Date of Submission	30/03/2018

IPL Project Annual Report Form 2017

1 January 2016 to 31 December 2017

1. Project Title:

IPL-198 (2015) Multi-scale rainfall triggering models for Early Warning of Landslides (MUSE)

2. Main Project Fields:

(1) Technology Development

A. Monitoring and Early Warning, B. Prediction of triggering in real-time

(3) Capacity Building

A. Setting up of Operational Early Warning Systems

3. Name of Project leader:

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Core members of the Project:

Nicola Casagli, Professor, DST-UNIFI
Veronica Tofani, Assistant Professor, DST-UNIFI
Michele D'Ambrosio, Research Fellow, DST-UNIFI
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4. Objectives:

The main objective of this candidate IPL project will be the enhancement of knowledge and methodologies related to the integration of landslide prediction models at different scales to build an effective operational multi-scale system for real-time early warning of rainfall triggered mass movements

5. Study Area:

For the first phase of the project, the study area was Tuscany region, that is heavily affected by landslides. During the second phase, we selected a second test area, consisting in a portion of the

Valle d'Aosta region, located in North-West Alpine mountain chain, where we applied the HIRESSS (High REsolution Stability Simulator) physically-based model, to forecast the occurrence of shallow landslides at regional scale.

6. Project Duration:

3 years

7. Report

1) Progress in the project: (30 lines maximum)

During the last year of the project the activities carried out are mainly related to WP1 and WP2.

WP1: Characterization of hillslope deposits in Tuscany region

The main aim of this activity is to provide a homogenous set of data concerning the principal geotechnical and hydrological properties of soils and deposits by means of an extensive campaign of in-situ and laboratory measurements. The specific objectives are: i) to determine the ranges of variation of the geotechnical and hydrogeological parameters that control shallow landslide triggering mechanisms; ii) to investigate a way to spatialize the geotechnical and hydrological data according to physical factors. The final intent is to improve the reliability of deterministic models output such as the HIRESSS (HIgh REsolution Slope Stability Simulator; Rossi et al., 2013).

The study area is the entire Tuscany region (Fig. 1), located in central Italy, that is heavily affected by landslides (over 90,000, according to the inventory of Tuscany Region). A total of 129 samples were collected in 102 different sites (Fig. 1), that were selected in order to have a representative sample of the main soil types producing shallow landslides while trying to keep a homogenous spatial distribution across the hillslopes of Tuscany.

Samples were collected at depths ranging from 0.4 to 0.6 m b.g.l. (below the ground level). The geotechnical and hydrological parameters for characterizing the soils were determined from a series of in-situ and laboratory tests. The in-situ tests included the Borehole Shear Test (BST; Dapporto et al., 2000; Lutenegger & Halberg, 1981), which provides the shear strength parameters under natural conditions without disturbing the soil samples, matric suction measurements with a tensiometer, a constant head permeameter test performed with the Amoozemeter instrument (Amoozegar, 1989) and sampling of two aliquots (~2 kg each) of the material for laboratory tests.

Additionally, a series of laboratory tests, including the determination of grain size distribution, the Atterberg limits and the phase relationship analysis (bulk porosity n; saturated, natural and dry unit weight, γ_{sat}, γ and γ_d respectively) were conducted in the laboratory following the ASTM (American Society for Testing and Materials) recommendations (ASTM D422–63 2007, ASTM

D2217–85 1998 and ASTM D-4318 2010).

Even though at the present stage the density of measures is still not suitable for a detailed characterization of the hillslopes deposits in the region, the data retrieved are considered beneficial as a first step to improve the reliability of numerical models aimed at simulating the stability of hillslopes and assessing the triggering mechanisms for landslides. Some parameters such as the internal friction angle, were found to be well represented by using normal probability distributions functions. Given an appropriate measure of the barycenter and the variance (e.g. arithmetic mean and standard deviation) derived from the analyzed data, this kind of parameters could be easily reproduced and simulated by deterministic models, as well as interpolated after studying autocorrelation properties by geostatistical tools, thus improving the efficiency with respect to the adoption of constant values and/or equiprobable distributions.

WP2. Application of physically based model to forecast shallow landslides at regional scale

The final aim of this activity is the set-up of an early warning system at regional scale, applying a physically based model (named HIRESSS model, High REsolution Stability Simulator) to forecast the occurrence of shallow landslides. The area test is the eastern part of Valle d'Aosta region (Italy), in North-West Alpine mountain chain. In the area selected, an in-depth study of the geotechnical and hydrological properties of hillslopes controlling shallow landslides formation was conducted, performing two campaigns (12 survey points) of in-situ measurements and laboratory tests. The geotechnical parameters measured have been statistically analyzed and linked to the main lithologies of the bedrock in order to define the input hydrological and geotechnical parameters for the HIRESSS model.

Furthermore, the HIRESSS model has been modified to take into account the effect of the root reinforcement to the stability of slopes based on the vegetation map and literature values.

All these data have been inserted in the HIRESSS model to obtain day-by-day maps of landslide occurrence probability. The HIRESSS model simulated two past events, one in 2008 and one in 2009, and the validation of the model performance was carried out comparing the results with the landslide regional database. This software makes use of Monte Carlo simulation technique to manage the uncertainty typical of geotechnical and hydrological input parameters, which is a common weakness of deterministic models. The Monte Carlo simulation achieves a probability distribution of input parameters providing results in terms of slope failure probability.

The validation of the results, carried out using a database of past landslides, has provided good results and a good prediction accuracy of the HIRESSS model both from temporal and spatial point of view (Fig.2).

2) Planned future activities or Statement of completion of the Project

In 2018 the activities foreseen are mainly related to the further applications of the HIRESSS model in selected test sites in order to define the sensitivity of the model to the variations of the input data (geotechnical and hydrological properties). Further improvements will be devoted to the implementation inside the HIRESSS of the contribution of the vegetation in terms of root reinforcement to the stability of slopes.

Further improvements will be carried out on the integration and harmonization of rainfall data of different type (measured and predicted) within the early warning system based on the HIRESSS model. In this approach, a new algorithm for the extraction of soil moisture from Sentinel SAR data will be tested to infer spatially distributed near-real time data on soil saturation.

3) Beneficiaries of Project for Science, Education and/or Society

The beneficiaries of this project are several: Civil Protection offices and institution, Research institutes, Universities, Public administrations, International organizations. In particular since we have worked for the selected test cases in close cooperation with the public administration in charge of risk management, we expect that the governmental administrations will use the project outcomes, to design, implement, and validate regional landslide early warning systems.

4) Results:

Tofani V., Bicocchi G., Rossi G., Segoni S., D'Ambrosio M., Catani F., Casagli N. (2017). Soil characterization for shallow landslides modeling: a case study in the Northern Apennines (Central Italy). Landslides, 7, Vol. 14, pp 1-16 – DOI: 10.1007/s10346-017-0809-8

Tofani V., Bicocchi G., Rossi G., D'Ambrosio M., Catani F., Casagli N. (2017). Soil characterization for landslide forecasting models: a case study in the Northern Apennines (Central Italy). In book: Advancing Culture of Living with Landslides, June 2017, pp.381-388 - DOI: 10.1007/978-3-319-53498-5_44

Salvatici T., Tofani V., Rossi G., D'Ambrosio M., Tacconi Stefanelli C., Masi E.B., Rosi A., Pazzi V., Vannoci P., Petrolo M., Catani F. and Casagli N. (2018) Regional physically-based landslide early warning model: soil parametrization and validation of the results. Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-425, in review.

Bicocchi G., D'Ambrosio M., Tacconi-Stefanelli C., Tofani V., Vannocci P., Casagli N., Lavorini G., Trevisani M., Catani F. (2018) Characterization of hillslope deposits for regional landslide prediction modeling. Engineering Geology, submitted.