Landslides risk mapping using the Vigirisks web-tool: application in Normandie (France)

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Abstract – Landslides threaten many parts of the world and cause many deaths and significant damage every year, and this should increase in the future due to climate change. To cope with this situation and prevent landslides impacts, a large variety of susceptibility and hazard mapping tools have been developed, either to assess current potential failure zones or to predict those that will appear in the near future. In the following, we present an application of the Vigirisks multirisks web-platform. This web-tools, developed by BRGM, propose computations allowing multi-risks mapping in a realistic manner, e.g., including cascading effects, vulnerability assessment and damages evaluation. The study site selected here is located in Diepe (Normandie, France); this is a typical case of complex flooding/landsliding processes. The Vigirisk web-tool was tested to evaluate risks when these two processes occur in the same time. We present here a simple "concomitant risks" workflow, implemented by using a weithing method.

Introduction

Landslides threaten many parts of the world and cause many deaths and significant damage every year, and this should increase in the future due to climate change. Landslides events are widely distributed throughout Europe, with a great concentration in mountainous areas. For example, between 1995-2014, 476 landslides caused 1370 deaths and 784 injuries. Annual economic loss in Europe is approximately estimated to 4.7 billion Euros (Haque et al., 2016).

To cope with this situation and prevent landslides impacts, a large variety of susceptibility and hazard mapping tools have been developed, either to assess current potential failure zones (Rossi et al., 2010; Reichenbach et al., 2018) or to predict those that will appear in the near future (Bernardie et al., 2021). A broad review of commonly used approaches can be found in Corominas et al. (2014) or in Reichenbach et al. (2004). Depending on the available data and its quality, we can use indirect empirical or data driven and physically based methods (Thiery et al., 2020).

In the following, we present an application of the Vigirisks multirisks web-platform (Tellez-Arenas, 2019). This web-tools (www.vigirisks.fr), developed by BRGM, has the ambition to propose a set of computations – implemented as workflows – allowing multi-risks mapping in a realistic manner, e.g., including cascading effects, vulnerability assessment and damages evaluation. The user can therefore realize several kinds of risks maps resulting from different kinds of hazard occurrence. In the present paper, we illustrate the case of a simple concomitant risks workflow occurring in the area of Dieppe (Normadie, France).

Data and method

The site selected in our study is located at the northern part of France, close to the city of Dieppe (Normandie, France); this is a typical case where complex flooding/landsliding processes can be observed, due to the particular geological settings and the occurrence of forcing rainfalls.

Different methods of analysis and mapping of the flooding or landslide hazard have been implemented in the Vigirisk plateform. The aim here is to show the possibilities offered by the original architecture of this web-tool in terms of single and multi-hazard analysis. Concerning landslides risks assessment, we already implemented and tested different algorithms, such as:

- The hierarchical analytical process technique (AHP): an empirical indirect method (Saaty, 1977) used for about fifteen years for mapping landslide hazard (Castellanos Abella and van Westen, 2008).
- The weight of evidence (WoE) method: a data-driven approach (Bonham-Carter, 1994). It needs to get sufficient data available to estimate the relative importance of evidential rules via the log-linear form Bayesian formulation (Spiegelhalter, 1986). It defines unconditional prior probability and conditional posterior probability, where the prior probability is the probability of an event, similar to past known events, for a given time period. This probability can be revised from various sources of information, to define the posterior probability and so, it can be successively revised and updated with the addition of new evidence.
- A damage indicator used to spatially evaluate risks caused by landslides and quantify potential multiscale consequences of elements at risk (EaR) when impacted by hazardous events. It extends the notion of Potential Damage Index (PDI) from Puissant et al. (2013) and Graff et al. (2019) by taking into account the specific number and nature of criteria to be integrated in the consequences analysis and weight them based on their spatial location or importance. In this way, it adapts and improves the PDI method to the context of our study by integrating spatial scales of EaR, taking advantage of the different geographical databases available.

In this paper, we only show the results of risk map obtained by a workflow to assess concomitant risk maps obtained with pre-existing hazard maps coupled with the extended PDI risks assessment approach. The concomitant effects are based on a predefined procedure specifically implemented to guide end-users. The concomitant risk map (CRC) obtained is therefore a weighted sum of these two risk maps with the possibility of predominance of the intensity of one risk over the other (0.75 vs. 0.25) or no predominance of one risk over the other (0.5 vs. 0.5).

From a computing point of view, Vigirisks is designed with a frontend Java-web connected to a backend server. The GUI is implemented as developed from various open source tools (Tellez-arenas et al., 2019). The OpenLayers JavaScript library allows the display and manipulation of produced maps. The backend server produces WPS services and uses a Postgres database for data management, scenarios translated into workflows, input parameters and simulation results (Fig.1). To operate such IT architecture a specific WebGIS interface was developed following the philosophy presented in Thiebes et al. (2013).

Results and conclusion

Figure 2 shows the CRC obtained after the realization of the workflows that combine, using a weighing approach, a landslide susceptibility map computed with AHP (Fig.2b) and a flooding map obtained by numerical modelling (Graff, 2020; Fig.2a). For the combination, each of the risk values of these maps where taken into account with the same weight of 0.5.

The resulting multi-risk map (Fig.2c) show the places where both of hazards could have an impact on assets located in the area. The level of risks appear to be generally medium over all the area with some places in low and high.

Even the combination of different kinds of risks can be interesting to have a global view of what could append in terms of damages in case of concomitance of several disasters, we see that some choice have to be made in the combination: we could have chosen to aggregate the two risks maps by taking the maximal value of each map’s pixels, the result would have been different, increasing the areas impacted with the flooding.

The advantage of the Vigirisks platform lies in the different possibility to design the workflows, to adapt them for the particularities of scenarios, so that the user can produce a processing chain adapted to its field observations. Each if these workflows are stored and commented in the system so that they can be disseminated to all interested users.

In the following developments, we are considering integration of additional susceptibility/hazard assessment approaches as well as different strategies to combine them, depending on time/space concomitance or cascading affects are needed to be taken into account.

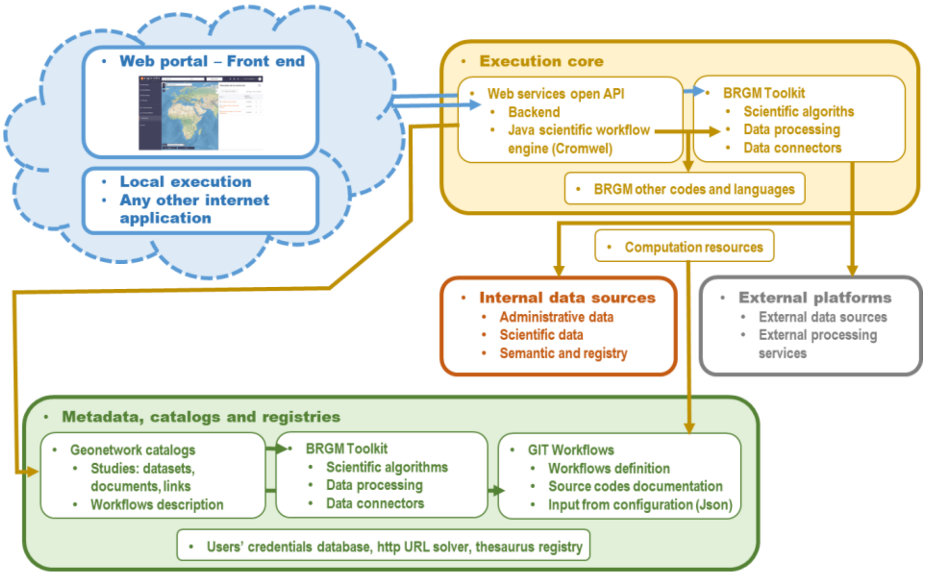

Figure 1: Vigirisks architecture

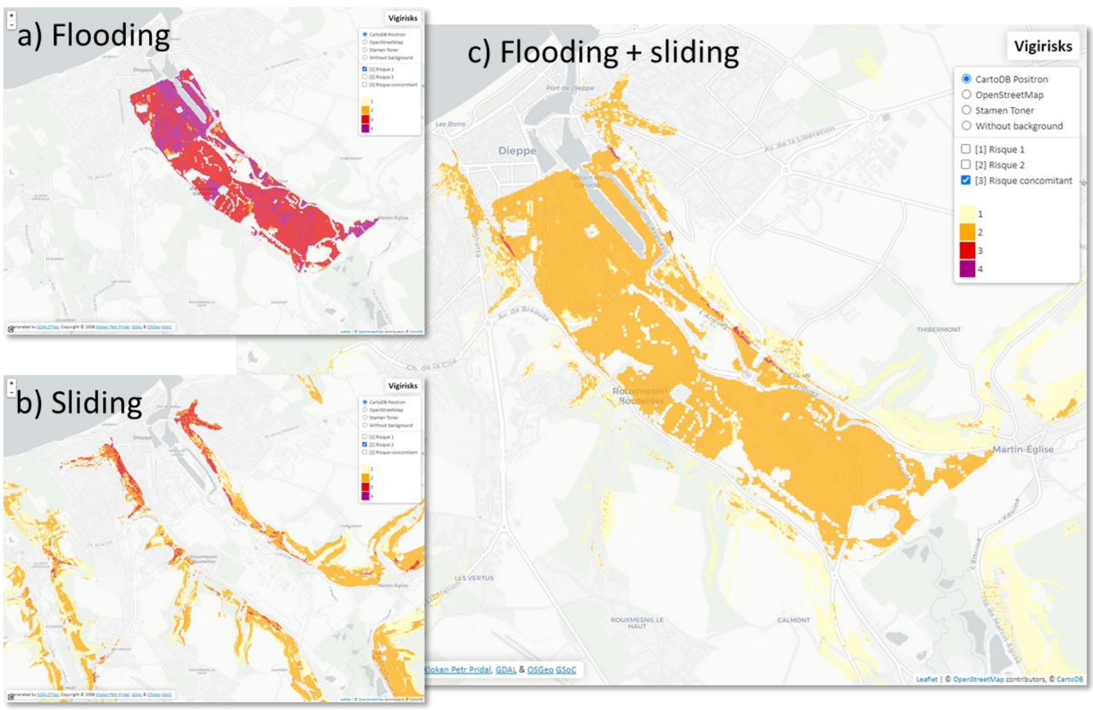

Fig.2: Resulting multi-risk maps from the Vigirisk workflow "concomitant risk": a) flood risks, b) sliding risks, and c) flooding + sliding risks.

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