STONEWALLS

DRY-STONE WALLS FOR CLIMATE CHANGE ADAPTATION

Preliminary scientific and technical report

Date:	14.09.2022
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Approved by:	PN5T staff
Deliverable ID:	A1.1

1 Introduction

The present scientific and technical report constitutes the Deliverable A1.1 of Action A.1 “Preparatory studies”, in the frame of the “Preparatory actions”. The report is divided in two sections that correspond to the two sub-actions of the Action A.1:

- Baseline investigation and collection of best practices;
- Scientific and technical assessment on the area of intervention.

The goal of the first section is to provide a collection of case studies in which drystone walls have been implemented as a measure for climate change adaptation purposes. Best practices are analyzed in order to gain information about scientific and technical aspects, as well as economic and social ones, which will help to face potential challenges during the implementation of STONEWALLSFORLIFE. At the end of the project, it will be also possible to evaluate the outcomes of the present project by comparing them to the results of the case studies collected here.

The second section focuses on the geo-environmental features of the pilot area. A detailed description and mapping of its geological and geomorphological features is presented, along with an analysis of man-made structures. In particular, dry-stone walls are characterised in terms of both spatial distribution and structural features. A small-scale land-use and land-cover map has been developed to highlight spontaneous-vegetation-covered areas, thus providing a quantitative overview on abandoned dry-stone walls and terraces. Furthermore, in order to use of dry-stone walls as climate change adaptation tools, some technical solutions to improve the resistance and resilience of these man-made structures are discussed. This work was performed by means of bibliographical research, GIS analysis and field surveys. The goal of this section if the creation of a wide and detailed scientific and technical base to perform the next phases of the Project.

2 Baseline investigations and collection of best practices

STONEWALLSFORLIFE targets a specific climate problem: the environmentally and socially adverse effects of more extreme weather events caused by climate change on the territories characterised by terraces build with drystone walls, such as those of the two areas of the project: Cinque Terre in Italy and Parc del Garraf in Catalonia.

This section aims at providing a thorough analysis of the use and performance of drystone walls for climate change adaptation purposes, considering also their use for more general environmental protection purposes, for the preservation of the territory, the conservation of landscape and the management of hydrological and geological risks.

The last part of this section presents the information about the lessons learned, the difficulties encountered, and the practical solutions found in the TERRASCAPE project (LIFE16 CCA/GR/000050), which also intends to use drystone walls as a climate adaptation tool. Networking activities with the coordinating beneficiary of TERRASCAPE (the University of the Aegean) are indeed ongoing, ensuring a continuous thus advantageous transfer of knowledge and experiences.

2.1 Drystone walls and hydrologic and geologic risks

Terraced territories commonly arise in steep terrains, which are delicate for their own nature because subjects to floods and landslides. The need of cultivable and well exposed areas determined the extensive anthropogenic terracing of the slopes. In these contexts, drystone walls have been a technology of choice because of their ability to drain water efficiently and, at the same time, to retain the soil to allow cultivation, withstanding the pressure of the fields located above and reducing the slope gradient.

Terraces can play a crucial role in hydrological and geological risk prevention and in the protection of the settlements located downstream of the terraces. Indeed, they increase water infiltrations and minimize the quantity and speed of surface runoffs, thereby leading to a reduction in soil erosion (Chen et al., 2012). Well maintained drystone walls and drainage channels can be crucial in contrasting hydrological and geological instability, especially during the intense rainfalls (Agnoletti et al., 2019).

Global warming and climate change affect the hydrological cycle and, most of all, rainfall regime, and are likely to increase the frequency, intensity and variability of extreme events. An increase of heavy rainfalls is expected also in areas where total annual precipitation is not prominently changed, as shown by many studies supported by the Intergovernmental Panel of Climate Change (IPCC). The

Mediterranean area is supposed to be one of the most reactive to climate change. The environmental functions of the terraces are amplified by climate change which, among other effects, involves a greater incidence of intense rainfalls.

Land use changes and farmland abandonment in the last century due to socio-economic changes have led to lack of maintenance of drystone walls and terraced slope degradation and coverage by overgrown vegetation (Tarolli et al., 2014). In particular, among the causes of decline there is the weak economic competitiveness of terraced landscapes, with a high intensity of manual labor, compared to those of lowland farming favoured by the mechanization. However, even after a long abandonment, terraced facilities, where not affected by generalized phenomena of collapse, can continue to perform the soil conservation and the control of water flows. These aspects are particularly important in specific geological contexts. In many cases, it would be possible to guarantee the continuity of these functions through limited maintenance.

2.2 Drystone walls and fire risks

Drystone walls can also be effective in preventing forest fires and in limiting the spread of wildfires, acting as firebreaks between forested areas. Indeed, well maintained drystone walls and terraces prevent the accumulation of dry matter and increase water infiltration in the soil, thus improving the water resources management against extreme temperatures or long periods of draught. This effect of drystone walls is especially evident in the area of the Park du Garraf, where different climatic, morphological and land use factors have created the conditions for forest fires and wildfires spread. Recovery of drystone walls and removal of heavy brush vegetation can help to reduce fire size and frequency.

2.3 Drystone walls for environmental protection and biodiversity enhancement

The environmental benefits of drystone walls restoration are both vast and broad. For example, rainwater conservation and increase of soil moisture and nutrients availability benefit plant growth, thus mitigating drought and increasing canopy coverage and surface cover, which in turn decreases raindrop energy and reduces splash, rill, and inter-rill erosion. By minimizing soil erosion, terracing can directly improve soil nutrient status as most nutrients are dissolved in water or attached to soil particles. The improved soil fertility and land productivity increase crop yield and ensure food security.

From an ecological point of view, terraced land habitats are characterized by significant plant and animal biodiversity and can also play a key role in terms of biodiversity enhancement. Re-constructing and improving habitats benefit ecosystem functioning and enhance biodiversity by improving the growing conditions for different species. In Japan, for example, the diversity of weed species in stone-walled terraces was recorded to be higher than that in sloping forests (Tokuoka and Hashigoe, 2015).

As shown in (Mariotti et al. 2002), in the area of Cinque Terre, the interaction between traditional farming and the natural environment maintained particularly high levels of natural biodiversity. Indeed, the Cinque Terre National Park includes in the area of intervention the Natura 2000 Site (IT1345005), recognised under the European Habitats Directive 92/43/EEC; the known flora of the CTNP consists of 866 species (Peccenini, 2005), confirming the biodiversity value of this relatively small area. Among the main protected natural habitats according to this Directive are the rocky cliffs that host many nesting raptors and endemic plant species and the hill tops that are covered by sparse woods of Maritime Pine (Pinus pinaster), Holm Oak (Quercus ilex) and European Chestnut Castanea sativa (Mariotti, 2008), but also the farmed areas contribute strongly to the biodiversity of the area, because there are numerous species which co-evolved with humans to adapt to an agricultural environment. In this context, the reconstruction of drystone walls and terraces are key since a partially farmed and partially wild environment is richer in biodiversity than a completely wild one (or a completely farmed one). This situation has been recognised by the European Union; as stated on the webpage https://ec.europa.eu/agriculture/envir/biodiv_en, “land abandonment and the withdrawal of traditional management may become a threat to biodiversity on farmland. Therefore, preventing these processes is a key action for halting the loss of biodiversity”. Furthermore, in the particular steep environment of the Cinque Terre, abandonment often does not lead to reforestation, because once the ability of the terraces to retain the soil is lost, massive landslides can lead to the exposition of the underlining rocks, as evident in the areas overlooking the sea which have been abandoned first. The loss of soil is accompanied by a strong loss of biodiversity. Preventing abandonment and the consequent landslides, with loss of soil actively and strongly supports the conservation aims of Natura 2000.

2.4 Cultural value of drystone walls

Terracing creates aesthetic landscapes and thus enriches eco-friendly recreational options and attracting countless tourists. Many terraces, among which the ones belonging to the Cinque Terre National Park, are even identified as “cultural landscapes that represent the combined work of nature and of man”, expressing harmony between humans and the environment and thus as World Heritage Sites (UNESCO, 2008).

2.5 Social, Institutional and Financial Best Practices

The social, financial and institutional aspects are a vital component of the project; while they are a relatively minor aspect of the present deliverable, their importance will grow substantially and continually as the project progresses, in particular as the focus will move from the preparation and implementation of the demonstration intervention to its replication and transfer. Therefore, these aspects will be analysed in depth and detailed in the dedicated actions (particularly **Action C3** Replicability and Transferability Strategy and Actions) and deliverables (particularly **C.3.1** Replication Preparation Studies and **C.3.2** Handbook on best practices on the use of drystone walls and terraces as a climate change adaptation tool). The short analysis below thus represents both a short summary of the information and experiences gathered so far and (more importantly) a statement of the approach that will be taken during the project to incorporate these vital elements in the replication strategy and activities. This will be done in the full knowledge that it will need to be further refined and enriched on the basis of the knowledge gathered through the demonstration action, the networking with other initiatives and projects (especially but not exclusively TERRACESCAPE), and the input provided by relevant stakeholders and institutions (particularly but not limited to the members of the Advisory Board).

The Social Dimension

As already stated above, the main recurrent issue when dealing with stonewalls as a landscape management and agricultural production tool is the **abandonment** of the terraces they hold. While the movement of the population from a rural to an urban setting is a usual feature of economic development, in the case of terraced territories it often translates into their complete abandonment with the consequent growth of vegetation and ultimate collapse of the walls. The main reasons for this different destiny from flatter terrains are:

- The rugged surface does not allow to replace labour with mechanisation, as it happens in the plains, which are therefore still farmed even after strong emigration.
- In many areas, property is very much fragmented as the traditional social structure consisted in widespread ownership of very small plots which are not economically viable.
- Not only agriculture, but also the building and maintenance of the stone walls themselves is labour-intensive and requires skills which are drained by the dwindling population.

It is clear that the successful use of stonewalls for climate change adaptation purposes is not realistic without a proper consideration of this aspect, as it has to happen on the territory, with the participation of the local population, and overcoming the obstacles posed by the fragmentation of property and emigration.

A thorough social analysis will thus be the first step for each replication case studies; only after identifying the local reasons behind the abandonment of the terraces and gathering knowledge about the local social context it will be possible to develop a strategy to encourage the use of drystone walls while detailing the role of the different target groups/stakeholder.

The Institutional Dimension

This aspect is deeply intertwined with the social one, but it is considered here from a less descriptive and more active point of view; it is about analysing which institutional settings and governance choices are most appropriate to ensure the sustainable and long-term use of the terraces. While there will clearly be no one-size-fits-all solution, given the differences to be found across the numerous terraces' areas around the world, the analysis of different approaches and their presentation in a succinct and user-friendly manner would allow to draw inspiration from and tap into different experiences, in order to subsequently design a solution tailored on local conditions. Among the approaches identified, the following ones are going to be featured prominently:

- The **STONEWALLSFORLIFE approach**, already tested at small scale by Fondazione Manarola and to be demonstrated at larger scale during the project. It consists of using a local association to overcome the issue of property fragmentation, by identifying owner, contacting them, renting from them the plots, and leasing them out to farmers for the long-term in bundles (so that the overall surface is big enough to be economically viable). This approach can be very successful but depends on the existence (or creation) of a strong association with deep ties with the local population to succeed.
- The **Land Stewardship** model being tested by TERRACESCAPE, in turn based on a number of experiences from different countries; it "involves voluntary cooperation of small landowners, farmers, local management bodies, research institutions, and local businesses to implement environmental-friendly cultivation practices and protect the agricultural landscape with contemporary, socially and economically sustainable practices". It is thus a socially broader approach, based on the effective collaboration of different actors; it is on the one hand effective once established, on the other it requires an even greater degree of collaboration which is not necessarily easy to obtain in territories where few farmers are left and/or are small plots holders unaccustomed to collective action.
- A more **market-oriented approach**: it is proven that regions that can boast high-value agricultural produce (wine regions such as the Langhe in neighbouring Piedmont area prime example) have been successful in preserving the terraces and their flood prevention function. Namely, the high

price of their produce compensates the high operating and investment costs linked with farming on terraces. However, often even these areas are abandoned, as the small size of the plots can make then nevertheless unprofitable. In such cases, solutions can consist in actions oriented to reinforce further the economics of farming: seeking the recognition (DOC, etc.) and labels which support higher prices; pulling together of resources to jointly own/use machineries, transformation facilities, marketing actions, distribution networks; joint application to funding institutions and schemes. Substantial coordination work is needed, and this can be achieved through establishing a dedicated institution or using existing ones (including local authorities).

Additional models will be identified and analysed during the project.

The Financial Dimension

As recovering and managing drystone walls is a costly endeavour, the financial dimension is a condition sine qua non for a successful intervention; even after proving the economic sustainability of the STONEWALLS approach through the demonstration, it will still be needed to raise substantial resources to kick-start the process elsewhere or expand it within the Cinque Terre National Park.

Therefore, both the replication studies and the Handbook will contain an analysis of all relevant financing opportunities, more specific to the selected areas in one case and more general in the other. The ones identified until now are:

- **Public agricultural funds** (often EU ones, normally disbursed through regional administrations). Their funds cover not only agricultural activities (funds are granted based on surface owned) but also, importantly, rural entrepreneurship and infrastructure. This makes them well adapted to the typical situation of terraced areas, where activities which are not directly agricultural (tourism, hospitality, production and commercialisation of typical products) but linked with the territory are an important source of revenue and employment. The main obstacle to be overcome is the complex nature of the application process and the time-consuming management of the funds once granted; this makes them difficult to access for small holders. Support via a local association, a public administration or a sector association could be instrumental in making them accessible.
- **Other kinds of public funds;** in addition to agricultural funds, also funds devoted to the preservation of landscape, heritage and environment (with the exclusion of LIFE, which has already been used for demonstration) will be considered; this includes local, regional, state and EU ones.
- **Private funds**, including both debt and risk capital; once proven the viability of the approach in the demonstration site, it is expected and

hoped that private lenders (local banks in particular) and companies (local agricultural entrepreneurs) would be more interested in investing in the restoration and use of terraces. This could be the case in particular for the areas which have good economics thanks to easy access (proximity to roads, etc.), continuity with already farmed plots, or better state of conservation. During the project, local entrepreneurs and banks will be interviewed to identify what makes investing easier/more attractive for them.

- **Sponsorship**: given the highest cultural value of the terraced landscapes (recognised by UNESCO as world heritage), and the extremely high visibility of some of them (5 million annual visitors in the Cinque Terre), it is possible to find the interest of donors. This approach has been tested at small scale by Fondazione Manarola with some success; a broader approach will be tested, developing a fund-raising strategy aimed at specific stakeholder categories such as visitors (the app will allow them to contribute to the recovery of terraces), large corporations (which could "adopt" a scenic landscape through donations), and local enterprises (including banks, which in Italy often devolve their profits to the non-profit foundations which own them).

3 Scientific and technical assessment on the area of intervention

This chapter deals with the detailed analysis of the pilot site (the so-called "Anfiteatro dei Giganti" in Manarola) in terms of geological, geomorphological features and man-made structures, and the technical solutions to improve the resistance and resilience of dry-stone walls under the climate-change adaptation perspective.

Firstly, a wide description of utilized data and applied methods to fulfil the action A.1 requirements is provided.

Secondly, the geological features, the landforms and the ongoing geomorphic processes shaping the landscape and the existing man-made structures that characterize the STONEWALLSFORLIFE Project pilot area are illustrated.

Finally, a number of technical solutions related to the dry-stone walls' construction techniques are discussed and a report on works in progress and next steps is provided.

3.1 Materials and methods

The investigation of geological, geomorphological and man-made structures features was performed through bibliographic research, GIS analysis and field surveys.

The results obtained through the field investigations were subsequently elaborated in a GIS environment and mainly 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 enclosed plots of land were excluded.

A thorough collection and review of existing bibliographic information was performed taking into account unpublished data, documents, reports and scientific papers concerning both the geological and geomorphological features of the STONEWALLSFORLIFE Project pilot site and the man-made structures located within it.

The most relevant information sources were:

- the geological, geomorphological and landslide-inventory maps of the Cinque Terre National Park dated back to 2019 and realized by the University of Genova together with the University of Napoli at 1:20'000 scale;

- the guidelines concerning the dry-stone walls construction and maintenance techniques realized in the frame of the LIFE 00 ENV/IT/000191 PROSIT - Planning and restoring of Cinque Terre coastal traditional agricultural landscape.

A wide set of geospatial data was collected from the Liguria Region geoportal (https://geoportal.regione.liguria.it/) and other archives (Cinque Terre National Park, University of Genova, etc.), including administrative borders, cadastral data, orthophotographs dated back to 2019 and 2016, historical maps, the Liguria Region topographical map at 1:5’000 scale, and two digital terrain models (DEMs) at 5 m and 1 m cell-size, respectively.

The 2019 orthophotos characterized by 0.05 m pixel and the high-resolution 1 m and 20 cm cell-size LiDAR DEM commissioned by the Cinque Terre National Park represent the most accurate topographic data and were used as a base for most of GIS analysis. These data were realized in the frame of the European Project Interreg Marittimo-IT FR-Maritime MAREGOT - MAnagement des Risques de l'Erosion cotière et actions de GOuvernance Transfrontalière, of which the Cinque Terre National Park is partner. The latter was used to perform a detailed morphometric analysis of the ground surface of the STONEWALLSFORLIFE Project pilot area, thus to highlight the geometrical and morphological features of the investigated slopes. The former was used as a base to create a Land Use and Land Cover (LULC) map of the aforementioned site. Three LULC classes were distinguished: Semi-natural areas, Agricultural areas, Discontinuous urban fabric, according to most of available LULC legends. The first class corresponds to agricultural areas abandoned over the last decades or at least 5 years, the second to currently cultivated plots of land and the third to small buildings located on the slope. This classification was adopted in order to satisfy the needs of the STONEWALLSFORLIFE Project, that is in order to identify the abandoned areas to be subjected to the project actions. The LULC polygons were manually digitized in a GIS environment at 1:250 scale. Field surveys allowed for the validation of remotely-sensed data.

The geological survey was conducted at the scale of 1:2’500. This is a very detail scale that allowed for the investigation of outcrops and structures presenting a linear extension greater than 2.5 m. The main outcrops of the bedrock were identified and mapped (Figure 2Figure 2) 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 was set up 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, and thus for the characterization of past and current geomorphological processes that shaped and are shaping the landscape, respectively.

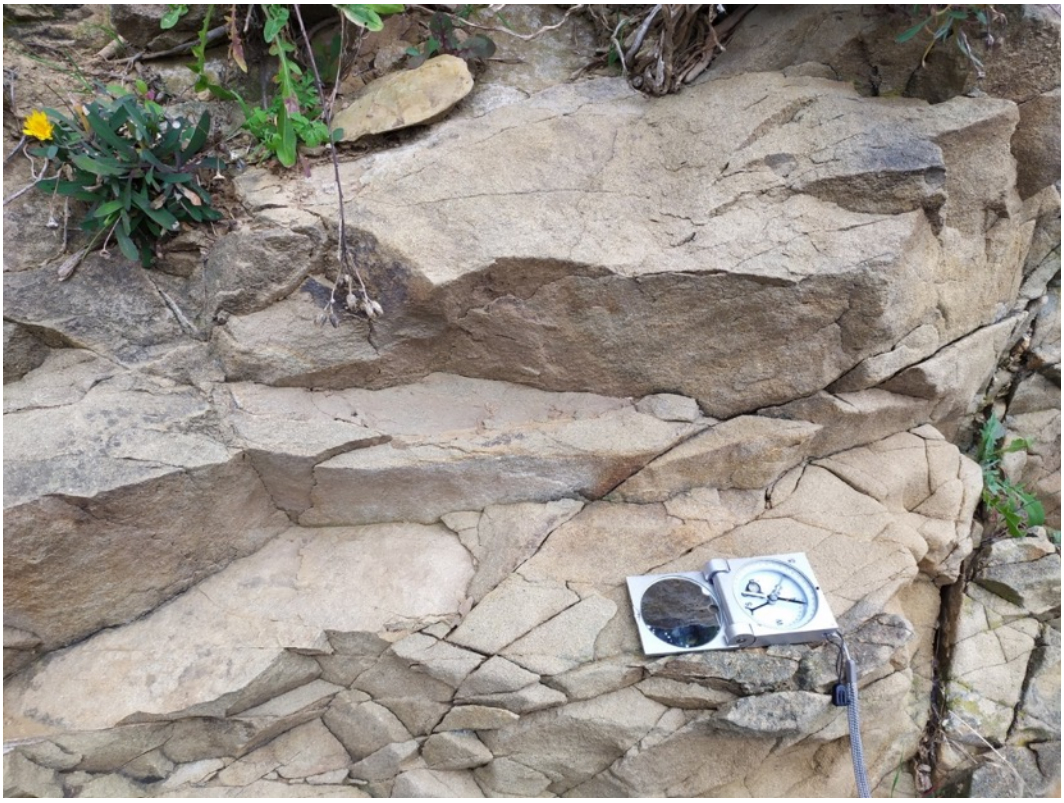

Figure 1 Geological survey of bedrock outcrop

Figure 2 Geological field survey

The peculiarity of the pilot area required the development of a site-specific legend to classify the identified landforms. This legend is mostly composed of man-made structures, that are anthropogenic landforms shaping the relief. The main anthropogenic landform/man-made structure within the pilot area is the dry-stone wall. In order to investigate their location and extension, dry-stone walls were manually digitized at 1:250 scale as linear elements. They were classified as frontal and lateral wall according to their position with respect to the slope, and as maintained or abandoned with respect to the LULC map. The total length of walls represents an indirect estimate due to the difficulty of mapping inside vegetation-covered plots of land that could have caused some misinterpretations during the digitizing phase (Figure 3).

Figure 3 Field survey in an area covered by spontaneous vegetation.

The quick assessment survey in terms of walls features, carried out together with a detailed geological, geomorphological and man-made structures survey, provided an overview about the structural and compositional peculiarities and in terms of dry-stone walls maintenance and critical issues regarding the pilot area (Figure 4). These data, along with bibliographical information, were collected for the development of a dry-stone walls' field survey sheet model: this product was created with the specific aim of facilitating the interpretation and classification of the walls' main features. It was tested and validated on field, and it may be subject to further changes and additions in order to record additional characteristics of the walls that weren't taken into account yet.

Figure 4 Field survey of dry-stone walls

Lastly, some technical solutions for the use of dry-stone walls as climate change adaptation tools were identified on the base of available documents, reports and information. About this subject, the limited literature background has been assessed and the definition of possible solutions to be implemented over the pilot site for the evaluation of their climate-change adaptation capabilities is still ongoing.

3.2 Study area

The STONEWALLSFORLIFE Project pilot area is located within the Cinque Terre National Park and specifically over the hamlet of Manarola, inside the Riomaggiore municipality (eastern Liguria Region, north-western Italy).

The Cinque Terre area is considered worldwide one of the most representative human-modified landscapes, presenting one of the most peculiar and dramatic examples of terraced coastal landscape within the Mediterranean region (Brandolini, 2017).

Based on the environmental, scenic and historical significance, such terraced coastal landscape has been recognized since 1997 as a World Heritage Site by UNESCO and since 1999 it has been declared National Park.

The Park boundaries are included in the 1: 50,000 scale cartographic Sheets "247 Levanto" and "248 La Spezia" and it falls within the 1: 25,000 scale Sections "248.3 Fabiano", "248.4 La Spezia" and "247.1 Levanto".

The STONEWALLSFORLIFE Project pilot area spreads over 125023 m^2 (12.5 ha), mainly at the outlet of the small V-shaped valley of the Groppo Creek, where the little urban settlement of Manarola is located. It is composed of two sectors, hereafter called northern sector (93077 m^2) and southern sector (31946 m^2), located on the hydrographic right and left slopes of the Groppo Creek catchment, respectively (Figure 5). The pilot area borders follow physiographic borders except for a brief portion of its perimeter at the seaside that follows cadastral limits for management purposes. The downstream limit of both sectors is the Manarola urbanized area.

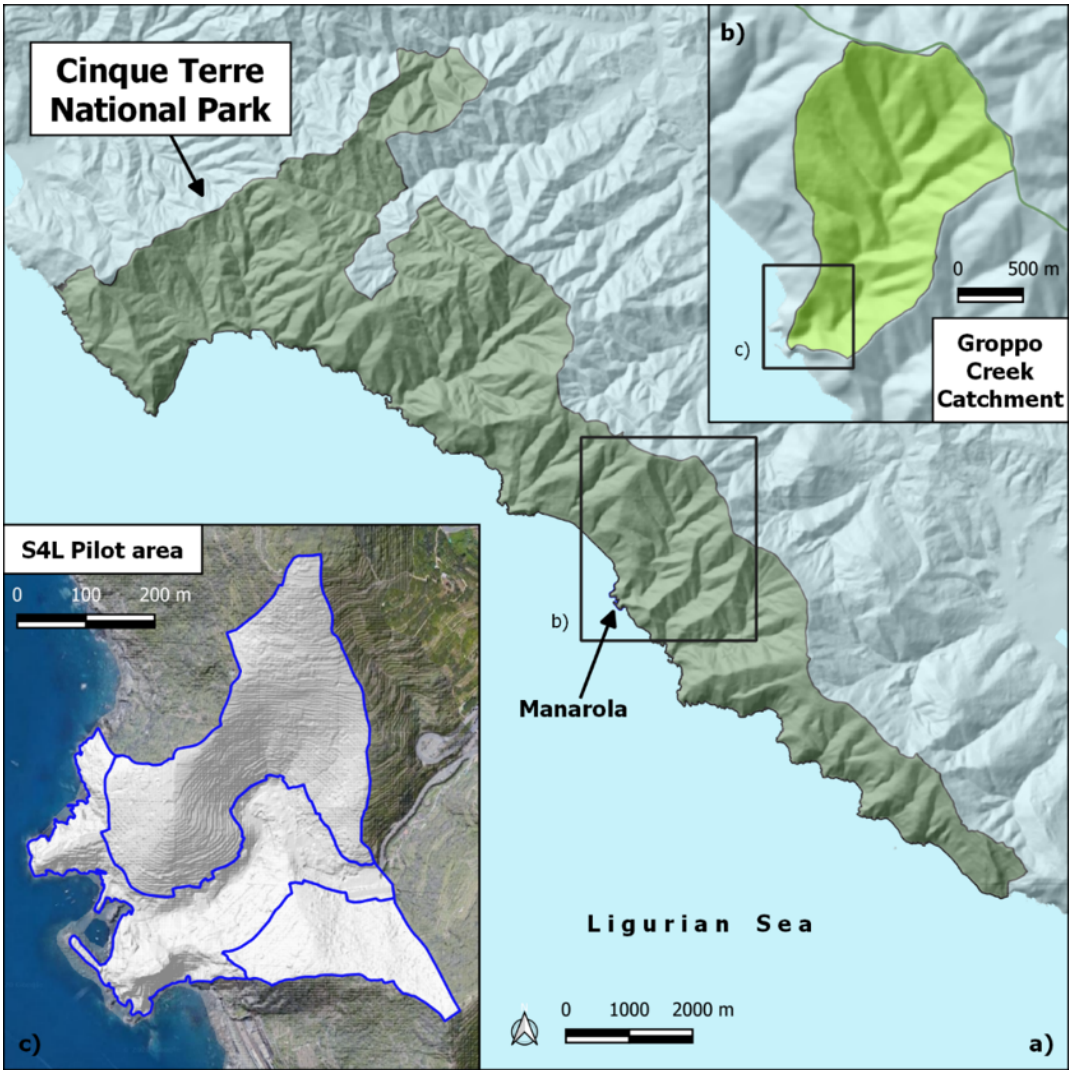

Figure 5 Geographical setting of the Groppo Creek catchment and location of the STONEWALLSFORLIFE Project pilot site.

The investigated area presents a maximum elevation value of 266 and 250 m a.s.l. on the northern and southern sectors, respectively. Both the slopes are very steep and completely terraced. However, large areas are currently abandoned, mainly within the southern sector (Figure 6). Table 1 illustrates LULC classes area referring to the whole pilot area and to the two sectors.

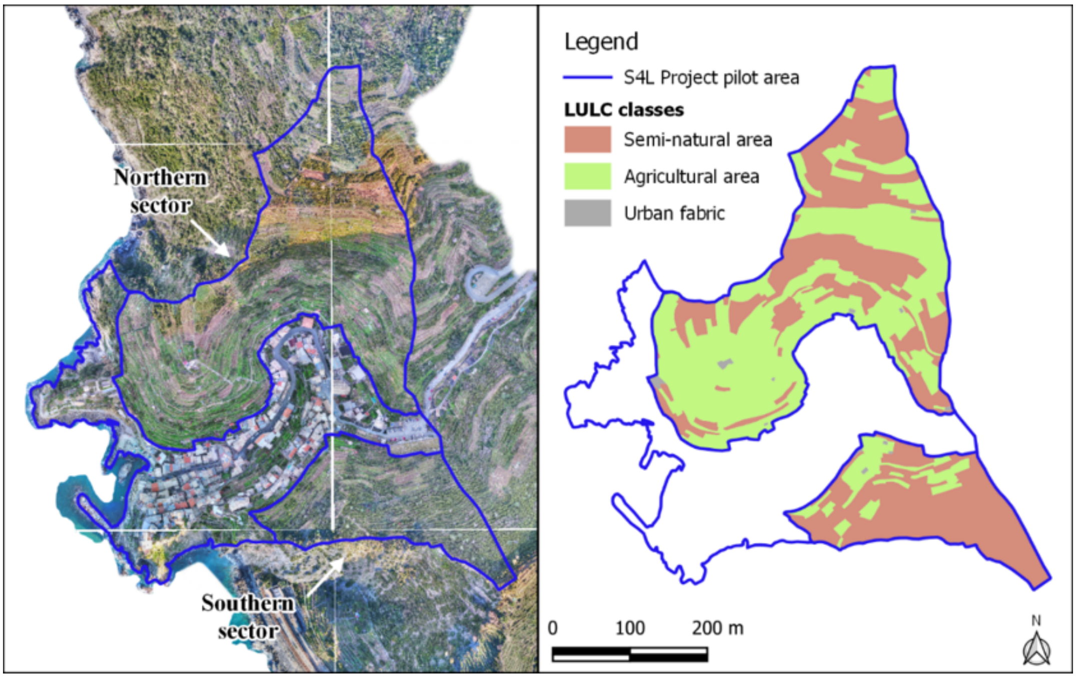

Figure 6 Land Use and Land Cover map of the STONEWALLSFORLIFE Project pilot site.

Table 1 LULC classes distribution over the STONEWALLSFORLIFE Project pilot area.

	Semi-natural area (%)	Agriculture area (%)	Urban fabric (%)	Total area (ha)
Southern sector	80.7	18.8	0.5	3.2
Northern sector	39.6	59.8	0.6	9.3
Total	50.1	49.3	0.6	12.5

3.3 Geological setting

The territory of the pilot site chosen for the demonstration intervention, close to the hamlet of Manarola, is fully comprised within the 1:50’000 scale geological map “248 La Spezia”, realized in 2005 by Liguria Region under the “CARG Project” (Geological CARtography) and published by I.S.P.R.A. (formerly A.P.A.T.). Updated geological and cartographic data have been obtained from the recent “Geological map of the Cinque Terre National Park” shortly described in the previous section, realized in 2019 by University of Genova and University of Napoli at 1:20’000 scale. This map is based upon the CARG cartography of the sheet "248 La Spezia" (APAP, 2005), integrated with geospatial data coming from the "Georisorse lapidee" vector level (i.e. “Stone geo-resources”), created by the Liguria Region in 2018 and available on the regional geoportal (https://geoportal.regione.liguria.it/). Both the data have been made homogeneous through field checks and subsequent validation. Finally, further geological information has been derived from the available scientific bibliography (Abbate, 1969; Abbate et al., 1970; APAT, 2005; Giammarino & Giglia, 1990; Raso et al., 2019).

Geologically, the territory of the Cinque Terre National Park belongs to a NW–SE oriented segment of the Northern Apennine, an orogenic chain formed during Tertiary (Abbate et al., 1970). This sector of belt is made up of a nappe sequence that includes six overlapping tectonic units (top to bottom): Gottero Unit, Bracco-Val Graveglia Unit, Ottone Unit, Canetolo Unit, Marra Unit and Tuscan Nappe (Figure 7). In the past some authors grouped the Gottero Unit and the Bracco-Val Graveglia Unit into one single unit, equally named Gottero Unit; sometimes in old publications ti could be found as the “Vara Supergroup”.

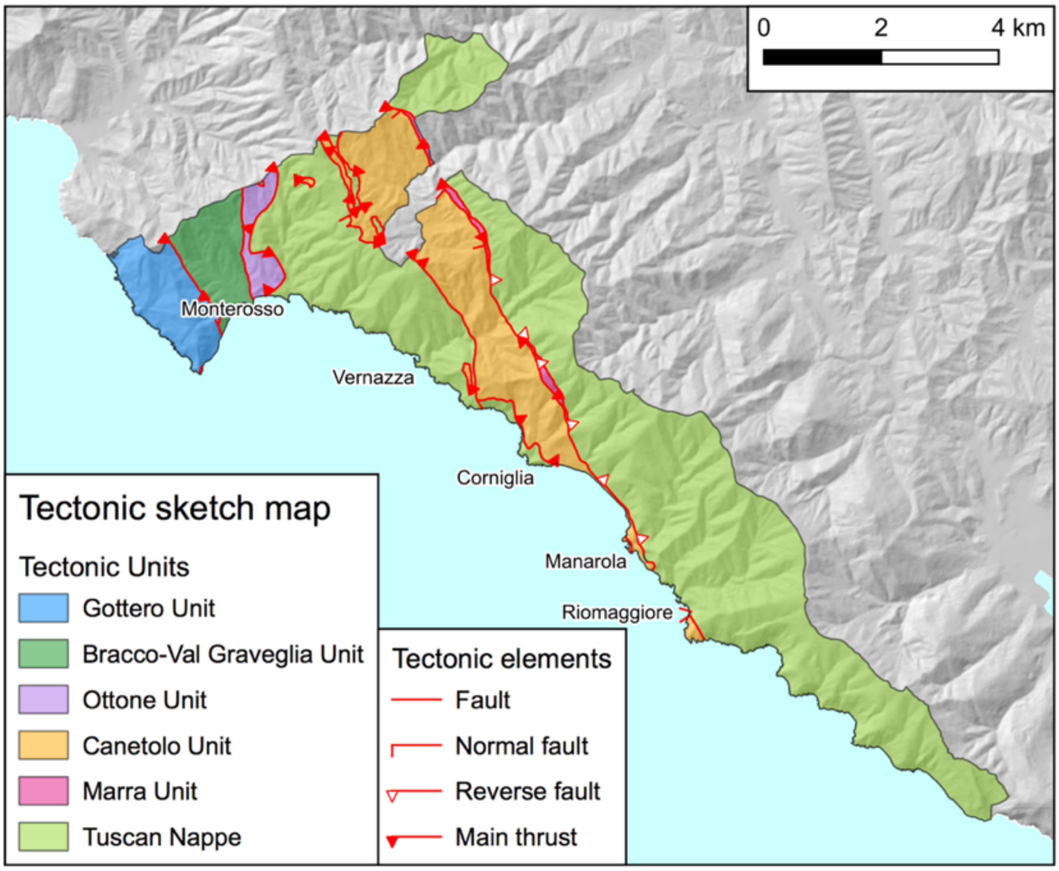

Figure 7 Tectonic sketch map of the Cinque Terre National Park, showing the six Tectonic Units outcropping in the territory of the Park.

The Gottero Unit and the Bracco-Val Graveglia Unit crop out in the westernmost sector of the study area, along the NE–SW trending headland of Punta Mesco, and mainly consist of ophiolite rocks (Bracco-Val Graveglia Unit, classically interpreted as the remnants of the Jurassic oceanic crust), followed by a turbidite sequence (Gottero Unit, Late Cretaceous). The Ottone, Canetolo and Marra units are localized in the western side of the Monterosso village and in the central sector of the national park. The first one is prevalently composed by pelitic rocks (Monte Veri Complex Fm.). The other ones occupy a narrow NW–SE oriented stretch of land encompassing the coastal villages of Manarola and Corniglia and it includes claystones with limestones and silty sandstones turbiditic rocks. The Tuscan Nappe occupies most of the Cinque Terre National Park as it outcrops on the eastern, central and western sectors. This unit is almost entirely represented by thick sandstone-claystone turbidites (Macigno Fm.), largely cropping out along the coast, and secondly by limestones, only cropping out in the easternmost part of the national park.

All these tectonic units belong to different paleo-geographic domains (and different sedimentary environment, with regard to sedimentary units) of the ancient Ligurian-Piedmontese Ocean, normally named from the internal (oceanic) to the external (continental) areas:

- Internal Ligurian Domain (Gottero and Bracco-Val Graveglia Units);
- External Ligurian Domain (Ottone Unit);
- Sub-ligurian Domain (Canetolo and Marra Units);
- Tuscan Domain (Tuscan Nappe Unit).

The main structural setting of the study area is predominated by a wide overturned SW-verging antiform fold (Giammarino & Giglia, 1990) and by multiple sets of Plio-Quaternary tectonic discontinuities that in turn strongly influence the local morphology such as coastline, hydrographic network, main and secondary watersheds (Cevasco, 2007).

Relatively to the STONEWALLSFORLIFE Project pilot area, a peculiar geological setting can be observed: the Tuscan Nappe Unit is here represented by a turbiditic sandstone-siltstone flysch, with coarse and medium-grained sandstone beds and thin interbedded siltstones, and by a turbiditic fine-sandstone flysch, with siltstone (“Macigno Formation, MAC” strictu sensu and “Zoned sandstones Lithofacies, MACa”) while the Canetolo Unit is represented by a fine-graindded sandstone turbidites (“Ponte Bratica sandstones Formation, ARB”) and by claystones with limestones and silty sandstone turbidites (“Canetolo shales and limestones Formation, ACC”). From a structural geology perspective, the area is characterized by the tectonic contact between the Canetolo shales and limestones Formation and the Macigno Formation, that is interpreted, in bibliography, like a high-angle reverse fault resulting in a tectonic overlap between the Tuscan Nappe Unit and the Canetolo Unit. Even the contact between Canetolo shales and limestones

Formation and Ponte Bratica sandstones Formation is interpreted, by the majority of the authors, as a tectonic contact reworked through a high-angle fault.

The geological analysis has started through the collection of existing geological data: the aforementioned geological map at 1:20,000 scale realized in 2019 by University of Genova and University of Napoli and the bibliographical studies. Secondly, a detailed geological survey, conducted at a 1:2’500 scale, made it possible to locate precisely the outcrops of the bedrock: this has led to a more detailed geological map if compared to the geological maps of the area available until now. Infact, some of the existing contacts (e.g. the ones between Ponte Bratica sandstones and Canetolo shales, Canetolo shales and Macigno Formation and between Macigno Formation litofacies) have been modified. Figure 8 shows the updated geological map of the pilot area.

As shortly mentioned in Section 3.1. (Materials and methods), during the geological survey the principal structural discontinuity planes of the bedrock outcrops have been measured: bedding (stratification planes) and fracture sets. Figures 9 shows the stereographic projections of the stratification planes (S0) and of the fracture sets (Sr) measured on the field; they are represented by poles, in the lower hemisphere of the Schmidt equal-area grid. Stratification planes are represented in a general plot (S0, the top-left panel) and in 5 single plots that show the rock attitude for each formation: Ponte Bratica sandstones (ARB), Canetolo shales and limestones (ACC) and Macigno Formation (both MAC formation and MACa lithofacies); ACC and MAC/MACa plots are also subdivided into northern and southern sector. The fractures sets are in accordance with the ones identified and analyzed in past bibliographical studies (Cevasco, 2007): the main brittle discontinuities are characterized by steep planes oriented in the directions ENE-WSW and E-W (Figure 10).

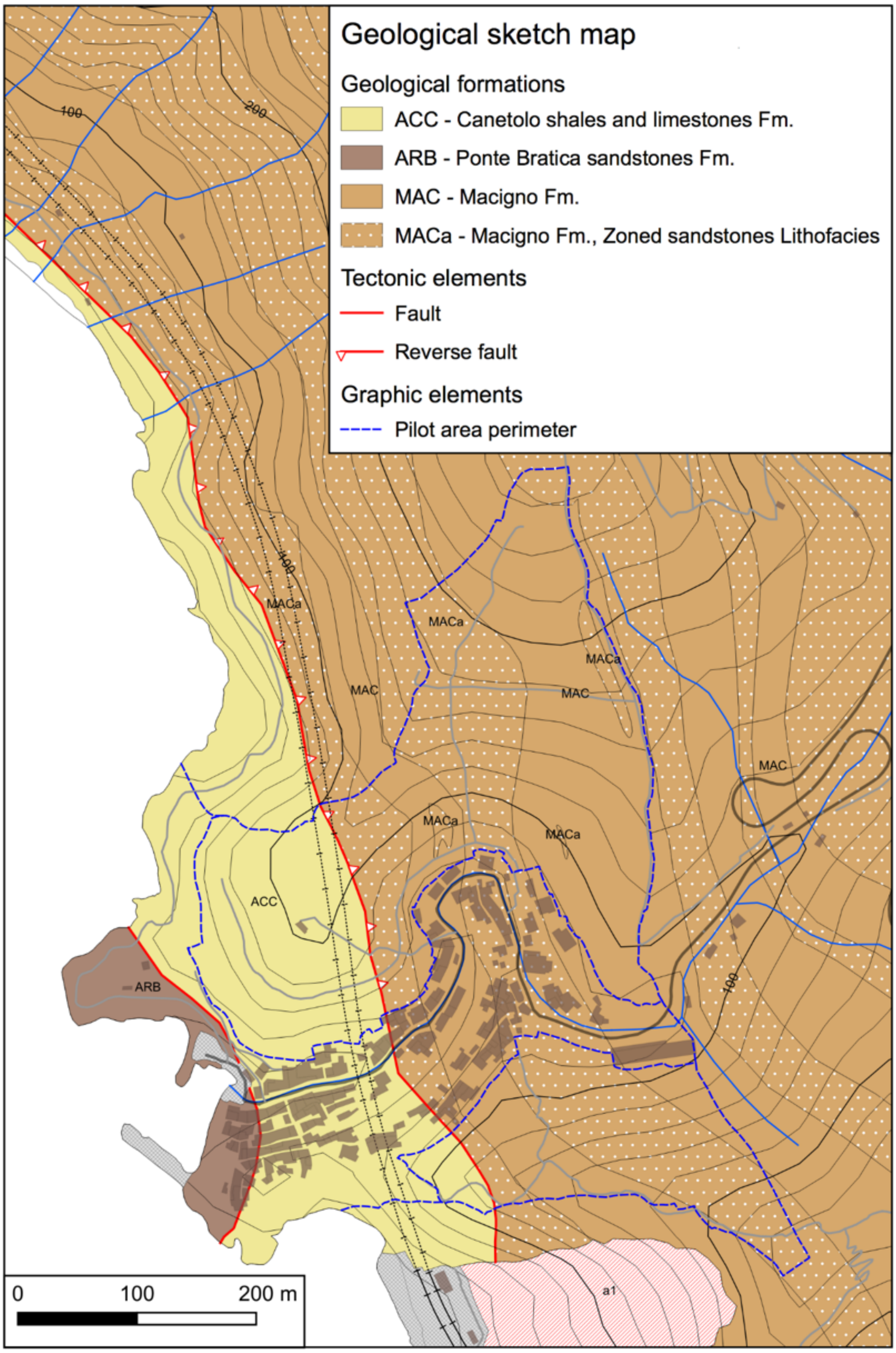

Figure 8 Simplified geological map of the pilot area (without bedding planes and fractures), showing the geological formations constituting the bedrock and their limits.

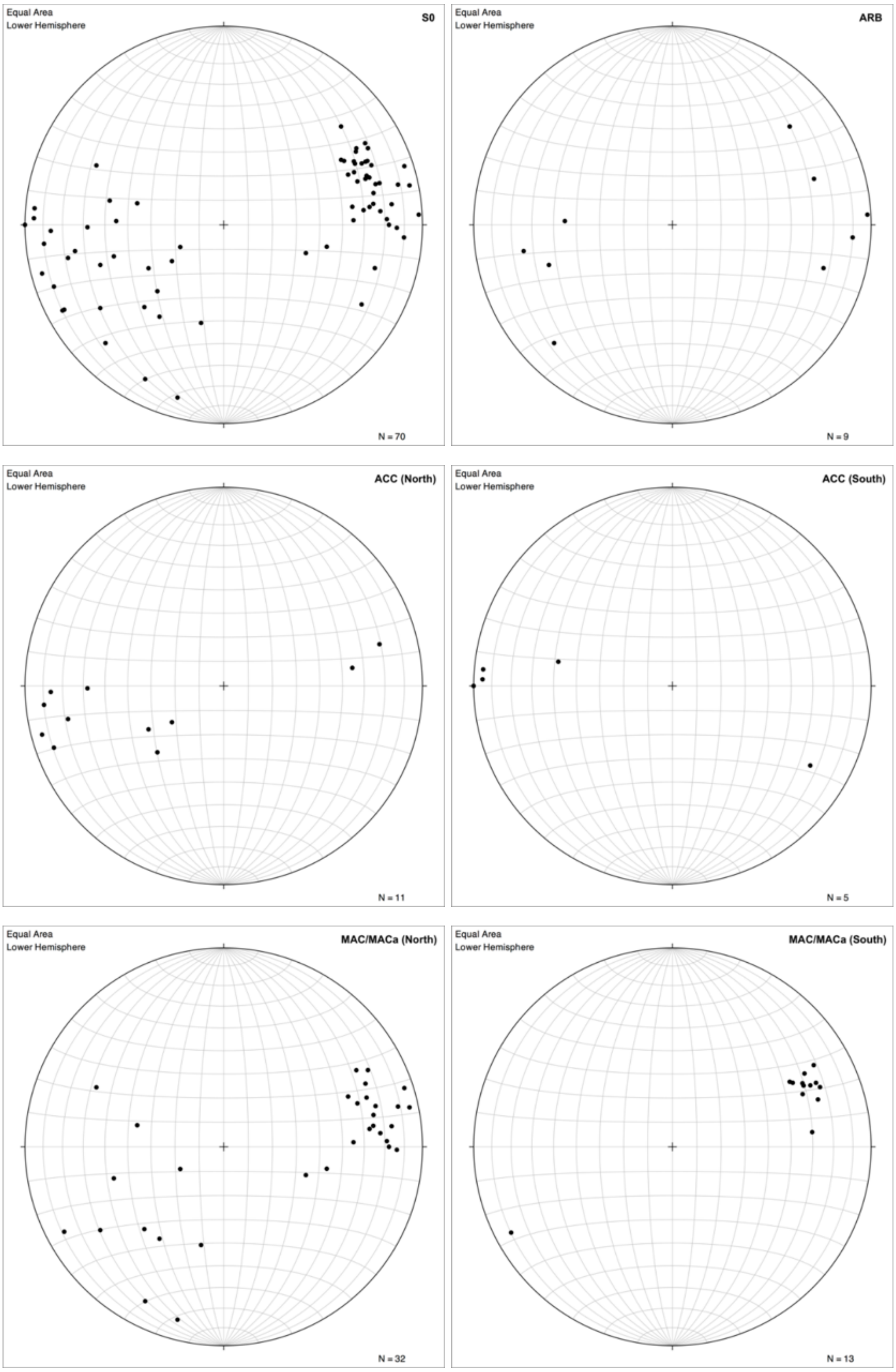

Figure 9 Stereographic projections of bedding planes (Schmidt Net, lower hemisphere) for the all 70 planes measured during the field survey and for each formation (ACC and MAC/MACa plots are also subdivided into northern and southern sector).

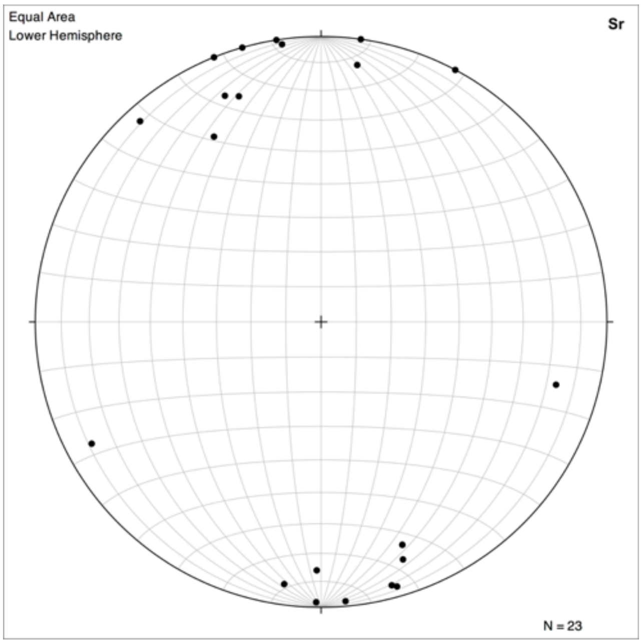

Figure 10 Stereographic projection of fracture planes (Schmidt Net, lower hemisphere) for the all 23 fractures measured during the field survey

3.4 Geomorphological setting and anthropic structures

The pilot site is located in a geomorphological setting that is characterized by high and steep slopes, small catchments with high relief energy, and short and steep fluvial stems that are very close to the rocky-coast seaside. Here, most of slopes were historically terraced through the construction of dry-stone walls for agricultural purposes. However, a significant percentage of traditional agricultural terraces is currently abandoned due to accelerated socioeconomic transformations occurred during the last century. The abandonment of mountain areas resulted in the lack of dry-stone walls and drain channels maintenance (Pepe et al., 2019).

The aforementioned morphological features, along with the geological setting of the region and the occurred land-use and land-cover changes, make the narrow belt of land that constitutes the Cinque Terre National Park an area severely affected by geo-hydrological hazards. In detail, this area is very prone to the occurrence of slope instability processes such as on the one hand rock falls, rock topples, and block slides (Cevasco et al., 2007), and, on the other hand, shallow landslides, debris avalanches and debris flow (Pepe et al., 2019; Raso et al., 2019). Furthermore, the physiographical features of catchments make them very prone to flash floods in case of extreme rainfall events (Brandolini et al., 2018).

The reference area of the STONEWALLSFORLIFE Project is located in the lower part of the Groppo Creek catchment and includes the whole overhanging slopes on the Manarola urban settlement and the west-facing slope close to the seaside upstream the Manarola Cemetery, north of the Groppo Creek mouth. The Groppo Creek catchment spreads over 2.65 km^2 in close proximity to the seaside. It presents a maximum elevation of 783 m (Mt. Capri), very steep slopes and the main fluvial stem about 2 km long (Figure 5).

The two sectors of the STONEWALLSFORLIFE Project pilot area are delimited by water divides towards adjacent catchments and secondary valley belonging to the Groppo Creek catchment itself. At the seaside, the northern and southern sectors are partially and totally delimited by a degradation escarpment edge, respectively. The respective sea-facing slopes are severely affected by rock falls and block slides. The top of the northern sector approximately corresponds to the edge of a sub-flat area that most probably is the remaining of a marine terrace.

The valley floor located between the two investigated sectors is completely urbanized. The Groppo Creek is culverted and presents a high-slope and rocky channel. Moreover, an artificially-elevated ground at the valley floor corresponds to the railway artificial gallery. Along the seaside, the rocky coast presents localized deposits constituted of sediments deriving from cliff erosion and slope instability processes. There are also two shoreline protection structures, that are a transverse groyne at the Manarola touristic port and a longitudinal groyne south of the study area at the railway station.

Focusing on the two sectors accurately investigated, their shape is currently depending on slope instability processes, run off, fluvial processes, weathering processes and anthropic activities. These last played a crucial role in conditioning the morphological evolution of the area, changing the natural environment into an anthropogenic landscape constituted of terraced slopes and entirely corresponding to an agricultural landscaped ground (Rosenbaum et al., 2003).

The study area is dominated by anthropogenic landforms. In particular, man-made terraces hold up by dry-stone walls and generally presenting a width value ranging between 3 and 6 m, totally cover the site for a total length of about 28 km. They changed the slope geometry and, as a result, the minor hydrographic network that drains the slope. The mapped anthropogenic landforms are dry-stone walls, underground cisterns, drain channels and walkways (Figure 11). Some of them correspond to very small features of the order of tens of centimetres to few metres.

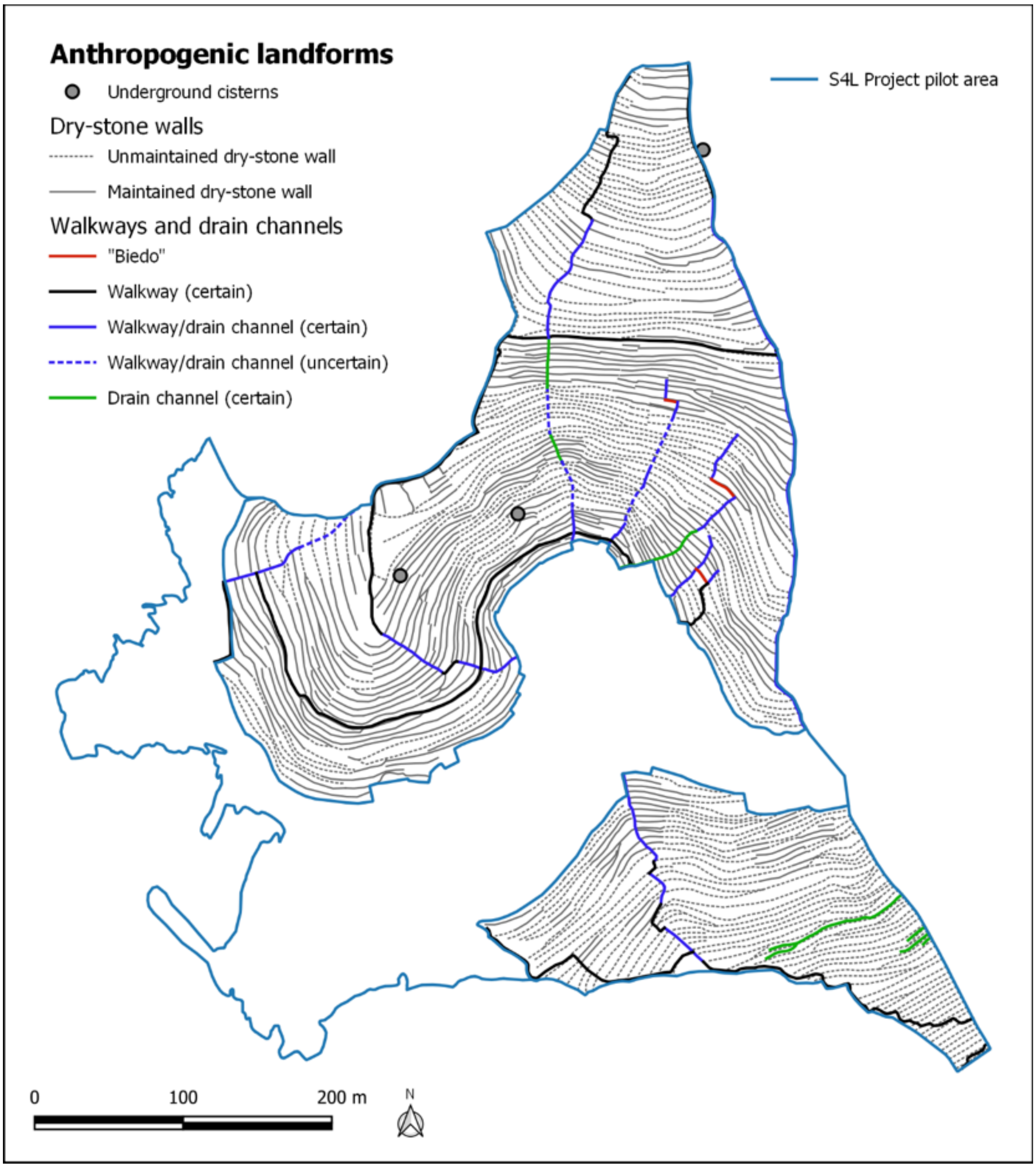

Figure 11 Map showing the anthropogenic landforms of the STONEWALLSFORLIFE Project pilot site.

Slopes are covered by eluvial-colluvial deposits overlying the bedrock that were anthropically reworked in order to build the terraces. Their thickness is generally comprised between 1 and 3 meters but somewhere the wall height implies a higher value, never exceeding 5 m of thickness. The bedrock locally crops out at the base of dry-stone walls and the largest outcroppings are located in the western and eastern parts of the southern and northern sectors, respectively. The slope-imposed profile makes the eluvial-colluvial deposits prone to be remobilized by rainfall-induced mass-movement processes and run-off erosion processes.

Within the pilot area, the slope instability processes are associated with the partial or total collapse of retaining walls (Figure 12). The documented cases highlight that generally after the initial triggering process the instability-process evolution lead to further wall collapses aligned along the maximum gradient downstream the first one.

Figure 12 Partial collapse (upper portion of the dry-stone wall)

As concerns fluvial landforms and processes, the drainage network of the pilot area is completely man-made, and no natural channels are identifiable. The sub-flat terraced surfaces present a noticeable decrease in elevation toward their frontal and lateral edges (Figure 13). This gradient was shaped aiming at promoting run off. Terraces that are sparsely-covered by vegetation and cultivated areas without grass are affected by splash and sheet erosion processes. In few cases, erosional landforms similar to rills and gullies affect the terrace surface located upstream a collapsed wall.

A small man-made channel, about 10-20 cm width, is rarely present at the wall toe to convey laterally and then downstream water drained by the wall itself. The main hydrographic network is composed of small man-made channels shaped both in parallel with and perpendicular to walls on the slope. They partially correspond to the walkways, although most of them are located in correspondence of water divides; in this last case their width is about 1-2 m, otherwise it is generally lower than 0.5-1 m. These channels are overall delimited by dry-stone walls and the bottom often presents outcropping bedrock. In contrast, the structures parallel to walls mapped in the southern sector are made of half of a corrugated steel pipe and most probably represent recent slope management works.

Figure 13 Terrace characterized by a certain slope toward downstream.

The drain channels headwater either blends along the upper part of walkways or correspond to an abrupt interruption of the channel at a dry-stone wall. Channels are mainly located in the central-eastern part of the northern sector. Drain channels that do not correspond to walkways are often blocked or damaged. As a result, the occurrence of slope instability processes can be promoted by unchanneled run off.

The identified drain channels parallel to walls located within the northern sector, so-called “biedi” (singular form: “biedo”) are rather interesting and represent a critical issue in terms of slope management. These small low-gradient channels connect two drain channel perpendicular to walls that are not located along the same axis. Three “biedi” were mapped: one has been clearly without maintenance for long time, one is blocked by a small landslide and one appears to be empty and running (Figures 14-15). The main issue in terms of geo-hydrological processes is associated with the upstream channel elbow because flowing water from upstream tends to follow the maximum slope gradient and thus to create a diversion that follows the upstream drain channel axis, triggering slope instability processes.

Figure 14 A maintained drain channel

Figure 15 An un-maintained drain channel

Finally, weathering processes play a relevant role in shaping the landscape referring in particular to dry-stone walls. In fact, they act on stones constituting them, that are mainly arenaceous and secondarily clayey and calcareous rocks, causing the deterioration of lithic elements and, thus, originating wall stability problems.

3.5 Dry-stone walls

The STONEWALLSFORLIFE Project pilot site is represented by two entirely-terraced slopes. Terraces are hold on by dry-stone walls whose comprehensive length is 28 km. This value represents an estimation, due to the difficulty in mapping walls covered by vegetation in abandoned areas. The identified lateral walls, that are those retaining the terrace laterally, represent the 1.7% of the aforementioned length. Table 2 illustrates in detail the walls length referred to the different sectors of the pilot site and to the preservation condition. Figure 11 highlights the spatial distribution of abandoned and maintained dry-stone walls.

Table 2 Dry-stone walls (dsw) length and maintenance condition referred to the whole STONEWALLSFORLIFE Project pilot area and to its northern and southern sectors. The maintenance condition values are referred to the frontal dsw.

	Frontal dsw (m)	Lateral dsw (m)	Maintained dsw (%)	Unmaintained dsw (%)
Southern sector	7295	85	13.2	86.8
Northern sector	20362	396	52.9	47.1
Total	27657	481	42.4	57.6

As concern the construction technique, the largest number of walls is composed exclusively of overlaying stones of arenaceous, clayey and calcareous nature, without binding materials (Figures 16-17). Field surveys allowed for the identification of few localized walls that were partly realized by using bricks, allochthonous stones and concrete elements, sometimes along with binding materials.

Dry-stone walls can be distinguished between historical and newly-rebuilt structures according to the origin of stones. They correspond to walls made from autochthonous stones and from almost-totally allochthonous ones (that is lithic material imported from outer quarrying sites in the last years), respectively (Figure 18). Most of newly-built walls are located in the eastern part of the northern sector of the pilot area.

Figure 16 Dry-stone wall composed of overlaying lithic elements, without binding materials.

Figure 17 Dry-stone wall composed of clayey and calcareous lithic elements, without binding materials.

Figure 18 Dry-stone wall reconstructed with autochthonous and allochthonous materials.

Generally, the dry-stone walls located within the pilot site are getting between 1,5 and 2,5 meters high, but locally values lower than 1 m or higher than 3 m were documented.

These walls are not continuous structures that shape a terrace characterized by a constant elevation value along the slope. They blend among themselves or present an abrupt lateral interruption, resulting into terraces located at different elevations in both cases. This feature makes the wall mapping activity very difficult, particularly in vegetation-covered areas. Dry-stone walls often present stairs to facilitate access between different terraces. These elements are both located at an offset in the wall and made of large free-standing tabular stones.

A large number of dry-stone walls are in a bad preservation status. Some critical issues were documented with respect to both the wall as a whole and the single stone element that constitutes it.

In the former case, they consist of structural deformations, such as bowing or bulging of walls, and fine-sediment filling of spaces among the wall-facing stones giving birth to strong water overpressure often determining a sudden collapse of the structure in case of intense precipitation rates; in the second one, they consist of deterioration of stone elements related to weathering or in the fall and lack of single stone elements from the wall facing and the wall crown.

Several walls are partially or totally covered by vegetation in both cultivated and abandoned terraces, that clearly makes difficult the assessment of their preservation and stability conditions.

Certainly, the wall collapse represents the total lack of man-made structure conservation: a large number of partial and total wall collapses was registered. Generally, these structure failures are affecting wall of different height values ranging from 1 to about 5 m and involve the stone elements of the wall facing and the anthropically-reworked deposit behind it. Dry-stone wall collapses that only affected the wall facing were rarely documented; it was noticed in the central or upper part of the wall, and it generally occurs when the wall facing is not fastened to the aforementioned deposit, manifesting a constructive defect.

The detailed recognition of man-made structures allowed for the assessment of the wide spectrum of features that characterize dry-stone walls in the STONEWALLSFORLIFE Project pilot area. As a result, a field survey sheet was developed in order to describe quantitatively and in detail the dry-stone wall geometrical and structural features, along with its conservation conditions. This sheet meets the needs arisen during field surveys to describe accurately the dry-stone walls and related terraces located within the STONEWALLSFORLIFE Project pilot area. Nevertheless, it was developed to be suitable in a wide number of different geographical settings. The reference unit for its application corresponds to the single wall, intended to be a linear stand-alone element.

3.6 Technical solutions for the construction of dry-stone walls under the climate-change perspective

The technical analysis phase aims at investigating suitable solutions and innovative techniques to be employed in terraced landscapes, that could improve the resistance and resilience of dry-stone walls, with regard to climate change. From a conceptual point of view, these solutions and techniques can be divided into three main groups::

- innovative construction techniques;
- soil consolidation techniques;
- innovative farming techniques.

The first two approaches address two different aspects of the stability of the whole “wall-soil system”: the first one aims at improving resisting forces provided by wall structures, while the second one aims at decreasing destabilizing forces that act against the structures by driving their degradation and collapse.

The last approach has a different purpose, as it is related to agricultural activities and practices resilient to climate change.

Innovative construction techniques

The main aim of these solutions is to make dry-stone walls better able to counteract climate change effects and to enhance their role as green-blue infrastructure for the protection of the territory. The proposed solutions increase the resisting forces provided by dry-stone masonries.

The identified innovative construction (or reconstruction) techniques were already tested on either previous EU projects or case studies or techniques used elsewhere in terraced areas, and could be summed up as follows:

- strengthening of the walls through the insertion into drillings of interconnected metal bars which anchor the stones to the soil, through load distribution plate (scope: anchoring the stone to the soil; product example: https://www.incofil.com/it/natura/consolidamento/ancoraggi/barre-d-acciaio);
- strengthening of the walls through the so-called "ombrello consolidatore" (Italian for "consolidator umbrella"), a particular type of single steel bar anchored to the stable ground through deep anchor rods and cross-shape plates (goal: anchoring wall portions to the soil; it allows a wide frontal frame for a better load distribution over the wall surface; product example: https://www.incofil.com/it/natura/consolidamento/ombrelli/);
- wire nets or geosynthetic nets (goal: reinforcing the external face of the walls; product example: https://www.incofil.com/it/natura/consolidamento/reti/);
- use of natural binder material (goal: strengthening the mutual interconnection between single stone elements of the wall; product example: https://products.kerakoll.com/it-IT/p/biocalce-intonaco).

Soil consolidation techniques

The main aim of these techniques is to identify possible solutions for improving the stabilization of anthropically reworked eluvial-colluvial soil deposits behind the walls, both for the improvement of geotechnical features of the loose soil cover retained by the dry-stone wall and the decrease of the shear strength driving forces through the rainwater drainage capacity and for the reduction of linear and surface erosion phenomena.

Moreover, a crucial issue strictly associated with the construction techniques will be the assessment of the dry-stone wall drainage capacity related to the presence of effective drainage (the infilling material on the back of the wall) and suitable spaces between the various lithic elements that make up the wall facing. The drainage capacity is fundamental to preventing the triggering of pore water overpressures.

An innovative soil consolidation technique can be the design or the renovation of drainage channels and systems specifically developed to withstand extreme rainfall.

Drainage channels are crucial elements of dry-stone terraces slope, but in this very case the innovation lies in the use of innovative materials like pre-assembled draining elements, coupling a traditional construction technique with a modern product suitable for easy installation.

Examples:

- design of drainage channels and surface drainage works specifically devoted to preventing adverse effects of runoff connected to extreme rainfall (goal: minimizing runoff and infiltration water (surface infiltration), thus reducing soil erosion). This can be obtained both through the restoration of traditional works (i.e. existing drainage systems through maintenance) and by installing prefabricated drainage systems within the soil volume during the dry-stone walls reconstruction phases (product example: https://www.borghiazio.com/prodotti/drenaggio).

As can be seen from the above description, a crucial issue, strictly associated with both the construction and the soil consolidation techniques, is the definition of the dry-stone wall drainage capacity, which is related to:

1. the hydraulic conductivity of the infilling material behind the walls and the agricultural soil;
2. suitable voids between the various stones of the wall face.

The drainage capacity is fundamental to prevent the increase of pore water pressure and the consequent dry-stone wall collapses.

Innovative farming techniques

The main aim of these approaches is to develop agricultural activities and farming techniques, looking for those that can be suitable to be resilient to climate change effects.

They may include:

- establishment of vineyards more resistant to water and temperature stress (e.g. by: drought-resistant rootstocks; high density of implantation; planting with espalier; substitution of the "*pergola bassa*" with different vine farming systems and pruning types, depending on both the vine variety and the conditions);
- experimental field trial of vine varieties of different origins, more resilient to drought, water stress, and later ripening and also different species alternative to the vine which can be suited to the local morphological and climatic setting (such as citrus fruits and olive trees, whose deeper root system increases of soil suction).

Innovative solutions proposed by the Design group

In addition to the previously mentioned innovative techniques to be tested in those 3 main sectors, the Design group actively involved in the operational phases of:

- vegetation removal
- topographic survey
- reconstruction of dry-stone walls
- reconstruction of drainage channels
- soil preparation and planting of vines and other species (e.g. citrus fruits, olive trees)
- development of agricultural activities

has proposed two additional intervention techniques to be tested in the pilot site of Manarola, respectively focused on:

- Ground/wall system reinforcement
- Drainage system
- Agronomic operations.

As follows, a brief description of each one of the previously mentioned techniques is presented:

Ground/wall system reinforcement

The following innovative solutions were especially thought in order to ensure the stability over time of the tallest walls (indicatively showing a wall-facing height comprised between 2.0 and 2.5m) and of those positioned in particularly weak areas (e.g. close to paths/public areas, or showing high slope steepness values) ; going into a more structural detail:

- When the collapse of the wall has led to a significant damage of the drainage system and a subsequent decay of the backfill geotechnical properties, the tested technique will consist in the introduction of passive tie rods made with simple nets in geotextile, commonly used in the construction of reinforced earth (*figure 19*). Such a structure will actively increase the shear strength (τ) of the wall-soil system, and will be fully integrated in the typical terraced landscape and will respect the main geo-hydrological features of the site, allowing to get a better performance in terms of drainage conditions.

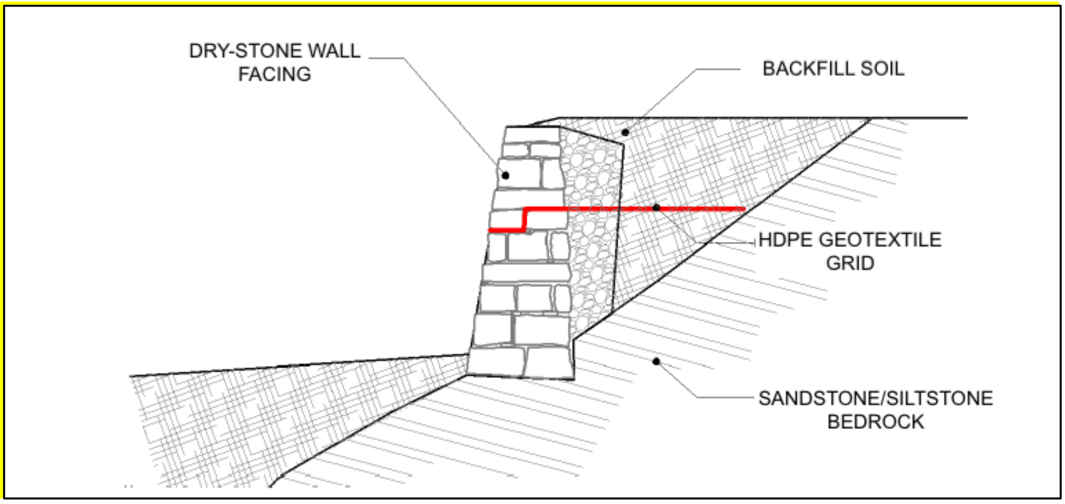

Figure 19 – Technical scheme of innovative solution for <u>ground/wall system reinforcement</u>

This solution will also imply very limited costs (material supply and put-in-place, which in any case will be carried out during the wall manual reconstruction phase without the need for further excavations) and will allow to get a considerable increase in safety factor coupled with a greater durability/sustainability over time.

- In the case of a wall to be rebuilt higher than 2.30 meters inside an area hit by several landslide events, it is possible to put in place a structural reinforcement through the insertion of internal diatoms consisting of spurs about 40-50 cm thick in between stone segments with a binder consisting of lime mortar with intervals of 4-5m to depending on the structural situation of the wall and structurally connected to the external dry stone masonry.

This kind of intervention represents a significant structural reinforcement and in the meantime preserves both the dry-stone wall drainage system and the landscape features of agricultural terraces.

Drainage system

The potential areas in which to insert new drainage collectors were identified in the first executive project (lot 2): their main technical aims is to channelize the superficial drainage – sewage and to reduce the water flow speed downhill towards the main stream; it is important to identify the most suitable areas in terms of concentration of superficial drainage phenomena (for example small, interconnected morphological depressions or wider areas already colonized by wetland grass (e.g. common reeds)) suitable for creating "rain garden" (figure 20) type structures that are composed by two main elements:

- areas of water collection and hypodermic absorption to delay the outflow;

- draining volume made of pebbles/gravel at the lower level;

- drainage pipe positioned at the bottom of the structure.

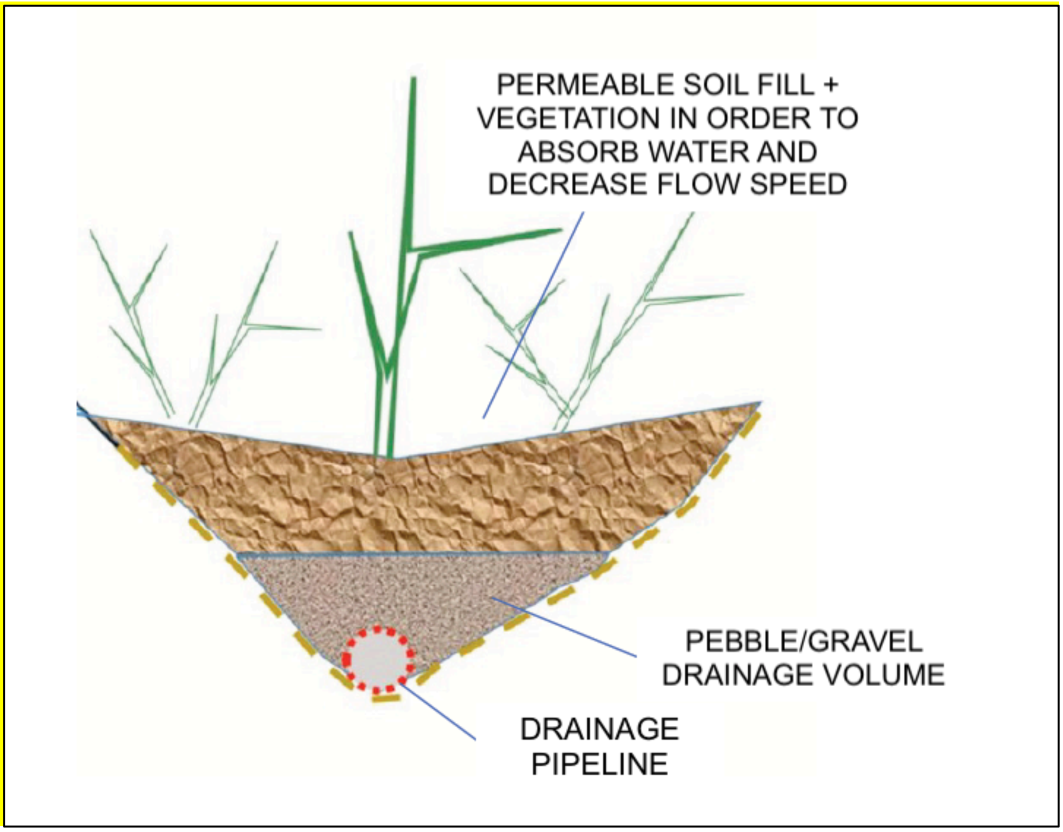

Figure 20 – Drainage system main technical scheme

Agronomical interventions

Innovative interventions must go in the direction of stress mitigation induced in plants as a result of climate change (alternation of heavy rains with prolonged periods of drought); moreover, it is necessary to rationalize fertilization practices in order to induce greater robustness in the plants.

Considering the project time range, the interventions will be focused on the use of soil improvers and basic organic fertilizers (based on the results of a soil, surface layer and deep layer sampling campaign, in order to evaluate physical and chemical parameters) at least 6 months prior to the start of the planting phase.

Specifically, to avoid the leaching of nutritional elements due to intense rainfalls, some eco-friendly organic fertilizers capable of gradually releasing the elements will be introduced in first layer of the soil; also, a combination of compost and “Biochar” (carbonaceous material obtained for thermal degradation typically obtained by pyrolysis of wooden material which possesses characteristics such as high active surface and porosity) will be tried as an effective measure also to improve the CO2 sequestration process naturally carried out by the soil.

Moreover, the LIFE TERRACESCAPE project gave us some tips both in order to address the future destination of restored agricultural terraces and to avoid some possible critical situations connected with the products obtained through the cultivation of agricultural terraces, specifically:

- Re-cultivation with local varieties (e.g. local species of olive trees – “Leccina”, “Frantoio”, etc., and lemon trees, aromatic herbs (e.g. sage, rosemary, oregano) adapted to local soil and climatic peculiarities to produce high-added value products;
- Enrichment of ground water potential due to the increased permeability of the soil;
- Avoidance of soil erosion due to the presence of terraces and cultivated crops along the terraces contribute to the containment of soil- resources (mechanically through retention walls, through the planted root systems);
- Attention due to the possible and future commercial attractiveness /appeal connected to specific cultures (the Greek project has shown some critical aspects in terms of selling specific cereals (e.g. barley, vetch, lupine, onion)).

3.7 Work in progress and next steps

The illustrated outcomes of the project phase concerning the preliminary investigations on geological, geomorphological and anthropic features of the pilot area represent the base for the further planned analyses.

In order to provide detailed information on dry-stone walls at site-scale, a further phase of man-made structures mapping and characterization will be carried out during the next months. This will allow for a progressive and continue updating of the developed geodatabase concerning the pilot area features.

The location of multi-parameters control station is not discussed in the present report as it has not been defined yet; further investigations are needed in terms of both technical and management aspects. As concerns the parameters to be investigated, one of the possible solutions, now under evaluation, is the use of sediment traps in terraced areas, to quantify the erosion rate with respect to a number of environmental variables. These traps could be used together with the aforementioned multi-parameter control stations to widen the spectrum of available data for the project actions implementation assessment.

Finally, further studies will be conducted to better define some possible solution to improve the resistance and resilience of dry-stone walls structures under the climate change perspective.

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