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Climate Change vs Cultural Heritage: An Adaptation Strategy for the Archaeological Site of Ancient Messene

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Abstract

This article examines the effects of climate change on archaeological sites, using as a case study the archaeological site of Ancient Messene in Greece, and proposes an integrated adaptation strategy. In order to determine the site's most significant risks, a climate data analysis was conducted, taking into account three different climate emission scenarios (Representative Concentration Pathways) and two future periods (2031-2060, 2071-2100). The Intergovernmental Panel on Climate Change (IPCC) vulnerability assessment methodology was adopted to assess the vulnerability of the archaeological site to the effects of climate change. This is the first time such a methodology has been followed in Greece. The analysis revealed that the site's critical hazards are fire, desertification, and flooding. The geographical location of the site in an intensely dry microclimate and the lack of safe and functional electromechanical and road infrastructure increase its vulnerability. The materials of the monuments are indirectly and directly impacted by climate change, whereas the vegetation is negatively impacted by the frequency of extreme events, especially wildfires. Based on the analysis results, a five-axis adaptation strategy was developed.

Keywords

Climate Change, Cultural Heritage, Archaeological Site, Vulnerability, Resilience, Adaptive Capacity, Adaptation Strategy

1. Introduction

Climate change has complex and dynamic effects on cultural heritage assets (monuments, archaeological sites, museum collections, historic settlements, and cities) (Daly et al., 2010). The range of climatic factors that cause these effects, the rates at which they happen in different places, and the severity of these effects change from place to place. Extreme events, such as excessive rainfall, wildfires, and storms, pose significant threats that are severe and apparent.

Indirect, but real and certain, is the danger that a cultural heritage asset is expected to face because of the small changes it goes through because of the constantly changing environment (e.g., accelerated evolution of material deterioration, such as corrosion, chemical deterioration, cracking, or impact on daily living conditions, changes in the ecosystem, etc.).

During the last decades, climate change adaptation research, policy, and practice were primarily focused on vulnerable sectors around the globe. Research about adapting diverse cultural heritage assets to the expected effects of climate change is a relatively new field (Heathcote et al., 2017). The severity of the issue is attracting vivid research interest. For instance, experts (Kapsomenakis et al., 2022) support that most heritage assets in the Mediterranean basin are increasingly vulnerable to the risks posed by extreme weather events.

To bridge the gap between climate change science and the planning and implementation of climate change adaptation for cultural assets, it is necessary to identify the barriers that arise during the adaptation process. According to Orr et al. (2021), the most significant obstacles associated with this endeavor are vague timescales, indistinct references to the natural environment, the absence of international cooperation, and the need to share information about climate change and cultural heritage. According to the findings of other researchers (Sesana et al., 2021), several research efforts are devoted to analyzing a single climate change scenario and a single climate model without considering the potential uncertainties regarding how the climate might actually change.

However, the academic literature provides an in-depth understanding of the significance of cultural heritage. Fatoric and Seekamp (2017) conducted a literature review on the frameworks, tools, and methodologies for assessing the climate risks and vulnerabilities of various categories of cultural assets. Interestingly, during the past few decades, several research studies examined the impact of climate change on cultural heritage, with a particular emphasis on the European context (Bonazza et al., 2021; Ciantelli et al., 2018; Gómez-Bolea et al., 2012; Grossi et al., 2007).

Increasing numbers of publications address incorporating cultural heritage into adaptation and mitigation strategies. However, there are still relatively few of these studies compared to those that examine the effects on individual structures or sites, specifically the effects of climate change on intangible heritage (Orr et al., 2021).

Research efforts investigating the effects of climate change on World Heritage Sites also increased considerably. Researchers (Sesana et al., 2020) developed a manual that assists administrators of World Heritage Sites (WHS) in analyzing climate change threats and how they are likely to impact WHS management.

The purpose of the guide is to comprehend how climate change may impact the features of a site that contribute to its Outstanding Universal Value (OUV), provide a framework for putting site-level climate change effects into the context of management, provide guidance on how to assess risk to the site's OUV; and provide suggestions for identifying how climate change may impact the site's OUV. In a similar effort, the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) established a system to protect the WHS' resistance to climate change and, as a result, to preserve its OUV. Other researchers (Sabbioni et al., 2008) concluded that future research in the field of climate change and cultural heritage should focus on modeling and projecting changes in heritage climate at high spatial and temporal resolution; understanding the vulnerability of materials to climate; accurately assessing future impacts; monitoring changes, especially on long time scales.

Protecting archaeological sites against the effects of climate change is one of the primary focuses of UNESCO, ICOMOS, and ICOM, which are all concerned with preserving cultural heritage. In studies developed and disseminated well over a decade ago (UNESCO World Heritage Centre, 2007, 2008), UNESCO acknowledged the need for additional research on the protection of archaeological sites against the effects of climate change. According to the results of a study conducted by the ICOMOS (ICOMOS Climate Change and Heritage Working Group, 2019), changes in temperature, precipitation, wind, and desertification are among the greatest threats to the world's cultural heritage.

Other researchers (Carmichael et al., 2017) developed a practical climate change risk analysis methodology for independent, community-scale management of cultural sites based on a participatory action research methodology. Dawson et al. (2020) implemented citizen science approaches to improve the management of coastal heritage. Hollesen (2018) developed a method to evaluate the effects of climate change on archaeological sites and landscapes and to describe how decision-makers should face these issues. Cassar (2016) combined the UNESCO and ICOMOS recommendations regarding the climate change protection of archaeological sites to propose a new management approach. Other research efforts (Sitzia et al., 2022) focus on topics directly related to protecting archaeological sites against climate change (e.g., materials).

Concerning archaeological sites of Greece, two studies (Fatoric & Seekamp, 2017; Sesana et al., 2021) have identified and characterized multiple categories of obstacles for their adaptation to climate change and strategies to overcome them.

The research question to which the paper aims to contribute is the formulation of a methodology, the application of which could contribute to assessing the impacts of climate change on an archaeological site. The analysis is used to formulate proposals to ensure the archaeological site's long-term preservation against climate change impacts. The paper is a continuation of the authors' previous work on cultural heritage and climate change adaptation (Maistrou et al., 2022a, 2022b, 2023, 2021; Lazoglou, 2022; Lazoglou & Serraos, 2021).

The paper's case study is the archaeological site of Ancient Messene, a prominent example of a dynamic archaeological site in southern Greece. The archaeological site of Ancient Messene was used as a case study because of its geographic location, monumental nature, regional significance, susceptibility to the anticipated effects of climate change, popularity, and finally, because the excavation and restoration works have been conducted there for decades.

It is worth noting that, in contrast to traditional approaches, in this paper, the Intergovernmental Panel on Climate Change (IPCC) vulnerability assessment methodology was adopted to assess the vulnerability of the archaeological site to the effects of climate change. This is the first time such a methodology has been followed in Greece. For this reason, this article may serve as a basis for future similar research, raising several issues that link climate change and archaeological site management for the first time in Greece. Moreover, the article examines the archaeological site of Ancient Messene as a set of critical parameters directly related to its sensitivity and adaptive capacity, such as the materials of the restored monuments and excavated sites, the vegetation inside and outside the archaeological site, and the capacity of the existing electromechanical infrastructure to meet current and future safety requirements. The approach is based on a quantitative analysis of climate data and indicators that use different emission scenarios to define the primary climate risks for the site. On the other hand, the final evaluation of the archaeological site's vulnerability to these threats is qualitative. This is because the extent to which climate change will affect an archaeological site like Ancient Messene depends on its condition, which is dynamic and evolving, as is climate change, for which it is not possible to predict precisely when extreme events will occur.

Critical phases of the methodology followed included documenting the existing site condition and evaluating expected climate change risks relative to the 1971-2000 reference period under three climate emission scenarios (Representative Concentration Pathways, RCPs). The period 1971-2000 was used as the baseline for calculating climate change because, according to the National Observatory of Athens (NOA), it was the only period for which comprehensive time series data were available for the study area. The analysis revealed that the site's critical hazards are fire, desertification, and flooding.

2. Materials and Methods

2.1. The Archaelogical Site of Ancient Messene

The archaeological site of Ancient Messene is located in the Peloponnese, southwest of the hills of Ithomi and Eva, in a lowland area of 500 - 600 hectares, approximately 35 km north of Kalamata, southwest of the settlement of Mavrommati of Ithomi, and northeast of the settlement of Arsinoe, at an altitude between 360 and 280 meters (**Figure 1**).

Ancient Messene is a prime example of a Southern Greek archaeological site, including significant ancient monuments. In addition, it is a highly popular site due to the constant archaeological excavation and restoration works conducted

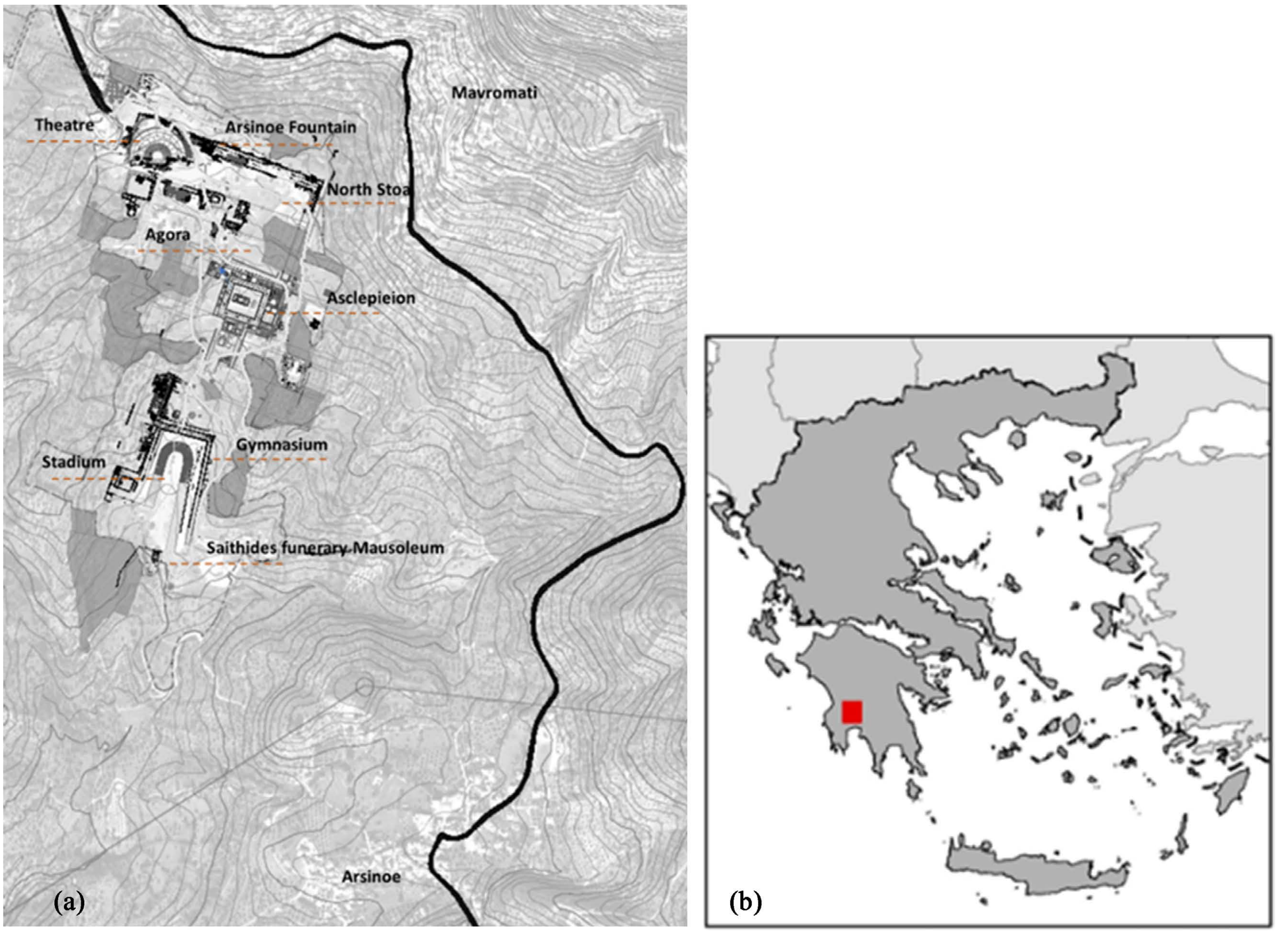


Figure 1. (a) Topographical plan of the archaeological site of Ancient Messene. Source of the map: Society of Messenian Archaeological Studies (Dimitriou et al., 2021); (b) The geographical location of the archaeological site.

there for decades.

The archaeological site was chosen based on its geographic position, historical significance, national and international significance, and vulnerability. The original assessment of the site's vulnerability primarily focused on the damage it has sustained due to previous extreme weather events. In particular, the archaeological site was severely damaged in August 2014 by a fire that began in a nearby settlement and in September 2016 by severe flooding. Moreover, Themelis (2010) mentions that the archaeological site of Ancient Messene has suffered many other disasters in antiquity, such as the devastating earthquake of the 4th century AD, which was accompanied by a fire, while the site's vulnerability to flooding is also mentioned.

2.1.1. Legal Framework

The archaeological site of Ancient Messene is adjacent to two traditional settlements, Mavrommati and Arsinoe. The development trend of these settlements has yet to be defined, affecting the archaeological site's protection status from possible incompatible land uses. It should be noted that the settlements predate the significant excavation and uncovering of the monuments of the archaeological site, which were only discovered in the last 50 years.

Regarding the legal framework, by Government Gazette (73/B/14-2-1991), the remnants of Ancient Messene, including the Stadium and the Theatre, the buildings and the sanctuaries of the 4th century BC, as well as the wider area surrounded by the fortification wall, were designated as an archaeological site. Government Gazette rezoned them twenty years later (240/AAP/21-09-2011).

The protection zones A and B still need to be established for the protection archaeological site of Ancient Messene, although a proposal outlining their exact boundaries has been submitted. According to the Greek legal framework (Law 4858/2021, Government Gazette 220/A/19-11-2021), an area where any building is prohibited from being constructed is designated as a Protection Zone A. In this area, only the construction of buildings or additions to existing buildings necessary for the enhancement or service of the monuments of the archaeological site may be permitted following a specially justified decision of the Minister of Culture and Sports. On the other hand, as a Protection Zone B is designated a surrounding area where certain special building conditions, land uses, activities, and the possibility and conditions for continuing existing legal activities may be permitted. The delayed acceptance of the decisions on the definition of the settlements of Mavrommati and Arsinoe by the responsible Municipality of Messene is vital for completing the procedures for establishing Protection Zones A and B.

2.1.2. Materials of Restored Monuments and Archaeological Excavations

Most of the stones at the archaeological site of old Messene are mostly sedimentary, notably limestones and sandstones. Mosaic flooring and clay bricks are also observed (Gandini et al., 2018).

Limestones are detected throughout the entire archaeological site (Theatre, Arsinoe Fountain, Basilica, North Lodge, Agora, Asclepieion, Stadium, and Gymnasium), mainly in the masonry, columns, capitals, and pediments (**Figure 2**). Sandstones are detected in three main areas: 1) in the North Gallery of the Agora, 2) in the Theater; 3) in the Asclepieion Temple. They are primarily used in columns, capitals, architraves, and masonry (Kaditis, 2021).

Regarding the characteristics of the materials of the archaeological site, based

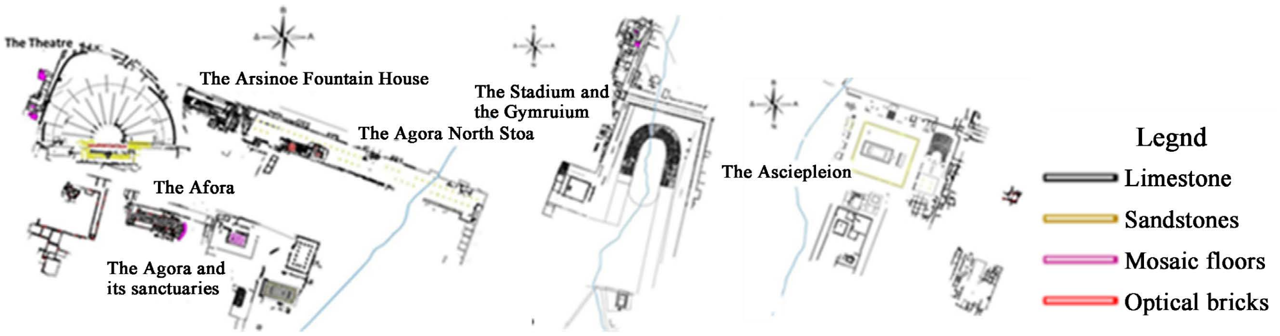


Figure 2. Illustration of the monuments with a legend of materials from the archaeological site of Ancient Messene (Kaditis, 2021).

on previous studies on the conservation of limestones and sandstones (Giannoulaki & Poulimenea, 2000), it has already been recorded that:

1) For limestones:

- The stone for the construction of the walls is of local origin and, in particular, comes from the mountainous area of Ithomi, where in antiquity, there was quarrying.
- The limestones that were buried in the ground and have now been excavated do not show any biological infestation and retain their decorative details better than those exposed. Soil analyses of the soil of Ancient Messene have shown that the soil is slightly acidic to slightly alkaline (pH 6.2 to 7.7).
- The total porosity of the limestone is very low (3.7%), of which 66% consists of large pores ($10 < r < 200$ μm). A small percentage of micropores ($0.001 < r < 0.01$ μm) is also included.
- The degree of water absorption is low. The limestone absorbs about 0.005% of its weight at the saturation point. The water absorption coefficient was considered extremely low.
- The percentage of pores involved in water movement is negligible. Also, the low water absorption coefficient combined with the low permeability indicated that water circulation in the limestone mass is difficult.

2) For sandstones:

- The color of sandstones is pale yellow, they have large pores, are composed of various clay-silicate impurities, there is a discontinuity in their mass, and their grains are of various sizes and shapes.
- The X-ray diffraction concluded that the sandstones of the archaeological site are rich in argilo-silicate features and are considered calcareous with minimal agglomerates because they contain large amounts of calcium carbonate ($CaCO_3$) and quartz (quartz SiO_2).
- Scanning electron microscopy showed that the sandstones have high porosity and low cohesion, are not compact, and have large voids in their structure. The total analysis of the mass of the stones detected a large amount of CaO (66.66%), a significant amount of SiO_2 (17.16%), and a small amount of Al_2O_3.
- The active porosity of the sandstones is relatively high (16% - 19%). It contributes to the movement of water in their mass and water vapor from the atmosphere (humidity), resulting in the crystallization of salts on their surface.

Some of the structural systems identified are limestone masonries, the post and beam system in the North Gallery of the Gymnasium, the two hollow theaters with retaining walls, the corbel building system in the treasury, the completely regular isodomum system in the Sylla monument, the tightly grouted masonries in a peudoisodomum system in the North Gallery of the Agora, as well as the remains of important monuments such as the Byzantine Basilica with its semicircular apse, three naves defined by colonnades, and a narthex at the western end of the temple.

2.1.3. Vegetation

The archaeological site has shallow vegetation covered mainly by trees, some also cultivated plant species, and secondarily, bushes (**Figure 3(a)**). Olive trees dominate, with vines and a few walnut, almond, and fig trees also found on the eastern side of the land. Fewer native shrub species can be found, mostly along fences (Kanellou, 2021; Karamesouti et al., 2018).

The majority of the surface of the archaeological site is seasonally covered by

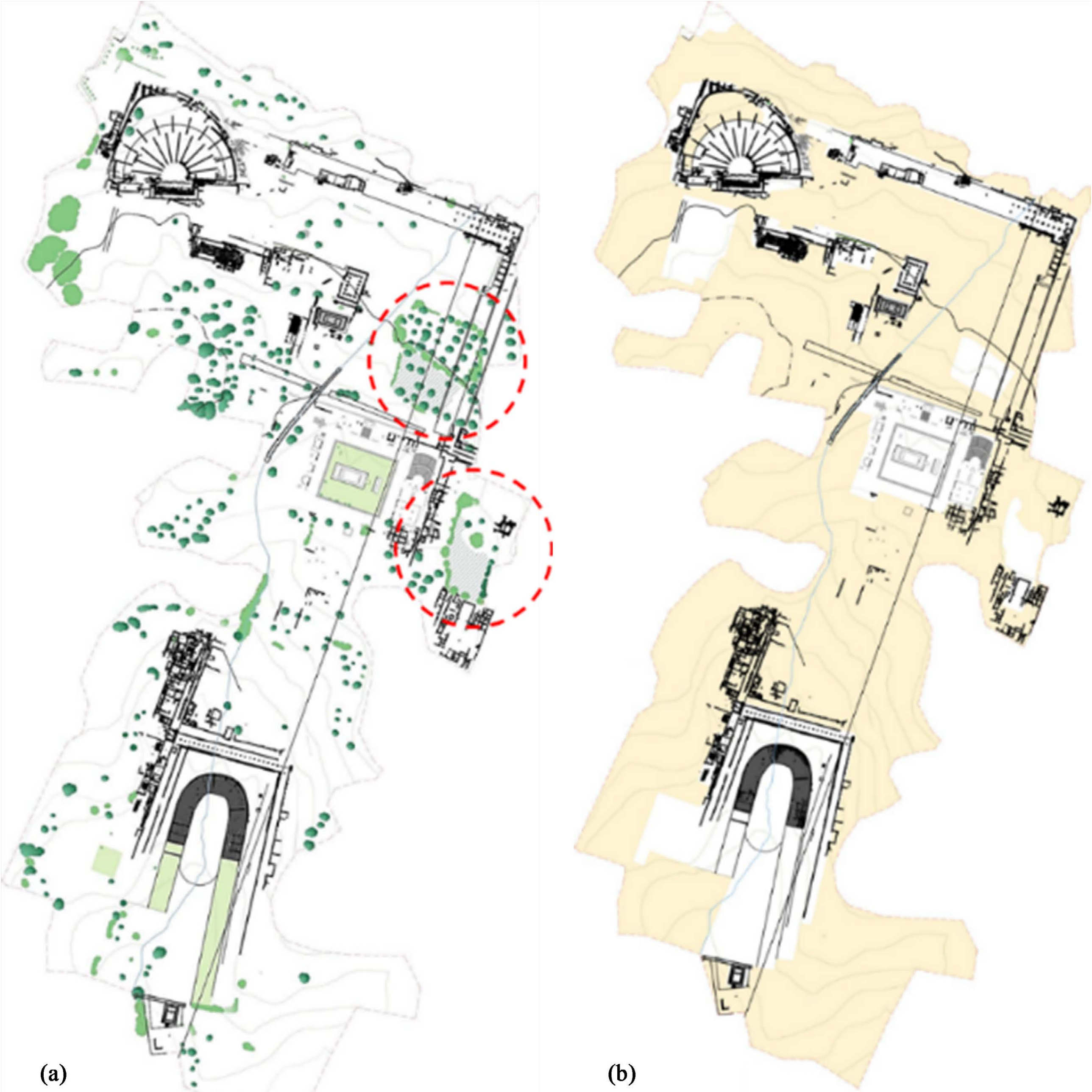


Figure 3. (a) The coverage of the trees and bushes (in green) in the archaeological site of Ancient Messene. The limited plant cover is distinguished by perennial shrubby and tree species. The pieces that have a cultivation character are marked in red (Kanellou, 2021); (b) **Figure 6**. Presentation of the surface of the archaeological site covered by seasonal herbaceous species (in yellow) (Kanellou, 2021).

herbaceous plants (**Figure 3(b)**). Most of them are winter-spring species germinating with the first fall rains and complete their life cycle in the spring when they dry up. Several summer-autumn species also occur during the warmer months (Kanellou, 2021).

Messinian land's surrounding countryside and natural environment develop around the ancient site. Rich native flora consisting primarily of evergreen, broad-leaved shrubs grows around the boundaries of the plots and on abandoned, bare terrain. There are olive groves and, to a lesser degree, fig orchards on the mild slopes to the east, south, and west of the site.

Ithomi Hill is located to the north of the site. No crops exist; the native vegetation consists primarily of evergreen bushes with large leaves. Around the Arcadian Gate in the northwest, the terrain is a mixture of native plants and olive groves. As a result of recolonization, the lush flora that presently covers these regions is the result of the regeneration of species before the 2014 fire.

2.1.4. Infrastructure

In Ancient Messene, the part of the ancient network of tiled drains that have been restored operates and absorbs the extra water from the Muska spring and a part of the rainwater south of Asclepieion for protection against rainfall. The remaining pathways release the rest precipitation load at the surface (Maistros, 2021).

The archaeological site and the village of Mavrommati, located upstream, use standard absorption cesspools that cover the sewage drainage needs.

The entry facilities have portable fire extinguishers to safeguard the archaeological site from fire. So far, neither a fire protection study nor a firefighting system has been prepared for the archaeological site (Maistros, 2021).

As noted in **Figure 4**, the road access to the archaeological site comes from the north Entrance A. In addition, there is informal parking between olive trees (up to 60 places) and under some canopies at Entrance A (8 - 10 total). Also, during high parking demand (e.g., during major events), on-street lane parking (estimated at up to 30 spots) occurs on one side (Kalantzopoulou, 2021).

Vehicle access for site needs, catering, disabled, and emergency service vehicles is provided through rural dirt roads with narrow widths, unsuited for regular cars, and without appropriate signage (**Figure 4**, Entrances B and C) (Kalantzopoulou, 2021).

The visitors' movement is carried out freely within the archaeological site between the monuments. The first part of the site, from the Theatre to the North Gallery of the Agora, is carried out through a sloping dirt road; after that, visitors are free to wander about the site without guidance (Kalantzopoulou, 2021).

2.2. Methodology

The methodology used to assess the effects of climate change on the archaeological site of Ancient Messene in order to formulate an adaptation plan with actions focusing on its protection and sustainable management consists of three

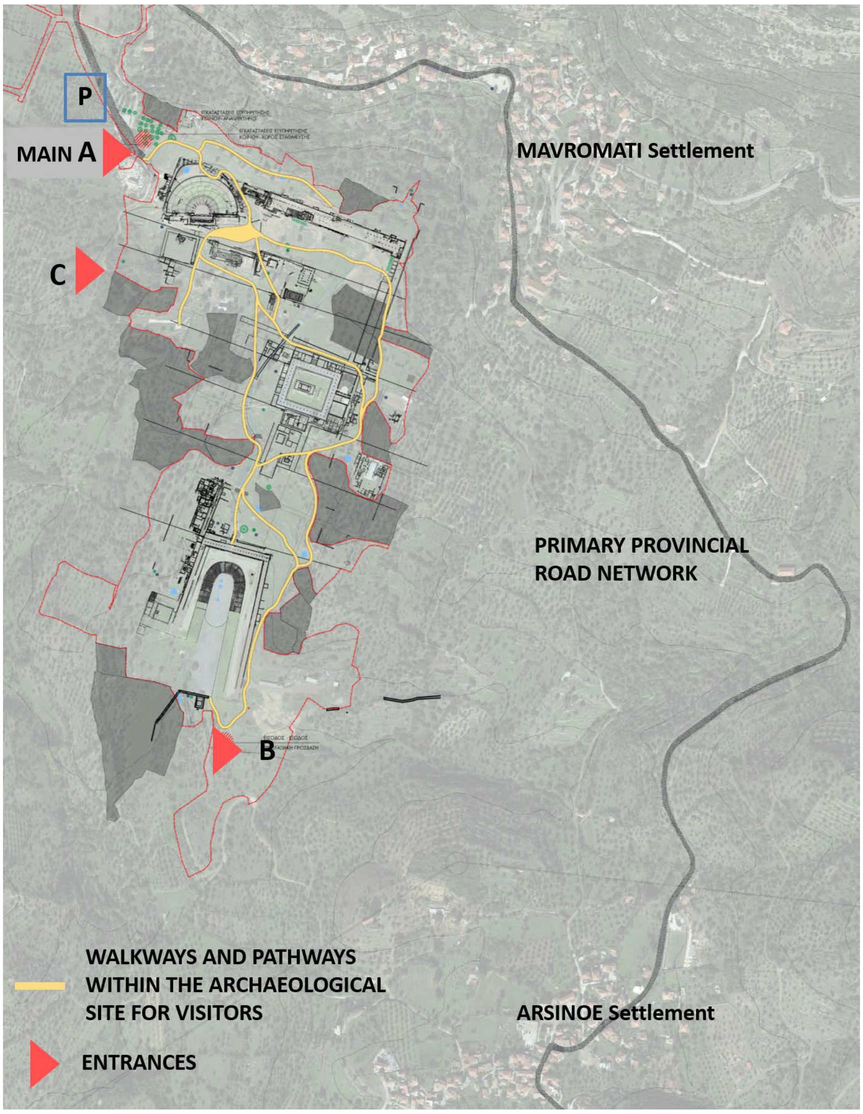


Figure 4. Existing Entrances A, B, C Road Accesses, and Parking Spaces (Maistrou et al., 2019). Edited by the authors.

steps (**Figure 5**).

In the first step, the climate data parameters and the expected changes for the archaeological site for the periods 2031-2060 and 2071-2100 and the three climate emission scenarios RCP2.6, RCP4.5 and RCP8.5 are analysed. Based on the analysis, a first assessment of the weather events expected to be the most critical for the study area is made. In the second step, the extreme weather events that pose the greatest threat to the archaeological site of Ancient Messene, as determined in the first step of the methodology, are evaluated for the periods 2031-2060 and 2071-2100. The third step of the methodology estimates the vulnerability of the archaeological site of Ancient Messene against to the most critical threats identified in the second step and projected to evolve significantly by 2100, according to the methodology outlined in the Third Assessment Report of the IPCC (IPCC, 2001).

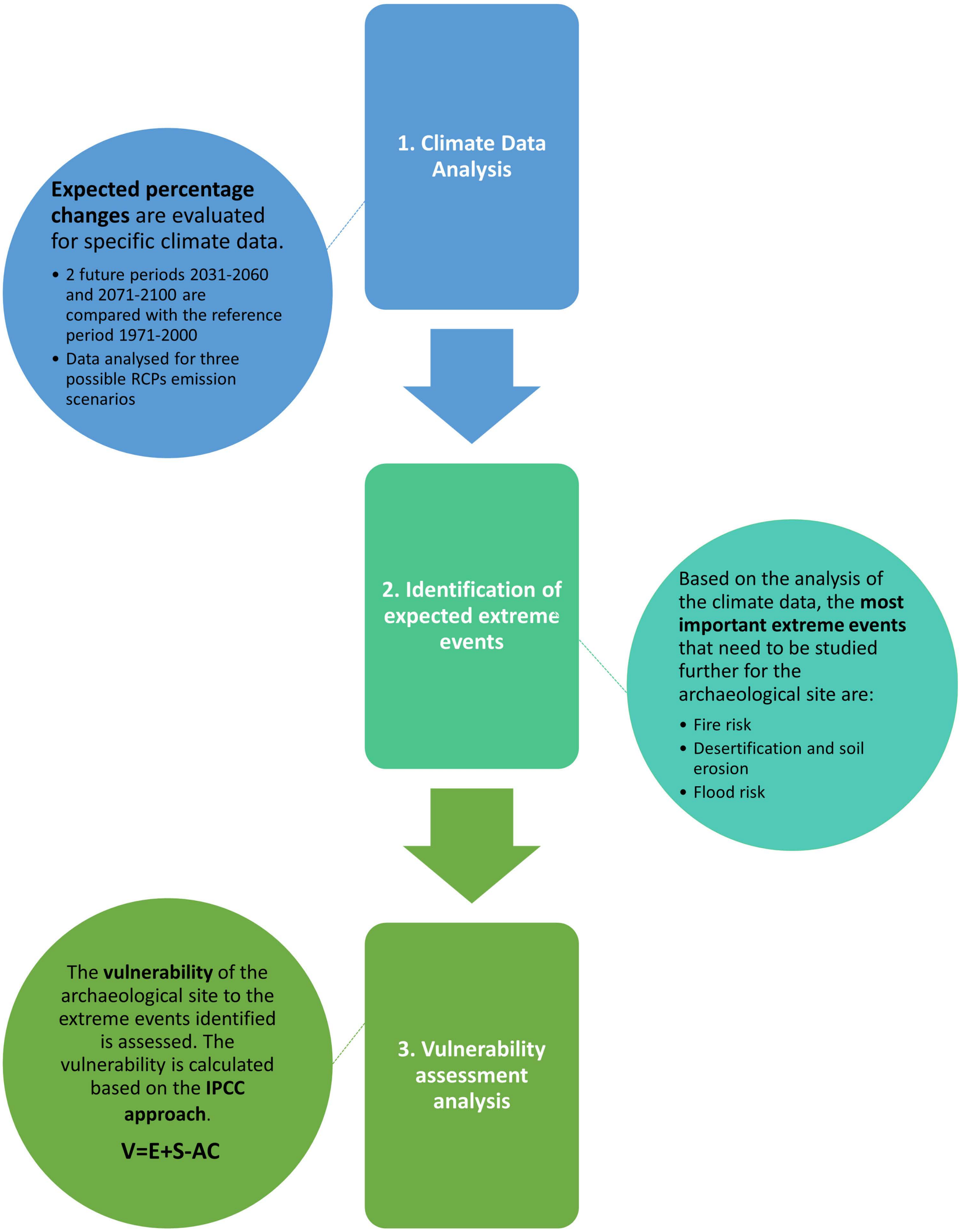


Figure 5. The methodological approach followed to assess the impacts of climate change on archaeological site of Ancient Messene (Dimitriou et al., 2021).

2.2.1. Climate Data Analysis

Based on the IPCC reports (IPCC, 1990, 1995, 2001, 2007, 2014, 2021), four (4) Representative Concentration Pathways (RCPs) scenarios have been developed. These scenarios include emission and concentration time series for all greenhouse gases, aerosols, and chemically active gases, in addition to land use data (IPCC, 2001).

Population growth rate, economic activity, lifestyles, energy sources, technological development, future land use, and climate change policies are the primary criteria that influence the RCPs. RCPs are crucial in formulating mitigation and adaptation policies. They include a scenario with significant mitigation (RCP2.6), two intermediate scenarios (RCP4.5 and RCP 6.0), and a scenario with extremely high GHG emissions (RCP8.5). The RCP2.6 scenario demonstrates a scenario that seeks to keep global warming below 2˚C above pre-industrial levels (**Figure 6**).

To assess potential changes in climate and consequent risks and extreme events at the archaeological site of Ancient Messene, a large number of climate variables and indicators were analysed, corresponding to those analysed in the IPCC assessment reports (IPCC, 1990, 1995, 2001, 2007, 2014, 2021).

The NOA provided the climate variables and indicators for Ancient Messene as time series. The original data were retrieved from two state-of-the-art RCM simulations carried out in the frame of EURO-CORDEX (Coordinated Regional Climate Downscaling Experiment), with a horizontal resolution of about 12 km (0.11˚) for three periods: the control 1971-2000, the near future (2031-2060) and the distant future (2071-2100) periods. The regional climate model (RCM) used for simulation and data analysis was selected by comparing precipitation and temperature records from 1974 to 2004 with simulations from five RCMs. This process resulted in the selection of the MPI. The RCA4 regional climate model of the Swedish Meteorological and Hydrological Institute (SMHI) is driven by

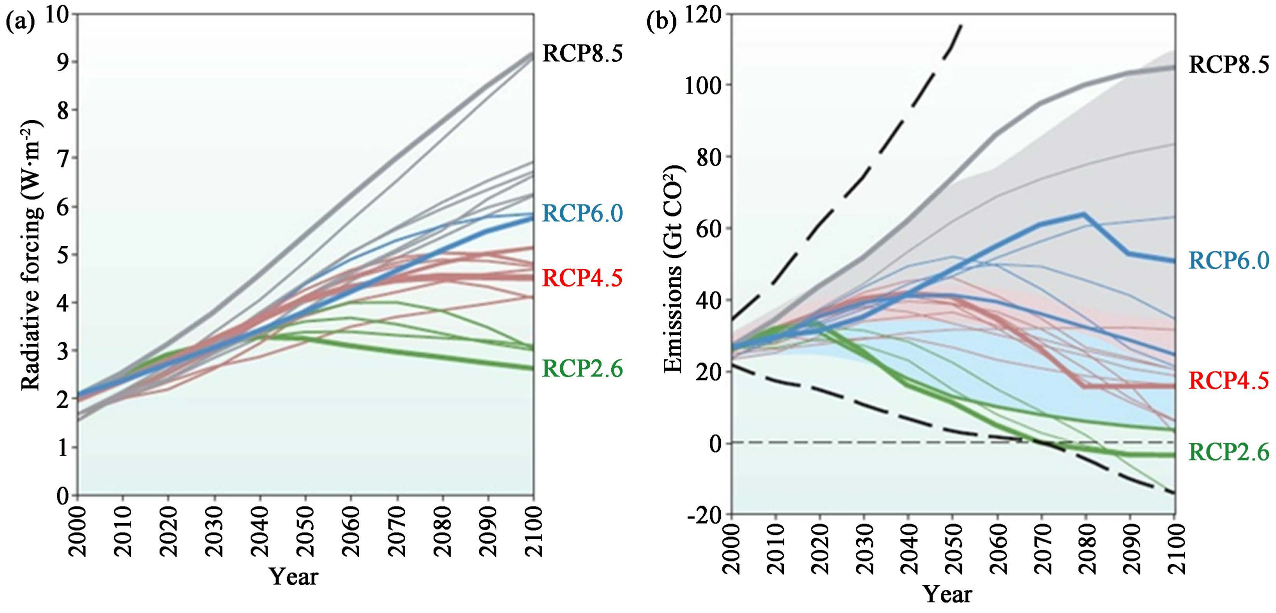


Figure 6. Representative Concentration Pathways, RCPs, (a) change in radiative forcing compared to the pre-industrial era, and (b) CO_2 emissions for the various RCPs. The four RCPs scenarios are marked in bold color and the individual scenarios in thin lines (Moss et al., 2010).

the global MPI-ESM-LR model of the Max Planck Institute for Meteorology model (RCA4-MPI).

The analysis was based on comparing the values of the variables and indicators selected for the period 1971-2000 with the expected values for two future periods, 2031-2060 (near future) and 2071-2100 (distant future), and for three of the four RCPs. The period 1971-2000 was selected as the reference baseline period to calculate the changes in climate as it was the only period with complete time series data for the study area according to NOA. The RCPs examined are the severe mitigation scenario RCP2.6, one of the two intermediate scenarios, namely RCP4.5, and the extremely high GHG emissions scenario (RCP8.5). The statistical significance of the differences between the obtained climate values was evaluated using the z-test when the sample size exceeded 30 observations and the t-test when the sample size was less than or equal to 30 observations. In particular, it was tested whether the two means of each variable and indicator were the same (the null hypothesis Ho). The differences between the samples were statistically significant, with a 95% confidence when z critical two-tail<z and $P (Z \leq z) < 0.05$ or respectively t critical two-tail<t and $P (T \leq t) < 0.05$.

2.2.2. Identification and Evaluation of Expected Extreme Events in the Archaeological Site of Ancient Messene

The second step of the methodological approach followed was identifying the most critical extreme events from the results of the climate data analysis (see section 2.2.1.). The analysis results, as highlighted in the relevant section (see Section 3.1.), led to the need for further consideration of the impacts of fire, desertification, and flood risks.

It was decided to assess fire risk through the FWI further. The FWI is a daily index that utilizes only meteorological parameters and considers the impact of fuel humidity and wind on fire behavior. Midday values of air temperature, humidity, wind speed, and 24-hour precipitation are required for its calculation (Viegas et al., 1999).

The index is subdivided into risk categories determined by area-specific sensitivity analyses. In the present study, the European forests’ index was used (EFFIS—European Forest Fire Information System). The FWI is categorized as follows: Very Low 5.2, Low 5.2 - 11.2, Medium 11.2 - 21.3, High 21.3 - 38.0, Very High 38.0 - 50.0, and Extreme > 50.

The risk was calculated by comparing the reference period values to the expected values for the two future periods, 2031-2060 and 2071-2100, which were calculated using three emission scenarios (RCP2.6, RCP4.5, and RCP8.5).

To determine the sensitivity of the area to land desertification where the archaeological site is located, it was decided to analyze the Environmentally Sensitive Area (ESA) indicator (Karamesouti et al., 2018). Specifically, the approach is an operational platform that estimates the contribution of various ecological (climate, soil, vegetation) and socioeconomic (land use, population density, human pressure) parameters related to land desertification (Ferrara et al., 2020).

Gibbs & Salmon (2015) say that this method has been used for empirical research and environmental reporting. It is noted that the term desertification describes the degradation of productive lands in arid areas or even deserts, incorporating both anthropogenic and climatic parameters that lead to this degradation (Aubréville, 1949). Immediate and short-term consequences of desertification include reduction or loss of soil fertility, alteration of natural vegetation, change in biodiversity composition and loss of biodiversity, degradation of water quality, and land erosion.

Regarding the flood risk, DHI's MIKE SHE 2020 hydrological model (DHI, 2020) was used to evaluate the level of the risk and find the most vulnerable parts of the archaeological site (Dimitriou, 2021).

The simulation of the hydrological model was based on the following parameters: 1) overland flow (OL); 2) unsaturated zone flow (UZ); 3) evapotranspiration (ET), and 4) saturated zone flow (SZ). The drainage basin downstream of the Messina archaeological site was designated as the simulation area. At the same time, the canal size was set to 2.00 m to achieve the optimal balance between representational accuracy and computational speed. The archaeological site's catchment area is 3.23 km^2 (Dimitriou, 2021).

Using the MPI regional climate model (GCMs/RCMs), the values of the variables and indicators for the three emission scenarios and the three time periods were simulated. The selection was made by comparing the values obtained from five distinct regional climate models for daily precipitation and daily mean temperature to the values recorded at the corresponding meteorological station from 1971-2000 (Dimitriou, 2021).

2.2.3. Vulnerability Assessment of the Archaeological Site of Ancient Messene

The IPCC vulnerability assessment analysis was followed in the third step of the methodological approach for assessing the impacts of extreme weather events, which resulted from the analysis of the climate data on the archaeological site of Ancient Messene. Through this process, it was presumed that it is possible to identify the site's needs as efficiently as possible, propose an integrated adaptation strategy, and prioritize the measures.

The vulnerability assessment of a system to the impacts of climate change as a methodology for risk assessment was first introduced after the publication of IPCC's Third Assessment Report in 2001 (IPCC, 2001). In this study, vulnerability assessment was viewed as an essential first step in developing or implementing measures to address the effects of climate change on all human activity sectors. This approach has the advantage over traditional risk analysis as it does not simply examine the exposure and sensitivity of the system to one or more risks but also considers its ability to adapt to new conditions and establish equilibrium within them.

McCarthy et al. (2001) describe system vulnerability as the degree to which a system is likely to be severely affected by climate change. This approach is based on three parameters: exposure, sensitivity, and adaptive capacity.

Exposure is the extent to which a system may be affected by a hazard due to its location (e.g., a coastal area is more vulnerable to storm events than an inland location) (McCarthy et al., 2001). Sensitivity is the extent to which a system is negatively or positively affected by climate-related events (McCarthy et al., 2001). There may be direct or indirect effects. Adaptive capacity is related to human activities (institutional provisions, technology, and infrastructure) but can also be a system attribute (McCarthy et al., 2001).

According to the following equation, vulnerability (V) is a function of exposure (E), sensitivity (S), and adaptive capacity (AC):

$$\mathrm{V} = \left(\mathrm{E} + \mathrm{S}\right) - \mathrm{AC} \tag{1}$$

A system's high vulnerability arises from its high exposure and sensitivity in conjunction with its limited adaptability. In contrast, the vulnerability of a system decreases as adaptive capacity increases and exposure and sensitivity parameters decrease.

For the case study of the archaeological site of Ancient Messene and the exposure criterion, it was determined to what extent the site will be adversely impacted by the risks of fire, desertification, and flooding due to its geographic location. The site's characteristics, such as drainage basin, topography, and geological structure, were also evaluated.

For the sensitivity criterion, the extent to which (a) the materials of the restored monuments and excavated finds and (b) native and cultivated vegetation would be affected, directly or indirectly, was assessed.

Using non-destructive methods, the existing condition and any existing damage under current climatic conditions were mapped to evaluate the materials' vulnerability to anticipated hazards. Specifically, the following tests were conducted: 1) macroscopic observation of areas of the archaeological site; 2) photographic imaging of the current condition of the materials; 3) microscopic observation with an optical fibre microscope of areas of severe deterioration; 4) Scotch tape test on healthy and deteriorated surfaces.

To assess the sensitivity of the vegetation, a field survey of all native, cultivated, and ornamental perennial, shrub, and tree species was conducted both within and without the archaeological site. Due to the lack of seasonal variation among perennial species, the survey was conducted during a single period in May 2021. The number of individuals growing on the site, by plant species and location, was recorded during site visits and plotted on a map. Except for shrub stands, where it was impossible to determine the number of individuals, each native plant was counted as a distinct individual. The identification of each genus and species was based on Flora Europea.

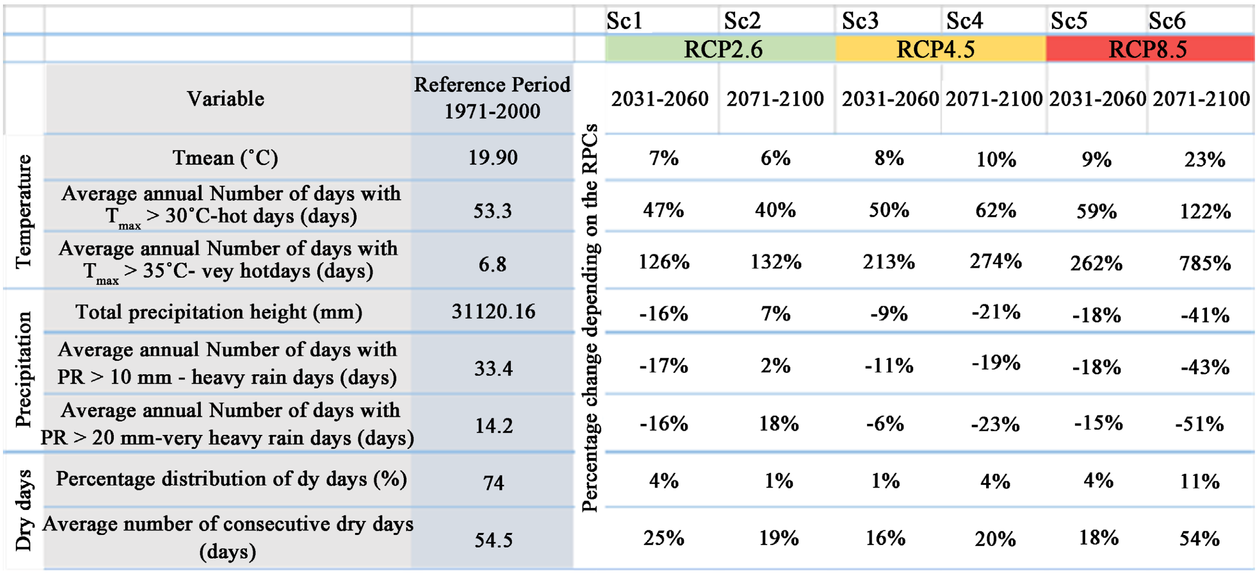
For the adaptive capacity criterion, the following were evaluated: 1) the adequacy of the electromechanical infrastructure; 2) the suitability of the traffic and road infrastructure and the level of safety they provide; 3) the management practices of the archaeological site; 4) In addition, the adequacy of the existing legislative framework for the protection of the monument and, by extension, the degree to which the archaeological site is protected at the institutional level from the pressures it is subject to were also evaluated (from human activities, climate change, etc.).

The approach is based on a quantitative analysis of climate data and indicators that uses various emission scenarios to define the site's primary climate risks. In contrast, the final evaluation of the vulnerability of the archaeological site to these threats is qualitative. Therefore, a qualitative approach is used to determine the extent to which climate change will impact an archaeological site such as Ancient Messene. For instance, the condition of the monuments, the plants, and the infrastructure must be considered. Furthermore, due to the dynamic nature of climate change, it is difficult to predict how and when extreme events will occur. Therefore, a qualitative approach was used to obtain the most accurate results.

3. Results

3.1. Expected Climate Changes

The most critical variables analysed in order to assess potential changes in climate and consequent risks and extreme events at the archaeological site of Ancient Messene are Daily Precipitation (days) and Daily maximum/mean/minimum Temperature (mm), as well as the climate indicators very hot days (HOT35) and hot days (HOT30), consecutive dry days (PR20), heavy precipitation days (PR10) and very heavy precipitation days (PR20). These parameters were chosen to be analysed according to the archaeological site's location and the recorded extreme events. The climate data analysis revealed, as shown in **Figure 7**, that the region's climate will become warmer and drier. In all emission scenarios (from severe to high), the frequency of hot and extremely hot days will increase



				Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
				RCP2.6		RCP4.5		RCP8.5	
	Variable	Reference Period 1971-2000		2031-2060	2071-2100	2031-2060	2071-2100	2031-2060	2071-2100
Temperature	Tmean (˚C)	19.90	Percentage change depending on the RPCs	7%	6%	8%	10%	9%	23%
	Average annual Number of days with T_{max} > 30˚C-hot days (days)	53.3		47%	40%	50%	62%	59%	122%
	Average annual Number of days with T_{max} > 35˚C- vey hotdays (days)	6.8		126%	132%	213%	274%	262%	785%
Precipitation	Total precipitation height (mm)	31120.16		-16%	7%	-9%	-21%	-18%	-41%
	Average annual Number of days with PR > 10 mm - heavy rain days (days)	33.4		-17%	2%	-11%	-19%	-18%	-43%
	Average annual Number of days with PR > 20 mm-very heavy rain days (days)	14.2		-16%	18%	-6%	-23%	-15%	-51%
Dry days	Percentage distribution of dy days (%)	74		4%	1%	1%	4%	4%	11%
	Average number of consecutive dry days (days)	54.5		25%	19%	16%	20%	18%	54%

Figure 7. Expected percentage changes for climate parameters according to different RCPs (Dimitriou et al., 2021).

while annual precipitation will decrease. Similarly, dry and continuously dry days are anticipated to increase by up to 54% in the scenario of high emissions and for the period 2071-2100.

Based on the above study findings and the expected climate change in the region, it was concluded that fire and desertification are the primary threats for which the vulnerability of the archaeological site should be assessed, followed by formulating an adaptation strategy. In addition, although the total daily and annual precipitation is expected to decrease, it was decided to assess the flood risk in the light of the damage caused by the 2016 floods at the archaeological site since the risk of an extreme flood event is mainly related to the rapidity of the rain and not necessarily to the daily loads.

3.2. Risk of Extreme Events

Based on the climate data analysis, it was concluded that critical hazards for the study area include fire, desertification, and flooding. It was therefore decided to assess further the degree to which they are expected to occur. A more extensive analysis of the results obtained for each hazard is provided separately.

3.2.1. Fire Risk

From the analysis of the FWI, an increase in the number of days with high fire index values is expected for all three emission scenarios, from the most favorable to the least favorable. Especially in July and August, the FWI values are projected to be extreme, in contrast to the reference period 1971-2000, where the values are in the "very high values" class. Overall, the riskiest months for fire are from June to September, with the highest values of the index being reflected in the extreme emissions scenario. The graphs below (Figure 8) show the average value of the index per month, depending on the emission scenarios.

In addition, a table was created, which shows the probability of high, very high, and extreme values of the FWI over 30 years, depending on each emission scenario.

As shown (Figure 9), under the worst-case emissions scenario RCP8.5, a large number of values, like 17% within 30 years and 24% in the far future, are expected to be in the extreme range.

3.2.2. Desertification

The ESA analysis showed (Figure 10) that the central area of the archaeological site falls into the category of "moderate sensitivity" to the risk of desertification. The hilly areas to the east are expected to be unaffected. In contrast, the section south of the archaeological site is likely to be affected in the long term (Kokkoris, 2021).

3.2.3. Flood Risk

The simulation of the study area with the MIKE-SHE hydrological model revealed that parameters such as surface runoff and the passage of an unnamed stream in a north-south direction through the archaeological site in the Agora

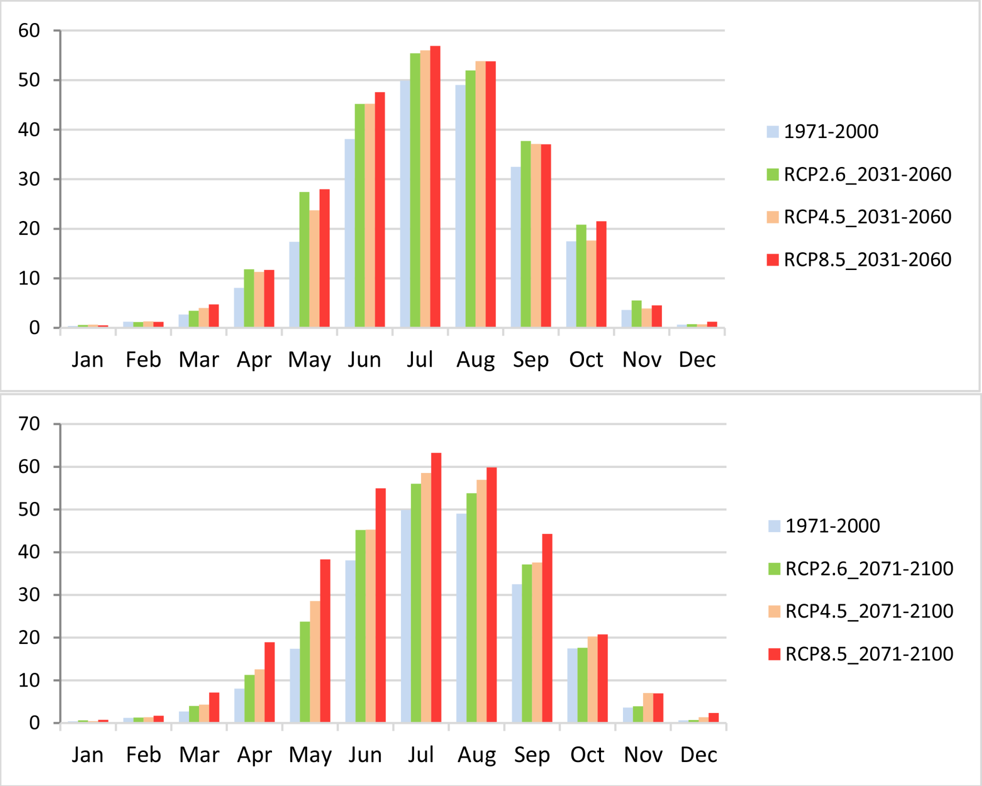
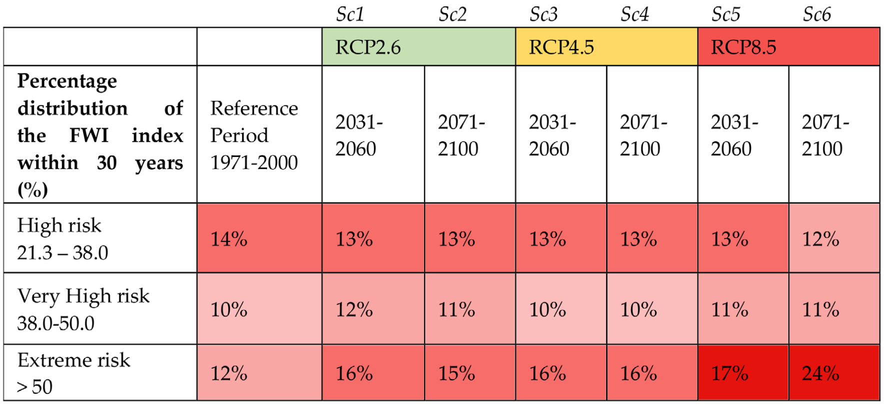


Figure 8. Comparative analysis of the monthly average FWI recorded for the reference period 1971-2000 and projected for the period 2031-2060 (above) and for the period 2071-2100 (below) for all three climate scenarios (RCP2.6, RCP4.5, and RCP8.5), according to the MPI climate model.



		Sc1	*Sc2*	*Sc3*	*Sc4*	*Sc5*	*Sc6*
		RCP2.6		RCP4.5		RCP8.5	
Percentage distribution of the FWI index within 30 years (%)	Reference Period 1971-2000	2031-2060	2071-2100	2031-2060	2071-2100	2031-2060	2071-2100
High risk 21.3 – 38.0	14%	13%	13%	13%	13%	13%	12%
Very High risk 38.0-50.0	10%	12%	11%	10%	10%	11%	11%
Extreme risk > 50	12%	16%	15%	16%	16%	17%	24%

Figure 9. Comparative analysis of the percentage distribution of daily FWI values for the three (3) periods, depending on the climate scenarios RCP2.6, RCP4.5, and RCP8.5, according to the MPI climate model.

area contribute significantly to the probability of a flood event. The probability increases in the case of the prevalence of the RCP2.6 and RCP4.5 emission scenarios and decreases in the case of RCP8.5 (Dimitriou, 2021).

Based on the model, the highest water concentration is expected in the Agora area, while the Asclepieion and the Stadium are at significant risk. These areas are depicted in **Figure 11** (Dimitriou, 2021).

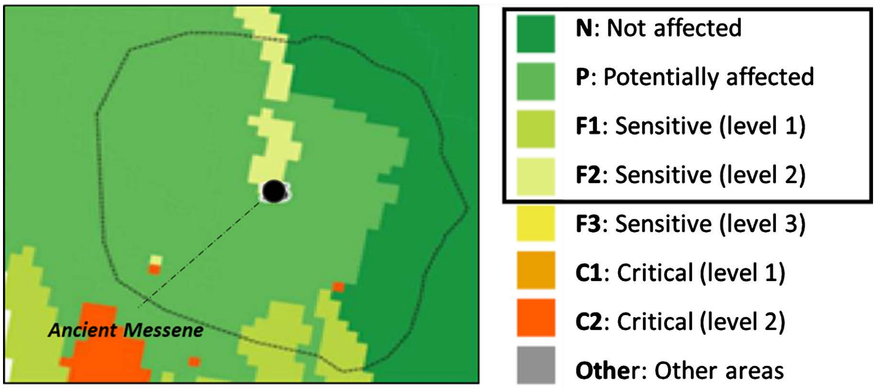


Figure 10. Classification of vegetation and land use units in desertification sensitivity categories (ESA index) around the archaeological site of Ancient Messene (Kokkoris, 2021).

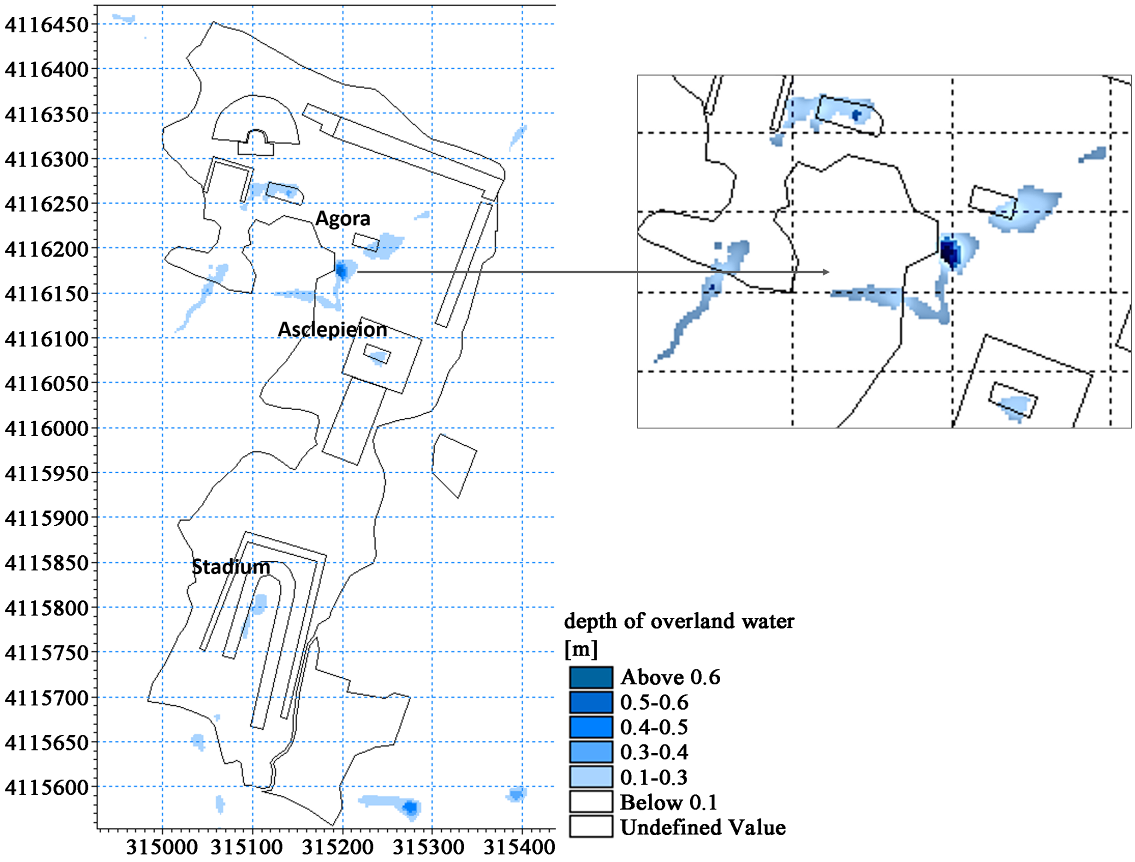


Figure 11. The areas with the highest risk of water concentration in case of a flood event, based on the MIKE-SHE hydrological model (Dimitriou, 2021).

3.3. Assessment of the Vulnerability of the Archaeological Site to Extreme Events due to Climate Change

After determining the probability of the extreme events of fire, desertification, and flooding, an attempt was made to determine the site's overall vulnerability. The method described in Section 2.2.2. was used to evaluate the IPCC-defined parameters of exposure, sensitivity, and ability to adapt.

3.3.1. Exposure of the Site to Climate Change Impacts due to Location

The site's location is considered to present a moderate-to-high risk of exposure. The Ancient Messene site is situated in an area that is moderately vulnerable to desertification and has a high risk of wildfire. It also receives heavy precipitation, which makes the soil vulnerable to erosion. It should be noted, however, that the degree of soil erosion risk cannot be precisely estimated, as it is influenced by the frequency and intensity of rainfall events that will occur in the region based on the RCPs, as well as by the infrastructure and measures that will be implemented to address these extreme events (Dimitriou, 2021). The combination of these parameters, taking into account its history with the relatively recent major fire in August 2014 and the subsequent floods in 2016, leads to the conclusion that a repeat fire in the near future could be particularly detrimental to the area and especially to the archaeological site, as it would pose a significant risk to the monuments and limit the natural regeneration, which is only now recovering from 2014.

3.3.2. Sensitivity of Materials and Vegetation to the Impacts of Climate Change

Overall, the risk for both the material and vegetation parameters is considered moderate.

For the monuments' materials of the archaeological site, from the non-destructive tests conducted (see section 2.2.2), it was found that the most common types of deterioration are: 1) in limestones, biological colonisation, differential erosion, microcracking, and localized loss of material; 2) in sandstones, which are primarily used in columns, capitals, architraves, and masonry, acupuncture, loss of material, rounding, and white and black crusts of biological origin (**Figure 12**).

The monuments most affected are the Mausoleum and the Stadium (**Figure 2**), due to their limited exposure to solar radiation and the route of running water, as well as the sandstone elements of the North Gallery of the Agora and the Asclepieion (Kaditis, 2021).

Even though total precipitation is expected to decrease in the worst-case climate scenarios, possible flooding events combined with the risk of desertification are


(a) (b)

Figure 12. (a) The surrounding area of the Arcadian Gate; (b) The Ithomi hill after the August 2014 fire. http://eleftheriaonline.gr/local/koinonia/item/43720-pyrosvestiki-vlepei-emprismo-ithomi is the source.

estimated to cause further soil retreat, threatening the monumental stones, whether composed of sandstone or limestone. The Theatre, the northern Gallery of the Agora, and the Asclepion, where the on-site inspection revealed both water accumulation and running water, appear to pose the greatest threat.

It is estimated that the increase in fire risk, especially during the summer months, in conjunction with the increase in dry days, will result in irreversible changes to the surface and aesthetics of the monuments, as well as their strength and stability. Regardless of building material, columns are more vulnerable than masonry. Similarly, the architraves, capitals, and pedestals spread throughout the archaeological site are at risk. Regarding construction materials, it is expected that limestones will be more sensitive to high fire temperatures than sandstones, as exposure to extreme temperatures has been observed to cause severe cracking and a decrease in their mechanical strength. In contrast, increased strength and stiffness are observed in sandstones under similar conditions (Hajpal, 2010).

For the vegetation parameter, the presence of species with annual or biannual biological cycles in the vegetation of the archaeological site and its surroundings leads to the conclusion that the site will be very sensitive to changes in the existing composition of plant communities. This applies to broad-leaved species (i.e., olive and walnut) sensitive to dry thermal conditions (Kanellou, 2021). Any change in composition, particularly a shift in the proportion of shrub species, will alter the floral identity of the site (Vrachnakis, 2015).

As the rate of change in perennial species ecosystems is slow, it is anticipated that native vegetation in the surrounding landscape and the archaeological site will be less sensitive to alterations in plant community composition (Mouillot et al., 2002). The impacts of climate change are expected to be more evident in unstable ecosystems that have not yet reached the most mature stage of biocommunity succession, such as the hill of Ithomi, which burned in 2014 (Mouillot et al., 2002; Penuelas, 2007). Although Ithomi Hill's bushy vegetation has recovered substantially, it has yet to reach the most mature stage of succession (Kanellou, 2021).

Within the archaeological site of Ancient Messene, the vegetation shows low sensitivity to the effects of climate change, especially to fire, if it continues to be maintained in good condition and surface and aerial (tree leaves, etc.) fuel is regularly removed (Kanellou, 2021). In the case of a flooding event, soil material and nutrients may be washed away, thus preventing plant regeneration (De Luis et al., 2001). If the frequency of fires increases, the phenomenon is likely to have a cumulative effect, affecting both the rate of recovery and the resistance of soils to flooding. Outside the archaeological site, as long as farming practices continue in the cultivated areas (east and west of the site) and olive groves, sensitivity is expected to be lower (Kanellou, 2021).

In general, the formation of the surface vegetation, exposure, and slope influence the occurrence and development of fires. The analysis revealed that such an incident is more likely to start outside of the archaeological site, particularly in areas including native shrub species, which, according to the literature, pose a greater fire risk and produce fires of high intensity and speed (Dimitrakopoulos, 2002). According to the analysis of climate data, the expected worsening of dry thermal conditions will cause the moisture content of fuel to decrease. The frequency of forest fires in these regions is anticipated to increase. As areas regenerated by fire are vulnerable to new fire outbreaks, a phenomenon is likely to occur cumulatively (Mouillot et al., 2002). Due to this phenomenon, the composition of evergreen shrub plant communities may be worsened by the increased interspersion of low fire-resistant trees (Vrachnakis, 2015; Calvo et al., 2002).

3.3.3. Adaptability of the Archaeological Site with Respect to Infrastructure and Management Practices

The functionality and safety of the existing infrastructure were evaluated to determine the site's adaptability. In addition, the site's current management practices and the suitability of the legal framework were also evaluated.

Regarding the existing infrastructure, the monument's drainage network and fire protection are the most pressing problems for the archaeological site (Maistros, 2021). The fact that the wastewater from the ancillary areas of the archaeological site and the settlement upstream in Mavrommati is discharged through septic tanks has led to the contamination of the aquifer's water, making secondary treatment necessary for at least before any disposal in the subsoil. At the same time, the safety and resilience of the site are equally seriously affected by the lack of a fire protection study and a well-organized fire-fighting system (Maistros, 2021).

Regarding access, traffic, and parking, the main factor affecting the resilience of the archaeological site is the inadequacy of the road network for access by emergency vehicles (e.g., fire engines). Apart from the main entrance A, the secondary entrances (Entrances B and C)) do not allow for rapid evacuation of the site by many visitors in the case of an emergency. Due to its insufficient width in all sections, the existing provincial road network also contributes negatively to the above, as it fails to ensure the safe two-way movement of vehicles (Kalantzopoulou, 2021).

In addition, important concerns are the need for clearly defined guidelines for visitor movements and the absence of appropriate signage on the paths leading to the exits. Similarly, the site makes it difficult for people with disabilities to guide (Kalantzopoulou, 2021).

Current management practices at the site, such as the regular removal of surface and aerial fuel, keeping the site clean, and the regular maintenance and restoration of monuments and artifacts, can significantly improve its resilience.

Regarding the existing legal framework, the failure to complete the procedures for the designation of Protection Zones A and B is presumed to have a significant impact on the legal protection of the site. By extension, this is considered to have a significant impact on the overall protection of the area from pressures such as climate change and human activities.

The overall archaeological site's capacity to adapt to anticipated climate change is moderate concerning its infrastructure and management practices. Existing access, movement, and evacuation conditions are insufficiently adapted and configured to promptly deal with an extreme event, which is the most critical issue affecting its response. Similarly, a crucial factor is the absence of a comprehensive fire protection system demonstrating the necessary preventive measures for this archaeological site.

4. Discussion

Based on the analysis of individual potential risks (see Section 3), Figure 13 illustrates the likelihood of climate-related extreme events. The degree of risk was qualitatively evaluated according to the three emission scenarios and for each climate projection period. The qualitative scale ranges from one to four, with one indicating low risk, two indicating medium risk, three indicating medium to high risk, and four indicating high risk. As shown in Figure 13, the risk of a fire event is particularly significant under the RCP8.5 scenario for both future time periods. The risk of drought follows the same pattern. The risk of flooding, which has traditionally been the greatest threat to the archaeological site, could be an equally critical threat under both the severe RCP2.6 scenario and the moderate RCP4.5 scenario. In the case of RCP8.5, the risk is significant, but it might come from a forest fire that would change the soil's characteristics, making it incapable of absorbing even low precipitation.

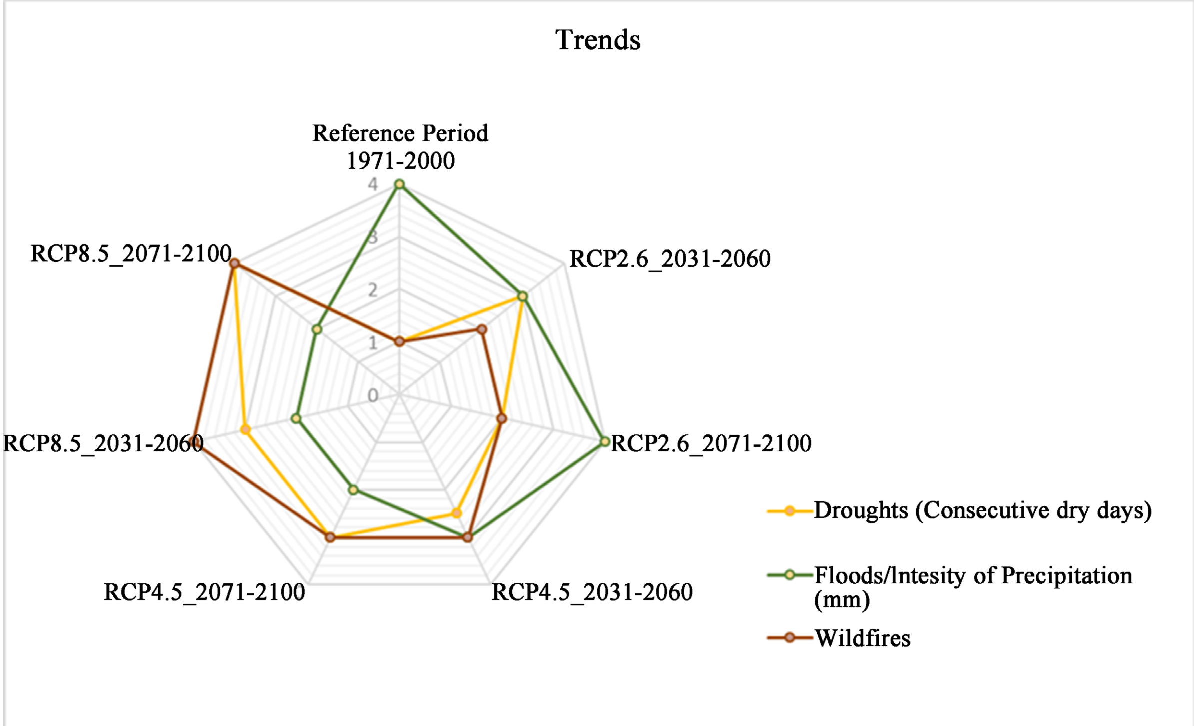


Figure 13. Qualitative assessment of the risk of extreme events occurring in ancient Messene as a result of climate change, as predicted by various emission scenarios (Dimitriou et al., 2021).

Concerning the Ancient Messene's vulnerability, the analysis revealed that it is especially vulnerable to the above risks and climate change-related extreme events due to several issues, such as the location and existing infrastructure. Specifically, the archaeological site is located in an environment with conditions projected to change to a highly arid climate, with a high probability of fire and desertification leading to flooding phenomena due to an inability to retain and absorb water. In addition, the inadequacy of critical infrastructure, such as roads, which does not adequately ensure functional and safe access/evacuation needs to/from the site and internal movement is another crucial factor affecting the site's vulnerability. The absence of a firefighting system is also crucial.

The materials of the monuments are indirectly affected by daily climate variations but directly impacted by extreme events. The vegetation within and around the archaeological site is resistant to change; however, a recurrence of extreme events could significantly limit the possibility of natural regeneration. The designation of protection zones A and B will affect the site's sensitivity to the climate change-related pressures it is or will be subjected to.

Regularly maintaining and restoring every monument significantly reduce the archaeological site's sensitivity.

Figure 14 summarizes the results regarding the exposure of the site to the effects of climate change due to its location, the sensitivity of its materials and vegetation, and the adaptive capacity of the archaeological site based on the adequacy of the infrastructure, the management practices implemented, and the legal protection framework. The values were formulated based on the estimated degree of risk to which the site is exposed to the expected impacts, depending on the evaluated parameter. The qualitative scale ranges from 1 to 4, with 1 indicating a low risk of an event occurring, 2 indicating a medium risk of an event occurring, 3 indicating a medium to high risk of an event occurring, and 4 indicating a high risk of an event occurring.

Based on the analysis of the individual potential risks and the assessment of the vulnerability of the archaeological site of Ancient Messene and aiming at enhancing its resilience to the expected impacts of climate change, an integrated strategic adaptation plan can be developed. The plan could be structured along the following axes (**Figure 15**).

1) Adaptation to climate change measures: A series of proposals were formulated to enhance the resilience and improve the site's functionality.

2) Institutional tools: Institutional tools were proposed to better protect the site from the effects of climate change.

3) Emergency Preparedness Action Plan: Several proposals were formulated for timely response and proper management of emergencies attributed to climate change and extreme weather events.

4) Information, education, and awareness: A series of proposals were formulated to inform, educate, and raise awareness of the public, students, and professionals.

5) Spatial Monitoring System: A series of proposals were formulated to better

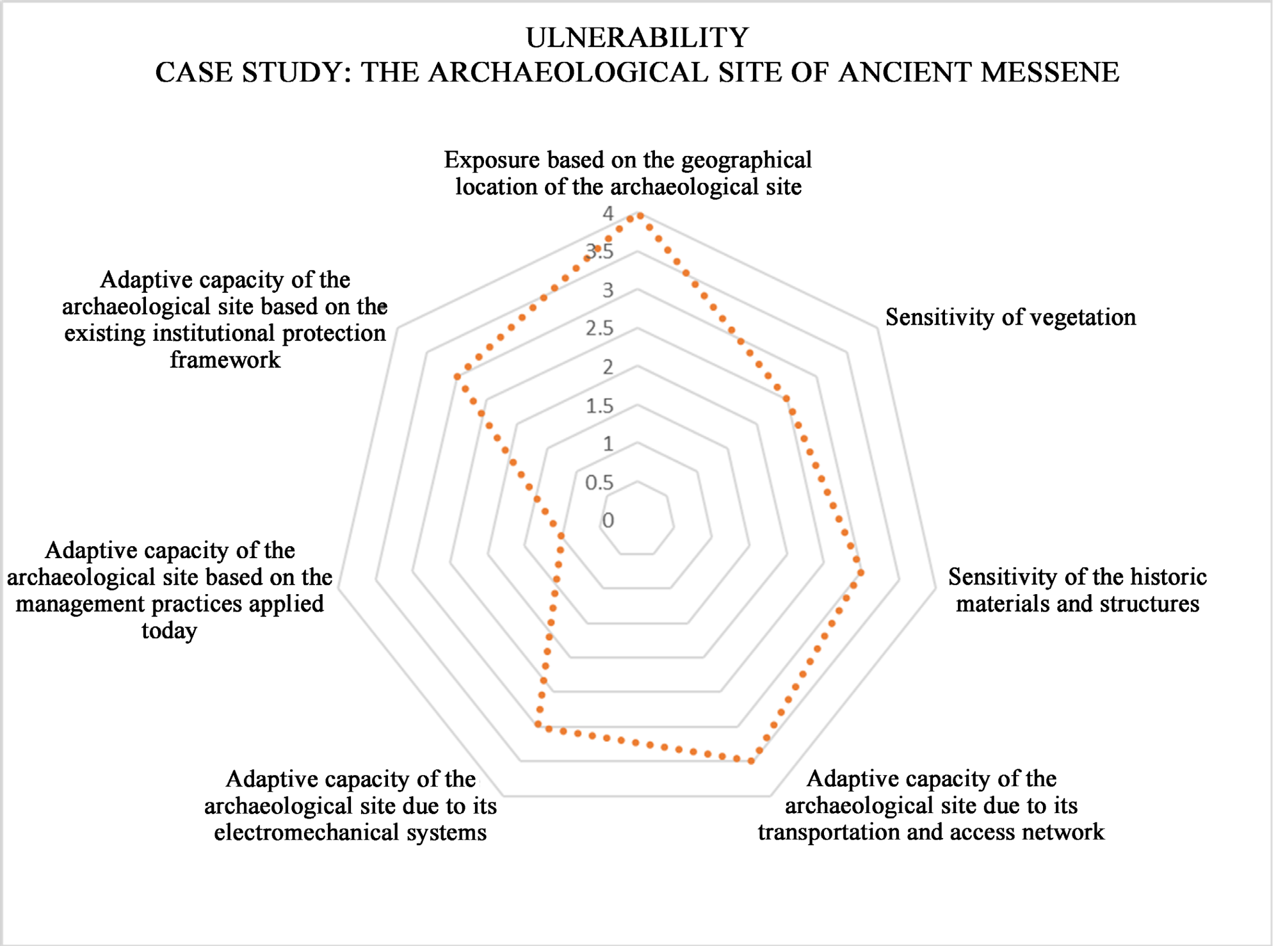


Figure 14. Vulnerability assessment analysis of the case study of ancient messene (Dimitriou et al., 2021).

Figure 15. Adaptation strategy plan for the case study of ancient messene (Dimitriou et al., 2021).

understand the relevant effects of climate change on the materials and structures of the site's monuments and monitor the effectiveness of any measure taken.

The series of proposals for improving the existing infrastructure is a crucial action of a strategic adaptation plan that can contribute to the more effective adaptation of the archaeological site against the effects of climate change. This is one of the most critical issues, which, according to the analysis, significantly impacts the site's vulnerability. Main proposals include the improvement of the road infrastructure outside the archaeological site for tourists and service vehicles (road geometry, signs, lighting, entrance and exit from the archaeological site), as well as movements within the archaeological site (by organizing routes, allowing disabled access, exit signage, and lighting). Equally important is the development of a fire protection study, the implementation of the necessary measures and works, and the protection of the site against flooding and erosion.

Regularly preserving and restoring restored monuments and archaeological materials is an additional measure that can enhance the site's resilience.

At the level of the legal framework, establishing protection zones around the archaeological site and defining neighboring settlements could make a decisive contribution to protecting the archaeological site of Ancient Messene from the effects of climate change. The Society for Messinian and Archaeological Studies has drawn a delineating proposal for the neighboring settlements and the A and B protection zones, which is recommended to be used (**Figure 16**). The development of

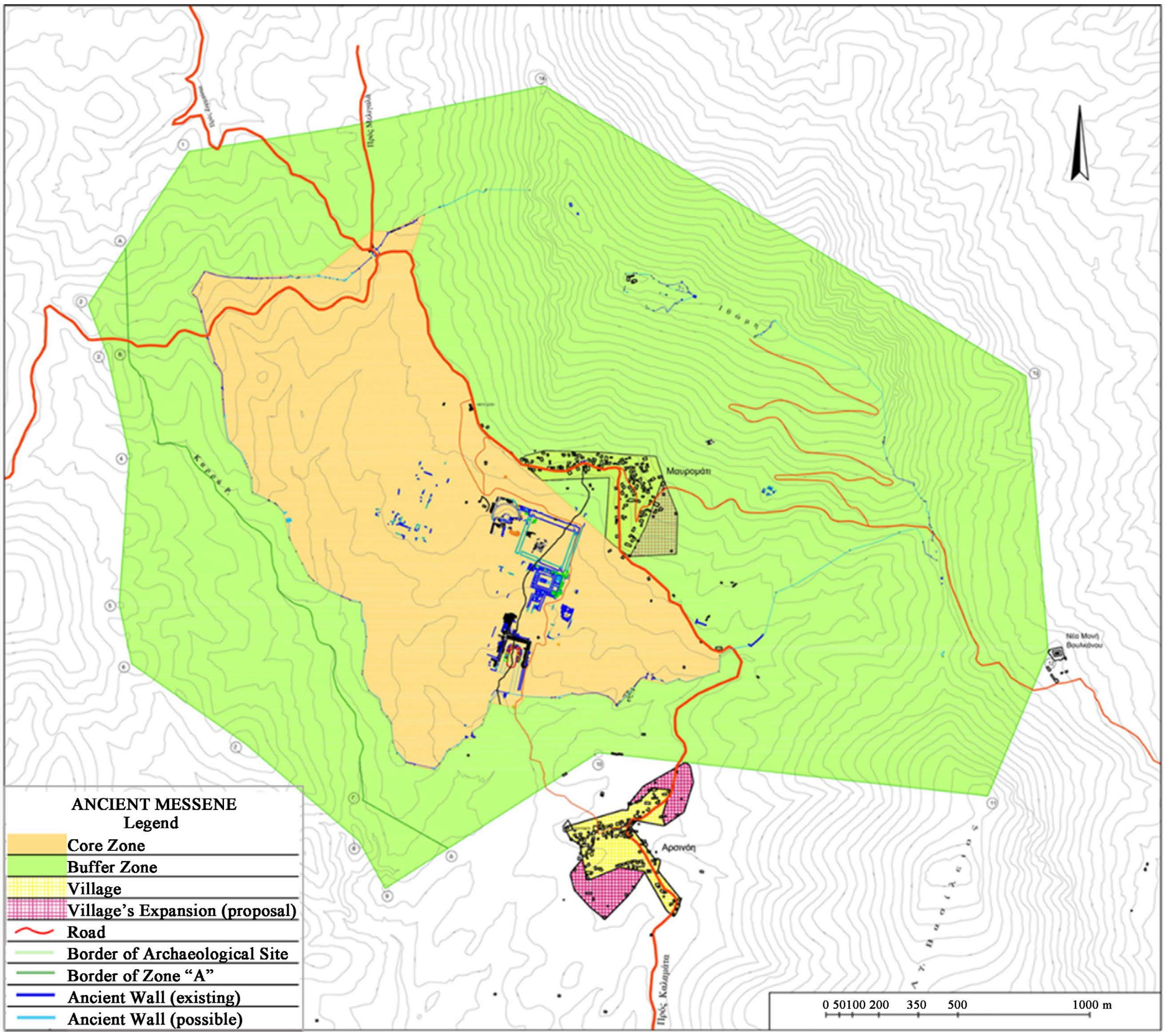


Figure 16. Proposal for the definition of Protection zones A' (core zone) and B' (buffer zone) for the archaeological site of Ancient Messene. The map was designed by the Society for Messinian and Archaeological Studies.

an emergency response plan, taking into account the number of visitors to the archaeological site as well as the number of events held in its restored monuments (Stadium, Theatre, Asclepieion) and the limitation of private automobiles at the site's entrances and organization of parking areas can also contribute to the effective protection of the site.

Organizing actions focused on informing, educating, and raising the awareness of employees, local communities, and site visitors regarding cultural heritage and climate change is important. Indicatively, it would be appropriate to organize personnel training for emergency management, information programs for the public regarding the consequences of climate change on the monuments, and educational programs for students and youth.

To continuously monitor the implementation of these actions and the impacts and predict the risks associated with climate change, it is necessary to develop a database in which specific data about the site's overall status will be recorded regularly. Installing recording sensors in some of the most significant monuments to periodically monitor factors such as temperature, relative humidity, and radiation intensity and establishing regular, non-destructive monitoring of historical monument deterioration and strength can also enhance the site's management and protection.

5. Conclusion

Assessing the impacts of climate change on the cultural heritage assets of Greece is a new field of research that will provide further information to those bodies responsible for protecting the cultural heritage of Greece. This paper assessed climate change's effects on archaeological sites, using the archaeological site of ancient Messene as a case study. Unlike previous studies in Greece, this paper used the IPCC vulnerability assessment methodology to assess the archaeological site's climate change vulnerability. For this reason, this article may serve as a basis for future similar research, raising several issues that link climate change and archaeological site management for the first time in Greece. Moreover, in this article, the archaeological site of Ancient Messene is considered the sum of all these parameters, i.e., the surrounding space/broader landscape, materials, vegetation, infrastructure, management practices, and even the institutional framework of protection.

The approach followed enables the identification of the parameters that increase the vulnerability of each element of cultural heritage and the development of the tools necessary to formulate, monitor, and implement the appropriate policies and measures to prevent and strengthen the resilience of each element of cultural heritage. Additionally, a culture of cooperation, data and knowledge sharing, and active engagement in policy formulation will be fostered to ensure the future protection of every cultural heritage asset.

In order to assess the extent to which climate change will affect an archaeological site, such as Ancient Messene, climate data (variables and indicators) were analysed in order to determine the main climate risks for the site based on different emission scenarios, while the final assessment of the vulnerability of the archaeological site to these risks was qualitative.

Three critical obstacles have become apparent by the analysis performed. The first obstacle was collecting data about the existing situation and other possible pressures (visitors, traffic loads, etc.) the monuments face in Greece. Consequently, continuous monitoring and recording in a database available to all administrative and scientific stakeholders of the condition of monuments and the conservation and/or restoration interventions carried out on them are critical to formulating successful policies. The second obstacle was differentiating between threats linked to climate change and those that may exist at a specific cultural site. Extreme weather occurrences and changes are inextricably linked to a site's or monument's current status: state of conservation, infrastructure, management practices, etc. Hence, both need to be studied and addressed simultaneously. They require an interdisciplinary approach. The third obstacle was the need to create an integrated and detailed management plan that, when implemented, will protect the cultural heritage site from all types of pressures and risks, as well as the transition to a new system of monument management, which will necessitate cooperation between various services and institutions. Protecting cultural resources, caring for their natural environment, making infrastructure work better and safer, and maintaining and restoring monuments should all be done simultaneously.

It has also been found that the most severe obstacles for projects attempting to assess the effects of climate change on Greece's cultural heritage are vague timeframes, unclear references to the natural environment, a lack of international cooperation, and the need to share information about climate change and cultural heritage. However, it is essential to note that collaboration with the proper authorities was critical in resolving these issues.

The analysis performed made clear also that to address the projected consequences of climate change on Greece's cultural heritage, it is necessary to develop integrated management plans with stakeholders' cooperation and establish conservation zones with controlled land uses. It was also recognised that using international protection principles and exchanging pertinent experiences can facilitate the development of more effective policies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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