An Open source GIS-based tool for economic loss estimation due to flood events

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Abstract

Two complementary GIS-based functions are designed and implemented to assess the expected degree of loss due to the occurrence of flood events. Each function processes institutional thematic layers and allows decision makers first to quantify the physical and the economic exposure of the elements at risk in a given study region and then to assess the expected degree of economic loss in relation to the flood water depth chosen for the analysis.

The functions are implemented using QGIS with GRASS Python API extension and the workflow is exposed as a QGIS plug-in. The GUI is built over QT multi-platform framework and, therefore, the results are consistently integrated into the QGIS system.

Introduction

Floods are among the most common natural hazards in Europe whose effects can be local, impacting a neighborhood or community, or regional, affecting entire river basins and multiple states (FEMA, 2004). Understanding flood statistics gives opportunities to manage, prevent and find solutions to reduce the impact of flood risk: in Europe, between 2000 and 2015 (source: The International Disaster Database - emdat.be), 356 flood events occurred causing 1.688 death and 7.667 injured on a total of 6.478.117 affected people. The total damage amounts about 90 billion dollars.

In EU, the Directive 2007/60/EC on the assessment and management of flood risks entered into force on 26 November 2007. The Directive requires "Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk". Its aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. Italy acknowledged the Directive by implementing two different approaches for flood risk assessment: expert driven-qualitative approaches and quantitative model-based techniques. Although the former are widely applied by Italian river authorities, quantitative approaches provide spatial planners and disaster

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managers with more in-depth knowledge in their decision making processes with respect to qualitative approaches (Molinari et al., 2016).

Research materials and data

Our research intends to propose two complementary GIS-based functions aimed at processing institutional thematic layers, available at regional/national WebGIS and Spatial Information sites: expert-driven or model-based flood hazard maps, digital elevation models (DEM), census tracts, real estate market values and (re)construction costs. The final aim is to support local/regional decision makers in preparedness and response to flood-related risks and, in so doing, mitigate the expected impacts and potential damage. By processing the institutional flood hazard maps (with different return periods - < 20years; between 20 and 200 years; and > 200 years), census tracts and real estate market values maps, the two functions calculate, for each unique-condition units (UCU), first the physical and the economic exposure of the elements at risk and then the expected degree of loss in relation to different classes of flood water depth. Exposure and expected degree of loss are expressed in monetary terms (€) with regards to real estate market values and (re)construction costs (fig. 1).

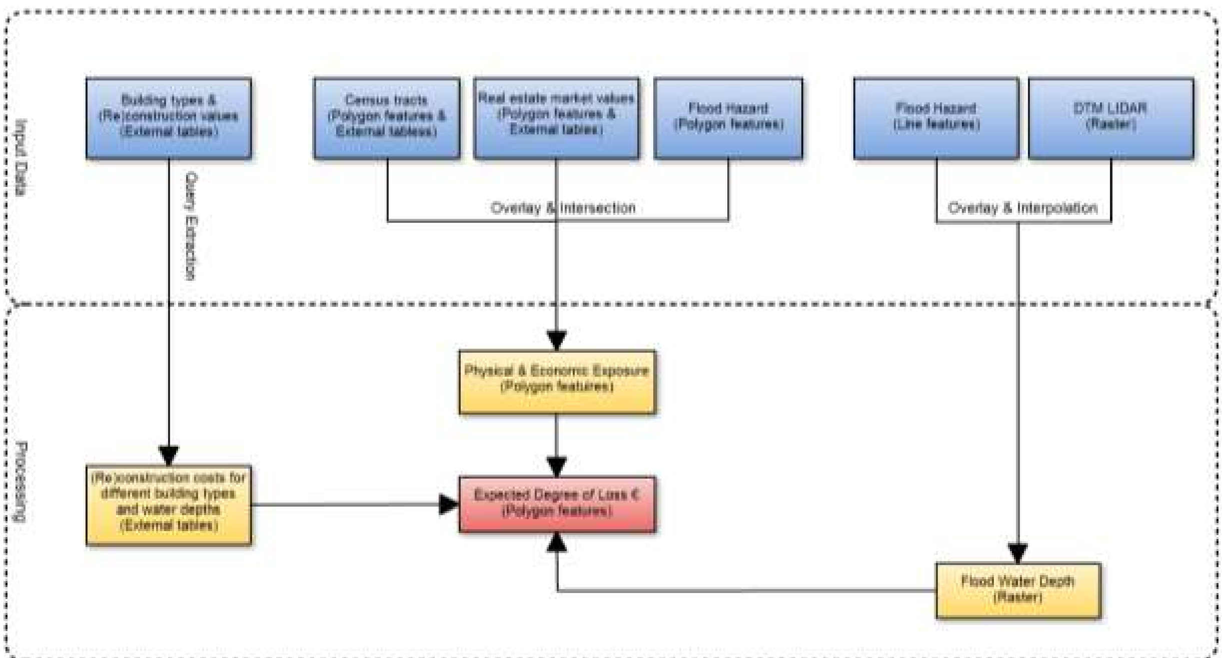

Fig. 1 - Conceptual scheme concerning inputs, outputs and geo-processing functions used in the analysis.

The GIS-based functions retrieve data for calculation from a database whose structure allows institutional information to be stored:

1. Flood hazard and risk maps. Flood hazard and risk maps have been implemented by the Italian River Basin Authorities and are now available for most of the major rivers at basin scale. These maps partially match the Flood Directive and assess the level of risk by using a matrix "… (that) measures risk levels on the basis of impact and hazard likelihood" (EU Commission, 2014). The matrix combines information on hazard frequency (referred to as P1, P2 and P3) and potential damage: the final map displays four risk levels (very high-

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red; high-orange; medium-light yellow; low-green). Only the hazard component is used into our analysis.

2. High detail Digital Terrain Models (1.0 m). To acknowledge the Flood Directive and implement 1D-2D hydraulic models, Lidar-based surveys have been achieved to generate high quality topographic data. The final aim is to obtain high resolution (1 meter) Digital Terrain Models (DTM) for alluvial plain of the major Italian rivers.
3. Census tracts. The Italian National Institute of Statistics makes available a warehouse of statistics constantly upgraded. The data warehouse of the 15th General Census of Population and Housing is used that contains information broken up to sub-municipal level, on the demographic and social structure of the population usually resident in Italy and the Italian housing stock. The reference date of the information is 9 October 2011 and its access is free. Data are presented in multidimensional tables which offer the possibility to compose tables and graphs by adjusting the variables and the reference periods. A broad array of metadata facilitates the retrieval and understanding of statistics by users. Data concerning population (demographic characteristics) and housing and buildings (type of buildings and their use) are downloaded and used.
4. Real estate market values. The Italian Revenue Agency manages the "Observatory of the real estate market" and technical and estimative services (GEOPOI®). It also establishes and updates the registry of real estate in operation on the national territory. GEOPOI® polygons are used to obtain precise delimitation of urban areas with different market values of the buildings. The reference date of the information is the second half of the year 2015 and its access is free. Market values may be subject to wide changes during time, mostly due to speculative reasons. As a consequence, all risk and loss estimations have to be considered “static” in the sense that they are relevant only for the date of preparation of the maps or for the time of analysis. However, by using market values, areas of higher and medium economic importance can be distinguished from economically marginal areas.
5. (Re)construction costs. (Re)construction costs, issued by the Society of Engineers and Architects of Milano (DEI 2014), are used to assess prospective damage estimation. (Re)construction costs are not subject to speculative changes during time in case of natural disaster and they are also usually applied for insurance purposes. (Re)construction costs are uniformly distributed over the area and particular disparities between economically different zones cannot be distinguished.

GIS-based functions

Two complementary GIS-based functions are designed, implemented and applied: the Spatial Overlay & Intersection and the Flood Water Depth functions (fig. 2). The former spatially overlays and intersects institutional flood hazard maps, census tracts and real estate market values maps to derive a new polygon thematic layer composed of unique-condition units (UCU). Each UCU allows decision makers first to quantify the physical and the economic exposure of the elements at risk in a given study region and then to assess the expected degree of economic loss for three different flood water depths (< 0.5 m; 0.5-1.0 m; > 1.0 m in this study). In more detail, database tables are provided in which different percentages of damage are made explicit against the water levels for different types of buildings. These values are derived from the Price

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List issued by the Society of the Engineers and Architects of Milan (DEI, 2014) and refer to the expected degree of loss concerning the different functional and structural components of different building types that may be potentially affected and damaged by a flood event for distinct classes of water depth. The original values provided may be changed by the end-users at their own convenience.

The Flood Water Depth function allows the end-user to retrieve a flood water depth value from available institutional flood hazard maps. If this value is not available from the maps, it can be derived by interpolating the 1 m resolution Digital Terrain Model (fig. 1) within the borders of each hazard class (for different time periods). The result allows decision makers to identify the most probable flood water depth value or class and, then, the most probable expected level of damage.

The two functions are developed by using the Python programming language. Beside the Standard Python Library, the code extensively leverages on QGIS API 2.15 and GRASS API functions (through GRASS-QGIS extension); therefore, the project adopts the GNU GPL licensing, development and distribution process.

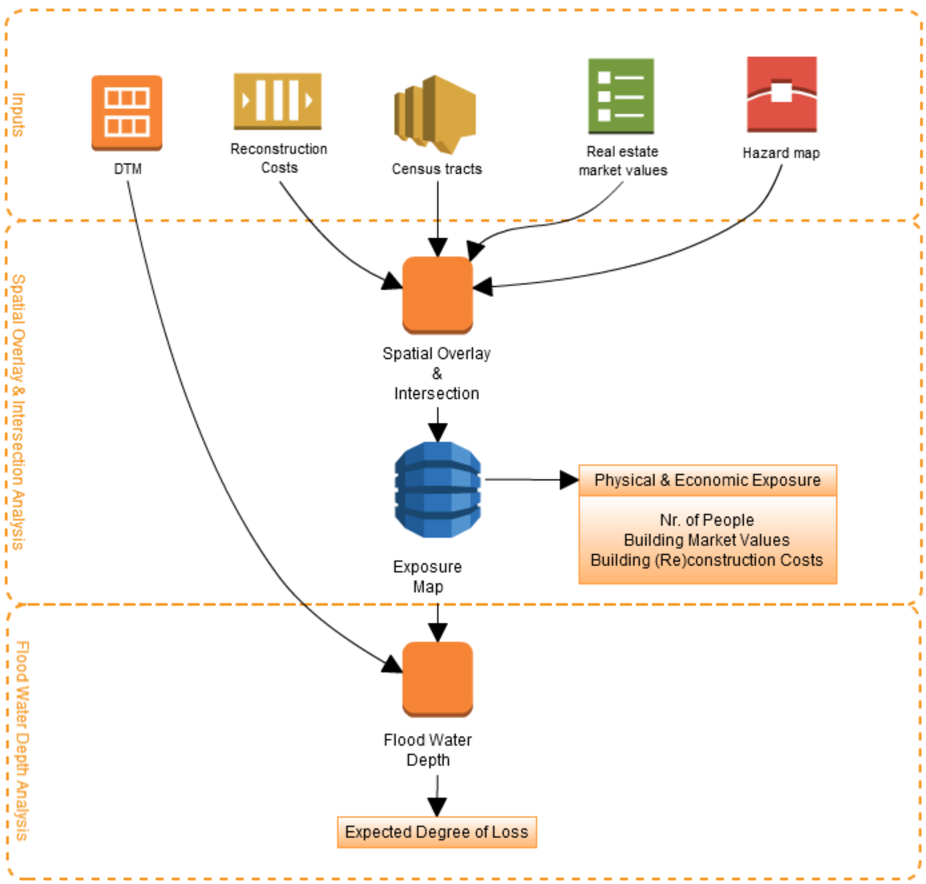

Fig. 2 - Functional Representation of inputs and outputs

In consequence of the existence of different types of input items and data formats, a QGIS integrated approach is preferred over file loading and parsing from disk. Consequently, the loaded layers and/or QGIS loading procedures for maps and attribute tables can be used as

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input data for the presented algorithms. The program exposes the described functions with its own API that is distributed as a bundled module of the QGIS plug-in itself, together with the integrated graphical user interface. The two complementary GIS-based functions are represented in figure 2. As the functions are serially connected each other, some mid-process data is generated (while processing the final output), such raw data are saved into temporary memory locations and available to the user using the QGIS Python interface.

Conclusion

Summing up, institutional data and methods are complemented by the proposed Open GIS-based tool to increase their original level of information; this allows spatial planners and risk managers to access and share relevant distributed authoritative, multi-source spatial data able to support decision making process aimed at reducing flood risks and building communities' resilience.

Acknowledgements

This research was supported by the Generali Foundation grant "La valutazione economica dei disastri naturali in Italia (Economic assessment of natural disasters in Italy)".

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