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## VIGIMONT project: towards landslide Early warning System

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**SUMMARY:** The general objective of VIGIMONT is to develop a new service within two existing early warning platforms, by adding modules dedicated to real-time debris-flow and landslide dynamic vigilance for safety authorities in mountain areas. Indeed, with the deployment of meteorological radars, the occurrence of debris flows and landslides induced by meteorological events will be analysed, based on antecedent precipitations quantification and event rainfalls definition. It will permit to determine critical rainfall thresholds for events occurrences, allowing events detection and mapping. A multi-scale approach is proposed by considering both the regional and the local (municipality) scales, with the development of services for end-users acting at these two scales. Phenomena addressed here are focussed on some typologies of movements: it concerns shallow landslides, deep seated landslides and debris flows.

**Keywords:** Early warning system, Landslide susceptibility, debris flows

### Introduction

Considering the current high number of landslides and the increase of events that might happen, there is a need to improve hazard assessment and risk mitigation. In many densely populated mountain regions, governmental agencies or the municipalities try to protect the habitants by different measures. Amongst these measures, territorial Early Warning Systems (**Te-EWS**) constitute one key challenge, as in mountainous areas, the living space is extremely limited. In particular, mountain regions have strongly benefited from recent advances in meteorological data acquisition for observation, process-understanding, and forecasting, with direct implications for prevention of natural hazards induced by heavy rainfall and snow episodes. Several EWSs have been developed at a regional scale (Gariano et al., 2015; Staley et al., 2017). Guzzetti et al., 2020, has analysed different Te-EWSs implemented in the world, through different features: the geographical location, the landslide and rainfall data considered, the threshold models used, the design of EWS considering the specialization, the operational framework, the advisory systems, the implementation, and the performance evaluation. They conclude that “operational forecasting of weather-induced landslide is possible and feasible today and it can contribute to mitigate landslide risk, reducing fatalities and economic losses”. They also propose some recommendations for further development or improvement of EWSs, and indicate that still many areas with numerous fatal landslides are not covered by Te-EWSs. Most of the systems use information from rain gauge networks, meteorological models, weather radars, and satellite estimates, and their forecasting models are based on rainfall thresholds, distributed slope stability models, and soil water balance models. Besides, despite a lot of EWS developed around the world, it appears that there is a lack of exchanges on this issue. In France, few Te-EWS have been developed, despite a lot of landslide events leading to traffic interruption, village isolation, and casualties and deaths.



**Objectives** - The objective of the project is to improve existing EW platforms and services dedicated to hazards in mountain areas, by providing real-time dynamic vigilance maps for stakeholders and safety authorities. Both regional and local (municipality) scales will be addressed. At regional scale, focus will be put on designing innovative approaches for assessing debris-flow and landslide spatialized triggering thresholds, including propagation, in order to complement existing platforms dedicated to meteorological and flood events (RhyTMME, Wikipredict). At local scale, implementation of EWSs tailored to the needs and preparedness of local authorities and populations will be considered. The specific objectives addressed by the project are: 1) to analyze social acceptability of EWS 2) to define improved debris-flow and landslide rainfall thresholds; 3) to improve the spatiotemporal variability characterization of debris-flow and landslide triggering conditions; 4) concerning active deep seated landslide, it is planned to test the automatic production of ground motion Time Series using INSAR; 5) to integrate runout scenarios into EWS by coupling triggering thresholds with shallow landslide and debris-flow susceptibility and physical propagation models; 6) to develop an operational forecasting system for deep seated landslides based on INSAR measurements and on precipitation predictions; 7) to integrate real-time landslide and debris-flow warning maps in available EWS with the definition of warning levels and analysis of associated uncertainties.

### **Preliminary actions**

A main drawback of landslide rainfall-based Te-EWS is their poor spatial prediction capacity: a threshold overcoming produces an alert for the entire area encompassing the events used for calibration, while the location of expected landslides is poorly constrained.

This is the main reason explaining why EWS only based on rainfall information generate many false alarms. To improve the spatial prediction of EWS, some authors proposed to combine rainfall fields to susceptibility maps. However, several issues have to be considered in defining the susceptibility maps. In particular there is a strong need for identification of the best geomorphic predictors and for their high-resolution mapping.

It is proposed here to indicate some preliminary results concerning landslide susceptibility map that has been computed in the south of France. For that, different steps are conducted:

*Structuring a landslide database* - the landslide inventory has been built based on several sources:

- National French database: it contains all the information available in France in the form of a shapefile point in a GIS. It includes the location of events, dates of occurrence, details (date, year, etc.) and other information such as surface area, volume, depth of rupture, etc. It has then been completed and improved by the work carried out as part of the AD-VITAM project specifically in Alpes-Maritimes department.

- an inventory carried out focusing on landslides triggered by the post-Alex storm. This inventory is based on the Ortho-Express-Tempête Alex (IGN, October 2020), focused on the Tinée, Roya and Vésubie valleys.

- a complementary inventory based on orthophotos from 2009, 2014 and 2020 with reference to intense rainfall events in 2009, 2014 and 2020. A procedure has therefore developed to identify landslide tracks on orthophotos so that they can be digitized.

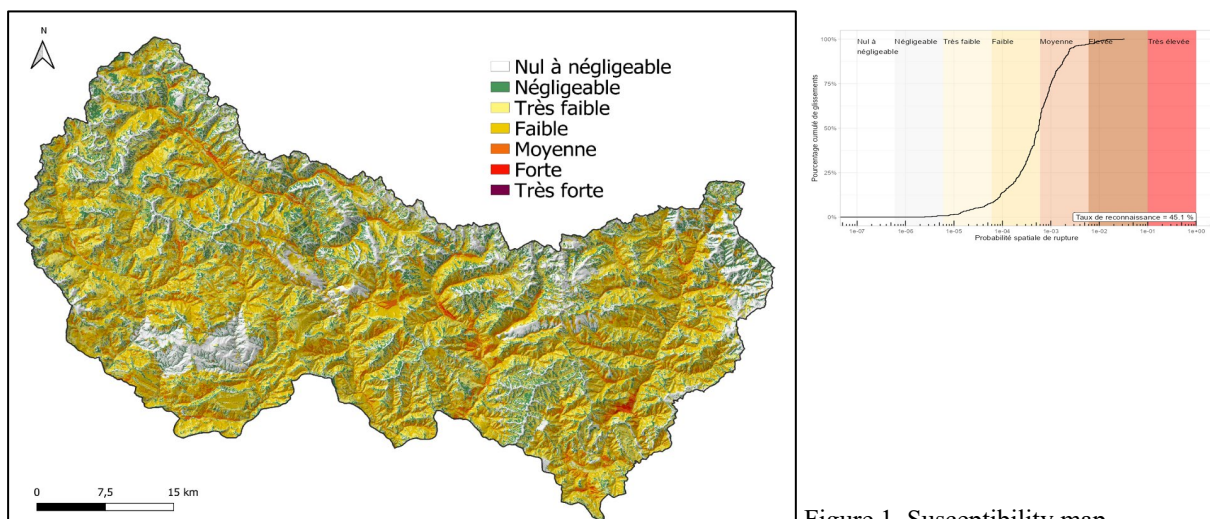
Four types of landslide are defined within the area: shallow mudflow; medium mudflow; shallow earthslide; medium earthslide. This classification is inspired by international standards, based on material type, landslide depth and surface area (Hung et al., 2014).



*Strategy of landslide susceptibility mapping* - The philosophy was guided by the need for project practitioners to easily understand the key factors. Therefore, the methodology for creating landslide susceptibility maps (LSM) was based on a straightforward and easy-to-implement approach. The quantitative method called weight of evidence (WoE) was selected (Bonham-Carter, 1996). The methodology is based on Baye's theorem (Bonham-Carter, 1996) and allows for a quick analysis of the influence of each variable class and obtaining failure probabilities based on the density of phenomena per class. Moreover, different updates can be easily carried out when new inventories or information become available at different time steps. Finally, the strategy employed to compute LSL was derived from Thiery et al. (2007) and involving a step-by-step selection of spatial variables best suited to compute the LSMs.

## Results

Among the different predictive variables selected 6 were sufficient to obtain results with satisfactory statistical tests with slope classes, landforms, lithology, curvature, landuse and aspect. However, even if the statistical tests yield satisfactory results, certain limitations have been identified. For instance, areas known for producing numerous landslides were not identified in the moderate high, or very high susceptibility classes. This could pose challenges when studying temporality and triggering factors. Thus, two key issues need attention for the remainder of the project: (1) the landslide inventory, despite combining field analysis and aerial photograph analysis, was not subdivided into initiation (failure) and propagation areas; only centroids were used for landslide susceptibility calculations. This likely underestimates failure probabilities and, consequently, the derived susceptibility classes (Thiery et al., 2007). (2) The lithological map was a compilation of several 1:50,000 scale maps that varied in terms of spatial accuracy and nomenclature. Certain classes, particularly surficial formations, were significantly underestimated spatially, while field observations indicated that many landslides originate in these formations



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## References

- Bonham-Carter, G. F. (1994). *Geographic Information System for Geoscientists: Modeling with GIS*. Pergamon Press. *Computer Methods in the Geosciences*, Vol. 13, pp. 398.
- Gariano, S.L. et al., 2015. Calibration and validation of rainfall thresholds for shallow landslide forecasting in Sicily, southern Italy. *Geomorphology* 228, 653–665. <https://doi.org/10.1016/j.geomorph.2014.10.019>
- Guzzetti F. et al., Geographical landslide early warning systems, *Earth-Science Reviews* 200 (2020)
- Hungr O., Leroueil S., & Picarelli L., (2013). The Varnes Classification of Landslide Types, an update. *Landslides*, 11(2), 167-194. <https://doi.org/10.1007/s10346-013-0436-y>
- Interreg Alcotra. (2020). Analyse de la vulnérabilité des territoires alpins méditerranéens aux risques naturels (mouvements de terrain) (Progetto Interreg Alcotra n°1573 "AD-VITAM"). <http://54.36.75.4/index.php/fr/>
- Staley, D.M., et al., 2017. Prediction of spatially explicit rainfall intensity–duration thresholds for post-fire debris-flow generation in the western United States. *Geomorphology* 278, 149–162.
- Thiery, Y., Malet, J., Sterlacchini, S., A, P., & Maquaire, O. (2007). Landslide Susceptibility Assessment by bivariate methods at large scales : application to a complex mountainous environment. *Geomorphology*, 92(1-2), 38-59. <https://doi.org/10.1016/j.geomorph.2007.02.020>