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Towards multi-hazard, border-independent exposure analysis for operational climate and disaster risk preparedness applications

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 # Topic
B. Supporting adaptation through extreme events analysis

 # Keywords
Exposure modelling, dynamic population modelling, risk assessment, extreme events.

Long abstract

Currently, available risk preparedness and prevention tools are increasingly lagging behind the growing threat of climate change, with multiple hazards often compounded, causing cascaded and intertwined impacts and damages to society and the environment (Fig. 1). Transborder mountainous areas are especially vulnerable to such threats, given the susceptibility to natural hazards as well as the remoteness of some settlements and the related importance of connectivity and accessibility. At the same time, mountains have experienced above-average warming (Adler et al., 2022) and potentially more climate extremes than other areas. Effective risk management requires transnational collaborative efforts. We hereby propose an integrated approach to risk assessment based on a homogeneous planar tessellation of hexagonal cells and an innovative representation of cells connections on the dual graph (Fig. 2), where multiple spatial datasets, such as climate and natural hazard forecasts, exposure datasets, impacts and vulnerability indicators can converge. Cell- and edge-based data aggregations at user-defined spatial scales allow us to find a balance between the complexity of the model and its computational efficiency for risk-related applications. By keeping a maximum resolution of 250 m, we ensure a sufficient degree of anonymity of potentially sensitive data at a scale still useful for civil protection risk management purposes.

An example of possible outreach of the proposed platform is presented in Fig. 3, where information from multiple sources can be consolidated into the tessellated model and serve as an instrument for effective impact forecasting. The figure depicts a simulation of how (hindcasted) landslide probability maps and wind intensities during the peaks of the well-known Vaia/Adrian storm (October/November 2018) can be used to spot areas of exposure elements at risk visually (protection forest and roads infrastructure in this case). Aggregated onto the hexagonal cells, both hazard probability profiles were used to define two levels of risk: high and very high, based on the 75^{th} and 90^{th} percentiles, respectively. Hexagons containing the exposure assets under analysis were then flagged based on the thresholds of the two hazards simultaneously via colour coding and hatchings. Indicators of roads vulnerability explaining which sectors are more critical for the

proper connectedness of the network were also overlaid as cells' connecting lines as an additional value to the risk assessment

For an effective risk assessment, dynamic multi-temporal exposure modelling is critical, in particular for the most volatile component of all: the population. Rooted in the mentioned tessellated spatial support, we propose a border-independent population flow model that estimates dynamic intra-day concentrations of residents, where the degree of flow attraction on each cell for different profiles of the population – daily commuters, schools, elderly – can be incrementally refined, based on the actual availability of auxiliary data on the cell: points of interest, employees/residents densities, touristic accommodations, etc. What-if scenarios for the simulation of changes in the underlying topology (e.g., road interruptions due to landslides or floods) can be efficiently explored to provide decision support to local authorities. To foster the discussion on exposure modelling for complex climate-related events, the hereby proposed system modelling approach can be viewed as an open and flexible platform on top of which additional data sets and processes can be superimposed and plugged-in, enabling higher-level applications, including adaptation planning, impact forecasting and early warning.

As a preliminary testbed of this platform, in the frame of the EU-co-funded TransAlp project, we generated an exposure model addressing the trans-national area that comprises South Tyrol in Italy, East Tyrol in Austria and the mountain community of Agordino in the Italian Veneto region (Pittore et al., 2023). Overall the ca. 10′000 km^2 study area was covered with 165′000 hexagons at 250 m horizontal spatial resolution. Exposure information covering the cross-border area under consideration was collected from authoritative sources as well as global datasets when necessary, harmonised onto the common tessellation, and used to showcase the potential impact of the presented multi-temporal modelling system to the local stakeholders.

Figures

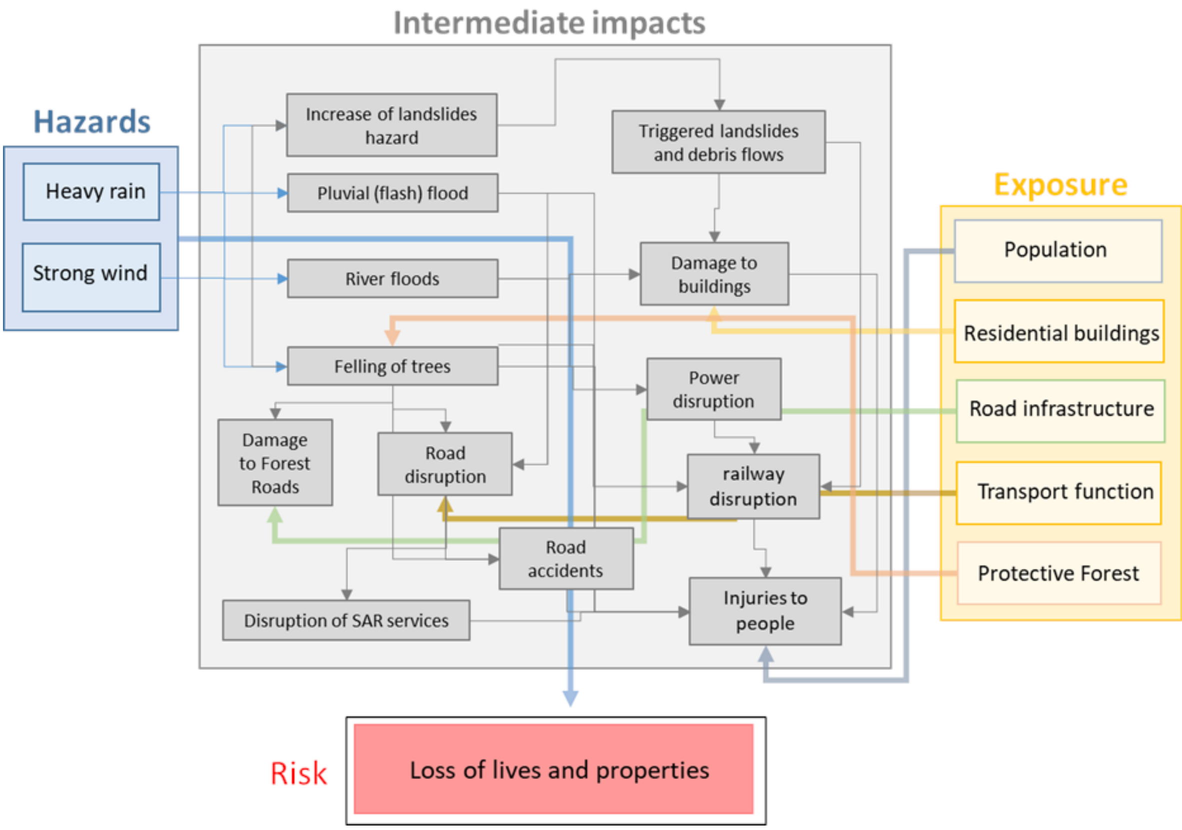

Figure 1. Impact chain (partial) of a storm event. On the left side the two considered hazards. On the right side the exposed assets and functions which are possibly exposed to damage and loss from the direct and indirect impacts (depicted in the central area). All components contribute to the main risk of losing lives and properties. We note that the vulnerability component is not shown.

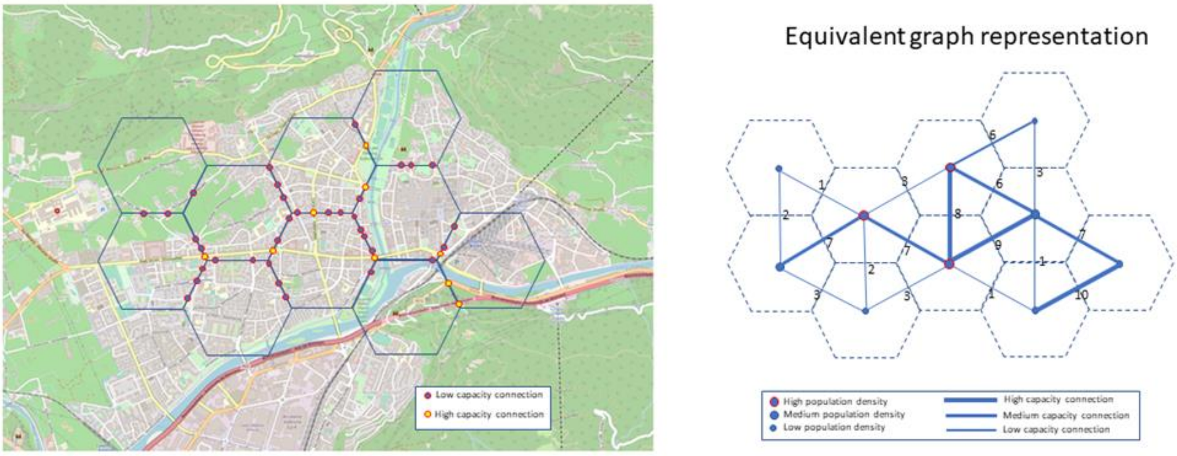

Figure 2. Example of mesh-based modelling (left) and equivalent graph representation (right). The numbers represent the nominal capacity of the arcs, obtained by summing up the capacity of the roads crossing the cells' borders. The connection points are depicted on the left; low and high-capacity connections contribute respectively with 1 and 5 to equivalent arc capacity.

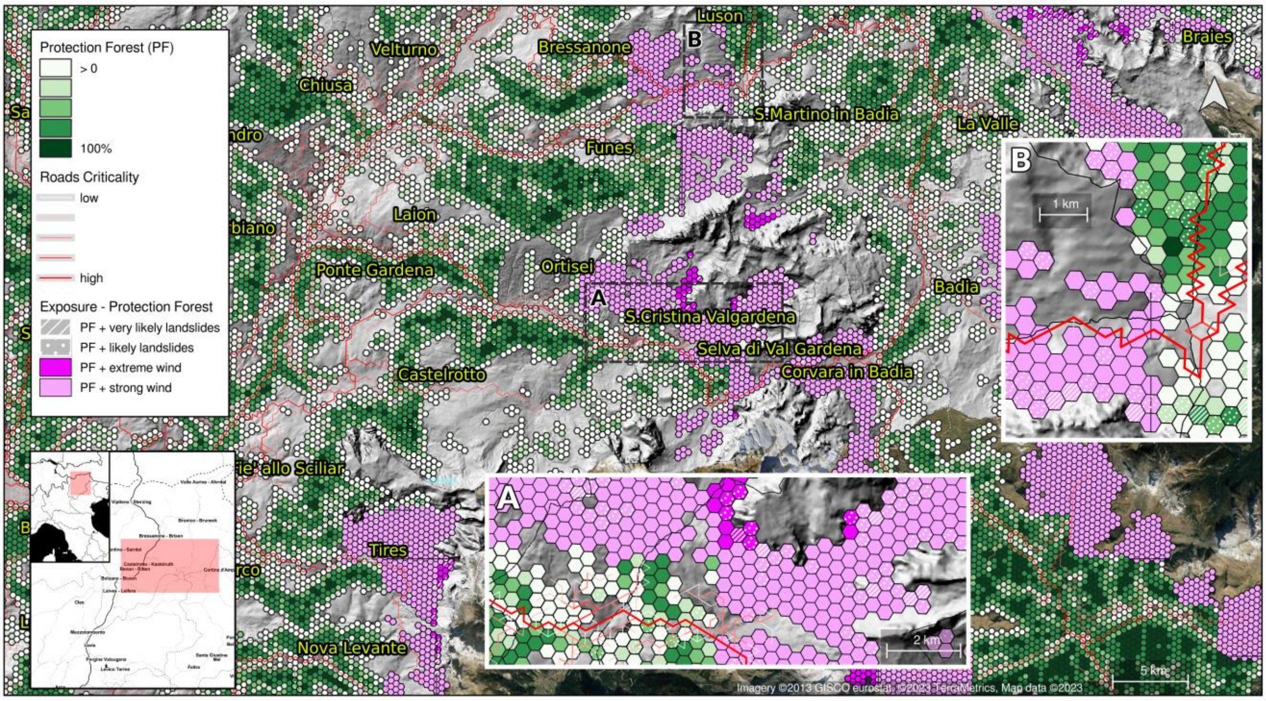

Figure 3. Spatial distribution of protection forest and roads exposed to strong winds and high susceptibility to shallow landslides. The different colours and hatching represent possible combinations of multi-hazard exposure. Roads are colour-mapped according to their expected criticality.

References

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 # Dissemination

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