Modelling the superficial formation thickness at slopes organized on agricultural terraces at Douro Demarked Region

Modelação da espessura das formações superficiais em vertentes organizadas em terraços agrícolas na Região Demarcada do Douro

C. Bateira[1 *], S. Pereira[2], P. SantAnna[3], G. N. Lima[2], F. Alves[4], M. Natário[4], J. Valente[4]

[1] Univ. do Porto, Dep. Geografia, Riskam-IGOT-CEG/FLUP-UPorto, Via Panorâmica ao Campo Alegre, s/n, Porto Portugal.
[2] Univ. do Porto, Dep. de Geografia, CEGOT, Via Panorâmica ao Campo Alegre, s/n, Porto; Univ. de Lisboa, IGOT, CEG.
[3] Univ. do Porto, Dep. de Geografia, Via Panorâmica ao Campo Alegre, s/n, Porto.
[4] Symington Family Estates, Vinhos SA. Vila Nova de Gaia, Portugal.
[*] carlosbateira@gmail.com.

ABSTRACT

The study focuses on the spatial modelling of the surface formations (SF) thickness that support the construction of agricultural terraces at the Douro Demarcated Region (RDD). The methodology uses an arithmetic model that integrates curvature, slope and normalized slope height. The validation was based on two approaches: (i) the field observation and measure of the terrace riser when the contact between the SF and the parent material is observable; (ii) the construction of electrical resistance profiles up to 2.5m depth. We considered that electrical resistance below 200Ω corresponds to SF materials.

Key words: *Surface formations thickness, terraced slopes, Douro valley.*

RESUMO

O estudo incide sobre a modelação espacial da espessura das formações superficiais (FS) que suportam a construção de terraços agrícolas na Região Demarcada do Douro (RDD). A metodologia baseia-se num modelo aritmético que integra a curvatura, o declive e a altura normalizada da vertente. A validação baseou-se em duas abordagens: (i) observação e medição dos taludes de terraços quando o contacto das formações superficiais com a rocha mãe é observável; (ii) construção de perfis de resistência elétrica até à profundidade de 2,5m. Considerou-se que a resistência elétrica inferior a 200Ω corresponde a materiais das FS.

Palavras-chave: *Espessura das formações superficiais, vertentes em terraços, Vale do Douro.*

1. INTRODUCTION

The Douro Valley is undergoing important changes in the vineyard systematization, in the steep-slope landscapes, both at economic and social levels, with implications on vine production with the widespread use of mechanization. This involves rebuilding the terraces adapted to the size of the machinery used. The new terraces have platform width of 2.30m to 2.50m, one vine row and earthen embankments.

During the construction process of the agricultural terraces, the slope regularisation of previous vineyard system recovers the morphology of the pre-installation vineyard. Subsequently, new terrace construction is based on the decision of the number of vine rows for each terrace. After the new terrace's construction, the platform's superficial formation materials (rock, thin soil layer and residual organic matter) are turned upside down to a meter deep to provide ventilation to the upper part of the superficial formation installed in the platform and prepare the installation of the vineyard.

This intervention determines a very significant change in the soil structure, which presents an absence of soil layers resulting from paedogenesis. The characteristics of these surface formations (SF) have an anthropic genesis, which also controls their thickness and structure. However, before the first vineyard installation the original SF thickness is very close to the SF thickness after regularization and before the new terrace's construction. The thickness of SF is an essential parameter for modelling terrace instability, both for statistical and mathematically based models.

The application of different models for soil thickness evaluation, with different methodologies, at different scales and different areas presents different performances (Catani et al., 2010; Pelletier et al., 2016).

The main objective of this study is to model and validate the SF thickness on metamorphic formations that support the vineyard installation, as well as evaluate the thickness of the SF after the installation of the new terraces.

This work is a contribution to the LivingSoiLL project that aims to create a network of five Living Laboratories (LL) across Europe, with at least 50 demonstration sites, focusing on permanent crops with economic, social, and cultural importance in the EU. These LLs will act as multidisciplinary and transdisciplinary collaborative platforms for code design, co-development and co-implementation of solutions that promote the conservation/restoration of soil health. By promoting locally adapted innovative and holistic solutions, spreading sustainable soil management practices, and strengthening soil literacy, the project aims to contribute to the global improvement of soil health and environmental resilience. In the case of the Luso-Galaico LL, its main objectives are: (i) to study/develop innovative solutions to mitigate soil degradation in vineyards and olive groves; (ii) test solutions at demonstration sites in different agricultural systems and environments; (iii) co-create successful local solutions for healthy soils (LivingSoiLL, 2024).

2. STUDY AREA

This study focused on a micro basin of 52.6ha located in the Pinhão village, on the North margin of Douro Valley, Portugal (Fig. 1). The elevation range is 209m and varies between 62m and 394m and the slope aspect is predominantly south. The lithology presents several stratified levels of pre-Cambrian and Cambrian phyllites and schists. The vineyards occupy 20.8 ha of the micro basin, mostly in terraces, with wall support with dry rock or earthen embankment. The area has a Mediterranean climate with an average annual rainfall of 658mm. However, while the temporal distribution of precipitation predominantly occurs in the wet season, heavy rainfall episodes ranging between 40mm/h and 80mm/h are frequent in the spring and fall seasons. Two precipitation events occurred on December 22, 2022, with 243mm for 30 days and return period (RP) of 3.6 years and on January 1, 2023, with 278mm for 30 days and RP of 5.5 years.

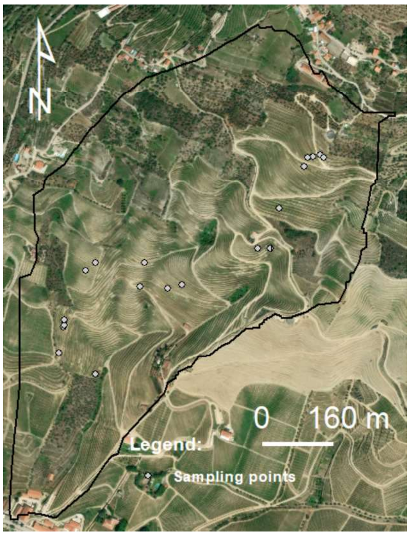

Figure 1: Micro basin at Bonfim estate and sampling points of the SF thickness.

The basin undertakes a terrace reconstruction, with the implementation of terraces with large platforms (3.5m) with two vine rows, narrower platforms with one vine row (2.3m) and a new drainage system. The terrace installation changes the SF characteristics and promotes water erosion and riser instability.

3. DATA AND METHODS

The information that supports the entire modelling was extracted from an unmanned aerial vehicle (UAV) flight that allowed the construction of a DEM with a 10cm spatial resolution. This model supports the altimetry used to model the SF thickness at two different scales. The modelling of the original slope morphology, before the installation of terraces, uses contour lines with equidistance of 5m. This information built a generalized DEM of the basin with a spatial resolution of 5m. This DEM allows the extraction of information on the slope angle, slope curvature, and normalized height for the hillslope to integrate as model parameters to assess SF thickness. With a detailed DEM with a spatial resolution of 40cm, we performed the new slope morphology with the new terraces and calculated the thickness of the excavated and mobilized materials during the terrace construction.
To validate the thickness obtained we measured the SF at 19 points (Fig. 1), with observation and measure of the parent rock contact with SF at the terrace risers. Additionally, we used electric resistivity tomography (ERT) that allowed the construction of eight electrical resistivity profiles, in sampling areas where direct field observation is not possible. We considered that the values under 200Ω correspond to SF materials (Palacky et al., 1991). These profiles support the analysis of the SF thickness. We calculate the correlation between sampling points and modelled points with the obtained data and validate the results of the SF thickness map.

4. RESULTS

The estimated maximum thickness is approximately 6m, the minimum is approximately 40cm, and the average value is 1.4m. The most frequent thickness of SF is the class of 0.5m-1m, with 39% of the basin area, followed by the class of 1m-1.5m, with 19.9% (Fig. 2). Considering the model variables, the greater thicknesses are located along the water lines and the wider areas of the lower classes along the upper part of the basin. The interfluves have lower values of the SF thicknesses, up to 1m. The correlation between observed values and estimated SF thickness values is good with a R^2 = 0.87, which corresponds to the adjustment of a potential trend line (Fig. 3).

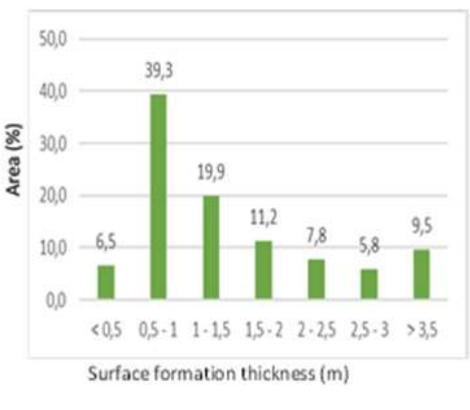

Figure 2. Areas by the surface formation thickness (m).

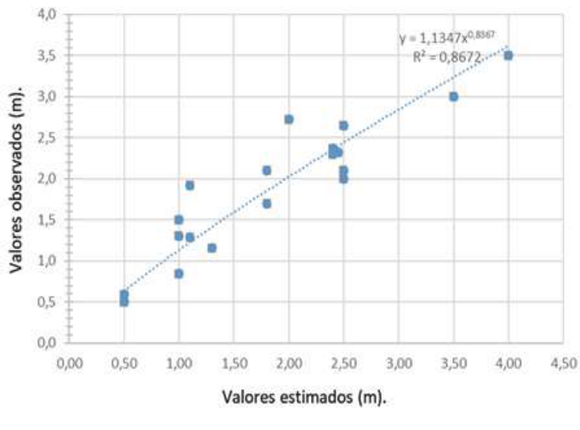

Figure 3. Correlation of observed surface formation thickness and estimated thickness.

The validation process presents some problems. The direct field measure of the SF thickness along the risers is higher than the vertical measure due to the riser inclination, although that difference is not relevant, especially at the higher values at a high slope gradient. This can explain part of the missing adjustment of the model to some of the higher values of direct field observation. The interpretation of the resistivity profiles focuses on the central part of the profile but must consider the interpretation of all profile but not only at the most profound place at the central part. The terrace construction mobilizes huge blocks at the middle of the profile resulting in huge electrical resistivity in part of the profile. Meanwhile, the lower levels under the block register lower resistivity values, contributing to the riser instability. All these elements can contribute to the SF thickness modelling.

SF thickness for the terraced area at the micro basin identifies the higher thickness along the water lines and the different thicknesses along the terraces due to the excavated and deposited materials for the platform construction. Nevertheless, the results are promising and ask for a wider validation.

CONCLUSIONS

The SF thickness is a very important parameter for slope instability modelling. The detailed cartography can represent a significant improvement in the evaluation of landslide modelling quality in areas with huge human activity. The proposed model is a promising solution since the validation process indicates a high value (R^2=0.87) for the potential trend curve. We must state that this model, built for metamorphic regions, may not adjust to other environments with different types of weathered materials. In that case needs calibration to produce acceptable results.

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