The contribution of PSInSAR interferometry to landslide hazard in weak rocks dominated areas

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1 GENERAL FRAMEWORK

One of the most important tasks within the context of the landslide hazard determination is the assessment of landslide susceptibility. Landslide susceptibility maps could be considered as one of the most important tools for land use management in order to mitigate locally the physical and socio-economic damages associated to the occurrence of landslide destructive events. Nevertheless, they are strictly dependent of our capacity to recognize the spatial patterns of different slope instability processes over time.

The study area is the Rio Grande da Pipa basin, Arruda dos Vinhos, Portugal (area of 110 square kilometers), which is dominated by weak rocks. Clays and marls (Abadia marls formation) outcrops in 57.8 % of the area and gentle relief dominate (slopes lower than 15º in 87.6 % of the total area). In the study area, the correct identification of slow moving landslides is constrained by two very specific situations: (i) the instability signs are not sufficiently observable and consequently may be not correctly identifiable through traditional geomorphologic survey techniques; and (ii) the non-timely recognition of precursor signs of instability in new or previously identified unstable areas.

In this context, Interferometric Synthetic Aperture Radar (InSAR) has demonstrated its potential to measure terrain deformations induced by landslides that are sometimes not recognized by direct field observations. In this work we evaluate the contribute of the application of the Persistent Scatterers technique, by using different time series of Synthetic Aperture Radar (SAR) images acquired by different sensors (e.g., ERS1, ERS2, ENVISAT, TerraSAR-X) from 1992 to 2010 in the determination of landslide hazard within the context of weak rocks dominated areas. This methodology, is based on the identification of a set of pixels (Persistent Scatterers) characterized by a stable interferometric phase on a time series of SAR interferograms. This methodology has been used, for example, to monitor slow landslide deformations, to elaborate terrain deformation maps or to reclassify the landslide state of activity.

Based on the potential of this marl and clay formation over the Rio Grande da Pipa basin to generate Persistent Scatterers (PS) the main objective of this work is to assess the potential of PSInSAR techniques to the determination of landslide hazard in weak rocks dominated areas. The specific objectives are to assess the capability of the technique to: (i) redefine the landslides state of activity; (ii) redraw landslide limits (iii) identify new landslides; (iv) improve the assessment of landslide susceptibility.

2 REGIONAL SETTINGS

The study area of Rio Grande da Pipa basin, Arruda dos Vinhos, Portugal, is characterized by a high number of landslides already identified and mapped at the scale 1:2000 through detailed field geomorphological mapping. The landslide inventory has more than 1400 slope movements (deep and shallow) mainly of rotational and translational types. In the study area the geomorphological settings are basically controlled by an alternation of rocks with different mechanical erosion, permeability and plasticity and by a geological structure favourable to slope instability. Additionally, most of the deep landslides occur in the marls and clays formation previously mentioned.

3 METODOLOGY/EXPECTED RESULTS

As a first result it is demonstrated the relationship between the capability to generate PS and the lithology, slope and aspect angles. Moreover it is also defined the relation between PS and Land Use (urban or bare soil/cultivated areas). These characteristics affect the scattering properties of the SAR signal and

the stability of the interferometric signal and as consequences the capability to generate a PS. The frequency distribution of Ps in terms of lithology, slope and aspect are computed and discussed.

Relatively to the four specific objectives:

(i) To redefine the landslides state of activity - The traditional geomorphological approach to characterize the landslides state of activity reflects essentially the dynamics and processes involved in the slope instability. Previous classifications were too dependent on the date of conclusion of landslide inventory and on the date on which the last landslide event occurred (2010 in the study area). The methodology adopted was based on the procedures proposed by Righini et al. (2012) and Cigna et al. (2012).

(ii) To redraw landslide limits – For previous mapped landslides, Persistent Scatterers deformation maps and deformation velocities were consider (Figure 1). Topographic and field validation was done. In field validation were considered the destruction marks on structural elements (e.g., houses, roads). In preparatory works, landslide limits were redraw for 19 landslides.

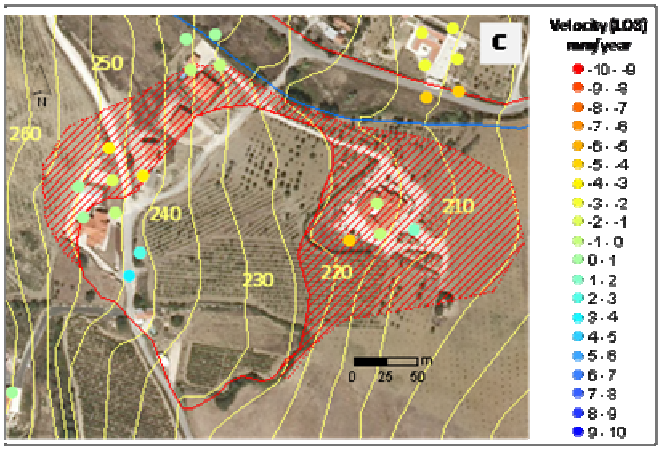

Figure 1. Example of a redraw of a landslide limits by integration of deformation obtained by PSInSAR technique. The additional landslide area is represented by the red diagonal lines.

(iii) To identify new landslides - Regarding the completeness of landslide inventory, the identification of new landslides was based on the Persistent Scatterers deformation maps and deformation velocities associated to the Persistent Scatterers. Topographic and field validation is done. Primary results allowed the identification of 71 new or potential landslides.

(iv) To improve the assessment of landslide susceptibility – The adopted strategy is formulated to identify PS where a significant terrain deformation activity occurred. Then, in those PS it is assumed that terrain deformation is related to landslide activity. This set of PS is then used as modeling landslide group and integrated with some landslide predisposing factors (e.g., lithology, slope angle, slope aspect, slope curvature, soil type, land use) in order to define natural susceptibility conditions to landslide occurrence. A bivariate statistical method is used. Validation with independent geomorphologic based landslide inventories is done. Susceptibility maps to landslide occurrence are obtained. The quality of this map is assessed through the computation of success and prediction rate curves, as well as by the definition of the respective Area Under the Curve (AUC).

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