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IPL Project 258 Report 2024

1. Project Title: **SLOPE STABILITY IN VINEYARDS WITH DIFFERENT MANAGEMENT PRACTICES (Acronym: WINESLIDES)**

2. **Main Project Fields**

(1) Technology Development

A. Monitoring and Early Warning, B. Hazard Mapping, Vulnerability and Risk Assessment

3. **Name of Project leader**

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Core members of the Project

- Domenico Calcaterra: Full Professor, Earth Sciences Department (UNINA), University Federico II, Naples (ITA)
- Fulvio Celico: Full Professor, Dept. of Chemistry, Life Sciences and Environmental Sustainability, University of Parma (ITA)
- Claudia Meisina: Full professor, Department of Earth and Environmental Sciences (ITA) - University of Pavia (UNIPV)
- Paola Revellino: Associate Professor, Dipartimento di Scienze e Tecnologie (UNISANNIO), University of Sannio, Benevento (ITA)

4. *Objectives*: (5 lines maximum; what you expect to accomplish?)

1) Analyze the effects of agronomic management practices on shallow landslide triggering in vineyards;
2) Connect geohydrological information with soil biodiversity in order to understand the influence of soil fauna on shallow landslides;
3) Identify agronomic management practices, sustainable in terms of economic profitability and impact on the environment, which allow to prevent shallow landslides;
4) Development of guidelines of agronomic management practices which can help local communities to develop effective policies and strategies for reducing the risk of shallow landslides in vineyards.

5. ***Background Justification*:**

Vineyards cover currently 7.5 million ha corresponding to about 0.5% of the entire agricultural areas in the world (OIV, 2017) and frequently they are severely damaged by rainfall-induced shallow landslides. Different agricultural practices adopted to manage the inter rows, like maintenance of bare soil, continued use of heavy machinery for tillage or permanent grass cover, influence soil physical and hydrological features, such as soil density, water content, hydraulic conductivity (Bordoni et al., 2019). The management practices have also an important impact on the distribution of grapevine roots in the soil. The density of roots together with their mechanical behavior related to shear and/or tensile forces, increases soil stability (Bischetti et al., 2009; Cohen and Schwarz, 2017) and is often used as an effective tool to decrease the occurrence of shallow landslides, which are widespread in different geological contexts characterized by traditional viticulture. For this reason, a quantification of root reinforcement of grapevines in vineyards with different management practices is fundamental to understand the practices that might promote the stability of sloping vineyards and the ones that cause slope instability.

6. *Study Area*:

Vineyards with different management practices in Italy (Oltrepò Pavese in Northern Italy, Chianti in Central Italy and Campania in Southern Italy). In particular the Oltrepo Pavese area has been selected as pilot site.

7. *Project Duration*: 3 years

8. Report

RESULTS

The work carried out in the last year concerned task 4 - Shallow landslide assessment in vineyards and task 5- Guidelines development.

Task 1 – Engineering geological model of the study areas: Six demo farms were selected as test-sites in Oltrepo pavese (Northern Italy), in order to represent the different geological, geomorphological and land use features of the territory. In each demo vineyard, a comparison was done between a local standard practice (e.g. permanent grass cover, alternating tillage-grass, tillage) and practices corresponding to one or more techniques (e.g. green manure and rolling) suitable to improve rain use efficiency as well as to reduce landslide.

Task 2 – Geotechnical, pedological soil characterization of the test sites. The soils of each demo farm were characterized from a multidisciplinary point of view.

After the geophysical surveys (ERT), two trench pits were opened in each tested vineyard. These pits were located along the same inter-row, in the upper and the lower parts of the slope to highlight possible differences on soil properties due to the different geomorphological position. The pits were averagely 2 m long and 1.5 m large, with variable depth according to the depth of the weathered bedrock . Generally, the pits were dug up to a depth of 1.5-2 m.

For each pit the following analysis were carried out:

- Description of the soil profile, with the identification of soil thickness and of the different diagnostic horizons;
- collection of undisturbed samples, for each identified horizon, for the laboratory analysis allowing to derive the following parameters: soil texture (sand, silt and clay percentages); soil chemical properties (pH; organic matter content; cation exchange capacity; carbonate content; active lime content; amount of Na, Ca, K, Mg, P; C/N ratio; electrical conductivity of the soil);
- collection of undisturbed samples, each 10 cm along the soil profile, for the physical laboratory analysis of soil volumetric features (unit weight, dry density, porosity, void index, water content, saturation degree)
- collection of undisturbed soil samples, for the representative soil horizons generally located between 0.2 and 0.7 m from ground level, for the determination of the soil water retention curve.

The general soil characterization was completed with the measure of soil hydraulic conductivity in field, at different depths along the soil profile. Soil hydraulic conductivity were measured in different position along the slope where a tested vineyard is located and in correspondence of inter-rows where different management practices are present.

In each demo farm, a set of monitoring tools were installed to measure in time the trends of the main meteorological (rainfall, air temperature, air humidity, atmospheric pressure, wind speed and direction, solar radiation) and soil hydrological (soil water content, soil electrical conductivity, soil temperature) parameters. The aim of this monitoring is to evaluate the effect induced by different management on hydrological behaviors in the soil, in particular relating to slope stability.

Task 3 - Data analysis. The data measured in the task 2 were integrated in order to evaluate the influence of the management techniques on:

A. the geotechnical (texture, volumetric characteristics and their vertical variations) and pedological parameters (calcium carbonate, organic matter, main ions, pH, etc. ..).

B. the hydrological parameters (hydraulic conductivity, infiltration).

C. the biological parameters (soil fauna biodiversity).

D. the density and reinforcement operated by the root system in the soil.

The soil hydraulic conductivity is the most influencing parameter by the inter-row management.

Permanent grass cover and alternating interrow management techniques guarantee larger amounts of organic matter, promoting a significant increase in root density (in temperate climate with enough rainfall amount during the ripening and the vegetative periods). Alternating presents the highest values of root reinforcement, particularly where slope instabilities occur (1.0 m depth).

Task 4 - Shallow landslide assessment. Given the necessity of including spatially distributed and management-specific inputs, the process-based landscape evolution model LAPSUS-LS was chosen and adapted to achieve a probabilistic approach which takes into account land management as an input by adopting management-specific values of root cohesion. The model was applied to four test sites in the Oltrepò Pavese (Italy), where different vineyard management techniques play a significant role in triggering landslides. The results for the four test areas had, cumulatively, an Area Under the Roc curve greater than 0.73, with false negative cells being < 1 % of the total for all simulations. In the model's application, land use practices characterised by higher root cohesion proved to benefit slope stability, whereas tilled vineyards, shrublands and abandoned vineyards were more prone to the formation of shallow landslides. In addition, we found that the inclusion of management-specific input parameters produced more accurate outputs and that in catchments characterised by average slope angles lower than 15°, varying the vineyard management, did not appear to affect the landslide susceptibility. Due to the model's high dependency on the land use and its ability to include land management, it can take into account the spatial variability of input values such as the root cohesion. Additionally, it can be applied i) to manage current conditions, ii) to explore future land use change, iii) to study less invasive yet beneficial land use management change scenarios and iv) provide farmers of at-risk areas insight on how to improve slope stability..

Task 5 – Guidelines development. Guidelines have been drawn up aimed at the application, on a territorial scale, of those agronomic practices that are able to reduce shallow landslide hazard in steep vineyards. The most successful results obtained in this research has been integrated into rural policies of the involved municipalities. 2 workshops were organized in the Oltrepo Pavese pilot site involving citizens and stakeholders in order to illustrate the results of the project.

8. **Project Beneficiaries:**

Landslide professionals, researchers, policy makers developing policies and strategies for reducing the risk of shallow landslides in vineyards, farmers and people living in areas with vineyards and similar cultivations, insurance companies, land use planners.

PUBBLICATIONS.

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2. Giarola A., Schoorl J.M., Baartman J.E.M, Bordoni M., Tarolli P., Zucca F., Heckmann T., Meisina, C. (2024). Exploiting the land use to predict shallow landslide susceptibility: A probabilistic implementation of LAPSUS-LS, CATENA, Volume 246, https://doi.org/10.1016/j.catena.2024.108437.
3. Giarola, A.; Bordoni, M.; Zucca, F.; Meisina, C. Analysis of the Role of Precipitati on and Land Use on the Size of the Source Area of Shallow Landslides. Water 2 023, 15, 3340. https://doi.org/10.3390/w15193340
4. Bordoni M., Vivaldi V., Giarola A., Valentino R., Bittelli M., Meisina C. (2024), C omparison between mechanical and hydrological reinforcement effects of cultivate d plants on shallow slope stability, Science of The Total Environment, 912, 16899 9, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.168999.
5. Sadeghi S.H., Zabihi Silabi M., Bordoni M, Nguyen T.N.A, Maerker M., Meisina

C. (2024),A game theory-based prioritization of drought affected demo vineyards using soil main properties in the Northern Apennines, Italy, CATENA, 237, 107767, ISSN 0341-8162, https://doi.org/10.1016/j.catena.2023.107767.

6. Vivaldi, V., Torrese, P., Bordoni, M., Viglietti, F., Meisina, C. (2024). ERT-based experimental integrated approach for soil hydrological characterization in rainfall-induced shallow landslides prone areas. Bull Eng Geol Environ 83, 167 (2024). https://doi.org/10.1007/s10064-024-03627-8.
7. Claudia Meisina, Domenico Calcaterra, Fulvio Celico, Veronica Tofani, Paola Revellino, Filippo Catani. Slope Stability In Vineyards With Different Slope Management Practices: State Of The Art In Italy. Oral resentation WLF6, Firenze.