35 Advanced Characterization of a Landslide-Prone Area by Satellite a-DInSAR

Alfredo Rocca, Paolo Mazzanti, Francesca Bozzano, and Daniele Perissin

Abstract

An area of about 15 km^2 in Central Italy, severely affected by landslide processes, has been studied by several approaches. Field surveys and multi-temporal aerial photos allowed to frame geomorphological setting and temporal evolution of instability slope processes. Starting from this information, Advanced Differential Interferometric SAR (A-DInSAR) analyses have been performed in order to improve our knowledge of the under study processes in terms of both spatial and temporal evolution and kinematics. A previous feasibility analysis has been carried out to define the suitability of A-DInSAR analysis for every recognized landslide. The adopted method was also useful to identify best available data to perform InSAR analyses in order to detect and measure expected deformation processes. A-DInSAR analyses have been performed with two different approaches: a standard Persistent Scatterers (PS) analysis with linear models to estimate PS velocity over the whole area and local scale analyses on some specific sub-areas with a no-model approach, more appropriate for non-linear deformation detection.

Keywords

Landslide • Landslide mapping • InSAR • Persistent scatterers

35.1 Introduction

Over the last years, the contribution of remote sensing techniques to the mitigation of natural risks has been very important. Satellite InSAR, in particular, proved to be a very useful methodology to study ground deformations and it has been applied both in monitoring perspective and for the acquisition of information related to past ground displacements (Cigna and Del Ventisette 2011). This specific feature makes InSAR and A-DInSAR in particular (i.e. Persistent Scatterers—PS, Small Baseline Subset—SBAS etc.), highly efficient in order to achieve information about ground deformation estimation, in a quantitative sense, also for wide areas. At present, such kind of results is not achievable with a comparable accuracy by using other techniques.

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35.2 The Study Area

The herein presented study has been carried out in a portion of a small basin located in the central sector of the Apennines, between the Maiella Mountain and low-hilly area in the Abruzzo Region (Italy). The basin is about 15 km^2 in size and is crossed by the Dendalo stream. From the morphological point of view, the landscape is featured by hilly structures with altitude ranging from 150 m and 440 m a.s.l., and gentle slopes facing the stream.

The basin, North-South oriented, falls within the Peri-adriatic Marche-Abruzzo basin, built on Plio-Pleistocene marine deposits (Bigi et al. 1995). The geological substrate of the investigated area is characterized by the Mutignano Formation, a marine Plio-Pleistocene sequence made of silty clay containing sand, which gradually increases towards the upper part of the formation. The terms of Pleistocene transition are represented by clays and conglomerates and can be found mainly on the top of reliefs on the right bank of the Dendalo stream. Continental Quaternary formations characterized by debris and colluvial materials, mainly of gravitational and alluvial genesis, also outcrop in the basin (Bigi et al. 1995, Centamore et al. 1997).

35.3 Landslide Features

By field surveys and multi-temporal analysis of aerial photos from 1954 to 2002, 98 landslides were identified and mapped. Landslides affect large part of the area and were

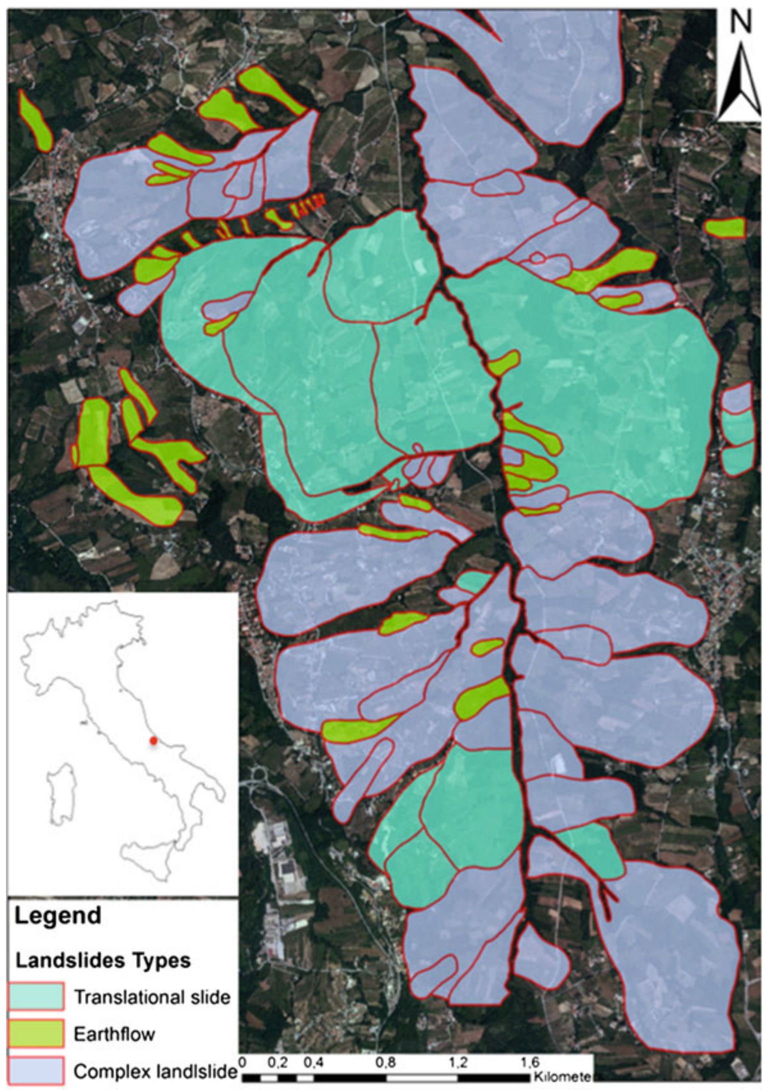

Fig. 35.1 Localization of the study area and landslide bodies mapped by aerial photo-interpretation and field surveys

classified as translational sliding (15 landside bodies), earth-flows (41 landslide bodies) and complex mass movements (42 landslide bodies). Landslides areas range from very few hundreds m^2 to some km^2. Smaller processes are mainly related to earth-flows, whereas largest landslides are represented by translational slidings (Fig. 35.1).

Landslide deposits are related to the mobilization of pelitic and psammitic lithologies belonging to the Mutignano Formation, especially in the middle and lower portions of the slopes. In the mainly pelitic areas, geomorphological elements related to the largest landslide phenomena, such as niches, scarps and counterslopes, are highly altered and degraded, and often modified by the strong anthropic activity in the area.

35.4 A-DInSAR Analyses: Feasibility and Used Methods

If compared to other ground deformation processes (e.g. subsidence), landslides are affected by several issues capable to invalidate InSAR analyses or results interpretation (Notti et al. 2010). To cope with this problem we performed a preliminary feasibility analysis on detected landslides in order to better define the best SAR data configuration and expected results. This approach is based on considering both landslide features (geometrical, geomorphological, kinematics) and interferometrics (images availability, sensor and processing method characteristics). Also thanks to the feasibility analysis outcomes, four different datasets have been selected to investigate landslides past displacements. Specifically, ERS 1&2 and Envisat satellite data both in ascending and descending orbits have been selected for the period 1992–2010. Mainly because of slopes orientation, in fact, the double geometry, has been considered mandatory to properly detect and describe all present processes in a kinematic sense.

SAR data have been processed by using SARPROZ (Perissin et al. 2011), a software tool specifically developed for multi-image InSAR analyses with PS methods (Ferretti et al. 2001; Perissin 2009; Perissin and Wang 2012). For this case study two different approaches have been used: (i) standard PS analysis where velocities are estimated using a linear model (Perissin 2009); (ii) local analysis of small areas, performed for selected sub-areas, which allowed to achieve higher accuracy in displacements time series estimation, and, especially, to detect non liner behaviours.

It is worth noting that non-linear movements are considered crucial for a suitable investigation of the landslide processes affecting the investigated area. The model used to unwrap the phase contribution related to deformation, in fact, represents one of main limitation of A-DInSAR methods. In most of them, a simple linear model to estimate velocity of deformation is adopted. Influence caused by this procedure to displacement time series results prevents, as a matter of fact, to detect non-linear behavior of deformation (accelerations, decelerations).

35.5 Results

A-DInSAR analysis allowed to achieve useful information for more than 55 % of the investigated area and more than 30 landslides especially for largest ones and for those affecting urbanized areas. Thanks to the long-term data available (1992–2010) displacements information allowed to refine landsides mapping and to derive the state and type of activity. Furthermore, some coalescent mapped landslides were recognized as linked to a unique process and some landslides were internally distinguished thanks to the identification of differential deformations.

Four areas of particular interest have been then analysed by a local analysis (see Fig. 35.2, areas 1–4). In the Area 1 no displacements affecting the landslide upper part of the crown in the whole period have been detected so confirming geomorphological features, which have been used to map such detected phenomena.

In the Area 2, located at the foot of a wide complex landslide with many coalescent bodies, displacements during the overall period 1992–2010 were detected. Thanks to the ascending and descending geometry combination it was possible to infer the movement direction that is mainly horizontal (Fig. 35.3). The upper part shows lower displacements starting from 2003 while in the lower part displacements are evident since 1992, with a higher rate and a more horizontal component. Furthermore, the movement trend is strongly not linear with several acceleration stages recognized. Displacement rates are high (>15 mm/yr).

Area 3 was classified as inactive by the preliminary investigation, but it shows phases of activity detected thanks to the ascending geometry especially in the period from 1995 to 2001. Observed displacements are homogeneous across the landslide portion and the movement trend is linear over time. Displacement rates are quite low (<3–4 mm/yr).

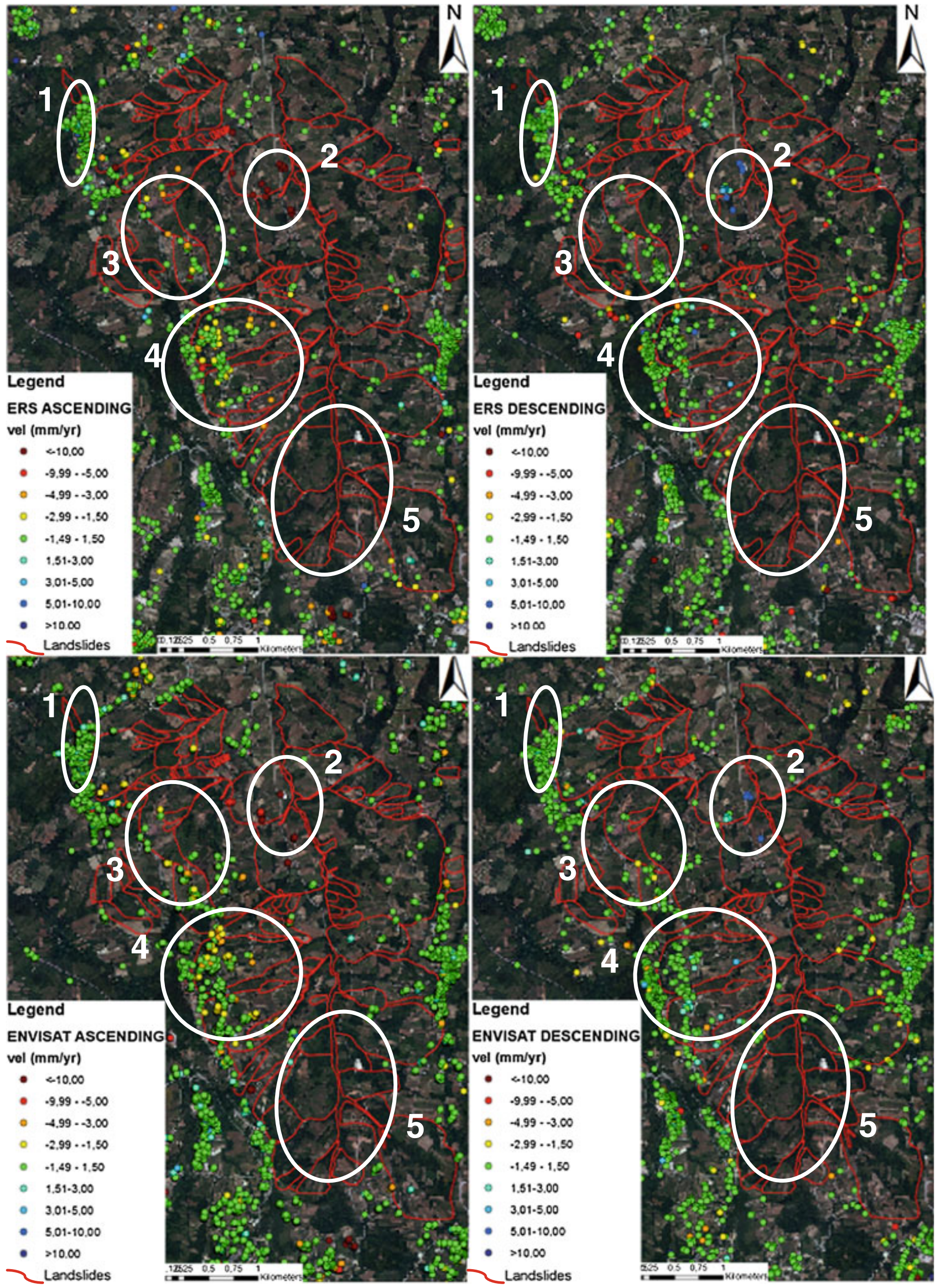

Fig. 35.2 A-DInSAR results: *red* polygons identify the mapped landslides. PS colours represent the deformational trend: away from the satellite (from *yellow* to *purple*), toward the satellite (from *light blue* to *blue*) and stable (*green*)

Also in the Area 4 displacements were recognized thanks to the ascending geometry due to its orientation. Observed displacements are heterogeneous across the landslide area with some portions affected by higher displacements and some others more stable, especially in the 2003–2010 period. The movement trend is linear.

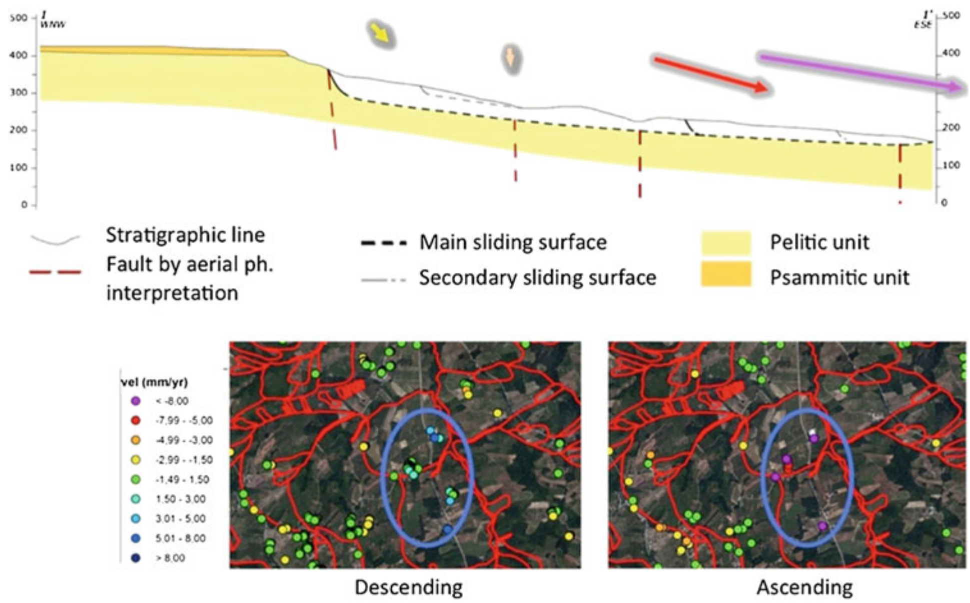

Fig. 35.3 Single landslide process dynamics derived combining ascending and descending A-DInSAR information. *Vertical* and *horizontal* displacement components have been inferred, so deriving the real displacement direction for all the landslide body portions

The area 5 (Fig. 35.3) instead, is a typical example of no achievable information mainly caused by absence of good backscattering targets.

35.6 Conclusion

The analysis performed through the integration of field surveys, aerial photo-intrepretation and A-DInSAR allowed to achieve a comprehensive knowledge framework on the study area. Multi-temporal aerial photographs analysis allowed to identify landslides activity in the Dendalo basin since 1954 but it was not enough to quantify the temporal evolution and displacement rate of the landslides. Thanks to PS Local Area analyses, it was possible to better define the state of activity and especially the temporal evolution of some observed phenomena. This aspect is crucial for a proper planning aimed to reduce landslide risk.

Specifically, the Est-facing slopes show a more intense and continuous activity both in the period 1992–2001 and 2003–2010.

For the sake of completeness, is well to remember that A-DInSAR technique is unable to detect displacements in areas without good scatterers as in the Area 5 where the activity of landslides would be very useful to be investigated. Another aspect to remark is the usefulness of the execution of local analysis which allowed the accurate and reliable determination of the displacements for the most critical areas. Finally, it is fundamental to highlight the importance of different source of data (e.g. both ascending and descending acquisition geometry for A-DInSAR) especially for basin-scale analyses where different phenomena in terms of dimension, orientation, displacements rate have to be investigated.

In conclusion we can state that A-DInSAR is changing standard methodology for analysis of large landslide areas. Moreover, quantitative results with higher information level related to geomorphological analysis are now available at relatively low costs.

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