Abstract code: EP7

Generating a Landslide Inventory Map Using Stereo Photo interpretation and Radar Interferometry Techniques - a case study from the Buzău Mountains area, Romania

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Extended Abstract

Introduction

The Buzău County region falls partly (around 2,800 km²) into the forested mountains from the southern end of the Eastern Carpathians group – the Vrancea and the Buzău Mountains, with heights up to almost 1,800 m. According to local authorities, landslides are the main source of surface movement in the region, moving from a few centimeters to several tens of meters per year. The landslides are mainly triggered by rainfalls mostly during spring and autumn, and may be combined with flash floods. The main concern of the authorities is the effect of the landslides on existing infrastructure, notably roads. The aim of this study is to provide a landslide inventory map, which helps to estimate landslide susceptibility and derive an exposure and risk map for the region.

Study area

Comprising parts of the Curvature Carpathians and Subcarpathians of Romania, the study area extends between Bâsca Chiojdului and Râmnic rivers. It represents an area marked by the presence of numerous landslides, covering a broad spectrum of processes and resulting forms. Within a very complex predisposing environment, the landslides' typology is following the petrographic, structural or morphometric parameters of two differentiated sectors: the flysch interior half (forming the mountainous unit of the Buzău Carpathians) and the molasse exterior one (representing the Buzău Subcarpathians hills and depressions). Prepared by intense neotectonic activity and long-lasting human activity, triggered by precipitation and earthquakes equally, the landslides show a high frequency and low magnitude in the Subcarpathian Hills and the reverse in the Carpathian Mountains (Micu and Bălteanu, 2009). For a more detailed description of landslide occurrence framework, see AP 24 by Damen et all., this volume.

Data and methodology

Two complementary methods were applied to derive the landslide inventory map:
i) digital stereo photo interpretation using colour aerial ortho-photographs of 2005, and
ii) radar interferometry with TerraSAR-X data from 2013 and 2014.

The digital stereo image interpretation focused on mapping large landslides from artificial stereo-models that were generated using the colour aerial-photographs and a Digital Elevation Model derived from a contour map. For the digital stereographic photo interpretation, colour aerial ortho-photographs (cell size 2m, resampled from an original

0.5m) from the year 2005 (ANCPI Bucharest) were used. The DEM (cell size 2 m due to the anaglyph interpretation) was obtained from linear interpolation of topographic contour lines (5 m. interval) derived from DTM (Military Topographic Direction) 1:25,000 topomaps.

The following methodological steps have been followed:

(1) Import of the data in the ILWIS Version 3.4 software,

(2) Resampling of the digital color aerial ortho-photographs to a cell size of 2m;

(3) Linear interpolation of the contour lines to a DEM cell size of 2m;

(4) Creation of anaglyph visualization in the "*stereopair from DTM*" program module of ILWIS 3.4 software;

(5) Visual stereo interpretation (using anaglyph 3-D visualization) and digitization of terrain boundaries of the scarp and body of landslides at approx. scale 1: 8.000;

(6) Differentiation of interpreted units into *Distinct* and *Indistinct* based on their stereo visibility;

(7) Terrain characteristics used:

a) slope steepness, slope form and slope length;

c) relative terrain position of the landslide elements, such as upper erosional scarp zone and lower depositional body;

d) detailed slope characteristics of the scarp such as for instance curved crown and concave lower slopes; and for the longitudinal body the more convex slopes;

e) break of slope between the scarp zone and landslide body;

f) vegetation anomalies.

(8) Landslide activity was interpreted based on image characteristics and field reconnaissance.

In order to be able to detect which of the landslides are actively moving, about 20 TerraSAR-X images (analyzed through SBAS method) were collected from May 2013 to February / May 2014 from both the ascending and descending orbit over selected footprints within Buzău County. Mainly due to the radar 'layover' effect occurring in mountainous areas, these two orbit geometries are necessary to measure landslide movement in the West-East and East-West directions, respectively. The footprints latter cover an area of about 50 km x 50 km, from the original area of interest of 40 km x 80 km (Figure).

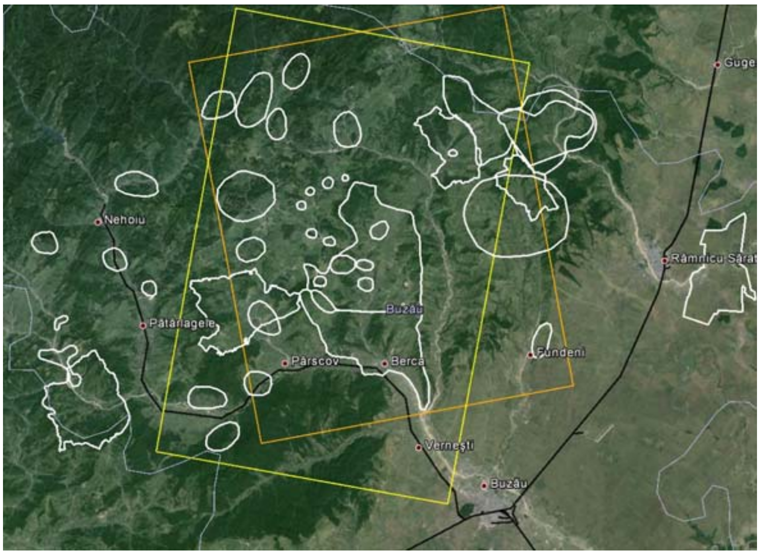

Figure 1: TerraSAR-X ascending (orange) and descending (yellow) acquisition footprints (and processing area) for the landslide areas of interest (white polygons) in Buzău County, Romania. Background image © Google Earth, 2014.

Results

The resulted landslide inventory consisted out of 1028 cases (deep-seated landslides), obtained through digital stereographic photo interpretation using colour aerial ortho-photographs.

The results show a large number of landslide complexes in the terrain, which may be related to past seismic activity in this earthquake–prone area. Their detailed morphology witnesses potential co-seismic or post-seismic landslides (Micu et all., 2014). Based on field recognition, data recorded by ISU Buzau and Google Earth imagery, the landslides were ranked (at the level of both body and scarp) as active or inactive. The different sectors were assumed as being active if throughout their extent, recent (during the last 5 years) reactivations were recorded.

The map (Fig.2) display, besides the deep-seated landslides, the recent historical landslides (compiled based on records from Buzau County Inspectorate for Emergency Situations) and also the most relevant points from the radar interferometry study (the highest measured velocity that correlates with the landslide inventory).

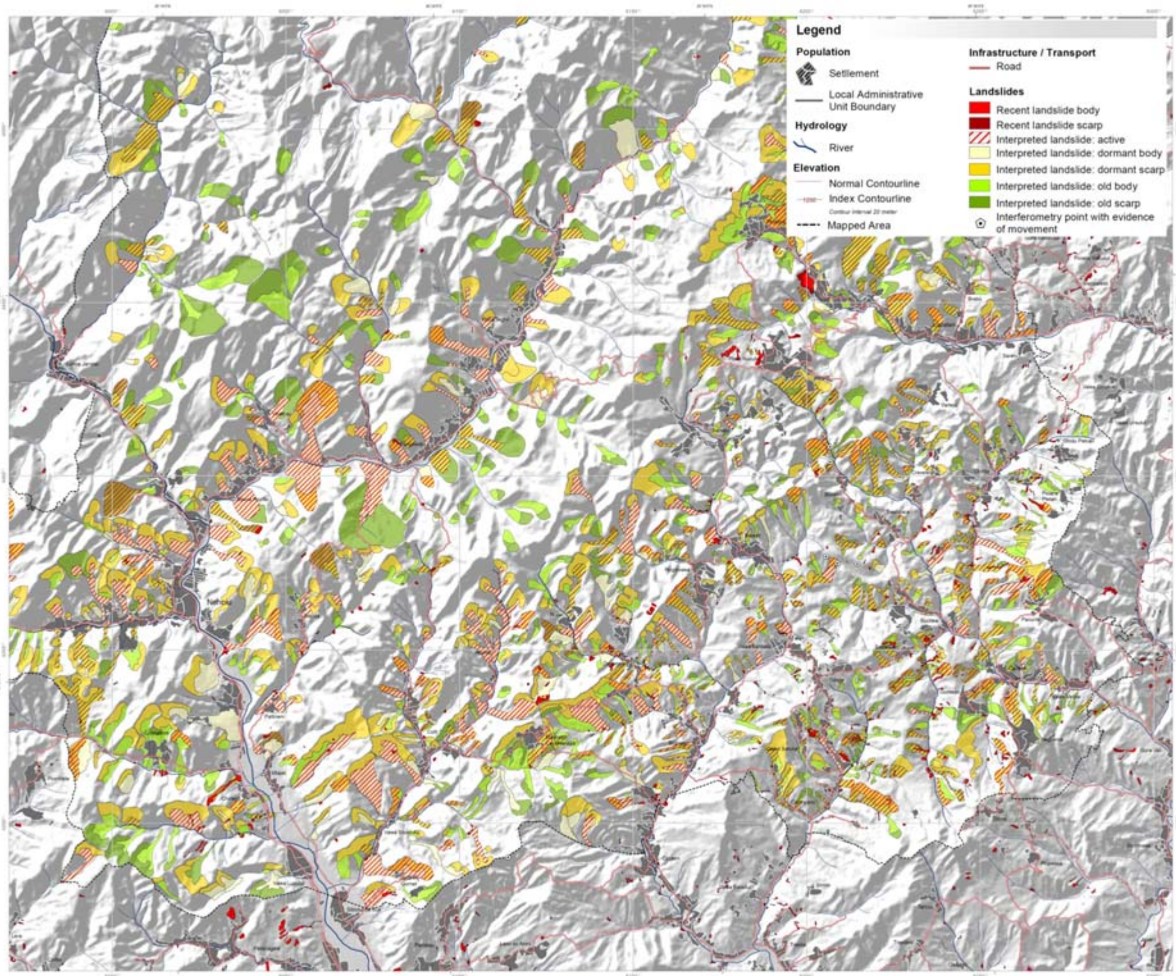

Fig. 1. The deep-seated landslide inventory

The radar interferometry technique was used with TerraSAR-X satellite scenes to derive surface movement maps over the area of interest. A time series analysis approach was applied to produce a time series of ground deformation for every measurement pixel.

Measurement pixels are only generated for surfaces that do not change their reflection behavior towards the satellite during the observation period. For example, the numerous mudslides that changed the reflection properties of the surface lead to no movement results over this area. In general, forested areas gave no measurement pixels.

As the last winter season was very dry, not many landslide movements could be detected and most of the measurement points have shown stable ground. Unfortunately, a high percentage of landslide areas occur on forested or heavily vegetated ground, for which the radar interferometry technique cannot deduct movement results. Most of the results were gained over infrastructure, rock surfaces or bare soil. However, some characteristic movements could be identified, such as the erosion across the mud volcanoes plateau near Beciu, and the movement of inhabited or non-inhabited landslide areas around villages such as Răteşti (3), Recea, Bărbunceşti and Berca.

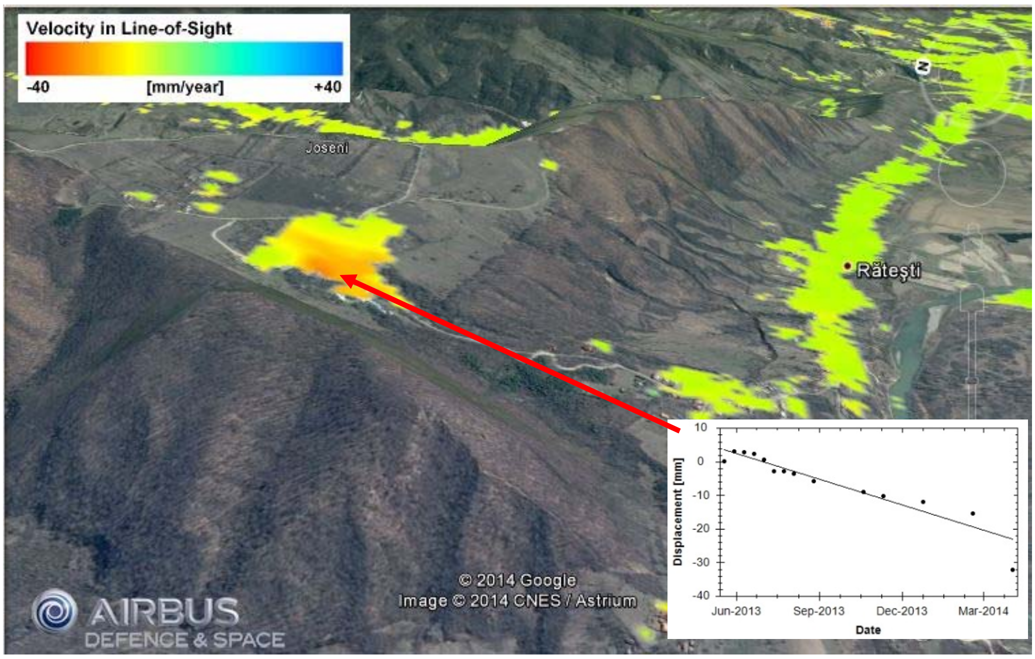

Figure 3: Surface movement result over Răteşti, Romania, derived with radar interferometry using TerraSAR-X data, together with the time series of an example measurement pixel. Measurement pixels are colour-coded according to legend. Background image © Google Earth, 2014.

Especially in the case of Răteşti, the interferometry gave very interesting results, since it outlined the slow-moving landslide whose occurrence was prepared during the timeframe of the acquisition. At the beginning of June 2014, the XVIIIth century monument was severely damaged by a landslide continuously active for more than 6 months.

Fig. 4. Răteşti monastery, affected by a landslide in June 2014

Conclusions

If radar data over a longer time period is considered, the combination of digital stereo photo interpretation and radar interferometry techniques is very promising to update landslide inventory maps, and a better indication of activity patterns, which in turn will improve landslide susceptibility and hazard assessment.

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