




Article

Web Mapping and Real–Virtual Itineraries to Promote Feasible Archaeological and Environmental Tourism in Versilia (Italy)

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Abstract: The Versilia plain (NW Italy) experiences forms of tourism that are mainly limited to the beach area and concentrated in the summer season. The area is rich in cultural and natural heritage, not yet adequately enhanced. The presence of four local archaeological museums and a natural park offers a great opportunity to favour feasible archaeological and environmental tourism. The aim of this study is to use a holistic methodology to improve a different type of tourism in the study area. We propose a consilient multidisciplinary approach based on geological, biological and archaeological data in order to enhance the cultural and natural heritage of the Versilia plain. We have based our study on the reconstruction of palaeoenvironment maps showing the evolution of the territory and used them as a leitmotiv to link the archaeological museums and the natural park. We define real and virtual itineraries to create a synergy between the most important archaeological and natural sites and museums. It is possible to promote a different type of tourism in the study area by decreasing human impact and creating a relationship between the fragmented natural and archaeological heritage. Palaeoenvironment maps and real and virtual itineraries can be consulted with the aid of a web application, more specifically web mapping, developed with free and open-source libraries. The web mapping also contains other geological, geomorphological and archaeological datasets, which allow to understand the evolution of the environment and the cultural and natural heritage of the study area. The dataset available on the web mapping is also downloadable.

Keywords: consilient approach; real itinerary; virtual tour; web application; sustainable tourism; web mapping; palaeoenvironment map

1. Introduction

Tourism on a global scale is an economic sector that has undergone tremendous growth over the last 50 years [1,2]. Unfortunately, this growth has not always had a positive effect on the destination locations that have sometimes experienced overtourism [3]. Fortunately, in recent years, this marked growth in the tourism sector has also seen a shift towards sustainable forms of tourism [4]. Sustainable tourism can be defined as tourism that considers its current and future impact on the environment, society and economy whilst meeting the

needs of customers, industry, the environment and host communities [1,2]. In sustainable tourism, the negative impacts on the destination (e.g., economic leakage, damage to the natural environment and overcrowding) need to be compensated by positive impacts (e.g., job creation, cultural heritage preservation and interpretation, wildlife preservation and landscape restoration) [5]. After 2017 (the year of sustainable tourism), public awareness of the concept has increased, consolidating a trend that is starting to make inroads in terms of expectations and conduct of both those who travel and those who operate in the industry [6]. In this global trend, Italy—for which the tourism sector accounts for more than 5% of GDP and more than 6% of employment—is not an exception [7]. Particularly relevant are the safeguarding and promotion of its cultural heritage, one of the country's indisputable assets, as well as the protection of its environment [7]. However, tourism potential still needs to be better exploited by the coordination of tourism policies [7]. Indeed, some areas still experience undersized tourism, while other areas risk overcrowded tourism [7]. Versilia is mainly characterised by seaside tourism focused on the beach, where there are overcrowded phenomena, especially during the summer season; on the other hand, the numerous cultural and environmental assets of the immediate hinterland are hardly known and visited. In this territory, there are four archaeological museums, several archaeological sites and important environmental assets, among which the Lake of Massaciuccoli (Site of Community Importance and hot spot of biodiversity—one of the most important wetlands of the Italian peninsula) stands out [8]. However, as a result of the lack of synergy and of a shared strategy among the managing bodies, tourism linked to these cultural/natural sites is still undersized.

Web mapping [9], which is the process of implementing and displaying maps on the World Wide Web, allows the visualisation and updating of geospatial data. Web mapping facilities are widely used to store and display geological and geomorphological data from national geological and cartographic surveys. The aim of web mapping is to create platform-independent software systems open to every computer connected to the internet and running on an appropriate web server [10].

Web mapping integrates two powerful technologies: GIS and the internet, by providing global connectivity [11]; the result of this synergy translates into greater ease in finding data, sharing analytical tools and reaching a greater number of users [12,13].

Several studies have developed WebGIS and web mapping in various fields, including radon risk management [14], a risk assessment system for heavy metal pollution [15], georeferenced bibliographies [16], wastewater treatment [17], systems for monitoring and managing the aquatic environment [18], planning and emergency phases in the event of floods [19] and management of transport infrastructures [20].

In the area of geoheritage studies, GIS and web mapping technologies have already been used in various fields, including digital field mapping [10,21], visualisation of geoheritage data on open-source interfaces [10,21–24] and virtual trips [23,25,26]. In particular, the purpose of such applications is to take advantage of new technologies to enhance the value of geodiversity and archaeology through a virtual itinerary [24,27–29].

In order to obtain a usable web map, the design should be adapted not only to the preferences and needs of the user but also to provide the requested information efficiently and easily. Third-generation mobile phones constitute an infrastructure with strong potential for the interpretation and promotion of geosites. They combine the necessary operating system (Android or iOS) with GPS georeferencing and an internet connection, which offers a wide range of opportunities such as location-based information [21,30], QR codes or multimedia content.

In this study, we would like to promote a new synergy among all the stakeholders involved (nonprofit associations, management authorities, museums, natural park authorities, research entities, tourism industry operators, local communities, tourists, etc.) in order to propose forms of archaeological and environmental tourism in an area characterised by high archaeological and natural heritage, not yet adequately known and visited.

All stakeholders are involved in the creation of real and virtual tours based on palaeogeographic maps and connecting the most important archaeological sites, museums and natural assets of the study area. These real and virtual networks are enhanced by the activation of an open-source web application for the visibility and consultation of different data typologies useful to improve the knowledge of the study area.

2. Study Area

2.1. Geological Background

The study area is located in a part of the so-called ‘Versilia plain’, administratively belonging to the Lucca Province and to the municipalities of Pietrasanta, Forte dei Marmi, Seravezza, Stazzema, Camaiore and Viareggio.

The area is morphologically divided into three altimetric bands, which are parallel to the coast. Indeed, we can distinguish a mountain sector with maximum elevations higher than 1500 m a.s.l. (M. Altissimo, M. Corchia, M. Pania della Croce), and characterised by a diffuse outcrop of Mesozoic metamorphic and carbonate rocks positioned on a Paleozoic schist-philladic basement [9–11,31–33].

This territory is historically characterised by rare and sporadic settlements of small villages associated with pastoral or mining activities (Vologno, Pruno, Azzano, Stazzema, Casoli) [34]. The second altimetric band is characterised by small hills and large alluvial fans formed in the Pleistocene and characterised by a low slope (generally less than 5%). In this altimetric band, some important villages (e.g., Massarosa, Pian di Mommio, Querceta) are located along the historic road axis (Aurelia and railroad), and others at the confluence with transversal valleys (Seravezza, Pietrasanta, Camaiore).

The third altimetric band is characterised by the coastal plain, whose formation took place in the Holocene as a result of the progressive juxtaposition of beach ridges formed thanks to the sediments brought to the sea by major rivers (Magra to the north and Serchio and Arno to the south) and reworked by coastal currents [35]. Locally there are wetlands (e.g., Porta Lake and Massaciuccoli Lake), which can be interpreted as relics of lagoon areas progressively isolated from the sea by the formation of seaside ridges [35–38]. These wetlands are strategic ecosystems: in terms of biodiversity, 40% of all plants and animals live or breed in wetlands and are quickly disappearing due to human impact and climate change. The importance of these areas is set off by the Ramsar Convention that protects both (<https://www.regione.toscana.it/-/aree-ramsar> (accessed on 11 May 2022)). Thus, this action would contribute to helping vulnerable regions and communities to improve their resilience in agreement with the goals of the UN 2030 Agenda: 13—Climate Action and 15—Life on Land.

Towards the sea, the system of beach ridges extends for about 4 km from the lake to the sea and ends with a large beach characterised by an uncommon advancement trend. An extraordinary system of coastal dunes is preserved in proximity to the current beach [37,39].

Since the early 1900s, progressive urbanisation has taken place in this area, starting from the city of Viareggio (located south of the study area; Figure 1). This phase of progressive urbanisation of the coastal plain has rapidly led to huge transformations, as far as the so-called ‘continuous coastal city’, which is the almost seamless urbanisation of the entire coastal strip, typical of several Mediterranean coastal plains. The increase in anthropogenic pressure in this area could threaten the ecosystems of the wetlands and of the dunes, which are particularly fragile.

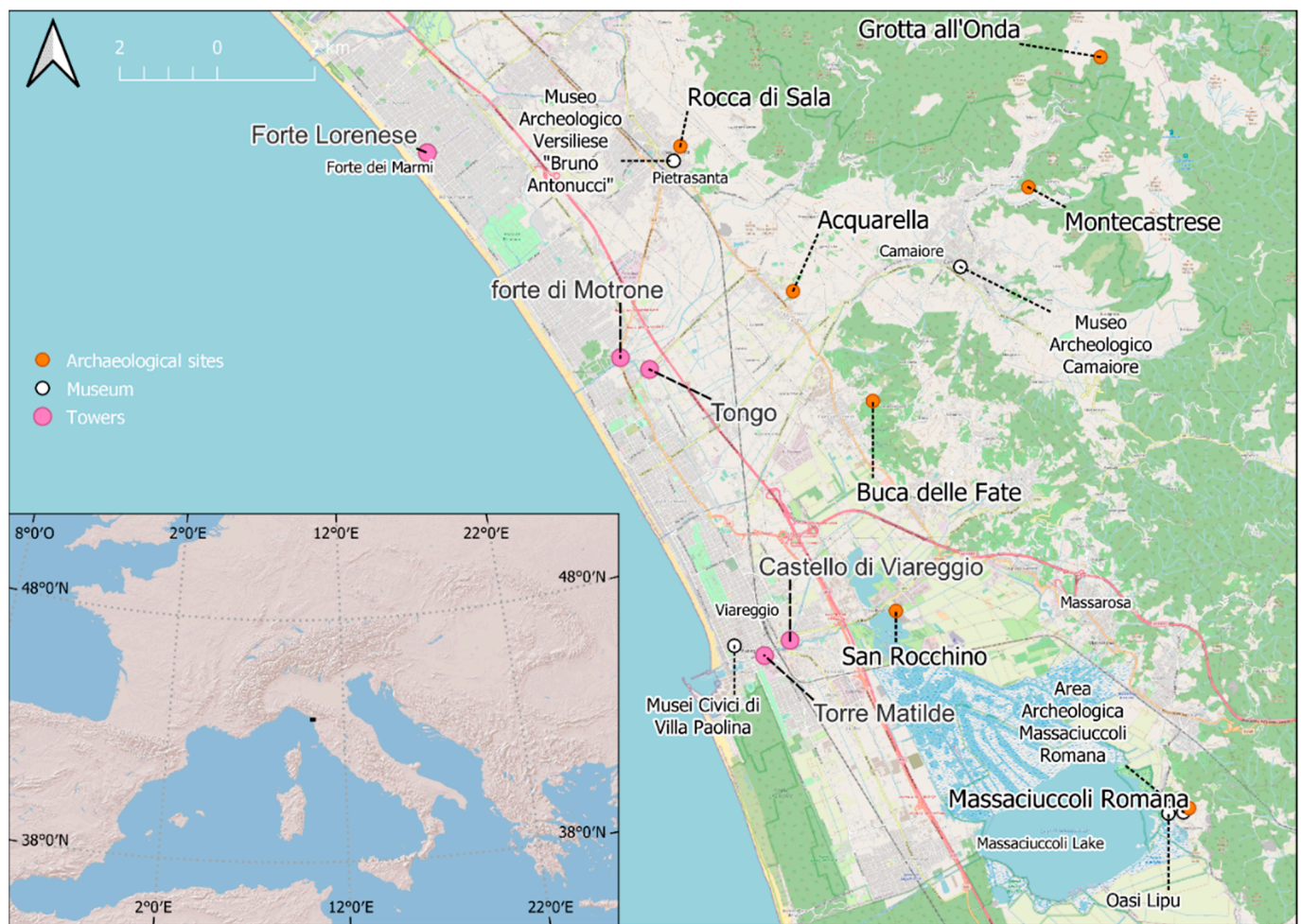


Figure 1. Study area. Background: OpenStreetMap (Cowley Road, Cambridge, United Kingdom) and ESRI ((Redlands, California, USA) Shaded Relief (insert).

2.2. Archaeological Background

Human settlements in the study area are testified by many archaeological findings that have been recorded since the 16th century.

Since the Neolithic period, human presence has been confirmed by the findings of several artefacts, especially those of the site of Grotta all'Onda (Figure 1) [40].

During the Etruscan Age, the relevance of maritime commercial activity is testified by the settlement of San Rocchino (Figure 1), located on the ancient coast. This site was continuously inhabited from the end of the eighth century B.C. to the third century B.C. and was located on the border of an ancient lagoon area, whose remains at present are identifiable in the Massaciuccoli Lake.

In the same period, the Migliarina site (Figure 1), a productive and specialised settlement dating back to the end of the seventh century B.C., developed on the beach ridge, separating the lagoon from the sea and marking the coastline position of that time.

Moreover, the Acquarella site (Figure 1) shows a remarkable continuity of human settlement from the Etruscan Archaic period to the early Middle Ages [41]. The burial site found at Villa Mansi, close to Acquarella (Figure 1), perhaps part of a necropolis, suggests the existence of a village and demonstrates the vitality of the area since the end of the seventh century B.C. [42].

As for the Roman Age, weak traces of centuriation, as well as occasional discoveries on the beach ridge (Figure 1), confirm the dense settlement of this area [35]. The most important evidence of Roman times is the land roads attested in this area by ancient sources, maps, aerial photograph analyses and archaeological remains [43]. An important road,

which could be identified with the Aurelia/Aemilia Scauri, ran along the past coast, another one along the foothill. Both roads linked Pisa to Luni. A third road connecting the inland (i.e., Lucca) to the coast is documented in the Camaiore valley near the Acquarella site.

Montecastrese, the most populated castle of Versilia, was built between the 10th and 11th centuries and occupied an important position in the control of the territory (Figure 1).

The Fortress of Motrone (Figure 1), erected in *maris litore* [44], and the Old Castle of Viareggio (Figure 1), built during the 12th century A.D., are important reference points for dating the shift of the coastal position during the Middle Ages. The construction in the 16th century of Tower Matilde in Viareggio and of Forte Lorenese in Forte dei Marmi (Figure 1), in a more advanced position than the old fortress, demonstrates the gradual advance of the coastline.

3. Materials and Methods

Our study aims to create a network among people with different jobs and competencies to intertwine different knowledge. This approach can help to create a synergy with researchers of different disciplines (e.g., geology, archaeology) and with people working on the territory, which could enhance the dissemination of cultural and natural heritage (archaeological museums, hiking associations, etc.). This holistic method would make it possible to complete and increase the great amount of knowledge already available in the territory and to put different subjects in synergy with one another. Figure 2 shows the workflow and stakeholders involved in each section.

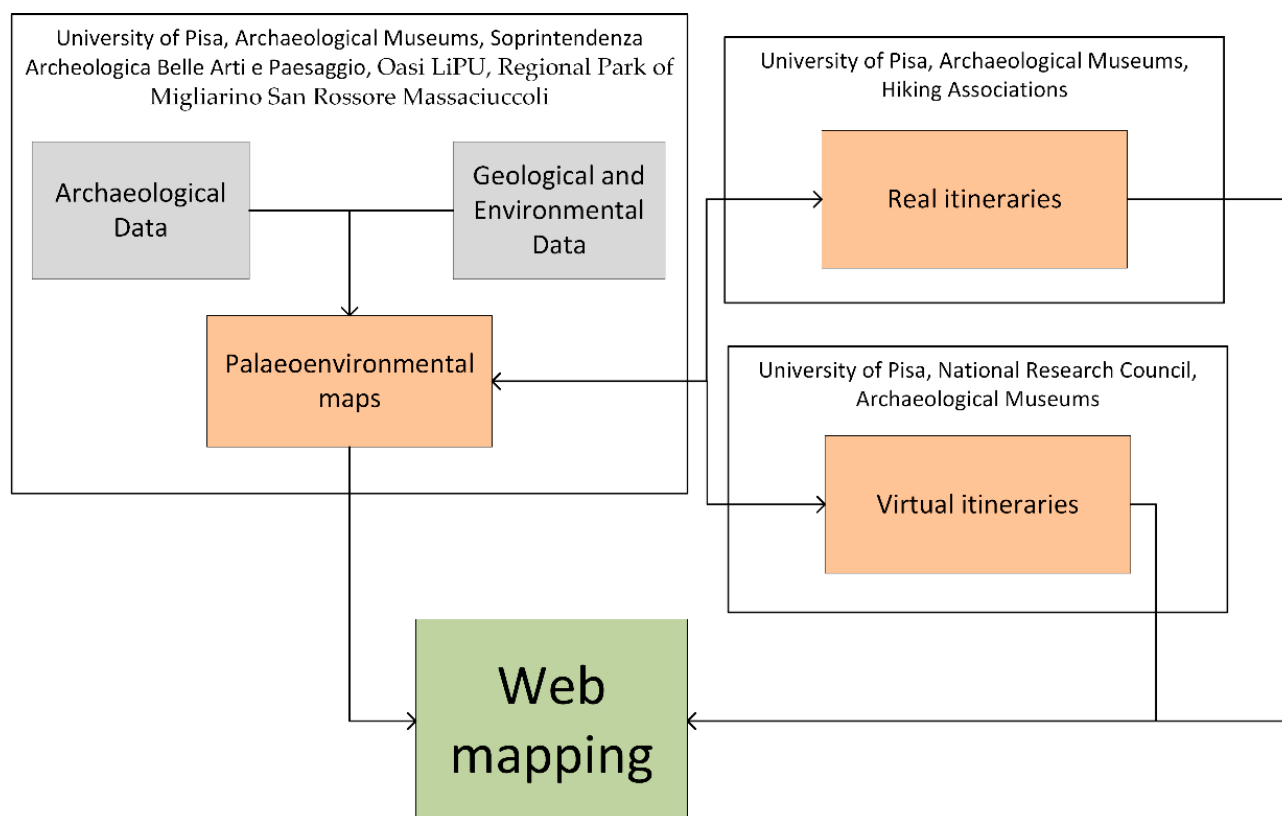


Figure 2. Research flowchart. The diagram shows the stakeholders involved in each section of the work. The grey rectangles are the bibliographic data, the red rectangles are the intermediate results and the green rectangle is the final result.

By the integration of different disciplines (geology, archaeology, biology), we reconstructed seven palaeoenvironmental maps describing seven chronological periods during which the area was settled. The periods investigated are the Last Glacial Maximum dated about 20,000 years B.P., the end of deglaciation about 7000 years B.P. and the Etruscan,

Roman, Middle, Modern and Contemporary Ages. The palaeoenvironmental maps were derived from a review of bibliographic analyses [31,35,36,45] and from newly integrated data coming from core analysis, historical cartography, remote sensing analysis, morphological analyses and geomorphological surveys. The analyses were conducted in a GIS environment using the open-source software QGIS v3.x. In particular, according to [46], we reconstructed the shoreline position at about 120 m below current sea level for the Last Glacial Maximum period and at about 8 m above current sea level for 7000 years B.C. [47,48]. In the maps, the estimation of the shoreline is based on the bathymetric measurement provided by the National Geoportal (<http://www.pcn.minambiente.it/mattm/>) (accessed on 11 May 2022) and on the digital elevation model (DEM) provided by the Tuscany region, with a resolution of 10 m.

The maps related to the other chronological periods were obtained from the integration of geological with archaeological data. For example, we used subsoil data to identify the extension of the Massaciuccoli Lake over time, and geomorphological combined with subsoil and archaeological data to identify the beach ridges.

This study is based on the implementation of a PostgreSQL database with a PostGIS extension to store and standardise the data produced and used in this project. The PostgreSQL database is installed on a hosting virtual machine accessible with the HTTP protocol and usable for the consultation of the data by desktop software and web applications.

A web application was developed by using HTML, JavaScript, PHP languages and exclusively open-source libraries. The front end of the web application is responsive and operates on both desktop and mobile devices. The web application is characterised by a web GIS implemented by the open-source geospatial library 'Open Layers'. The application is interfaced with the PostgreSQL database through the employment of the Geoserver application. The Open Layers library allows to load Web Feature Services (WFSs) and Web Map Services (WMSs) on a map by querying the Geoserver service. All layers are stylised according to the types of geometries and the database of the vectors. The web mapping allows to create an interaction between the user and the data of this research with two specific functionalities. The former consists of the possibility of clicking on one or more features to obtain some important information with the initialisation of a table on the interface. The visualised data can be texts, images or hyperlinks, and this allows to explain the geographic data and create an interaction between the user and the data of this research. The latter consists of the possibility of exporting the WFS in KML format, compatible with several GIS applications, such as desktop software (e.g., QGIS), web applications (e.g., Google Earth) and mobile apps for smartphones and smartwatches. This functionality makes it possible to apply the fundamentals of the open-data concept. The web application contains the palaeo maps, the virtual tours and the main natural and cultural heritage, together with several other layers that can help improve knowledge of the territory, as well as cultural and archaeological sites such as museums, environmental data, cartographies and aerial photos. In collaboration with some hiking associations, we identified nine itineraries that could link the different natural and cultural sites together, for example, an archaeological museum with its relative site and with other museums. The hiking associations will organise excursions so as to evaluate the real practicability of the itineraries in terms of distance and travel time. These itineraries are achieved in the PostgreSQL database with PostGIS extension using QGIS v3.x.

We have realised some information panels of the main archaeological and natural sites (such as Grotta all'Onda, LiPU, etc.) in both Italian and English. Some of these information panels have been installed along the real itineraries, and all the information panels are available for consultation through the web application.

The network between the sites and the museums is also incentivised with the development of virtual itineraries available for consultation on the web application.

The elaboration of the virtual tours is based on photos taken in indoor and outdoor environments by using two photographic instruments: (i) Canon 550D APS-C camera with 16 mp, 8 mm fisheye optic, panoramic head with eight sequential photoshoot posi-

tions for a resolution of 12K; and (ii) six images Kandao ObsidianR 8K 360° camera with pixel-level synchronisation technology. The images are processed by the open-source software RawTherapee for calibration of the chromatic dominant and for luminosity control. We applied the high dynamic range (HDR) technique to the 360° photos by combining a minimum of three images acquired with different exposition values: normal (0 EV), overexposed (+2 EV) and underexposed (−2 EV). The HDR technique allows for the creation of environment images with illumination levels that are more extensive than those resulting from a single photograph: the shadows and highlights are made legible by bringing the brightness and contrast values of the image closer to the perception level of the human eye. The virtual tours are based on 360° images with the Krpano software, which uses XML language. XML language allows to manage the graphic layout, modality of fruition, hyperlinks, organisation of the various graphic elements, text contents, multimedia elements, photos, video and audio of the virtual tour.

4. Results

Figure 3 shows the palaeoenvironmental maps referred to as 20,000 years B.P. (a), 7000 years B.P. (b), Etruscan Age (c), Roman Age (d), Middle Ages (e), Modern Age (f) and Contemporary Age (g). The oldest period is characterised by a sea level lower than the current one by about 120 m [46]. This corresponds to a shoreline position located about 20 km westwards of the current one. The area between the current shoreline and the Last Glacial Maximum shoreline was occupied by a wide coastal plain. With progressive deglaciation, we observe a sea level rise in the Versilia plain about 7000 years ago, when the sea reached the foothill of the mountains [47]. In the Etruscan Age, owing to the sediment carried by the main rivers and reworked by coastal drift, the first beach ridge system formed, isolating coastal lagoons behind. Successively, we observe a progressive shift of the beach ridge system towards the west, which allowed the development of the coastal plain in its current conformation. In some periods, the Massaciuccoli Lagoon gradually became a coastal lake and wetland developed in its surroundings. Specifically, between the Roman and the Middle Ages, the Massaciuccoli Lake assumed a shape that was very similar to the current one. For each historical period, Figure 3 reports the main human settlements and coastal towers located near the shore so as to be able to precisely identify the shift of the lake over time.

Figure 4 shows the nine natural and cultural itineraries identified in synergy with the local hiking associations. The first, second, third and fourth itineraries link the archaeological sites of Montecastrase and of Grotta all'Onda with the Camaiore Museum. These routes create a link between the archaeological sites and the Camaiore Archaeological Museum, where the findings and the documentation of these important sites are stored. The fifth itinerary links the archaeological area of the Roman Massaciuccoli with the Chiarone Nature Reserve situated within the Migliarino San Rossore Massaciuccoli Natural Park and then to the small village of Torre del Lago Puccini. A track around the lake starts from the small village and ends on a wide natural beach characterised by a system of well-preserved coastal dunes. The sixth itinerary is a little city route linking the Pietrasanta Archaeological Museum with the cultural site of Rocca di Sala. The seventh itinerary starts from the civic museums of Villa Paolina in Viareggio and ends at the Camaiore Archaeological Museum, going past the geoarchaeological site of Buca delle Fate. The eighth itinerary links the Museum of Camaiore with the geosite of Buca delle Fate through a mountain and hill track. Finally, the ninth itinerary links the museums of Pietrasanta and Camaiore through the Via Francigena route, the most famous of the medieval tracks.

The real itineraries are associated with the virtual tours, and some example images are reported in Figure 5. The virtual tours are available for consultation at the link (<http://tlweb.it/pantarei/gis/>) (accessed on 11 May 2022). The virtual itineraries are based on the creation of a link between the archaeological sites and the museums. We have also increased the multimedia and content information on the cultural and natural places that are worth visiting. With the same purposes as the natural tours, we have realised five virtual tours

according to the different chronological periods analysed on the basis of the relative palaeogeographical maps. The five virtual tours are, specifically:

1. 'Grotta all'Onda', which shows the prehistoric environment in Versilia;
2. 'Museo di Viareggio', which allows to create a transition from the prehistoric to the historic period;
3. 'Museo di Pietrasanta', which regards the Etruscan Age in Versilia;
4. 'Villa Mansio, Villa Venulei Appropriati', which is referred to the Roman Age;
5. 'Il paesaggio naturalistico attuale', which describes the LIPU site and the importance of the wet areas and their preservation.

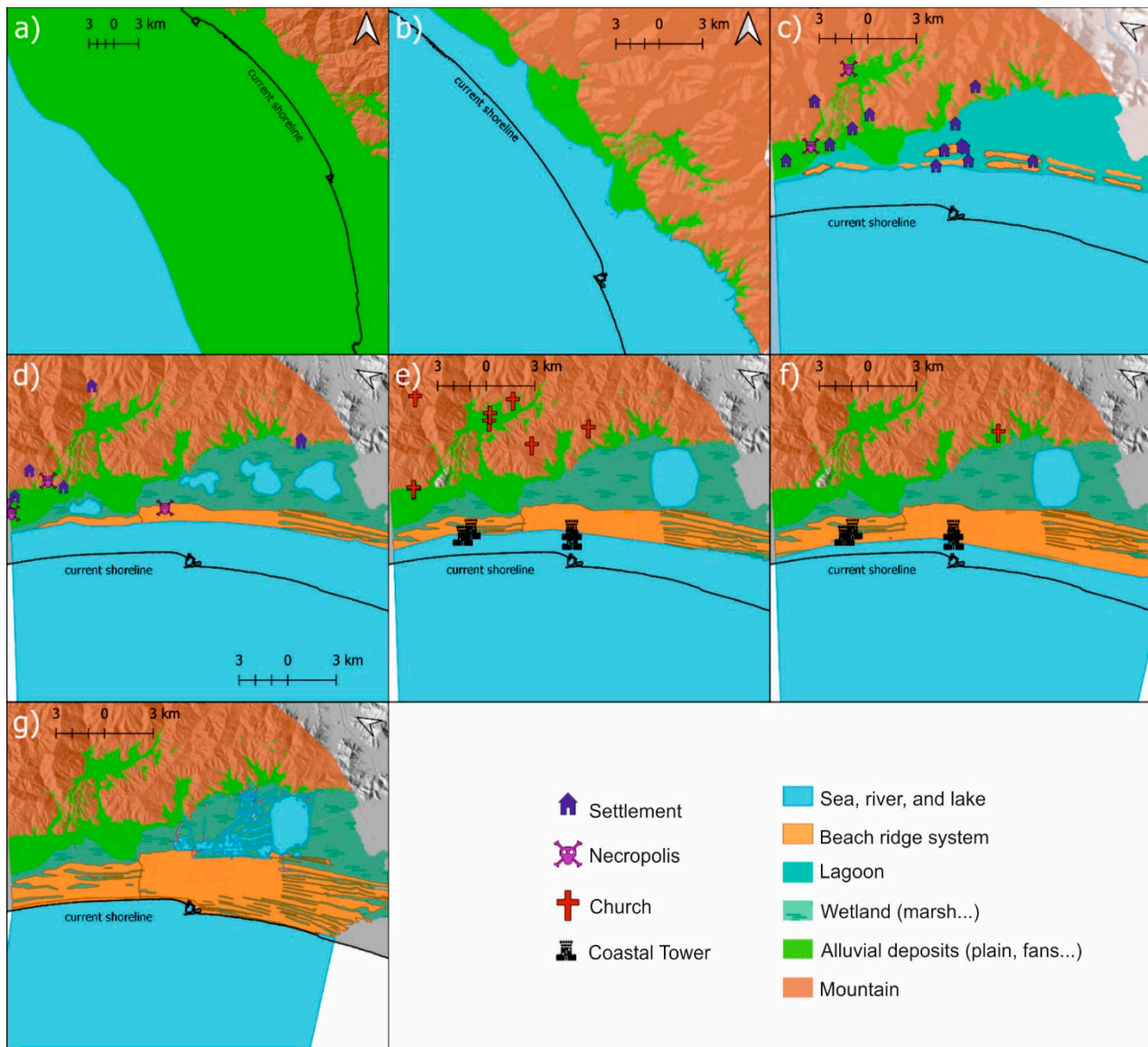


Figure 3. Reconstruction of the palaeoenvironment of (a) about 20,000 years B.P., (b) about 7000 years B.P., (c) Etruscan Age, (d) Roman Age, (e) Middle Ages, (f) Modern Age and (g) Contemporary Age.



Figure 4. Real itineraries linking the archaeological sites with the museums, as proposed in this study. These initiatives can help to incentivise inland tourism. Background: OpenStreetMap.

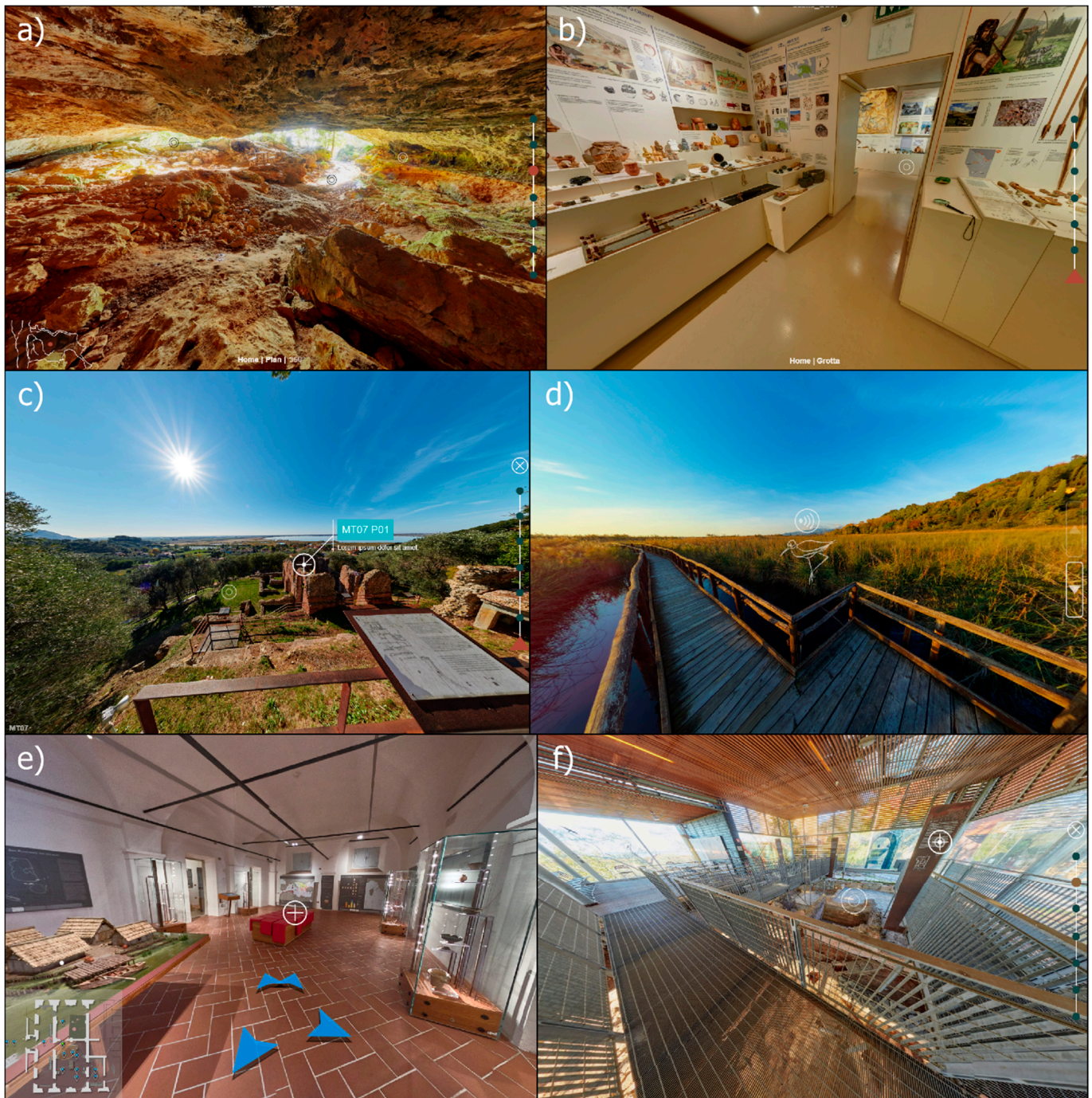


Figure 5. Some 360° images used to create the virtual tours: (a) Grotta all'Onda; (b) Museo Archeologico Camaiore; (c) Massaciuccoli Domus from a viewpoint; (d) Oasi Lipu; (e) Museo Archeologico Versiliense 'Bruno Antonucci' (Pietrasanta); (f) Massaciuccoli Terme.

The web application interface is composed of a toolbar on the left, a map in the centre and a menu on the right (Figure 6). The web application is available for consultation at the following link: <http://tlweb.it/pantarei/gis> (accessed on 11 May 2010). The toolbar is provided with some functions for the navigation, selection and management of the map. In the menu, the layer tree view in the menu permits to manage the layers, with the possibility of making them visible, moving them, downloading the dataset and viewing the style of the layers. By using the web application, it is possible to visit both the real and the virtual itineraries and to gain territorial as well as cultural information.

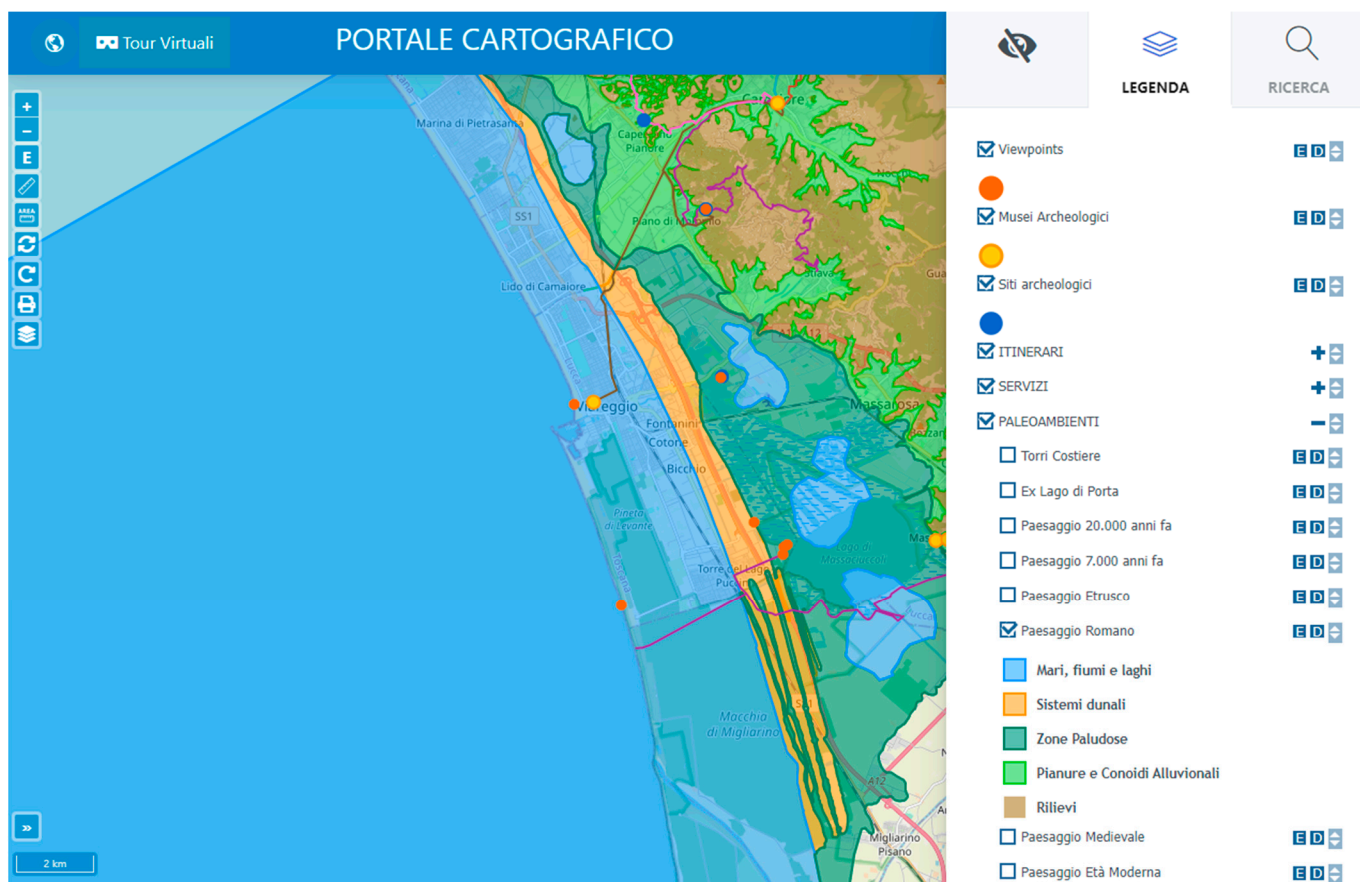


Figure 6. Web application developed in this study. The application is a web GIS reporting all the results of this study (palaeoenvironmental maps, heritage and virtual tours). The web application aims to improve the link between results and to provide an interface for querying and disclosure of the data.

5. Discussion and Conclusions

The use of web mapping for disclosure of territorial information and the enhancement of cultural and natural heritage was a valid instrument in agreement with several previous studies (i.e., [10,21–25]). The web mapping, usable by different devices (PC desktop, smartphone, etc.), can provide visibility to the territory, and this is accentuated with the creation of virtual itineraries [24–28].

This study takes a step forward compared to others by creating a triple link between real and virtual tours and making them available on a platform that allows you to consult geographic information but also other information such as information panels, tabulated data, images, etc.

The Versilia plain witnesses the history of a long human–environment interaction dating back to the Prehistoric Age. This history can still be read through the cultural and natural assets characterising the area, which tell the story of both environmental evolution and the history of settlement.

Thanks to a strong integration of data from different sources, it is possible to describe a story that can intrigue the visitor, going beyond administrative and cultural limitations.

Visitors receive information about the landscape during prehistoric times, the location of the sites that have returned prehistoric finds and the museums where these findings can be observed. Similarly, it is possible to accompany the visitors by describing the discovery of the Etruscan landscape and of the museums closely related to the history of the Etruscan period. The same can be applied to the Roman period.

The visit to the LIPU oasis shows a picture of the current environment and allows reflections on the most likely future evolutions.

The creation of both natural and virtual itineraries can help to easily connect the different historical periods in an overall evolutionary framework. Broad sharing of data allows for the dissemination of knowledge and increased awareness among both tourists and local communities.

Access to these data (through web mapping and the virtual tour) increases the visibility of a territory that, although very close to areas of great tourist flow, is actually excluded. The availability of free and open-source informatic instruments makes it possible to employ replicable instruments and methodologies in other contexts as well. The involvement of all stakeholders right from the design stages has led to a growth in synergies among the different bodies involved in the project. This collaborative effort and multidisciplinary approach have contributed to the dissemination of knowledge and to the achievement of more holistic results.

The future use of the platform and future integrations of data and functionalities will make it possible to refine the study and provide an increasingly advanced solution for the dissemination of cultural and natural heritage.

This study has proved useful for the creation of IT tools that potentially allow the dissemination of knowledge of the environmental and cultural heritage contained in the territory. However, real enhancement of the territory can only be achieved through the willingness and commitment of the managing bodies to the use and advertising of these tools.

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Data Availability Statement: The data are available at the following link: <http://tlweb.it/pantarei/gis/#> (accessed on 11 May 2022).

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