Measuring long-term landscape change using historical photographs and the WSL Monoplotting Tool

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ABSTRACT

This paper assesses the potential of software developed by the research group of the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in order to georeference and vectorise historical landscape photographs. The use of this 'Monoplotting' Tool introduces a new application for topographical photographs and opens up the possibility of using such photographs for measuring land-use change. This paper reviews the literature on the use of historical photographs for landscape history. It introduces the new software and then goes on to examine how vectorised topographical photographs may help in the measurement of land-use changes in the mountainous landscape of Liguria and Trentino in the late nineteenth and twentieth century.

KEYWORDS

GIS technologies, historical photographs, land-use change, Liguria, Trentino, Italy, WSL Monoplotting Tool

INTRODUCTION

The reconstruction of past rural landscapes is often based on the analysis of maps and aerial photographs. In landscape history aerial photographs and maps are an important source to measure changes in vegetation and settlement. GIS (Geographic Information System) software allows historical documents to be georeferenced and vectorised to create land-use maps which can be overlaid and compared (Agnoletti 2006; Morgan *et al*. 2010; Morgan *et al*. 2017). This methodology has been applied in many different parts of Europe but it suffers from some inherent limitations. For example aerial photographs and maps are available only for certain years; in some cases they can be expensive to purchase. Many historical maps, such as those of the Italian Istituto Geografico Militare of the nineteenth and twentieth centuries provide an indication of different land uses but do not provide their boundaries. Aerial photographs are not readily available, apart from First World War battlefields, before *c*. 1920. The first American aerial photographs providing national coverage date from the 1930s (Stockdale *et al*. 2015); in Italy, the first national coverage was in 1954–55.

For earlier years scholars have made use of topographic photographs, which can go back to 1870s. For instance, Gruell (1980) used historical photographs to trace vegetation changes in some areas of the United States between 1871 and 1982 (for more detail, see Rogers, Malde & Turner 1984; Swetnam, Allen & Betancourt 1999). Within historical geography paintings, drawings and photography are recognised as an important source for understanding changes in landscapes and land uses (Piana *et al*. 2012; Piana *et al*. 2018; Watkins 2018). They have been used in two main ways: first, for understanding the cultural history of landscape representation, the creation of aesthetic categories and the development of local place identity (Cosgrove & Daniels 1988). Second, they have been used at a local scale to examine the rural practices and material processes which have shaped the landscape (Vecchio 2009; Gemignani 2010; 2013). Svenningsen *et al*. (2015) argue that oblique aerial and ground photographs can be an important means of improving people's awareness of the landscape history of the places in which they live. Exhibitions of historical photographic collections can encourage the discovery of previously unknown photographs through crowdsourcing and increase public participation in the conservation of cultural and natural heritage (Svenningsen *et al*. 2015; Gemignani 2010).

English researchers have included photography in the range of sources for investigating the relationship between history, ecology and landscape (Hoskins 1955; Peterken 2013). Scholars have discussed the documentary value and legitimacy of photography (Tucker & Campt 2009; Chabod 1978; Giordano 1981). Clarke (1997, pp. 55–74) stresses the importance of understanding the context of photographs and the entire process of production in interpreting it as a source. Certainly, photographs 'do not always tell the truth about the appearance of the landscape' (Howard 1991, p. 1). Peterken notes that 'it is tempting to treat paintings, drawings and, latterly, photographs as records of historic agricultural scenes and activities'; but that 'even detailed and apparently objective images are subjective and selective' (2013, pp. 332–3).

'Repeat photography' is a common method for the analysis of changes to vegetation at the local scale (Proctor, Spooner & Spooner 1980; Métailié 1986; Métailié 1988; Carré & Métailié 2008; Hendrick & Copenheaver 2009; Webb, Boyer & Turner 2010). As with other historical sources, photography needs to be interpreted and contextualised (Burke 2001; Mignemi 2003). According to Gemignani (2013), historical photographs should be considered in three stages. First, the picture needs to be contextualised, taking into account the date, the photographer, and the technical choices made. Second, the viewpoint needs to be identified on the ground, and the photograph needs to be compared with the current landscape. Third, the information from the photograph needs to be compared with other sources (textual, cartographic and botanical) in order to identify specific themes such as agricultural practices, vegetation, land use and settlement.

In Italy the first use of photography to investigate landscape history dates back to the work of Emilio Sereni in the 1960s on agricultural history (Vecchio 2009; Rossi & Rombai 2011). More recently, Moreno (1990, p. 52; Moreno & Montanari 1989) reflected on the value of historical photographs in ecological history, emphasising their increasing potential for collecting and providing detailed data. Moreno *et al*. (2005) argue that photographs are a key source, which together with documents, maps, field surveys, and oral histories constitute an essential tool for historical ecologists. The Laboratory of Archaeology and Environmental History (LASA) team of the University of Genoa (Italy) have used photographic evidence to reconstruct changes in landscape features and past land management practices. Cevasco (2007, pp. 106–9) used repeat photography to analyse changes in vegetation cover in Ligurian Apennine valleys. On the Mesco promontory in the Cinque Terre the changing pattern of vineyards has been demonstrated through the interpretation of historical photographs (Gabellieri & Ruzzin 2015). Gemignani (2013), analysing a photographic archive at Santo Stefano d'Aveto in the Apennines, defined photography as 'an active tool of work' to document landscape transformation in the twentieth century. Photographic collections in public and private archives are a valuable resource for the study of landscape evolution and changes in land use and settlement (Kull 2005). Postcards are a rich and readily available source of topographic photographs especially for the twentieth century (*c*. 1890–2010) and have great potential for studying the landscape as they frequently take in extensive views and are of high quality (Métailié 1986, p. 180; Watkins 1990, pp. 32–5; Perać 2009; Prochaska & Mendelson 2010; Robinson 2018).

Historical topographic photographs as a source for understanding land-use change have many advantages. Krebs and Conedera (2004) point out that nineteenth- and early twentieth-century photographs depict landscape views prior to the first aerial photographs, and can provide detailed evidence which is invisible from the aeroplane. But the use of repeat photography for change analysis has a number of weaknesses, particularly when compared to more systematically collected sources (Villareal *et al*. 2013, p. 196). For instance, the oblique angle of ground photographs makes it difficult to identify the precise location of depicted details. More importantly, the use of photographs has until recently been limited by the difficulty in georeferencing the picture in order to allow quantitative analyses of changes. For all these reasons, therefore, research has normally been limited to qualitative and relative assessment of landscape changes.

METHODOLOGY: THE MONOPLOTTING TOOL

The analysis of a single image is a subset of photogrammetry (Bozzini, Conedera & Krebs 2012, p. 502). Makarovic (1973) coined the term 'monoplotting' to describe a method for making a 3D reconstruction of a single oblique and unrectified photograph taken from the ground. In 2011, the Bellinzona Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) group developed computer software called the WSL Monoplotting Tool, which allows the georeferencing and vectorisation of topographic photographs. This application has the advantage of being intuitive, easily to use and shareware.[1]

Through this tool it is possible to vectorise landscape features represented in a single topographic photograph. The raster image is 'overlapped' on a digital terrain model (DTM), linking each pixel to attributes by geographic coordinates (latitude and longitude) and altitude. If the user identifies at least five control points between the DTM and the picture, the software is able to calculate the camera position and view and to georeference the image (Conedera *et al*. 2013). Later, the image can be vectorised in the form of punctual, linear and polygonal elements (Fig. 1). These geolocated elements can be exported as layers in GIS software, and overlaid with cartographic elements. Likewise, vector data can be imported into the platform and superimposed on ground photos (Bozzini, Conedera & Krebs 2013).

Fig 1

The reliability and accuracy of the georeferencing process are influenced by a number of factors: the quality of the picture; the number, distribution and precision of anchor points; the DTM definition and calibration accuracy. In addition it is important know the angle of perspective incidence on the surface of the DTM because as the incidence angle increases there is generally an increase in the accuracy obtained. For an effective result it is important that the specific area of interest is clearly and completely visible in the image (Bozzini, Conedera & Krebs, 2012). In other words, the analysis works well in hilly and mountainous areas; photographs of plains and valley bottoms are useful only if they are taken from a high point of view and with a sufficiently oblique angle. Bozzini, Conedera and Krebes (2012) and Steiner (2011) emphasise that the site morphology should remain substantially unaltered so that the current DTM is similar to the image. If these conditions are satisfied, georeferencing can be accurate to within 1 metre (Stockdale 2015). The method allows satisfactory geolocalisation with photographs but is less successful with paintings and drawings (Bozzini, Conedera & Krebs 2012; Stockdale *et al*. 2015). The utility of the software has been tested for assessing changes in mountain landscapes (Steiner 2011; Wiesmann *et al*. 2012), for changes in the amplitude of glaciers (Scapozza *et al*. 2014), for the reconstruction of landslide phenomena (Conedera *et al*. 2013) and for the evolution of vegetation cover (Stockdale *et al*. 2015; Conedera *et al*. 2015).

This paper considers the value of the WSL Monoplotting Tool software in analysing landscape change in three case studies, two in Liguria and one in Trento (Fig. 2). The data needed for the georeferencing process are:

- An historical photograph
- An aerial photograph or a georeferenced topographical map of the area depicted in the photograph
- A digital terrain model (DTM)

In our case, historical photographs were digitised at 300 dpi. Their georeferencing was carried out using the Regional Technical Map [Carta Tecnica Regionale (CTR)] of 2009 and the digital terrain model (DTM) of 2007, both produced by the Liguria Region.[2] For each image, at least nine anchor points were identified on the CTR, corresponding to immutable and easily recognisable elements of morphology or settlement, such as spires or buildings. Once the vectorisation operation had been completed, the elements were saved in shapefile format, imported by Qgis, the open source geographic information system, and then compared to the other available map sources.

Fig. 2

THE SANTO STEFANO D'AVETO VALLEY AND THE AGRO-SILVO-PASTORAL LANDSCAPE

In recent years the Laboratory of Archaeology and Environmental History (LASA) at the University of Genoa has developed a multi-disciplinary micro-analytical approach and applied it to environmental resources. This approach documents as precisely as possible local production systems and social practices that have affected environmental resources and created specific landscapes (Moreno 1990). Recent studies have examined how such knowledge of landscape history can be used to inform land managers and members of the public interested in the management of abandoned landscapes of historical and ecological interest (Gabellieri & Pescini 2015). Methodically, this approach is based on a local scale analysis and the use of a wide range of evidence to understand the processes that have given shape and content to the current landscape. Sequences of historical maps and aerial photographs are used to reconstruct the historical dynamics of vegetation cover and land use, emphasising continuities and discontinuities (Cevasco 2007).

Plate I [Fig. 3]

Plate I is a photograph of Santo Stefano d'Aveto in north-east Liguria with the readily identifiable Groppo Rosso Mountain in the background. The area is now part of the Regional Natural Park of Aveto and in 2010 it was selected for the National Register of Historical Rural Landscape (Agnoletti 2010). In the nineteenth century the area was well known for cattle and sheep breeding (Cevasco 2010).[3] According to Casalis (1849) in Santo Stefano there were 2,000 cattle, 1,160 sheep and 550 goats in the 1840s. Some traditional land management practices, such as grazing associated with cheese production, continue today (Cevasco & Poggi 2000).

The photograph was taken by the local photographer Adalberto Giuffra about 1889 (Gemignani 2007, p. 126; 2013, p. 65). The early date and high quality of the image make it particularly valuable for studying the history of land use. The area surrounding the town is intensively exploited: there are many terraces which are carefully cultivated; there are relatively few trees, and those that occur are found along the margins of the terraces to allow for cultivation and mowing. Some terraces are arable and others are used to grow hay; these different uses are intermixed. It is likely that many of the trees growing on the terraces are fruit trees including apple, pear and plum.

Using the Monoplotting Tool, the picture was georeferenced and partially vectorised.[4] The vectorised areas (which covered around 212 ha) were imported as a shapefile in Qgis. The vector layer was rectified and partially modified, in order to correct inaccuracies due to picture vectorisation. For instance, some small pieces of land which were not completely visible were integrated with adjacent land-use parcels. The different land uses are indicated by different colours on Fig. 3 which maps land use in 1889. Most of the land surrounding the town appears to be cultivated at this time. Around 33 *per cent* of the depicted area (70 ha) is arable land; some steeper slopes are terraced. Around the 20 *per cent* of the arable land is fallow which creates a pattern of different colours in the picture. Individual trees are scattered across the area. The upper parts of the slope (from 1,140 to 1,380 metres above sea level) are totally without trees and woodlands and are mainly devoted to pasture for grazing (53 *per cent* of depicted area, 114 ha).

Fig. 3 [4]

This map was compared with the information collected from the *Carta Generale degli Stati Sardi di Terraferma* of 1852 and the 2015 Land Use Map of Regione Liguria.[5] The 1852 map indicates broad areas classified as ‘cultivated field’ and ‘pastures’, and these were found to correspond with equivalent places on the 1889 photograph (Plate I). Since 1889 the area has undergone very significant rural depopulation and land abandonment. The resultant increase in woodland through natural regeneration of abandoned land and afforestation is clearly shown by comparing the 1889 and 2015 land-use maps. The two layers were overlapped using the tool *intersect* of Qgis (Fig. 4). This shows that 38 *per cent* of the area has become wooded (both natural regeneration and afforestation) and 26 *per cent* of the area has been abandoned and is covered by shrubs and rough grassland. The land nearest the town has been developed for houses and roads. The abandonment is mainly on the middle hill slopes while the new woodland is found on the mountain tops and in the steep river valleys. About 27 *per cent* of the area remains under the same land use. The photograph allows us to identify areas of ancient woodlands, which are of very small size, and former pasture areas, as well as the areas of new vegetation. The vectorisation allows us to identify those areas, mainly at the top of the slopes, where there is some continuity in the herb and shrub vegetation and which are likely to be fruitful sites for more detailed botanical and ecological surveys.

Fig. 4 [5]

TERRACED LANDSCAPES IN THE CINQUE TERRE NATIONAL PARK

Terraced landscapes are one of the most important and characteristic human imprints on Mediterranean landscapes (Dunjo, Pardini & Gispert 2003; Varotto 2008; Galland *et al*. 2016). They are increasingly being studied from different analytical and interdisciplinary perspectives (Palet & Riera 2000; Blondel 2006; Gimenez Font 2011). The historical and archaeological study of terracing is part of a broader interest in rural landscapes and the agro-sylvo-pastoral systems which shaped and safeguarded them. Now that many of these terrace systems have been abandoned for fifty years or more there is considerable interest in how they should best be conserved and managed as landscape features of heritage importance. There is also a need to understand the historical land management processes that sustained them. Scholars have stressed the importance of terracing in soil maintenance and to reduce erosion (Grove & Rackham 2003; Watkins 2004), as well as the increase in soil erosion due to their abandonment from the 1940s (Agnoletti *et al*., 2012; Tarolli, Preti & Romano 2014; Petit, Konold & Höchtl 2012). At Riomaggiore (Cinque Terre National Park), multi-disciplinary research at Case Lemmen and Cacinagora stressed the complex rural system of which the terraced olive orchards and vineyards formed a part. Seasonal pastures were integrated with the terraced fields, which required sheep and goats to fertilize the soil with the manure (Maggi *et al*. 2006; Stagno & Molinari 2014).

Various sources have been used to reconstruct past terraced landscapes (Scaramellini & Trischitta 2006). At Montalcino (Tuscany, Italy), for example, aerial photographs from 1954 were the main source (Armellini 2012); on the Greek island of Nisyros the research was based on field observation because of the low quality of the aerial photos (Petanidou, Kizos & Soulakellis 2008); in north-west Spain place names were used as evidence for terraced areas (Calvo-Iglesias *et al*. 2012). No existing studies have used vectorised topographical photographs for analysing changes in terrace landscapes.

The second case study examines historical photography in the Cinque Terre which became a UNESCO World Heritage site in 1977 because of its high landscape and cultural value. In 1999 it was designated a National Park because of its importance for the environment and natural history and it is enormously popular with tourists for its rocky coast, terraced vineyards and fishing villages. The majority of the steep coastal slopes are characterised by terraces, supported by dry-stone walls, for the cultivation of vines and olives. The abandonment of farming and the neglect of terraces from the 1950s onwards have led to a rapid increase in land degradation with serious threats to coastal settlements from erosion and rock falls. The case study is on the Mesco Promontory, which has been studied by LASA using historical cartography and archaeological survey. Field observation showed that there were many terraces which had not been depicted on nineteenth- and twentieth-century maps (Gabellieri & Pescini 2015). Can the vectorisation of historical photography help to locate unmapped terraces accurately? Moreover, can it be used to measure changes over time? Plate II - shows the northern side of the Mesco Promontory; the photograph was taken in 1911 from the town of Levanto. The resolution of the photograph is not particularly high, but terraces are clearly recognisable.

Plate II

The Monoplotting software was used to vectorise the visible terraced areas which were then imported as a shapefile into Qgis.[6] This allows comparisons to be made with maps of 1833 and current aerial photographs.[7] The comparison has been limited to a small area which corresponds to the most visible part of the picture. The results shown in Fig. 5 - indicate that in the selected area totalling 75 ha, the area of terraces has decreased from 40 ha in 1833 to 9 ha in 1911 and only 3.4 ha in 2016. This demonstrates that the greatest part of the decline took place in the second half of the nineteenth century, rather than the twentieth century. This decline can be linked to a reduction in the production of Levanto wine for the Genoese market and the decreasing importance of agriculture on the Mesco Promontory (Gabellieri & Pescini 2015). Another photograph, taken in Riomaggiore in 1962, offers more potential (Plate III). Due to its high definition, it is possible to recognise and vectorise every single terrace located on the northern slope of the town.[8] When the shapefile is imported into Qgis it is possible to measure the length of every dry stone wall. On a slope of 5.4 hectares with a mean slope of around 43 *per cent*, 5.5 km of walls were identified (Fig. 6); in the 1960s the land around Riomaggiore had a density of one kilometre of stone walls per hectare. This shows that the Monoplotting software can be an important tool for identifying and measuring the conservation importance and management requirements for terraces of heritage importance.

Fig 5, Plate III, Fig. 6 [7, 8, 9]

THE PRIMIERO VALLEY AND NATURAL DISASTERS

According to Dickie, Foot and Snowden (2002, p. 3), ‘there is no European society whose modern history has been more deeply marked by disaster than Italy’s’. However, Italian geographers have often neglected past and present risks and disasters as a field of study (Forino & Porru 2013). Researchers on landslide distribution still refer to the monumental work of Roberto Almagià (1907; 1910) who used data collected from local municipalities and institutions and field surveys to map all Italian landslides which took place around 1900. More recently, Palmieri investigated the historical distribution of landslides in Southern Italy (2004; 2006) and Flora and Gabellieri (2016) discussed the utility of place-names to identify landslide areas in Tuscany using historical records and field surveys integrated in GIS. The leading role in this field of research has been assumed by geologists. For instance, in 1991 the 7th AVI Project (*Aree Vulnerate Italiane*, Damaged Italian Areas) was set up with the aim of collecting and cataloguing all available data on landslides and floods occurring in the twentieth century (Guzzetti, Cardinali & Reichenbach 1994).

The introduction of GIS technologies has been a turning point for research in landslides and floods. GIS allows the integration of remotely sensed data, maps and field surveys from the national to the local scale, both for the study of past landslides and the prediction and monitoring of future hazards (Van Westen 1994; Carrara *et al*. 1999; Yamagishi & Bhandary 2017). Conedera *et al*. (2015) pointed out that the Monoplotting Tool can be useful for documenting natural disasters. The effects of landslides have often been hidden or removed subsequent to the event and later interventions make it difficult to identify their footprint using field survey or aerial photographs. Historical photographs of landslides can also provide useful information to planners and public institutions.

Plate IV [Fig. 10]

This case study focuses on two photographs of the flood and the landslide which damaged the town of Mezzano (Trento) in November 1966 (Plate IV). The pictures show the Primiero Valley and the flood of the River Cismon: the town was hit by a mudslide from the higher slopes and the small Stona Valley. Both photographs were taken by the first rescuers who reached the valley the day after the disaster.[9] In aerial photographs of 1988–89, the town appears completely rebuilt and the river canalised.[10] However, the georeferencing and the vectorisation of the two photographs allows us to identify the part of the town covered by the mudslide, and the level reached by the River Cismon in the lower valley.[11] The two features were vectorised as polygonal shapefile (the mudslide) and as linear shapefile (the overflow level), imported in Qgis and overlaid on the current vector map (Regional Technical Map 2012) (Fig. 7). As a final result, we can visualise in 2D maps the part of the city hidden by the landslide. The mud flood covered an area of 18 ha, from the Stona stream down the slope to the very centre of the town. In addition the part of the valley which was flooded in 1966 is now built up, mostly with storage buildings. This example demonstrates the potential of historical photographs to identify and map the impact of a past natural disaster at a site scale, so as to provide useful information for land management and planning.

Fig. 7 [Fig. 11]

CONCLUSIONS

The three case studies have demonstrated the significant potential of the Monoplotting Tool for analysing historical photographs for measuring small-scale land-use changes. It enables precise estimates to be made of the areas covered by different land uses at specific dates and comparisons can be made with current field surveys and other sources to measure landscape and land-use change. The first two case studies demonstrated the value of historical photographs for examining changes to the once intensively cultivated terraces and steep slopes characteristic of much of Liguria. The agro-silvo-pastoral system that included pastures, temporary arable cultivation and tree and woodland management has almost completely disappeared as a result of the agricultural exodus which began in the 1920s. Ligurian rural areas have been affected by land abandonment, the cessation of cultivation and grazing, and the natural regeneration of woodland and afforestation. In the case studies the cross-comparison between data collected from photographs and other sources is a step towards a better understanding of landscape history and the requirements of sustainable management of the landscape. In the third case study, the Monoplotting Tool allowed us to identify precisely the level reached by the river and the urban areas damaged by the mud landslide in the Primiero Valley during the 1966 natural catastrophe. Such identification is impossible using aerial photographs taken in 1974.

The use of georeferenced historical photographs can enrich historical analysis based on comparisons between maps and aerial photographs in GIS. First, historical photographs allow us to extend photo-interpretation analysis back to the late nineteenth and early twentieth centuries before the arrival of aerial photographs. Second, the photographs can provide different information than that in contemporary cartography, increasing the range of data available. The WSL Monoplotting software allows a qualitative and quantitative interpretation of repeat photography. In mountainous and hilly areas, therefore, the application of this technique enables quantitative assessments of land-use changes to be derived from historical photographs.

NOTES

1. The software is freely downloadable from the Swiss Federal Institute for Forest, Snow and Landscape Research WSL website https://www.wsl.ch/en/services-and-products/software-websites-and-apps/monoplotting-tool.html[01/06/2018].
2. The CTR and DTM of Liguria Region territory are available on the website *www.cartografia.regione.liguria.it/* [01/06/2018].

3. The Monoplotting software provides also the value of the georeferencing error for each control point. The height of the calculated error depends on the difference between the pixel values of the photo and the corresponding world coordinates in the DEM of the control points. Moreover, a statistical mean value represents the average of all point errors. In this georeferencing, the average error is around 30 metres. The maximum precision is in the centre of the picture and in the upper part (9.7 metres error value); the maximum of the error value (450 metres) is located in the right and left borders..
4. The *Gran Carta degli Stati Sardi* was created by the Sardinian Kingdom Army in 1850s to map the whole territory of the Kingdom. The document shows information on the settlement, roads and cultivation (Gran Carta degli Stati Sardi, Real Corpo di Stato Maggiore dell'Esericto Sardo, 1:50.000, 1853, sheet n. LXIX, Monte Penna). The Land Use Map was created in 2015 by the Liguria Region through photointerpretation of aerial photos (Carta Uso del Suolo, 1:10,000, 2015, Regione Liguria, available online by WMS service on the Ligurian Region cartography website http://www.cartografia.regione.liguria.it [25/06/2018]).
5. In this case, the calculated average error of the georeferencing is 600 metres. The lower degree of accuracy is due to the lower quality of the picture. Nevertheless, the maximum of the error value is located in the lower part of the picture, which represents the flat area (around 7000 metres); terraced areas are located where the error value is minor (8.9 metres).
6. Tavolette di campagna manoscritte eseguite per la Carta degli Stati di S. M. Sarda in Terraferma, 1:9450, Corpo di Stato Maggiore dell'Esercito Sardo, 1827-1833, sheet Levanto 20. Current photographs are at website of Regione Liguria.
7. The calculated average error of the georeferencing is around 40 metres. Nevertheless, around the town the error values are less than 7 m, while in the most distant cliffs the values are more than 500 metres.
8. Both photographs are at websites that commemorate the disaster:
9. Aerial photos of 1988–89 are at the Geoportale Nazionale of Italian Ministry of Environment (http://www.pcn.minambiente.it/geoportal) [06/06/2018].
10. In this case, the calculated average error is around 50 metres. The upper part of the picture have calculated error values of more than 700 metres, while the central part has higher precision (9.2 metres error value).
11. In this case, the calculated average error is around 50 metres. The upper part of the picture have calculated error values of more than 700 metres, while the central part has higher precision (9.2 metres error value).

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Captions for illustrations

Fig. 1. Screenshot of WSL Monoplotting Tool during the vectorisation of terraces from photographs of Riomaggiore (Liguria). The photographs are in the upper window; at the bottom the current CTR and the DTM of Ligurian Region.

Fig. 2. Location of the three case studies: Santo Stefano d'Aveto, the Mesco Promontory near Levanto and Riomaggiore (Liguria) and Mezzano in the Primiero Valley (Trentino Alto Adige).

Plate I. [Fig. 3] The town of Santo Stefano in the Aveto Valley, Adalberto Giuffra, 1889 (Gemignani 2007, p. 126; 2013, p. 65).

Fig. 3. [Fig. 4] Land use and coverage around Santo Stefano d'Aveto in the nineteenth century; result of the vectorisation of topographical photograph (1889) and historical map (1852).

Fig. 4. [Fig. 5] Changes in land use and coverage around Santo Stefano d'Aveto from 1889-2015: comparison of the 1889 map (Fig. 3) and the current Land Use Map of Liguria Region (2015).

Plate II [Fig. 6] *Levanto da strada della Baracca*, postcard, Levanto, 1912 (Gabellieri & Pescini 2015, p. 66).

Fig. 5. [Fig. 7] Terraced areas in the northern side of Mesco Promontory (Levanto). The map is the result of the vectorisation of historical cartography (T*avolette di campagna*, 1827), the historical postcard (1912) and current aerial photographs (2016).

Plate III [Fig. 8] *Le Cinque Terre, Riomaggiore, Panorama*, Postcard, 1962.

Fig. 6. [Fig. 9] Terraced area close to Riomaggiore (Liguria) in 1962. The map is the result of the vectorisation of the 1962 postcard using the WSL Monoplotting Tool (Plate III). Each terrace was vectorised and overlapped on the Regione Liguria CTR (2012).

Plate IV. [Fig. 10] The town of Mezzano (TN) immediately after the flood of November 1966.

Fig. 7. [Fig.11] Map of the mudslide and flood extension which affected the town of Mezzano (TN) in 1966. The map is the result of the vectorisation of photographs (Plate IV) using the WSL Monoplotting Tool. The layer was overlapped on the current CPT vector layer of the Province of Trento.