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Quick mapping by mobile sensors for landscape values monitoring and conservation

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Abstract Geomatics researches, applied to architecture and landscape, are becoming increasingly focused on development of innovation in survey techniques and digital data management. Quick techniques are sought, with a high level of automation and versatility, to support knowledge management and protection of cultural heritage, be it referred to artistic and architectural heritage or, overall, to whole varied landscape assets, in so such highest density in the country as to consider Heritage itself.
The investigation and conservation initiatives in the field of landscape heritage must constantly deal with many conditions of risk exposure, and that is not always possible to make up with preventive protection, whether if it is a constant risk like that intrinsic to the status of the property, or sudden and unforeseen risks, or if it is only partially predictable, determined by an environmental emergency.
In these test-sites, which have a typical vulnerability resulting from their intrinsic conditions of exposure to risk, is interesting to experiment and combine technological research with the public interest for the protection and preservation of the value of the asset. This paper is intended for the testing of systems for the expeditious acquisition of spatial data in a outstanding test site, an area of the Cinque Terre, devastated by the flood of autumn 2011.

INTRODUCTION

Nowadays the territory is more and more considered a widen cultural asset and connected built heritage is evaluated for its intrinsic values and above all the values are connected with the relations exinting among assets and spatial-temporal context.
The comparative observation of different scaled maps enable to compare the object of interest, the isolated assets, the urban contexts, or areas with high landscape values with the natural components of the land. For example it is often valuable to take into account the land morphology and hidrology, with all the other antropic elements among which the street network is particularly relevant togetther with their relations with other urban contexts or other environmnetal or cultural assets.
The diachronic readings of the urban or rural settlements, are supported by different times maps and they enable to observe diverse aspects of the modification of the land and the buildings.
The high scale maps, in which the buildings boundaries and their 3D content were descripted, enable the relevant reading of building typology and the type of urban settlement; the chance to discover

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agreement and disagreement can explaine the process of buildings generation; the analysis will be based on historical inquiries that will be always supported by the maps as an essenxial tool for comparing deepening analises.
The innovation on geographic information reached in the present, both regarding the acquisition systems (Remote sensing and satellite topography, aerial LiDAR, mobile mapping systems) the new mapping products (digital maps, orthophotos and dense DTM) and also the innovation on sharing and disseminating data (spatial data infrastructures, standards on spatial data, geographical browser and mapping server) enable some particularly enriched and dinamic analyses. These last allow to deepen complex issues and to foresee future sets.
Another very relevant topic is the direction of researches towards the achievement of higher automation and versatility for the collecting and managing methods; often this trend is applied in some specific fields of application and then it conditions other sectors, reaching new relevant outcomes.
For istance, in this perspective it is rather exemplary the development of acquisition techniques for quick mapping, related to the emergency mapping, which is an essential tool in the Early warning or post disasters situations.
The present paper is purposed to highlight the effectiveness of some equipments such as smartphone, image and video cameras and palm-sized GPS; all these instruments use advanced technologies even though they are easy to use, so they have been largely widespread and they took part to the main human activities. If these instruments are used as a component of a huge systems of spatial data collection and managing, they are able to provide a set of key relevance information in emergency scenarios (Boccardo 2013), possibly in a crowdsourcing process.
In the applicative section of this work we are going to explain how georeferenced images and videos, acquired by mobile sensors, have been used in order to derive linear geographical datasets and related thematic information. We used the digital mapping approach, with rules of spatial data standards, with the aim to analyse and evaluate the permanence of landscapes values in a territory subjected to the UNESCO protection and shocked by an environmental disaster.

SOME INNOVATIONS IN SPATIAL INFORMATION

Nowadays the spatial information is generated, managed and disseminated by technological tools requesting that data could be structured and logically related. The Information Technologies enable to acquire, record, process and share information that are essential to support the managing functions of diverse sectors authorities and corporations that need to control and use the geographically referenced information.
The innovation related to spatial information are so relevant that some new branch of knowledge have been inspired and established. Following the different phases of the spatial information generation, starting from the data survey, to the mapping and finally to the information sharying and dissemination, we are going to summarize the main techniques, products and standards since they are substantial even for the analyses, the evaluation and rules activitities directed to the the landscape.

Acquiring

The digital mapping, the orthophotos and the digital terrain models are surely the most modern pruduct of the mapping science, that have significantly enhanced the descriptive and analysis potential compared with traditional mapping. Some survey methods development have provided new benefits: for istance the multiscale representations needs, that are very proper for the protection and adminstration of the land featured by landscape values, can be supported by the RPAS/UAV Photogrammetry (*Remotely piloloted aerial systems,* Unmanned *aerial Vehicles*). The RPAS photogrammetry combines the features of the close range photogrammetry (high precision and static acquisition) with those of the aerial photogrammetry and it is employed for nadiral multi-images applications (Eisenbeiß, 2009, 2013).

The aerial LiDAR technology is largely esteemed and used for the achievement of dense and accurate terrain models, for example it is successfully applied on urban areas in order to generate the 3D city models (Zhou, Neumann 2008; Cheng *et al.* 2011).

An area under an high risk, and thus surveyed by arerial Lidar in advance, if subject to a disaster such as a landslide, it could be surveyed again after the event. Starting from the two photogrammetrical models, it is possible to generate a third model generated as a difference between the two original ones, the first representing the pre-event situation and the second the post event one.

Such information, if available during the first phase of disaster management, enables to properly front the first impact event and the evaluation of damages.

Another interesting acquiring technique is the mobile mapping method, thank to the quick anche low cost traits. The so-called mobile mapping is a survey method from mobile vehicles, aimed to the collecting of georeferenced data thank to a positioning and navigating system. Often the purpose is the mapping updating: the GPS receiver provides the position together with the inertial platform controlling the vehicle balance, and any sensor such as laser scanner or image/termic camera acquire the data along a route.

The survey systems combining navigation and acquisition devices, most of them directed to collect data for GIS storing and managing or purposed to the 3D modeling of streets and their surroundings, are called Mobile Mapping Systems (MMS) (De Agostino *et al.* 2010; Ajmar *et. al.*, 2013).

A mobile mapping system tipically employed for sharing data in a popular navigation browser (*Street view*) uses different vehicles (cars, bicycles, snow vehicles) equipped by systems able to acquire and calibrate overlapped images or they use spherical lens for panoramic shootings. In addition to the movement sensors, that is purposed to survey also the positions, the lidar devices acquire 3d profiles in order to determine the distances of the images, and a PC, that acts as the control station, allows the performing of all the necessary adjustments and the recording of data. (Haala, Kada, 2005)

The mobile images and videos sensors we used in the experience we are going to present, are not equipped by balance sensors, but simply a time synchronisation between the GPS receiver and the image sensors is provided. (Boccardo *et. al.* 2013)

So the main purpose is not the collection of 3d georeferenced data, but only the storing of images and videos that is possible to relate to the geographical position with a technical map precision; moreover the extraction of thematic data for generating the linear spatial datasets is only partially automated.

Spatial Data Infrastructure - SDI)

One of the most considerable achievement regarding the spatial information is the appearance of Spatial Data Infrastructures; an SDI is considered a base collection of technologies, datasets, human resources, policies, istitutional agreements and partnerships that facilitate the availability, the exchange of, the access and the use of geographically related information using standards practices, protocols and specifications.

The SDI establishment is promoted by the UE commision INSPIRE (*INfrastructure for SPatial InfoRmation in Europe*)[1], in Italy it is put into effect by the National Mapping portal project of the Environment Ministery and by the INTESA GIS project. It enables the sharing and exchange of geographical and

1 http://inspire.jrc.ec.europa.eu

environmental information among local administrations and national authority. The availability and the easy access to updated spatial databases, or to Web-GIS applications that enable the quick representation or analyses of data, for authorized or free users, is surely a powerful tool for all advanced uses of maps, one for all the mapping sector facing the emergencies (Disaster Managing).
The readings and studies of landscapes require the multiscale approach, contemporary with the need that the maps were harmonized with socio-demographic, economic or cultural data. All that and the purpose to adopt a decision making process, make the availability of SDI a primary need.

Standards

It is not conceivable the existance of SDI if spatial data standards were not available; in fact rules for sharing data are necessary in order to achieve a real interoperability.
The spatial data standards have been formalised and adopted as a rule especially with the aim to balance the geometric and thematic specialization of spatial data, for performing enriched analyses infering new information in GIS.
The Geographic Markup Language (GML) is codified by the Open Geospatial Consortium (OGC) and adopted as a rule in the ISO 10136[2]. The GML is one of the most adaptable and complete standard for modeling spatial data (2D and 3D data, vector or raster, in separate geometric and topological model, and it is possible to implement thematic and temporal data). It is based on the formalization of ISO/TC211 standard that use the meta-language XML tools.
The development of the City Geographic Markup Language (CityGML) has run parallel to GML, for the high scale urban mapping (3Dcitymodels). This is a mixed geometric and topologic model, implemented to enable the multi-scale and multi-visualization of urban features. The multi scale structure is rest on the definition of a series of levels of detail (LODs – Levels of Details).
With the aim to integrate the data modeling standards, the OGC has also codified some standards for the web interface services concerning the geographical information. The *Web Map Service Interface Standard* (WMS) enables the dynamic maps visualization from geographical data, using the html protocol from any web browser. Similarly, the *Web Feature Service* (WFS) has been codified in order to enable the web access to vector data and connected metadata. [3]

VERNAZZA AND THE *CINQUE TERRE* LANDSCAPE

The experience that we choose to take as sample is the test site of Vernazza (La Spezia), in the *Cinque Terre National Park*, which has been protected by UNESCO in 1997.[4]

The territory of the *Cinque Terre* can be defined in all respects complex, consisting of several parts interacting with each other, suitable to describe the characters found in the Eastern Liguria and in particular Cinque Terre landscape.
The complexity is not only about the structure of the territory from the point of view of nature and the environment, but also the landscape aspects (in his broadest sense of the heterogeneity of "*characteristic features of a territory, which allow you to perceive and describe it not identical to another*").[5]

2 OGC. Open GIS Geography Markup Language (GML) Encoding Standard v.3.2.1 07-036. Open Geospatial Consortium. (2007)

3 OGC. OpenGIS Web Map Service Client (WMS) Implementation Specification 06-042 (ISO 19128) (2006). OGC. OpenGIS Web Feature Service (WFS) Implementation Specification (1.0.0) 06-027. Temporality Extension 12-027 (2006-2012).

4 WHC-97/CONF.208/17, *Convention concerning the protection of the world cultural and natural heritage*, Napoli, 1-6 December 1997.

5 Da: Relazione Generale del PTCP, pag.4, ("*Piano Territoriale di Coordinamento Paesistico*").

These are those tangible and intangible marks of the man-made assets developed there, since it depends and arising from this complexity primary, which was the natural environment.[6]
This landscape, in a narrow strip of land of a few tens of kilometers, which separates the mountainous hinterland from the sea, collects different natural conformation, as well as many different types of urban and rural settlements, and the historical development of its local economy, made mainly of terraced territories with stone walls for the cultivation of vineyards and olive groves.

For these reasons and for "[...] to *being an outstanding example of a traditional human settlement, of use of local or marine resources or representative of a culture (or cultures), or human interaction with the environment, especially when it has become vulnerable under the impact of irreversible change*[7]" the *Cinque Terre* area "[...] *continuous and living cultural landscape of exceptional value*[8]" were recorded in December 1997 in the World Heritage List of UNESCO.

Figure 1.a (left-side) Terraced slope of the Cinque Terre. **1.b** (right-side) View of the coast between Vernazza and Corniglia.

25 October 2011: the area and the landslide risk

These places were the scene of the notorious disaster occurred in 2011, following the hydro-geological instability caused by a flood of unexpected and remarkable intensity (Ortolani 2011). Research into the causes and consequences, not without a realistic observation of the effects beyond the familiar chronicle of the events created in recent years, should be directed to the analysis of the hydrogeological causes distinctly from those meteorological.
A substrate geologically unstable and not fixed, like that of the subalpine terraced slopes of the Cinque Terre is, in many parts abandoned and unmaintained, where the plant growing naturally has gradually appropriated the mountain walls modified by men centuries ago for the development of farming. This is closely related to a critical urban layout as that of the Cinque Terre villages, built on the watershed valley of a river or stream flow (covered with a culvert as in the case of the Rio Vernazzola to allow employment of a greater surface area of the soil for the settlement).

6 *"[...] Tutta la storia della Liguria è connessa alla varietà del suo ambiente naturale, marino e montano, che a volte ha favorito, a volte ha contrastato lo sviluppo della vita e della civiltà"* in: N.Carbonieri, A. Maniglio Calcagno, P.Marchi, F.Marmori, *La Liguria di Levante*, Istituto bancario San Paolo, Torino1975, pag.17, e in P.Falzone, V. Garroni Carbonara, P. Marchi, *Centri storici in provincia di Genova e La Spezia* – Liguria Territorio e Civiltà, Genova, SAGEP Editrice 1976 pag. 61.

7 (v) criteria of selection by UNESCO, according to the "*Convention concerning the Protection of World Cultural and Natural Heritage*", 1978, expressed in the document of 1997 with the award of the title of Cultural and Environmental asset in Word Heritage List to the Cinque Terre, WHC-97/CONF.208/17, *cit.*

8 ICOMOS, "*Dossier-Valuation of nomination in the World Heritage List - N°826 Portovenere/Cinque Terre*", Settembre 1997.

Everything must be considered in conjunction with a flood event of unforeseen intensity of considerable size at the turn of the orographic between Liguria and Lunigiana Tuscany, very slow and steady combined with a "storm system multi-cell self-powered" (Staiano 2011), caused the hydro-geological disaster that we all remember. In six hours, the weather station Brugnato recorded a total of 472 mm of rainfall (overall 542 mm in 30 hours), for an estimated volume of water throughout the affected area of 200 Mm^3 (Ortolani 2011).
The damages that have occurred in the area due to the weather event were exponentially amplified by the response that the soil has given to the event, and it was as well unstable as uncontrollable.

Figure 2.a Flood damages in July 2012.

Figure 2.b The rough side of the mountain behind Vernazza,

from: http://www.informazionesostenibile.info/date/2010/12/

THE DI.REC.T. TEAM FOR ENVIRONMENTAL EMERGENCIES

Team Direct (Disaster Recovery Team)[9], through the project of 2012 on the test-site of Vernazza (SP), has played an integrated multi-pronged, with regard to the management of emergencies and environmental disasters (DM - Disaster Management), and the collection of information and geo-referenced images immediately usable for updating the geographical maps, as well as the analysis and monitoring of risk areas. The emergency is evaluated, in this case, both the risk for a prompt and sudden events (natural or man-made calamity: flood, earthquake, landslide, volcanic eruption, nuclear threat, humanitarian crisis, *etc*...) and a systematic and continuous risk to which the architectural and environmental assets are exposed (wear and degradation, for example, in the city center with its historic or archaeological excavation). Some students have been involved as an internship experience - a two-week of full immersion hands-on experience and activities - during that period a wealth of information about the built heritage of Vernazza, the path network in the Cinque Terre National Park, the bed consistency of the Vernazzola stream, the bathymetric survey of the harbour have been collected. Moreover the marine shoreline of the Vernazza village as a result of the sudden morphodynamic agents acting on the morphology of the coast and deriving from the flood event have been surveyed. (Boccardo *et al.* 2012; Federici *et al.* 2001)

9 DIRECT – Disaster RECovery Team. The Direct Project was created in 2012 through the initiative of a group of students and tutors and it is supported by the Politecnico of Torino with the funds of 5x1000. The initiative aims to spread the focus on land conservation and enhancement of the landscape and architectural exposed to environmental risks. This objective was achieved through the formation of a team of crisis mappers with expertise in the field of advanced metric survey, with testing of innovative techniques integrated laser scanning, digital photogrammetry, GPS video, management of data in a GIS.

Figure 3.a Volunteers of the DIRECT Team during the stage of July 2012.

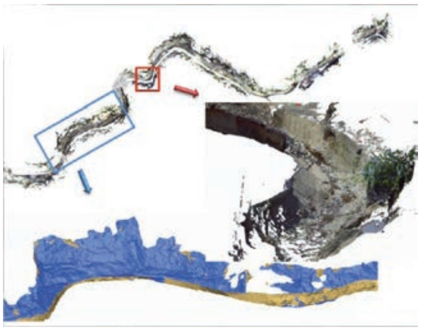


Figure 3.b the 3D model of the Vernazzola stream, detected with Laser Scanner Focus 3D Faro Cam2: point cloud, coloured model and textured model.

Surveys and mapping by mobile sensors for accessibility of Cinque Terre National Park path network

The intention of the Vernazza city, and then the Cinque Terre National Park[10], concerned the monitoring through the technologies used by Team DIRECT of the city lay after the disaster and the capillar documentation of damages occurred to the network trails running through the park and connecting the nodes of interest of the coastal and sub-mountainous area. These operations had been directed to the tourism promotion, even by means of the hiking trails preservation, and to a complete documentation of the landscapes assets, aimed so much of their improvement[11], as the control and management of assistance in case of danger. In addition to these purpose the occurrence of the flood has added the monitoring of the state of conservation and viability of these routes, partly damaged by hydro-geological landslides.

The L.R. N°24 in 2009, concerning prescriptive provisions regarding the hiking trails network of Liguria Region, intends to enhance the historical Ligurian lanscape and its natural heritage as the footpaths network in a sustainable manner. In particular, this rule promotes the achievement of guidelines for updating the paths tracks and the state of conservation of the signs; moreover the rules encourage the digital format of the maps, with the help of the CAI and the tourist systems and local authorities.

The DIRECT team tested in Vernazza some applications of the expeditious survey by mobile vehicle (*mobile mapping*) on the path network, in the post-disaster scenery, where the objectives planning, the instruments choise, together with the organization of the timing collection compared to the optimization of results, is needed as relevant as ever.

A team of cyclists explored according to the situation of feasibility, and has carried out an expeditious survey about the entire trails network, by mountain bike equipped by 2D and 3D video recording and GPS receivers.

10 The Cinque Terre Park Authority was established on 1995, with the foundation of Cinque Terre Regional Natural Park (L.R. n°12/1995), in the same year of the decision to submit an application to the World Heritage List of UNESCO (From *http://www.parconazionale5terre.it*).
Establishment of the National Park with D.P.R. of 06/10/1999.

11 We recall that the path assets of the *Cinque Terre* is considered by the Landscape Territorial Coordination Plan (PTCP) as the best way of reading the landscape, and its normative indications suggest an improvement and strengthening of this network, namely: the "*Blue path*", the "*High path*" and the "*Path of the sanctuaries*".

Figure 4 The mountain bike fitted with 2D and 3D shoot devices for the survey of the trails network in Cinque Terre National Park.

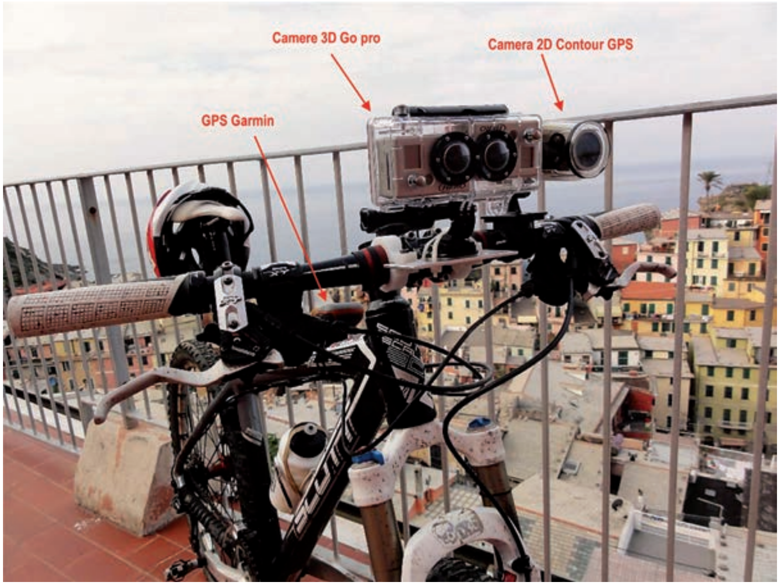


Figure 5.a Stop motion of 3D video from a pair of stereoscopic HERO2 cameras.

Figure 5.b Handheld receiver Garmin GPS 60 CSx.

Figure 5.c Camera Contour HD Plus2 detector with built-in GPS

During the trekking, a pair of GoPro cameras recorded many 3D video with high information value; by means of the proprietary software with video processing it's possible to capture 3D metric information from this digital media, which, associated with the activation of GPS positioning, enables to build an archive storing the quality consistency and the geometric features of the elements taken from video. The camera Contour HD Plus2 with internal GPS detector was instead used for HD video in “*.mov” associated with a GPS track in two format: “*.xmp” (Extensible Metadata Platform for compact storage of metadata about the track) and “*.nmea” (spatial data format standards defined by the National Marine Electronics Association). The handheld GPS receiver Garmin has finally registered a GPS track more precisely aligned to 2D and 3D video.

The track has dual format “*GPX” (The file contains tracks, routes, and points of interest with their geographical coordinates, is a format to open license that allows the transfer of geo-referenced data between different media and is compatible with almost all GPS devices) and “*.KMZ” (the format used by Google Earth and Google Maps)[12].

The video and GPS data acquired were handled by the proprietary software of the two instruments. Contour Storyteller software (*http://www.contour.com*) allows loading, viewing, analyzing, storing and sharing videos recorded with Contour cameras. An interactive mobile window can follow the GPS track progressing with the video, and check the information recorded at the time of purchase along with the video: traveling speed; altitude (measured on geode); distance traveled. The Garmin Basecamp (*http://www.garmin.com/it*), is used for the management of data to be loaded or to be exported from the GPS device. The interface allows you to download updated maps and create personalized itineraries.

Figure 6 The software Contour storyteller interface in which we can analyze shooting HD video with GPS tracking advancing in parallel on aerial map satellite and movie technical parameters such as: *speed*, *altitude*, *traveled length*.

The survey, planned few months after the flood of 2011 and organized through the trails network in the Park, has been able to directly document the viability of the paths network and the status of conservation the paths themselves and the signaling system of the trail network . Indirectly, the effects that the disaster caused on terraced landscape and on the whole rural architecture system has been documented too.

A GIS ORGANIZATION FOR LANDSCAPE HERITAGE, INTEGRATED BY GEOREFERENCED IMAGE-DATA

After the results of the practical experiences and thank to the ideas suggested from multidisciplinary approach of the team, a master thesis has been developed (Sammartano 2014) focusing the applicability of this expeditious survey technique to the situations of risk for the environment and built heritage. The study has been applied to the Cinque Terre test case and to the trails network that runs along the sides of the town of Vernazza, through the terraced farm plots and along the dry walls.

12 It is a *container* of “*.xml” data (Keyhole Markup Language) graphic only, because they contain spatial information. You can create a file “*.xml” with “*GPX” but not always the opposite). From: *http://www.easytrialsgps.com/it/tutorials*

The project was aimed, designing a GIS, to the monitoring of spatial information regarding the landscape and the state of conservation of architectural and landscape heritage, involving the reading and storing image data, with direct reference to the area located within the village of Vernazza and Corniglia.

Specifically, it was interesting to evaluate the issues concerning the *diffuse landscaped* terraces of the park and the trail network crossing it, that coincide with the chance of success of the park itself and with the perception of its value[13].

This area in fact is the UNESCO site and Park Authority is responsible for its protection.

A GIS managing was essential, since it is suitable and flexible for the reading, understanding and the control of local natural and human phenomena, for complex processing of spatial data, for the deepening of the phenomena and their representation by geo-referenced data.

The GIS aimed to the environment and landscape data management has been designed for the representation of information purposed at the definition of the status quo and the preservation of the architectural and environmental heritage, with the purpose of planning and support political decision-making.

This required a new site inspection and a new survey, carried out in the spring of 2014 with a 2D camera with GPS tracking. The purpose was to study the applicability of this technique for the expeditious survey for data management on the landscape heritage and monitoring the state of conservation and the eventual transformation of the trail network from 2012 to the present. We have chosen to focus on the most relevant information surveying useful to perceive the landscape value of the section of trail: *accessibility*, *distance*, *conservation*, *safety* and *enjoyment* of architecture paths that runs along the terraced landscape between Vernazza and Corniglia, as particularly corrupt by flooding in 2011, in compliance with the proactive guidance of the PTCP[14]. The digital map that formed the cartographic base was obtained by free download from the infrastructure of geographic data *OpenData* of the Regione Liguria in vector *shape file*[15] (reference system Gauss-Boaga transformed into the WGS84 datum-ETRF89). Other datasets were created after the extraction and selection of thematic geo-referenced data obtained from the reading of the images and videos related to linear geometric datasets. Consistent with the assumptions of interoperability and free exchange of information, it has adopted the open-source tool QuantumGIS.[16] (Figure 7)

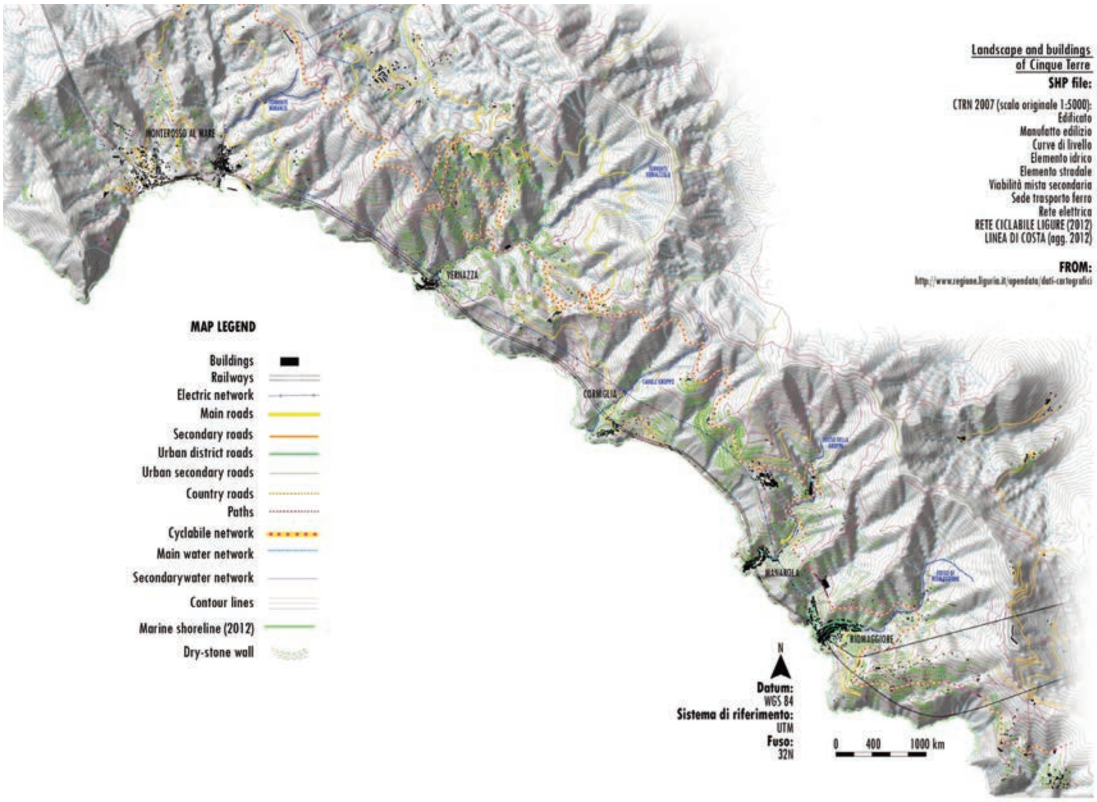
13 "*[...] potenziamento e miglioramento della rete pedonale, che rimane comunque il tessuto di massima connessione e di migliore lettura dei valori del paesaggio come già specificato negli indirizzi della pianificazione per l'assetto insediativo, guida le principali azioni proposte. Si prevede in particolare di rafforzare le tre principali direttrici di percorrenza longitudinale corrispondenti all'itinerario di lungo mare chiamato anche "Sentiero azzurro"; alla via baricentrica "dei Santuari" in parte appoggiata alle rotabili esistenti ed in parte ancora da segnalare: ed infine alla via di crinale estesa da Portovenere fino a Levanto detta anche "Sentiero rosso" [...]*" from the Record Card of the '"*Ambito Territoriale 93 - Cinque Terre*" of the "*Piano Territoriale di Coordinamento Paesistico*", D.C.R. n°6 26/02/1990.

14 The Record Card *n°93* underline: "*Si prefigura inoltre l'opportunità del miglioramento e del potenziamento della rete pedonale che rimane comunque l'asse portante di tutti i collegamenti di superficie alle piccole e medie distanze*." (From the "*PTCP*", cit.)

15 The cartographic database reference was, briefly: the CTR - Topographic Database II, 3D edition 1:5000 of 2007, integrated by: Administrative boundaries (Municipal, Provincial, Regional) layer, 1:5000 scale, 2011; Updated marine shoreline, 2012; Classification of Water Bodies Status, 2009-2011; Soil Use Map, 1:10000 scale, 2012; Ligurial cycling network layout (REL), 2014; Forest types map, 1:25000 scale, 2010.

16 http://www.qgis.org

Figure 7 Overview map of the *Cinque Terre* area, (Sammartano 2014)[17]



Geo-spatial database for interpretation of terraced landscape between Vernazza and Corniglia

The landscape of Cinque Terre and its information data has been coherently addressed across different scales of interpretation, by potentiality of the GIS tool (and in particular the software open-source QGIS).

It was initially explored the local context and the set of information collected around the concept of ***landscape***, differentiated primarily according to their feature popularizing, that is, what type of information they convey: *qualitative-descriptive* or *quantitative-numeric spec.* These related to the various aspects of the historical and geographical landscape of the typically rural region of the Eastern Liguria, which includes the five coastal villages of Montero's, Vernazza, Corniglia, Manarola and Riomaggiore and their rural areas, that are classified under the name of *Cinque Terre*. They peculiarities of uniqueness and cultural value attributed to the historical and architectural terraced heritage have now become recognized and shared. This region saw in the past centuries, through building skills and technical devices, the steady practice of farming in terraces of dry-stone wall on the slopes and rugged steep, that are unfavorable to crops such as vineyards, olive groves, chestnut trees.

17 Every map of this paper was in Sammartano 2014.

Figure 8 Images collected during the survey of the second part of path connecting Vernazza to Corniglia

The categories of interpretation of Cinque Terre *landscape* are 3, and for each we drew up a thematic map. They are:

- the ***natural*** *landscape*
- the ***anthropic*** *landscape*
- the ***Risk factors*** for the *landscape.*

The datasets related to the physical structure of soil, in terms of geomorphology and vegetation, were grouped and structured for optimal viewing by GIS; then we have added all the data related to human action or to the traces of its establishment and its work of modification of the soil, and the resulting potential *hazard*. (Figures 9-12)

The second phase of work involved the analysis of the sample area between Vernazza and Corniglia (path 2b[18]), and its data on those three aspects of the landscape. The focus here has divided the information according to 3 categories of interpretation of the terraced landscape typical of the Cinque Terre:

- the ***path***
- the ***terraces***
- the ***vegetation****.*

18 http://www.parconazionale5terre.it

Figure 9 Analysis map of the agricultural terraced landscape

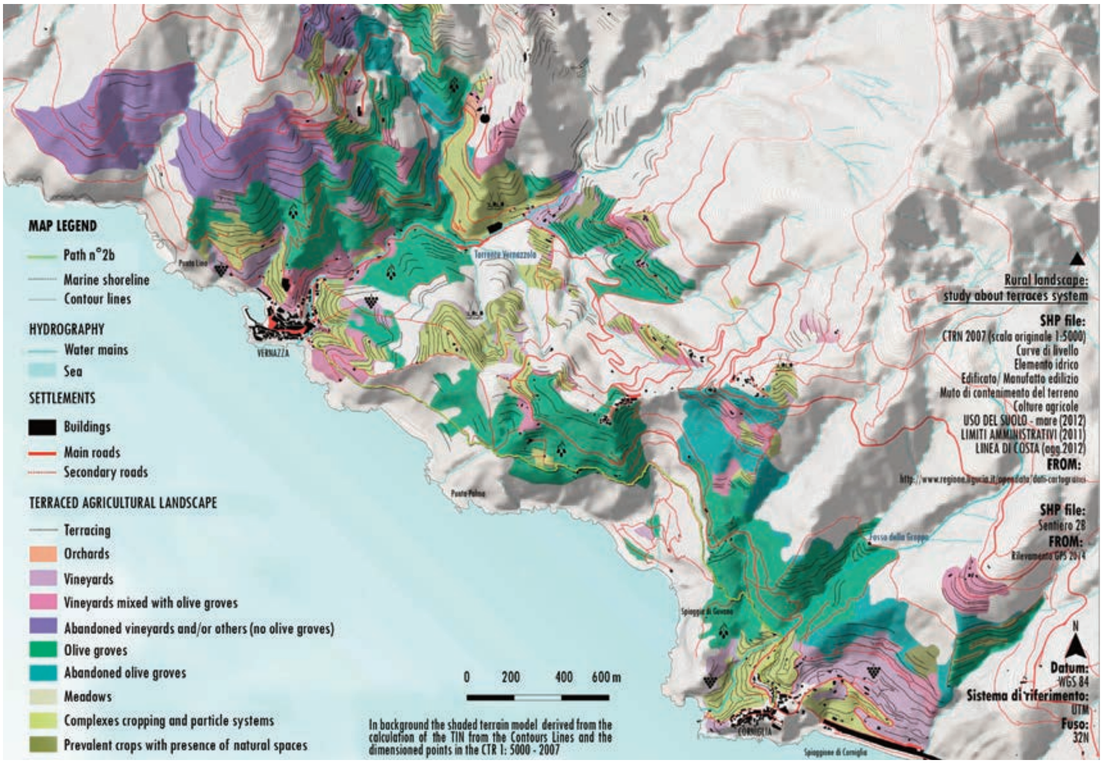


Figura 10 Morphological map of the area

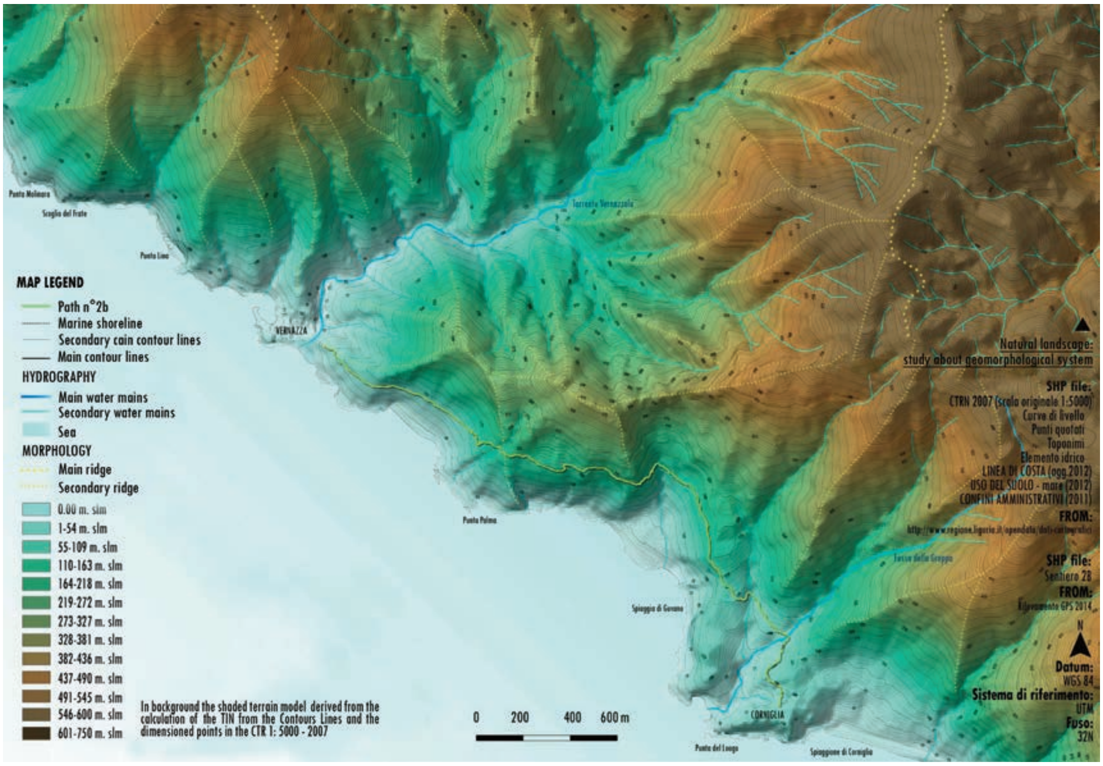


Figure 11 Anthropological landscape map

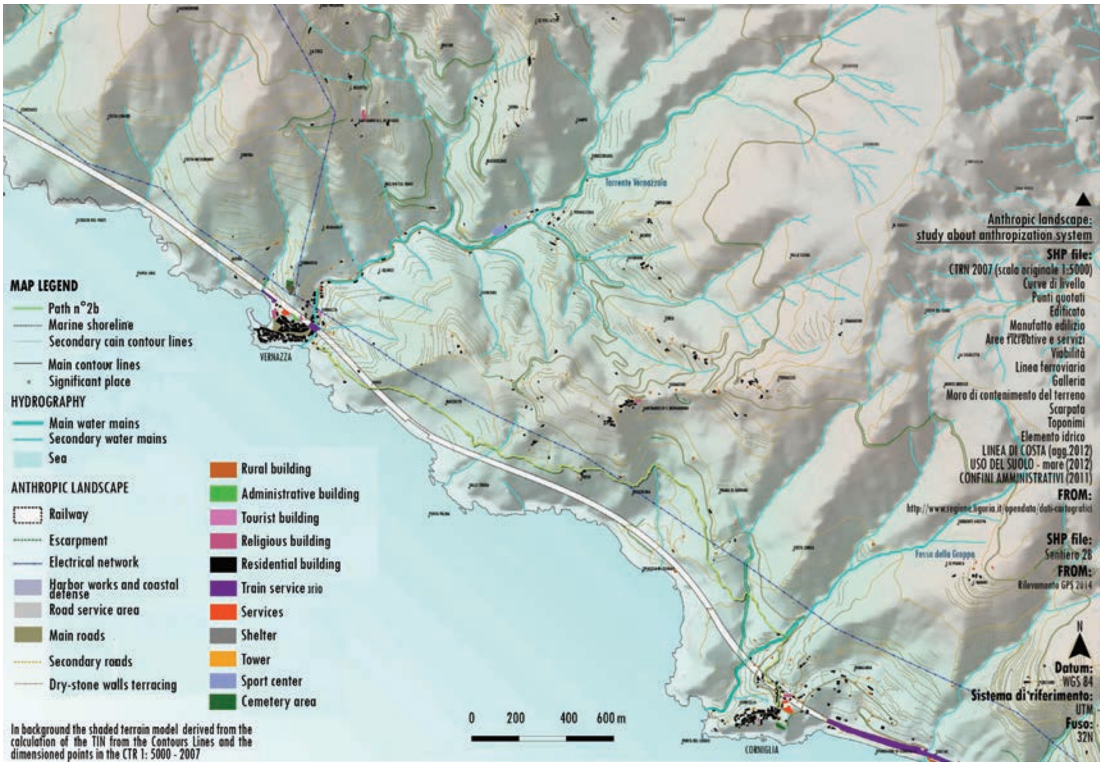
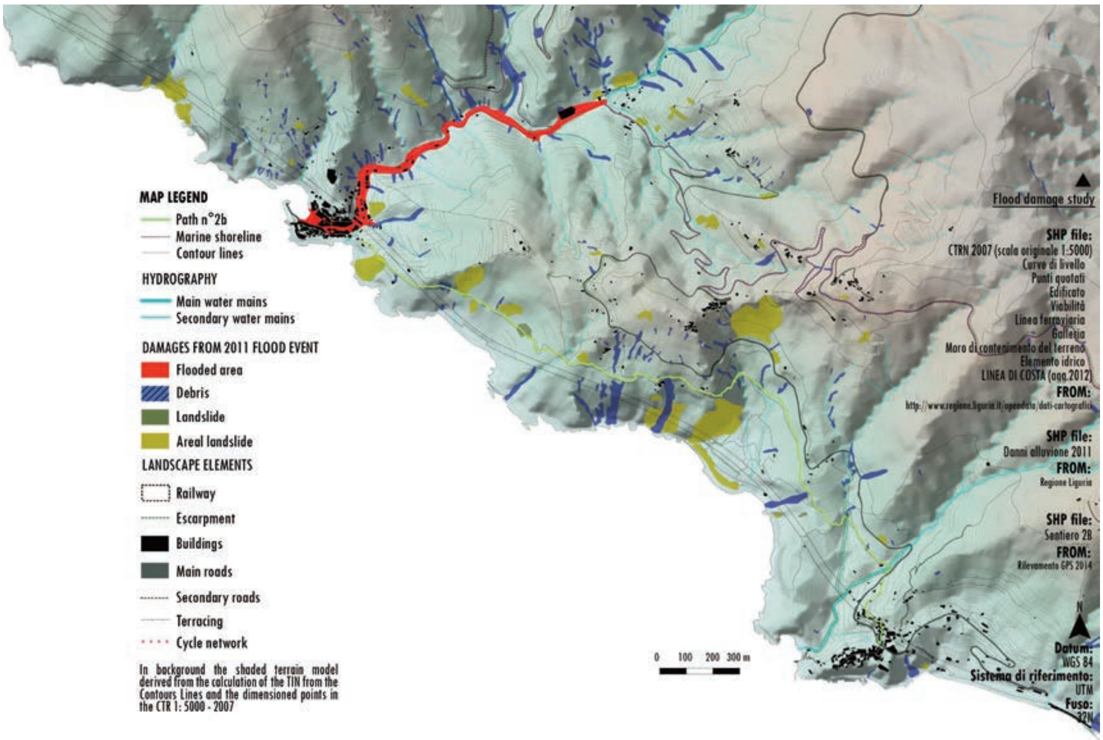


Figure 12 Hydro-geological risk map for Vernazza landscape, after the flood of 2011



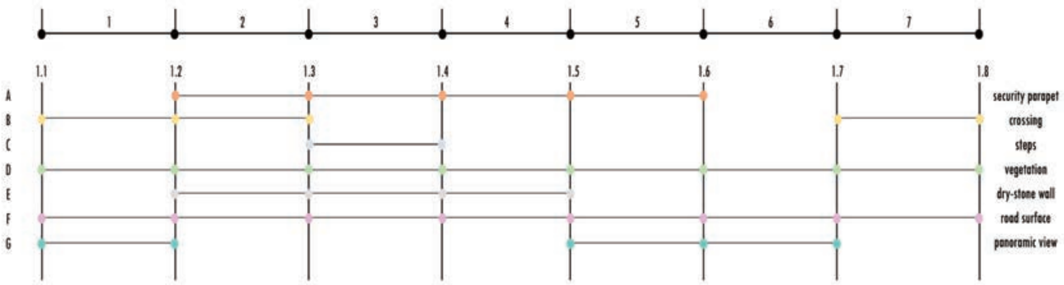
These three elements have been declined compared to two distinct types of information obtained from the survey:
- the *status quo* and *physical substance* features of the landscape
- the *protection* of the landscape and the *state of conservation* of the features.

The results (Table 1) is a series of classified and coded information in groups of datasets: a fundamental distinction has to be done about the basic data which characterize the physical substance features of the landscape in their status quo at a generic time "x ", that is, the geometry and the shape of the path, the dry-stone walls, and the vegetation, instead of those characters regarding the landscape and the state of preservation and/or are the result of the flood event of 2011, or the general degradation of the landscape, in reference to the above three macro-groups of "objects".

Table 1 classified information about the agricultural terraced landscape features

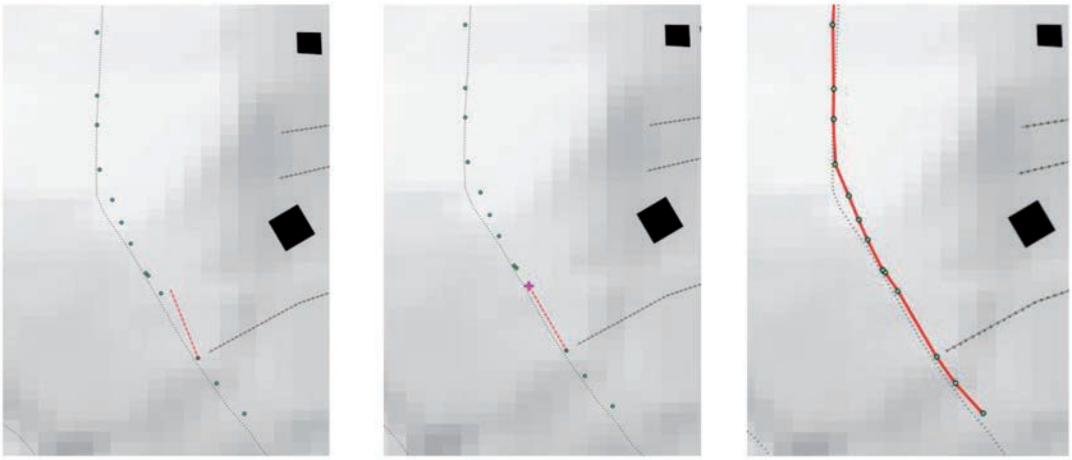
CATEGORIES OF INFORMATION		PATH	TERRACES	VEGETATION
	Status quo and physical substance features	• Width • Road surface • Steps • Crossing	• Dry-stone walls type • Dry-stone walls size • Crops	• Vegetation type
	Protection of the landscape and the state of conservation of the features	• Damages • Safety	• Dry-stone walls state of con servation • Dry-stone walls damage or deterioration	• Invasiveness on the path or on the dry-stone walls • Panoramic views

Figure 13a Diagram of tracking the path stretch, characterized by a single geometric element and visualization of the decomposition of the stretch made by *nodes* for the connection of *features attributes*.



The ultimate goal of the development of the data collection, was to translate the information into a topological *arc-node* structure, which is typical for linear vector datasets in GIS.
The first step was to classify information according to their subsequent transformation in the structure of *arcs-nodes*: *punctual entities* (***nodes***) were coded by data as a close off spot, such as a street intersection or a wall collapse, and *linear entities* (***arcs***) bounded by two points, were coded where the information was continuous along a section, such as a stretch of the path in which is present a security parapet.

Figure 13b Cartographic editing of a section of trail in the topological structure of *nodes* and *arcs*



The three elements of the landscape (*path*, *terrace*, *vegetation*) were read through these spatial elements (*linear* and *punctual*), and described by the non-spatial data tables attached to them.

Table 2 Attributes of linear and punctual features of the landscape classes analyzed

PATH	
LINEAR ELEMENTS	**PUNCTUAL ELEMENTS**
• Width percorribility • Road surface • Steps • Secirity parapet • Crossing	• Road nodes • Damages • Tourists
TERRACES	
LINEAR ELEMENTS	**PUNCTUAL ELEMENTS**
• Dry-stone wall size • Dry-stone wall type • Dry-stone wall state of conservation	• Dry-stone walldamages
VEGETATION	
LINEAR ELEMENTS	**PUNCTUAL ELEMENTS**
• Prevalent type • Invasiveness • Panoramic views	• Scenic points of interest

Therefore the project has actualized by the achievement of a geo-spatial database containing information of the two analysis scales related to the study area. On one hand there are the spatial data selected and organized for the documentation of the context and of the landscape values of the Cinque Terre, particularly about Vernazza: this assessments have laid the foundation of the critical approach targeted the next step.

On the other hand, there are the data produced by the experiment using 2D video mapping with GPS, along the path, which has taken an evaluation and selection of informative content about landscaped observed by the path. The processing of qualitative information from the images through their intrinsic geographically reference potential (GPS track recorded along with the video), in spatial data represented in the GIS.

Finally it was decided to prepare for the test-site two reading and valuation asset approaches: the documentation of the *geometric consistency* (Status Quo) and *landscape value* (State of Conservation).

The best way to read the elements of the landscape was undoubtedly the display for thematic maps. (Figures 14a, b, c) A major potential in terms of providing information, management of map data in GIS is just to be able to process different views of the same data, which is encoded according to the attribute in the user's choice.

Figure 14.a Features mapping which characterizes the physical-geometrical consistency of the path: the *width*

PATH WITH

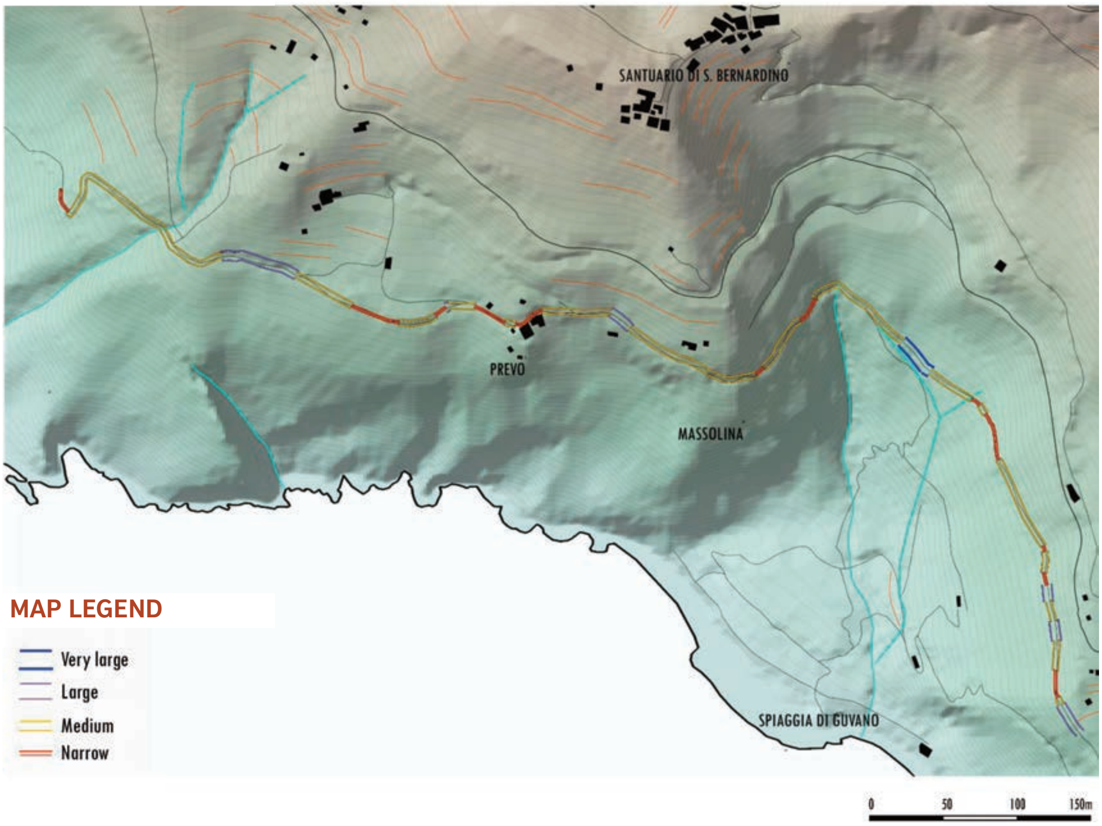


Figure 14.b The state of conservation mapping of the dry-stone walls in the path stretch analyzed

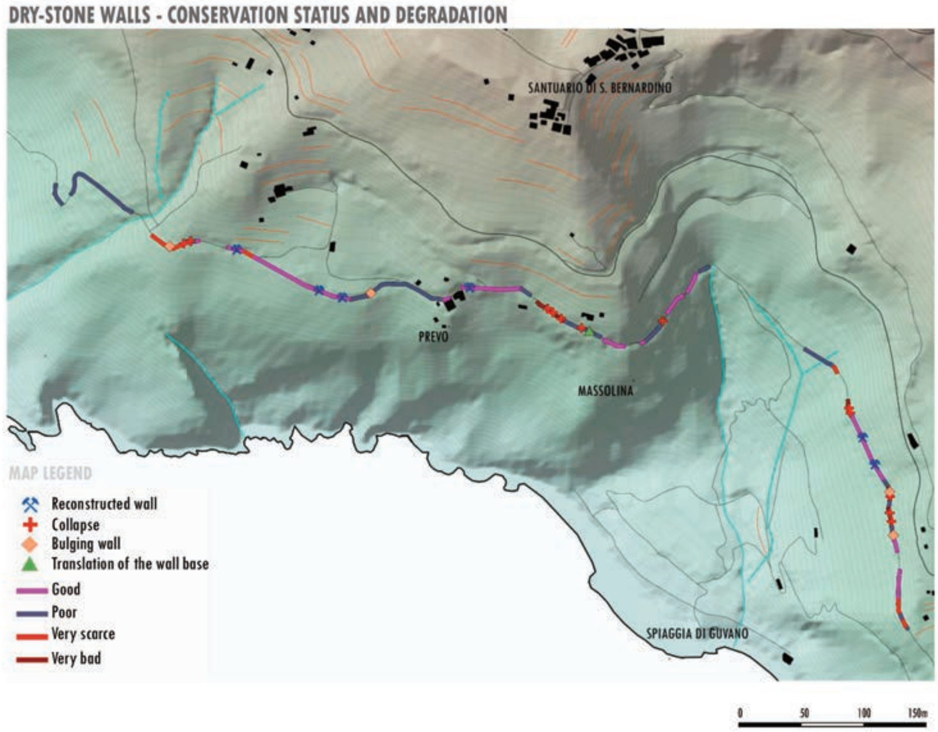
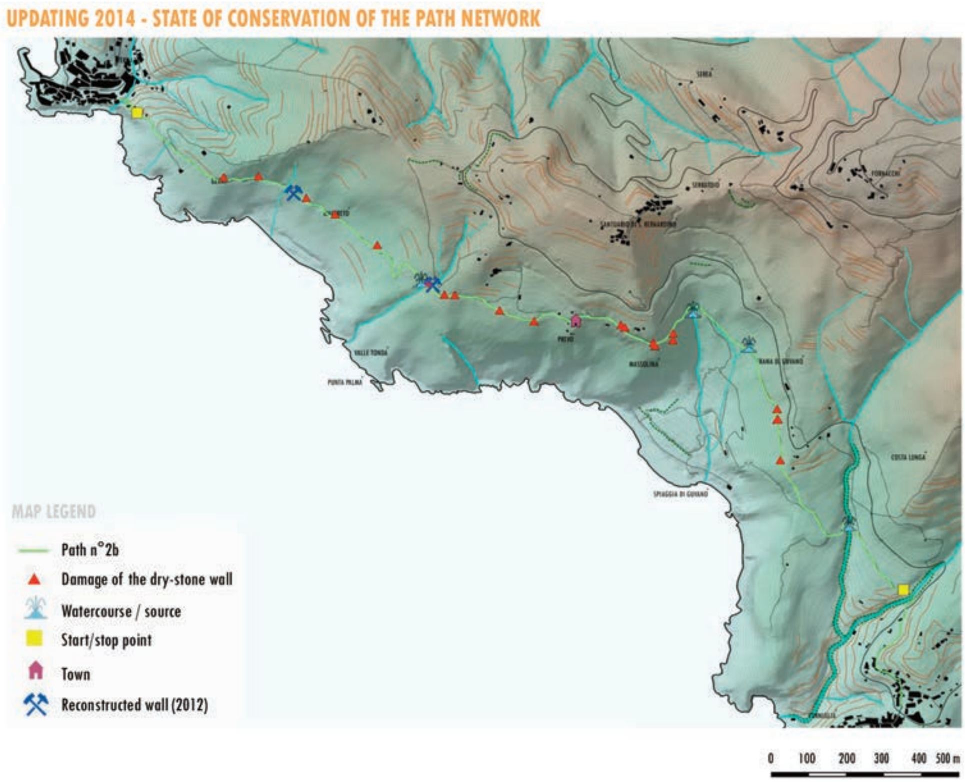


Figure 14.c Map showing the *path 2b* updating in 2014, compared to its condition detected in 2012



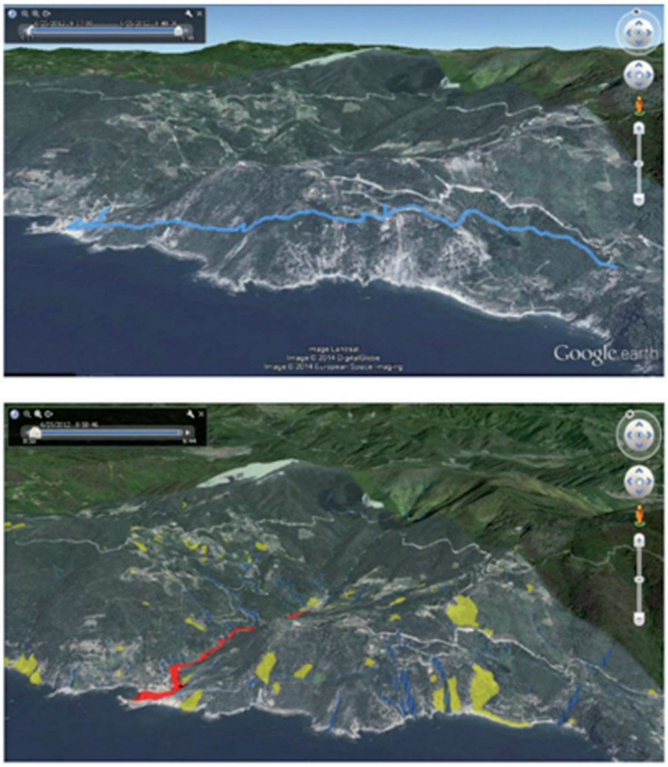
FUTURE PROSPECTS

The detection system illustrated is about the use of GPS technology in speed survey of spatial elements and information of the territory. As their size and distribution, they require a coordinated geospatial management, organized and controlled continuously in time, through an Information System. In the specific case of the *Cinque Terre* we tried to study the terms of the applicability of this quick survey in reference to the architectural heritage of terraced landscape, through the use of the path, as the vantage point for assessing the elements, but not unique object of survey itself.
Interesting details in such analytical work, can be any character with spatial value of the landscape that, through this method, can be accurately detected and recorded according to a previous planning. The proposal of the WebGIS of the path network of CAI, aimed at optimizing the detection time and the use of instruments, is certainly a relevant reference. (Vassena 2006, 2007)

By doing so you can build a real database useful to local authorities, and to the same Park Authority, consisting of geo-referenced spatial information, classified by codes, integrated and potentially upgradable at any time. This process can be done both by the user-experienced, locally, through the design of a of real-time update system (from the information on the ground to the infrastructure which manages the data), and by the same administrative system, in order to periodically upload data and information about state of preservation of the elements from time to time considered.
The possibility of web sharing (by mapping viewers of 2D and 3D maps) this information is very high: an example is the real-time visualization of 3D GIS data processed in Google Earth. (Figure 15)

From the operational point of view, GIS and WebGIS are increasingly interfacing with the users and with the possibility to use the data exchange on the web via PC or mobile devices. The development of operational protocols and a rigorous determination of a series of action levels, to encode user and administration and their related tasks, will increasingly facilitate the sharing, streamlining and refining operations for data exchange on the web.
The design of the management system must be planned from the beginning by a protocol that establishes order, accessibility and operations, broken down by the different levels of expertise that contribute to the management of the system. The good spread of this technology provides a very significant challenge to the spread of the culture of protection and preservation of local heritage, especially at risk.

Figure 15 Views of the flood damage in 2011 and a themed mapping path, by linear and areal datasets introduced in Google Earth system



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