

A novel risk assessment workflow for differential land subsidence based on satellite InSAR and urban settlement data: present-day risk scenario in the metropolitan cities of Italy

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Scientific goals

Differential land subsidence affects many world metropolises, impacting their infrastructure and population, and causing significant socio-economic impacts.

This work showcases an **innovative methodology for exposure-vulnerability rating, hazard quantification and risk assessment** that integrates InSAR-derived ground displacement data, land cover and urban settlement characteristics. Such an integrated approach represents a significant step forward from displacement velocity-based approaches that are nowadays common in the specialist literature, to actionable risk information that are still rare.

The workflow is exploited to estimate **present-day land subsidence-induced risk in Italy**, one of world countries most affected by ground deformation processes. Its 15 metropolitan cities host > 21.7 M inhabitants (out of 59 M censed in the country) across 54,380 km².

Risk assessment workflow

Land subsidence-induced deformation and structural stress on urban assets are quantified within the 15 metropolitan cities, along with the distribution and amount of residential/non-residential infrastructure and population exposed.

An innovative exposure-vulnerability (EV) scoring building upon urban settlement characteristics

Input datasets:

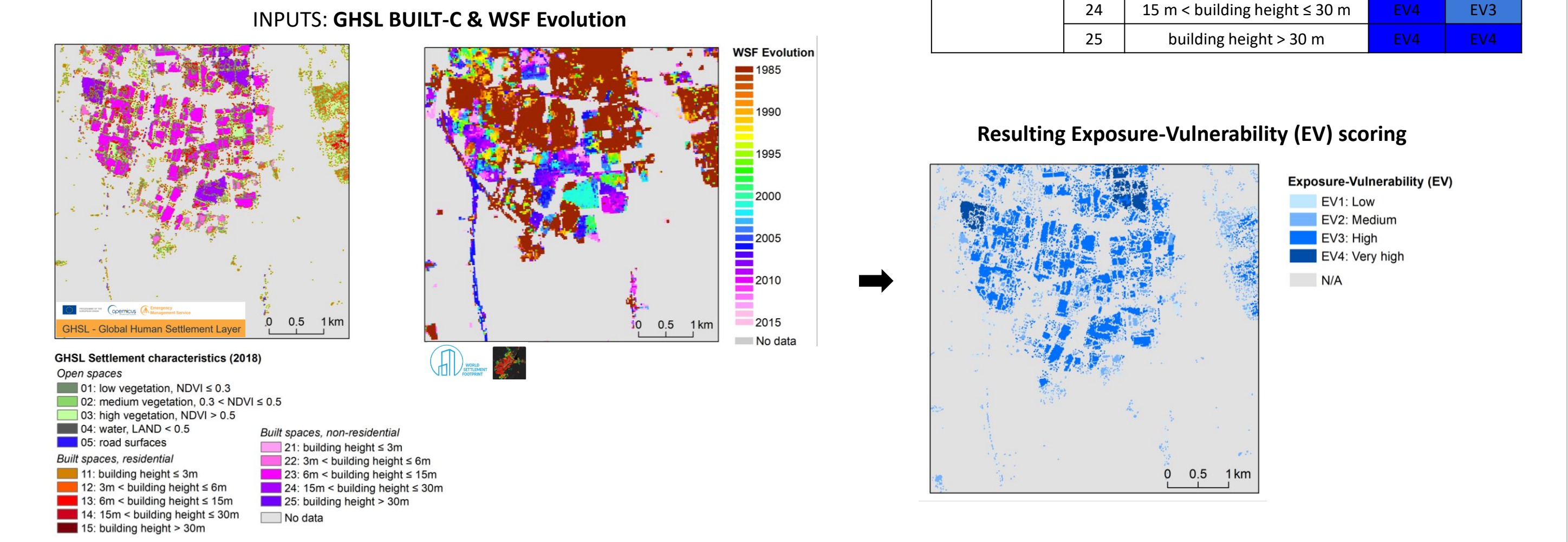
- Global Human Settlement Layer (GHS-L) BUILT-C settlement characteristics → [type, height]
- World Settlement Footprint (WSF) Evolution → [construction year]

Assumptions:

- Non residential buildings (e.g. hospitals, churches, industrial sheds) are more vulnerable
- Older buildings are more vulnerable (by law, new buildings use reinforced concrete vs. masonry/old buildings)

Age

	≤ 1985	> 1985		
Open spaces	01-05	low to high vegetation, water and road surfaces	n/a	
Built spaces, Residential	11	building height ≤ 3 m	EV2	EV1
	12	3 m < building height ≤ 6 m	EV3	EV2
	13	6 m < building height ≤ 15 m	EV3	EV2
	14	15 m < building height ≤ 30 m	EV4	EV3
	15	building height > 30 m	EV4	EV3
Built spaces, Non-residential	21	building height ≤ 3 m	EV2	EV2
	22	3 m < building height ≤ 6 m	EV3	EV2
	23	6 m < building height ≤ 15 m	EV3	EV3
	24	15 m < building height ≤ 30 m	EV4	EV3
	25	building height > 30 m	EV4	EV4



A refined hazard (H) assessment based on the structural stress induced by differential displacement

Angular distortion (β)

$\beta = \frac{\Delta d_{U_i}}{l}$

Δd_{U_i} = Vertical differential displacement occurred between the two points
 l = distance between the two points

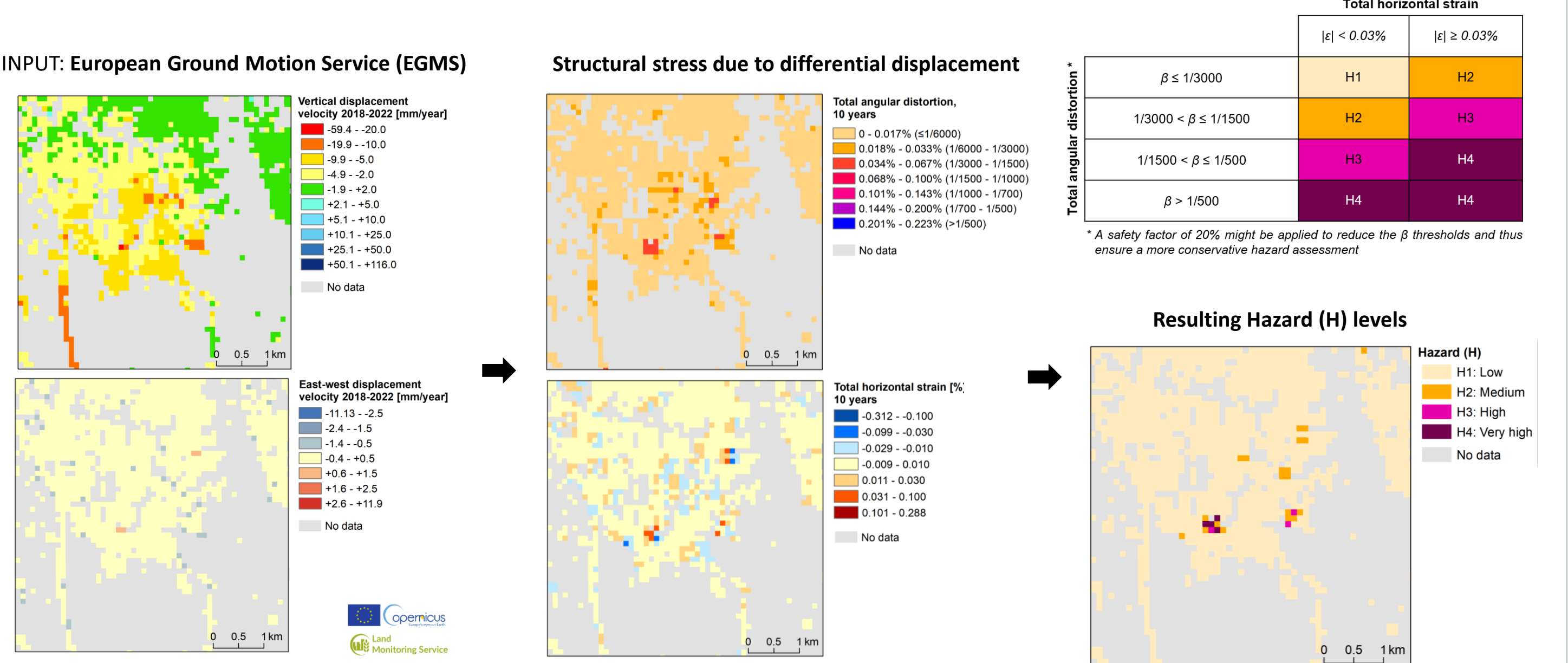
e.g. $\beta = 0.22\%$ (1/450) refers to a total of 22 cm differential displacement over a 100 m distance

Horizontal strain (ϵ)

$\epsilon = \frac{\Delta d_{E_i}}{l}$

Δd_{E_i} = E-W differential displacement between the two points
 l = distance between the two points

e.g.: $\epsilon = 0.15\%$ (1/670) refers to a total of 15 cm differential displacement over a 100 m distance



Geospatial combination of H and EV through a tailored risk matrix

Risk = Hazard x Exposure x Vulnerability

Inputs:

- Hazard (H1 to H4)
- Exposure-Vulnerability (EV1 to EV4)

Output:

- Risk classes (R1 to R3)
- NoData (no hazard data)
- N/A (unbuilt spaces)

HAZARD

	H1	H2	H3	H4
EV1	R1	R1	R2	R2
EV2	R1	R2	R2	R3
EV3	R2	R2	R3	R3
EV4	R2	R3	R3	R3

EXPOSURE-VULNERABILITY

R1 = low → Acceptable risk level, no actions

R2 = medium → Relevant risk level, potential for structural damage, tailored monitoring is recommended

R3 = high → Maximum risk level, high likelihood of occurred/incipient structural damage, site inspections and mitigation measures are recommended at single-infrastructure scale

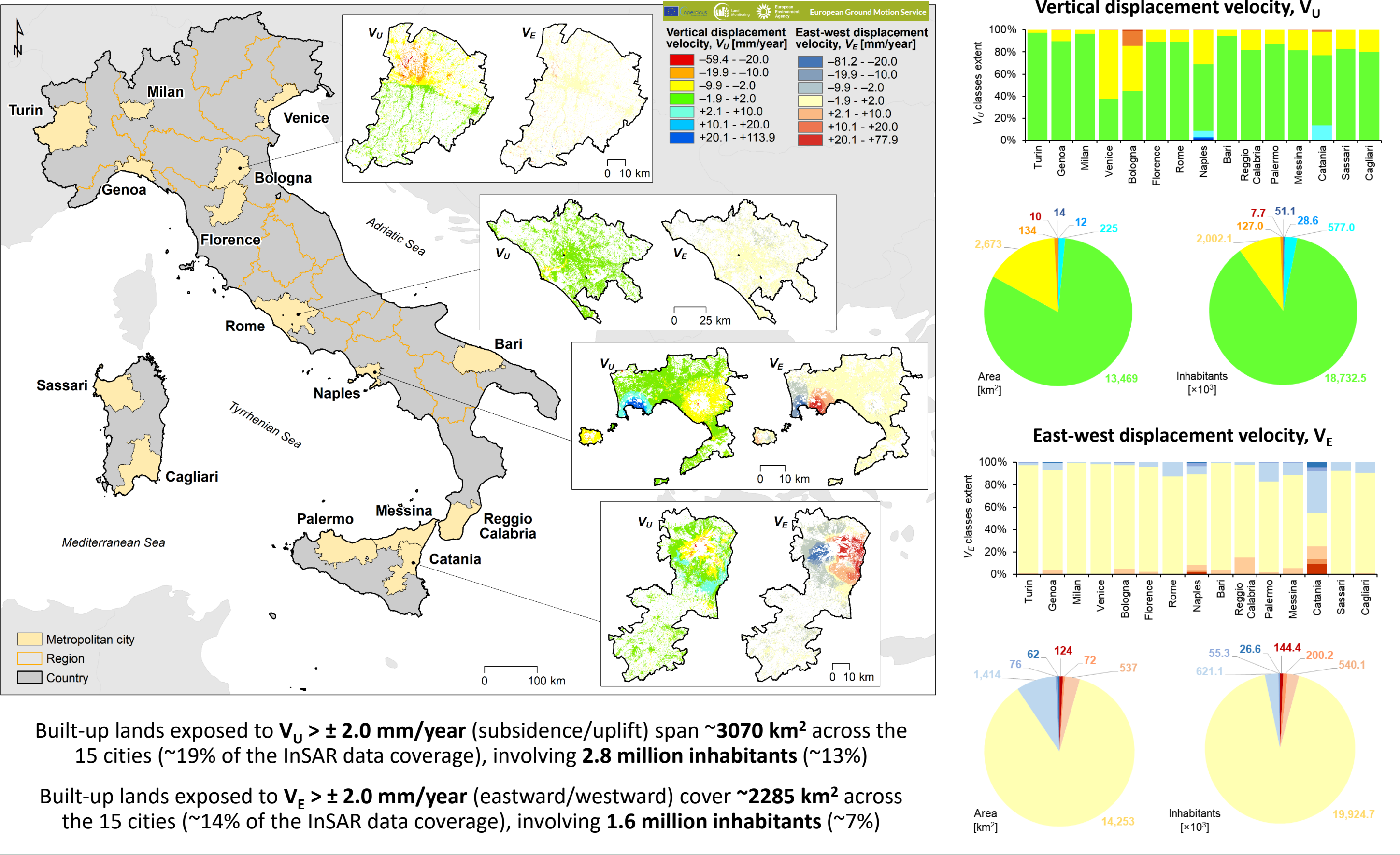
Risk (R)

- R1: Low
- R2: Medium
- R3: High
- No data

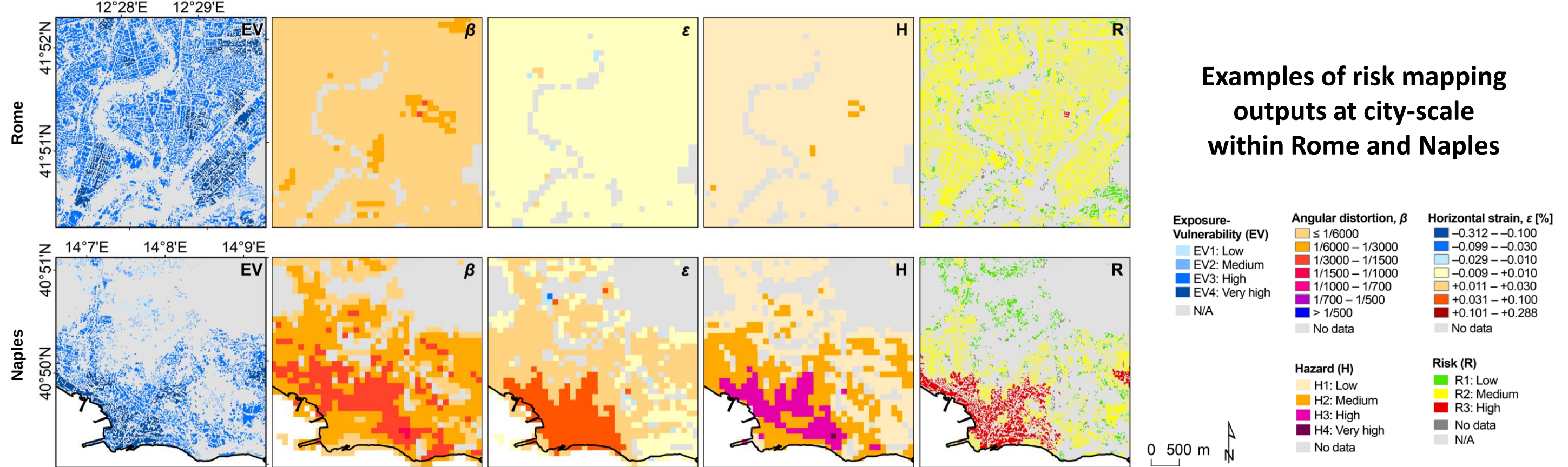


Enhancing our understanding of Subsidence RISK induced by groundwater exploitation towards sustainable urban development

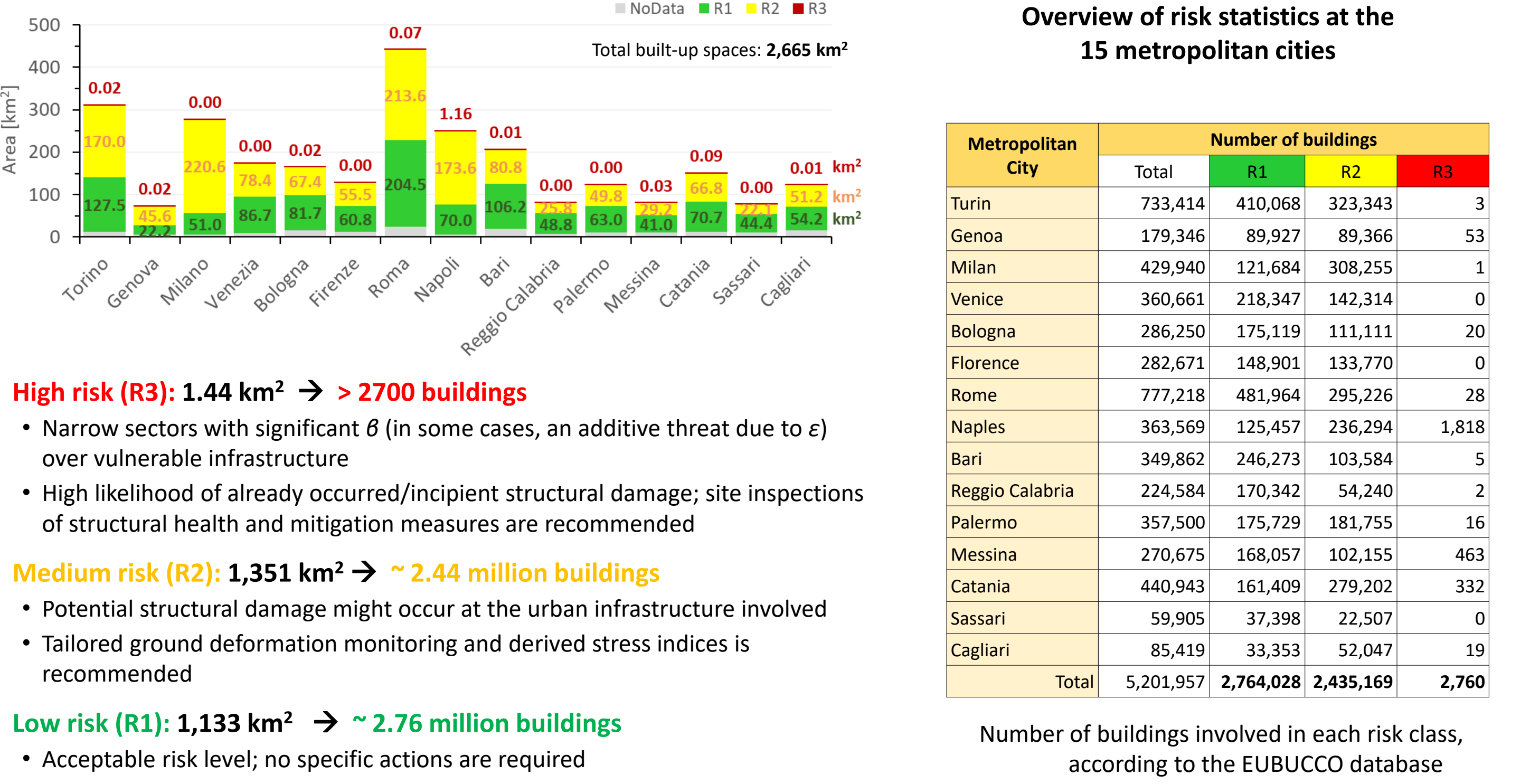
Urban land and population exposed to displacement



Present-day differential displacement-induced risk (R)



The analysis shows that a total of 1.44 out of 2665 km² urbanised land within the 15 cities is at high risk (R3) due to significant angular distortions (and, sometimes, additive threat from horizontal strain) affecting very high exposure-vulnerability infrastructure. Moreover, it is estimated that, for more than 2700 buildings within the 15 cities, there is high likelihood of already occurred/incipient structural damage.



Conclusions

The reference knowledge-base on present-day subsidence-induced risk can inform land and risk management at national scale, and provides a baseline for future assessments to build upon with a look to the next decades and sustainable urban development.

Acknowledgements

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FULL PAPER

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