Assessment of the risk of shallow landslides integrating InSAR and optical data with a distributed eco-hydrological model

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Abstract

Landslides induced by extreme and prolonged rainfall pose significant risks, leading to fatalities, extensive damage, and economic losses annually. Physically-based deterministic models for rainfall-triggered landslides offer advantages over empirical methods of enabling the evaluation of relationships between rainfall characteristics, soil hydrological conditions, and soil shear strength response during rainfall infiltration. However, one of the scientific challenges is the complexity of the physically-based distributed approaches which require spatially and temporally distributed parameters [1,2]. Integration of remote sensing and InSAR technology with a physically-based distributed model may enhance the applicability of this last method in two key aspects: firstly, enabling the estimation of soil parameters for soil characterization, and secondly, understanding the correlation between soil moisture and deformation history. In terms of soil characterization, calculating soil thickness is crucial as it significantly influences the mobilized soil weight and therefore the indicator of stability, named as factor of safety (FS).

In this study we exploit and propose a framework which integrates a dynamic eco-hydrological and stability model named tRIBS-VEGGIE-Landslide (*Triangulated Irregular Networks-based Real-time Integrated Basin Simulator and Vegetation Generator for Interactive Evolution*) [3,4] with InSAR data. In the hydrological component, the infiltration module is based on Richard's equation, which allows for an accurate representation of the time evolution of soil moisture transport through the soil column. The predicted soil moisture is used to assess the FS index based on the infinite slope model [4]. However, the hypothetical failure surface strictly depends on the specific soil characteristics and it should be constrained. Therefore, accurately characterizing soil thickness (H) is crucial for assessing the FS [1,4]. To determine soil thickness, we plan to test the application of thickness inversion approach [5,6], which uses displacement rate estimation. This involves using surface velocity data from InSAR measurements and applying mass conservation principles. InSAR data from Sentinel-1 will be used to derive the displacement rate. This data, from the *European Ground Motion Service* (EGSM) [7,8], offers ground motion information on a European scale (Figure 1). Other hydrological parameters, such as the soil water retention curve properties, can be derived by using pedotransfer functions.

The framework will be tested in a case study area selected in the Friuli-Venezia Giulia region (Italy), focusing on well-documented history of alluvial events triggering shallow landslides. The values of certain soil parameters in this area would serve as a crucial reminder for landslide researchers to carefully consider the geology and geomorphology of study areas where complex active movements are detected using InSAR technology. For landslide documentation and detection, we utilized a landslide catalogue ITALICA (*ITAlian rainfall-induced LandslIdes Catalogue*) and a public domain data from the national project IDROGEO, which contributes to the Italian Landslide Inventory (IFFI) [9,10].

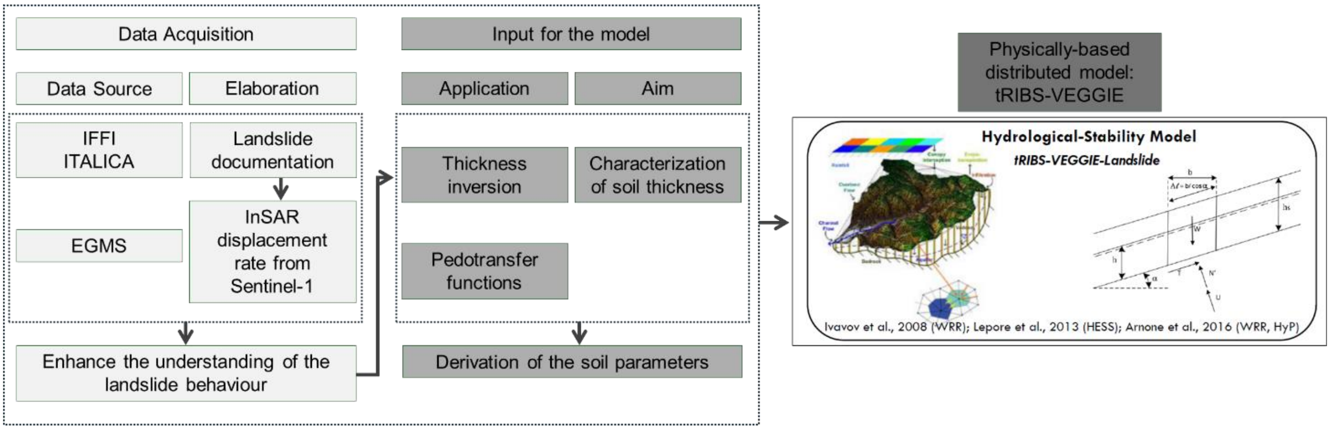

Figure 1: Flowchart describing the planned methodology which integrates InSAR data with physically based and distributed approach.

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