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# From 3D Modeling to Landscape Mapping—A Workflow for the Visualization and Communication of the Asinara Island Park Plan

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**Abstract:** This paper aims to present the method for producing visual media for communicating the Asinara Island National Park plan. These products are landscape visualizations capable of fostering landscape preservation both from the point of view of the management of the landscape and of the citizen's involvement in the communication of the historical and environmental values of the landscape. Starting from landscape information gathering, the research has experimented with an operative method for processing different graphic representations from the same geographic database, calibrating the outputs to different audiences, their needs, objectives, and literacy skills. Three different types of products are presented as results of the research: The first is a digital, dynamic, and multisectoral decision-making GIS tool for park management. The second is a 3D model, aimed at virtual fruition. The third is a map of the zoning park plan drawn to be easily readable to the non-expert public. The results of this case study can be applied to other context and planning processes because of the replicability of the experimented method, which allows for processing the landscape information to make different visualization tools from a single geographic model, to meet the different requirements that arise from a complex landscape planning process.

**Keywords:** maps; 3D visualizations; landscape

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**Citation:** Cicalò, E.; Valentino, M.; Sias, A. From 3D Modeling to Landscape Mapping—A Workflow for the Visualization and Communication of the Asinara Island Park Plan. *Sustainability* **2023**, *15*, 16730. https://doi.org/10.3390/su152416730

Academic Editor: Stelios Zerefos

Received: 30 October 2023
Revised: 6 December 2023
Accepted: 7 December 2023
Published: 11 December 2023



## 1. Introduction

This article aims to present the communication project of the planning process of a natural park, the Asinara Island National Park, which has investigated the role of communication actions to support preserving a national natural park's historical and cultural heritage. In the course of this experience, the representations of the plan were not only aimed at the visualization of the planned zoning, as the traditional approach requires, but also investigated an operational process capable of bringing together all the different forms of visualization, which, in addition to representing zoning, could also become a tool for the management of the park's resources, for virtual enjoyment, and for the communication even to a public without specialist knowledge or high levels of graphicacy and digital literacy.

This article faces one of the most important challenges relating to sustainability, which is the weakening of relationships between people and places that underlies the abandonment and degradation of environments. The analysis, management, and visualization tools that have been experimented with make it possible to strengthen the transmission of information related to spatial plans and their objectives, toward the populations that will have to live and take care of territories, thus producing an impact not only in terms of environmental protection of the most fragile ecosystems but also in terms of promoting sustainable use of resources and the inclusion of citizens in decision-making processes and landscape preservation. Cultural heritage communication is nowadays considered a fundamental action to preserve heritage itself as it fosters education, information, awareness, enjoyment, perception, knowledge, and the involvement of the citizens, who, in these ways, can take care of it, thus enhancing and supporting the process of protection [1]. Therefore, following national and international guidelines, recommendations, and regulations, landscape preservation, as part of cultural heritage, must be linked to communicating values to the citizens [2–4]. Furthermore, the relationship between conservation and communication actions has become mandatory in light of the new role in landscape transformation processes of public opinion [5,6], which is increasingly becoming a key player thanks to the spread of new digital communication media. The effectiveness and success of landscape transformation projects are increasingly connected to the behavior and perceptions of citizens, which can lead to the success or failure of transformation design actions. For this reason, visualizations aimed at strengthening the awareness of the public and the knowledge of landscape communication have gained centrality in recent decades and have become an essential area of scientific experimentation at the architectural scale, as in the case of place narration [7–9] or of architectural and historic heritage [10,11] at the urban scale with the studies about virtual city models [12,13].

However, research appears to be less deep at the landscape scale. Indeed, at this scale, research on visualization focuses mainly on the production of single images aimed at fostering awareness of environmental issues throughout the rendering of landscape transformations by the elaboration of scenarios [14] in the fields of climatic changes [15,16], coastal floodings [17], ecosystems evolution [18], and infrastructures localization [19]. These kinds of visualizations are also used within plan processes to foster communication with the public, to facilitate citizen participation [20,21], to support collaborative design processes [22,23], and to evaluate the environmental impact [24,25].

Although covering numerous application areas, a gap emerges from the debate on landscape visualization regarding the potential of digital technologies and the use of 3D digital visualizations within the design process [26,27] and in the stakeholder engagement [28,29], that is the field of experimentation of the research presented in this article.

## 2. Background

Visual landscape communication has a long tradition in landscape architecture and planning [30,31]. In particular, visual landscape research has its roots in research on the representation of the perception of the urban environment studied by Lynch [32], Cullen [33], and Appleyard et al. [34]. Starting from these studies, an approach to visual landscape research was developed by De Veer and Burrough [35] in the 1960s in the Netherlands and continues today. In the last decade, landscape visualizations have become especially popular in the field of communication aimed at environmental impact assessment to involve local people in decision making about landscape transformations and in communicating environmental changes [36].

Indeed, landscape visualizations are used to communicate both existing conditions and alternative landscape scenarios [28,37]. Scenario visualizations are important means of engagement for communication in the broader context of participatory decision making [38]. Indeed, the outcomes of planning and forecasting processes and representations of landscapes often need to be more abstract to give a clear vision of the future to non-specialized audiences. For this reason, new forms of representation have been experimented with by applying digital technologies [39].

Thus, digital 3D modeling technologies have been widely applied in the fields of architecture and urban cultural heritage as an excellent means of providing access to cultural content and as a hub for information gathering [39–41].

Although visualization has a long tradition in design communication at the architectural scale, the research differs for the landscape scale. In centuries past, three-dimensional physical models played this role in architecture, particularly in the Renaissance. At the same time, at the landscape scale, the visualization of scenery was mainly based on freehand sketches and, since the last century, photomontages. In the past, landscape representations instead took a variety of different forms, such as drawings, photomontages, and paintings.

Today, these forms of representation can include diagrams, infographics, maps, sections, renderings, digital models, and animations [42,43]. Since the 1990s, the use of digital techniques for landscape visualization has increased dramatically [44,45]. The possibilities for digital representation have been greatly enhanced by the improved capabilities of linking CAD, GIS, and landscape visualization software.

Today's typical approach is to collect information in a CAD or GIS database and then generate outputs of different types, such as maps, rendered images, animated sequences, and real-time models in which the user can freely navigate a landscape [46]. However, these types of landscape representations are not always accessible to users without the language tools necessary for their understanding. Typically, images are produced regardless of the user's cultural level, preventing his or her effective involvement in the decision-making process. As public involvement in landscape decisions has increased, the need for visualization has increased, favoring more ductile and explicit forms of expression such as virtual reality [47,48]. Another response to this need has been the application of video game technologies to landscape visualization. Games provide a familiar context to unfamiliar issues and allow non-experts to enter multidisciplinary environments supported by the best available data and models [49,50].

However, there has been little but growing interest in the possibilities that three-dimensional digital landscapes can potentially offer to improve citizen participation and communication in urban planning [27,51]. The use of visualization and 3D technologies in participatory processes is often demonstrated to foster participation and communication in planning [52,53]. Several recent studies have demonstrated that people consider 3D digital landscape visualizations more explicative, realistic, and comprehensible than 2D maps at different stages of landscape planning [54–56].

Visualization to support communication, participation, and stakeholder engagement within plan processes has been investigated at the urban scale. Biljecki et al. [57] made a review of the scientific literature related to applications of these 3-D city models and found that visualization in the urban planning process is a common practice. The communicative aspect of public participation is facilitated using 3D visualization, which allows citizens more clearly to understand the visual impact that proposals would have [58]. In addition, the advantages of 3D visualization include the addition of contextual information to visualize the proposal within the cityscape, shadow effects, and the ability to navigate the environment [59].

Three-dimensional visualizations at the territorial scale are mainly limited to the use of 3D GIS. About protected areas, 3D GIS has been experimented with as a basic platform for participatory planning and monitoring [60]. The use of 3D GIS for participation has given rise to 3D PPGIS, which enables realistic visualization of space, flyovers from different viewing angles, immediate addition–subtraction of information, and the ability to interact in real-time [61]. These visualizations on the web through 3D Web GIS applications which enable the publication of interactive web maps and database information have been developed to provide users with the ability to consult products produced using the Internet [62].

The development of these forms of digital access to visualizations poses the problem of including different audiences with different visual and digital literacy levels. Thus, there is a need to integrate different forms of communication to make information more accessible to all.

## 3. Tools and Method

This study aims to present the creation process of graphic-visual products for the communication of the Asinara Island National Park, in the northern part of the island of Sardinia in Italy (Figure 1).

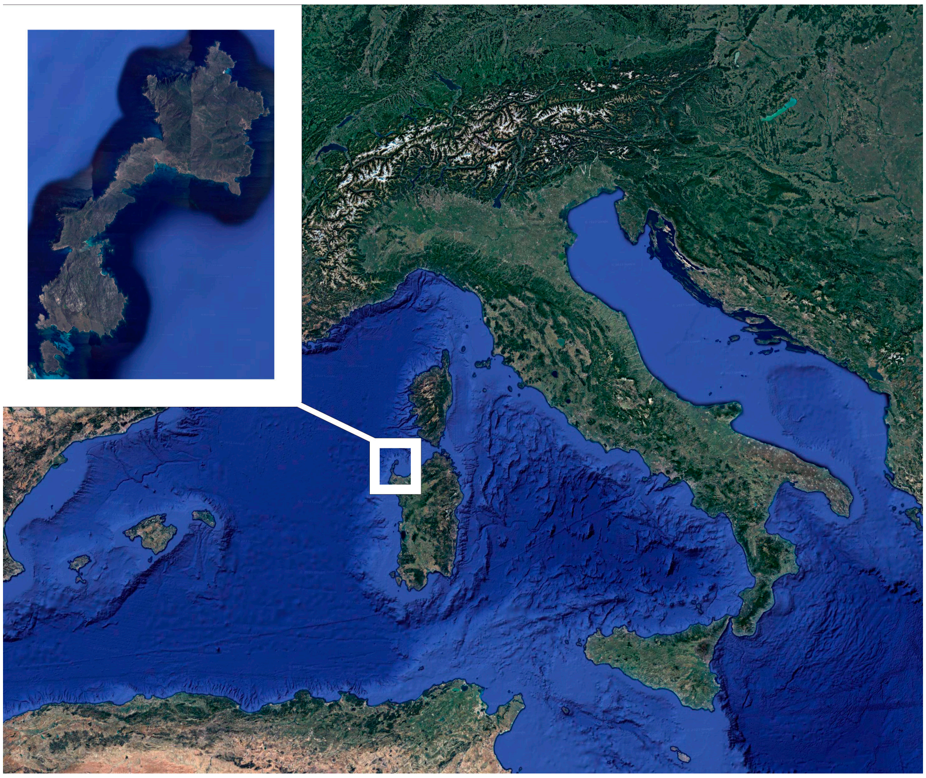

**Figure 1.** Asinara Island.

The workflow experimented is part of an agreement to support the communication of the update of the Asinara Island National Park plan, required by legislation ten years after its inauguration. The proposal put forward in response to this request envisaged a wide-ranging plan of activities extended to different media aimed at engaging and reaching different audiences in terms of belonging to different demographic and socio-cultural categories (Figure 2). Information held in the park authority's archives related to projects, studies, and research carried out in the first ten years of activity was acquired, cataloged, and prepared for entry into a GIS system. Geographic information was digitized and integrated with regionally available geographic information; textual information was linked within the database. From this information base, it was possible to elaborate a three-dimensional model through a hybrid mesh model enabling a multiplicity of visualizations. Some of these have already been realized, such as three-dimensional views, maps, immersive environments, and three-dimensional prints; others can be realized in the future, including popular illustrations, the realization of evolutionary scenarios, and access to GIS information through the web. These visualizations can be experienced through different communication channels both analog and digital, both static and dynamic, and are capable of being enjoyed by different audiences with different levels of knowledge, literacy, and skills.

This study aimed at producing different types of visualizations for different audiences, a topic not yet explored in the scientific literature on the geographical context being examined here. Among the different visualizations proposed to the park authority, this study presents the workflow related to the production of three specific forms of visualization. The first one is designed to be used by an expert audience involved in the management of the natural park and consists of a digital, dynamic, and interactive tool that would facilitate the simultaneous and georeferenced reading of environmental features through the interpolation of different territorial levels of information. The second and the third visualizations are aimed at a non-expert public and consist of a more traditional cartographic representation. These parts of the study are strictly connected in one production process in four steps: The first step aims to develop the GIS platform, from which are exported the geospatial layers that are rendered and photo-edited to produce the visualizations (Figure 3). Through the open-source software QGIS 3.27, it was possible to implement the platform and processing in a GIS environment, allowing data from the CAD environment to be implemented through online extensions and the ability to manage the backend interface directly within the software. In the second step, the data collected within the GIS system were unified consistently with the standards required by regulations and geometrically corrected to enable internal consistency within the system. In particular, the layers related to the theme of morphology, built-up areas, and major infrastructure as well as zooning of the park were created. From this base, in the third step, it was possible to create a rendering then used as the basis for drawing the maps through photo-editing and graphic design operations. Semantic coding made in the fourth step.

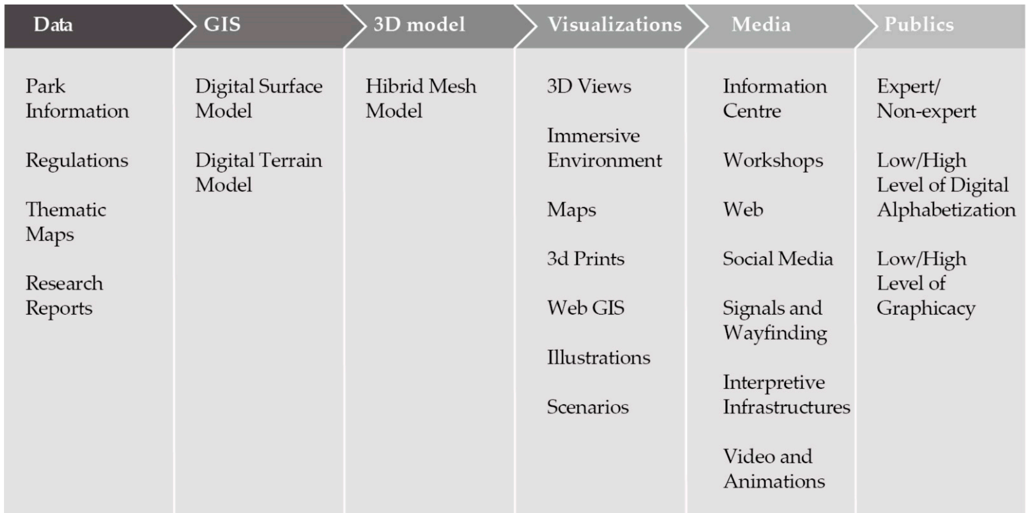


**Figure 2.** Workflow diagram used for the communication of the plan: from the collection of data for the realization of the geographical database to the realization of the analogue and digital products.

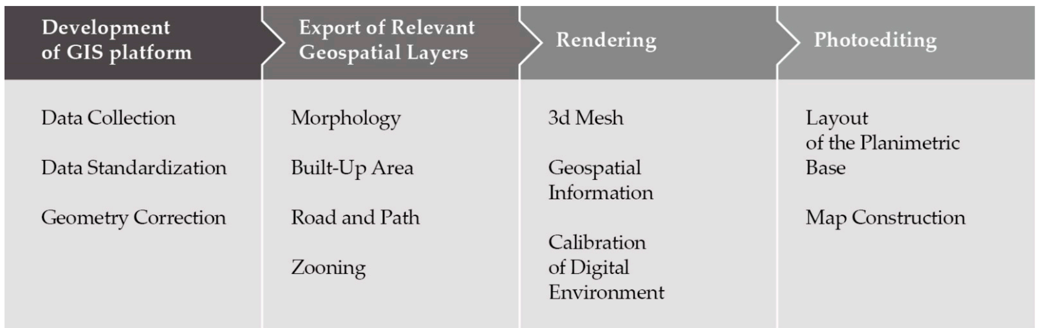


**Figure 3.** Workflow diagram of the four steps for the realization of graphic products for the non-expert.

These steps mainly involved modelling typical rendering elements, such as textures and meshes. The textures were coded through vector graphics software such as Inkscape. At the same time, the mesh elements were modelled and rendered through the open-source software Blender 3.4, which allowed the textures to be mapped onto the meshes through the visual programming language.

### *3.1. GIS for National Park Management*

The first step led to the development of a Geographical Information System (GIS) that systematically and organically collects all the information from experts of different disciplines who have collaborated on studies aimed at the plan for Asinara Island National Park. To obtain all the valuable information, two of the most authoritative databases for producing geographic-territorial data areas were considered: The Regional Geoportal and the Asinara National Park Authority—Marine Protected Area Asinara Island.

In the Regional Geoportal, the territorial layers of the island were identified and used to reproduce its geographical features in vector and raster formats. The use of the regional database ensured that the downloaded data were updated and in compliance with the current regulations on data reprojection (IGM Geodetic Directorate, January 2022). The vector layer was used to describe the coastal boundaries at a scale of 1:2000; the existing built-up area, containing not only the footprint of the built-up area on the ground but also its intended use; the road and footpath network, with the attribution of the type of road surface; the river network, with the description relating to the presence of perennial or seasonal water in the watercourse; the Strahler grade, identifying the complexity of the branching of the hydrographic network and the length of each rod; and lakes and reservoirs, to represent the systems of water bodies present in the territory. The Regional Geoportal database has also provided raster data. The Digital Elevation Model (DTM) highlights the reliefs and landforms that the Region of Sardinia elaborates to the definition of 10 m. The Digital Surface Model (DSM) is a datum with a similar appearance to the previous one but which is constituted with a much higher resolution both in terms of the size of the single cell (1 m) and in terms of the data collected since the DSM was created. The DSM aims to implement the DTM by highlighting the quantitative characteristics of the objects present on the surface, such as vegetation and buildings (Figure 4).

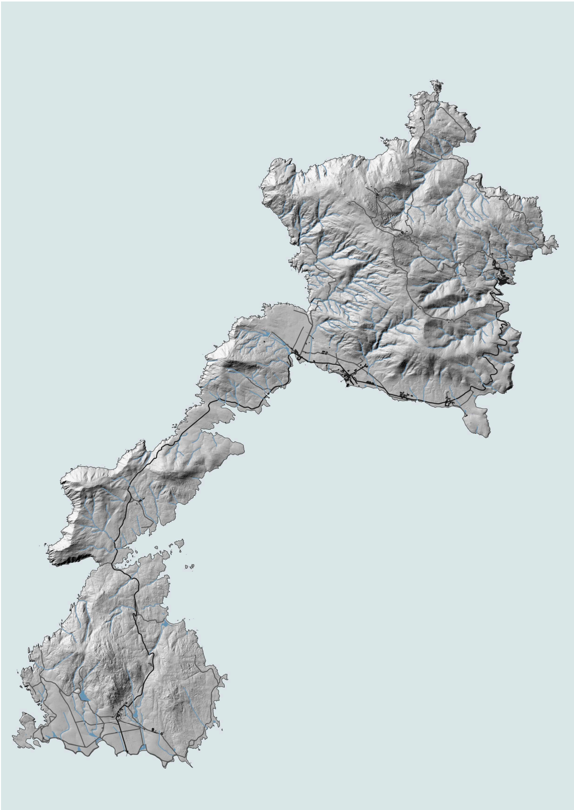

**Figure 4.** GIS representation of the island of Asinara through the layers downloaded from the Regional Geoportal. Image processed by the authors.

Furthermore, the GIS platform has been implemented with the Web Map Service (WMS) to display the historical series of satellite images related to the region of Sardinia. Implementing the WMS allows various comparative analyses regarding anthropogenic and natural changes. The regional catalog provides orthophotos from 1955 to 2020.

These layers formed the updated cartographic base for the plan maps, on which the sectorial technical information developed by the Park Authority was presented. The cartographic data owned and processed by the Asinara National Park Authority and Protected Marine Area were subsequently processed. Both cartographic and textual data related to the analyses carried out during the preparation of the Park Plan, published in 2005, were received. A total of 52 maps were processed to represent and describe the environmental system: geology, pedology, land capability, potential vegetation, land use, fishery biology, marine and terrestrial biocoenosis, settlement system, historical and cultural heritage, the previous plan zoning, and the geographic and socioeconomic region to which Asinara Island belongs. The available documentation was limited to virtual printouts of information in PDF and text format. This involved converting the information into editable formats and subsequently making corrections. Specifically, the corrections were carried out both from the point of view of data typology and information completion and from the point of view of updating geometric-spatial reprojections. These operations involved exporting the editable drawing to vector drawing environments, where the first corrections to the elements were made, and then importing them into QGIS to ensure correct overlap with the data taken from the Geoportal.

The geometry correction work done in CAD included operations to subdivide the geometry into point, linear, and areal elements in context with the reorganization of the layers in CAD. The operations performed on the point elements consisted mainly of replacing the geometric shapes used in the printed map visualization with simple points so that the attributes needed to describe the element could be uniquely assigned. This procedure was carried out in the cartographies identifying water sources, wells, and springs, the location of electrical substations and poles, and the point location of historical cultural assets. The latter were located as point elements to facilitate the construction of the attribute table containing the textual description of each asset. Next, corrections were made to the linear elements, which consisted mainly of joining the various broken polylines resulting from the conversion of the file from PDF to DWG format. These operations were carried out in the information layers of the road and path network, correlating the information related to the type of road surface, the type of walkability, and the total length of the path and the water supply or sewerage network, and implementing the graphical information with the textual information related to the type of pipeline, the length, and the date. As can be easily guessed, the most significant amount of information was related to areal elements. For this type of geometry, corrections were made by verifying individual perimeters. After the conversion, the initial raster contributed with CAD tools on the PDF had been transformed into linear elements rather than as fills.

Consequently, it was necessary to extrapolate only the perimeters, converting them into regions to allow the new spanning. Once the graphic information was converted and corrected, the geometries were imported into the Qgis open-source application (Figure 5), where the work of creating and compiling the attribute table began. The features shown in both the reports and the legends were inserted into the datasets to implement the graphical component with the textual one, making the platform queryable.

This was accomplished by creating Excel sheets containing the information from the individual descriptions associated with the cartographic elements; these were then integrated with the information available from the technical implementation rules of the National Park Plan. The sheets were then uniquely linked to the single geometries in the digital platform through a “join” operation within the GIS environment.

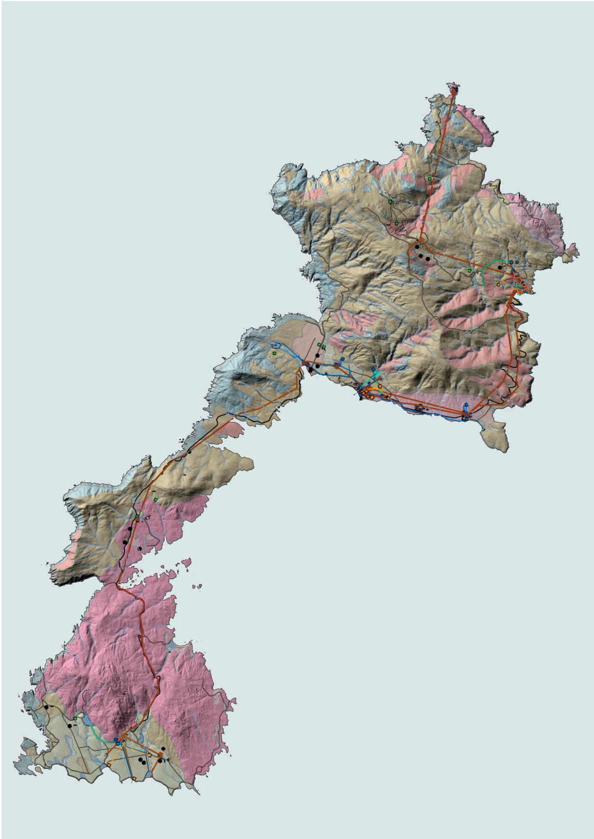

**Figure 5.** GIS representation of Asinara Island through the corrected layers from the Asinara Island Park Authority. Elaborated by the authors.

### *3.2. 3D Modelling for the Landscape Visualization*

Several representations were experimented with to facilitate the communication of the park plan even to less experienced people. Firstly, a representation was experimented with by using a rendered mesh model. This type of processing was achieved by exporting the mesh model generated by the Digital Surface Model (DSM) from the GIS platform and then processing it with the Blender rendering engine. Using the "Blender-GIS" plug-in, the mesh, georeferenced at a scale of 1:1, was imported into the rendering software, which was processed by applying the material constructed from the orthophoto to the model (Figures 6 and 7).

Next, information on all natural and anthropogenic features was placed on top of the rendered model, which was used for the perimeter of the land areas. The model produced in this way provides the basis for an immersive experience of the park plan zoning (Figures 8–11) and allows interpretation of the relationships between the project and the morphological, historical, and environmental characteristics of the island. The navigable model of the park plan zoning constitutes an innovation over the traditional graphic products typically used to communicate the results of territorial plans. However, this experimentation resulted in a product that was difficult to use because the file size did not allow for easy visualization of the document, and, more importantly, it was not possible to export the graphic product to scale. Furthermore, not all audiences can enjoy this form of communication due to inadequate digital alphabetization and scarce availability of digital tools. As a result, it was necessary to rethink the type of graphic product to be developed to meet the needs of communicating the plan to a non-expert audience.

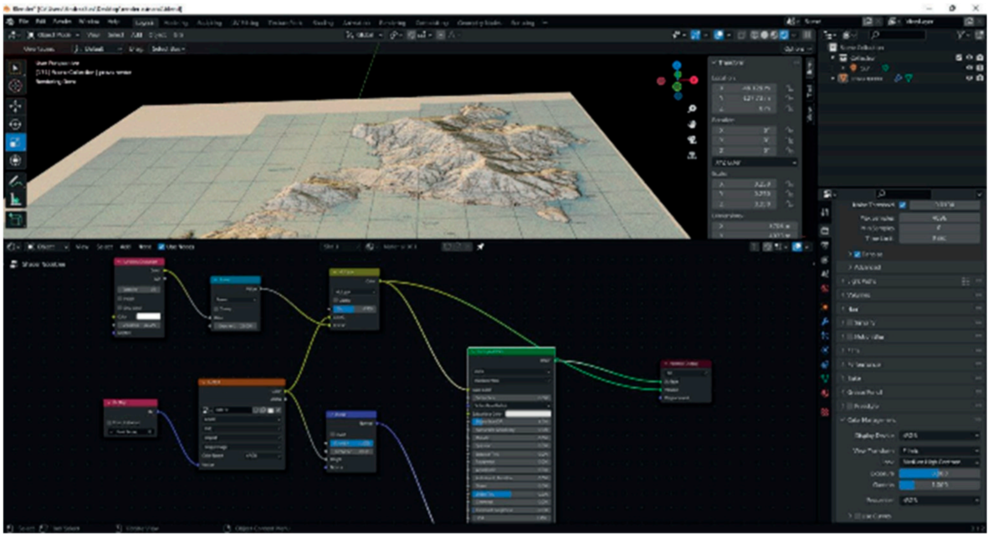

**Figure 6.** VLP workflow used for the rendered representation of the Asinara Island National Nature Park. Elaborated by the authors.

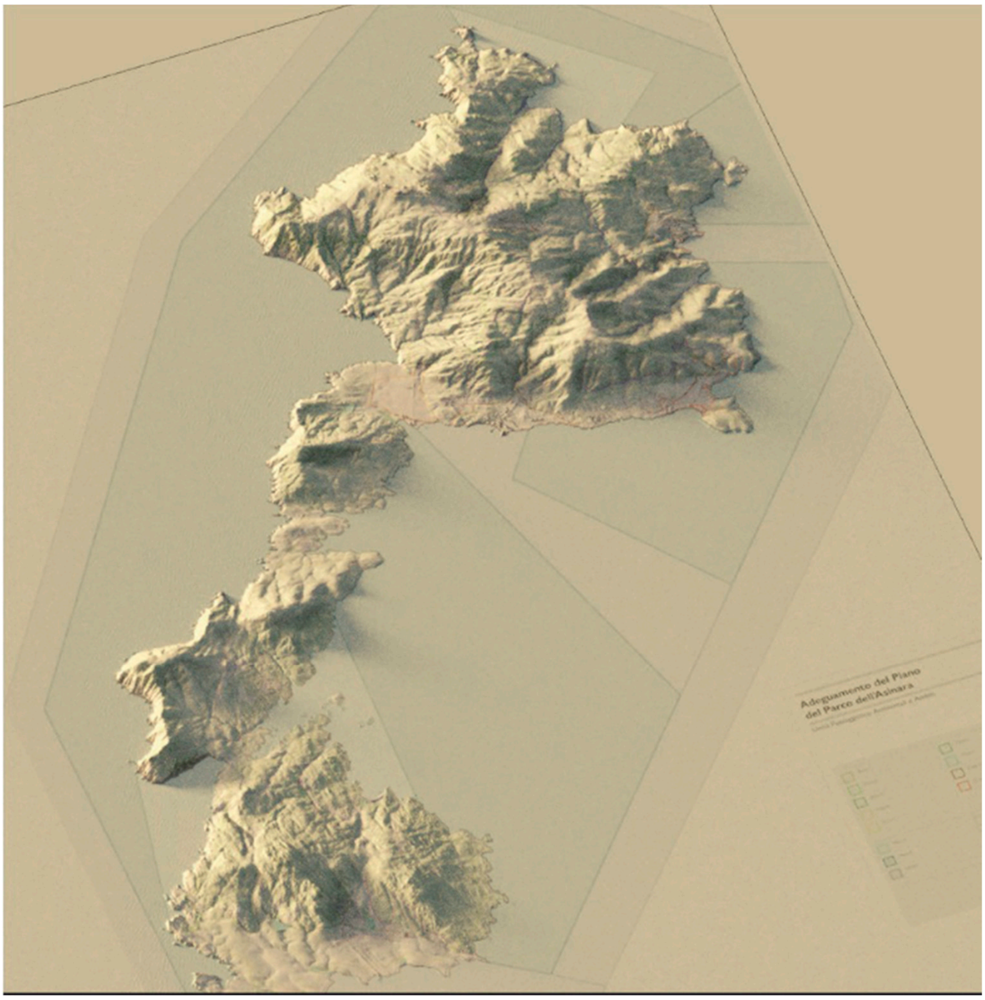


**Figure 7.** Rendered representation of the Asinara Island National Nature Park. Elaborated by the authors.

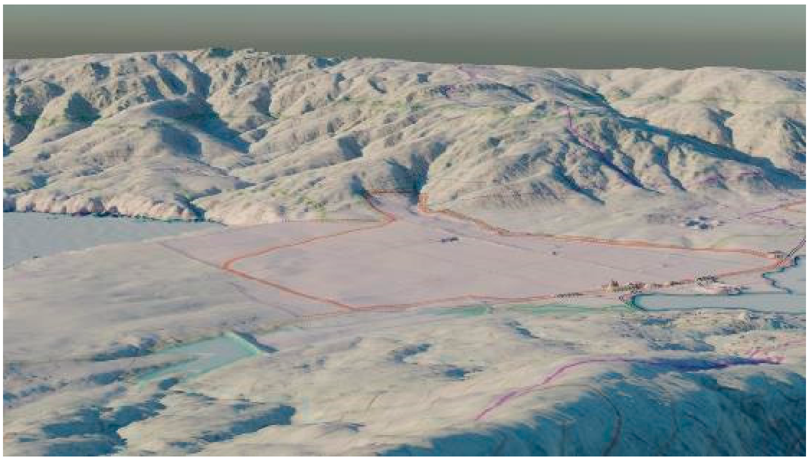

**Figure 8.** Visualization of plan zoning through virtual navigation of the tridimensional model. Graphic elaborations by the authors.

**Figure 9.** Visualization of plan zoning through virtual navigation of the tridimensional model. Graphic elaborations by the authors.

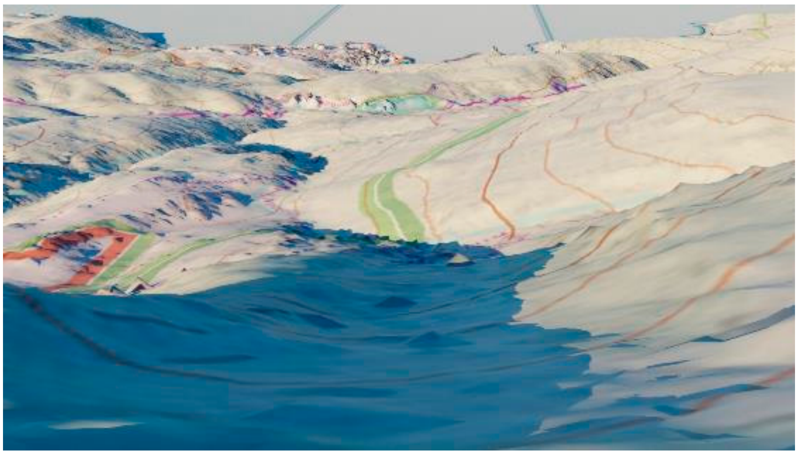

**Figure 10.** Visualization of plan zoning through virtual navigation of the tridimensional model. Graphic elaborations by the authors.

**Figure 11.** Visualization of plan zoning through virtual navigation of the tridimensional model. Graphic elaborations by the authors.

### 3.3. The Cartographic Representation of the Plan Zoning

In order to elaborate a graphic media easily understandable by the non-expert audience, a semantic approach was adopted to represent graphical spatial information emphasizing the structural aspects of spatial areas. Especially for the raster information, conducting a preliminary analysis in a GIS environment was necessary to preserve the three-dimensional aspect of the territory as much as possible. To this aim, three different analyses were carried out on the digital terrain model imported into the GIS: shading calculation, slope analysis, and the study of shadows cast on the terrain.

In the first case, QGIS' native hillshade symbology was used for the shading calculation to display the correct shadows. The direction of the light coming from the northwest was set to a light source height of 45 degrees, resulting in a black-and-white visualization of the DTM. The slope analysis was created as a vector layer using hatching. The processing was carried out through various analyses performed on the DTM: the hillshade, slope analysis, and contour layer were created at the same time; the series of equidistant points were subsequently placed on the contour layer. The 'geometry generator' operation performed on the points made it possible to transform each point into a segment, always perpendicular to the curve that generated it, of variable length depending on the percentage of slope closest to the point.

The last phase of information collection and systematization concerned the implementation of the platform of the spatial zoning used by the Park Authority to describe and regulate activities in the various areas of the Island of Asinara. It was necessary to propose a new graphic language to give these representations a semantics capable of communicating the peculiarities of the territory and the characteristics of the new regulations. Within the Inkscape software 1.3.2, it was possible to rework the data generated by facilitating the reading of the environmental and anthropogenic characteristics that generated the territorial scopes.

This visualization aimed to facilitate the reading of the information using a graphic code familiar to an audience with a nonspecialist background. The choice was to refer to the traditional graphic languages of the cartographies inspired by the maps of the Italian Geographic Military Institute IGM (Figures 12 and 13).

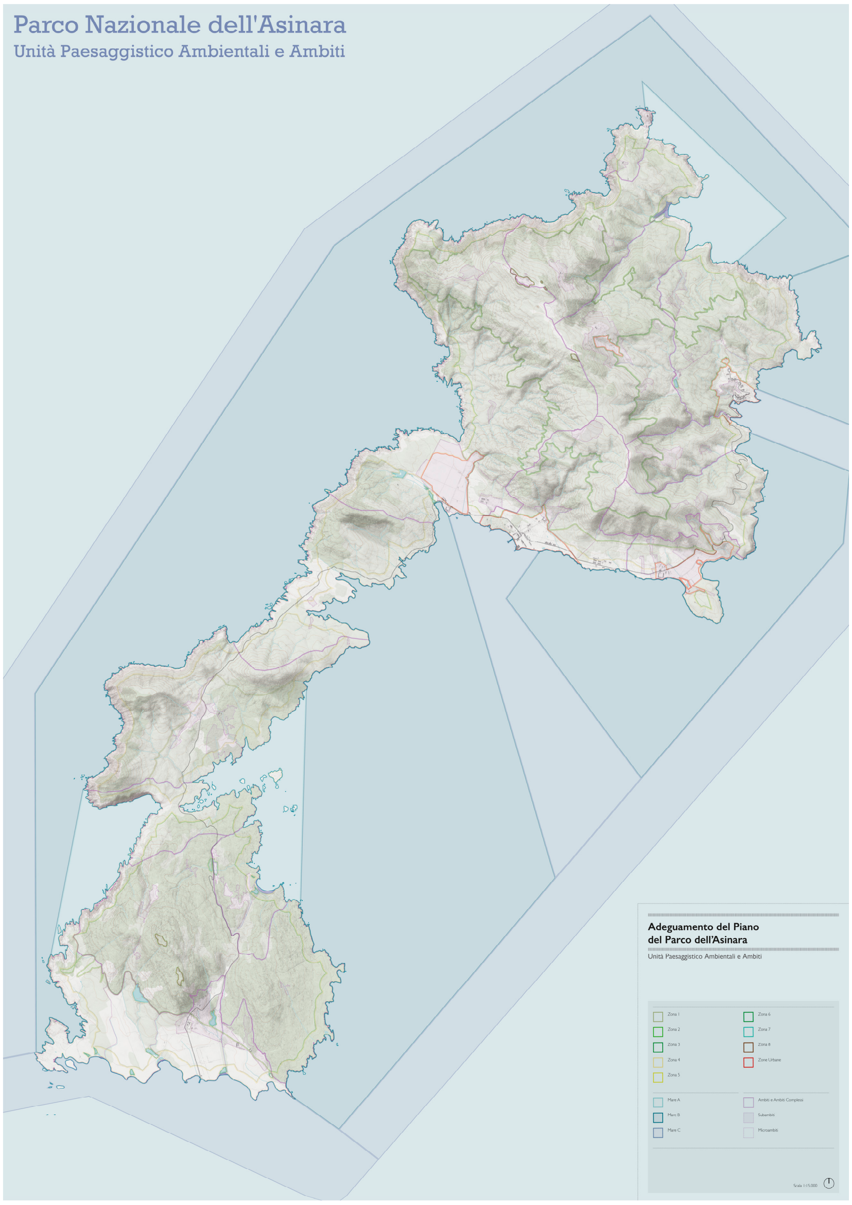


**Figure 12.** Final graphic elaboration for the representation of territorial ambits. Elaborated by the authors.

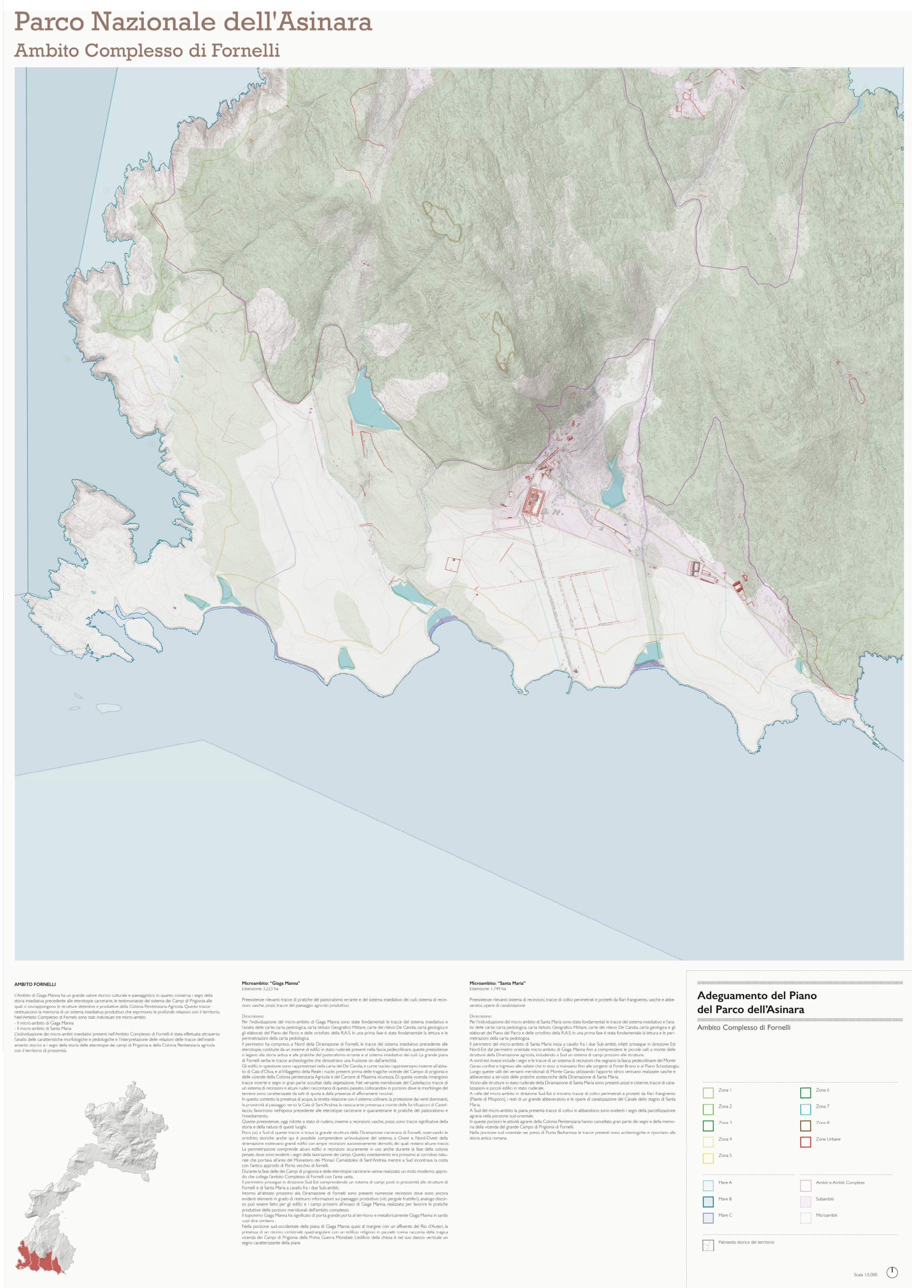


**Figure 13.** Final graphic elaboration for the representation of territorial ambits. Elaborated by the authors.

## 4. Results

The research presented here has enabled the achievement of several results. Firstly, the different visualizations produced can be considered as the first result of the research (Figures 4–13). Secondly, the method by which the visualizations were produced, and thus the workflows defined and described in Figures 2 and 3, must be considered the result of the research. Starting from these results, it is possible to formulate some reflections that are configured as theoretical results emerging from the experimentation.

The graphic products previously described made it possible to achieve two different objectives: the first was to provide the Asinara Island National Park—Marine Protected Area with a digital, dynamic, and multisectoral decision-making tool; the second was to create visualizations that could best communicate to the public the park plan and its environmental and historical-cultural references.

Starting with the systematization of various types of information from twenty years of the history of the park and their implementation within a single territorial information system, it was possible to develop a basis on which to build a digital model of the island's landscape from which to derive various possible forms of visualization.

Therefore, the research has resulted in an operational workflow that proposes the construction of a single spatial model for the processing of multiple forms of visualization capable of reaching different audiences with different skills and abilities to read and understand the information. The GIS system for park management, the immersive digital environment for the virtual use of the spatial device of the park, and the traditional cartography of the park plan constitute the different possible forms of visualization derived from the same geographical database.

## 5. Discussion

The research presented experiments with an operational method aimed at communicating spatial information to different audiences with different levels of skills, literacy, and knowledge from a single geographic information system. The results presented thus go beyond the simple 3D GIS or 3DPPGIS traditionally used to support participation, involvement, and communication with nonspecialist audiences. In fact, 3D GIS and 3DPPGIS presuppose digital skills and graphic-visual literacy on the part of audiences who must interact with these tools. In contrast, the workflow presented differs from the established methods in that it addresses the problem of the differences between the different possible audiences which the plan addresses—differences in demographic category, sociocultural level, and specific skills. The experience thus moves toward a more inclusive approach in which the audience is not just an abstract interlocutor but consists of real people who also need different communication tools and strategies. Some of these strategies have been tested in this study in parallel with a single information model, but others would need to be developed to further broaden the inclusive potential of the model.

In addition, the workflow used makes it possible to achieve higher-quality visualizations in terms of resolution and readability of information. This is necessary because the audience is not offered the sort of simple visualization derived from 3D GIS, which is usually flat and very technical but offers photorealistic images thanks to the graphic postproduction to which the model has been subjected. Postproduction is necessary for the construction of traditional maps aimed at including an audience without advanced digital skills. Postproduction is also essential to improve the readability of the immersive model and three-dimensional visualizations as well.

## 6. Conclusions

The experimentation presented in this article demonstrates that focusing on different audiences can lead to the full potential of the work required by park authorities to respond to regulatory requirements. The same information system can be used to communicate territorial information and knowledge to different audiences by calibrating the visualizations to different levels of alphabetization and different objectives, be they those of expert knowledge (GIS platform) or those of non-expert audiences, be they with a high level of digital literacy (immersive 3D virtual environments) or images using traditional graphic languages (maps). The difference in terms of the effectiveness of communication is, therefore, the ability to prefigure a valorization of the database built for purely normative purposes, the ability to manage technological tools, and the ability to hybridize different forms of visualization by crossing disciplinary traditions, approaches, tools, and techniques creatively and experimentally.

The research developed only a part of the initially hypothesized workflow. The managing authority was more interested in responding to national regulations prescribing management tools and less willing to experiment with new forms of involvement and interaction with citizens. For this reason, the part of the workflow developed was only made possible by the GIS for park management, which was, however, also exploited for the elaboration of traditional maps that are easily readable even by the non-expert public and to suggest new forms of information use such as immersive environments.

The urgency of responding to regulatory requirements overshadowed the experimental part of the communication on digital channels via the web and social media, which remained to be explored and which is configured as the most compelling part of the communication process, especially if it is connected to and based on the forms of visualization produced.

**Author Contributions:** Conceptualization, E.C.; methodology, M.V.; software, A.S.; validation, M.V.; formal analysis, A.S.; investigation, M.V.; resources, A.S.; data curation, A.S.; writing—original draft preparation, E.C. and A.S.; writing—review and editing, M.V.; visualization, M.V. and A.S.; supervision, E.C.; project administration, M.V.; funding acquisition, E.C. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by Ente Parco Nazionale dell'Asinara.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** No new data were created or analyzed in this study. The data used are from the park authority's archives.

**Conflicts of Interest:** The authors declare no conflict of interest.

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