UNIVERSITÀ
DEGLI STUDI
FIRENZE

DST
DIPARTIMENTO DI
SCIENZE DELLA TERRA

Wi-GIM: Wireless sensor network for Ground Instability Monitoring

LIFE12 ENV/IT/001033
A project co-funded
by the EU life program

Conventional monitoring for Wi-GIM data validation on the Roncovetro landslide

Firenze, April 2015

Project leader

Prof. Nicola CASAGLI

Technical manager

Dott. Giovanni Gigli

Working group

Dott. Francesco Mugnai
Dott. Emanuele Intrieri
Dott. Luca Lombardi
Dott. Massimiliano Nocentini

TABLE OF CONTENTS

1 Introduction

In this document, an update of the conventional monitoring currently used on the Roncovetro earthflow is described.

Traditional monitoring data of the Roncovetro earthflow have been recorded starting from May, 2014, with the aim of identifying the general deformational field of the investigated site and, consequently, of choosing the best location for the Wi-GIM nodes. This activity is very important and will allow to save a lot of time for Wi-GIM node installation, since the selected earthflow is very wide (Figure 1), and the displacement field is not supposed to be uniform, both in space and in time.

In particular, two different techniques are being used: Terrestrial laser scanning and robotized total station.

Figure 1. Aerial view of the Roncovetro earthflow.

2 LASER SCANNING TECHNIQUE

The laser scanning technique uses a coherent light beam (laser) to scan a target under a predefined solid angle and with a regular scan pattern. The result of the scan is a matrix of points materializing the surveyed surface, expressed in polar coordinates with respect to the centre of the apparatus (range r, horizontal angle θ, vertical angle ϕ). The spatial resolution of the points is function of the angular resolution and the distance.

The point cloud produced by the scan is directly the 3D digital model of the scanned object and can be dealt with any 3D graphic elaboration software. From the point cloud, a mesh can be obtained, that is a continuous 3D surface.

The instrument used for Roncovetro landslide uses the time of flight technique; the distance of the target is deduced from the time between the emission of a short laser pulse and its backscattering to the instrument itself. The distance of the hit target is given by the following relation:

$D = c\,t/2$

Where c is the speed of light. Differently from the ideal case, where every pulse has an identical corresponding backscattered signal, in reality the backscattered signal is altered by the characteristics of the reflecting object, by atmospheric conditions and by the fact that the laser beam, although very concentrated, always has a certain divergence.

The terrestrial laser scanner does not need positioning corrective systems, since the distances are referred to a Cartesian space centred on the instrument itself. The georeferencing on an absolute system can be achieved afterwards by knowing the geographical coordinates of some reference points individuated in the scan (Figure 2) through a high precision GPS device (Figure 3).

The main advantage of this technique is its high spatial resolution and the possibility to scan areas that are not accessible or not easily visible from airplane. Modern terrestrial laser scanners used for geological applications allow for centimetric to millimetric accuracy, depending on the method used for evaluating the distance of the reflecting method.

For the Roncovetro landslide the scans have been carried out with a 3D Laser Imaging Sensor LMS-Z420i, a terrestrial apparatus produced by Riegl Laser Instrument Systems (Figure 4).

Its main characteristics are:

- Maximum range: up to 800 m, function of the reflectivity of the object;
- Accuracy: ± 10 mm;
- Minimum vertical scan pace: 0.008°;
- Minimum horizontal scan pace: 0.01°;
- Scan speed: up to 12000 points/second;
- Wavelength: near infrared;
- Beam aperture: 0.25 mrad.

The area covered by the two scans is highlighted in Figure 6

Figure 2. Reference point employed for Terrestrial Laser Scanning data referencing.

Figure 3. Employed GPS device.

Figure 4. Employed laser scanning device. View of the upper scan position

To date, the following laser scanning surveys have been performed:

- May 28th, 2014
- July 7th, 2014
- October 31st, 2014
- December 10th, 2014
- March 11, 2015

The surveys are focused on the upper and more active sector of the earthflow, and are acquired from two different scan positions (Figure 5), in order to reduce the shadow areas as much as possible.

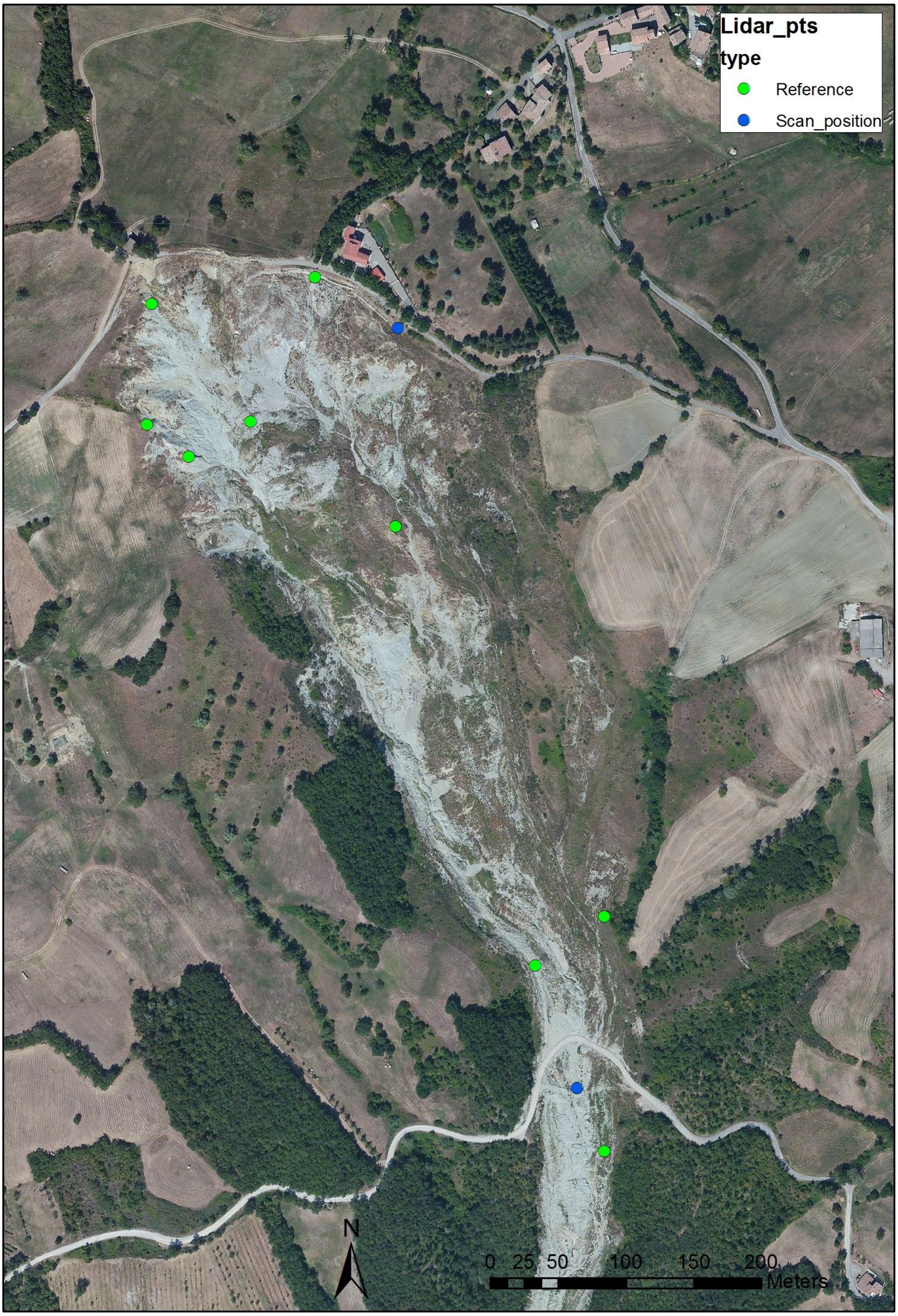

Figure 5. Terrestrial laser scanning scan positions (blue points), and reference reflectors (green points).

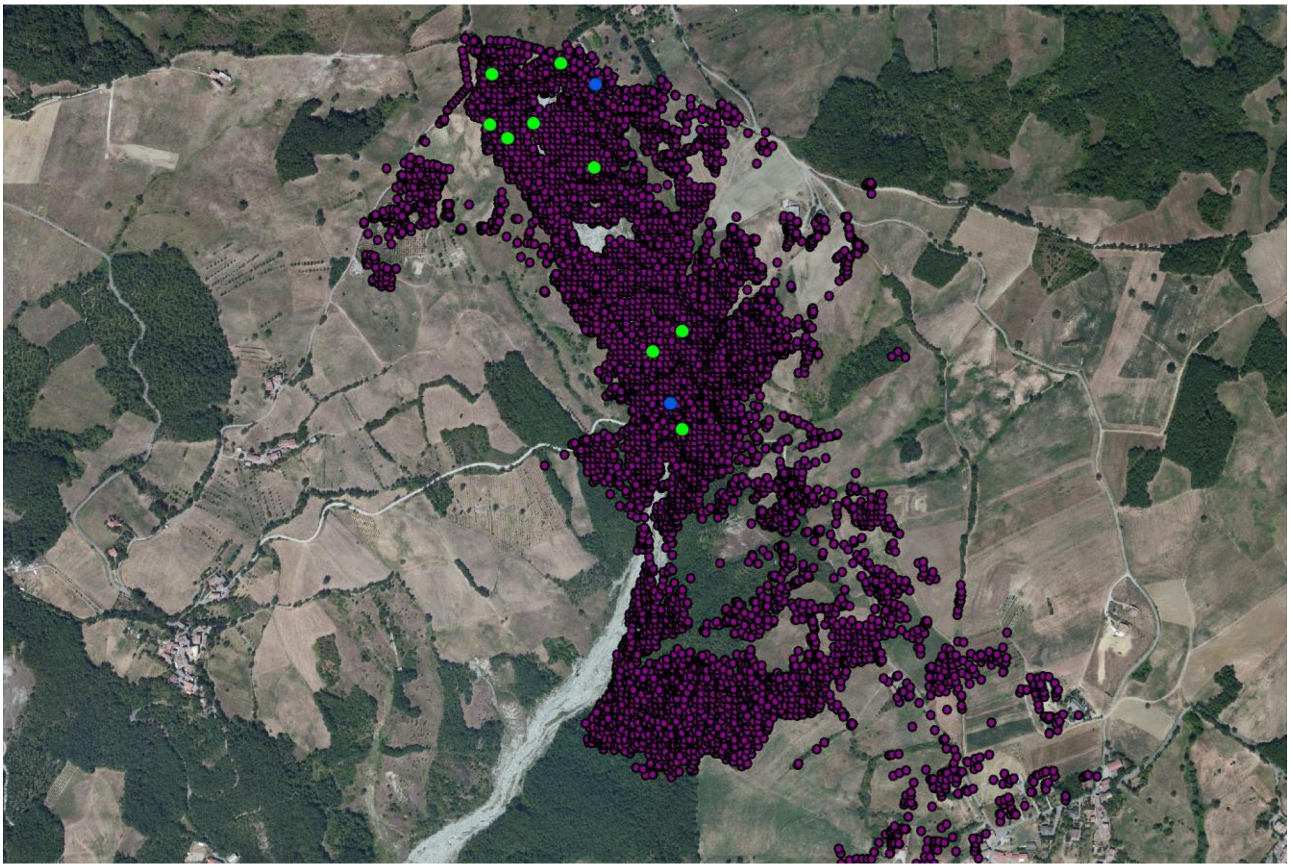

Figure 6. Area covered by the laser scanning surveys (purple points).

The raw product of a laser scanning survey is a high resolution and high precision point cloud (Figure 7).

By comparing point clouds acquired at different times it is possible to reconstruct the general deformational field of the investigated landslide (Figure 8, 9, 10).

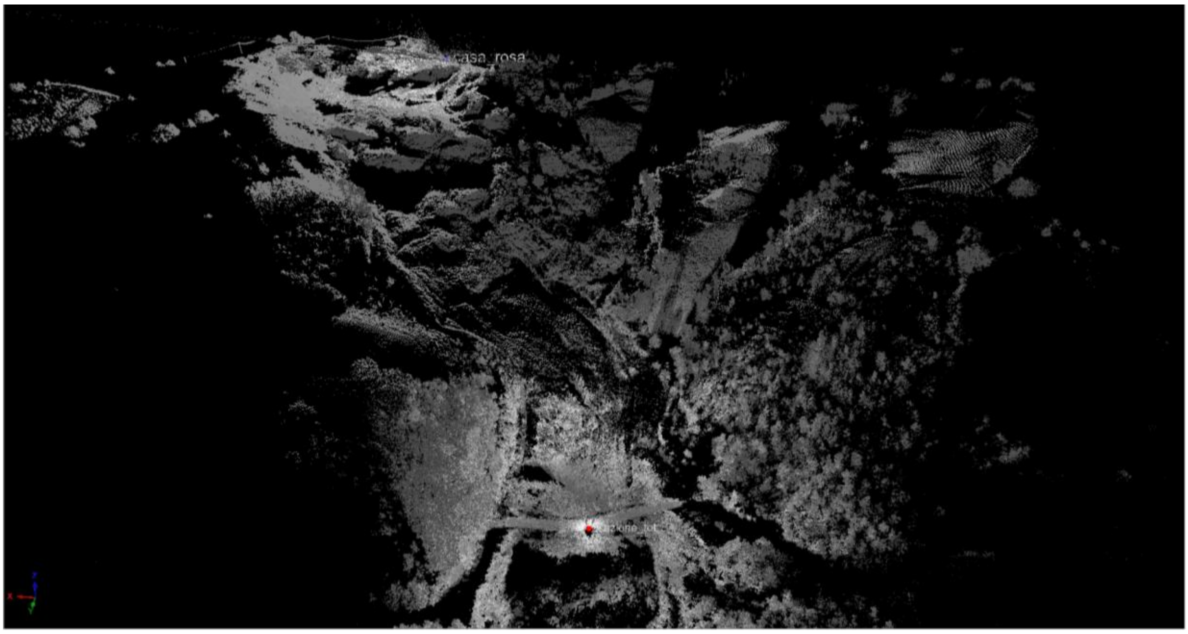

Figure 7. Intensity coloured high resolution point cloud, composed of about 5 million points.

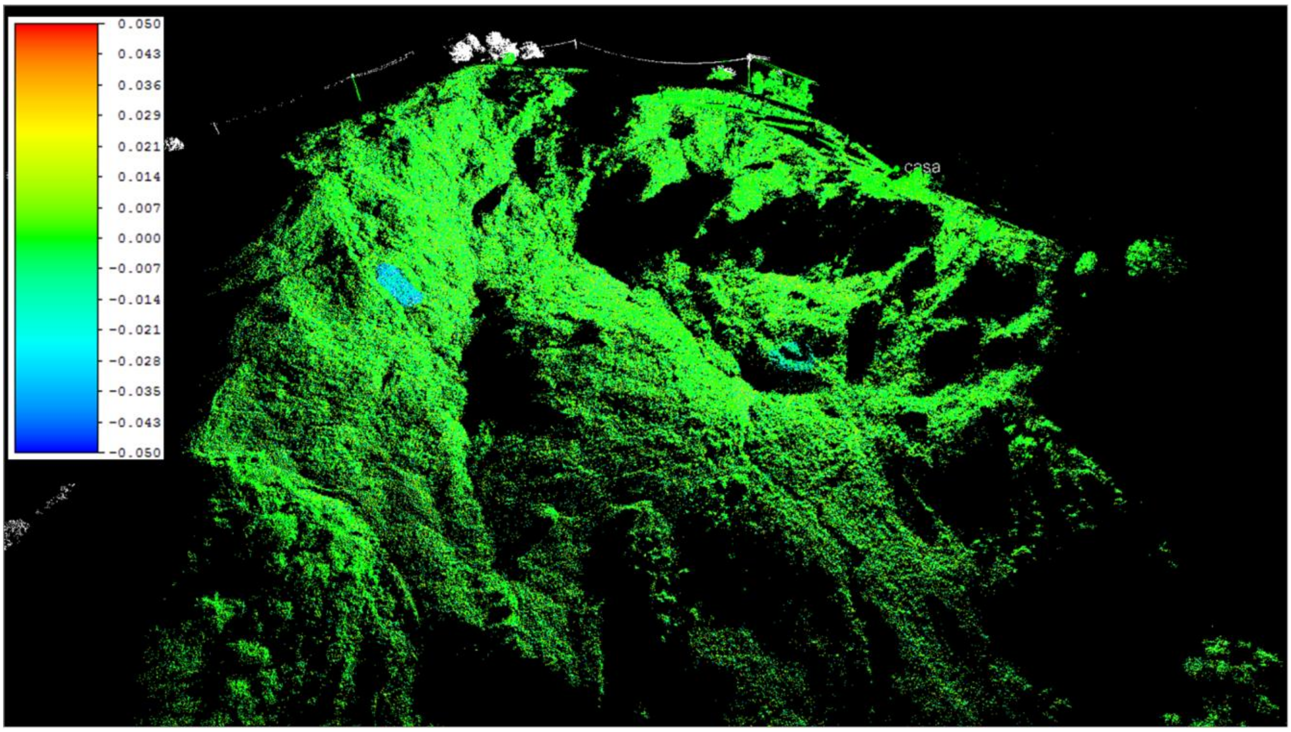

Figure 8. May, 28th – July, 7th point cloud comparison (displacement values are expressed in meters).

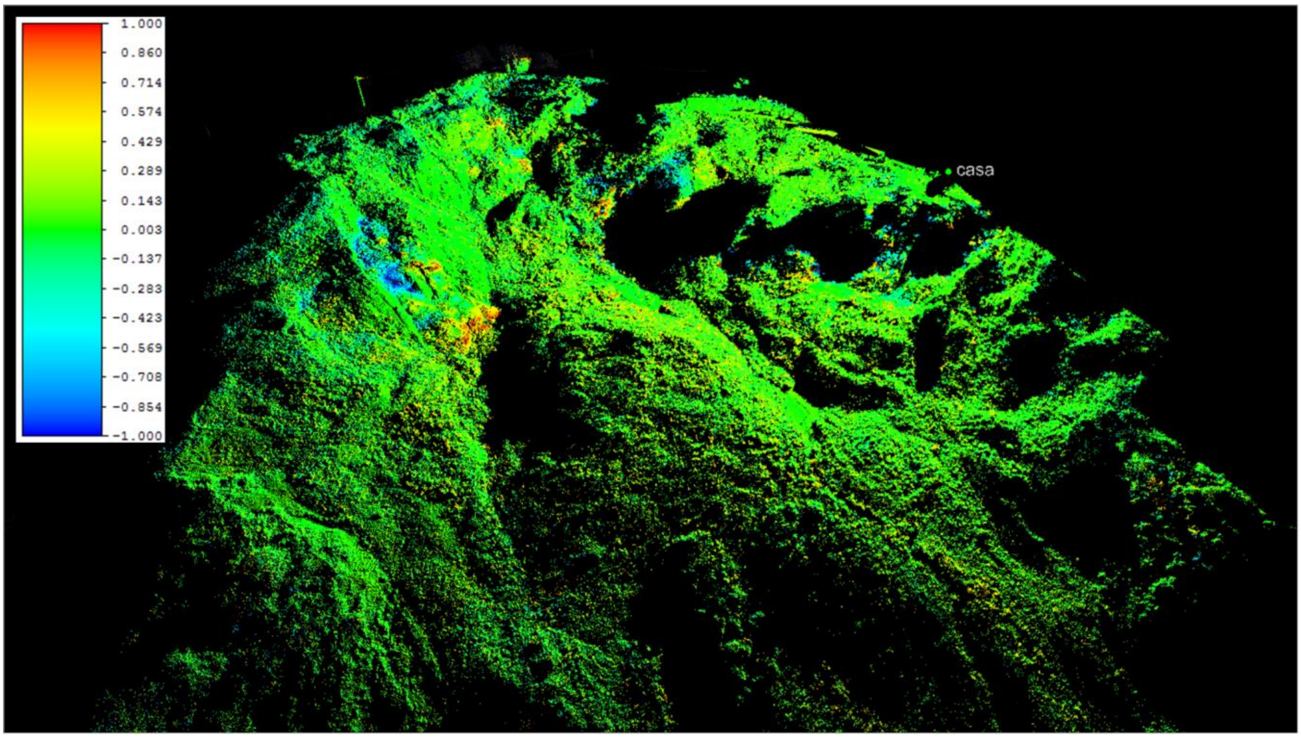

Figure 9. May, 28th – December, 10th point cloud comparison (displacement values are expressed in meters).

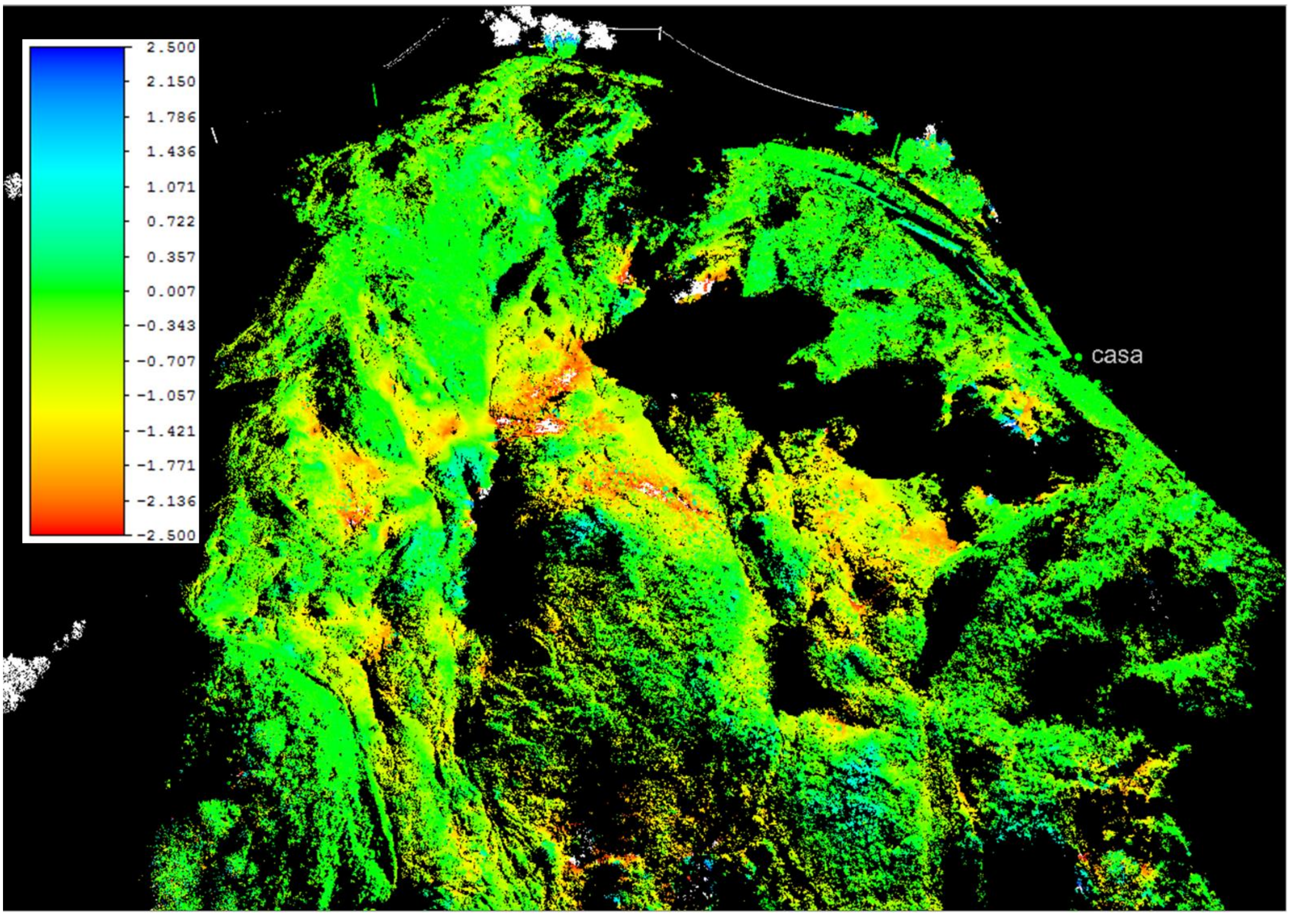

Figure 10. May, 28th – March, 11 point cloud comparison (displacement values are expressed in meters).

The monitoring survey of March 11 2015 has been delayed by many days due to the presence of a thick snow layer. The fast melting of the snow which happened in early may caused an evident and diffuse reactivation of the earthflow (Figure 11).

By evaluating the position of a reflector employed for georeferencing the point cloud, a displacement of 17.904 meters can be measured in the central-upper portion of the earthflow (Figure 12 and Figure 13).

Figure 11. Interruption of the road due to earthflow reactivation.

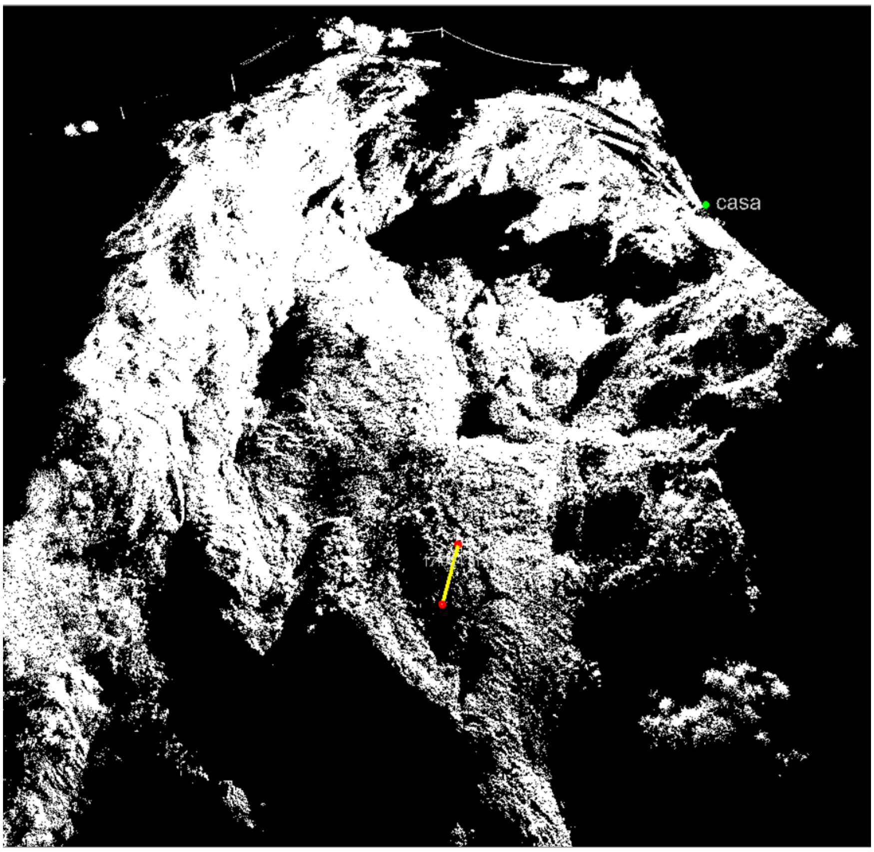

Figure 12. Measured displacement in the upper central sector of the earthflow.

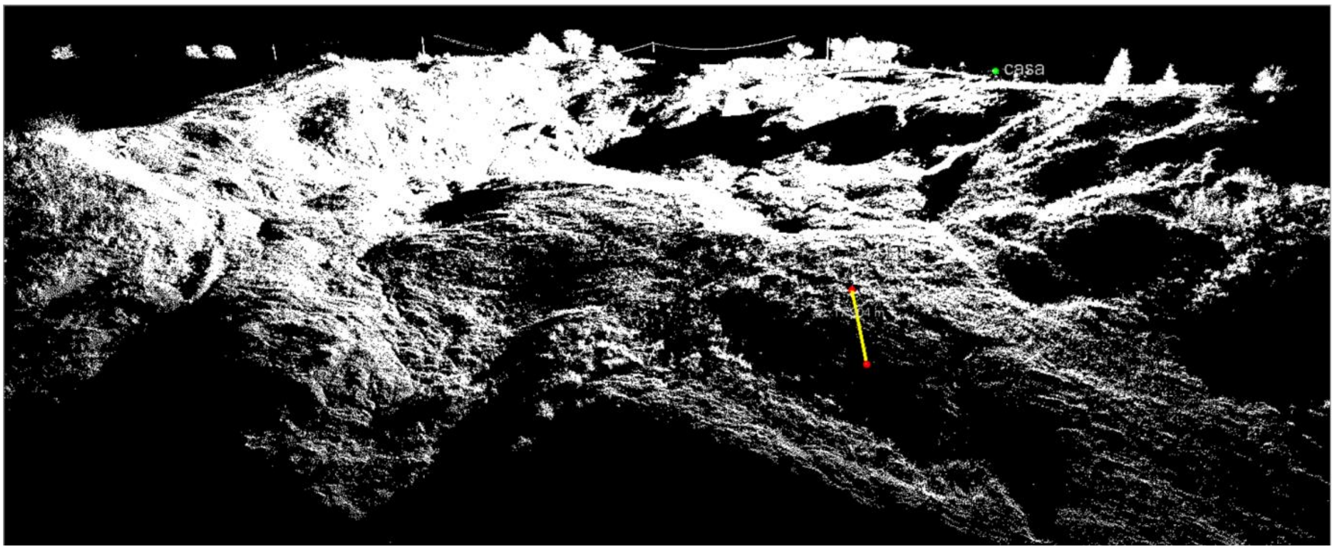

Figure 13. Measured displacement in the upper central sector of the earthflow.

3 ROBOTIZED TOTAL STATION

Nowadays the total station is the most commonly used instrument for the direct survey of single points. With respect to a traditional optical-mechanical theodolite, it has an electronic distancemeter and a computer for storing and calculating data. It permits to measure angles and distances of a series of points and to determine their exact location with respect to a predefined coordinate system.

The instrument is composed of:

- the basement, which is fixed to a tripod through a central screw. It comprises a laser plummet for centring the point and three horizontal screws for centring the bubble;
- the alidade, which comprehends the telescope, scope, spherical bubble, azimuth and zenith micrometric screws, starting button, computer and battery slot.

The computer has a display and a keyboard with function keys for the main operations, alphanumeric keys for inserting data, navigation keys for browsing inside the computer.

The total station operates within a polar coordinate system x, y, z centred in the optical centre of the instrument itself. In order to determine the position of a point it is necessary to perform three measurements: horizontal (azimuth) angle, vertical (zenith) angle, inclined distance. The azimuth angle is given by the rotation of the alidade on the horizontal plane and is calculated in relation to the polar axis (corresponding to the y axis, which lays on the horizontal plane and is set by the operator). The zenith angle is given by the rotation of the telescope on the horizontal plane and is calculated with respect to the z axis (which lays on the vertical plane).

The inclined distance is performed through the electronic distancemeter embedded within the total station. A laser beam is generated by the telescope, hits the targeted point and is reflected. The instruments record the time occurred for the light pulse to reach the target and calculates the travelled distance accordingly. The first distancementers only worked by hitting special mirrors (prisms) usually mounted on tripods or other structures. The laser produced by more recent apparatuses can be reflected even by less reflective surfaces such as buildings. This contributed to reduce the entire survey procedure and even allows for the measurement of not accessible points. The most evolved version of this instrument is the motorized total station, equipped with servomechanisms that permit to automatically collimate a moving prism if it is framed by the telescope.

The total station used for the traditional monitoring of Roncovetro landslide is Nova MS50 produced by Leica Geosystems Italia. It integrates the measurements of 3D point clouds within a linear work flow. This permits to acquire and visualize data of the topographical survey and high resolution laser scans all together. Leica Nova MS50 furnishes the functionality of a total station integrated with a sensor for high precision in a completely automatic measurement procedure. It has a panoramic wide-angle camera and a 30x autofocusing coaxial camera. It provides real time video data on the embedded display in order to enable the visualization of high quality images.

The following topographic monitoring surveys have so far been performed:

- July 7th, 2014
- October 31st, 2014
- December 10th, 2014
- March 11st, 2015
- March 18th, 2015

First of all, a stable concrete pillar for hosting the total station was built (Figure 14).

Figure 14. Employed total station device for Roncovetro earthflow traditional monitoring on concrete pillar

First of all, the accuracy of the topographic monitoring system has been evaluated, to state if it will be suited for the Wi-GIM validation phase.

Figure 15 shows that the precision of the measurements which will allow the validation of the Wi-GIM system is millimetric, according to the proposal statements.

Furthermore, the design of support for prism and slave nodes was done taking into account both the characteristics of prism and wireless nodes and the geometrical proprieties of the scenarios, which may control the disposition of the monitoring devices (Figure 16).

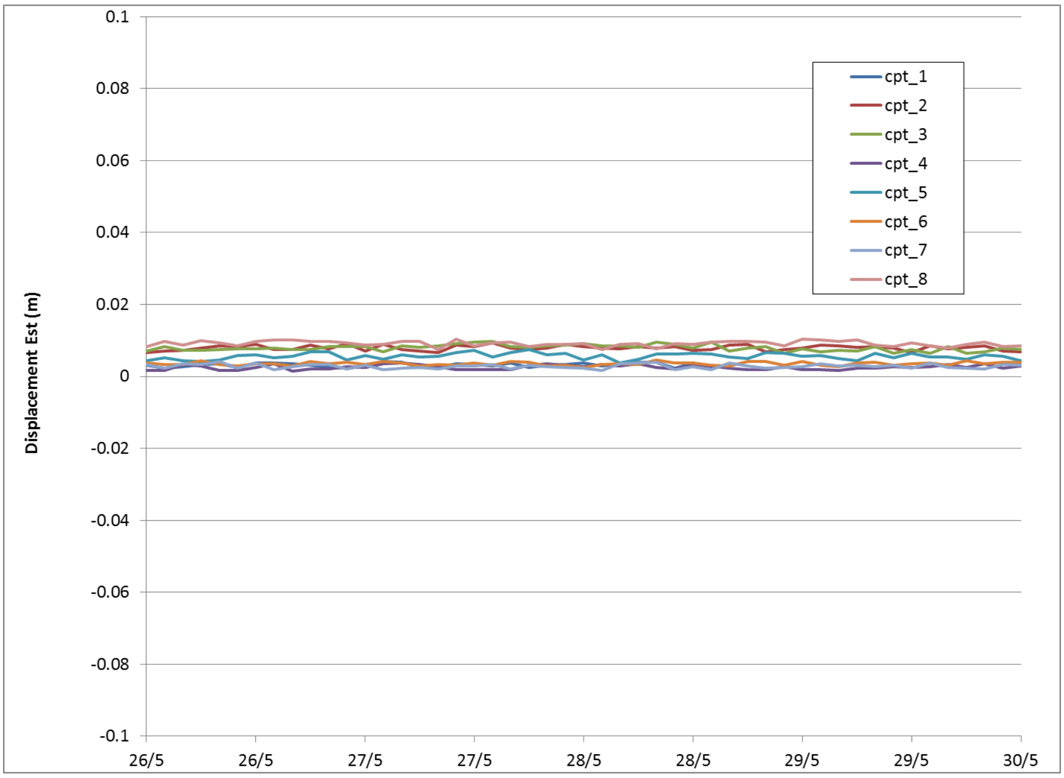

Figure 15. RTS displacement vs time chart of in field test on Roncovetro Landslide.

Figure 16. In-field mounting of node support housing a topographic prism.

The reactivation of the earthflow caused the loss of many benchmarks installed during the first survey (Figure 17).

Only benchmark n. 4 was found, allowing to estimate a displacement of about 32 m in correspondence of the road crossing the earthflow (Figure 11).

Each monitoring survey allows for a displacement field update, and consequent re-adaptation of the topographic monitoring setting, with the aim of finding the best logistic solution for Wi-GIM node installation.

For this reason, on March 11, a new distribution of monitoring targets was put in place on the upper part of the Roncovetro earthflow, as shown in Figure 18.

On March 18 a new survey has been performed leading to centimetric to decimetric measured displacements (Table 1).

TPS	Est	Nord	Quota
5	-0.194	-0.0085	-0.0037
6	-0.1626	-0.0171	-0.009
7	-0.037	-0.0346	-0.0065
8	-0.0632	-0.015	-0.0051
9	-0.2096	-0.0027	-0.0004
10	-0.1241	-0.0436	-0.0073

Table 1. Measured displacement through topographic monitoring from March 11 to March 18.

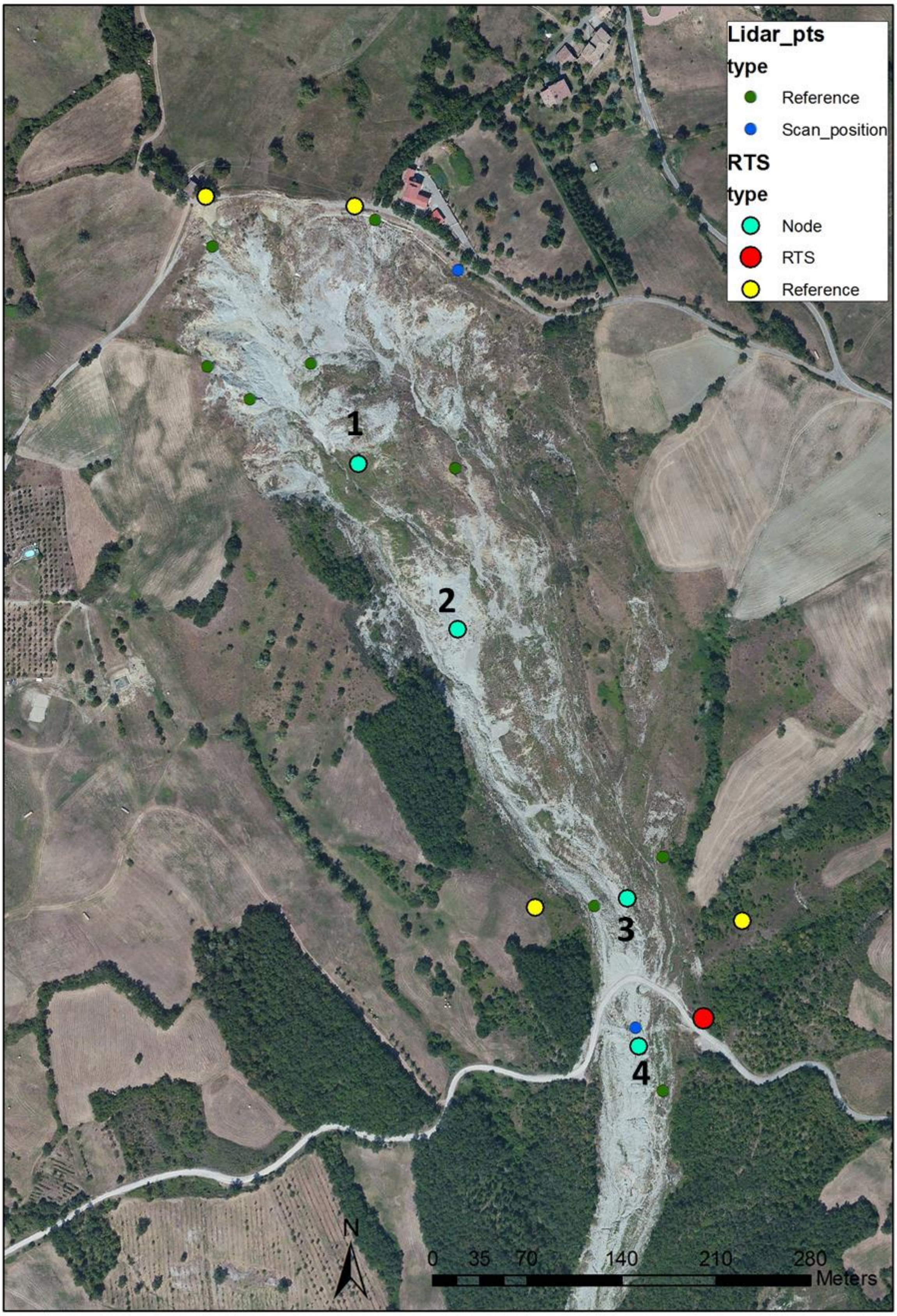

Figure 17. Former topographic monitoring setting

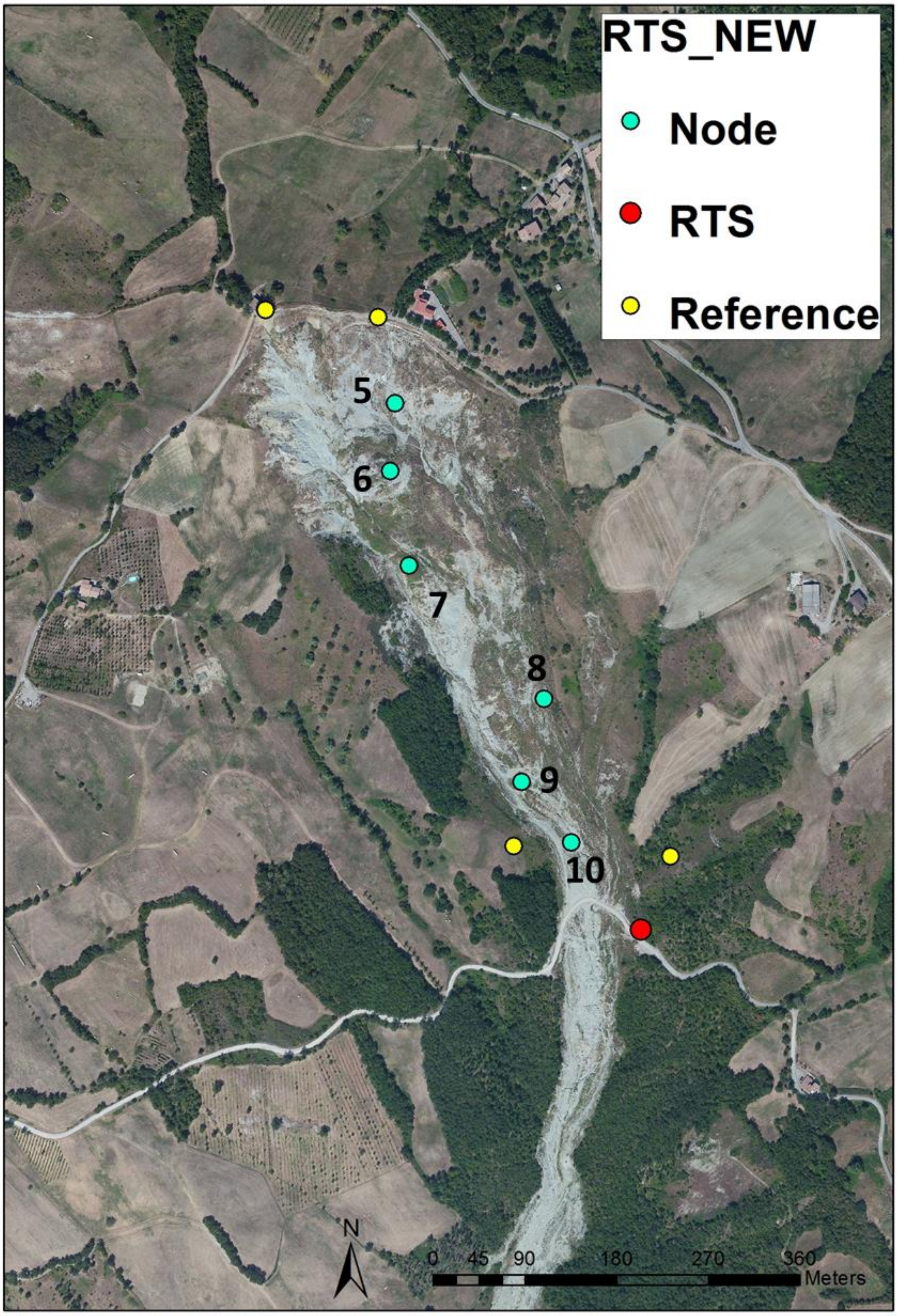

Figure 18. Total present distribution of monitoring target on the upper part of the Roncovetro earthflow.

4 Concluding remarks

The Roncovetro earthflow experienced a marked reactivation after heavy snow melting happened in early March 2015. The displacements measured at some topographic benchmarks were higher than 10 m. Many benchmarks were also lost due to very high displacements occurred.

This preliminary monitoring activity through traditional methods will be useful to define the most proper location of Wi-Gim nodes, in order to avoid the loss of some of them due to possible intense reactivation phases of the earthflow.