




Article

Sustainable Management of UNESCO Landscapes to Foster Natural and Cultural Capital

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Abstract

UNESCO landscapes, as socio-ecological systems of high natural and cultural value, must be well managed and protected for future generations. The study area of the present research includes the UNESCO site of the Etruscan necropolis of Cerveteri (Central Italy). The main aims of the study are as follows: (1) to compare landscape dynamics of the study area from 1954 to 2023; (2) to assess the potential positive effects of the recognition of the area as a UNESCO site in terms of mitigating landscape change and fragmentation; (3) to identify potential sustainable conservation actions aimed at promoting the connectivity between the site and its landscape context. There was a change in the land cover in the entire study area from 1954 to 2023, which was 23%, with different dynamics at different times, while fragmentation was evident in the UNESCO buffer. This is particularly a concern because it includes the ancient Etruscan city, and it is not subject to adequate protection measures. Finally, this research identified crucial management strategies, including the expansion of the core area to include the ancient city; the restoration of naturalistic connections (e.g., the ancient path) between the city, necropolis, and natural context; and the reforestation of sensitive archaeological areas to mitigate landscape fragmentation.

Keywords: UNESCO site “Etruscan Necropolises of Cerveteri and Tarquinia”; multifunctional landscapes; land cover dynamics; landscape management



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1. Introduction

Socio-ecological landscapes [1,2] are the result of the interplay between natural and anthropogenic elements, which has been the basis for the natural and cultural development of traditional landscapes. One of the greatest issues concerning the sustainable management of socio-ecological landscapes is the knowledge of the modality through which ecological and biophysical processes combine with human presence [3,4].

World Heritage Sites and Biosphere Reserves of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) represent an international system of sites devoted to the protection of cultural and natural heritage around the world due to their value to humanity [5]. In this way, world heritage sites belong to all the peoples of the world, independently of the territory where they are located. However, many landscapes are under a growing threat due to several factors, including [6] the urbanization of rural communities, deforestation, land cover change, and climate change. Therefore, one effective

tool has certainly been the identification of areas where the impact of human activities can be limited [7,8].

Thus, these sites are living evidence of human coexistence with nature, and they are included in an international treaty called the Convention on the Protection of the World Cultural and Natural Heritage, adopted by UNESCO in 1972 [9]. The UNESCO recommendations recognize the preservation of the beauty and structure of natural and rural landscapes as a priority for the possible inclusion of an area in the World Heritage List (WHL) and its sustainable development [10]. The objectives of the Convention were the recognition, conservation, and “handing over” of cultural and natural heritage to future generations [11,12]. The core elements of UNESCO landscapes can include wetlands, forest areas, or habitats of high ecological value, as well as historical urban centers and archaeological sites [13], thereby allowing for the integration of tangible and intangible natural and cultural heritage [14,15].

Since these sites are in a landscape context, where different drivers threaten the cultural and natural values, it is crucial to analyze these sites from a landscape ecology perspective to identify the spatial patterns of the different landscape elements along different temporal windows. In this perspective, the aims of this research were as follows: (1) the analysis of the landscape dynamics of an UNESCO site from 1954 to 2023; (2) the analysis of the potential positive effects of this international recognition in terms of landscape change mitigation, based on a comparison of the landscape before and after the inclusion of the area in the UNESCO list; and (3) the identification of potential sustainable policies to promote natural and cultural conservation and to achieve a high level of socio-ecological connectivity between the UNESCO site and its landscape context.

The Linkage Between Cultural and Natural Heritage

The word heritage refers to an umbrella concept linking together cultural and natural components, and it should be studied within the context of socio-ecological landscapes [16]. According to [17], landscape usually refers to broad geographic areas that comprise multiple land cover types with varying degrees of anthropogenic dominance. An important update in the European concept of landscape came with the European Landscape Convention promoted by the Council of Europe [18], which defines landscapes as a part of the territory, as perceived by the population, whose character is the result of natural and/or human factors and their interaction. In this perspective, the Italian Constitution regulates the multifunctional landscapes for their historical and natural value [19]. In particular, they represent landscapes with several ecological functions, such as priority areas for conservation [20].

Natural capital represents the stock of natural resources and biodiversity together with the abiotic elements that sustain it [21,22]. As natural capital links the traits and processes inherent in ecosystems, it is crucial to recognize the connection with other types of capital, such as human or cultural capital, which are embedded in society and, in turn, are embedded in nature [23]. The interaction between these types of capital is a key element underlying the concept of strong sustainability, which assumes that natural capital cannot always be replaced by other types of capital [24]. Therefore, awareness of the strategic components of natural capital [25] is a fundamental requirement: biodiversity and natural capital are presented as focal topics that can be applied to the promotion of sustainable development. So, it is an absolute priority to combine conservation powers and the sustainable use of natural capital, while preserving other types of capital, to achieve sustainable possibilities for the future [26].

Natural and cultural heritage, both tangible and intangible, plays a crucial role in recognizing the close link between human and natural elements, contributing to sustainable

development [27,28]. Even in the same 2030 Agenda for Sustainable Development ratified by the United Nations and adopted by 193 member states, explicit reference is made to heritage conservation in Sustainable Development Goal (SDG) 11.4: “Strengthen efforts to protect and safeguard the world’s cultural and natural heritage” [29]. Conservation of natural and cultural heritage can have a direct impact on improving their quality and availability for present and future generations, enabling humanity to continue to benefit from them.

A particular type of socio-ecological landscape is the cultural landscape that is the result of social and ecological changes that have taken place over time [30,31]. The threats facing cultural and natural landscapes are several and are related to urban sprawl, land use and land cover (LULC) changes, intensification of agricultural activities, and fragmentation in the context of global climate change. Therefore, it is crucial to develop conservation policies to avoid the risk of losing the cultural and natural capital of these valuable landscapes [32]. In this sense, the guidelines for the management of UNESCO sites are based on the identification of different zones [33]. A core zone, delimited by the boundaries of the nominated property, is the most protected area, where human activities are severely restricted or prohibited. This is the area devoted to the conservation of the cultural and/or natural universal value, which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. The buffer zone, which surrounds the core zone, supports an effective protection of the nominated property. In this area, human activities compatible with conservation are possible, but with restrictions placed on the use and development of the area to give an added layer of protection to the property. These different levels of conservation should affect the landscape dynamics. Therefore, it is possible to expect that the core area is more stable in terms of land use/land cover change than the buffer zone, which is more stable than the landscape context.

2. Materials and Methods

2.1. Study Area

The study area spans across two municipalities: almost the entire area is included in the boundary of Cerveteri, with a small part in the boundary of Bracciano (Lazio Region, Central Italy) (Figure 1). It is divided into three parts (Figure 1):

- The “UNESCO core area” (198 ha) in blue, where there is the best-preserved necropolis in the world (the Banditaccia Necropolis). The “Banditaccia Necropolis” contains thousands of tombs organized in a city-like plan, with streets, small squares, and neighborhoods [34]. The site contains very different types of tombs: trenches cut in rock, tumuli, and some also carved in rock, in the shape of huts or houses with a wealth of structural details. The “Banditaccia Necropolis”, among the largest in antiquity, reproduces the “city of the living”. Since there is little surviving written information on the Etruscans, this site provides exceptional testimony of Etruscan domestic architecture from archaic times to the Hellenic period [35]. It has been expropriated for public use, and consequently, the property is part of the “Cultural domain” and part of the UNESCO World Cultural and Natural Heritage List since 2004. Recently, the area has also been put under the protection of the Archaeological Park of Cerveteri and Tarquinia, established with D.P.C.M. n. 123 24 June 2021. The core area presents a natural context constituted by the native vegetation of the Lazio region and an anthropized context made by a multitude of Etruscan funerary monuments. This combination of nature and archaeology, which can also be found in other archaeological sites, has assumed in Cerveteri a particular balance and dialogue between vegetation and ancient ruins that has enabled the development of a unique

landscape where it is impossible to establish with certainty the boundaries between nature and archaeology [36]. The national legislation, under Italian Legislative Decree, n. 42/2004, provides appropriate safeguarding measures, ensuring total control over archaeological assets, managed by the ministry responsible for cultural heritage.

- The second area is the “UNESCO buffer area” (1814 ha) in knurled blue, which includes almost the total ancient Etruscan city named Caere (in yellow in the map). The site is a relevant testimony of the Etruscan civilization, which lasted in Etruria (Central–Northern Italy) from the Iron Age (11th century BC) to the 1st century BC, when the Roman civilization prevailed over the Etruscan one [37,38].
- The last part of the study area is the “Context area” (1595 ha) in dotted red, selected for its high ecological and natural value. It is characterized by a rich landscape and environment, including wooded areas, a dense river network bordered by lush riparian vegetation, and little “waterfalls” in the northern part; in the southernmost part, it also includes a scattered urban area surrounded by cultivated and uncultivated fields alternating with richly vegetated plateaus.

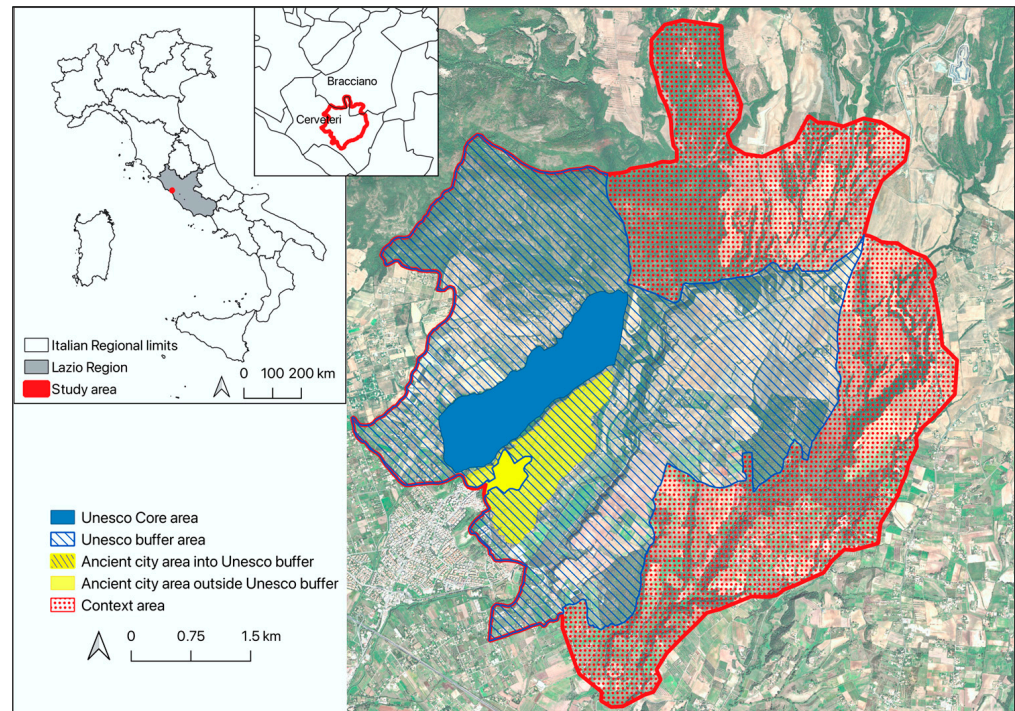


Figure 1. Study area. Blue indicates the UNESCO core area, knurled blue indicates the UNESCO buffer area, yellow indicates the ancient city, and dotted red indicates the context area.

Both areas of the UNESCO site (core and buffer) under study are part of a larger UNESCO site known as the “Etruscan Necropolises of Cerveteri and Tarquinia”. However, the area falling within the territory of Tarquinia has been excluded from this study.

The study area is partly characterized by the Special Protection Area (SPA) named the Tolfetano–Cerite–Manziante district (IT6030005). This is a sub-coastal hilly area of extreme naturalistic importance, home to significant populations of all zoological groups. Of particular note is the presence of diurnal forest birds of prey and carnivorous mammals. There are also phytogeographical features.

The population of Cerveteri grew steadily during the analyzed time range, rising from approximately 8058 inhabitants in 1954 to 37,973 in 2023, highlighting strong demographic growth due to the expansion of the city and its proximity to Rome, which has favored its development as a residential center [39]. This growth has been determined not only by its

strategic location but also by its quality of life and ability to offer services and opportunities, transforming it into a demographically important center [39].

In the Cerveteri area, slow and gradual population growth began in the 1950s, primarily due to the subdivision of agricultural land into a significant number of farms following the reform of the Agro Romano by the Maremma corporation [40]. In the following decade, an initial phase of urban expansion led to strong development of the construction sector; this constituted an important economic activity for the Cerveteri area, which was supported in the 1970s by the development of tourism along the coastal area. In the 1980s, a definitive shift away from the agricultural land model began [40].

2.2. Data Acquisition and Methodologies

This research is based on an interdisciplinary approach aimed at emphasizing knowledge of the territory and the reconstruction of past landscapes through the production of thematic maps and the photointerpretation of aerial photographs. To analyze the landscape dynamics of the UNESCO site of Cerveteri from 1954 to 2023, three steps have been followed:

- STEP 1—Photointerpretation of images and orthophotos for the elaboration of land use/land cover maps from 1954 to 2023.
- STEP 2—Landscape dynamics analysis.
- STEP 3—Landscape fragmentation analysis.

2.2.1. Photointerpretation and Elaboration of Land Use/Land Cover Maps

The first step aimed at elaborating land use/land cover maps for the years 1954, 1988, 2000, 2006, 2008, 2012, 2018, and 2023, over approximately 70 years.

In particular, the following images and orthophotos were used for the analysis:

- A geo-referenced mosaic of black and white images created by ARSIAL (Regional Agency for Agricultural Development and Innovation in Lazio), using images from the “Volo Base” or “Volo G.A.I.” flight carried out in 1954–1955, acquired from the Military Geographic Institute.
- Black and white orthophotos, acquired with a digital camera during the flight carried out by the Military Geographic Institute in the period 1988–1989.
- Color orthophotos from aerial photos acquired by the Military Geographic Institute flights in 2000, 2006, and 2012.
- Geo-referenced mosaic of color orthophotos created by ARSIAL (Regional Agency for the Development and Innovation of Agriculture in Lazio), using images from the flight carried out in 2008, acquired from the Military Geographic Institute.
- Sentinel-2 satellite images selected from the set available for 2018 and 2023.

Given the different resolutions of the source of data, a detailed photointerpretation was carried out by applying the ESA World Cover classification for each homogeneous landscape unit. This classification is broader than the CORINE land cover and helped in the classification of the oldest images, where it is not possible to validate the classification. All maps were created using QGIS 3.28 open-source software.

Finally, the accuracy of the maps was analyzed using the K statistic in the Semi-Automatic Classification Plugin in QGIS, and in particular, the interpretation of the K coefficient in Table 1 was employed. The accuracy of all maps was assessed using an error or confusion matrix, showing the class types that are determined from the classified map in rows and the class types that are determined from the reference source in columns [41].

Table 1. Interpretation of K coefficient used to estimate the accuracy of the LULC maps [42].

Kappa	Agreement
<0	Less than chance agreement
0.01–0.20	Slight agreement
0.21–0.40	Fair agreement
0.41–0.60	Moderate agreement
0.61–0.80	Substantial agreement
0.81–0.99	Almost perfect agreement

2.2.2. Landscape Dynamics Analysis

The second step focused on the analysis of the landscape dynamics in terms of land use/land cover (LULC) change in two time ranges: 1954–2000 (before the UNESCO recognition) and 2006–2023 (post UNESCO recognition). This analysis was carried out in the whole study area and in the subareas: the UNESCO core, UNESCO buffer, and context area.

Afterward, the comparison of LULC before and after the UNESCO recognition helped in analyzing the effects of this international recognition on the socio-ecological landscape dynamics and in terms of cultural and natural capital conservation. Specifically, from the LULC maps, statistical data on the main classes were derived, and change detection was carried out using the Semi-Automatic Classification Plugin in QGIS [43].

2.2.3. Landscape Fragmentation Analysis

Finally, to verify the ecological effects of the UNESCO recognition on the structural stability of the socio-ecological landscape under study, two landscape metrics suitable in landscape ecology studies [44] were used: number of patches (NP) and mean patch size (Area_MN) in m² by using Fragstats 4.2 [45]. Both metrics are simple measures of the degree of fragmentation of each patch type [45]. An increase in NP can suggest greater fragmentation, with potential effects on biodiversity, since fragmentation potentially affects the ability of animal species to move and to complete their life cycle, maintaining healthy populations. In line with NP, the Mean Patch Area can give an indication of the risk of losing specific land cover when the area has faced a reduction. At the same time, some species can be sensitive to patches too small or too fragmented. They are deeply important for many ecological processes, such as pollination [46], as they are related to the landscape structure integrity in areas under protection. Since few undisturbed landscapes remain, the integrity of a UNESCO core area provides a benchmark against which to compare the other parts of the study area that have been affected by human impact [47]. To evaluate the structure and the complexity of the landscape mosaic and its transformation, these two metrics were assessed before the establishment of the UNESCO site (in 2000) and after the establishment of the UNESCO site (in 2023).

3. Results

3.1. LULC Maps from 1954 to 2023

Maps in Figure 2 show the LULC in the whole study area in 8 different years over almost 70 years. It is possible to observe that tree cover is more concentrated in the north-west part and grasslands in the north-east area and the center of the study area, while the southern part is characterized more by croplands.

Figure 3 shows the LULC classes in percentage in each sub-area and in the total study area from 1954 to 2023. The detailed percentages are reported in Supplementary Materials Table S1.

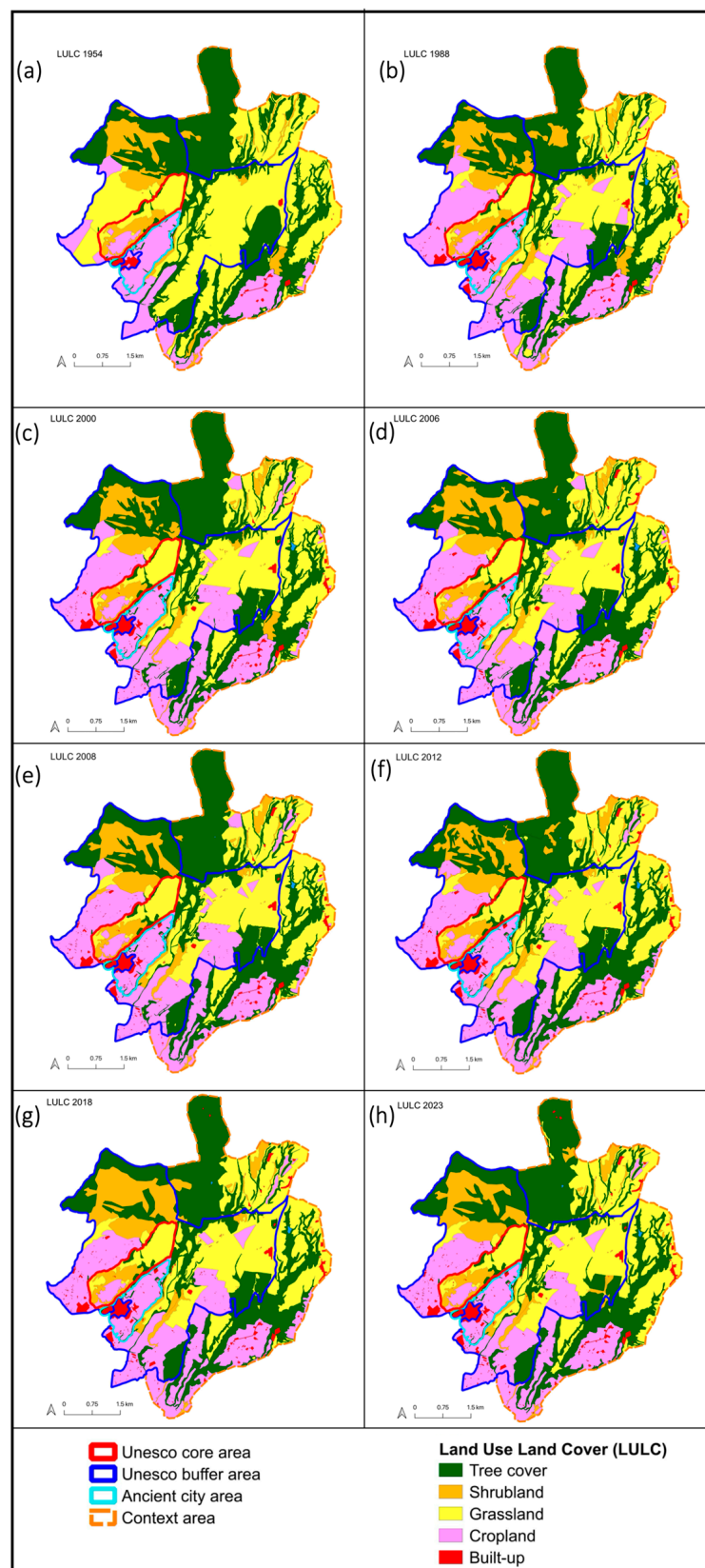


Figure 2. Land use/land cover maps and K-coefficient for each map: (a) LULC map 1954 (K-coefficient 0.98—almost perfect agreement); (b) 1988 (K-coefficient 0.99—almost perfect agreement); (c) 2000 (K-coefficient 0.99—almost perfect agreement); (d) 2006 (K-coefficient 0.99—almost perfect agreement); (e) 2008 (K-coefficient 0.77—substantial agreement); (f) 2012 (K-coefficient 0.74—substantial agreement); (g) 2018 (K-coefficient 0.91—almost perfect agreement); (h) 2023 (K-coefficient 0.91—almost perfect agreement).

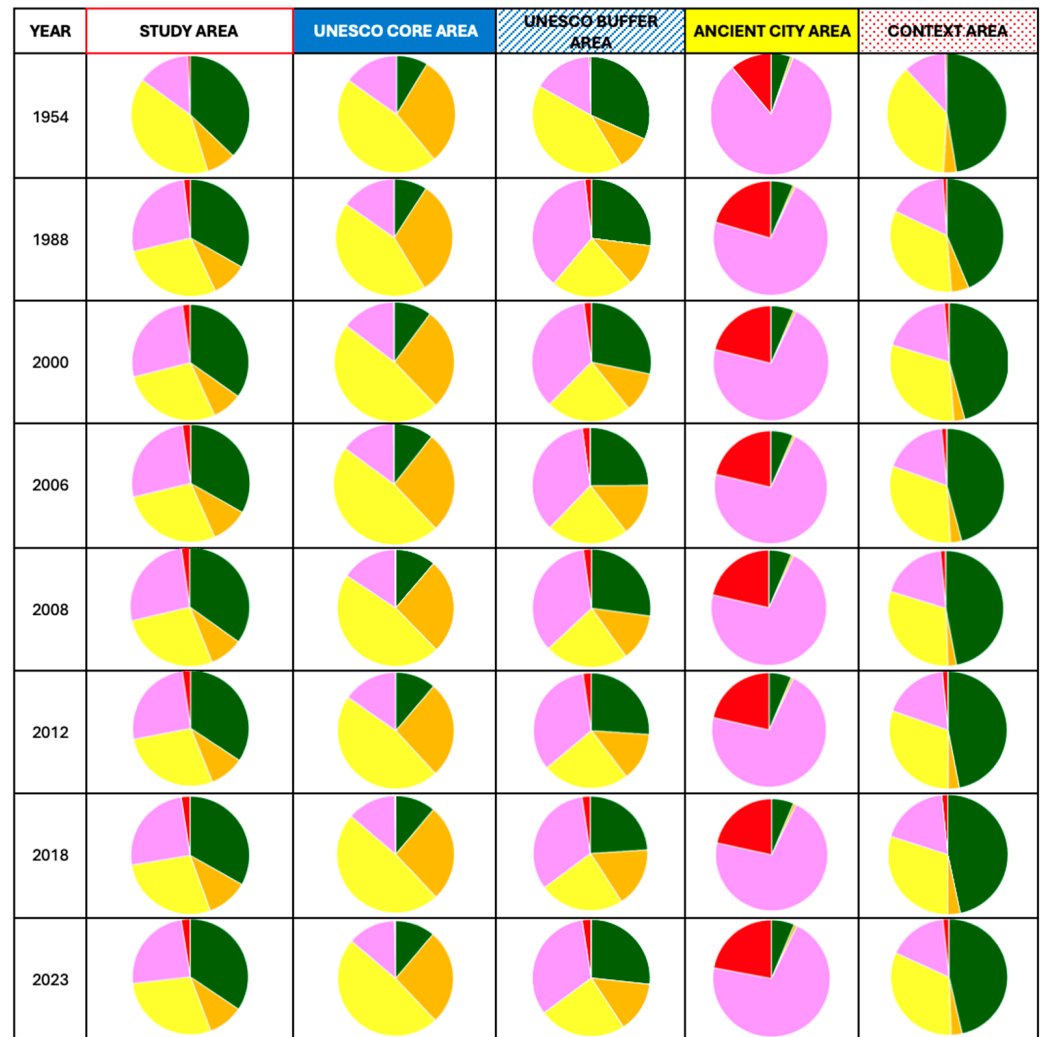


Figure 3. Land cover classes in percentage in each sub-area and in the total study area from 1954 to 2023. The detailed percentages are reported in Supplementary Materials Table S1.

As we can see in Figure 2 and in Figure 3, the dominant LULC classes are grasslands (in yellow), croplands (in pink), and tree cover (in green) in the whole study area, as in the UNESCO buffer area. In the UNESCO core area, the dominant LULC classes are grasslands and shrublands, while in the ancient city area, they are croplands and built-up. Finally, the context area is characterized by tree cover and grasslands.

In the first time range (1954–1988), it is possible to notice an important change in the total study area where croplands replace part of the grasslands (Figures 2 and 3). The UNESCO core area seems the most stable, and human-dominated land covers characterize only a small portion (Figures 2 and 3—UNESCO core area). In this area, grasslands (in yellow) and shrublands (in orange) are the most prevalent. On the contrary, the UNESCO buffer area is much more dynamic, since it displays a strong increase in croplands (in pink) and urban areas (in red) (Figures 2 and 3—UNESCO buffer area). This is also common in the case of the ancient city within the UNESCO buffer area, which is highly at risk since it is dominated by human LULC (built-up and croplands). In particular, the urban LULC increases with the consequent increase in land-take, while a small portion of the landscape is characterized by tree cover (in green). Finally, the context area, selected for its natural LULC (tree cover, grasslands, and shrublands), is the most stable (Figures 2 and 3), and it is used as a target to verify the conservation status of the UNESCO areas.

3.2. Analysis of Landscape Dynamics and Potential Effects of UNESCO Recognition

Land use/land cover (LULC) change was analyzed spatially for the whole area from 1954 to 2023 by considering two different time ranges: 1954–2000 and 2006–2023, which represent the period before and after the UNESCO recognition, respectively. The LULC change was analyzed spatially through maps to identify where the landscape has changed (Figure 4a,c), and temporally through the Sankey diagrams to quantify what and how much has changed (Figure 4b,d,e,f).

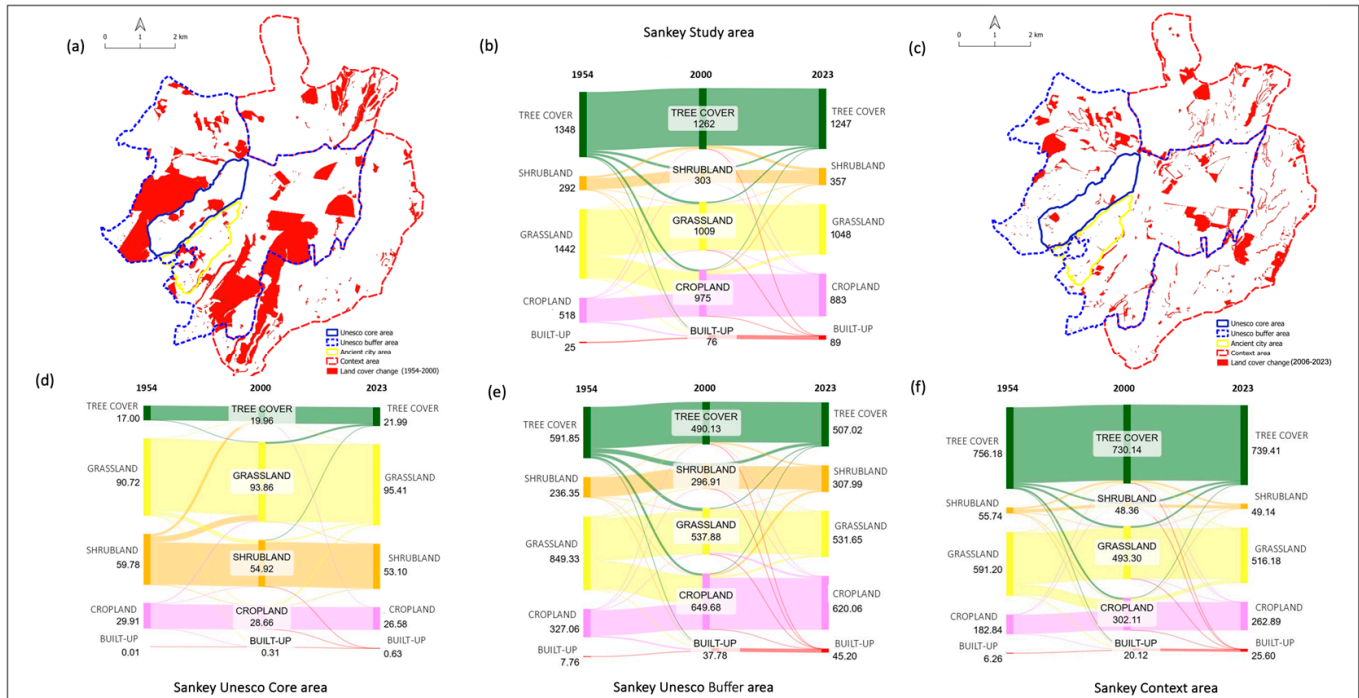


Figure 4. (a) Map of land cover change from 1954 to 2000 in the whole study area before the UNESCO recognition; (b) Sankey diagram in two time ranges, 1954–2000 and 2000–2023, for the total study area, reporting the numbers of hectares for each classes of LULC; (c) map of land cover change from 2006 to 2023 in the whole study area after the UNESCO recognition; (d) Sankey diagram in two time ranges, 1954–2000 and 2006–2023, for the UNESCO core area, reporting the numbers of hectares for each classes of LULC; (e) Sankey diagram in two time ranges, 1954–2000 and 2000–2023, for the UNESCO buffer area, reporting the numbers of hectares for each classes of LULC; (f) Sankey diagram in two time ranges, 1954–2000 and 2000–2023, for the context area, reporting the numbers of hectares for each classes of LULC. The detailed data are reported in Supplementary Materials Tables S2–S6.

The total study area showed a 23% change in the period 1954–2023, and the Sankey diagram, including the area units, shows that the main LULC change involves grasslands changing to croplands from 1954 to 2000. Detailed data are reported in Supplementary Materials Table S2. The maps in Figure 4a,c show two different LULC change percentages: 20% of change in the time range 1954–2000 and 8% of change in the time range 2006–2023. In particular, the UNESCO core area shows a LULC change of 9% in the period 1954–2000 and 4% in the period 2006–2023. The specific Sankey diagram (Figure 4d) highlights the main conversion: in the first time range, it is possible to observe a change from shrublands to grasslands and then from croplands to grasslands with a general increase in the built-up class. The dynamic increases in the case of the UNESCO buffer area, which includes the ancient city of Caere. In this area, the LULC change from 1954 to 2000 accounted for 29% of the total buffer area, while after the UNESCO recognition, the LULC change had a strong reduction to 9%. In general, the LULC changes regard the conversion of grasslands to croplands, and, as in the case of the core area, it is possible to highlight a general increase

in the built-up class (Figure 4e). Finally, the context area is characterized by a LULC change of 12% in the first time range (1954–2000) and 8% in the second time range. In this area, the main changes regard the conversion of tree cover in different land cover classes and the re-conversion of tree cover in the second period (Figure 4f).

3.3. Landscape Fragmentation Results

The analysis of the structure and functioning of the landscape mosaic has focused on two different years: 2000 and 2023, before and after the UNESCO recognition, respectively. In the Figure 5a, it is possible to observe that both in the core and in the buffer areas, there has been an increase in the “NP” index (number of patches). On the contrary, the context area showed a decrease in the NP index in the two different periods, probably because an aggregation process due to reforestation has characterized the most dominant tree cover class, which plays a stabilizing role for the landscape.

Looking at the second index (Mean Patches Size—“Area_MN”) in the Figure 5b, the decrease in the average patch area is more evident in the UNESCO buffer area than in the core area, where the index has remained almost constant, indicating stronger fragmentation in the UNESCO buffer landscape than in the core area. Instead, in the context area, the Area_MN index increased, thus highlighting an increase in the average patch area with effects on biodiversity.

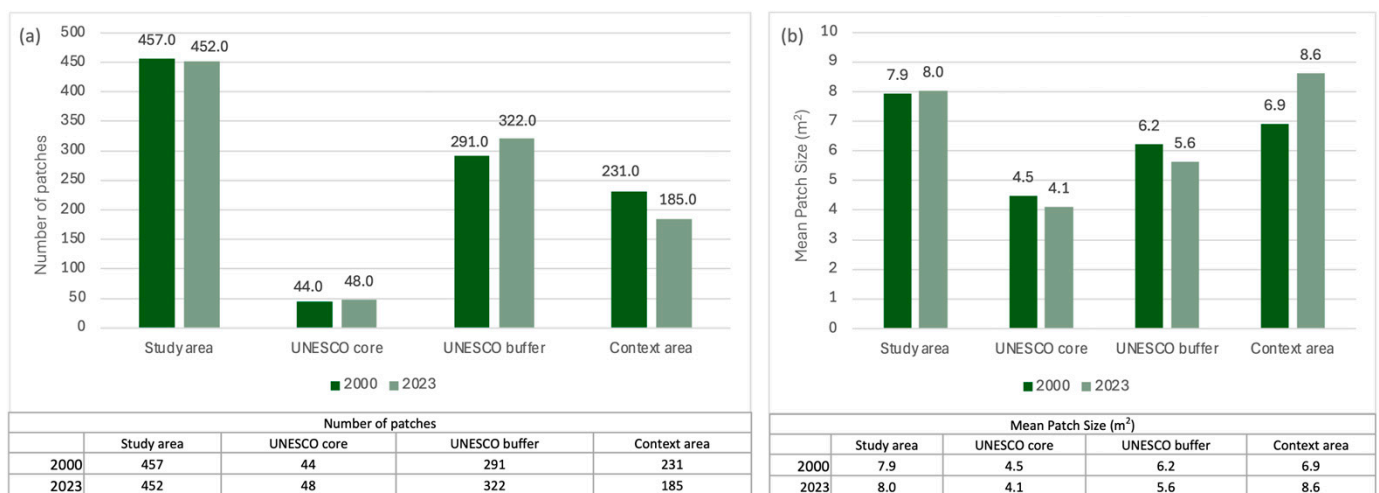


Figure 5. (a) Number of patches in 2000 (before the UNESCO recognition) and in 2023 (after UNESCO recognition) in the whole study area, in the UNESCO core area, in the UNESCO buffer area, and in the context area; (b) mean patch size in 2000 (before the UNESCO recognition) and in 2023 (after UNESCO recognition) in the whole study area, in the UNESCO core area, in the UNESCO buffer area, and in the context area.

4. Discussion

Landscape is the context where the combined effects of humans and nature become visible [48]. Given the dynamic features of human society and nature, change is intrinsically part of every landscape, as recognized in [49]. Clearly, landscape change can have negative consequences, as in the case of land degradation or urban sprawl, but when the change mimics the natural disturbance regime, it can also have positive consequences. This is the case of emulating natural disturbance regimes in North American forest management, where, for the conservation of biodiversity and function in forest ecosystems, changes associated with both traditional forest management and human change of natural disturbance regimes are used to restore forest ecosystems’ resilience to a wide range of environmental challenges [50].

Furthermore, the concept of landscape is transdisciplinary, and it holds significant value in the context of sustainability, since it considers the relationships between people and the environment as a whole [51–54]. The current landscapes are the result of numerous interactions between humans and the environment; therefore, humans have re-shaped their landscapes several times [55]. However, landscape changes, due to changes in land use/land cover and climate change [56,57], are detectable only using long-term analysis. In the case of cultural landscapes, the systematic monitoring of heritage sites and their landscape is important to understand the “context” where a heritage site is located [58]. This is of fundamental importance in light of the fact that, like natural heritage, cultural heritage is also threatened by climate change, which can also cause population movements or a reduction in the number of communities, resulting in a loss of tangible and intangible heritage [59]. Climate change-related hazards for cultural heritage include changes such as extreme summer temperatures and warm or extremely cold winters, and changing precipitation patterns, which can lead to flooding or droughts, unusually strong storms, and high winds. Buildings, historic sites, and cultural heritage sites in general are threatened by changes in humidity levels, fluctuations in freeze–thaw cycles, wildfires, and, among other factors, the resulting biological degradation caused by microorganisms and insect infestations can cause materials like stone and brick to crack and split, destabilizing the structure of buildings and damaging archaeological sites [59].

Archaeological sites are often characterized by the coexistence of valuable historical remains and natural goods [34] in a concept of landscape, where nature is perceived through culture [36]. The Etruscan archaeological site “La Banditaccia” represents an outstanding cultural landscape in Central Italy, with a millennial human presence coupled with a relevant natural component characterized by the presence of woodlands of sclerophyllous and semi-deciduous trees and *Laurus nobilis* residual forests [60]. In the last few decades, all landscape elements have gradually hidden the historical remains of every kind of settlement related to Caere and its very important territory with ports and sanctuaries, as historical sources and archaeological evidence indicate [61].

Several relevant studies [62–67] have already tested the benefit of using archival aerial images to monitor and detect changes in the archeological landscape [68–70], which are landscapes characterized in the past by the presence of ancient communities and where the rest of ancient settlements are still evident. In the specific case study analyzed in this research, the time range covered about 70 years, showing that the LULC changes have been more evident in the first time range, 1954–1988, probably because it includes 34 years, in a period before the UNESCO recognition, when attention to economic development was over the environmental and cultural conservation. This could explain why it is possible to see an increase in croplands and in built-up areas, both human-dominated classes, since this has been a period where human development was not in line with the principles of sustainability.

It has been possible to notice a change by comparing the period before and after the UNESCO recognition in the core area, where more strengthening measures have been applied than before, while the buffer area has not seemed strongly affected by the conservation measures.

Fragmentation, as land use/land cover change, is the effect of human activities, and it is evident in the UNESCO core and buffer areas, even if in the second case, the NP (number of patches) has increased more strongly. This is of particular concern since this area includes the ancient Etruscan city, which is not under the same protection restrictions as the UNESCO core area. The increase in agricultural fields in the buffer area represents a risk to the environmental and archeological goods, since agricultural intensification is one of the main recognized drivers of landscape change [71,72] and can threaten the UNESCO

site. On the other side, the context area has shown a process of aggregation due to an increase in the mean patch size. This is due to the dominant natural land cover classes “Tree cover” and “Grasslands”. In particular, the presence of forests has confirmed its important stabilizing role for the landscape structure.

Management Recommendation Framework

In general, the results of this study, based on spatial and temporal analyses, can provide useful information to decision makers and, very often, are more understandable than the results coming from sophisticated models perceived as black boxes. Considering the dual value of the UNESCO site “la Banditaccia”, from both an archaeological and natural point of view, a valid management policy of the site could include actions to promote:

- More strict management actions to promote an increase in area conservation, as well as the inclusion of the ancient city in the UNESCO core area.
- Sustainable recreational activities that connect the necropolis, the remains of the ancient city, and the natural resources provided by the landscape. In particular, the ancient path (named “via degli inferi”) connecting the Etruscan Cerveteri, Caere, with the rest of the Banditaccia necropolis, currently impassable due to the dense scrublands, could be restored and made accessible to citizens and tourists who want to be in contact with Etruscan civilization (cultural capital) and, at the same time, enjoy the natural capital provided by the landscape in the context area (Figure 6).

In this sense, the management authority of this site has carried out several activities to promote tourism in the area and to improve the conditions and the fruition of the site. For instance, the Plan for the Elimination of Architectural Barriers is an active tool, defined through stakeholder participation, aimed at expanding the audience of potential users.

A possible alternative method is to expand attention beyond the site’s boundaries, considering other historical infrastructures that connect Etruscan civilization with the Mediterranean Sea. Finally, given the landscape stabilizing role of tree cover class, a reforestation strategy appropriately planned could mitigate human impact in sensitive archeological areas in the UNESCO buffer area, and this could be a possible solution for reconciling natural and cultural diversity conservation with agricultural activities [73]. This reforestation could also represent a local adaptation strategy to climate change.

These actions will be integrated with more specific archaeological actions and proposed to the management organization to identify potential obstacles and solutions, as well as to determine the necessary financial resources at the regional and national levels for their implementation. However, these management strategies will be further refined, both by incorporating field investigations and by implementing expert consultations to evaluate their feasibility and effectiveness, thereby providing more concrete guidance for decision makers. In this perspective, the visitor centers in UNESCO sites should play the role of a bridge between the site management authorities and local communities and tourists, and the administration of Cerveteri municipality should include specific actions in its urban plan to allocate economic resources to the valorization of the area. In general, these actions will require specific feasibility projects to verify how they can be implemented to promote the integration of the UNESCO sites within their socio-ecological contexts to achieve sustainable development.

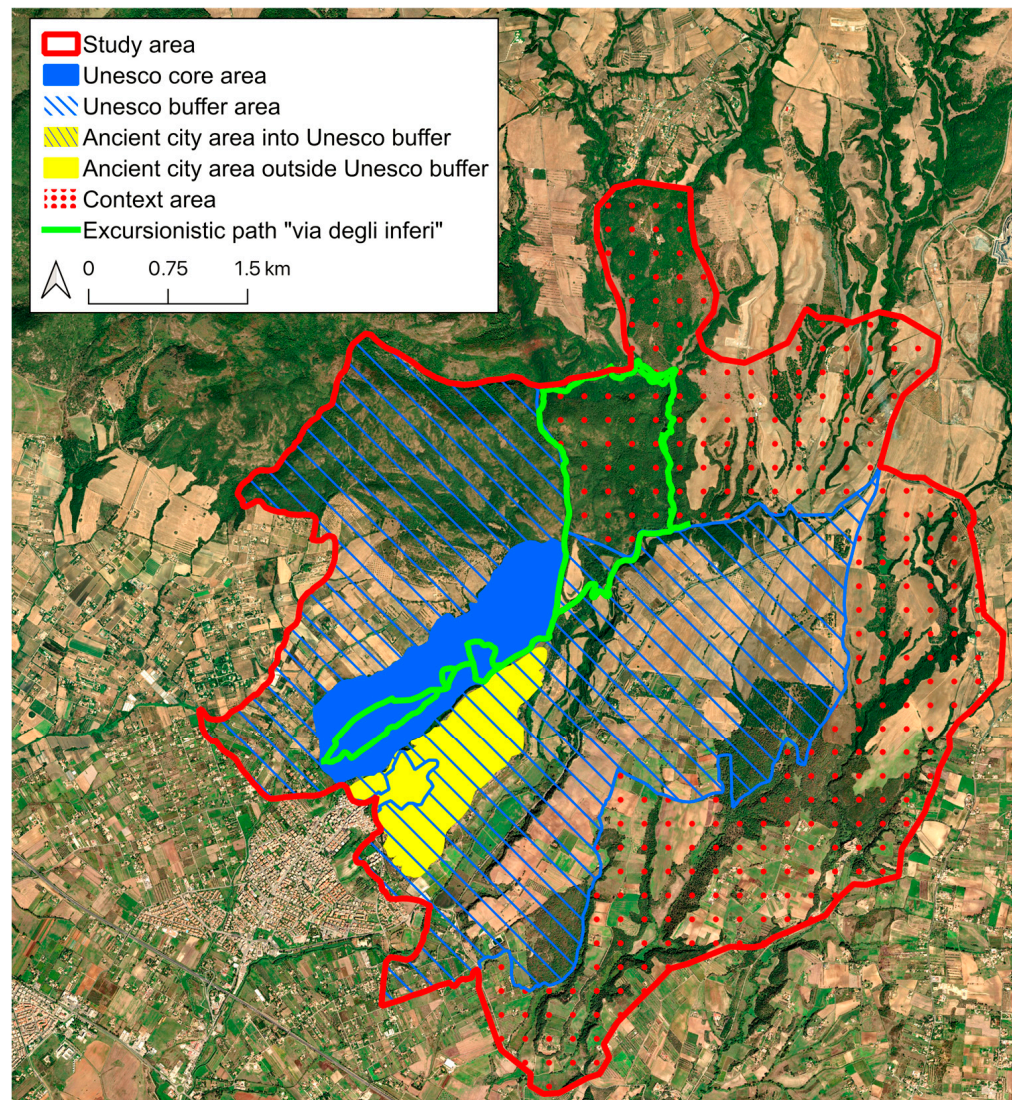


Figure 6. The recovery of the ancient path (named “via degli inferi”) connecting the Etruscan Cerveteri, Caere, with the rest of the Banditaccia necropolis (cultural capital), along with the landscape in the context area (natural capital).

5. Conclusions

The identification of UNESCO heritage sites represents a suitable way to recognize their natural and cultural value. However, the mere recognition is not enough to guarantee that the site will be protected and promoted, as in other cases where the only recognition of an area for its natural value has been demonstrated, which is not a guarantee for the maintenance of natural capital [74]. The analysis of landscape changes based on remote sensing and geographical information systems (GIS) can enhance our understanding of the interplay between ongoing human and natural processes and the landscape structure. The analysis of landscape change has been useful for understanding biophysical-human interactions in socio-ecological systems [75]. The results can inform the UNESCO site managers promptly about the risk of landscape degradation in the core and buffer area due to LULC changes, as well as promote the sustainable development of tourism. Such analyses can justify the need to enlarge the core area and its specific conservation measures to other nearby areas, like the specific case of the Etruscan ancient city, and the recovery of ancient paths to reconnect cultural and natural capital. In general, UNESCO recommends governance mechanisms to protect urban heritage, which requires the integration of UN-

ESCO heritage conservation with the urban development plans, where future landscape actions are programmed. In this sense, research perspectives can help develop an understanding of underlying socio-economic mechanisms and policy orientations, as well as an understanding of community behavioral patterns. The engagement of local communities in managing their local heritage should enable them to identify their landscape's cultural capital, set goals, and agree on actions to safeguard their heritage and promote the sustainable development of the UNESCO site.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su17198895/s1>, Table S1: Land-cover classes in percentage in each sub-area and in the total study area from 1954 to 2023; Table S2: Land-cover change in percentage in each sub-area and in the total study area in the range time 1954-2000, 2006-2023, and 1954-2023; Table S3: Land cover class change in hectares and in percentages in the range time 1954-2000 and 2000-2023. Study area (ha 3,625); Table S4: Land cover class change in hectares and in percentages in the range time 1954-2000 and 2000-2023. UNESCO Core area (ha 198); Table S5: Land cover class change in hectares and in percentages in the range time 1954-2000 and 2000-2023. UNESCO Buffer area (ha 1,814); Table S6: Land cover class change in hectares and in percentages in the range time 1954-2000 and 2000-2023. Context area (ha 1,595).

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