Where floodwater meets mobility: A GIS approach to bridge risk and rerouting in the Flood@Road project

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Introduction

Flood events increasingly threaten the functionality and safety of transport infrastructure, particularly in riverine regions where bridges represent critical nodes. Bridge overtopping not only endangers drivers but also causes significant disruptions in mobility, emergency response, and logistics. While traditional flood risk assessments focus on hydrological scenarios, they often overlook geomorphological predisposition and cascading effects on traffic (Pregnolato et al., 2017, Shahdani et al., 2022).

This work presents an integrated approach developed within the FLOOD@ROAD project, combining overtopping risk screening with traffic impact simulation. A key innovation lies in the use of a web-based GIS platform that visualizes at-risk bridges and evaluates the consequences of their closure on regional mobility through dynamic rerouting simulations.

Materials and methods

The proposed methodology combines large-scale geospatial screening and dynamic traffic simulation to assess the risk of bridge overtopping and its systemic impacts on road network performance. The case study focuses on the Magra River basin in north-western Tuscany (970 km²), one of Italy’s rainiest and most flood-prone regions.

The first phase involves catchment-scale screening using LiDAR-derived DSM and DTM, OpenStreetMap (OSM) road data, and hydrographic layers. Each road–river intersection is identified via GIS and analyzed morphometrically. The intersection height (Hi)—the difference between road level and river thalweg—is computed, while a Terrain Ruggedness Index (TRI) is applied to filter DSM noise caused by vegetation and artifacts.

The cross-section height (Hs) is extracted through unsupervised classification (Iso Cluster) of morphometric indicators such as profile curvature and elevation variance. Intersections with Hi < Hs are classified as overtopping-prone (Figure 1). Field surveys at selected locations validate Hi estimates, with error analysis stratified by TRI and Strahler stream order.

In the second phase, traffic disruption scenarios are modeled in SUMO (Simulation of Urban Mobility). A baseline network, built using ISTAT and AISCAT mobility data, is compared with flood scenarios in which at-risk bridges are removed. SUMO computes rerouting effects and quantifies travel time increases, detour lengths, and accessibility losses. Macroscopic simulations support the vulnerability assessment through indicators like Weighted Cost and Accessibility Index.

Simulation results are reintegrated into GIS, providing spatial insight into disruption patterns and supporting targeted, resilient infrastructure planning in the Magra River basin (Figure 2).

Results and concluding remarks

The methodology was applied to the Magra River basin (970 km²), identifying 231 road–river intersections. About 30% showed Hi < Hs, indicating high overtopping susceptibility under flood conditions.

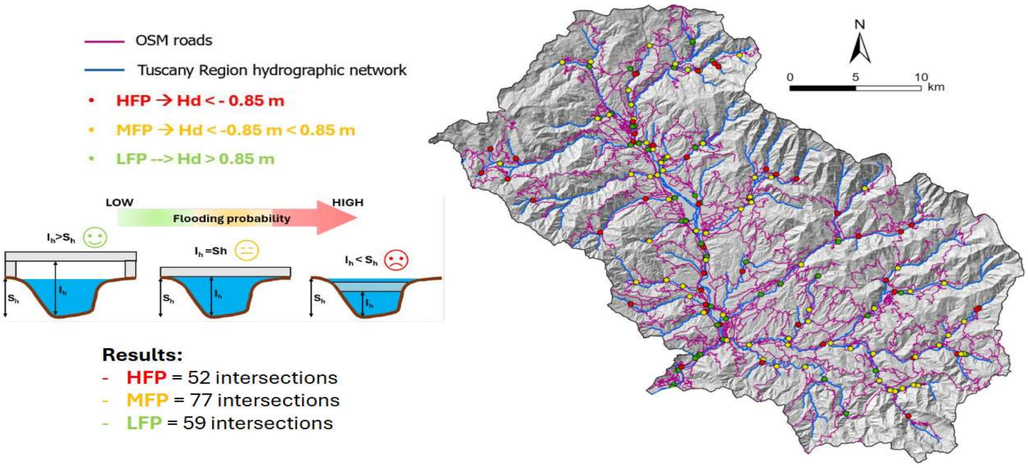

Figure 1. Flood overtopping risk at road–river intersections in the Magra River basin, based on morphometric screening (Hi < Hs).

Field validation showed that the accuracy of remotely sensed Hi varies with stream scale. For Strahler < 4, the median error (Δhe) was ~2 m (40%), due to vegetation and misalignment in narrow channels. For Strahler > 3, accuracy improved significantly, with Δhe ~0.4 m (12%), consistent with the DTM's 0.3 m resolution and typical stream widths (~35 m).

These findings (Figure 2) confirm the method's suitability for large-scale, low-cost screening of overtopping risk using only geometric and morphometric data. It effectively prioritizes critical sites for further hydraulic and traffic impact analysis, offering a replicable framework for flood-prone areas and supporting early warning, risk-informed planning, and resilience strategies.

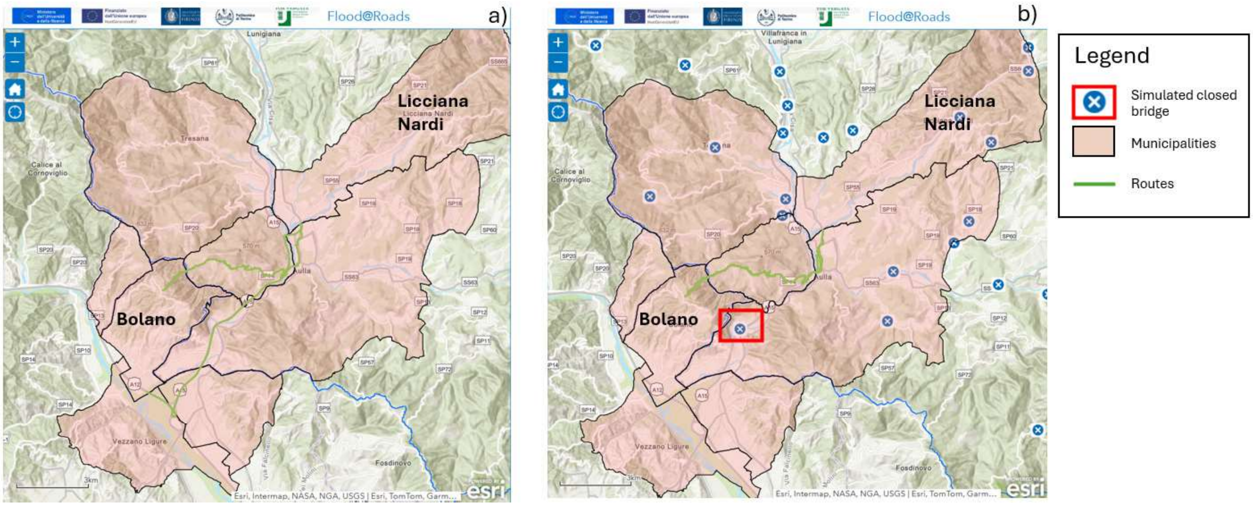

Figure 2. Web GIS app output of traffic network under flood scenarios; panel a) baseline condition, panel b) impact of single bridge closure due to overtopping.

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References

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