

# Update on urban canopy parameters for EXTPAR

## Survey of the existing datasets to derive ISA

Apreda C., Schulz J.-P., Reder A., Mercogliano P.

*REgional Models and geo-Hydrological Impacts (REMHI) Division, CMCC Foundation*



# 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**

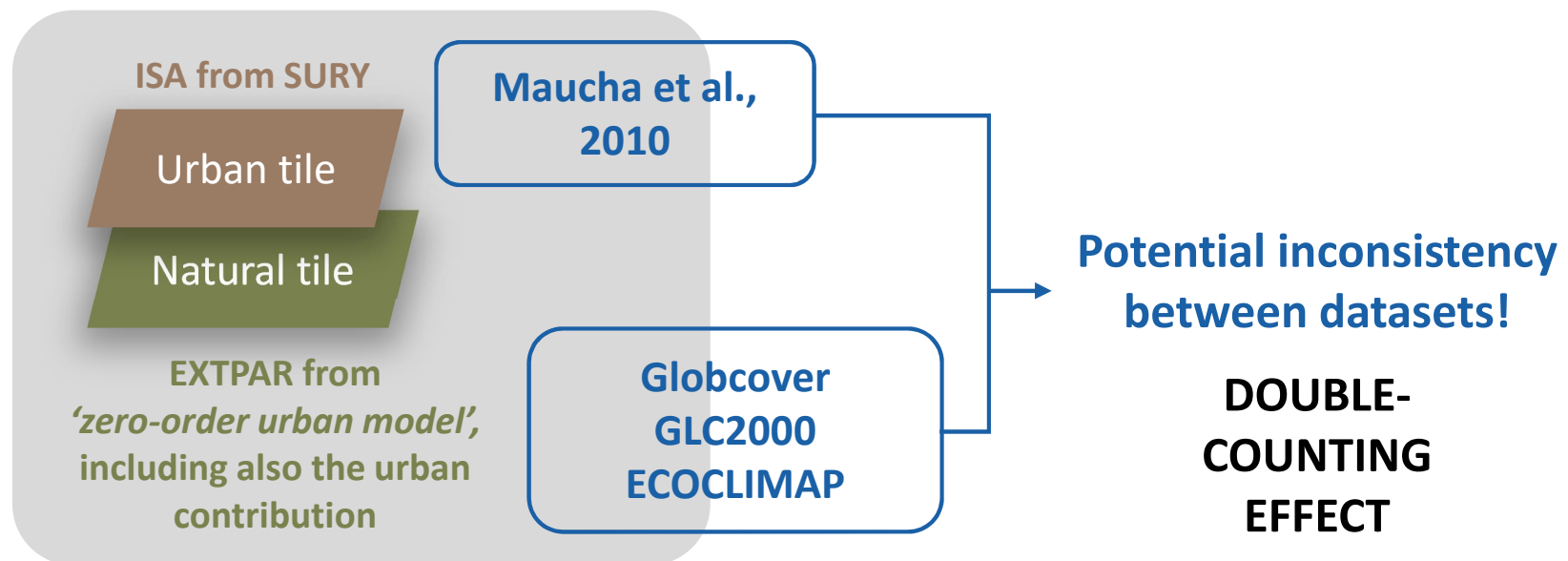


# Potential inconsistency when TERRA\_URB is activated

TERRA\_URB activated

■  
tile approach

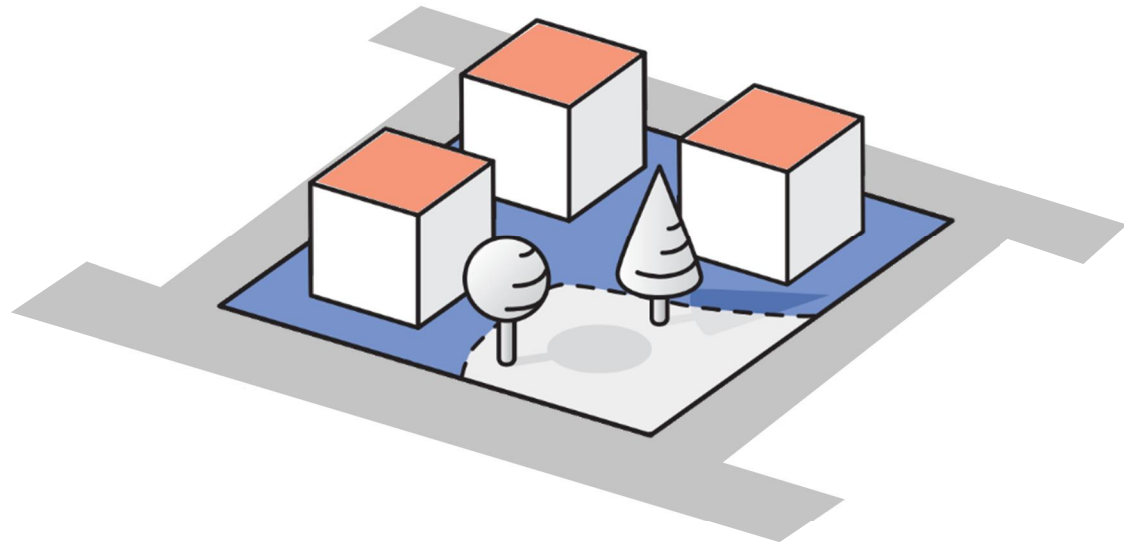
If the urban scheme is activated (TERRA\_URB=TRUE), a **tile approach** is implemented in which each cell is divided into two tiles, an urban tile and a natural tile.



# 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).

$$\begin{aligned} \text{ISA} = & \\ & \text{Roof areas (Built-up areas)} \\ & + \\ & \text{Paved areas (sidewalks,} \\ & \text{parking lots, etc.)} \\ & + \\ & \text{Streets} \end{aligned}$$





# Desk review of datasets to derive ISA available for Europe

Dataset/Producer	Resolution		Coverage		Classification scheme	Source
	Spatial	Temporal	Spatial	Temporal		
<i>Land cover datasets (Urban field)</i>						
<b>GlobCover/ESA &amp; UCLouvain</b>	300 m	Single year	Global	2009	FAO LCCS 22 classes	<a href="https://bit.ly/3uzxbxC">https://bit.ly/3uzxbxC</a>
<b>ESA CCI/C3S LC project/VITO on behalf of the ECMWF</b>	0.002778° (≈ 300 m)	yearly	Global	1992 -2020	FAO LCCS 22 classes	<a href="https://bit.ly/3twOnCp">https://bit.ly/3twOnCp</a>
<b>GLC2000 (Regional dataset)/EU-JRC</b>	0.00892857° (≈ 960 m)	Single year	European	2000	FAO LCCS 23 classes	<a href="https://bit.ly/3ot9tAE">https://bit.ly/3ot9tAE</a>
<b>CORINE Land Cover, CLC/EEA</b>	100 m	Single year	European	1990 - 2000 - 2006 - 2012 - 2018	44 classes	<a href="https://bit.ly/3yI57dL">https://bit.ly/3yI57dL</a>
<i>Land cover dataset with LCZs</i>						
<b>ECOCLIMAP-SG/CNRM</b>	300 m	Single year	Global	2018	33 classes (from ESA-CCI GLC v1.6.1 and CLC)	<a href="https://bit.ly/3bihmDJ">https://bit.ly/3bihmDJ</a>
<i>Impervious areas datasets (ISA field)</i>						
<b>GAUD/Liu et al., 2020</b>	30 m	yearly	Global	from 1985 to 2015	Urban grid	<a href="https://bit.ly/3wf9xqw">https://bit.ly/3wf9xqw</a>
<b>GAIA/Gong et al., 2020</b>	30 m	yearly	Global	from 1985 to 2018	Non-impervious/ impervious areas	Gong et al., 2020 <a href="https://bit.ly/3bhABxb">https://bit.ly/3bhABxb</a>
<b>CLMS Imperviousness Density, IMD/EEA</b>	100 m 20 m 10 m (2018)	Single year	European (EEA39)	2006 – 2009 – 2012 – 2015 - 2018	Degree of imperviousness (0-100%)	<a href="https://bit.ly/2Qwkipf">https://bit.ly/2Qwkipf</a>

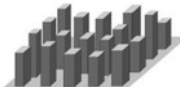





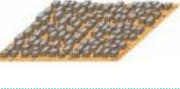





# Description of artificial classes – “URBAN” DATASETS

Dataset/Producer	Classes	Descriptions
<b>GlobCover/ESA &amp; UCLouvain</b>	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).
<b>ESA CCI/C3S LC project/VITO on behalf of the ECMWF</b>	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]
<b>Corine Land Cover, CLC/EEA</b>	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.
<b>GLC2000 (Regional dataset)/EU-JRC</b>	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	<ul style="list-style-type: none"> <li>• Strong built-up NDVI <math>\leq 0.2</math> and high rise buildings (3D roughness 50-100m)</li> <li>• Strong built-up NDVI <math>\leq 0.2</math> and very high rise buildings (3D roughness <math>&gt; 100\text{m}</math>)</li> </ul>
	 25. LCZ2: compact mid-rise	<ul style="list-style-type: none"> <li>• Continuous urban fabric (from CLC)</li> <li>• Strong built-up NDVI <math>\leq 0.2</math> and medium rise buildings (3D roughness 25-50m)</li> </ul>
	 26. LCZ3: compact low-rise	<ul style="list-style-type: none"> <li>• Strong built-up NDVI <math>\leq 0.2</math> and low rise buildings (3D roughness <math>&lt; 25\text{m}</math>)</li> </ul>
	 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	<ul style="list-style-type: none"> <li>• Medium built-up <math>0.2 &lt; \text{NDVI} \leq 0.3</math> (o 6)</li> </ul>
	 29. LCZ6: open low-rise	<ul style="list-style-type: none"> <li>• Light built-up <math>0.3 &lt; \text{NDVI} \leq 0.4</math></li> </ul>
	 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	<ul style="list-style-type: none"> <li>• Industrial or commercial unit, Airports (from CLC)</li> <li>• Built-up with highly reflecting roof (associated to productive and commercial use)</li> <li>• Roads</li> </ul>
	 32. LCZ9: sparsely built	<ul style="list-style-type: none"> <li>• Road and rail networks and associated land, Mineral extraction sites, Dump sites, Construction sites, Green Urban Areas, Sport and leisure facilities (from CLC)</li> <li>• Very light built-up NDVI <math>&gt; 0.4</math></li> </ul>
	 33. LCZ10: heavy industry	<ul style="list-style-type: none"> <li>• Port areas (from CLC)</li> </ul>



# Description of impervious classes – “ISA” DATASETS

Dataset/Producer	Classes	Descriptions
<b>GAUD</b> / <i>Liu et al., 2020</i>	Urban areas	Pixels that are dominated by built elements (for example, buildings, roads, runways and so on).
<b>GAIA</b> / <i>Gong et al., 2020</i>	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.
<b>CLMS Imperviousness Density, IMD/EEA</b>	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
<b>GAUD</b> / <i>Liu et al., 2020</i>	Urban areas	Pixels that are dominated by built elements (for example, buildings, roads, runways and so on).
<b>GAIA</b> / <i>Gong et al., 2020</i>	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.
<b>CLMS Imperviousness Density, IMD/EEA</b>	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%).

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.**

<b>GAUD</b> / <i>Liu et al., 2020</i>	30 m	yearly	from 1985 to 2015
<b>GAIA</b> / <i>Gong et al., 2020</i>	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%)**.

<b>CLMS Imperviousness Density, IMD/EEA</b>	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](#))



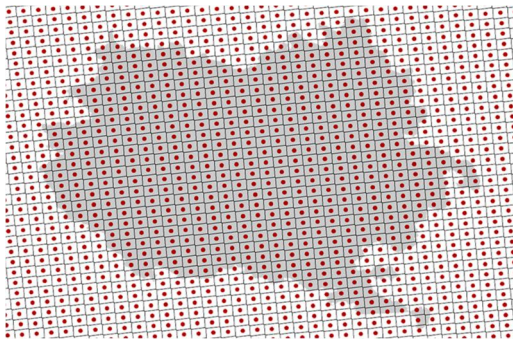
# Methodology

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

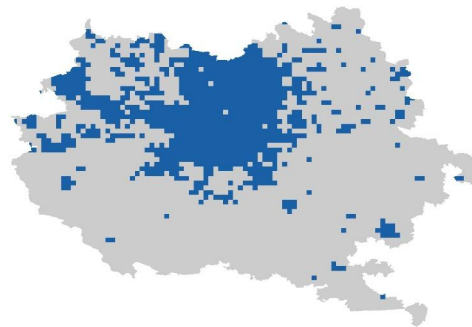


The target grid is centered on the points of the COSMO-CLM domain

- 2 Convert the raster version of datasets into polygon features

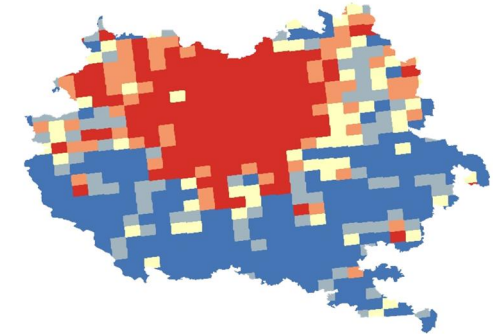
**ISA datasets**

*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



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 <b>more recent</b> and <b>more detailed</b> datasets
			C2.2	GAUD 2015 GAIA 2018 CLMS – IMD 2018	Original resolution 2 km grid	
			C2.3	GAUD* GAIA*	2 km grid	Verify the potential update of current ISA field (Maucha et al., 2010) with <b>more detailed</b> datasets for a selected year
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 <b>LCZ classes</b> and/or <b>imperviousness density</b> .	

\*Open issue → selection of the year for GAIA and GAUD: to be discussed with the EXTPAR group!



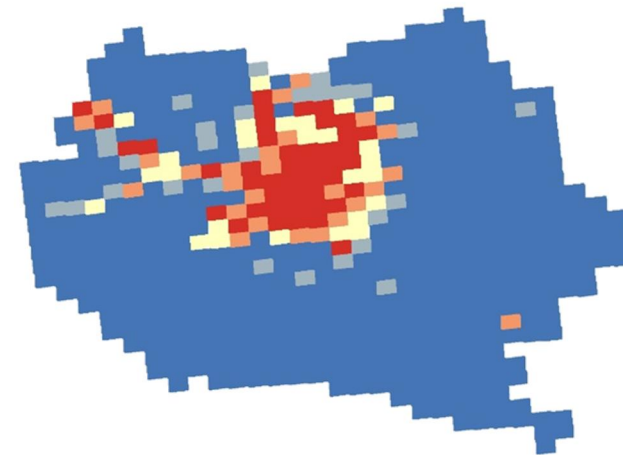


## Milan (2 km grid)

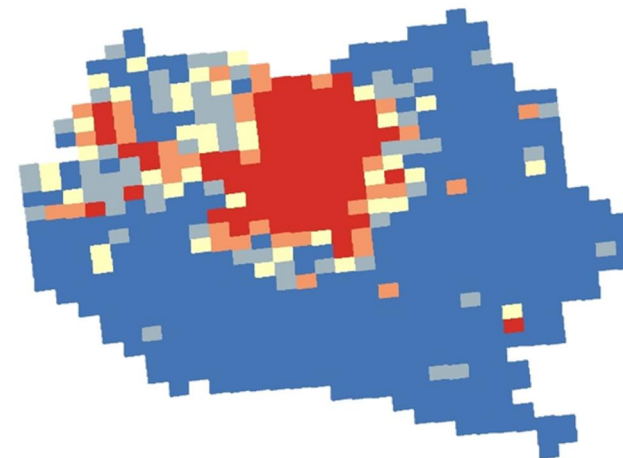
Open issue: check with the project team the interpolation method adopted in COSMO-CLM for land cover classes and the method to derive URBAN areas from GLC2000 dataset!!!



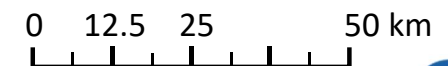
The map highlight an increase in the % of urban areas as compared to the data adopted in the COSMO-CLM simulation



URBAN field from COSMO-CLM (GLC2000)

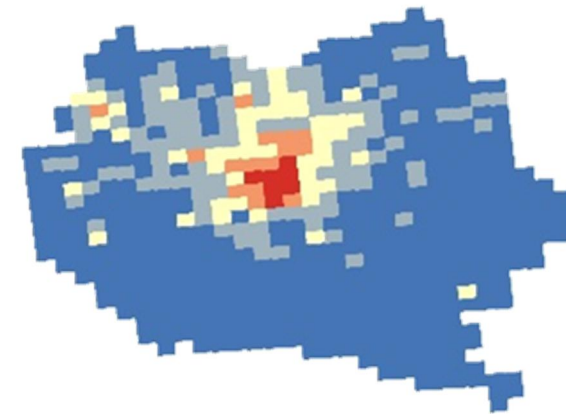


URBAN field from GLC2000 dataset

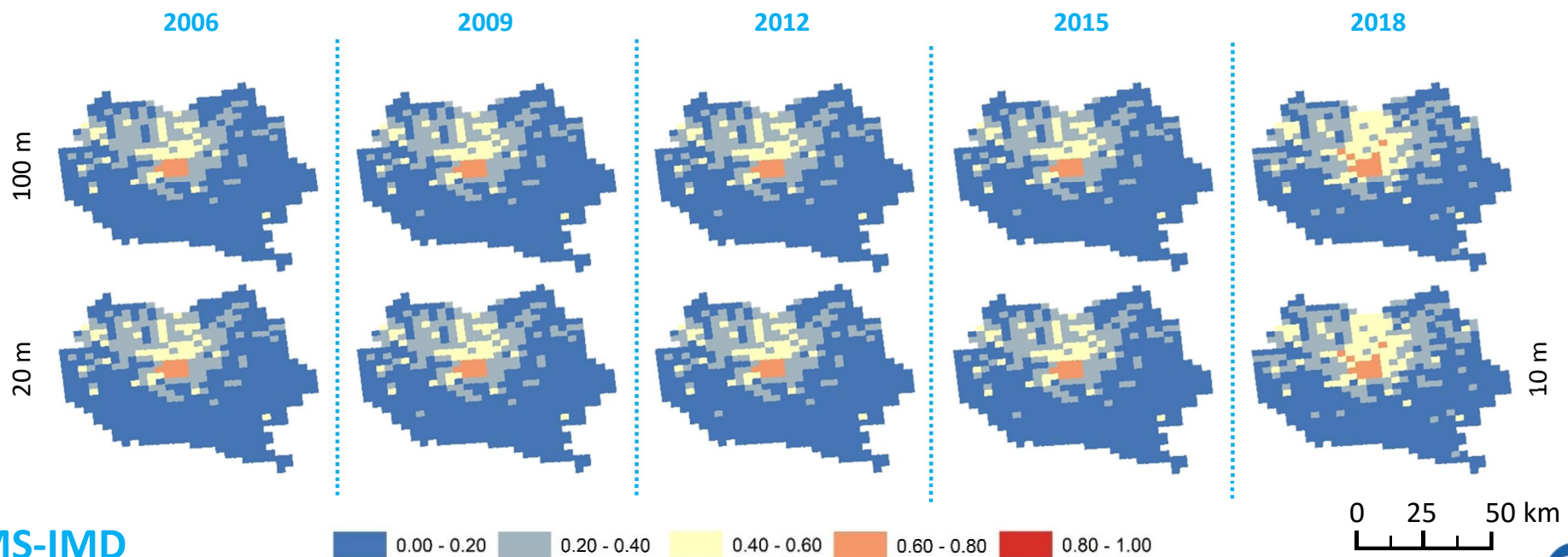


## Milan (2 km grid)

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)

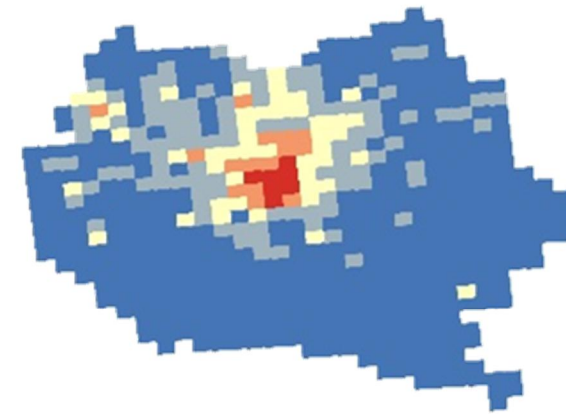


# Comparison between ISA datasets at local level

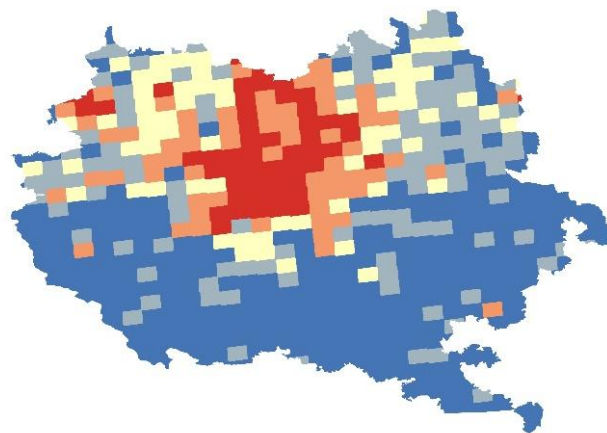
C2.2

## Milan (2 km grid)

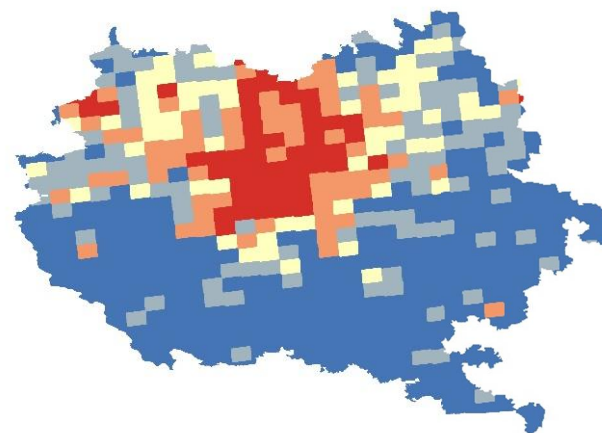
In GAUD and GAIA datasets, impervious pixels are considered 100% sealed surfaces. Furthermore, due to their lower spatial resolution as compared with CLMS-IMD, they tend to overestimate ISA.



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)

0.00 - 0.20 0.20 - 0.40 0.40 - 0.60 0.60 - 0.80 0.80 - 1.00

0 12.5 25 50 km

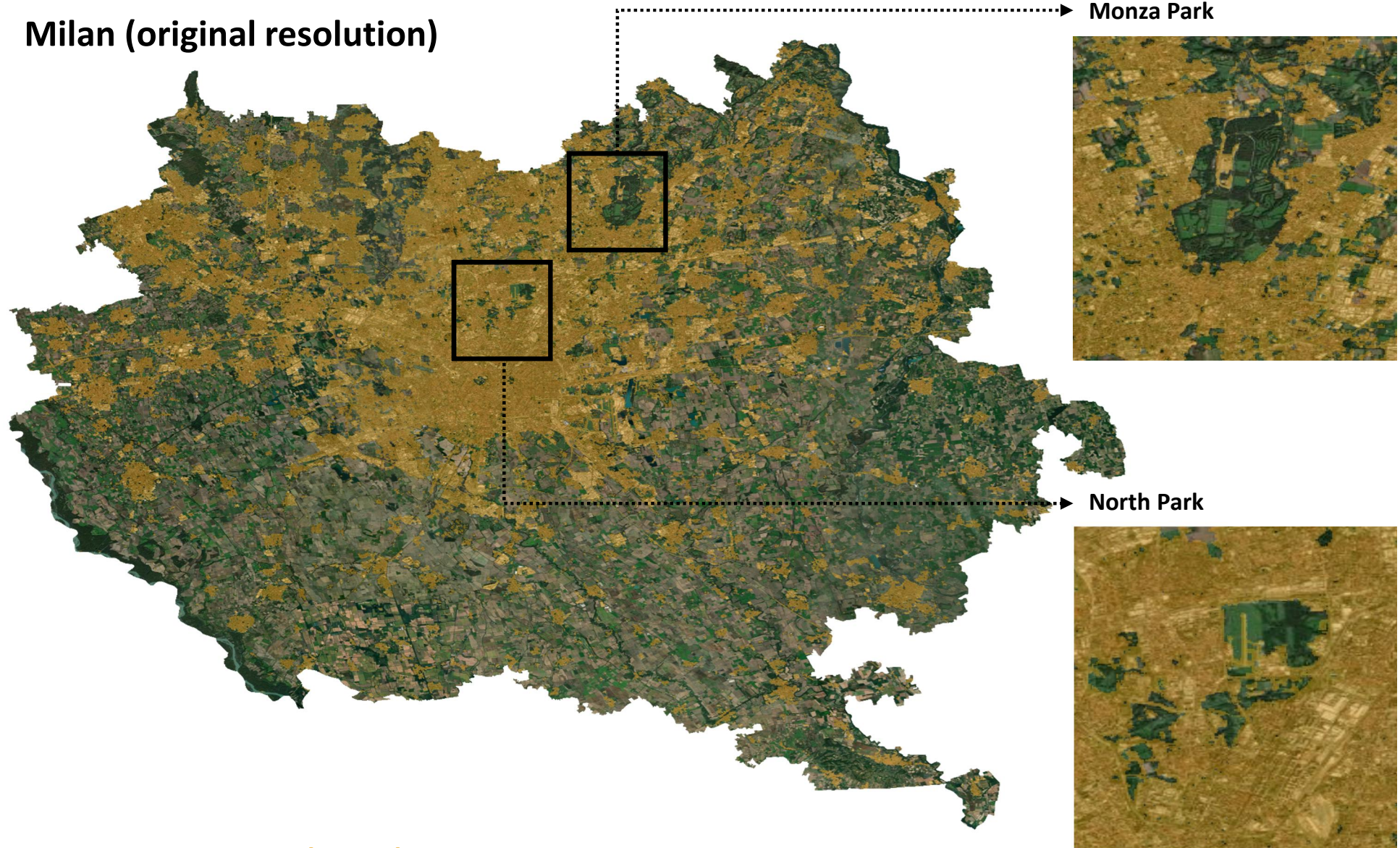




# Comparison between ISA datasets at local level

C2.2

Milan (original resolution)



ISA – GAUD 2015 (30 m)

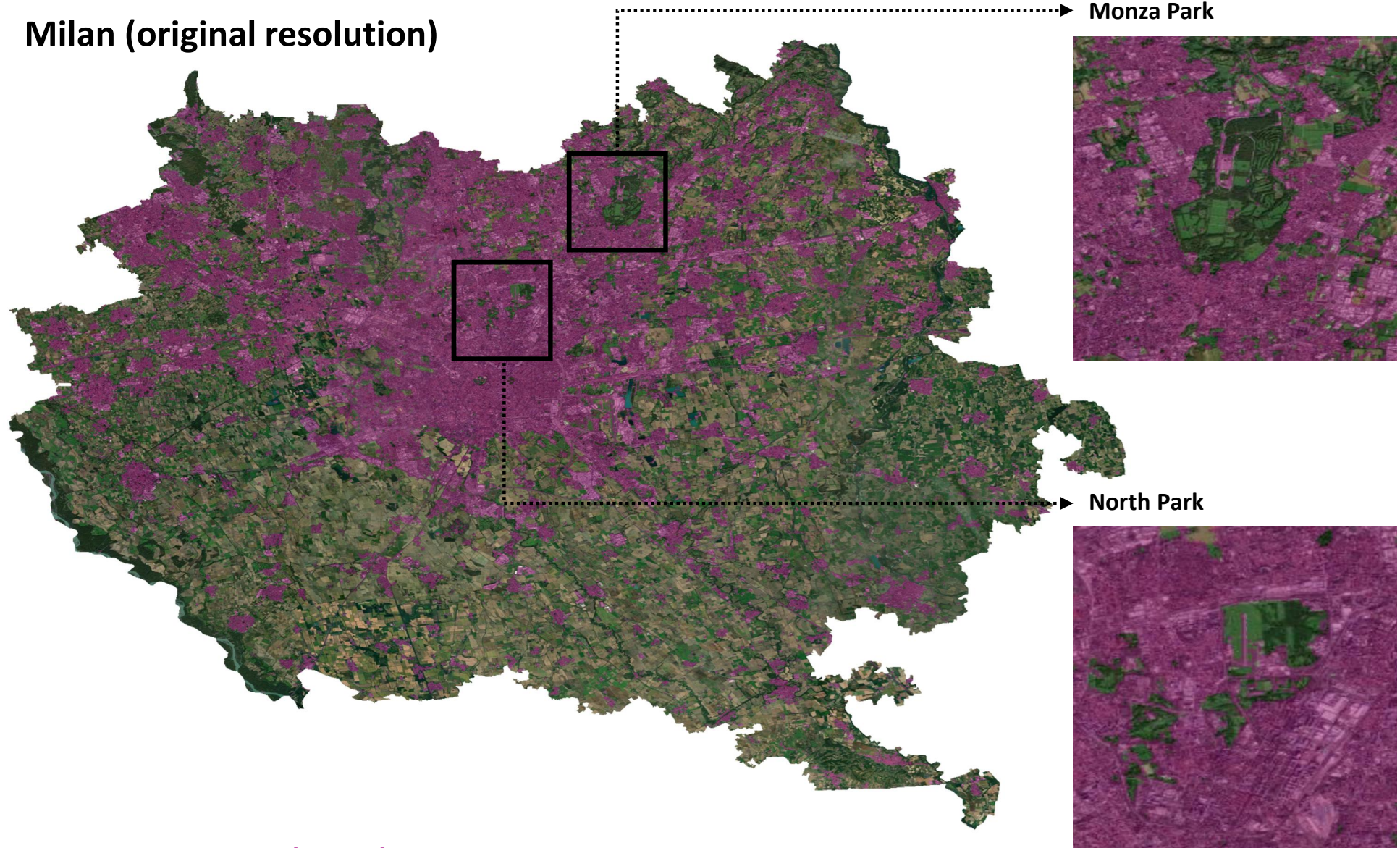




# Comparison between ISA datasets at local level

C2.2

Milan (original resolution)



ISA – GAIA 2018 (30 m)

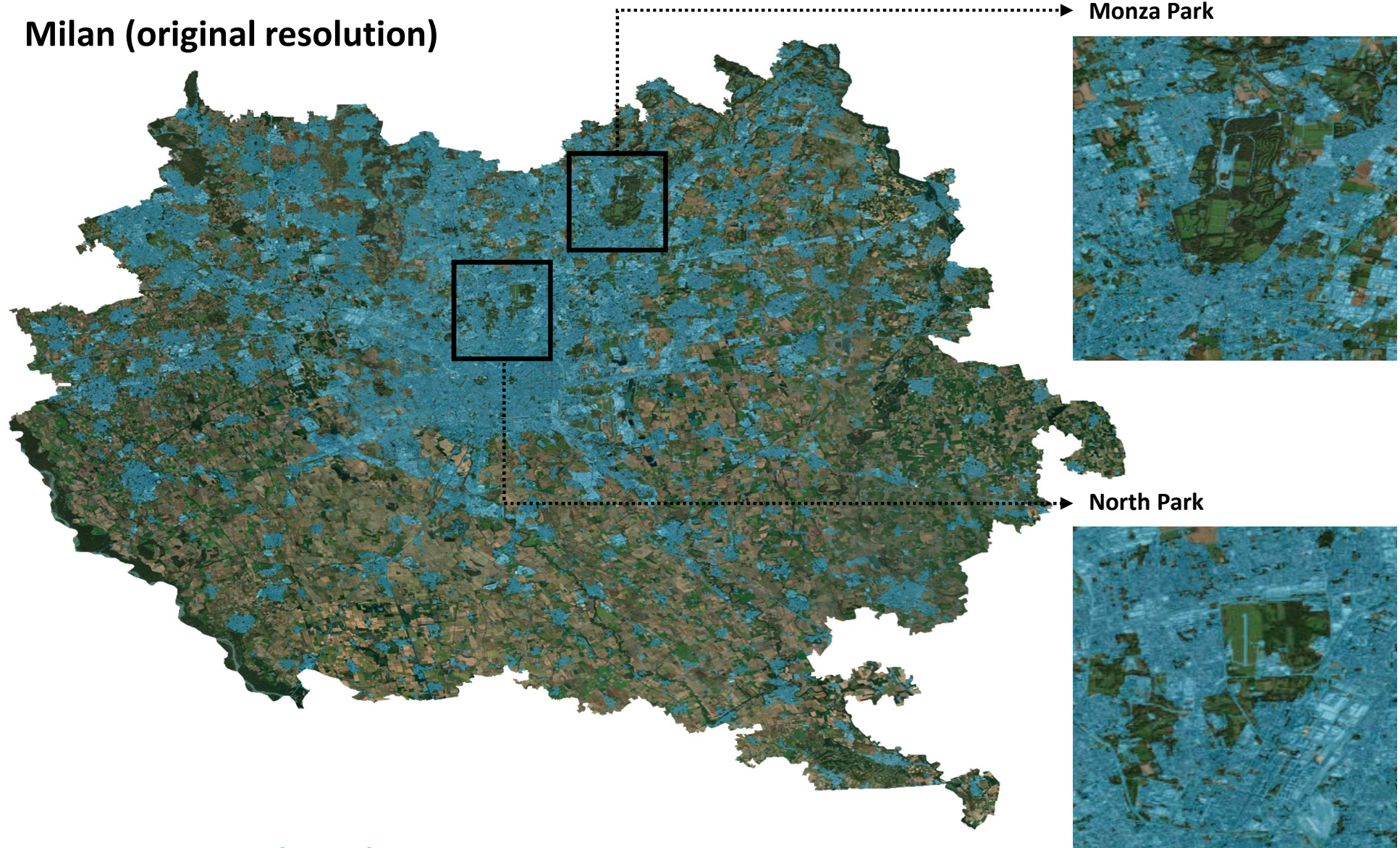




# Comparison between ISA datasets at local level

C2.2

Milan (original resolution)



ISA – IMD 2018 (10 m)

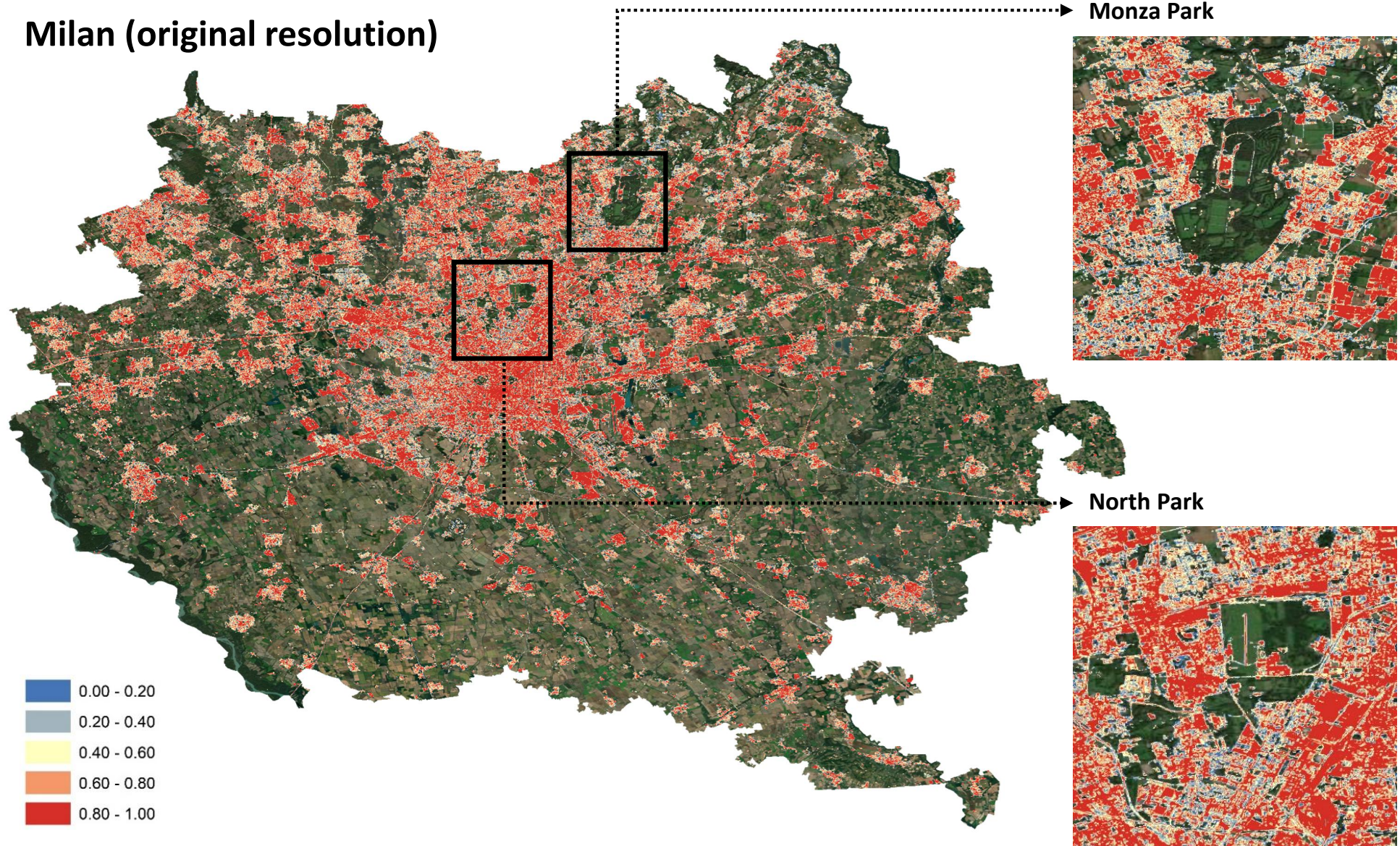




# Comparison between ISA datasets at local level

C2.2

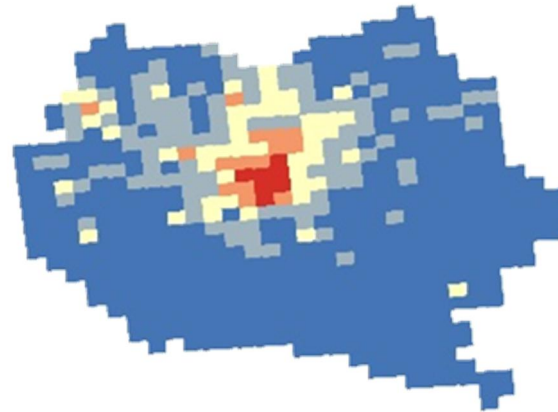
Milan (original resolution)



ISA – IMD 2018 (10 m)



Milan (2 km grid)

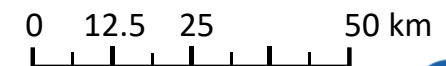


ISA field from COSMO-CLM simulation (Maucha et al., 2010)

**\*Open issue → selection of the year for GAIA and GAUD: to be discussed with the EXTPAR group!  
(It depends on the reference year of dataset in Maucha et al., 2010)**

ISA – GAUD\* (30 m)

ISA – GAIA\* (30 m)





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



**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

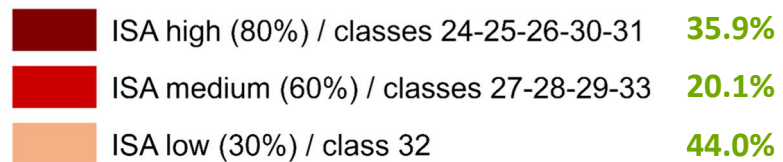
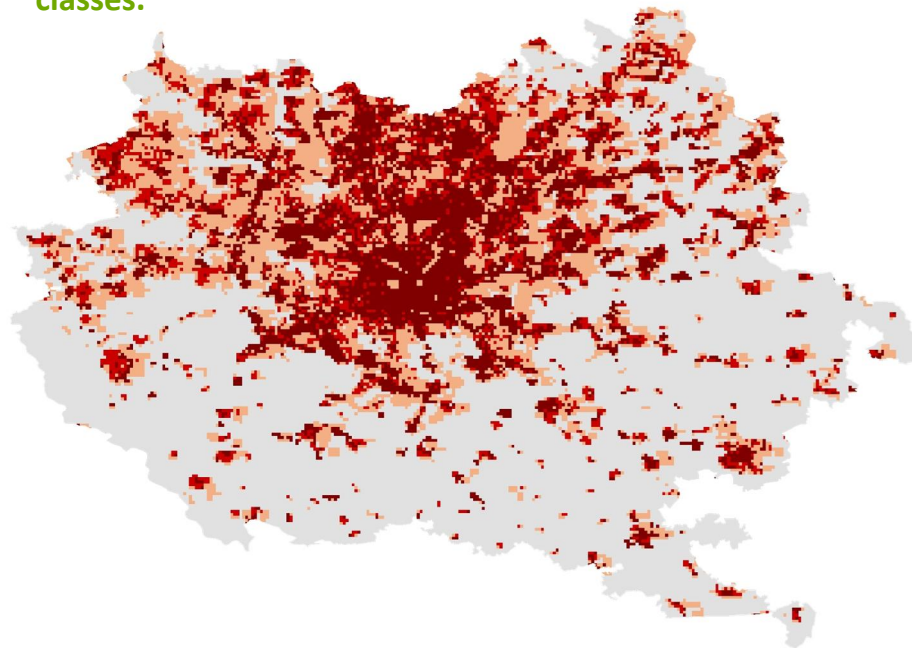
CLMS-IMD
71-100%
41-70%
1-40%

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



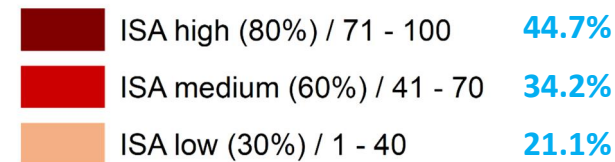
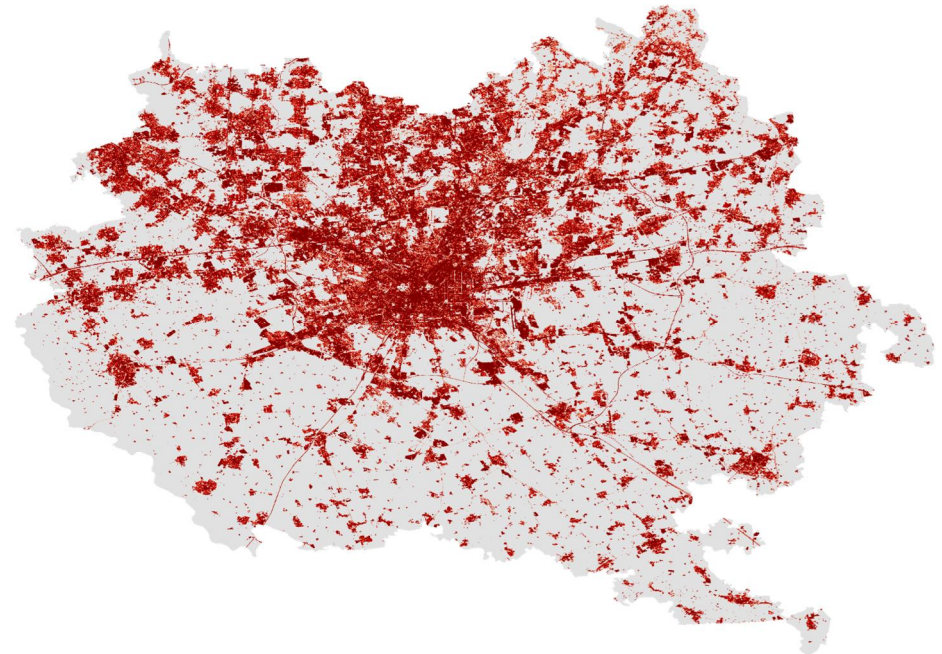
## Milan (original resolution)

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



ECOCLIMAP-SG (300m)

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

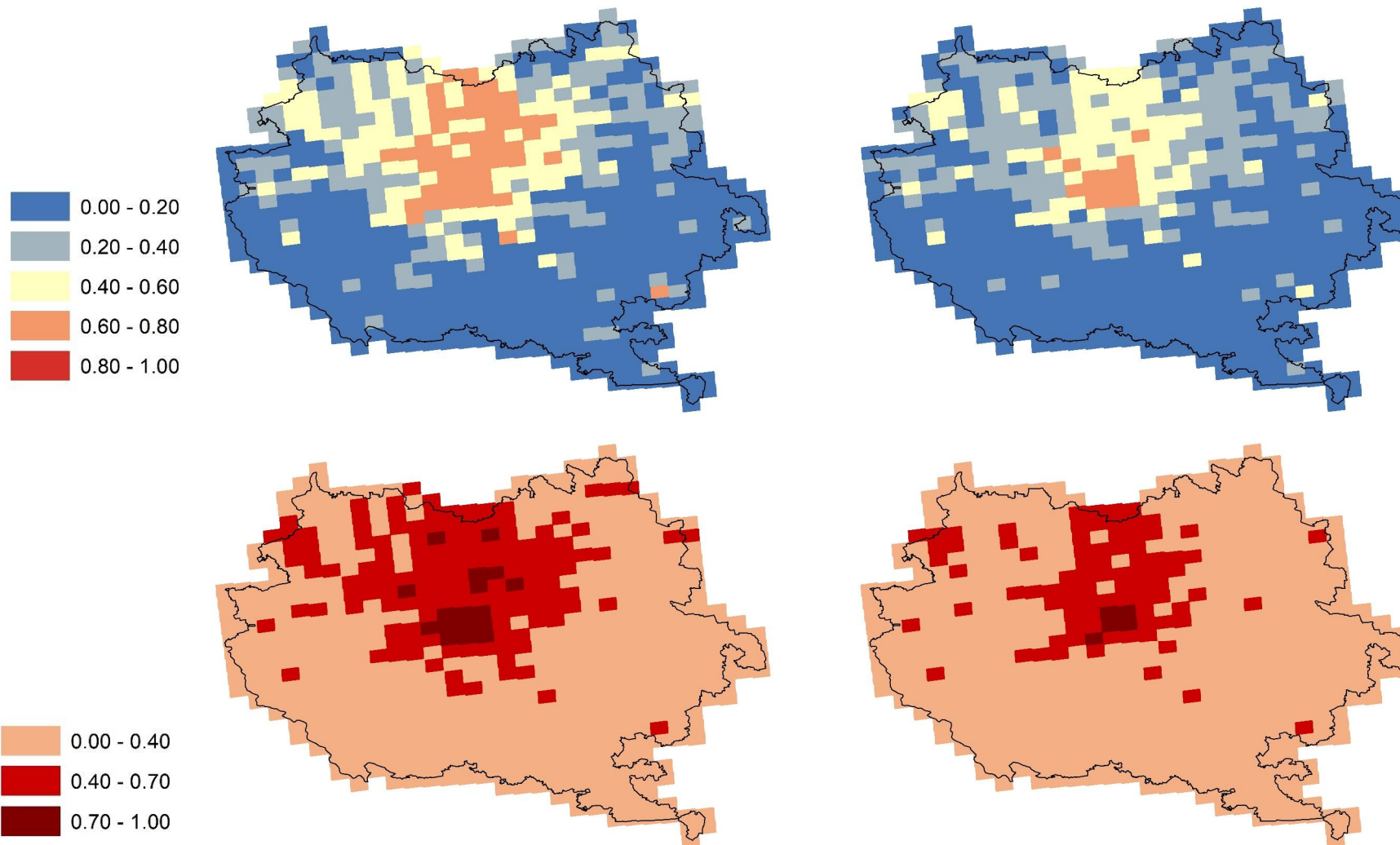


CLMS-IMD 2018 (10 m)

0 5 10 km



## Milan (2 km grid)



ECOCLIMAP-SG (300m)

CLMS-IMD 2018 (10 m)

0 10 20 km



# 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 ISSUE**

- 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

**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!

carmela.apreda@cmcc.it  
Jan-Peter.Schulz@dwd.de  
alfredo.reder@cmcc.it  
paola.mercogliano@cmcc.it