COSMO PP CITTÀ kick-off meeting

04 November 2021

Update on urban canopy parameters for EXTPAR

Survey of the existing datasets to derive ISA

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CONSORTIUM FOR SMALL SCALE MODELING COSMO

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

Overview

- Background
- Definition of ISA
- Desk review of datasets to derive ISA available for Europe
- Methodology
- Comparison between datasets at local level: results
- Summary and conclusions

Goal of the TASK 2 of PP-CITTÀ

The main goal of the **Task 2** is to update the current EXTPAR fields in TERRA_URB scheme within the ICON(-LAM) model.

The **subtask 2.2** aim to replace **Impervious Surface Area** (ISA) and **Anthropogenic Heat Flux** (AHF) global fields with more recent datasets by investigating the availability of suitable impervious cover classes within land cover datasets, adopting also Local Climate Zones (LCZs.)

The workflow is structured around the following items:

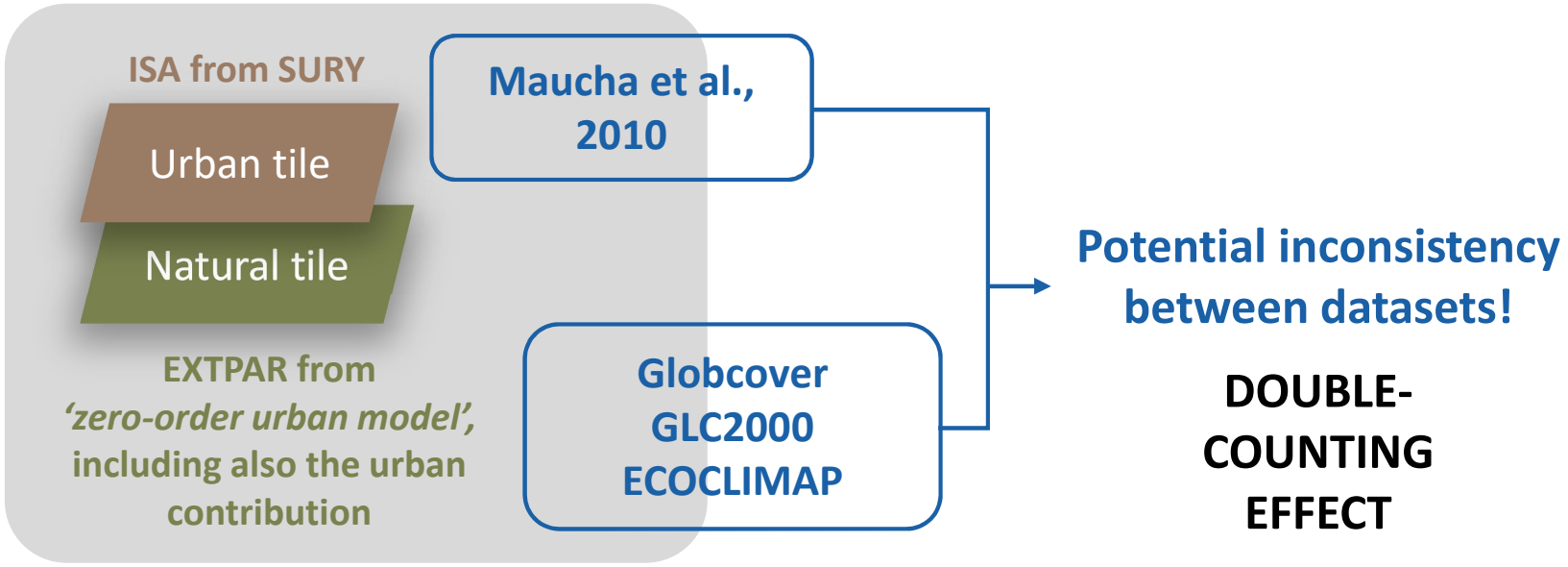
1. **Survey of the existing datasets**
2. **Derive a complete dataset for climate modelling at urban scale**
3. **Implement the dataset in EXTPAR**

Potential incosistency when TERRA-URB is activated

TERRA_URB activated

tile approach

If the urban scheme is activated (TERRA_URB=TRUE), a **tile approach** is implemented in which each cell is divided into two tiles, an urban tile and a natural tile.



Definition of ISA – Impervious Surface Area

The Impervious Surface Area (ISA) field defines the impervious surface of urban areas including all the sealed areas (covered by materials such as asphalt, concrete, brick and stone) such as buildings, streets and parking lots, without the vegetation cover (e.g. gardens, parks).

ISA =

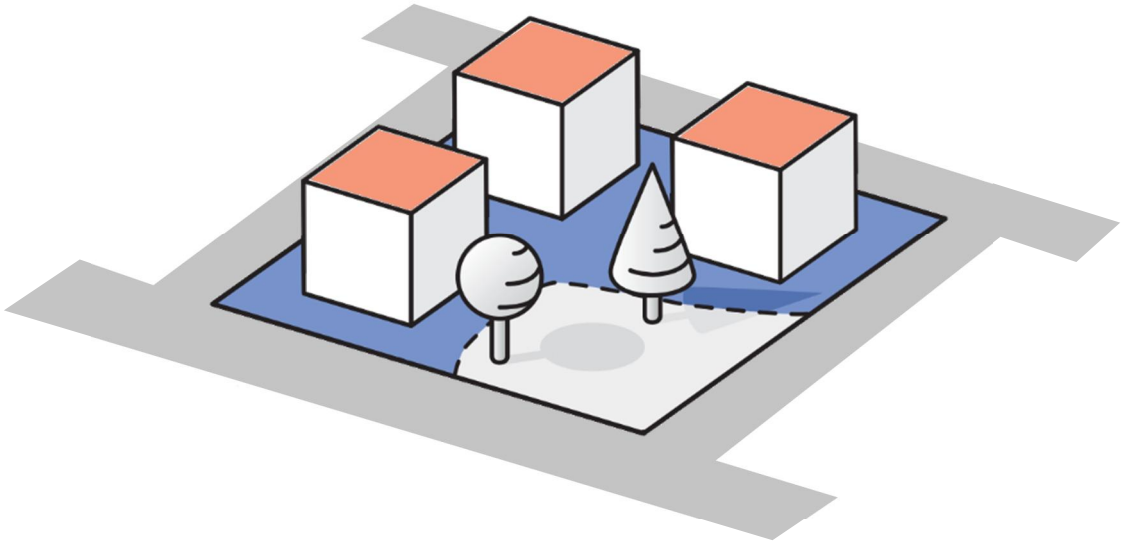
Roof areas (Built-up areas)

+

Paved areas (sidewalks, parking lots, etc.)

+

Streets



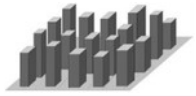
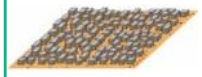
Desk review of datasets to derive ISA available for Europe

Dataset/Producer	Resolution		Coverage		Classification scheme	Source
	Spatial	Temporal	Spatial	Temporal		
Land cover datasets (Urban field)						
GlobCover/*ESA & UCLouvain*	300 m	Single year	Global	2009	FAO LCCS 22 classes	https://bit.ly/3uzxbxC
ESA CCI/C3S LC project/*VITO on behalf of the ECMWF*	0.002778° (≈ 300 m)	yearly	Global	1992 -2020	FAO LCCS 22 classes	https://bit.ly/3twOnCp
GLC2000 (Regional dataset)/*EU-JRC*	0.00892857° (≈ 960 m)	Single year	European	2000	FAO LCCS 23 classes	https://bit.ly/3ot9tAE
CORINE Land Cover, CLC/*EEA*	100 m	Single year	European	1990 - 2000 - 2006 - 2012 - 2018	44 classes	https://bit.ly/3yI57dL
Copernicus Global Landcover/*Buchhorn et al., 2020*	100 m	yearly	Global	2015-2019	10 classes (pecent coverage!)	https://lcviewer.vito.be/2019
Land cover dataset with LCZs						
ECOCLIMAP-SG/*CNRM*	300 m	Single year	Global	2018	33 classes (from ESA-CCI GLC v1.6.1 and CLC)	https://bit.ly/3bihmDJ
European LCZ map/*Demuzere et al., 2019*	100 m	Single year	European	???	17 rural & urban LCZs	https://figshare.com/articles/dataset/European_LCZ_map/13322450
Impervious areas datasets (ISA field)						
GAUD/*Liu et al., 2020*	30 m	yearly	Global	from 1985 to 2015	Urban grid	https://bit.ly/3wf9xqw
GAIA/*Gong et al., 2020*	30 m	yearly	Global	from 1985 to 2018	Non-impervious/ impervious areas	Gong et al., 2020 https://bit.ly/3bhABxb
CLMS Imperviousness Density, IMD/*EEA*	100 m 20 m 10 m (2018)	Single year	European (EEA39)	2006 – 2009 – 2012 – 2015 -2018	Degree of imperviousness (0-100%)	https://bit.ly/2Qwkipf
Global Man-made Impervious Surface (GMIS) Dataset From Landsat	30 m	Single year	Global	2010	Non-impervious/ impervious areas	https://sedac.ciesin.columbia.edu/data/set/ulandsat-gmis-v1

Description of artificial classes – "URBAN" DATASETS

Dataset/*Producer*	Classes	Descriptions
GlobCover/*ESA & UCLouvain*	190. Artificial surfaces and associated areas (Urban areas >50%)	This class describes areas that have an artificial cover as a result of human activities such as construction (cities, towns, transportation), extraction (open mines and quarries) or waste disposal (LCCS).
ESA CCI/C3S LC project/*VITO on behalf of the ECMWF*	190. Urban areas	the class relies both on the Global Human Settlement Layer [Pesaresi et al., 2016] and on the Global Urban Footprint [Esch et al., 2017]
Corine Land Cover, CLC/*EEA*	111. Continuous urban fabric	The class is assigned when urban structures and transport networks are dominating the surface area. > 80% of the land surface is covered by impermeable features like buildings, roads and artificially surfaced areas. Non-linear areas of vegetation and bare soil are exceptional.
	112. Discontinuous urban fabric	The class is assigned when urban structures and transport networks associated with vegetated areas and bare surfaces are present and occupy significant surfaces in a discontinuous spatial pattern. The impermeable features like buildings, roads and artificially surfaced areas range from 30 to 80 % land coverage.
	121. Industrial or commercial units	Buildings, other built-up structures and artificial surfaces (with concrete, asphalt, tarmacadam, or stabilized like e.g. beaten earth) occupy most of the area. It can also contain vegetation (most likely grass) or other non-sealed surfaces. This class is assigned for land units that are under industrial or commercial use or serve for public service facilities.
	122. Road and rail networks and associated land	Motorways and railways, including associated installations (stations, platforms, embankments, linear greenery narrower than 100 m). Minimum width for inclusion: 100 m.
	123. Port areas	Infrastructure of port areas (land and water surface), including quays, dockyards and marinas.
	124. Airports	Airports installations: runways, buildings and associated land. This class is assigned for any kind of ground facilities that serve airborne transportation.
GLC2000 (Regional dataset)/*EU-JRC*	22. Artificial surfaces and associated areas	The land cover consists of built up area(s).

Description of LCZs classes – ECOCLIMAP-SG

Dataset/*Producer*	Classes*	Descriptions
ECOCLIMAP-SG/*CNRM*	 24. LCZ1: compact high-rise	• Strong built-up NDVI <= 0.2 and high rise buildings (3D roughness 50-100m) • Strong built-up NDVI <= 0.2 and very high rise buildings (3D roughness > 100m)
	 25. LCZ2: compact mid-rise	• Continuous urban fabric (from CLC) • Strong built-up NDVI <= 0.2 and medium rise buildings (3D roughness 25-50m)
	 26. LCZ3: compact low-rise	• Strong built-up NDVI <= 0.2 and low rise buildings (3D roughness <25m)
	 27. LCZ4: open high-rise	n.a. - Despite the class is included in the legend of ECOCLIMAP-SG, the data are not available in the European map. Technical documentation doesn't provide further details.
	 28. LCZ5: open midrise	• Medium built-up 0.2 < NDVI <= 0.3 (o 6)
	 29. LCZ6: open low-rise	• Light built-up 0.3 < NDVI <= 0.4
	 30. LCZ7: lightweight low-rise	n.a. - Despite the class is included in the legend of ECOCLIMAP-SG, the data are not available in the European map. Technical documentation doesn't provide further details.
	 31. LCZ8: large low-rise	• Industrial or commercial unit, Airports (from CLC) • Built-up with highly reflecting roof (associated to productive and commercial use) • Roads
	 32. LCZ9: sparsely built	• Road and rail networks and associated land, Mineral extraction sites, Dump sites, Construction sites, Green Urban Areas, Sport and leisure facilities (from CLC) • Very light built-up NDVI > 0.4
	 33. LCZ10: heavy industry	• Port areas (from CLC)

**Stewart I.D., Oke T.R., 2012. Local Climate Zones for Urban Temperature Studies. Bull Am Meteorol Soc., 93(12):1879-1900. doi:10.1175/BAMS-D-11-00019.1*

Description of impervious classes – “ISA” DATASETS

Dataset/*Producer*	Classes	Descriptions
GAUD/*Liu et al., 2020*	Urban areas	Pixels that are dominated by built elements (for example, buildings, roads, runways and so on).
GAIA/*Gong et al., 2020*	Artificial impervious area	Artificial impervious areas are mainly man-made structures that are composed of any material that impedes or prevents natural infiltration of water into the soil. They include roofs, paved surfaces, hardened grounds, and major road surfaces mainly found in human settlements.
CLMS Imperviousness Density, IMD/*EEA*	All impervious areas (1-100%)	The classes include all artificially sealed areas produced using automatic derivation based on calibrated Normalized Difference Vegetation Index (NDVI). They are per-pixel estimates of impermeable cover of soil (soil sealing) and are mapped as the degree of imperviousness (0-100%).

Description of impervious classes – "ISA" DATASETS

Dataset/*Producer*	Classes	Descriptions
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The first two datasets, **GAUD** and **GAIA**, are based on binary information: zero means non-impervious, values greater than zeros indicate impervious pixels, also specifying the urbanized year. **Impervious pixels are considered 100% sealed surfaces**.

GAUD/*Liu et al., 2020*	30 m	yearly	from 1985 to 2015
GAIA/*Gong et al., 2020*	30 m	yearly	from 1985 to 2018

CLMS-IMD dataset include information on all artificially sealed areas, which are mapped as the **degree of imperviousness (1-100%)**.

CLMS Imperviousness Density, IMD/*EEA*	100 m 20 m 10 m (2018)	Single year	2006 – 2009 – 2012 – 2015 - 2018

Desk review of datasets to derive ISA available for Europe

Urban datasets are based on artificial classes that include green urban areas such as garden and parks or on built-up areas without considering other sealed areas on the ground.

The following datasets are adopted for the comparison of ISA values:

1. **ECOCLIMAP-SG**
2. **GAUD, Global Annual Urban Dynamics**
3. **GAIA, Global Artificial Impervious Areas**
4. **CLMS Imperviousness Density, IMD**

Furthermore, such datasets are compared with the ISA dataset adopted in COSMO-CLM simulation (reference dataset → **Maucha et al., 2010**)

Methodology

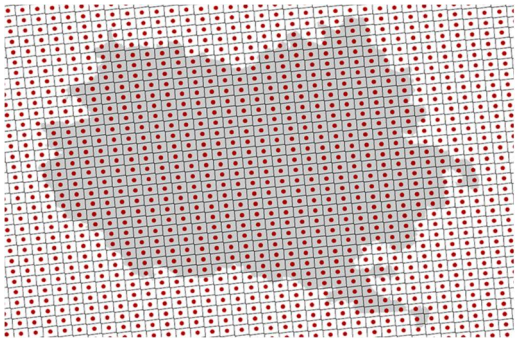
To make a comparison between datasets with different spatial resolution, a 2km grid is adopted as a reference grid.

The operational workflow is organized in **3 steps** (ArcGIS workflow):

1 Create the target grid (polygons) from points (centroids)

Target grid

2 km grid

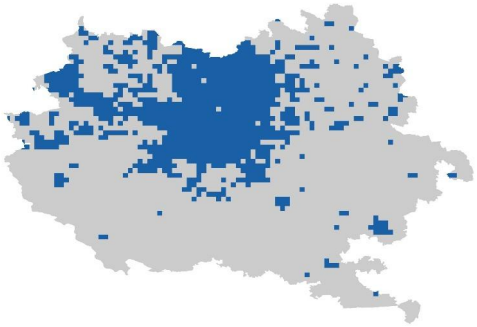


The target grid is centered on the points of the COSMO-CLM domain

2 Convert the raster version of datasets into polygon features

ISA datasets

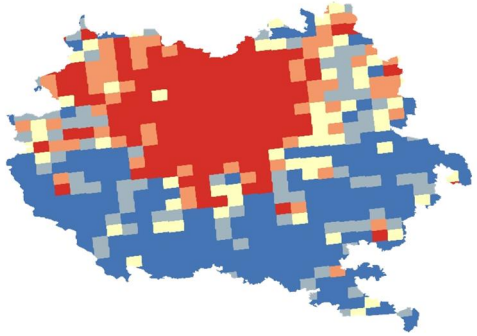
original resolution (100m, 30m, 10 m ,…)



3 Calculate the % of ISA within each cells of the target grid

% of ISA within each cell

2 km grid



Comparison between datasets at local level

Compared with

ID	Type	Reference datasets	Datasets (our elaboration)		Spatial scale	Scope
C1	«Urban» dataset	**GLC2000 from COSMO-CLM simulation**	**GLC2000**		2 km grid	Verify the consistency of the interpolation method adopted to derive the urban values from GLC2000 (is the same method adopted to derive ISA values)
C2	«ISA» dataset	**Maucha et al., 2010 from COSMO-CLM simulation**	**C2.1**	**CLMS – IMD 2006** **CLMS – IMD 2009** **CLMS – IMD 2012** **CLMS – IMD 2015** **CLMS – IMD 2018**	2 km grid	Verify the potential update of current ISA field (from Maucha et al., 2010) with **more recent** and **more detailed** datasets
			C2.2	**GAUD 2015** **GAIA 2018** **CLMS – IMD 2018**	Original resolution 2 km grid	

ID	Type	Datasets (our elaboration)	Spatial scale	Scope
C3	LCZs + ISA dataset	**CLMS – IMD 2018** **ECOCLIMAP-SG**	Original resolution 2 km grid	Verify the potential update of current ISA field (from Maucha et al., 2010) with **LCZ classes** and/or **imperviousness density.**

Comparison between URBAN datasets at local level

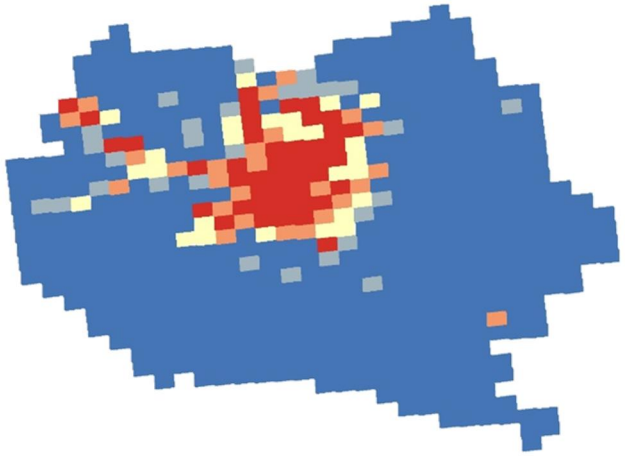
C1

Milan (2 km grid)

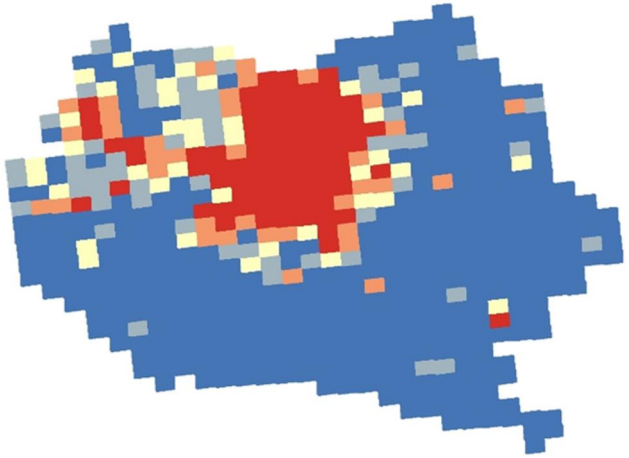
Open issue: check with the project team the interpolation method adopted in COSMO-CLM for land cover classes and the method to derive URBAN areas from GLC2000 dataset!!!

↑↑↑

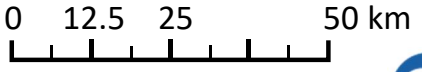
The map highlight an increase in the % of urban areas as compared to the data adopted in the COSMO-CLM simulation



URBAN field from COSMO-CLM (GLC2000)



URBAN field from GLC2000 dataset

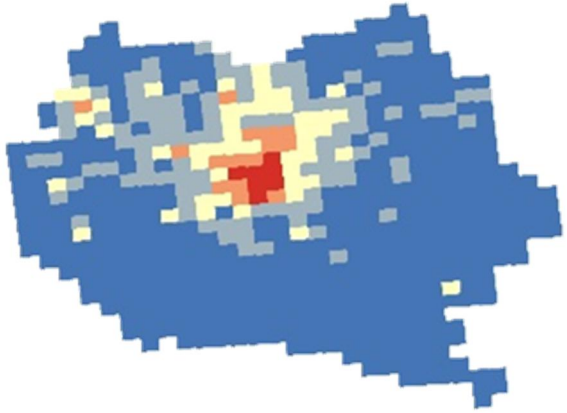


Comparison between ISA datasets at local level

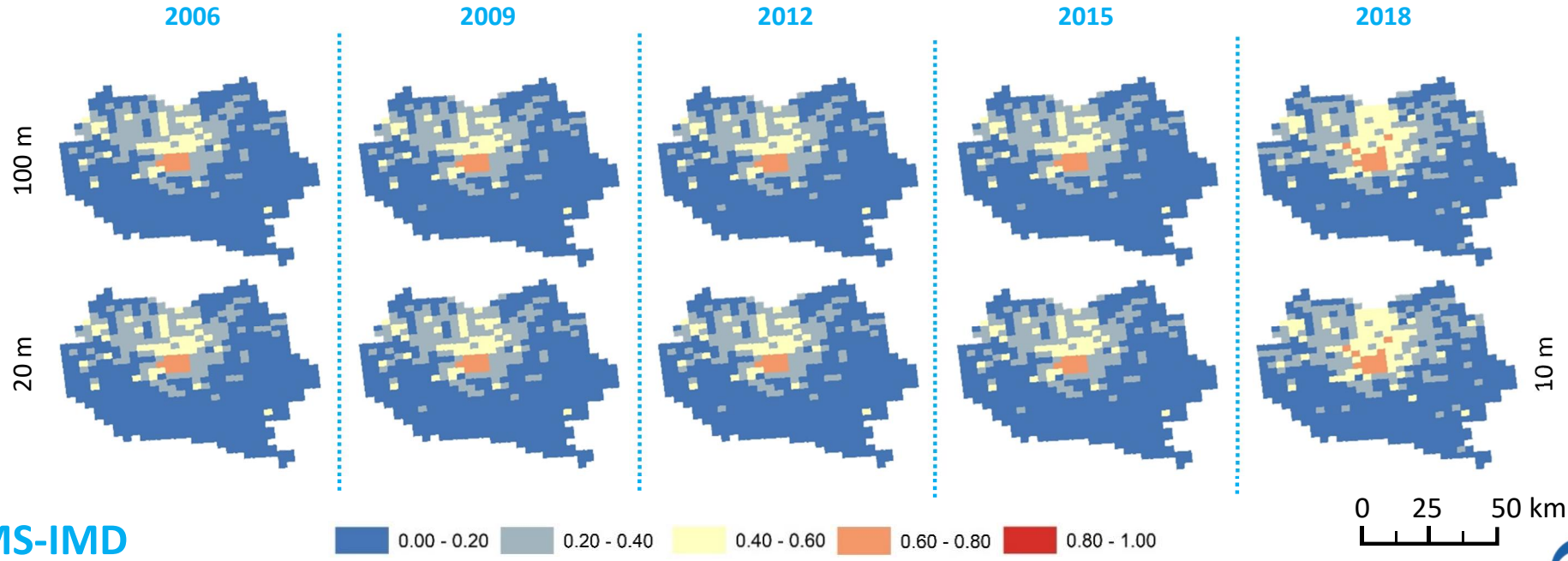
C2.1

Milan (2 km grid)

5 different years of CLMS-IMD dataset are compared by considering two spatial resolutions, 100 and 20 meters (10 meters for 2018). There is an increase in ISA values in 2018 in the northern part of the city.



ISA field from COSMO-CLM simulation (Maucha et al., 2010)

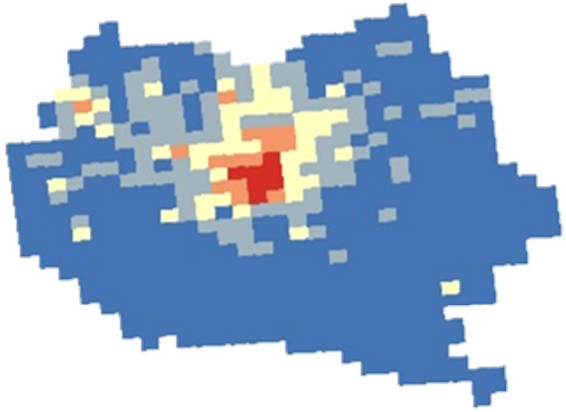


Comparison between ISA datasets at local level

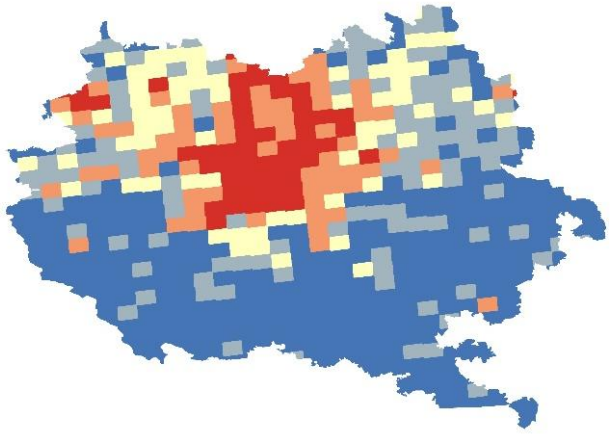
C2.2

Milan (2 km grid)

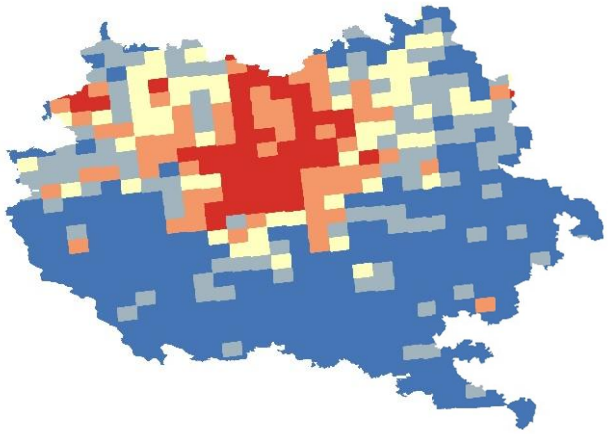
In GAUD and GAIA datasets, impervious pixels are considered 100% sealed surfaces. Furthermore, due to their lower spatial resolution as compared with CLMS-IMD, they tend to overestimate ISA.



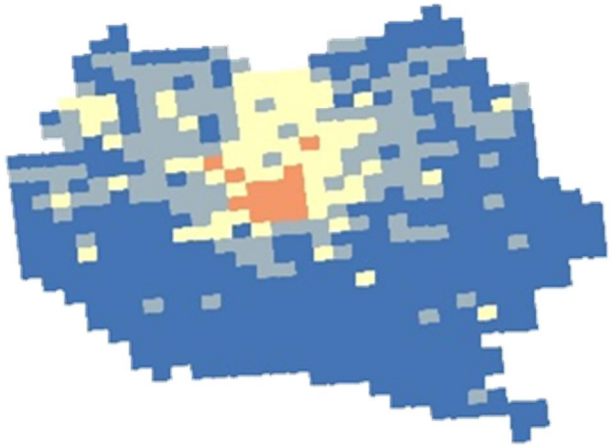
ISA field from COSMO-CLM simulation (Maucha et al., 2010)



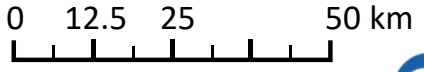
ISA - GAUD 2015 (30 m)



ISA - GAIA 2018 (30 m)



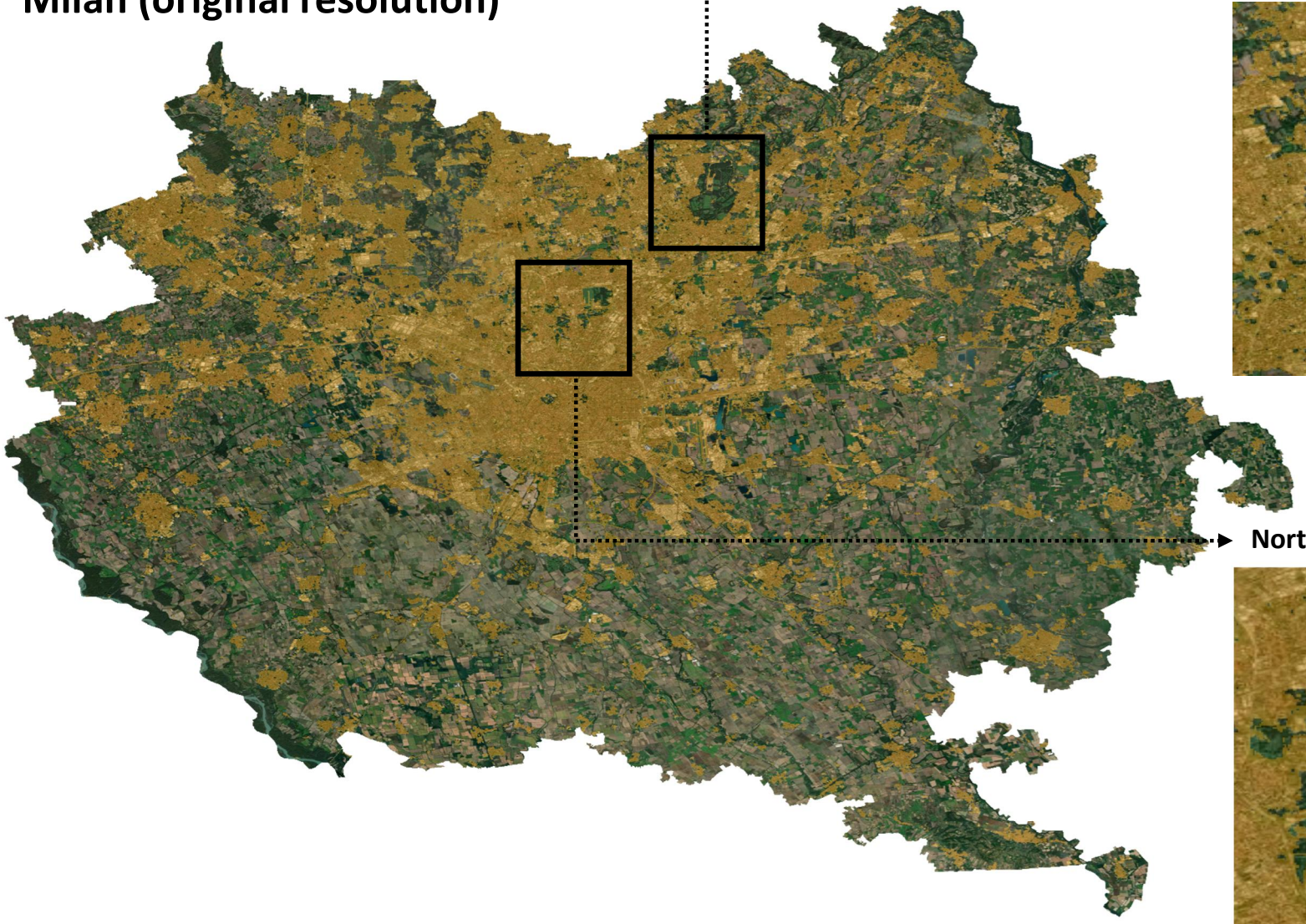
CLMS-IMD 2018 (10 m)



Comparison between ISA datasets at local level

C2.2

Milan (original resolution)



Monza Park

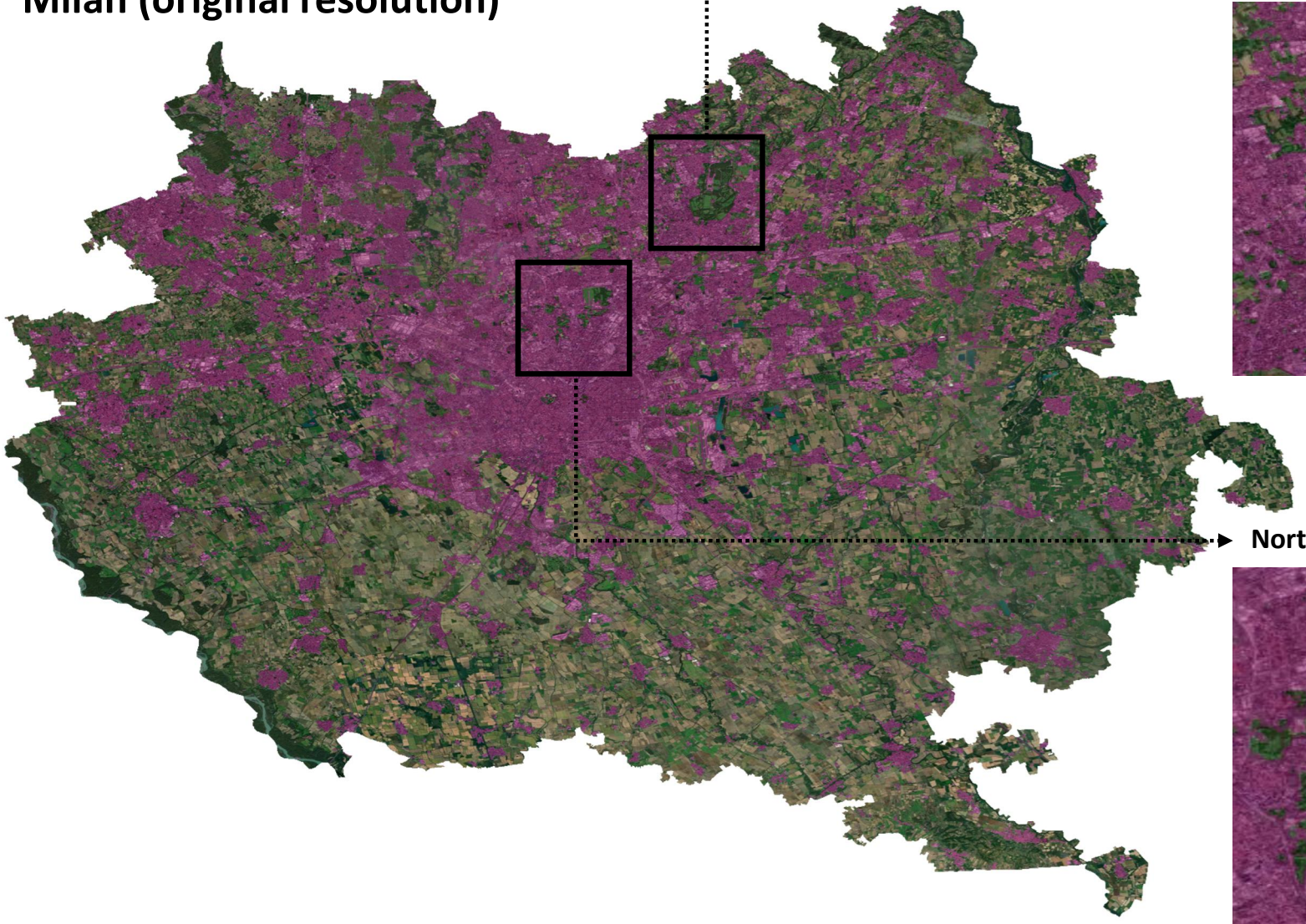
North Park

ISA – GAUD 2015 (30 m)

Comparison between ISA datasets at local level

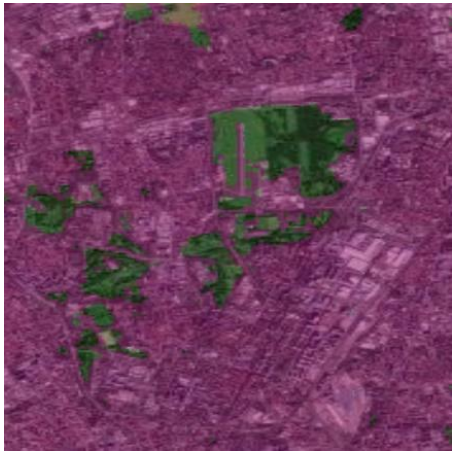
C2.2

Milan (original resolution)



Monza Park

North Park

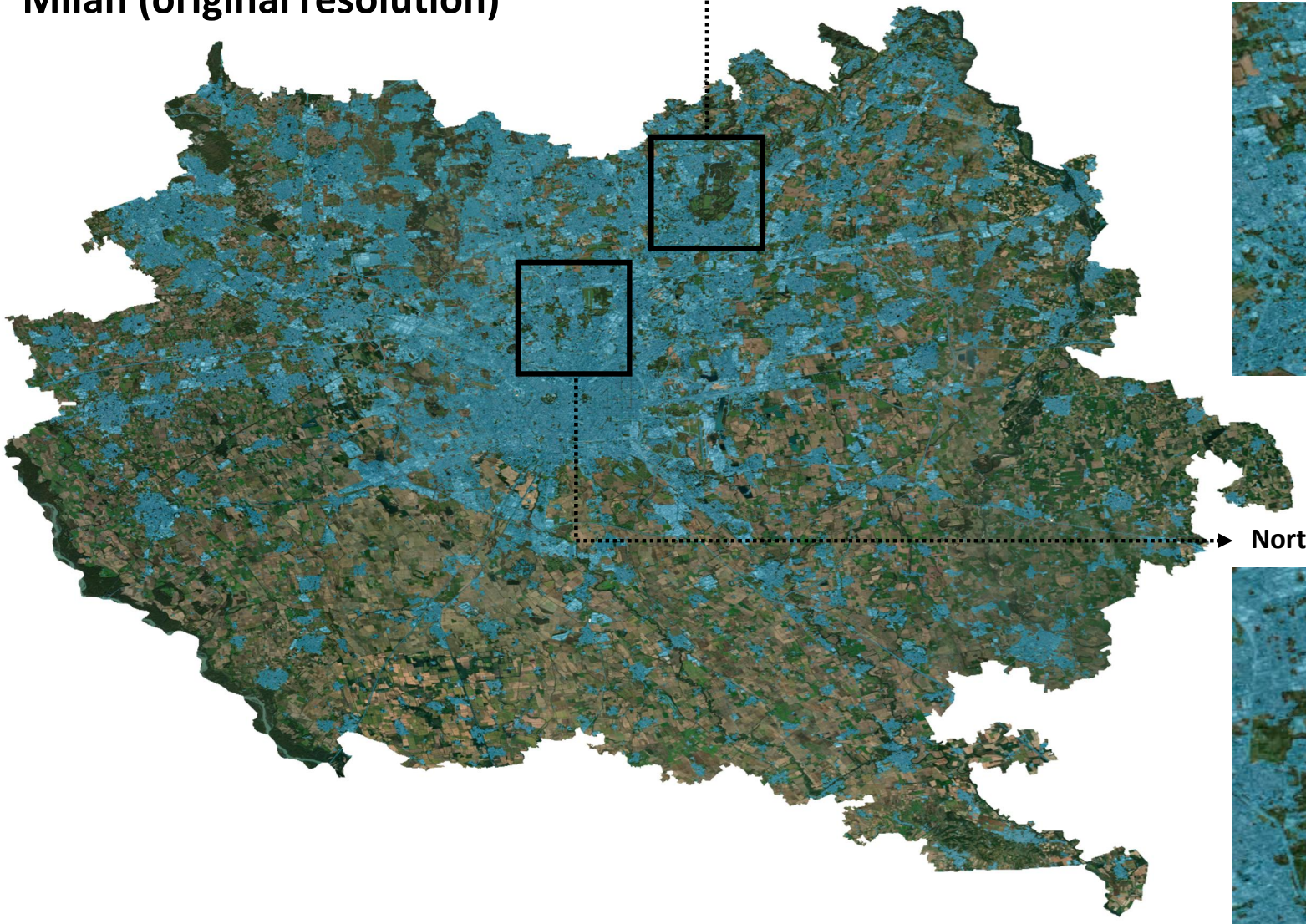


ISA – GAIA 2018 (30 m)

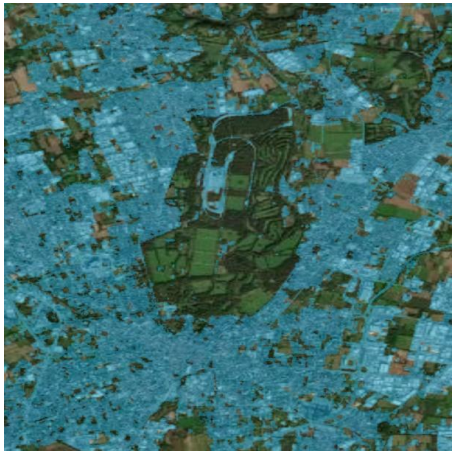
Comparison between ISA datasets at local level

C2.2

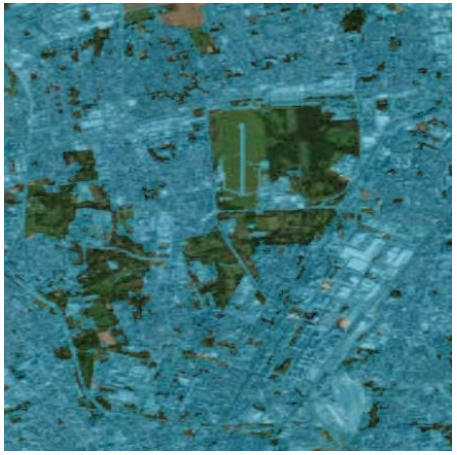
Milan (original resolution)



Monza Park



North Park

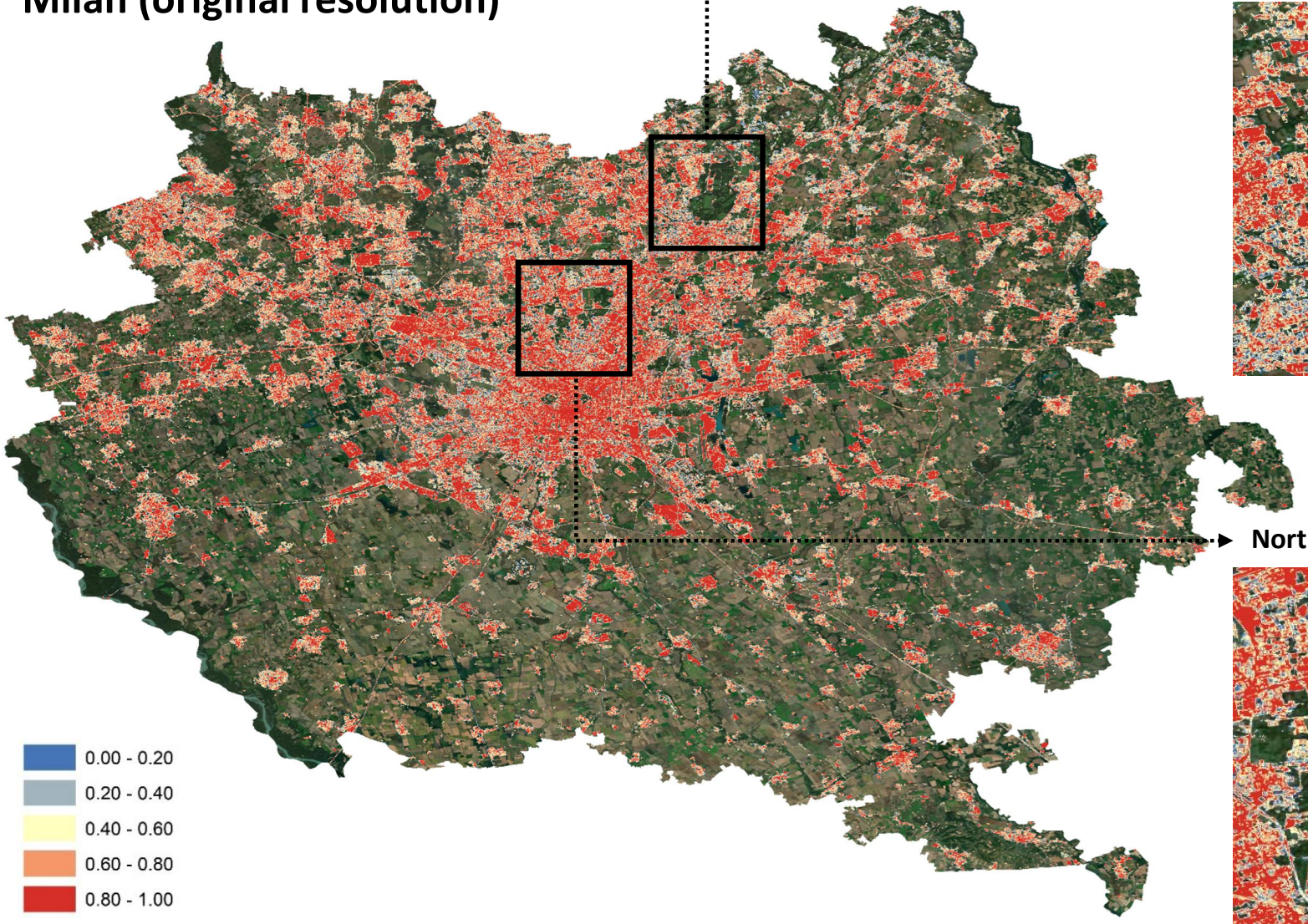


ISA – IMD 2018 (10 m)

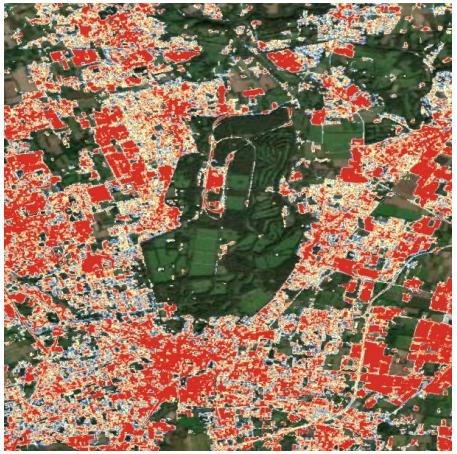
Comparison between ISA datasets at local level

C2.2

Milan (original resolution)



Monza Park



North Park

ISA – IMD 2018 (10 m)

Comparison between LCZs and ISA dataset

New ISA classes	
ISA high=80%	3
ISA medium=60%	2
ISA low=30%	1

Comparison between LCZs and ISA dataset

CLMS – IMD 2018
ECOCLIMAP-SG

C3

LOCAL CLIMATE ZONES - LCZs

ECOCLIMAP-SG include 10 urban classes derived from CORINE urban classes and translated by adopting LCZs classes.

ISA dataset

The classes of CLMS-IMD include all artificially sealed areas, which are mapped as the degree of imperviousness (1-100%).

New ISA classes	
ISA high=80%	3
ISA medium=60%	2
ISA low=30%	1

ECOCLIMAP-SG	
ECOCLIMAP-SG classes	LCZs
24-25-26-30-31	1-2-3-7-8
27-28-29-33	4-5-6-10
32	9

CLMS-IMD
71-100%
41-70%
1-40%

Such a classification is our proposal, all suggestions are welcome!

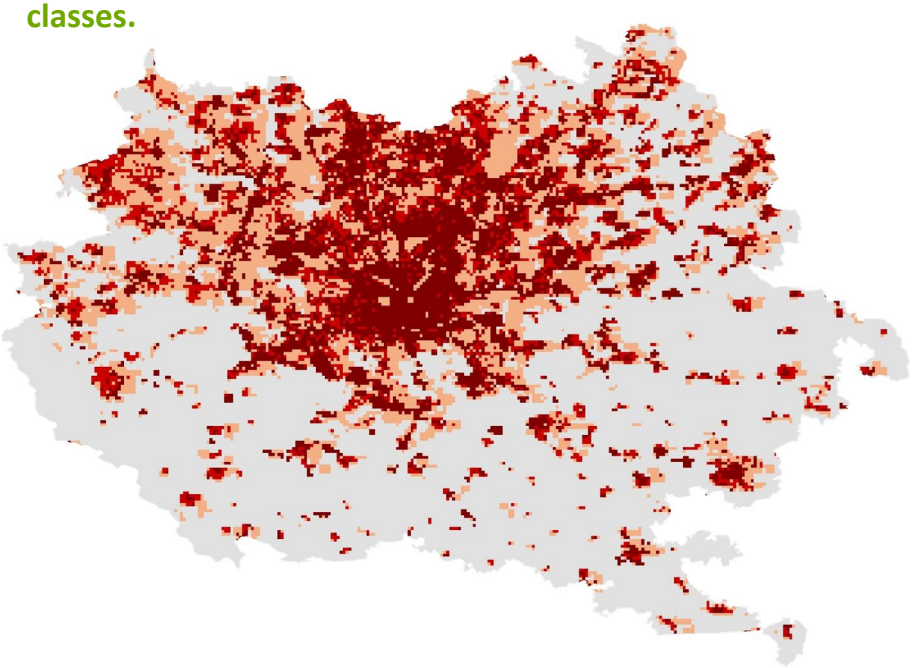
Comparison between LCZs and ISA dataset

CLMS – IMD 2018
ECOCLIMAP-SG

C3

Milan (original resolution)

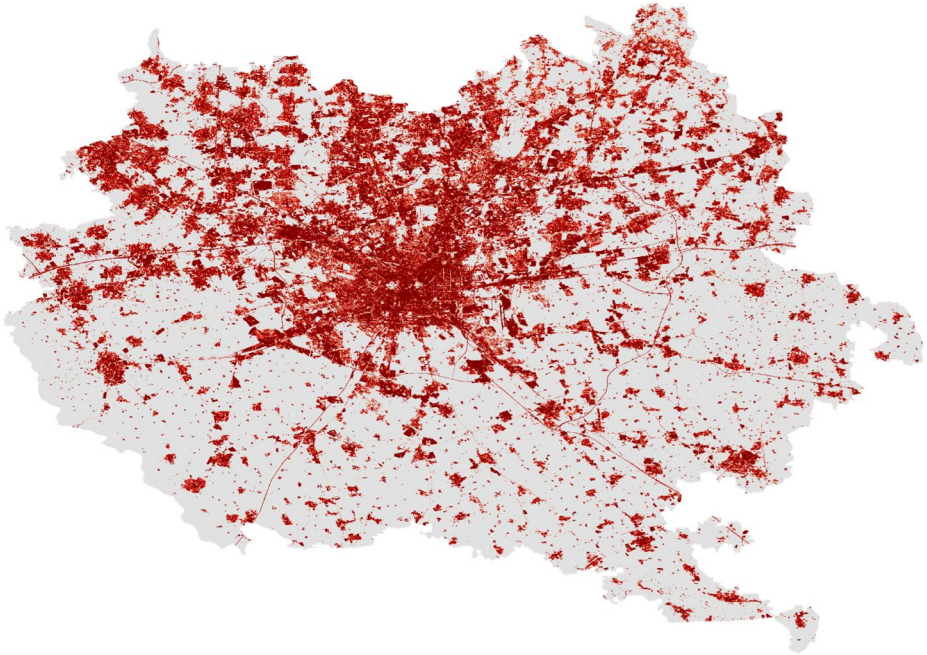
ECOCLIMAP-SG include 10 urban classes derived from CORINE urban classes and translated by adopting LCZs classes.



ISA high (80%) / classes 24-25-26-30-31	35.9%
ISA medium (60%) / classes 27-28-29-33	20.1%
ISA low (30%) / class 32	44.0%

ECOCLIMAP-SG (300m)

The classes of CLMS-IMD include all artificially sealed areas, which are mapped as the degree of imperviousness (1-100%).



ISA high (80%) / 71 - 100	44.7%
ISA medium (60%) / 41 - 70	34.2%
ISA low (30%) / 1 - 40	21.1%

CLMS-IMD 2018 (10 m)

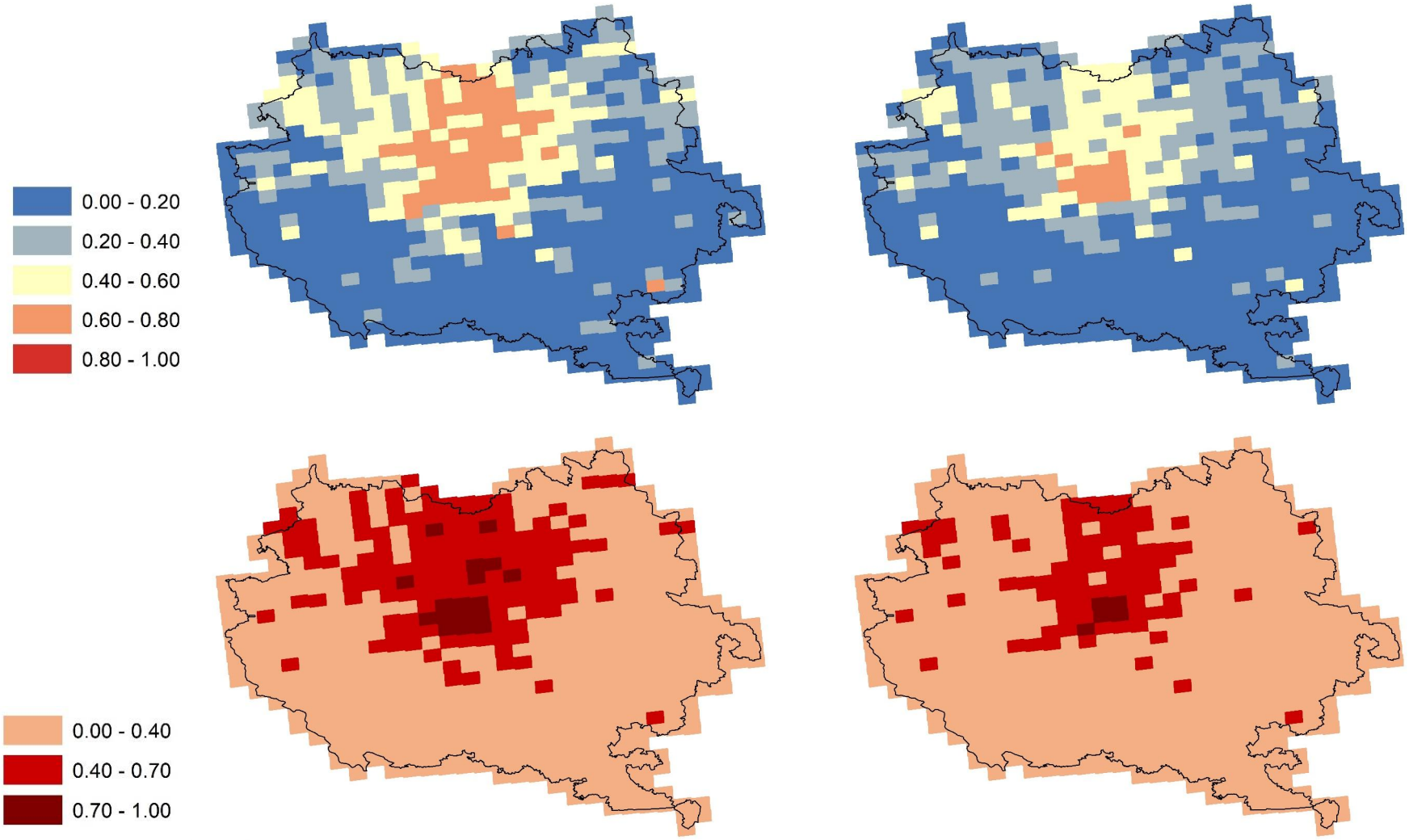
0 5 10 km

Comparison between LCZs and ISA dataset

CLMS – IMD 2018
ECOCLIMAP-SG

C3

Milan (2 km grid)



Summary and conclusions

The study selected and analyzed datasets to derive ISA currently available over Europe identifying 3 main typology:

1. Land cover datasets with artificial/urban classes → **GLOBCOVER**, **ESA-CCI/C3S**, **GLC2000**, **CORINE** (URBAN dataset)
2. Land cover dataset with LCZs classes → **ECOCLIMAP-SG**
3. Datasets with impervious classes → **GAUD**, **GAIA**, **CLMS-IMD** (ISA datasets)

Then, the study focus on datasets with impervious classes by comparing them with each other and with the reference dataset for ISA in COSMO-CLM simulation (Maucha et al., 2010).

Some considerations

- LCZs looks very promising for the aims of PP-CITTÀ
- CLMS-IMD could have an added value related to the degree of imperviousness (1-100%)
- We need to further check the relevance of spatial resolution in determining ISA

Summary and conclusions

OPEN ISSUES

- check with the project team the interpolation method adopted in COSMO-CLM for land cover classes
- identify the reference year for dataset of Maucha et al., 2010
- fine-tuning of range/intervals for classifying ISA

POTENTIAL FUTURE ACTIVITIES (beyond the aim of the task 2)

- conversion of Arcgis workflow into Python scripts
- running simulations with new datasets (e.g. run the same year with different ISA datasets)
- preparing a paper

All comments and suggestions are welcome!

References

[dataset] CNRM, *ECOCLIMAP Second Generation*. https://bit.ly/3bihmDJ

[dataset] Copernicus LMS (2020). *Imperviousness Density 2018*. https://bit.ly/3oDkdMQ

[dataset] European Commission, Joint Research Centre (2003). *Global Land Cover 2000 database*. https://bit.ly/3vnFMDH

[dataset] Huang, Y. (2019). *GAIA File List*. https://bit.ly/3bhABxb

Gong P., Li X., Wang J., Bai Y., Chen B., Hu T., Liu X., Xu B., Yang J., Zhang W., Zhou Y. (2020). Annual maps of global artificial impervious area (GAIA) between 1985 and 2018. *Remote Sensing of Environment, 236*. https://doi.org/10.1016/j.rse.2019.111510

[dataset] Huang, Y. (2020). *High spatiotemporal resolution mapping of global urban change from 1985 to 2015*. https://doi.org/10.6084/m9.figshare.11513178.v1

Liu, X., Huang, Y., Xu, X. et al. (2020). High-spatiotemporal-resolution mapping of global urban change from 1985 to 2015. *Nat Sustain 3*, 564–570. https://doi.org/10.1038/s41893-020-0521-x

Maucha, G., Büttner, G., Kosztra, B., 2010. *European validation of GMES FTS Soil Sealing Enhancement*, Final draft. European Environment Agency, European Topic Centre Land Use and Spatial Information.

Thank you!

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