Rend. Online Soc. Geol. It., Vol. 35 (2015), pp. 121-123, 3 figs. (doi: 10.3301/ROL.2015.79)

A geomatic approach for emergency mapping of shallow landslides

Giuseppe Esposito ([a]), Riccardo Salvini ([a]), Marco Sacchi ([b]) & Fabio Matano ([b])

([a]) University of Siena - Department of Environment, Earth and Physical Sciences and Centre of Geotechnologies, Via Vetri Vecchi, 34, 52027 San Giovanni Valdarno (Arezzo) Italy. E-mail: giuseppe.esposito@unisi.it
([b]) National Research Council (CNR) - Institute for Coastal Marine Environment (IAMC), Calata Porta di Massa – Porto di Napoli, 80133, Napoli, Italy.

Document type: Short note
Manuscript history: received 28 December 2014; accepted 22 March 2015; editorial responsibility and handling by Gabriele Uras.

ABSTRACT

Nel presente contributo viene proposto un approccio geomatico per mappare e caratterizzare dal punto di vista geomorfologico i fenomeni franosi superficiali in situazioni di emergenza. Il metodo è stato applicato durante il rilevamento di una frana che il 27/10/2013 ha interessato la falesia costiera della località "Baia dei Porci", nel Comune di Monte di Procida, in provincia di Napoli. Durante il rilevamento, eseguito parzialmente da barca, sono state scattate 95 foto successivamente elaborate con il software Agisoft PhotoScan™. Il prodotto ottenuto dall'elaborazione è stato un modello digitale 3D della frana (DEM), georeferenziato nel sistema UTM 33N-WGS84. Dall'elaborazione del DEM eseguita in ESRI ArcGis™ è stato possibile ottenere la carta topografica della frana in scala 1:500, la carta delle pendenze, l'area delle zone di distacco e di deposito ed il volume del materiale franato.

Visti i risultati ottenuti si ritiene che l'approccio proposto sia idoneo per essere applicato in situazioni di emergenza provocate da frane superficiali, a supporto delle autorità di Protezione Civile.

KEY WORDS: Campi Flegrei, Cliff, Geomatics, Landslide.

INTRODUCTION

Rapid mapping and geomorphological analysis represent important tools to support civil protection authorities in the management of emergencies caused by landslides (Manconi et al., 2014; Giordan et al., 2013). Event inventory maps realized after occurrence of landslides document the full extent and magnitude of landslides and are useful for post-event recovery efforts (Guzzetti et al., 2012). Different methods are used to map landslides for emergency response. Conventional methods include geomorphological field mapping and visual interpretation of stereoscopic aerial photographs taken immediately after the event (Guzzetti et al., 2012). Satellite, aerial and terrestrial remote sensing technologies represent new mapping methods being able to survey dangerous areas with limited accessibility, acquiring data with high accuracy and high spatial resolution.

In this paper we present a geomatic approach aimed to rapidly map a shallow landslide occurred along the coastal sector of the Campi Flegrei volcanic district, Southern Italy. The approach is based on the integrated use of digital photogrammetry and GIS techniques allowing to geomorphologically characterize the landslide, and to create a high resolution Digital Elevation Model (DEM) as well as a series of thematic maps in a relatively short time.

TEST SITE

The landslide analyzed in this work occurred on October 27, 2013 along the costal cliff named "Baia dei Porci", in the municipality of Monte di Procida, near Naples, Italy (Fig. 1). The geological background of this area includes a succession of pyroclastic lithotypes, both coherent and incoherent, derived from explosive activity of the Campi Flegrei volcanic district (Di Girolamo et al., 1984; Rosi & Sbrana, 1987). The cliff hit by landslide is characterized by a sequence of tuffaceous and ignimbritic layers with thicknesses variable from few centimeters to a dozen meters (Lirer, 2011). The top of the stratigraphic sequence is represented by an anthropic deposit filling up an old tuff quarry. The entire succession was visible in the landslide scar after the event.

From a geomorphological point of view the cliff rises from

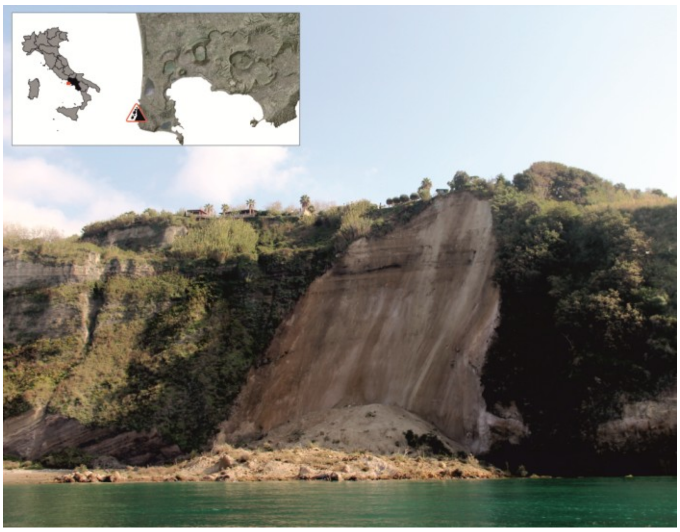

Fig. 1 - Photo of the landslide taken from a boat; inset map shows the location of the study area.

the average sea level to an height of about 100 m a.s.l., following a sub-vertical profile. Its surface is characterized by a series of runoff-driven incisions as well as old landslide scars, whose related deposits form small talus debris on the underlying pocket beach. Locally, herbaceous vegetation covers the less steep portions of the cliff, including some layers characterized by a major resistance to subaerial weathering agents (wind, rain, temperature, saltwater spray).

METHODS

The day after the event a field survey was carried out both from the sea and on land. On the latter, part of the landslide scar close to the houses that could be involved by future retreats was surveyed. Here, some measures of the open fractures caused by the slope movement were performed and local residents were interviewed to have useful information for assessing time occurrence and landslide characteristics. In order to perform a photographic survey of the frontal part of the involved coastal cliff, a small boat was used. A total of 95 photos were taken by using a Canon™ EOS 600D digital camera. Photos were acquired from different positions and distances in order to cover the whole scene to be reconstructed with the aim of minimizing the “blind-zones”. After acquisition, photos were processed by means of PhotoScan™ (version 1.0.4), a photogrammetric software based on the latest multi-view 3D reconstruction technology operating with arbitrary images (AgiSoft, 2014).

In order to build the 3D model of the analyzed landslide, the following workflow was applied:

- loading photos into PhotoScan™;
- inspecting loaded images, removing unnecessary images;
- alignment of photos;
- sea surface masking;
- dense point cloud building (Fig. 2);
- dense point cloud editing;
- Mesh (3D polygonal model) building;
- Mesh editing;
- Export of results.

To georeference the 3D polygonal model in the UTM 33N - WGS84 coordinate system, some markers recognizable in most of the photos were used as Ground Control Points (GCPs) being characterized by known full 3D coordinates. In this way, the georeferenced Digital Elevation Model (DEM) useful to perform morphometric analysis was produced. The DEM was loaded in ESRI ArcGis™ (version 10.1) where the first step was to define the boundaries of landslide deposit and source zone. This operation was made considering the acquired photos, the ortophoto created within PhotoScan™, and the shape of contour lines extracted by the Spatial Analyst tool within ArcGis™. Successively, we isolated portions of DEM corresponding to the landslide deposit and source zone in order to calculate their 3D areas and volume. It is worth noting that it was possible to calculate only the volume of deposit above sea level being captured by photos. Further elaborations of DEM performed through the Spatial Analyst tool gave us the slope map as well as the hillshade of the landslide (Fig. 3).

RESULTS

Results from fieldwork show that landslide caused a series of soil fractures characterized by apertures of few centimeters

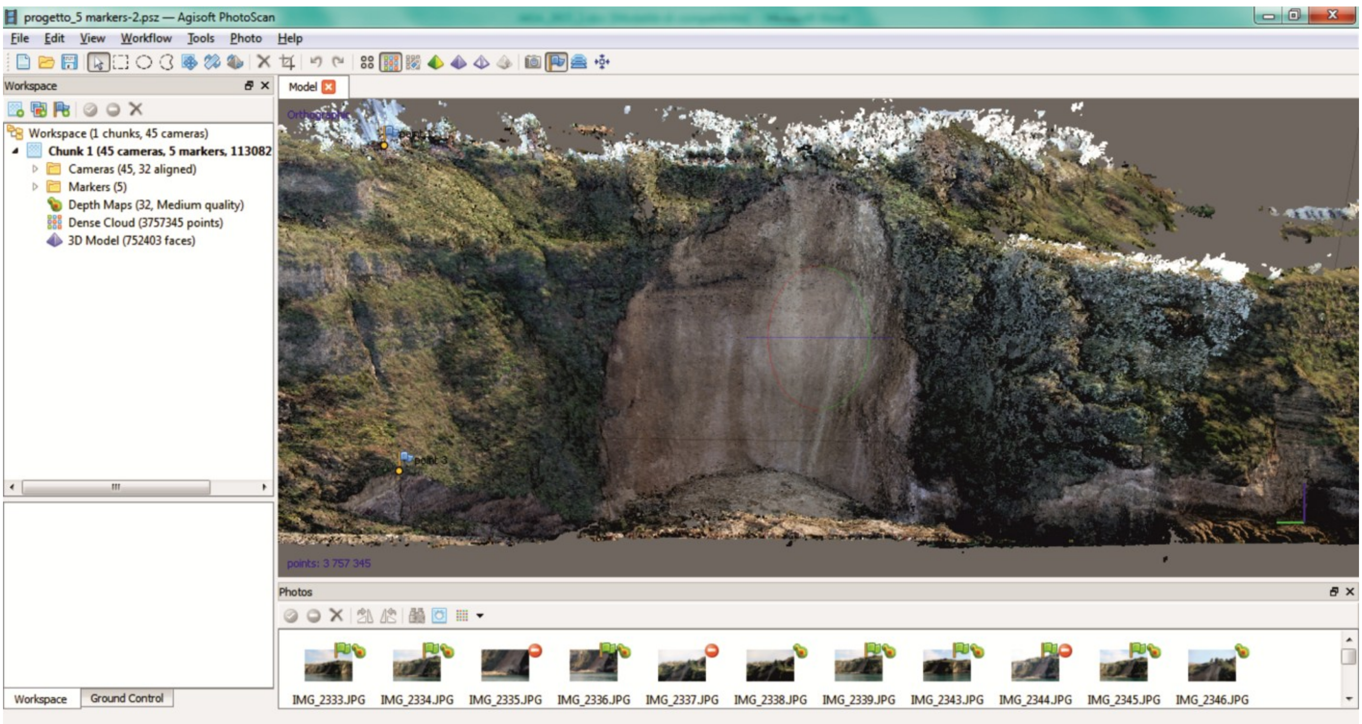

Fig. 2 - Snapshot of the dense point cloud of the landslide shown in PhotoScan™.

and lengths of about 10 m behind the scar. Interviews to local residents allowed us to know that landslide occurred at 2.30 p.m., when residents saw a big cloud of dust rising from the cliff and they heard a loud noise inducing heavy tremors to their buildings. This information together with field observations allowed us to classify the landslide as a rapid rock slide (Cruden & Varnes, 1996) that involved pyroclastic deposits ranging in thickness from 1 to 3-4 m. It is not clear which was the triggering mechanism of the mass movement. Indeed, a rapid analysis of rainfall data collected by the rain gauge located on the local municipal building's roof showed that no rain was recorded in the day of landslide occurrence; the last rainfall was recorded 11 days before the event. Considering that other landslides like the one under study involved cliffs of the Campi Flegrei coastal area during dry days, further analyses are needed to find triggering mechanisms related to this type of instability processes probably due only to subaerial weathering agents, gravity and land cover.

A georeferenced 3D model, 25 cm cell size, was built through photos processing within PhotoScan™. Further operations carried out within ESRI ArcGis™ allowed us to create and compute: the new topographic map at a scale of 1:500 with 2 m contour interval (Fig. 3); the slope map; the 3D areas of landslide deposit and scar (respectively equal to 7,787 m^2 and 6,064 m^2); the deposit volume above sea level (about 70,000 m^3).

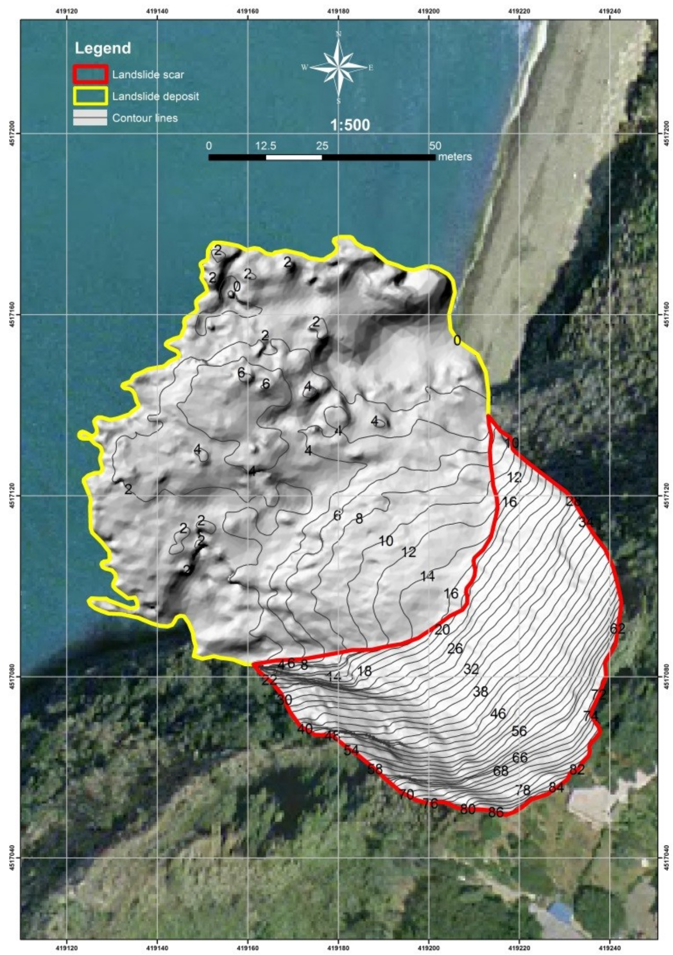

Fig. 3 - Hillshade of the landslide and main geomorphological features; ortophoto of the entire area in background (UTM 33N - WGS84 coordinate system).

DISCUSSION AND CONCLUSIONS

Analysis of the landside here described allowed us to test a rapid geomatic approach aimed to the geomorphological mapping and characterization of shallow mass movements. Advantages of this approach are the simplicity of use, rapid processing, and low cost. The main weakness consists in the need of GCPs for 3D model georeferencing. It could represent a difficulty in some areas where field markers could be not easily identifiable because of either inaccessibility or geological and land cover characteristics. Indeed, by a dedicated topographic/GPS survey, coupled with photogrammetric acquisition, it is possible to reach very high accuracy values and precise products. Otherwise the use of markers included in already georeferenced maps or available ortophotos could lead to accuracy errors up to some meters.

In the future, it could be very important to apply this approach in further case studies to reach a more high reliability and to identify eventual weaknesses that could give the chance to improve the entire processing.

REFERENCES

Agisoft (2014) - Agisoft Photoscan User Manual: Professional Edition, Version 1.0. http://www.agisoft.com/downloads/user-manuals/

Cruden D.M. & Varnes D.J. (1996) - Landslides Types and Processes. In: Turner A.K. & Schuster 328 R.L. (Eds.), Landslides: Investigation and Mitigation.

Di Girolamo P., Ghiara M.R., Lirer L., Munno R., Rolandi G. & Stanzione D. (1984) - Vulcanologia e petrologia dei Campi Flegrei. Boll. Soc. Geol. It., 103, 349-413.

Giordan D., Allasia P., Manconi A., Baldo M., Santangelo M., Cardinali M., Corazza A., Albanese V., Lollino G. & Guzzetti, F. (2013) - Morphological and kinematic evolution of a large earthflow: The Montaguto landslide, southern Italy, Geomorphology, 187, 61-79.

Guzzetti F., Mondini A.C., Cardinali M., Fiorucci F., Santangelo M. & Chang K.-T. (2012) - Landslide inventory maps: New tools for an old problem, Earth Sci. Rev., 112, 42-66.

Lirer L. (2011) - I Campi Flegrei. Storia di un campo vulcanico. Quaderni dell'Accademia Pontaniana, 57, 1-178.

Manconi A., Casu F., Ardizzone F., Bonano M., Cardinali M., De Luca C., Gueguen E., Marchesini I., Parise M., Vennari C., Lanari R. & Guzzetti F. (2014) - Brief Communication: Rapid mapping of landslide events: the 3 December 2013 Montescaglioso landslide, Italy. Nat. Hazards Earth Syst. Sci., 14, 1835–1841.

Rosi M. & Sbrana A. (1987) - Phlegraean Fields. CNR Quaderni della Ricerca Scientifica, 114 (9), pp. 175.