**Title:** Dynamic landslide susceptibility modeling: a new generation of artificially intelligent early warning systems

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**Research Program**

Geo-hydrological hazards are expected to increase as the frequency of extreme weather events is projected to increase in response to climate change. This implies that estimates of how prone a given landscape is to generate landslides (a concept referred to as susceptibility) may not be useful or at least informative in the years to come. In other words, the notion that landslide susceptibility is a static landscape characteristic may need to be revised in favor of a much more dynamic susceptibility. In fact, dynamic properties such as land use, vegetation density, road development, ground motion and rainfall discharge contribute to significant temporal variations of the susceptibility.

Where the community has acknowledged the temporal complexity of the landslide phenomenon usually falls within the early-warning-system (EWS) category. However, the way traditional EWS are built exclusively look at rainfall patterns, then intersect this information with a previous landslide presence/absence dataset, only to retrieve rainfall thresholds. This framework may also be flawed as it uniquely relies on the spatio-temporal distribution of the rainfall and neglects the predisposing factors of a given landscape.

In this context, large improvements can be made by merging the two frameworks into a single one, effectively moving from rainfall thresholds to landslide probability thresholds. This can be done by using a consolidated modeling framework typical of the susceptibility assessment, while introducing the rainfall as an additional parameter. In turn, an artificial intelligence should be capable of: 1) extracting both the static characteristics that make any landscape prone to slope failures, 2) while contextually assessing whether an incoming storm may generate clusters of potentially unstable slopes in space and time.

Multiple geohazards have been under consideration of assessing the threat they bring, with the increase in frequency of extreme weather events. Human settlements, spread over different topographies and landscapes face one or more natural disasters which result in economic and human loss. One of the many concerning hazards are landslides, which are widely classified as the downward movements of the slope under the influence of gravity but can be triggered by external factors. With the advancement and availability of large remotely-sensed datasets, expanding globally, that aid in the assessment and understanding of landslide occurrences supported the development of landslide analysis and resulted in common preparation of susceptibility maps. However, these maps are commonly built from a single event-inventory covering an affected region and lack a temporally dynamic component. Such maps are static in time and nature, because they rely upon a single isolated event in time over a region which most likely has dynamic patterns affecting its slope stability. The time-variant components can be influential, and even the main trigger factor such as changing rainfall patterns. This lack of understanding poses a greater threat when such information is distributed to management authorities to make decisions affecting a larger community. Multiple Early Warning

Systems (EWS) are based on the reasoning and reliance of empirical models, which may be consuming incomplete information to define the probability of failure.

Steps in this research direction have already been made. For instance, to run real-time forecasting of rainfall triggered landslides, Landslide Hazard for Situational Awareness (LHASA) was developed at National Aeronautics and Space Administration’s (NASA) Goddard Space Flight Center. This LHASA uses surface susceptibility as the static base layer and integrates Global Precipitation Measurement (GPM) as the time-variant component to create real-time visualization of landslide susceptibility. However, the current version of this model is solely valid on a global scale and at a resolution which is far from any real application. The artificial intelligence behind the LHASA can also be vastly improved, an uncertainty estimation is not part of the NASA near-real-time routines and in general the rainfall data they use comes from satellite estimates at a very coarse spatial scale.

The proposed PhD position aims at developing a new generation of artificially intelligent EWS, by improving on the research directions mentioned above and by making it so that its applicability can be extended towards regional and even catchment scales.

**Proposal for PhD Position**

A PhD position is proposed in a multi-disciplinary and cross-national scientific environment, with several research centers already envisioned to work together towards a common goal. Specifically, analyses of large spatio-temporal landslide databases, as well as the required landscape and rainfall characteristics will be conducted in collaboration with the University of Twente (Netherlands) and the King Abdullah University of Science and Technology (Saudi Arabia). We consider such collaborations fundamental for the cultural growth of the doctoral student, as well as for the achievement of shared and validated scientific results within the international scientific community. Therefore, during the three years of the PhD several multi-disciplinary and international activities are expected to take place, and details are provided below:

1- First year experience in big data management, this will set the standard for processing, handling, analysing and later produce probabilistic estimates of landslide occurrences. And, it will make use of cloud computing platforms such as Google Earth Engine.
2- The second and part of the third years will move to the analytical aspects of the doctoral experience and specifically towards two aspects of artificial intelligence. On the one side, statistical models will support interpretation of the analytical results whereas a machine/deep learning architecture will offer a complementary perspective on the potential predictive skill that the expected EWS will produce.
3- Part of the third and final year will be dedicated to translating the results into a WEB-GIS platform, accessible to the public and where the EWS will automatically update itself on a daily basis, as the incoming weather forecast data is streamlined from cloud resources.

Potential study areas will fall in portions of the territory affected by different geohazards known from the literature (landslides, floods...), where the availability of monitoring data is known at the same time.

Cost for field surveys and other project-related activities will be covered by the departmental funds of the Research Group in Engineering Geology.

The candidate should have a solid background in natural hazard analysis, mathematics, physics, geo-statistics, computer science and GIS. Knowledge of programming languages represents an appreciate skill (Matlab, R, etc.).