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Airborne LiDAR and Hyperspectral Data to Support the Seismic Vulnerability of Urban Environments

Antonio Costanzo [1], Antonio Montuori [1], Juan Pablo Silva [2], Malvina Silvestri [3], Massimo Musacchio [3], Maria Fabrizia Buongiorno [3], Salvatore Stramondo [3]

[1] Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Rende (CS), Italy

[2] Comisión Nacional de Actividades Espaciales, Agencia de Recaudación de la Provincia de Buenos Aires, Argentina;

[3] Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Roma, Italy;

Outline

- **Motivations**
- **Methodology**
- **Case Study**
- **Intermediate products**
  - **DTM & DSM**
  - **Built-up areas**
  - **Land-use and land-cover map**
- **Value-added products**
  - **Topographic assessment map**
  - **Building assessment map**
  - **Road assessment map**
- **Conclusions**

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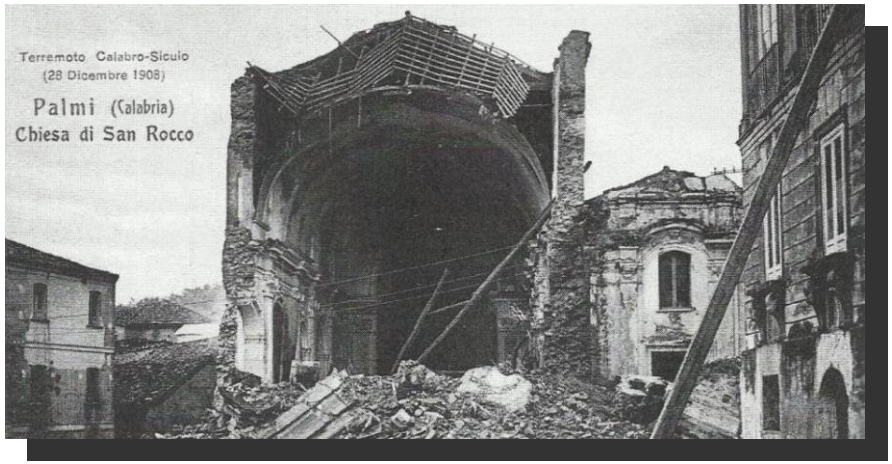
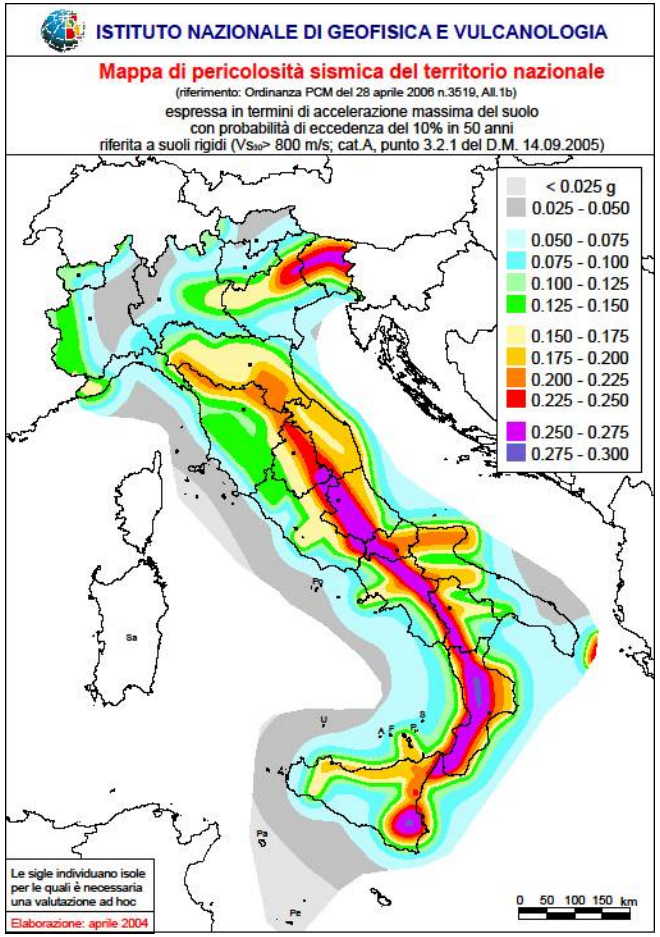
Motivations

The seismic vulnerability analysis of urban environments concerns the comprehensive knowledge of both building structural features and soils geophysical parameters, especially when considering areas that are prone to natural and/or anthropogenic disasters (e.g. earthquakes, landslides, fires, flooding and so on).





The formulation of operational seismic vulnerability assessment procedures could be possible in a holistic manner by considering several time dependent variables related to the vulnerability concepts at different spatial scales.

Motivations

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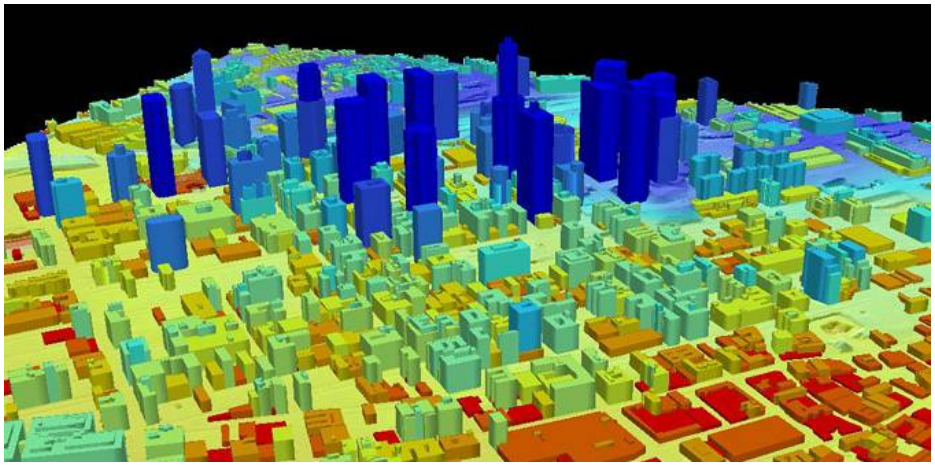
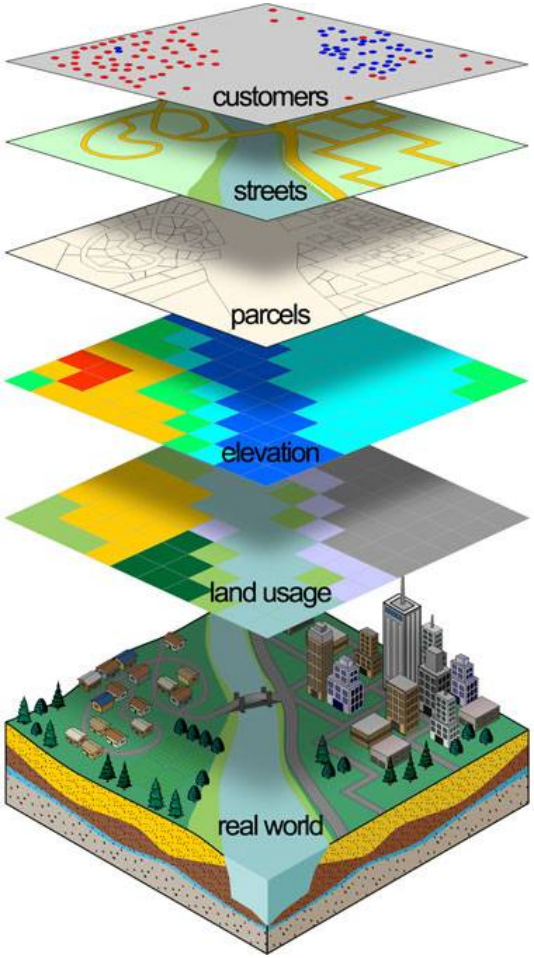
Our Approach →Combine airborne LiDAR and Hyperspectral measurements within a GIS platform to support the seismic vulnerability assessment of urban seismic areas





The present work is supported and funded by Ministero dell'Università, dell'Istruzione e della Ricerca (MIUR) under the research project PON "MASSIMO" - "Monitoraggio in Area Sismica di SIstemi MOnumentali".

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Methodology

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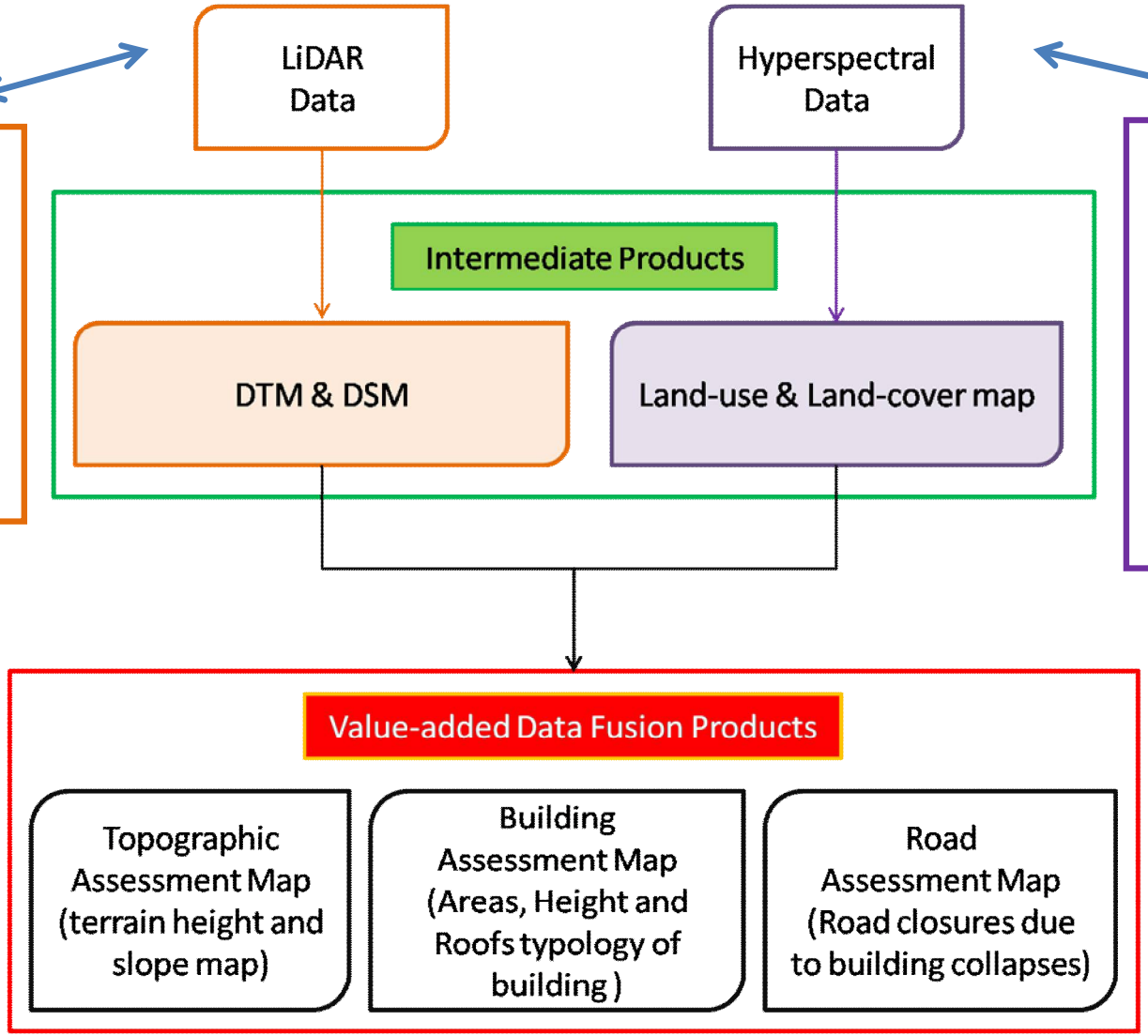
The airborne LiDAR survey is carried out by RIEGL LMS-Q680i sensor, which is able to interface with the GNSS/INS NOVATEL SPAN /SE receiver



IMSpectorV10E visible and near-infrared (VNIR) measurements have been acquired by the airborne IPERGEO sensor.

Block scheme of the methodology proposed to integrate airborne LiDAR and Hyperspectral data and hence carry out intermediate and value-added products.

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Case study: Urban area of Cosenza (Calabria, South Italy)

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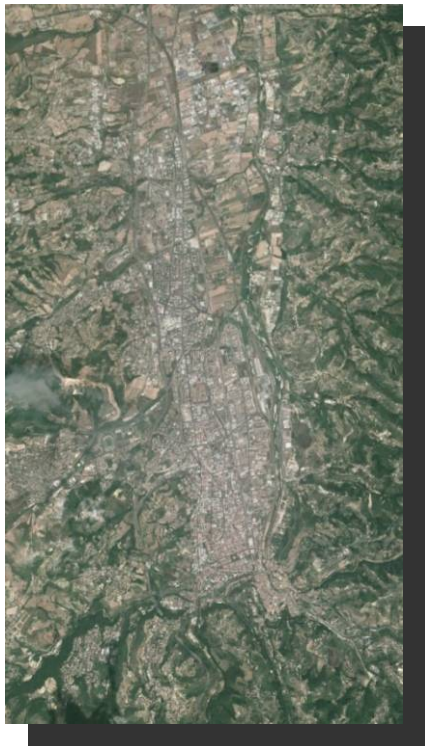
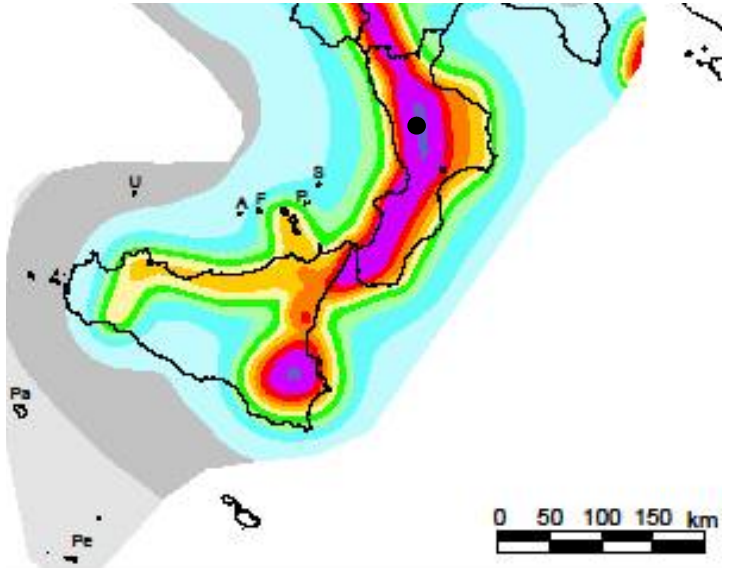
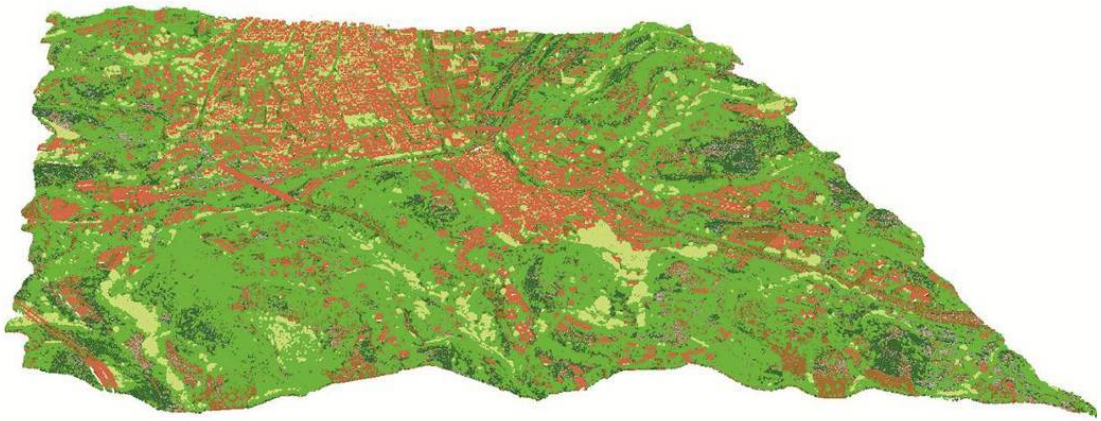




Urban area of the Cosenza city



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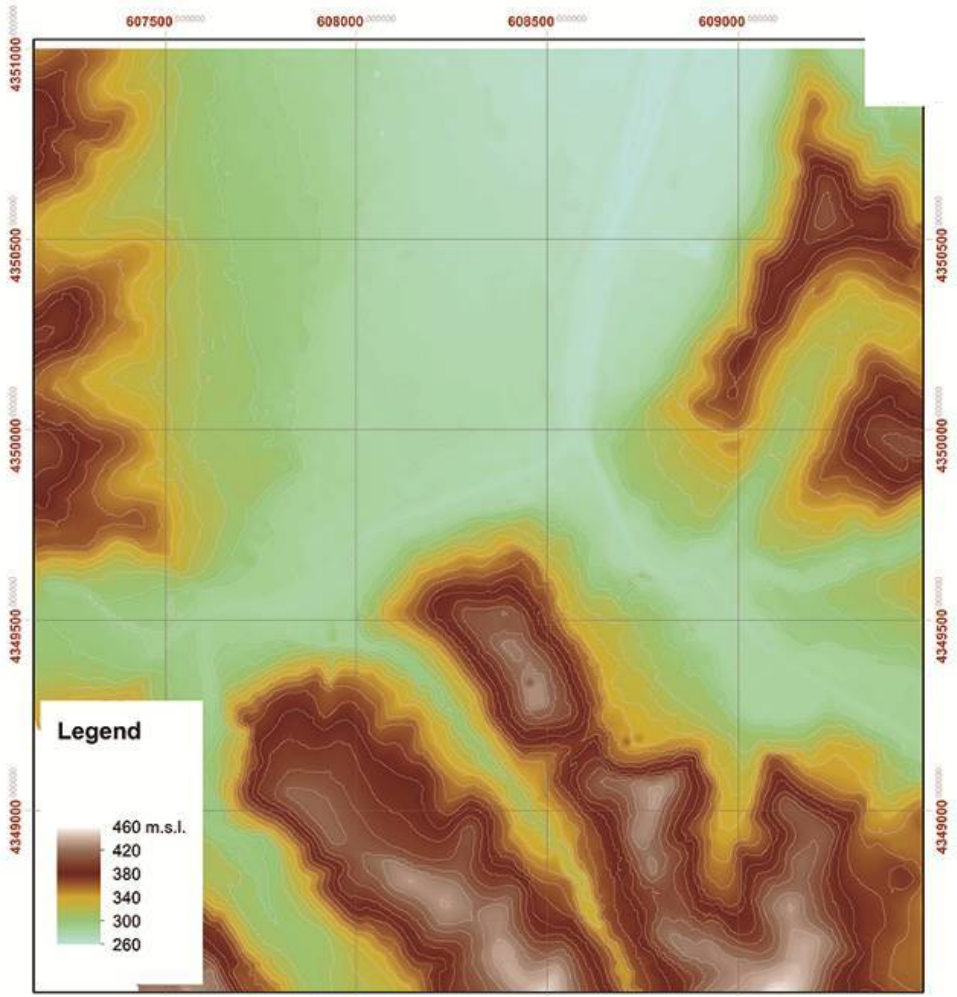
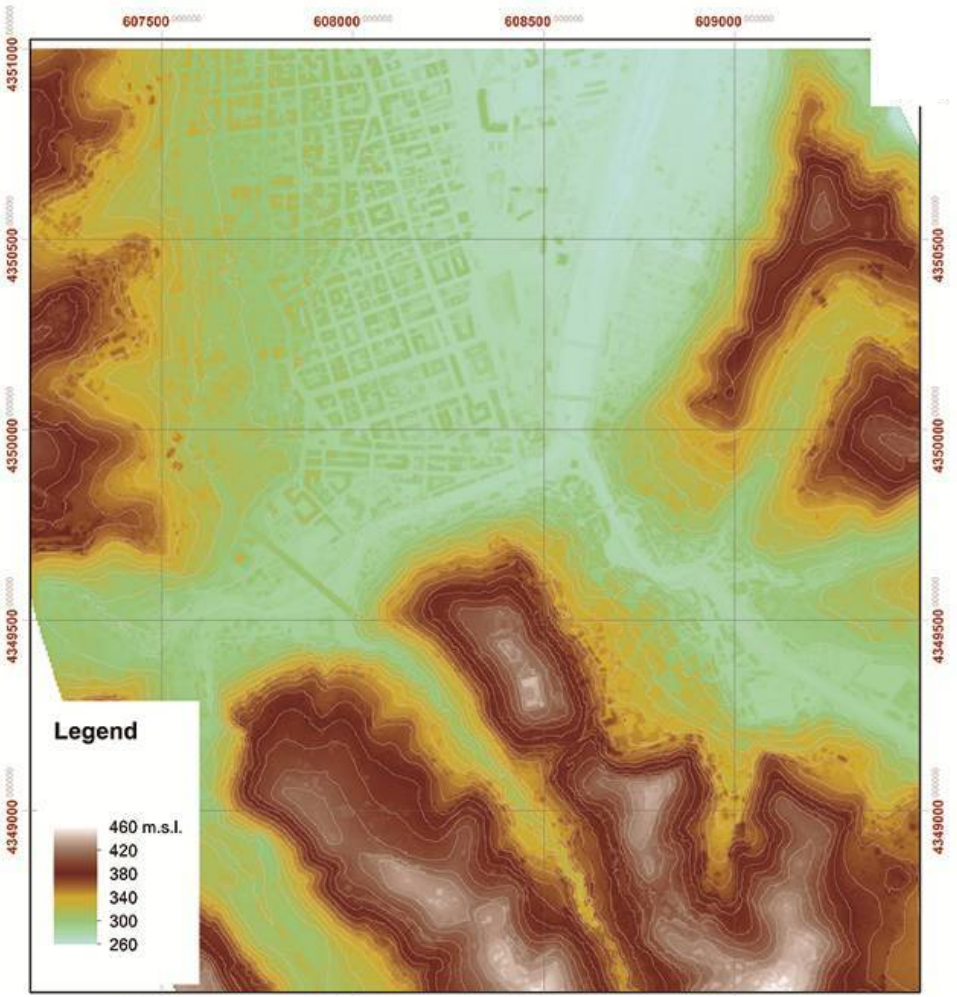
Intermediate product: DTM & DSM

Digital Terrain Model (DTM)



Digital Surface Model (DSM)



Intermediate products: Built-up areas

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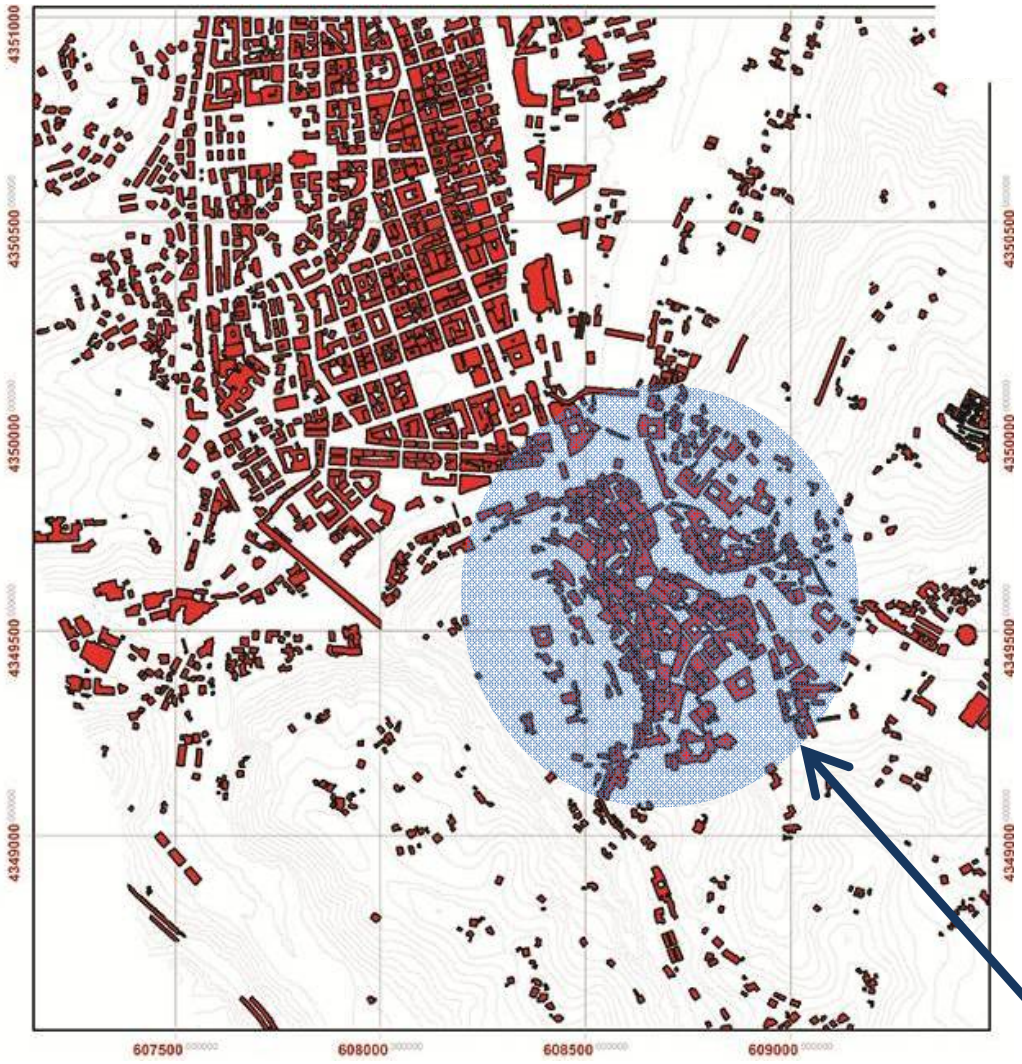
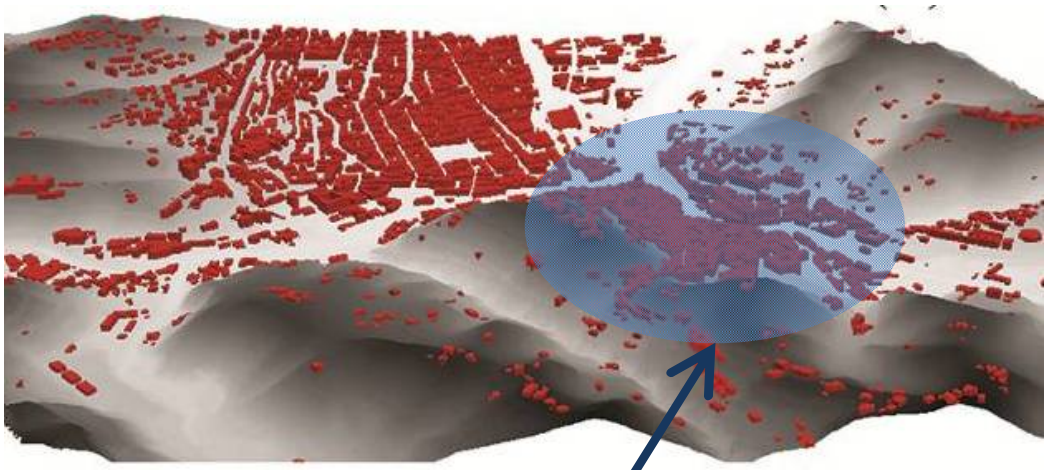
Built-up areas

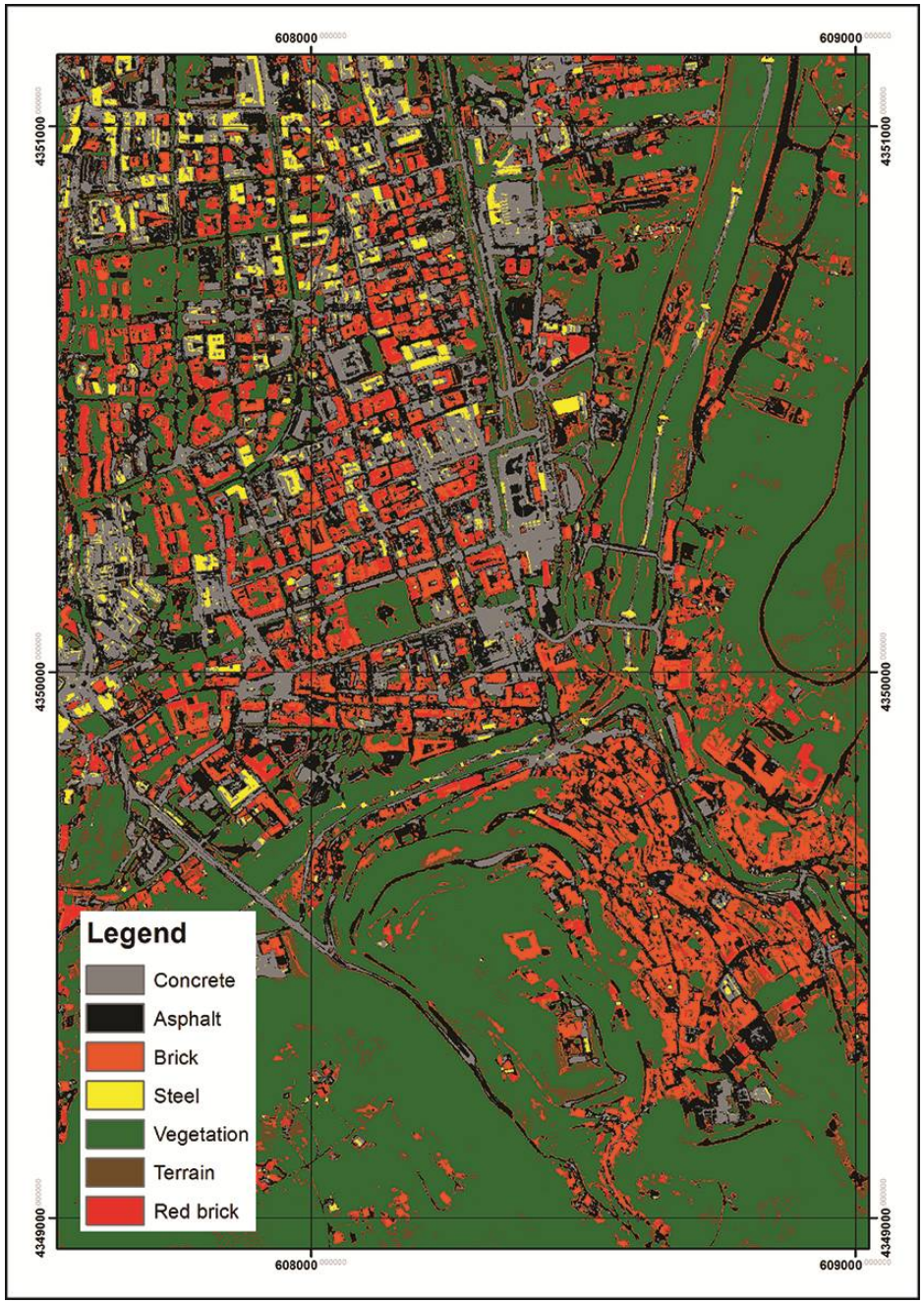


Projection of built-up areas on the DTM



Historical centre of Cosenza city dating back to Roman domination and the Middle Ages

Intermediate products: land-use and land-cover map



Land-use and land-cover map based on Spectral Angle Mapper algorithm, in order to detect :

- vegetated area
- urbanized area
- road facilities
- roof materials

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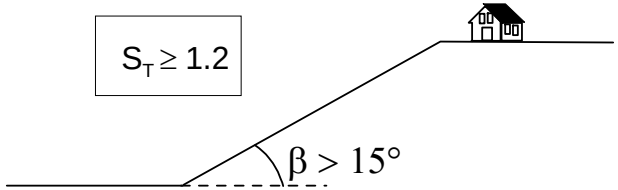
Value-added products : topographic assessment map (1)

Suggested values for the topographic amplification factor in Eurocode 8 (Part 5 Annex A).

$\beta \leq 15° \rightarrow$ T1

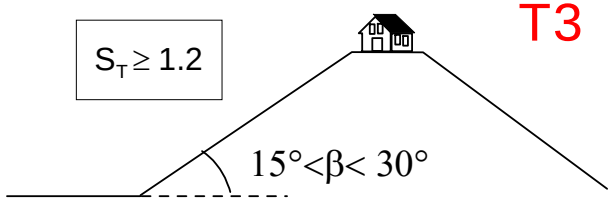
Isolated cliffs and slopes

T2

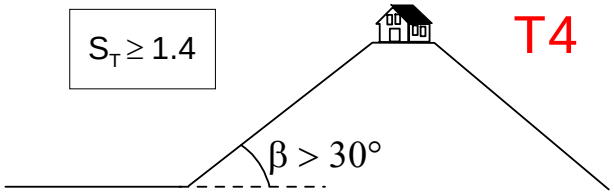


Ridges with crest width significantly less than the base width

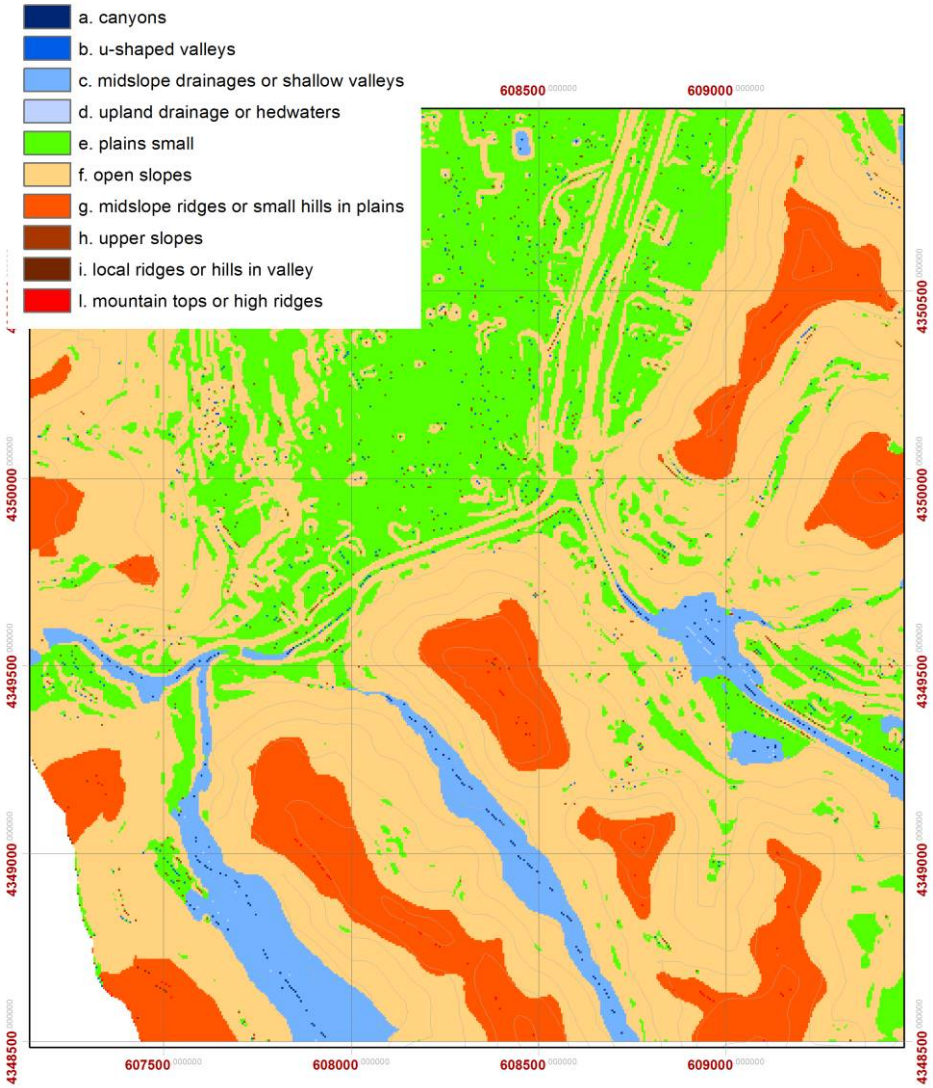
T3



T4



Classification based on landform carried out by Weiss's procedure



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Value-added products : topographic assessment map (2)

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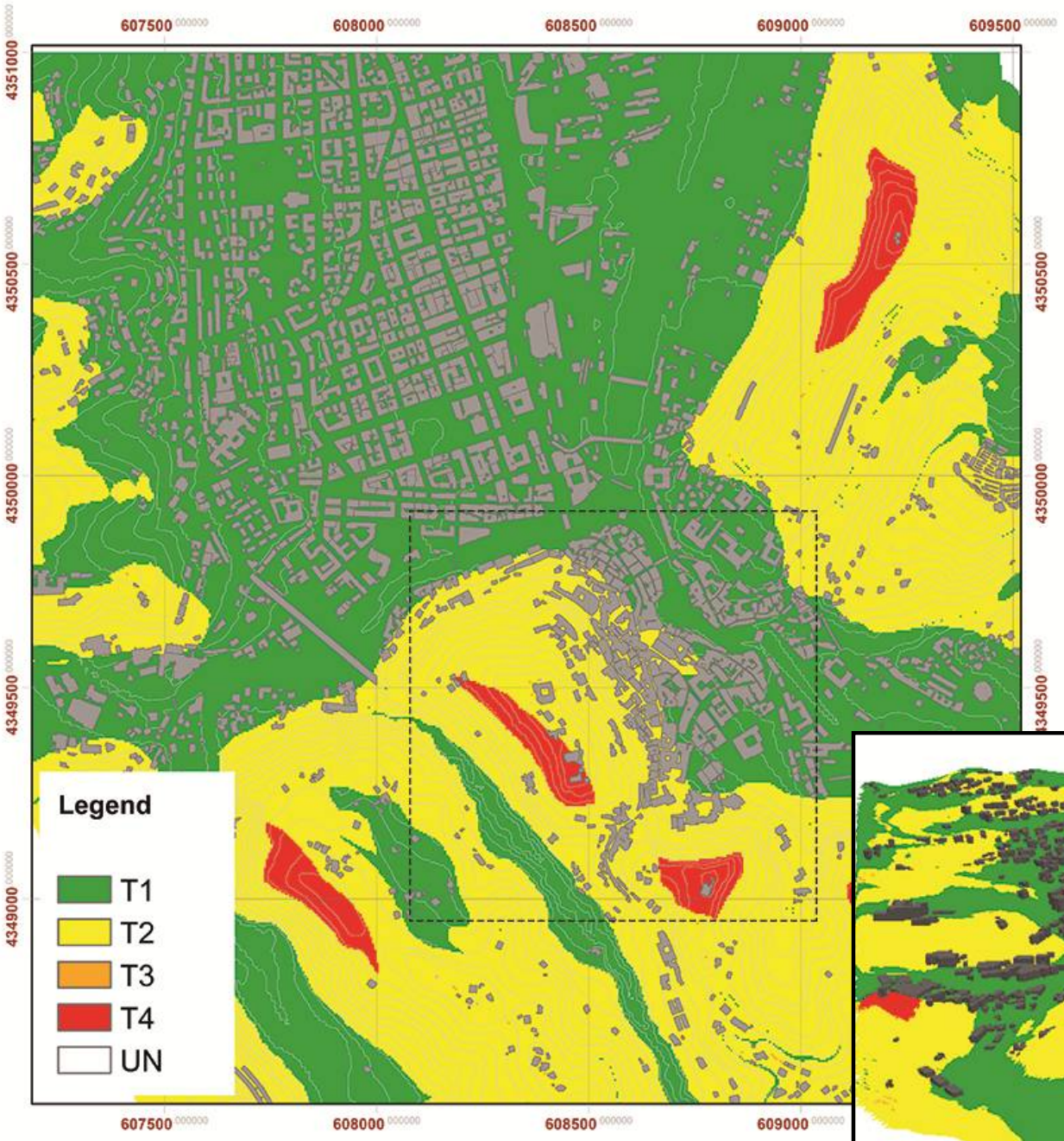
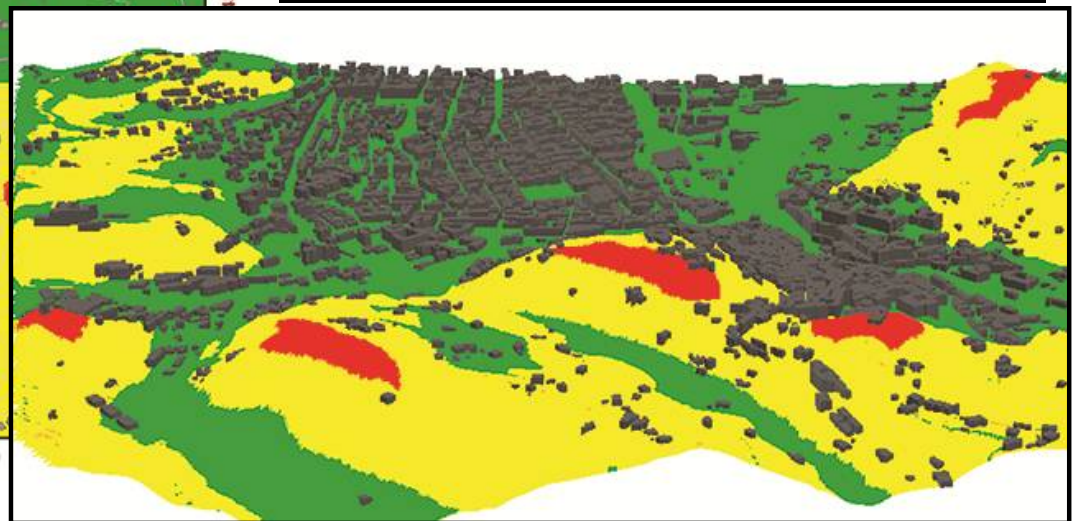


Classification of the topographic amplification based on technical code (EC8):

- **56% of the area → T1**
- **42% of the area → T2**
- **2% of the area → T4**

The historical centre is susceptible to not negligible topographic amplification phenomena (dashed box).



Value-added products : building assessment maps (1)

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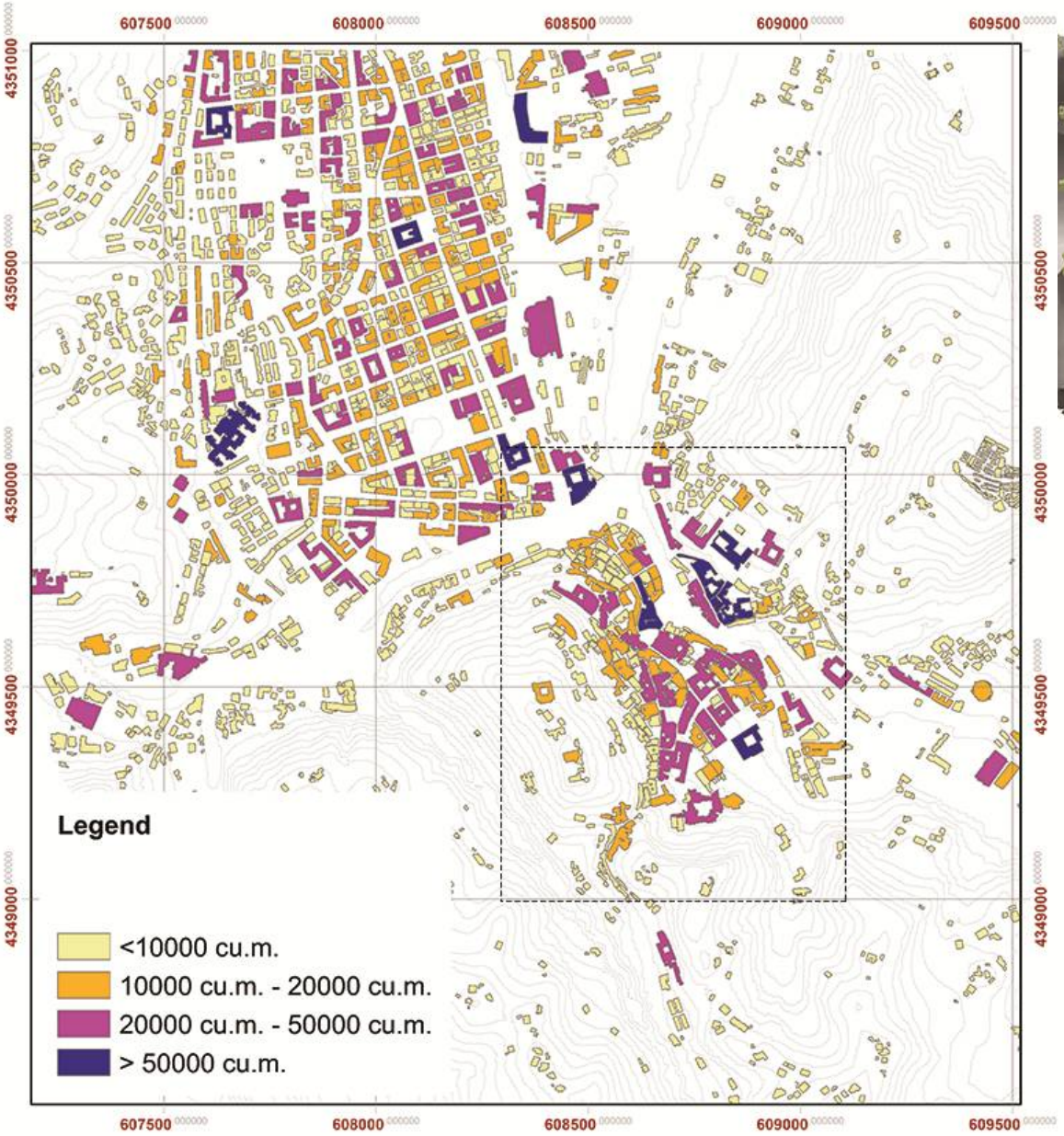
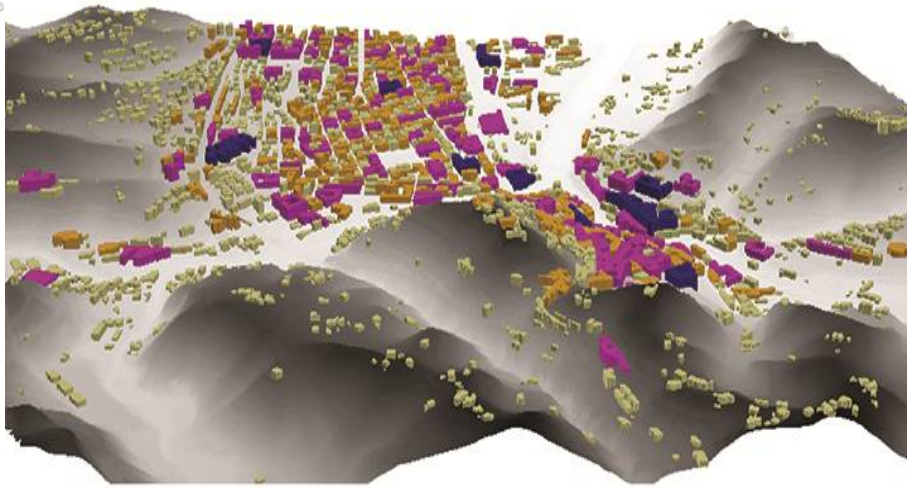
Classification of the buildings in the urban area of Cosenza based on the volumes





- The most part of buildings shows a volume less than 50000 cu.m.
- The strategic structures are high and characterized by wide extension (e.g. hospital and prefecture).
- Referring to the historical centre of the city (see dashed box), a great number of buildings shows a volume greater than 20000 cu.m. due to the aggregate structures and big cultural heritages (i.e. theatre and religious compounds).

Value-added products : building assessment maps (2)

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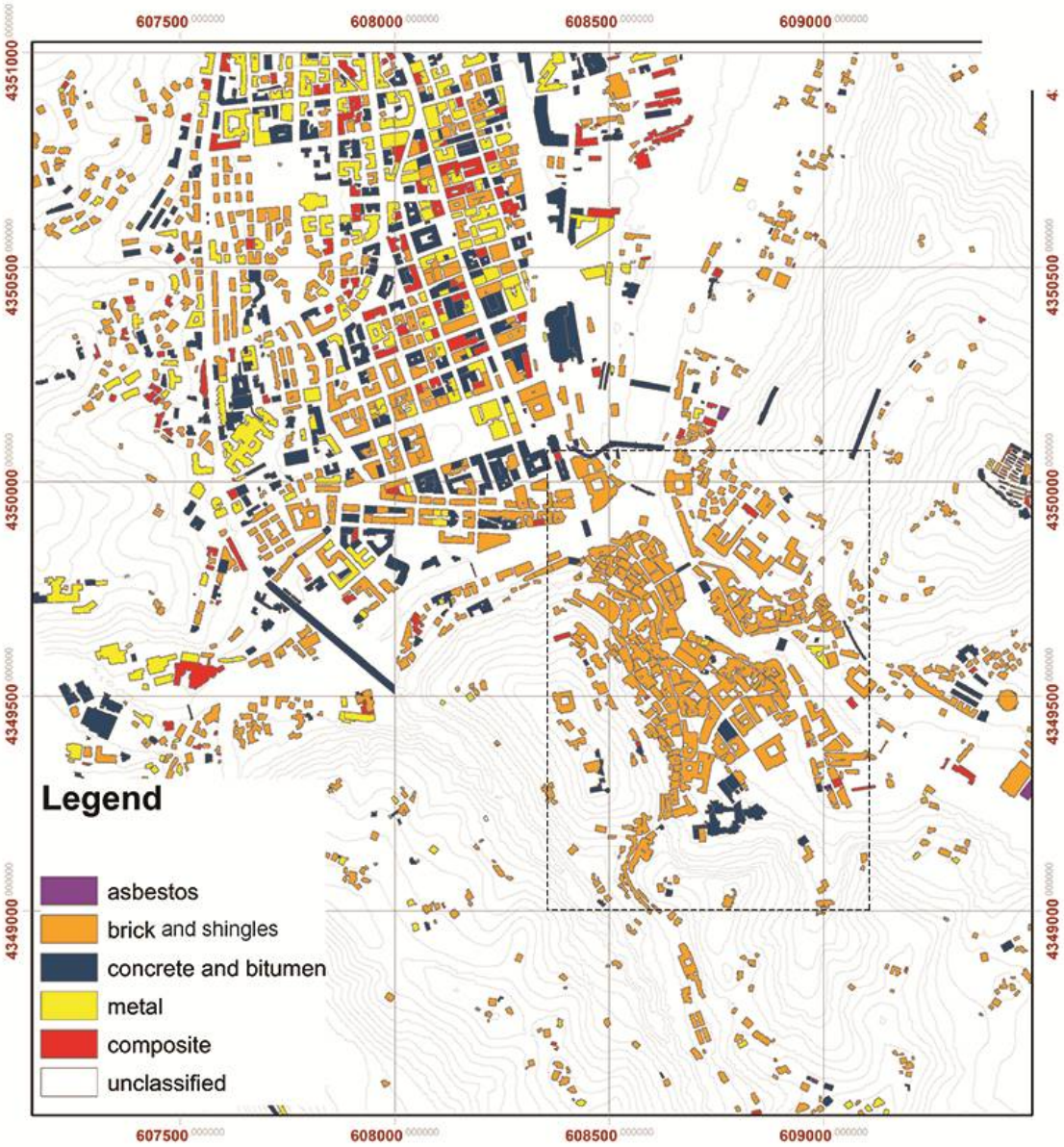
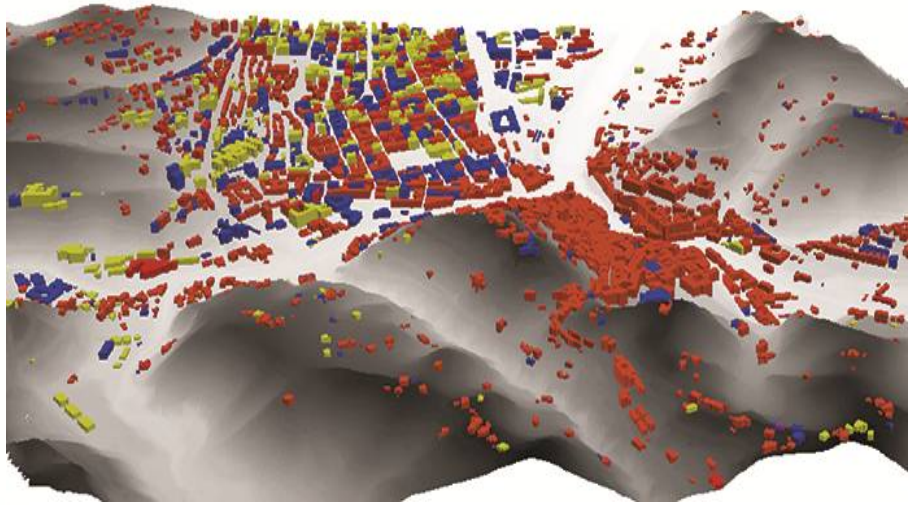
Classification of the buildings in the urban area of Cosenza based on the roof material

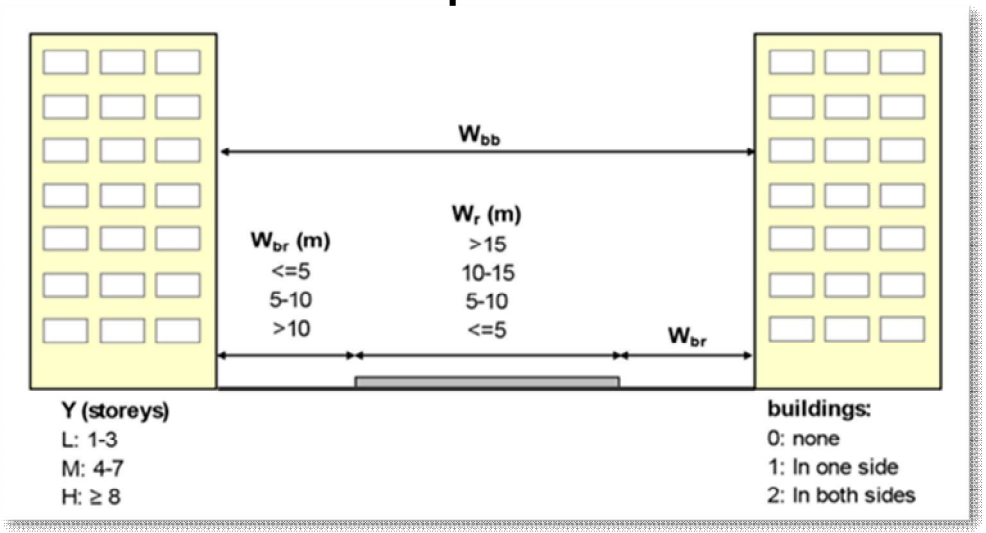




- The most recent part of the city (see the central-upper part of the 2D map) is characterized by different heterogeneous roof typologies.
- Conversely, the historical city centre (see dashed box in the 2D map), is mainly characterized by buildings with brick and shingles roofs.
- Some asbestos roofs are clearly recognized and detected, which are relevant to some industrial building.

Value-added products : road assessment maps (approach)

Features of urban roads for their typological description against building collapse risk.



where :

- ✓W_{br} is the distance between building and road
- ✓W_{bb} is the distance between opposite buildings
- ✓W_r is the width of the road

Characteristic height (Y) by digital models:

- •for "Low buildings" on both sides, Y = 10m;
- •for "Medium buildings" on both sides, Y = 22m;
- •for "High buildings" on both sides, Y = 25m;
- •for buildings with two different heights on both sides, Y is equal to the average height;
- •for buildings only on one side of the road, Y is equal to the 50% of the height;
- •for multiple buildings with different heights in the stretch, Y is the one that dominates more than 60% of the buildings.

Index of roadblocks risk

$$D_{HR} = \frac{Y}{W_{br}}$$

1. **low risk for $D_{HR} \leq 2.0$**
2. **moderate risk for $2.0 \leq D_{HR} \leq 4.0$**
3. **high risk for $D_{HR} > 4.0$**

W_{br} has been measured directly or statistically through W_{bb} and W_r by using both LiDAR data and hyperspectral classification results

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Value-added products : road assessment maps (2)

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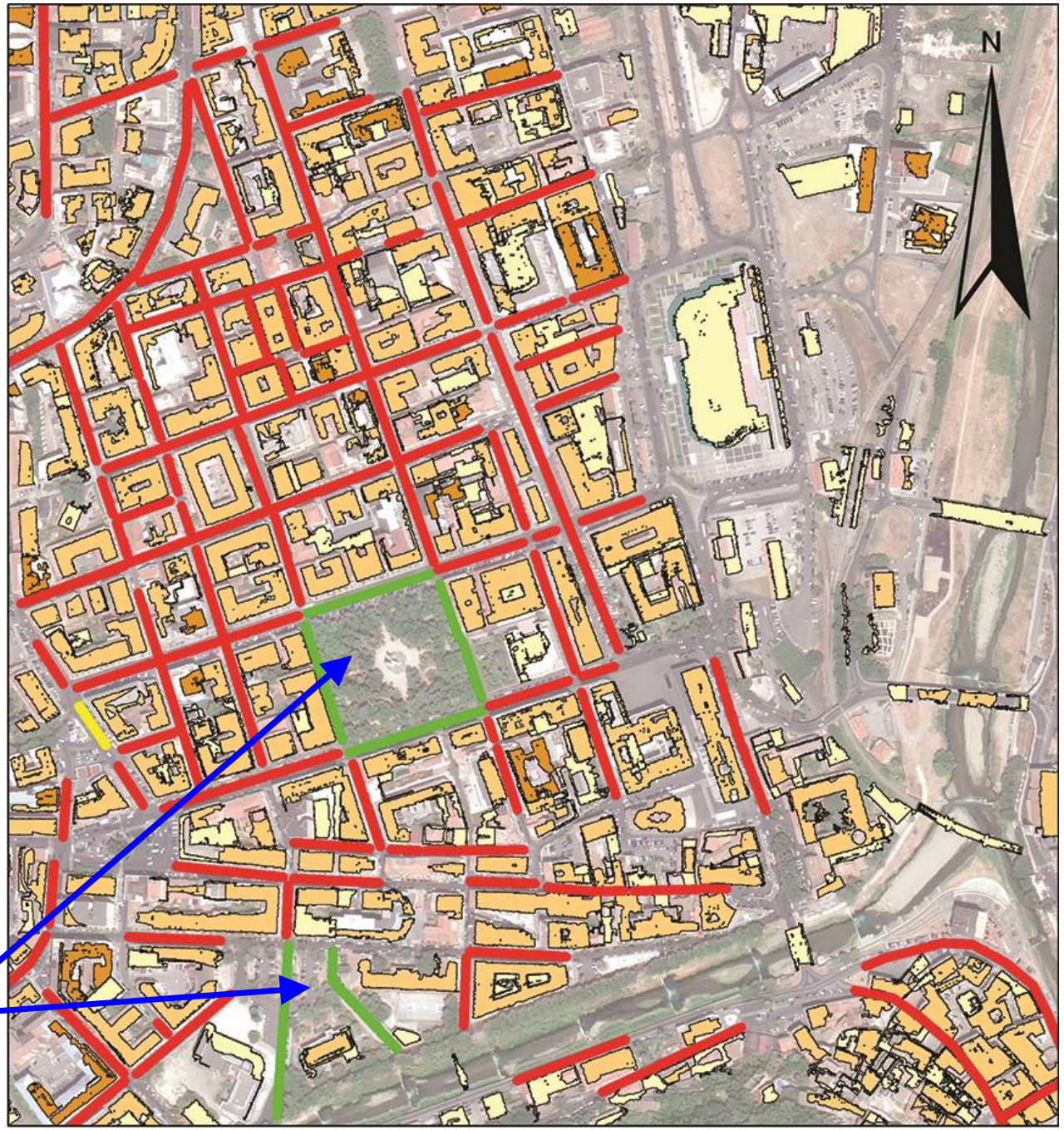
Risk of Road Closure

- Low closure risk: DHr ≤2.0
- Moderate closure risk: 2.0< DHr ≤4.0
- High closure risk: DHr >4.0

Buildings Heights

- Low buildings: 1-3 storeys (Y= 4 -10m)
- Medium buildings:4-7 storeys (Y= 13-22m)
- High buildings: 8 or more storeys (Y >25m)



- Most of the urban roads are characterized by high risk of blockages.
- Small areas in the southern part and the central sector, where is present a wide square, show a low risk of road blockage.

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Conclusions

- Airborne remote sensing sensors and techniques have been combined and integrated within a GIS platform to provide an innovative methodology for supporting seismic vulnerability assessment and risk mitigation plans.

- Intermediate remotely sensed maps (DTM, DSM, built-up areas, land-cover & land-use classification maps) have been integrated within a GIS platform, to obtain topographic, building and road assessment maps for supporting the mitigation of urban seismic vulnerability.

- Experimental results in Cosenza have demonstrated the powerful capabilities of the joint use of LiDAR and Hyperspectral products to provide synthetic value-added thematic maps of the seismic urban environment.

- Such results allow evaluating and assessing the exposure level and the seismic vulnerability of urban areas in case of earthquakes, based on the analysis of co-located topographic amplification, structural building and road facilities.

- The outcomes demonstrate the high seismic vulnerability of the historical centre of Cosenza.

- The risk map of road closure allows to infer that the city of Cosenza might have serious drawbacks for evacuation in case of building collapses during a strong seismic event.

Thank you for the attention !!!