RESIDUAL FLOOD-RISK: ASSESSING THE EFFECTIVENESS OF ALTERNATIVE LARGE-SCALE MITIGATION STRATEGIES

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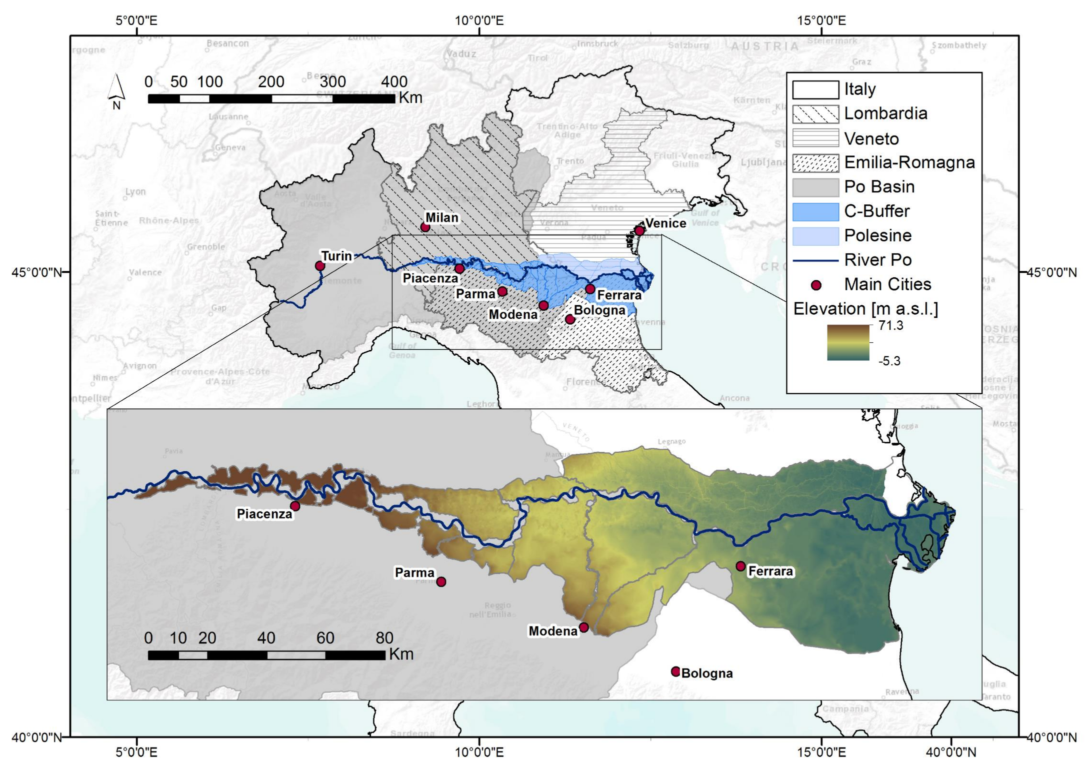
STUDY AIM

Which is the optimal levee scenario that minimizes the expected damages in flood-prone areas and how can we estimate it?

Following the EU Flood Directive 2007/60/CE, the study focuses on the identification of large-scale flood-risk mitigation strategies, aimed to manage the residual flood-risk relative to a catastrophic flood event (i.e. the remaining risk even in the presence of defense works designed and verified for a specific return period). To this purpose, the analysis aims at finding the optimal configuration to mitigate the residual flood-risk in case of an extreme flood by coupling a quasi-2D hydraulic model with empirical tools that we term "Hypsometric Vulnerability Curves" (HVCs).

STUDY AREA



Po River

- Total length ~ 652 km
- Main embankment system length ~ 2 900 km
- Main embankment system return period = 200 years
- Basin surface ~ 74 000 km²
- Basin population ~ 16 mil

Floodable areas

C-Buffer
Area, external to the main embankment system, floodable in case of major event (e.g. 500 year event)
Area ~ 6 100 km²

Polesine
Area, external to the main embankment system, which suffered significant damages during the 1951 flood
Area ~ 1 700 km²

Fig. 1. Study area.

AVAILABLE DATA

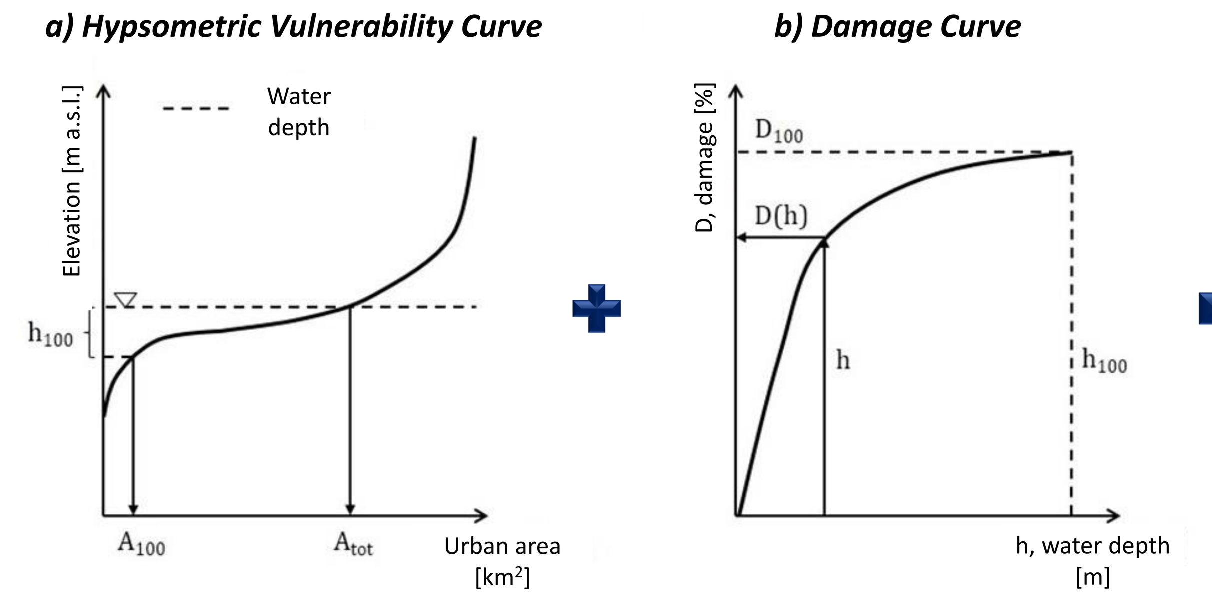
Land use maps for urban areas, obtained from aerial imagery available for 2008 (AGEA-2008) and classified referring to the standardized classes aggregation adopted by the Corine Land Cover project (2006);

Assets economic values: economical values of residential buildings in the alluvial area, obtained by the Italian Revenue Agency taking into account different classes for residential buildings and the overall economic well-being of the region;

Topographic information: digital elevation model (DEM) for the entire country (TINITALY / 01 - Tarquini et al., 2007), horizontal resolution = 10 m;

Quasi-2D hydraulic model, implemented by Castellarin et al. (2011), and following amendments, calibrated by referring to the flood event of October 2000. It simulates an extreme flood event with a return period of 500 years. Floodable areas are represented as storage areas (thah we call "compartments"), connected to the main river by means of lateral structures, that reproduce the main embankment crests. Volume-level curves regulate the hydraulic behavior of all storage areas, and, in case of inundation, the simulated water level is computed as a function of the water volume exchanged with the main river.

METHODOLOGY: FLOOD-RISK ASSESSMENT BY HYPSOMETRIC VULNERABILITY AND DAMAGE CURVES



$$D_{tot} = A_{100} \cdot E + \int_{A_{100}}^{A_{tot}} d[h(A)]dA \cdot E$$

Fig. 2 Schematic representation for calculating damages by combining Hypsometric Vulnerability Curve - panel a - and Damage Curve – panel b.

- Built for urban areas for each compartment;
- Obtained by the combination of the DEM with the land use map of interest;
- Assuming the horizontal line as a hypothetical water depth, its intersection with the HVC provides an estimation of the extension of the flooded urban areas (A_{tot});

- Depth-damage curve implemented in the Multi-colored Manual (MCM; Penning-Roswell et al., 2010);
- The asset percentage of tangible damage (*D*) is defined as a function of the relative water depth (*h*);
- h_{100} is the water depth beyond which the damage is the total economic value of the building (D_{100});

- A_{100} indicates the urban area totally damaged because submerged by water depth higher or equal to h_{100};
- For the remaining portion of the urban area damages vary according to the water depth, *D(h)*;
- *E* (€/m²) indicates the average economic value of residential buildings;
- Total damage, D_{tot}, in a specific compartment for residential areas is equal to the sum of the two contributions. (Domeneghetti et al., 2015)

RESULTS

Scenarios

- *Hypothetically unerodible levees scenario*: consolidation of all embankments overtopped during the 500-years event ➡ water volume to be managed, and temporarily stored, in the outside compartments;
- *Current scenario*: natural opening of breaches in the embankment system in case of overtopping;
- *Controlled breaches scenario I (< volume)*: breach openings are controlled in location, time and size, in order to minimize total overflowed volumes;
- *Controlled breaches scenario II (< damage)*: breach openings are controlled in location, time and size, in order to minimize total expected damages.

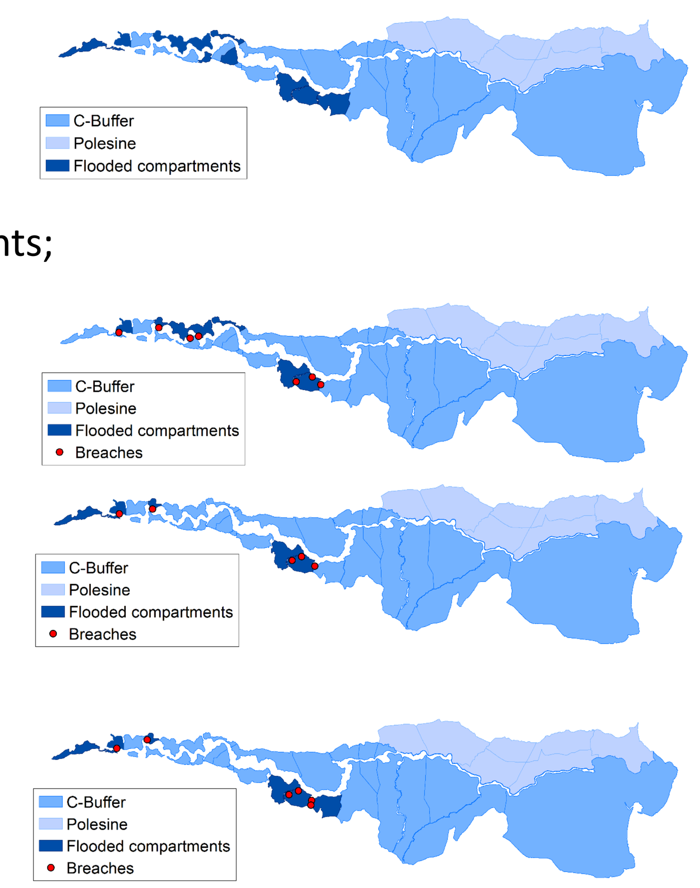
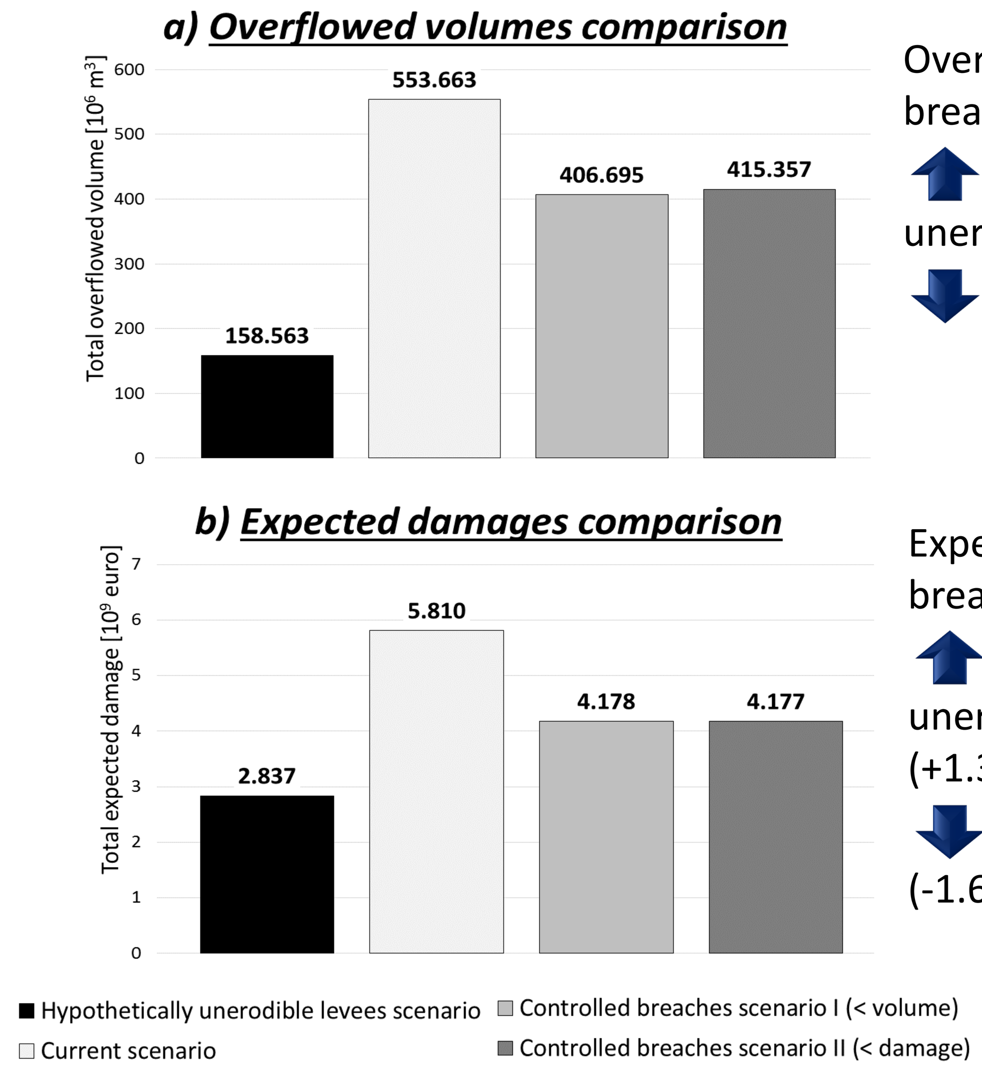


Fig. 3 Flooded compartments in different considered scenarios: hypothetically unerodible levees scenario, current scenario, controlled breaches scenario I and controlled breaches scenario II, respectively.



Overflowed volumes in controlled breaches scenarios:

⬆ than in the hypothetically unerodible levees scenario (as expected);

⬇ than in the current scenario (-30%).

Expected damages in controlled breaches scenarios:

⬆ than in the hypothetically unerodible levees scenario (+1.3 billion euros);

⬇ than in the current scenario (-1.6 billion euros).

Fig. 4 Comparison of results in terms of expected damages – panel a - and overflowed volumes - panel b - for the four different considered scenarios.

CONCLUSIONS

- **UTILITY OF THE HCVs** AS SIMPLIFIED EMPIRICAL TOOLS FOR **LARGE-SCALE** VULNERABILITY ANALYSIS;
- **EFFECTIVENESS OF CONTROLLED BREACHES SCENARIOS** IN TERMS OF REMARKABLE **DAMAGE REDUCTION** DUE TO FLOOD EXTREME EVENTS, WHEN COMPARED WITH THE CURRENT SCENARIO (LEVEE COLLAPSE IN CASE OF OVERTOPPING).

FUTURE AIMS

- Assessment of damages in industrial, commercial and agricultural areas;
- Evaluation of indirect, intangible and other damage typologies;
- More complex models (e.g. fully 2D models), aimed to perform a more correct simulation of flood dynamics.

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