A LiDAR based analysis of hydraulic hazard mapping

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A LiDAR Based Analysis of Hydraulic Hazard Mapping

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Abstract

Mapping hydraulic hazard is a complex procedure involving technical and socio-economic aspects. The availability of high resolution topographic data makes it nowadays possible to address this issue with innovative procedures both for hazard mapping and for hazard maps validation purposes. The present work describes a new procedure for fast preliminary analysis of hazard maps based on topography only. It is not intended by any means to replace more sophisticated analysis based on hydraulic modelling.

The geometrical and topological procedure for the validation of the hydraulic hazard maps is made of two steps. In the first step the whole area is subdivided into fluvial segments. In the second step the segments are analyzed one by one. Every segment is split into many reaches, so that within any of them the slope of the piezometric line can be approximated to zero. Every reach is a polygon, delimited laterally by the hazard mapping boundaries and longitudinally by two successive cross sections, usually orthogonal to the thalweg line. Simulating for every reach the progressive increase of the river stage, with a horizontal piezometric line, allows the definition of the stage-area and stage-volume relationships.

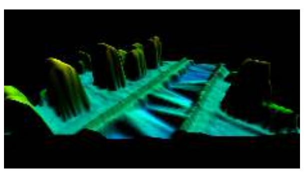
The maximum flooded area resulting from the simulation is finally compared to the potentially floodable area described by the hazard maps, to give a flooding index for every reach. Index values lower than 100% show that the mapped hazard area exceeds the maximum floodable area. Very low index values identify spots where there is a significant incongruity between the hazard map and the topography, and where a more detailed inspection is probably needed.

Study area

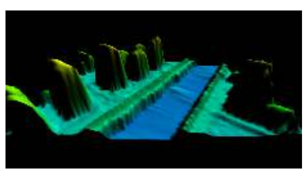
The present case study involves the river Montone, located in central Italy, in the Emilia Romagna region. This river originates from the Apennines, is 90 km long, and flows into the northern Adriatic sea, with an average discharge of 5 m^3s^{-1}.
To apply the described procedure, the whole river was split into several segments, with variable length: the results reported here concern only one singl esegment of the river.

Methods

The hazard maps validation requires detailed elevation models. Therefore, airborne LiDAR survey data was used with an average point density of 2 points m^{-2}. The raw points were classified in three classes: ground, building and overground. From the ground points raster Digital Elevation Models (DTMs) with a 1 m cell resolutions were generated, and then combined to the Digital Building Models (DBMs) obtained from the building points. The option of using the standard Digital Surface Model (DSM) was not viable, as the DSM represents the vegetation canopy as solid volumes, resulting in unrealistic barriers to water flow. In addition, in sensitive areas (e.g.: levees, dykes), breaklines were added to render the elevation model more accurate in terms of flow barriers description.



DTM+DBM without breaklines

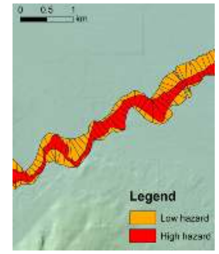


DTM+DBM with breaklines

Once accurate elevation models had been produced for the whole area covered by the hazard maps, the maps themselves underwent a series of processing steps before the flooding index could be calculated:

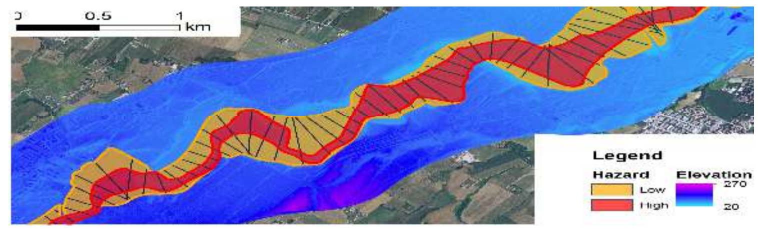
1) The polygon representing the hazard areas was split into segments, with length chosen as a reasonable trade-off between the need to keep the hydrographical unit as complete as possible, and the need to separate sections of the river bed with significantly different morphology.
2) The polygon representing the segment (with its two hazard classes) was split into many reaches. Within every reach, the slope of the piezometric line could be approximated to zero. As a consequence, the hydraulic profile in every reach (open channel flow) was assumed horizontal both downslope and on the cross-section. Each reach can be seen as a polygon, delimited laterally by the hazard mapping boundaries and longitudinally by two successive cross sections, usually orthogonal to the thalweg line.
3) For every reach, the outer boundaries of the different hazard class polygons were extracted, and for each of them the minimum boundary elevation retrieved from the elevation model.
4) For every reach, the minimum elevation was retrieved from the elevation model.
5) Every reach was flooded with a progressive stage, from the minimum reach elevation to the minimum perimeter elevation of the high hazard class. The procedure was then repeated for the lower hazard class. The stage-area and stage-volume relationship were so defined for every hazard class of every reach.
6) For every reach, the maximum flooded area resulting from the simulation was compared to the potentially floodable area described by the hazard maps, to give a flooding index for every hazard class of every reach.

Hazard map for a single river segment, with two hazard classes



Detial of some reaches

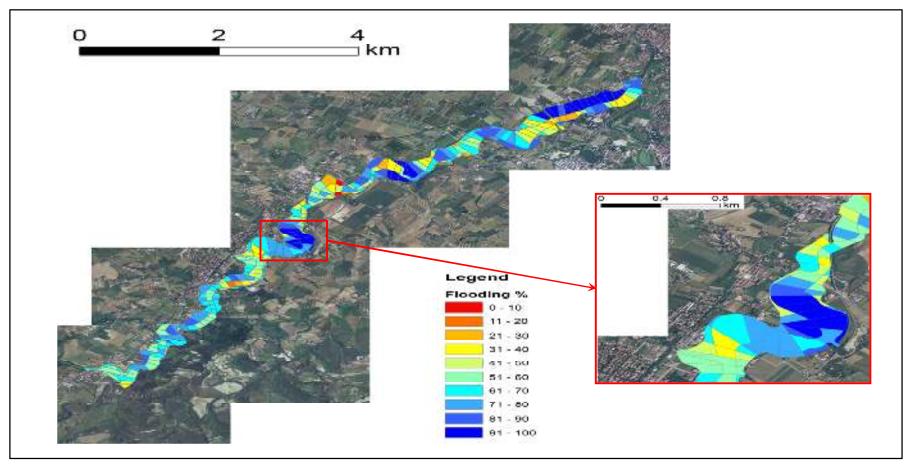
Detail of boundaries



Detail of reaches. The reaches boundaries are highlighted, and the elevation model used to simulate the flooding is visible on the background.

Results and conclusions

The final output of the validation procedure is a map showing, for each hazard class area of every reach, the percentage of flooding attained. High flooding values indicate that the hazard map is consistent with terrain topography. Low flooding values indicate that there is some kind of discrepancy between the topography described by the elevation model and the hazard zoning. This methodology must be considered as a fast investigation tool to spot out in an efficient and objective fashion possible problems arising from an inaccurate, or outdated hazard maps. As it turns out, false positive (i.e.: reaches where low flooding values area detected but the hazard maps is correct) or false negatives (i.e.: reaches where high flooding values are detected even in presence of mapping anomalies) are possible.



Final map showing the flooding percentage of every reach. In the detail, a meander where it can be seen that the two hazard classes areas have different flooding values.

Acknowledgments

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