 11 indicators

SDG 11 Targets	SDG 11 Indicators	Quantifiable Derivatives (Sub-Indicators)	Other Ancillary Data
T11.1: Safe and affordable housing transport systems	11.1.1. Proportion of urban population living in slums, informal settlements or inadequate housing.	1. Proportion of households with non-durable housing	• Building layer with information on building use i.e., residential, commercial, industrial, decaying building
		2. Proportion of households living in housing residing on or near hazardous areas	• **Building layer/settlement map** • Hazard maps
		3. Proportion of households with insufficient living space	• **Building layer/settlement map** • **Building heights layer (optional)**
T11.2: Affordable and sustainable	11.2.1. Proportion of population that has convenient access to public transport by sex, age and persons with disabilities	1. Proportion of population that has convenient access to public transport	• Street network layer • Bus stop map • Metro/tramway stop map
T11.3: Inclusive and sustainable urbanization	11.3.1. Ratio of land consumption rate to population growth rate	1. Ratio of land consumption rate to population growth rate (LCRPGR)	• **Settlement map**
T11.6: Reduce the environmental impacts of cities	11.6.2. Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population-weighted)	1. Annual average exposure to PM2.5 (population-weighted) 2. Annual average exposure to PM10 (population-weighted)	• Annual mean levels of fine particulate matter maps. Source: Local Agency of Environmental Protection

*Input from EO



Bari case study (southern Italy)

+ 2 city followers: Bologna and Reggio Calabria (Italy)

Open data municipality providers:

- https://opendata.comune.bari.it/
- http://dati.reggiocal.it/
- https://opendata.comune.bologna.it/pages/home/

[Figueirido, L.T. Honiden and A. Schuman (2018), «Indicators for Resilient Cities», OECD Regional Development Working Papers, 2018/2, OECD Publishing, Paris].

Essential variables for SDG 11 indicators: population mapping

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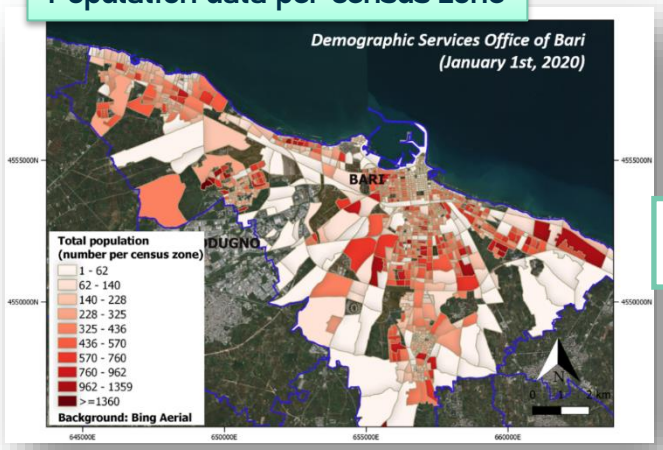
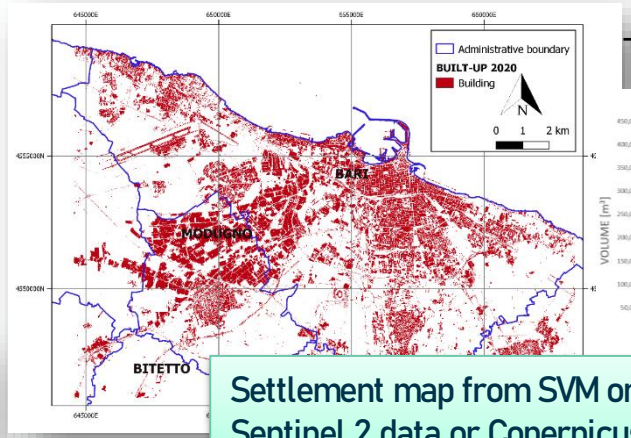
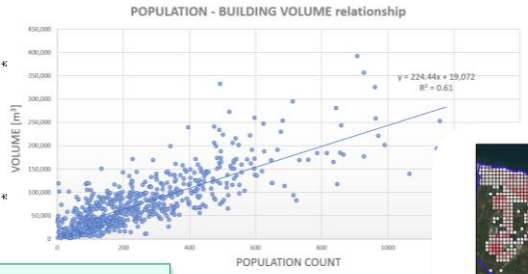
Aquilino, M.; Adamo, M.; Blonda, P.; Barbanente, A.; Tarantino, C. Improvement of a Dasymetric Method for Implementing Sustainable Development Goal 11 Indicators at an Intra-Urban Scale. Remote Sens. 2021, 13, 2835, doi:10.3390/rs13142835.

Population data per census zone





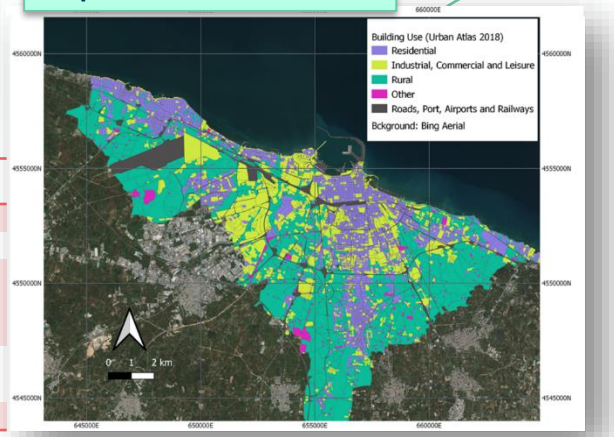
\+ Building heights [optional input]



Settlement map from SVM on Sentinel 2 data or Copernicus ESM

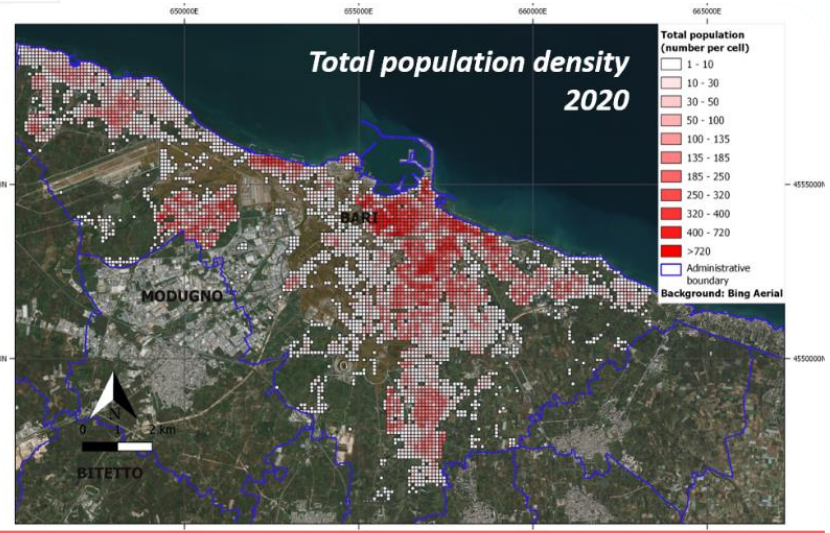
AUTOMATIC WORKFLOW

Copernicus Urban Atlas



Building Use	$Corr_{factor}$
Residential	1
Rural	0.7
Industrial, Commercial and Leisure	0.1
Roads, Railways, Port and Airport	0.01
Other	0

OUTPUT:
grid population density map at 100 m x 100 m of spatial resolution



Uncertainty Estimation	Dasymetric Version 1.0 (Based on Building Footprint Area)	Dasymetric Version 2.0 (Based on Building Volume)
$MAE = \frac{1}{N}\sum_{n}^{N}\lvert P_{n,grid} - \widehat{P_{n,grid}}\rvert$	6.2 (population count)	2.3 (population count)
$RMSE = \sqrt{\frac{1}{N}\sum_{n}^{N}\left(P_{n,grid} - \widehat{P_{n,grid}}\right)^2}$	16.0 (population count)	4.1 (population count)
$MAPE = \frac{100}{N}\sum_{n}^{N}\left\lvert\frac{P_{n,grid} - \widehat{P_{n,grid}}}{P_{n,grid}}\right\rvert$	23.0%	8.6%

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Essential variables for SDG 11 indicators: settlement mapping

During the UN-Habitat III conference in October 2016, the European Union, the OECD and the World Bank launched a voluntary commitment to develop a global, people-based definition of cities and settlements. This commitment will support the implementation of the New Urban Agenda. It will also support the monitoring and comparison of the urban Sustainable Development goal. Several of the indicators linked to this goal are highly sensitive to such definitions [European Commission, CROS. Collaboration in Research and Methodology for Official Statistics].

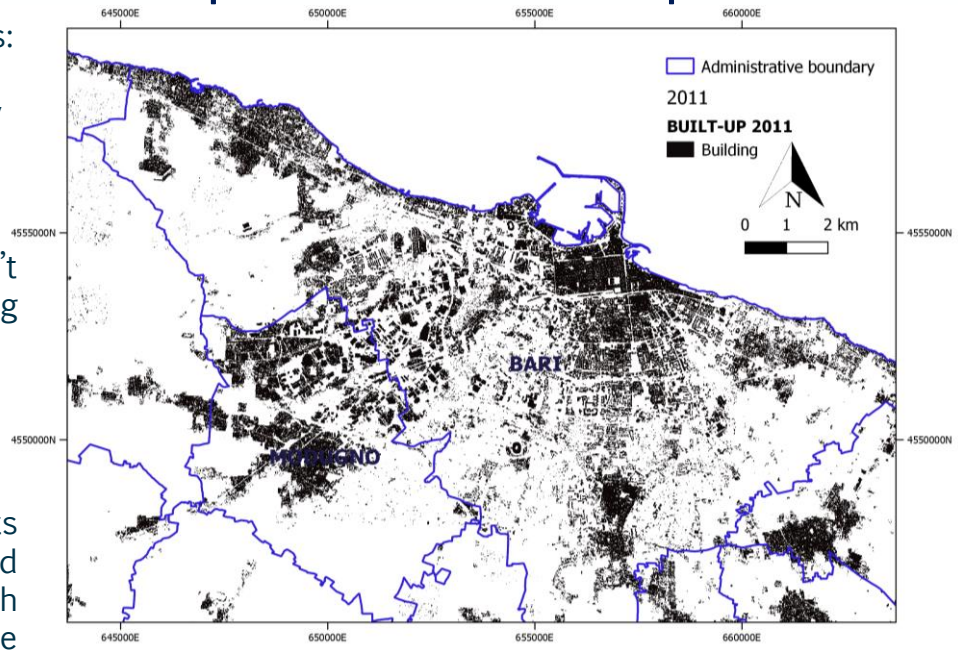
EO data scientists/ modelers

- Semi-automatic classification approaches:
  - DATA-DRIVEN pixel-based (applicable only if ground truths are available)
  - KNOWLEDGE-DRIVEN Object-based (does't require a training datasets).

EO-domain not-expert users

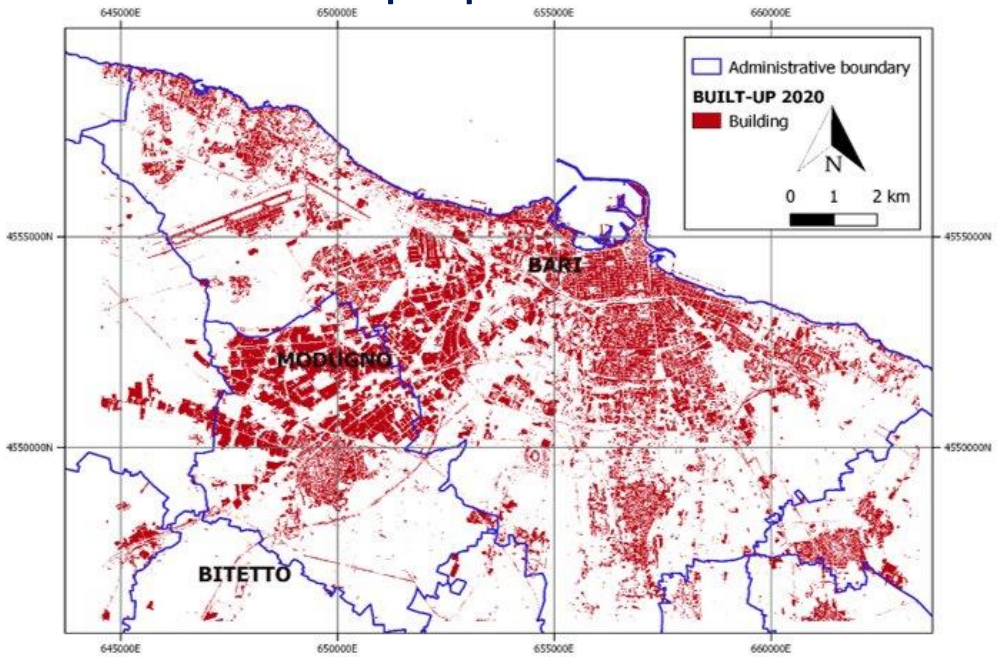
- Istitutional products such as ESM provided by the Joint Research Center (JRC) of the European Commission (EC). Distribuited by Copernicus Land Monitoring Service.

European Settlement Map (ESM)



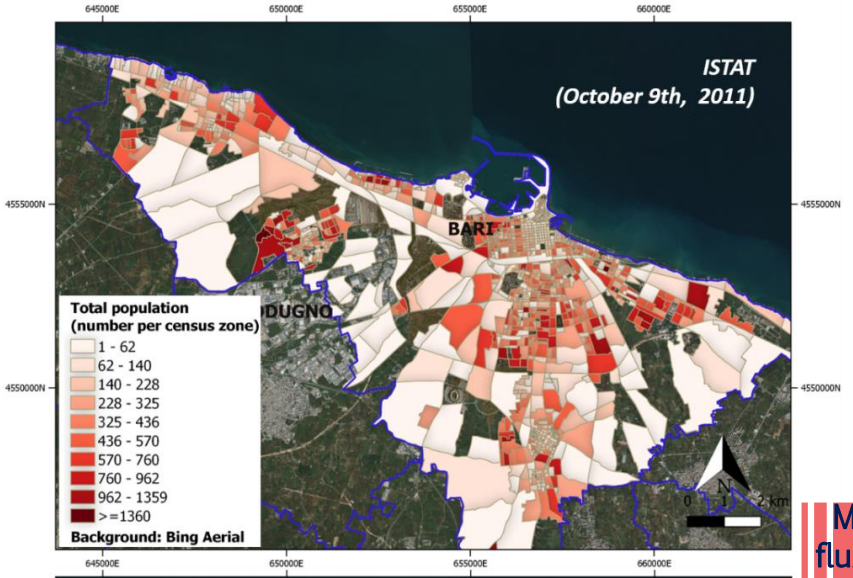
Source: European Settlement Map 2011-2012 (Release 2017, Joint Research Center)

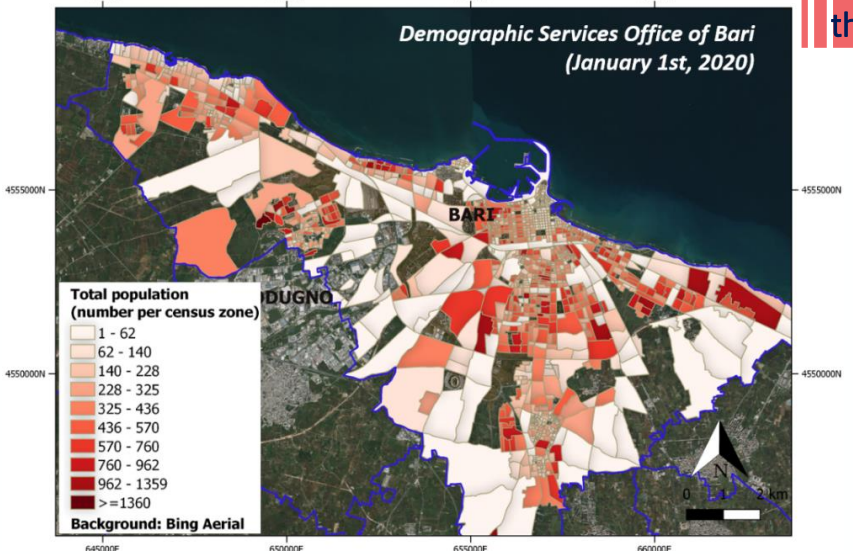
Settlement map updated from EO data



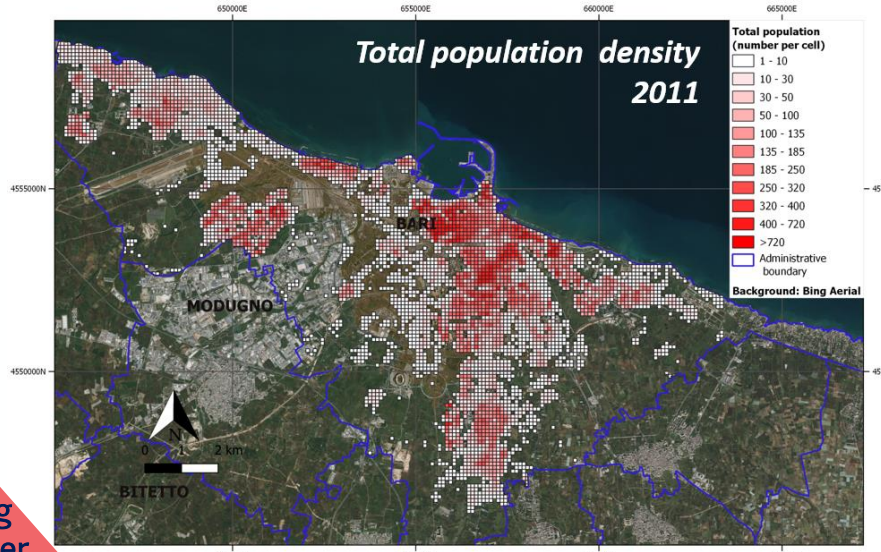
Source: CNR-IIA automatic multi-purpose classification based on SVM algorithm applied to multi-temporal Sentinel 2 data.

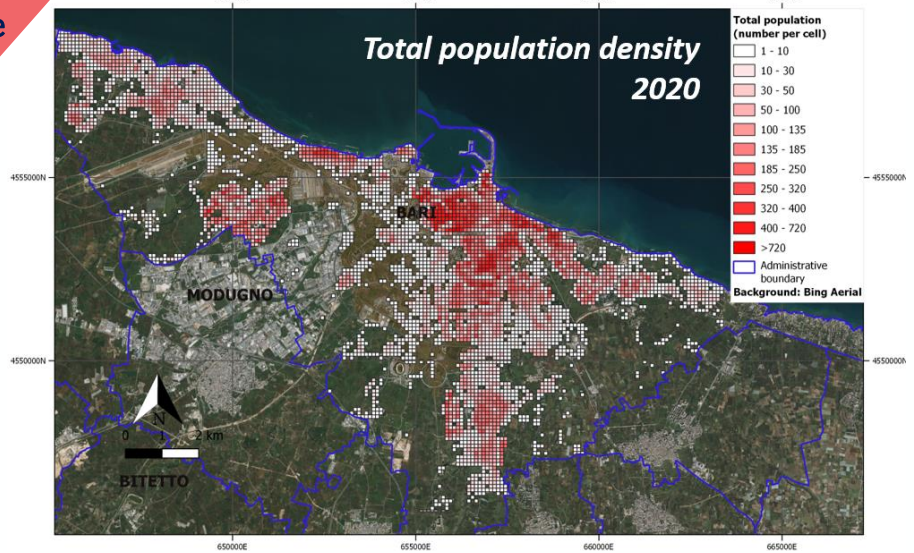
Reproducibility for different epochs

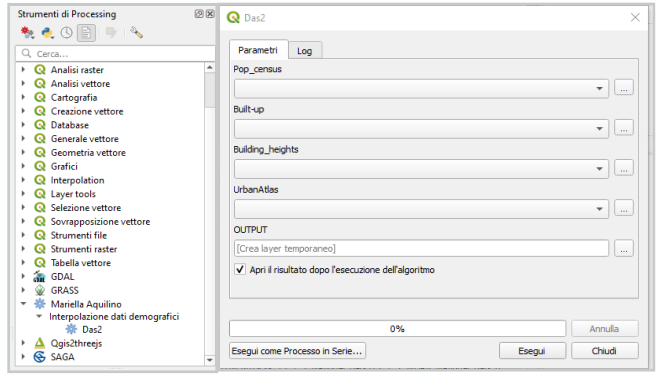




Mapping fluxes over the time







pyQGIS

https://plugins.qgis.org/plugins/dasy/

FLEXIBILITY IN INPUT: GDAL/OGR standard formats are accepted such as GeoTiff, Shapefile, Geopackage, etc.

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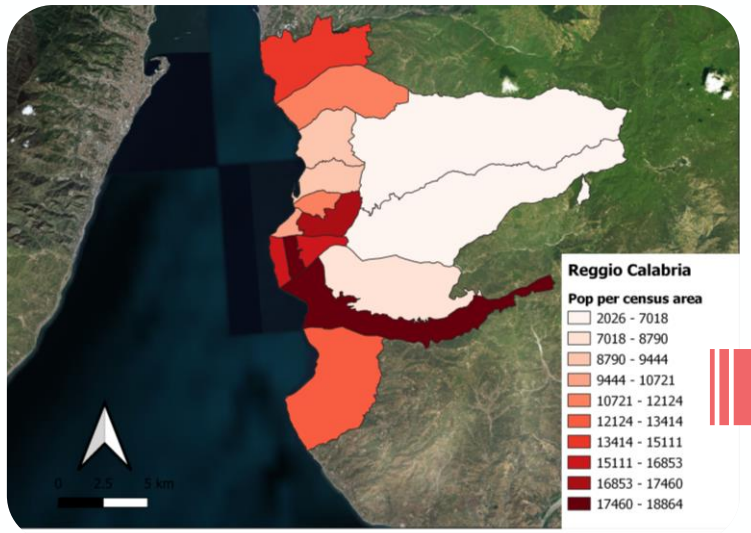
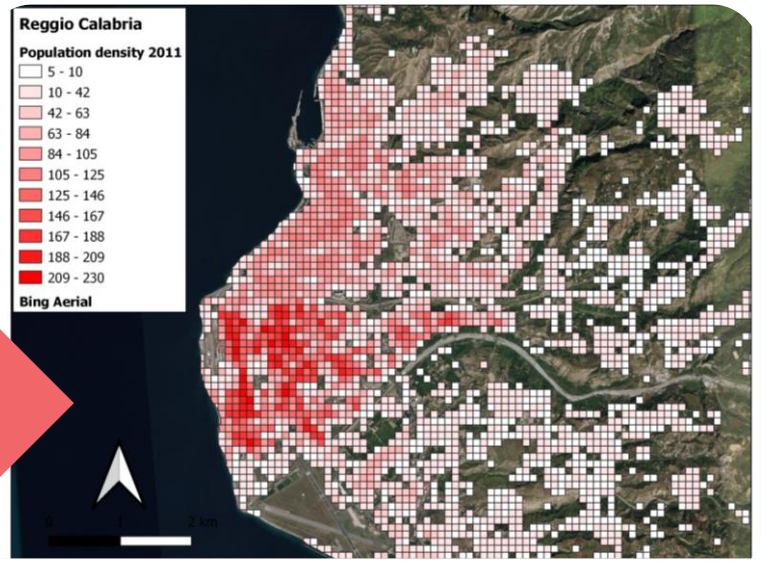
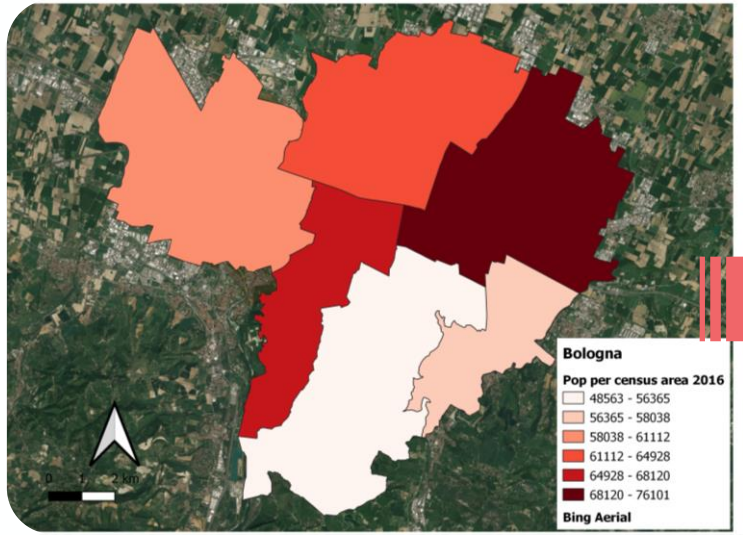
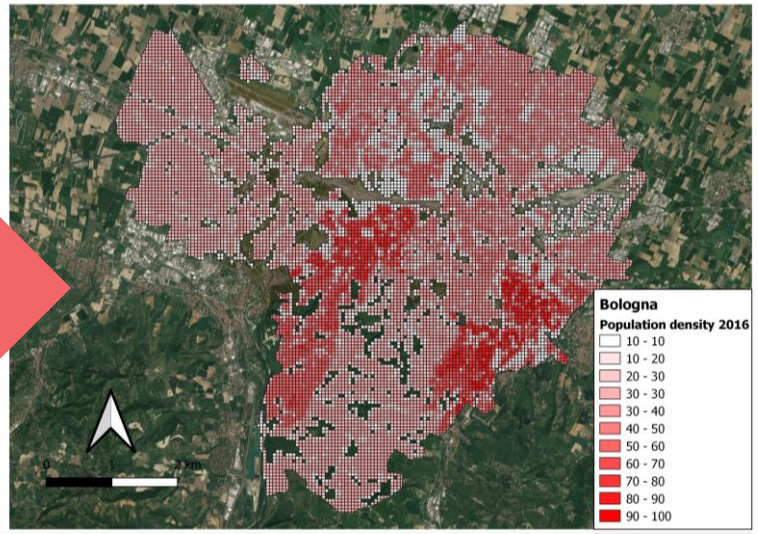
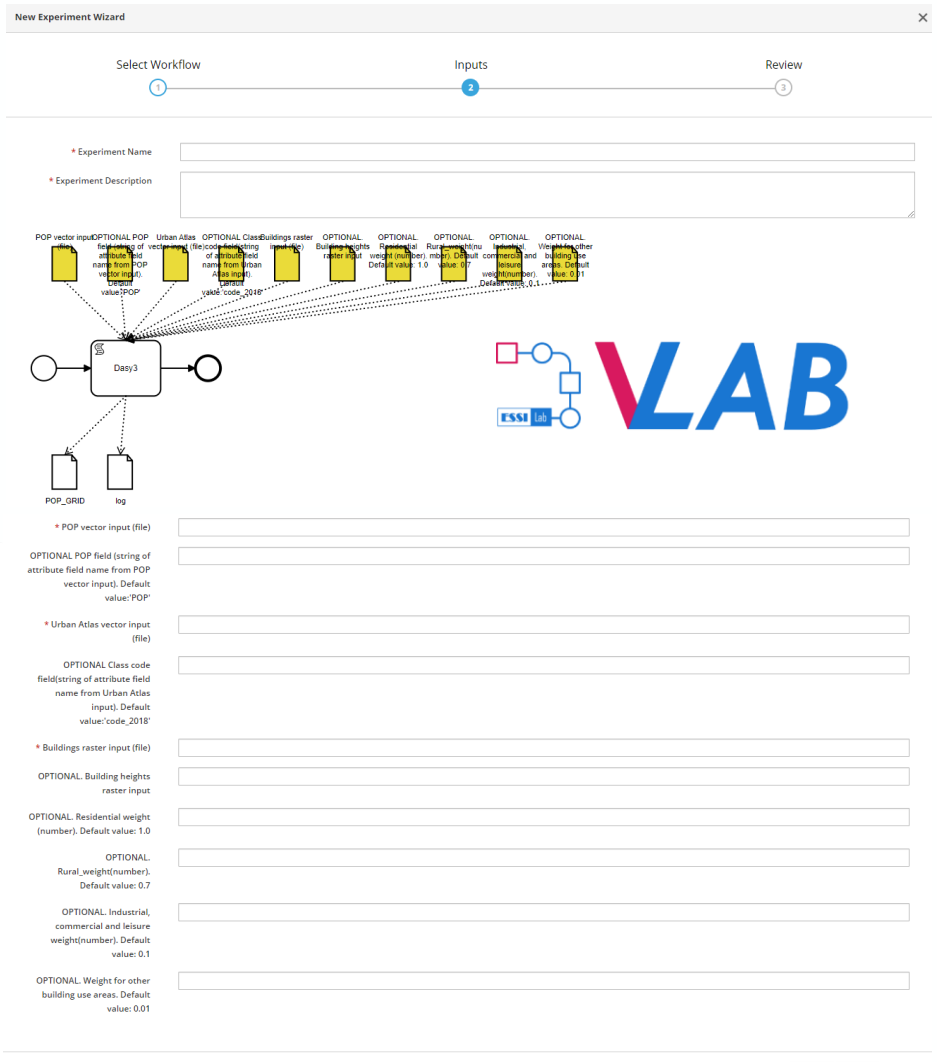
Reproducibility for other urban areas











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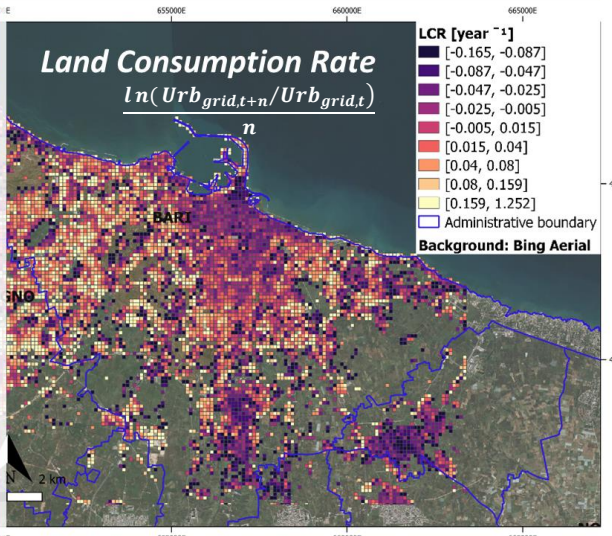
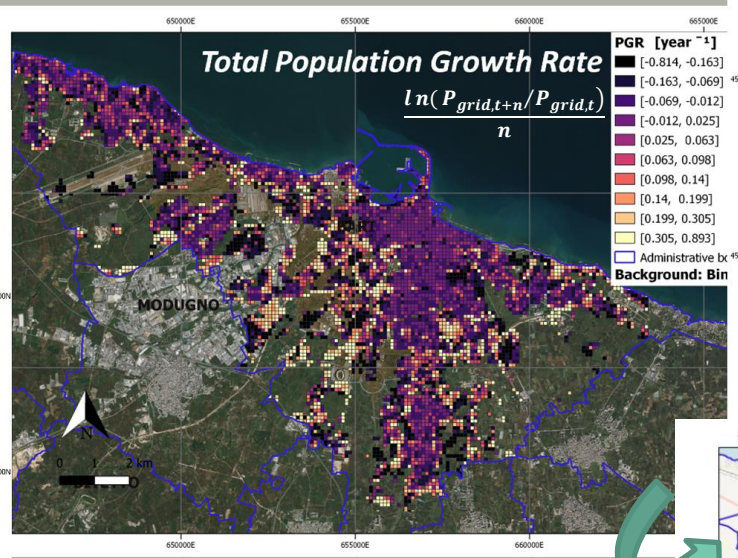
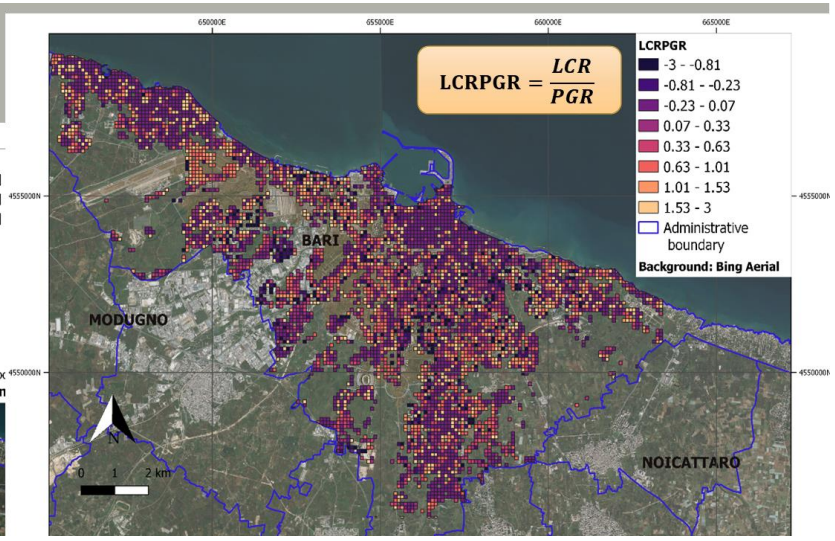
Overview of SDG 11 indicators for Bari city (11.3.1)

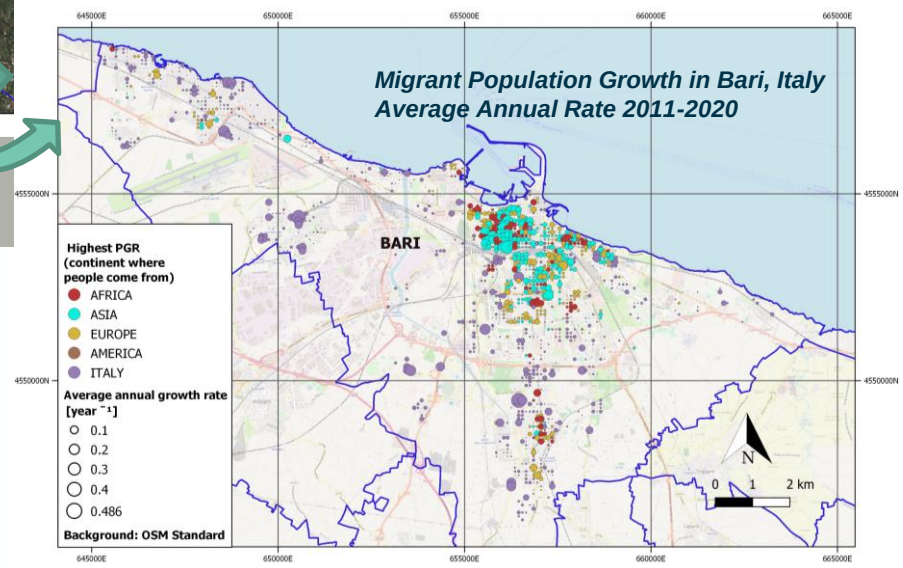
INDICATOR 11.3.1: LAND CONSUMPTION RATE TO POPULATION GROWTH RATE (LCRPGR)

T 11.3









Essential variables

- Grid population map
- Settlement map

City scale value in support to comparative statistics

Quantifiable Derivatives	Value at City Scale	Temporal Reference (Population Data)
11.3.1. Ratio of land consumption rate to population growth rate	0.40 (Average value)	Interval between 2011 and 2020

UN Habitat, 2018a. SDG 11.3.1. metadata (2018 release). Available from: https://unhabitat.org/sites/default/files/2020/07/metadata_on_sdg_indicator_11.3.1.pdf.

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Overview of SDG 11 indicators for Bari city (11.1.1)

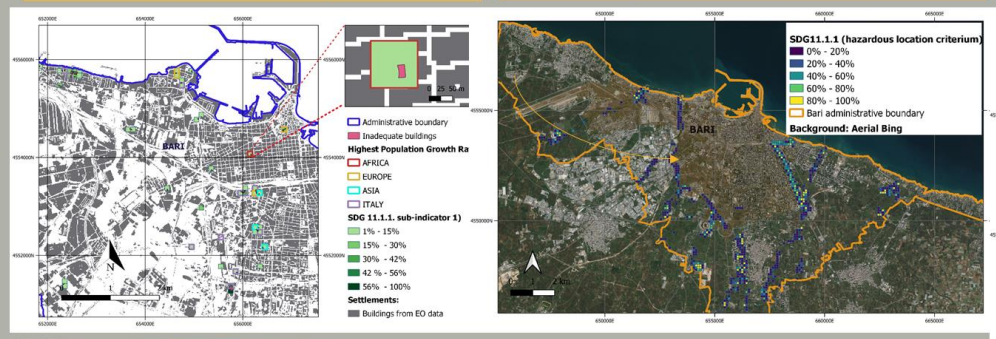
INDICATOR 11.1.1: PROPORTION OF URBAN POPULATION (TOTAL) LIVING IN INADEQUATE HOUSING HOUSEHOLDS

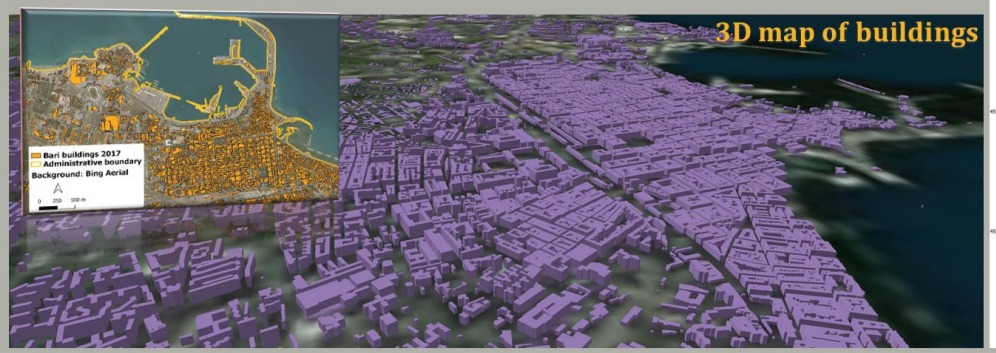
T 11.1

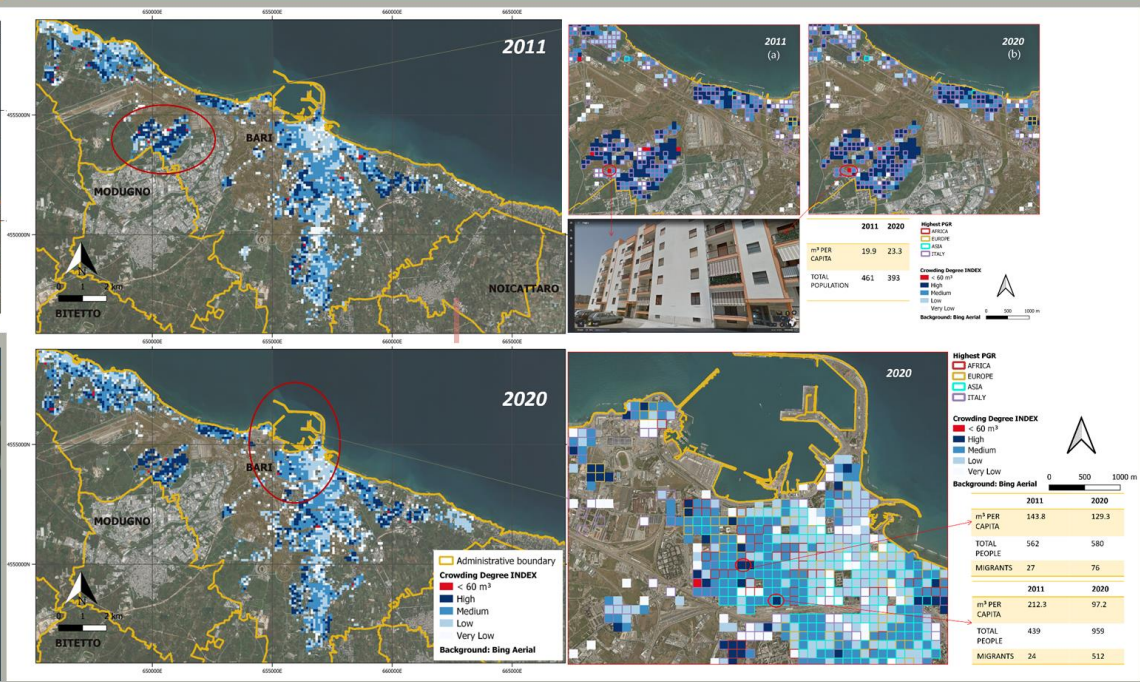
1) Proportion of households with non-durable housing

2) Proportion of households living in housing residing on or near hazardous areas

3) Proportion of households with insufficient living space







Essential variables

- Grid population map
- Settlement map

Input from local providers

- Building layer with information on building use i.e., residential, commercial, industrial, decaying buildings
- Hazard maps
- Building heights layer (optional)

[UN Habitat, 2018b. SDG 11.1.1. metadata (2018 release). Available from: https://unhabitat.org/sites/default/files/2020/06/metadata_on_sdg_indicator_11.1.1.pdf.]

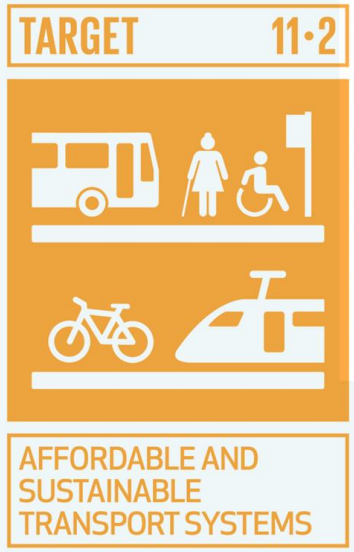
Quantifiable Derivatives	Value at City Scale	Temporal Reference (Population Data)
1. Proportion of households with non-durable housing	0.2%	2020
2. Proportion of households living in housing residing on or near hazardous areas	1%	2020
3. Proportion of households with insufficient living space	1.8%	2011
	0.88% (2848 people)	2020

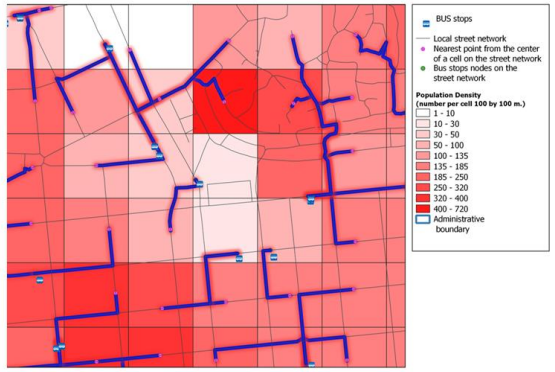
Overview of SDG 11 indicators for Bari city (11.2.1)

INDICATOR 11.2.1: PROPORTION OF THE (TOTAL/MIGRANT) POPULATION THAT HAS CONVENIENT ACCESS TO PUBLIC TRANSPORT

11.2

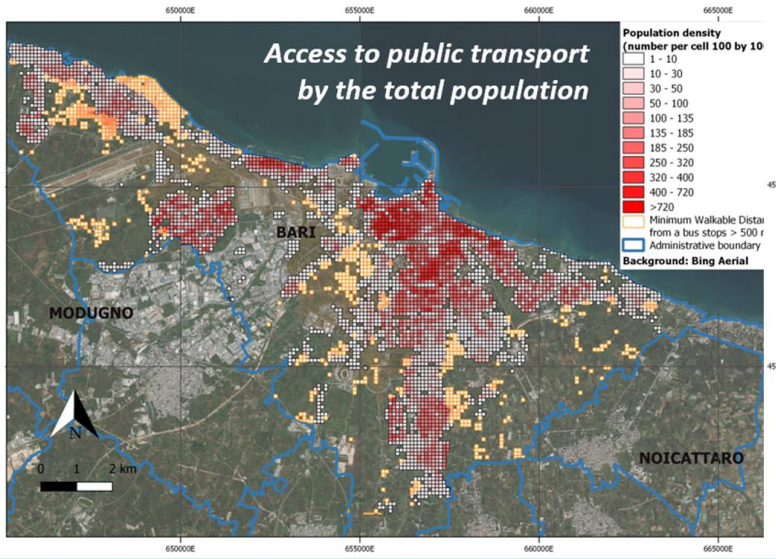
TARGET 11·2



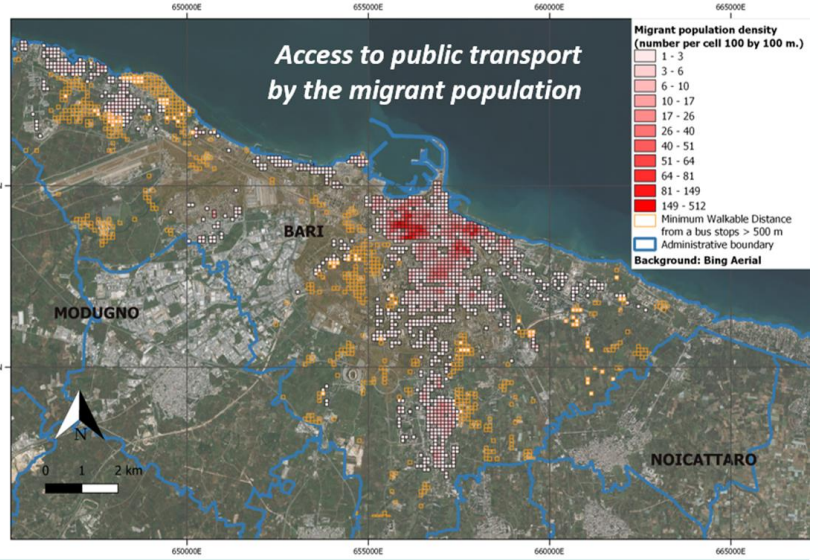


Required Input: Local road network map or OpenStreetMap; Bus stops geolocations.

1) Proportion of total population people that do not have convenient access to public transport



2) Proportion of migrant population people that do not have convenient access to public transport



Essential variables

- Grid population map

Input from local providers

- Local road network map
- Bus/Train/Tram/Metro stops map

City scale value in support to comparative statistics

Quantifiable Derivatives	Value at City Scale	Temporal Reference (Population Data)
1. Proportion of population that has convenient access to public transport	3% (10,135 people)	2020

[UN Habitat, 2020. SDG 11.2.1. metadata (2020). Available from: https://unhabitat.org/sites/default/files/2020/06/metadata_on_sdg_indicator_11.2.1.pdf.]

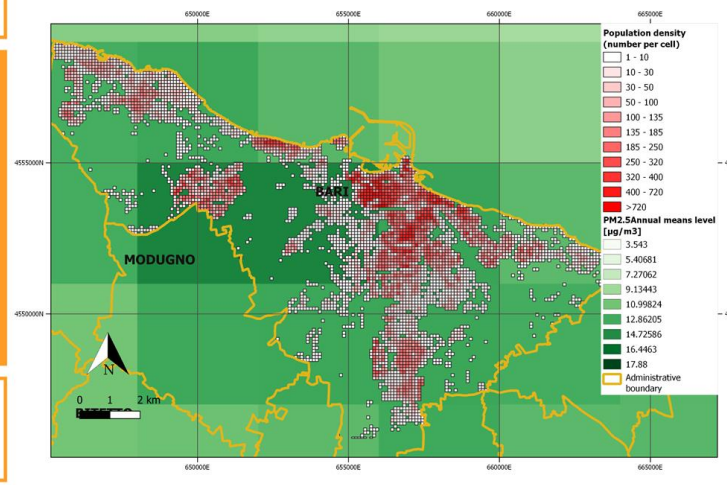
Overview of SDG 11 indicators for Bari city (11.6.2)

INDICATOR 11.6.2: ANNUAL MEAN LEVELS OF FINE PARTICULATE MATTER (E.G. PM2.5 AND PM10) IN CITIES (POPULATION WEIGHTED)

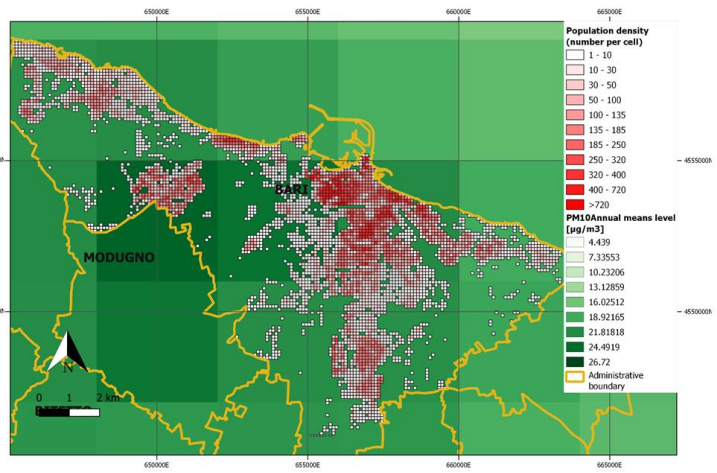
T 11.6

TARGET 11·6

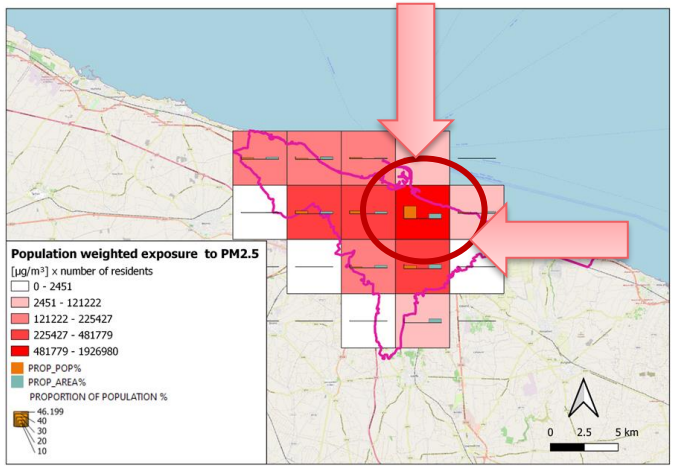
1) Annual mean levels of PM 2.5 in cities



2) Annual mean levels of PM 10 in cities



Population Weighted Exposure Levels (PWELs)



Essential variables

- Grid population map

Input from local providers

- Annual average exposure to PM2.5
- Annual average exposure to PM10

$$PWEL = \frac{\sum_{i=1}^{n} C_{\,4\,km \times 4\,km} * \sum_{j=1}^{m} P_{GRID\_j}}{P_{city}}$$

	Stat [µg/m³]	PWELs [µg/m³]	Regulation limits in force in Italy [µg/m³]
PM2.5	MAX: 15.1, **MEAN: 12.4**, MEDIAN: 12.7, MIN: 10.2,	**13.5**	25
PM10	MAX: 25.1, **MEAN: 20.4**, MEDIAN: 20.8, MIN: 15.5,	**22.1**	40

[UN Habitat, 2017. SDG 11.6.2. metadata (2017). Available from: https://unhabitat.org/sites/default/files/2020/07/metadata_on_sdg_indicator_11.6.2.pdf]

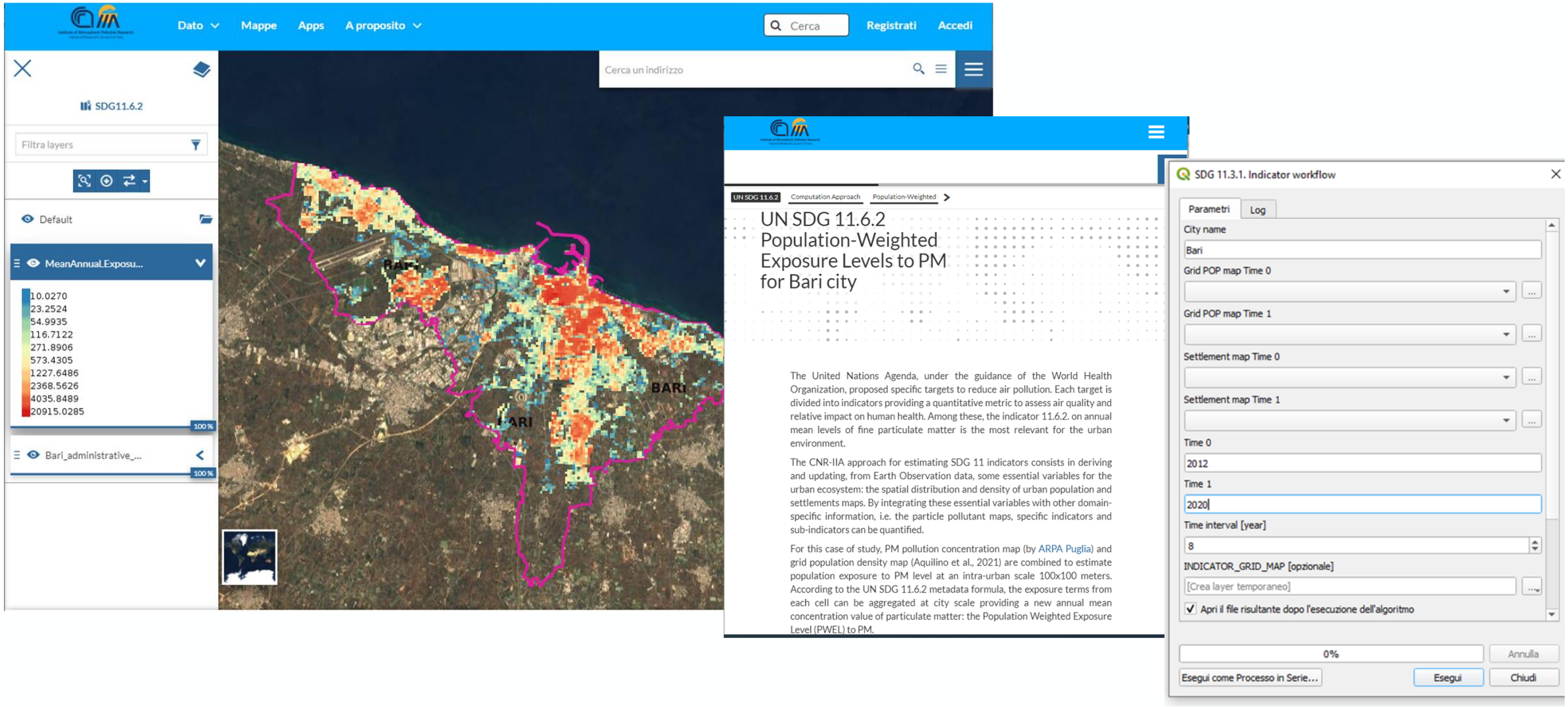
CONCLUSION

This study provides methods and tools (automatic workflow, QGIS plugins, web applications) to facilitate the integration of EO data, from different observational platforms, in SDGs monitoring mechanism, with the aims:

- to generate a multi-level knowledge for a wide range of users, included local decision-makers who need to design policies for resilience cities and communities and fostering social cohesion and inclusion;
- to accelerate the progress on UN 2030 Agenda through a direct engagement of Local and Regional Authorities, also in the light of the New Urban Agenda policy framework;
- to demonstrate the feasibility of the implementation of SDG 11 indicators at the intra-urban scale through the skillful combination of EO data with open data from local providers.

The results can enable us to understand what kind of city growth/sprawl we should expect in the future and how much great could be the impact of the informed decision-making processes in driving these changes.

…TO BE CONTINUED!



Thanks for your attention!

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