Combined approach for terraced slopes micromorphological analysis through field survey and 3D models: the Stonewallsforlife project

Emanuele Raso[1], Paolo Ardissone, Leandro Bornaz, Andrea Mandarino, Andrea Vigo, Ugo Miretti, Rocco Lagioia, Alba Bernini, Marco Firpo

[1] Università degli Studi di Napoli Federico II
Complesso Universitario di Monte Sant'Angelo, Via Cinthia – 80126, Napoli, Italy
emanuele.raso@unina.it

Abstract—**The analysis of terraced slopes has implications in many different research areas, since this topic is influenced by natural, socioeconomic and cultural dynamics. The ancient technique of dry-stone walling has provided an effective contrast to concentrated erosion and shallow landslide triggering and run out, and in the meanwhile has created a strong cultural identity between the populations involved in this practice. To this aim STONEWALLSFORLIFE (S4L), a LIFE project financed by the European Commission in which the Cinque Terre National Park is involved as coordinating beneficiary, wants to demonstrate how an old technology - drystone walls - can be effectively used to improve the resilience of the territory to climate change through the adoption of a socially and technically innovative approach. The 6ha pilot site of Manarola, located in the heart of the Cinque Terre National Park (Italy), has been investigated through a traditional geomorphological and geological survey together with an accurate terrain analysis through the use of 3D model extracted by a point cloud generated by laser scanner coupled with GNSS survey, laser scanning and UAV photogrammetry. One of the main goals of the project is therefore to provide a deep and precise morphological assessment of the site pointing out the most vulnerable sectors of the pilot area. The results will be elaborated in order to obtain an exportable method in terms of micromorphological characterization of terraced slopes.**

I. Introduction

The Cinque Terre National Park is a 38 km^2 wide coastal sector of the eastern Liguria region (northwestern Italy) which embraces five small towns (less than 4000 inhabitants) connected by several coastal trails that represent a worldwide-known tourist destination. Since 1997, this area has been included in the 'World Heritage List' of UNESCO for its high scenic and cultural value, being one of the worldwide referenced 'cultural landscape', while in 1999 it has been declared National Park for its environmental and naturalistic relevance. The most relevant feature of this coastal sector is the terraced landscape, which is characterized by agricultural terraces retained by thousands of kilometers of drystone walls, mainly built for vineyards and olive groves (Brandolini, 2015; Terranova, 1984). As reported by Terranova et al. (2002), it can be assumed that in the nineteenth century terraced slopes covered up to 60% of the whole Cinque Terre territory. The STONEWALLSFORLIFE, a LIFE project financed by the European Commission in which the Cinque Terre National Park is involved as coordinating beneficiary, is aiming to demonstrate how an ancient technology - drystone walls - can be effectively used to improve the resilience of the territory to climate change by adopting a socially and technically innovative approach. The project will showcase its environmental, social and economic benefits, prepare the ground for replication and transfer, and draw on actions and experiences in other territories with different conditions and priorities to develop deep and broad knowledge which can then be applied in accordance with local circumstances.

The pilot site (6 hectares wide) is the so called "Anfiteatro dei Giganti" (literally, Giants' amphitheatre) located just above the hamlet of Manarola (Figure 1): this area includes part of the right and left sides of the Groppo creek catchment, has been affected by a progressive abandonment of terraced areas and nowadays is the heart of this new restoration project.

One of the main goals of the project is to perform a complete geomorphological, geological and morphological characterization of the site, together with an accurate terrain analysis through the use of 3D model extracted by a point cloud generated by laser scanner coupled with GNSS survey and UAV photogrammetry.

Emanuele Raso, Paolo Ardissone, Leandro Bornaz, Andrea Mandarino, Andrea Vigo, Ugo Miretti, Rocco Lagioia, AlbaBernini, and Marco Firpo (2020)

Combined approach for terraced slopes micromorphological analysis through field survey and 3D models: the Stonewallsforlife project:

in Massimiliano Alvioli, Ivan Marchesini, Laura Melelli & Peter Guth, eds., Proceedings of the Geomorphometry 2020 Conference, doi:10.30437/GEOMORPHOMETRY2020_19.

II. METHODS

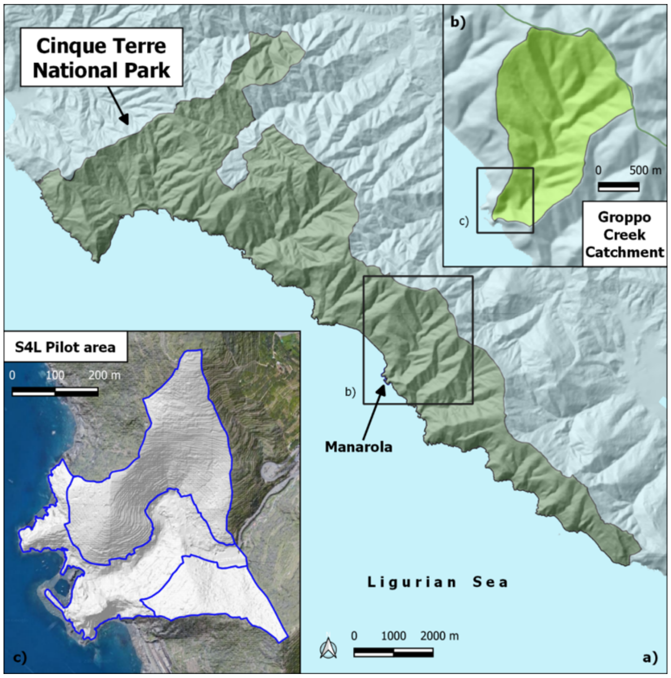


Figure 1. Geographical setting of the Groppo Creek catchment and location of the STONEWALLSFORLIFE Project pilot site.

A. Geological and Geomorphological survey

First, a detailed geological and geomorphological study of the project area through original field surveys and the use of existing IT data was performed: later on, collected data were elaborated in a GIS environment (e.g. high-resolution digital terrain models, vector and raster files available on "Geoportale Regione Liguria", etc.); the main purpose was therefore to obtain:

- A geological-structural model that can provide precise indications on the spatial relationships between discontinuity planes (stratification, substrate fracture planes) and the dry-stone walls structures characterizing the slopes inside the project area.

- Detailed mapping of the main erosional and depositional forms (punctual, linear and areal) inside the study area in order to identify any dangerous factors related to the construction and maintenance of dry-stone walls and terraced strips.

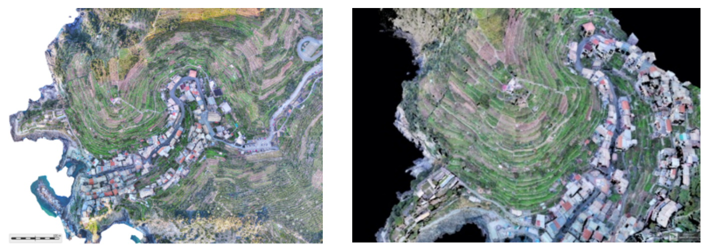
The investigations were conducted in a GIS environment and carried out by means of the free and open source software QGIS and GRASS GIS. The extensive field survey campaign was carried out in January 2020 and was supported by the use of the software QFIELD combined with a common GNSS device. This activity was focused on accessible areas, thus densely-vegetated and impervious plots of land were excluded.

B. Creation of a 3D model from laser scanner and aerial photogrammetry

For the cartographic description of the site, different survey techniques were used: GNSS, Terrestrial Laser Scanner and UAV Photogrammetry.

The first field activity was the materialization and measurement of a benchmarks network: a total of 308 fixed points was measured with GNSS techniques for the calculation of the cartographic parameters and the calculation of the geodetic rules for a correct passage from a local to a global reference system.

Subsequently, following the survey project developed together with the geological managers of the Park, several activities were performed with the double function to check the effective Terrestrial Laser Scans (TLS) coverage and to generate a first 3D model of the areas capable of describing the morphological features of the pilot site, with a good level of detail, and the presence of any obstacles for drone flights (e.g. presence of high vegetation, presence of overhead lines etc.).



2A 2B

Figure 2a High resolution (5cm x 5cm) orthophotos showing the pilot area of Manarola, Cinque Terre National Park; 2b: 3d model of the hamlet of Manarola

Furthermore, a specific 3D flight programmer was used to design flight plans considering the actual 3D shape of the terrain. Flight paths, acquisition points and camera configuration were preset and loaded onto the drone navigator unit, which simultaneously received instructions on speed, route to follow, take-off and landing point.

In this way photogrammetric strips are obtained with always nadiral images, always at constant height above the ground: this aspect is fundamental for obtaining constant resolution data on the surveyed area, since the Cinque Terre territory is characterized by a morphology with strong differences in height. Moreover, the flight routes, programmed following this 3D approach, do not exceed the regulatory limits imposed by ENAC, the Italian Civil Aviation Authority.

III. Results and conclusions

A. Geological and Geomorphological survey

The geological survey was conducted at the scale of 1:2’500, allowing for the investigation of outcrops and structures wider than 2.5 m. The main outcrops of the bedrock were identified and mapped and their principal structural discontinuity planes were measured (bedding or stratification planes, fracture, etc.), in order to obtain a geological-structural model of the substrate. As a result, a set of georeferenced geological data were prepared in order to describe accurately the geological features of the site.

Similarly, the detailed geomorphological survey allowed for the identification and mapping of landforms and deposits at the micro-scale (mainly anthropogenic landforms consisting of dry-stone walls, underground cisterns, drain channels and walkways), and thus for the characterization of past and current geomorphological processes that shaped and are shaping the landscape, respectively.

B. Creation of a 3D model from laser scanner and aerial photogrammetry

About the creation of 3D model (Figure 3) fifty-two 3D flight plans were designed and carried out in order to properly cover the survey area: a total of 7000 images were acquired and processed to generate 3D models using automatic photogrammetry techniques and algorithms. In fact, images were acquired with a aerial photogrammetric logic.

Figure 3. 3D model obtained through the combined use of different survey techniques such as GNSS, Terrestrial Laser Scanner and UAV Photogrammetry

Using the flight plan parameters, it was possible to obtain the approximated position and shooting orientation of the individual frames. These approximate positions have been recomputed for relative orientation which defines the relationship of reciprocal position between images. The relative orientation was calculated considering the geometric behavior of the camera and applying automatic photogrammetric algorithms.

In order to have a good relative orientation, on the acquired images a radiometric recalibration procedure was applied, which had three functions: to highlight morphological details, to eliminate high variation of lights and shadows and to homogenize colors and tones between images and between the different photogrammetric strips.

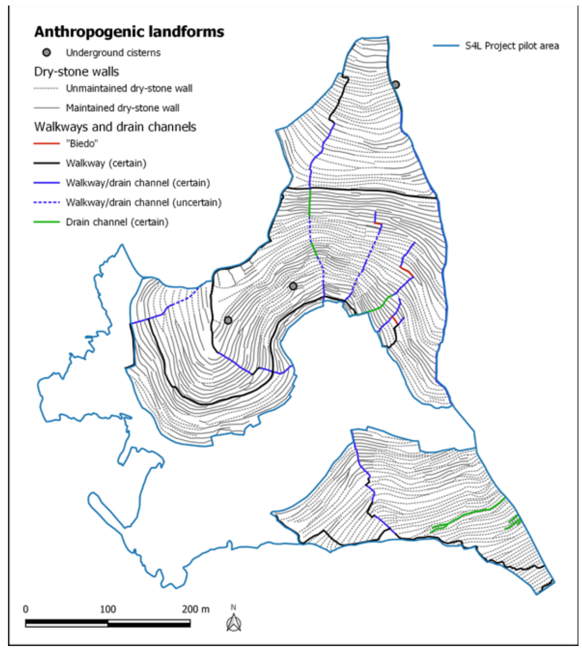


Figure 4. Map showing the anthropogenic landforms of the STONEWALLSFORLIFE Project pilot site.

Through the use of GNSS control points, the absolute orientation of the photogrammetric blocks was defined and globally compensated (bundle adjustment).

Subsequently, 3D models were created, using automatic photogrammetry algorithms, which define the 3D position of points covered by multiple oriented images.

After detailed checking of the image orientations, high-resolution 3D models were generated, keeping under control precision and accuracy. In particular, for the generation of 3D models from images, different algorithms were tested and then used. In fact, these procedures assign different weigh to precision and distribution in the recognition of common points. Three different 3D models were therefore generated, using different algorithms and then merging them together. The integration between the models generated by the different computational procedures allowed to obtain a better result in terms of accuracy and coverage.

A total of 65 3D models were generated at a constant resolution of 20 cm, and later on they have been classified: the vegetation has been selected and assigned to a specific class (Vegetation), using a semi-automatic procedure: more specifically, it allows to identify and select points that aren't part of the terrain/topographical surface according to a statistical analysis; on a subsequent stage, operators check the results and validate or invalidate it; by re-launching the procedure in different computation sessions, the result has been refined.

Starting from these classified models it was possible to generate global 3D model of the area, contour lines, and DTMs. These data, along with the orthophotos, made it possible to quantitatively investigate the morphometric features of the S4L pilot area and to identify and map the anthropogenic landforms of the whole pilot area, with a high spatial accuracy.

In particular, the geometric features of terraced strips, drain channels and pathways were quantitatively analyzed through common raster and vector geoprocessing tools and terrain analysis tools. Moreover, the dry-stone walls location and total length were pinpointed and measured, respectively.

The outcomes are, thus, based on the analysis of the aforementioned 3D model and DTMs, and on a large photointerpretation activity.

This in-progress research highlighted the great relevance of using the illustrated combined approach for the implementation of a morphologic analysis in such complex areas as the S4L pilot area is.

REFERENCES

[1] Brandolini, P., Cevasco, A., Capolongo, D., Pepe, G., Lovergine, F., & Del Monte, M. (2018). Response of terraced slopes to a very intense rainfall event and relationships with land abandonment: A case study from Cinque Terre (Italy). Land Degradation and Development, 29, 630–642.

[2] Camera, C., Djuma, H., Bruggeman, A., Zoumides, C., Eliades, M., Charamboulos, K., Abate, D., Faka, M., 2018. "Quantifying the effectiveness of mountain terraces on soil erosion protection with sediment traps and dry-stone wall laser scans". Catena 171, 251-264.

[3] Capolupo, A., Kooistra, L., Boccia, L., 2018. "A novel approach for detecting agricultural terraced landscapes from historical and contemporaneous photogrammetric aerial photos". Int J Appl Earth Obs Geoinformation 73, 800-810.

[4] Cevasco, A., Pepe., G., Brandolini., P., 2014. "The influences of geological and land use settings on shallow landslides triggered by an intense rainfall event in a coastal terraced environment". Bull Eng Geol Environ 73, 859–875.

[5] Crosta, G. B., Dal Negro, P., Frattini, P., 2003." Soil slips and debris flows on terraced slopes. Natural Hazards and Earth System Science, 3, 31–42.

[6] Moreno-de-las-Heras, M., Linderberger, F., Latron., J., Lana-Renault, N., Llorens, P., Arnàez, J., Romero-Diaz, A., Gallart, F., 2019. "Hydro-geomorphological consequences of the abandonment of agricultural terraces in theMediterranean region: Key controlling factors and landscape stability patterns". Geomorphology 333, 73-91.

[7] Pepe, G., Mandarino, A., Raso, E., Scarpellini, P., Brandolini, P., Cevasco, A., 2019. Investigation on farmland abandonment of terraced slopes using multitemporal data sources comparison and its implication on hydro-geomorphological processes. Water, 111, 1552.

[8] Pesci, A., Teza, G., Bisson, M., Muccini, F., Stefanelli, P., Anzidei, M., Carluccio, R., Nicolosi, I., Galvani, A., Sepe, V., Carmisciano, C., 2016. "Monitoring of a Coastal Zone by Independent Fast Photogrammetric Surveys: the Case of Monterosso al Mare (Ligurian Sea, Italy)". Journal for Geosciences and Geomatics 4, 73-81.

[9] Pescini, V., Montanari, C.A., Moreno, D.T., 2018. "Multi-proxy record of environmental changes and past land use practices in a Mediterranean landscape: The Punta Mesco cape (Liguria - Italy) between the 15th and 20th century". Quaternary international 463, 376-390.

[10] Raso, E., Cevasco, A., Di Martire, D., Pepe., G., Scarpellini. P., Calcaterra, D., Firpo, M., 2019. "Landslide inventory of the Cinque Terre National Park (Italy) and quantitative interaction with the trail network". Journal of Maps 15, 818-830.

[11] Rodrigo-Comino, J., Seeger, M., Iserloh, T., Senciales-Gonzalez, J.M., Ruiz-Sinoga, J.D., Ries, J.B., 2019. "Rainfall-simulated quantification of initial soil erosion processes in sloping and poorly maintained terraced vineyards - Key issues for sustainable management systems". Science of the total environment 660, 1047-1057.

[12] Spanò, A., Sammartano, G., Calcagno Tunin, F., Ceris, S., Possi, G., 2018. "GIS-based detection of terraced landscape heritage: comparative tests using regional DEMs and UAV data". Applied Geomatics 10, 77-97.

[13] Stavi, I., Gusarov., Y., Halbac-Cotoara-Zamfir, R., 2019. "Collapse and failure of ancient agricultural stone terraces: On-site geomorphic processes, pedogenic mechanisms, and sol quality". Geoderma 344, 144-152.

[14] Terranova, R. (1984). Aspetti geomorfologici e geologico-ambientali delle Cinque Terre: Rapporti con le opere umane (Liguria orientale). Studi e Ricerche di Geografia, 7, 39–90.

[15] Terranova, R., Brandolini, P., Spotorno, M., Rota, M., Montanari, C., Galassi, D., Mus-Amezquita, M. (2002). Patrimoni de marjades a la Mediterrania Occidental. Una proposta de catalogaciò. Commissiò Europea DGX, Programa Raphael, Palma Di Mallorca, Fodesma, pp 243.

[16] Wei, W., Chen, D., Wang, L., Daryanto, S., Chen, L., Yu, Y., Lu, Y., Sun, G., Feng, T. 2016. Global synthesis of the classifications, distributions, benefits and issues of terracing. Earth-Science Reviews 159, 388-403.