

# Sustainable management and climate adaptation in historic sites: Insights from Side Ancient City

Leila AKBARISHAHABI<sup>1</sup>

<sup>1</sup>leila.akbarishahabi@kapadokya.edu.tr • Department of City and Regional Planning, Faculty of Architecture, Design and Fine Arts, Cappadocia University, Nevşehir, Türkiye  
ORCID: 0000-0002-0547-7874

*Received: October 2024 • Final Acceptance: May 2025*

## Abstract

Climate change presents an increasing threat to cultural heritage, causing direct physical damage and accelerated material deterioration. This study focuses on the Side Ancient City in Antalya, a culturally and archeologically significant site vulnerable to climate-induced risks. As a popular tourist destination, Side faces a complex blend of environmental, social, and economic challenges, requiring a nuanced understanding of climate impacts. The study aims to identify the risks posed by climate change in Side and to develop strategies for protection and adaptation. Using a qualitative research approach, the study combined a literature review and field analysis to assess the site's vulnerabilities. In the field analysis, historical structures and archaeological sites on the Side were observed within the scope of the impacts of climate change, and the necessary data were collected. Then, a SWOT analysis evaluated the Side's current condition and resilience against climate change. In the subsequent step, the adaptation strategies were formulated and a Matrix was developed to illustrate the connections between climate impacts, SWOT components, and the corresponding adaptation strategies. Based on these findings, the study proposed various adaptation strategies, including physical interventions, regulatory policies for development and tourism, and community-driven approaches for sustainable heritage management. These recommendations aim to protect Side's cultural heritage from ongoing and future climate-related threats and contribute to broader discussions on adapting historic sites to climate change.

doi: 10.58278/0.2026.117

## Keywords

Adaptation, Climate change, Historic site, Side Ancient City.

## 1. Introduction

Anthropogenic activities, primarily through the emission of greenhouse gases, have indisputably led to global warming, with the global surface temperature rising by 1.1°C above the 1850-1900 levels during the period 2011-2020. The increase in global greenhouse gas emissions has persisted, characterized by unequal historical and ongoing contributions resulting from unsustainable practices in energy use, land use and land-use changes, and various lifestyles and consumption and production patterns across different regions, between and within nations, and among individuals (IPCC, 2023). Climate change is increasingly recognized as a critical challenge that threatens not only natural ecosystems but also cultural heritage sites worldwide. Over the past 20 years, there has been growing concern about the climate change risks poses to cultural heritage. Various efforts have been made to evaluate its projected impacts on different heritage categories, addressing both outdoor and indoor environments (Bonazza & Sardella, 2023; Sesana et al., 2021). Climate change poses significant threats to historic sites around the world, impacting their preservation and the ability to maintain their cultural and historical significance. Historic sites are integral to our cultural identity and understanding of history, and the impacts of climate change pose a unique challenge to their preservation. Climate change impacts such as extreme weather events, changes in precipitation patterns and temperature, more intense rainfall and prolonged periods of drought, can damage or degrade historic materials (Fatorić & Seekamp, 2017; ICOMOS Climate Change and Heritage Working Group, 2019; Kapsomenakis et al., 2023; B. Prieto et al., 2020; Sabbioni et al., 2010; Sesana et al., 2021).

The Side Ancient City in Antalya, Türkiye, exemplifies a cultural heritage site at risk from climate change. Renowned for its archaeological significance and historical continuity, Side faces threats from natural and human-induced factors. The city's

proximity to the Mediterranean coast makes it particularly susceptible to rising sea levels and coastal erosion, while increased temperatures and humidity pose additional risks to its ancient structures and artifacts. Additionally, tourism and urban development intensify these environmental challenges, necessitating comprehensive management strategies. This study investigates the specific impacts of climate change on Side and proposes adaptive strategies tailored to its circumstances. Employing a qualitative approach that includes a literature review and field analysis, the research explores global adaptation strategies to protect cultural heritage. Field-based research investigates climate risks on the Side and a SWOT analysis assesses the site's conditions, identifying challenges and opportunities for resilience. In the next step, adaptation strategies were identified and a matrix was developed that shows how climate impacts are linked to the SWOT components and subsequently to the adaptation strategies identified. Figure 1 shows the study framework.

The findings underscore the importance of integrating climate adaptation into heritage management to preserve Side's cultural assets for future generations.

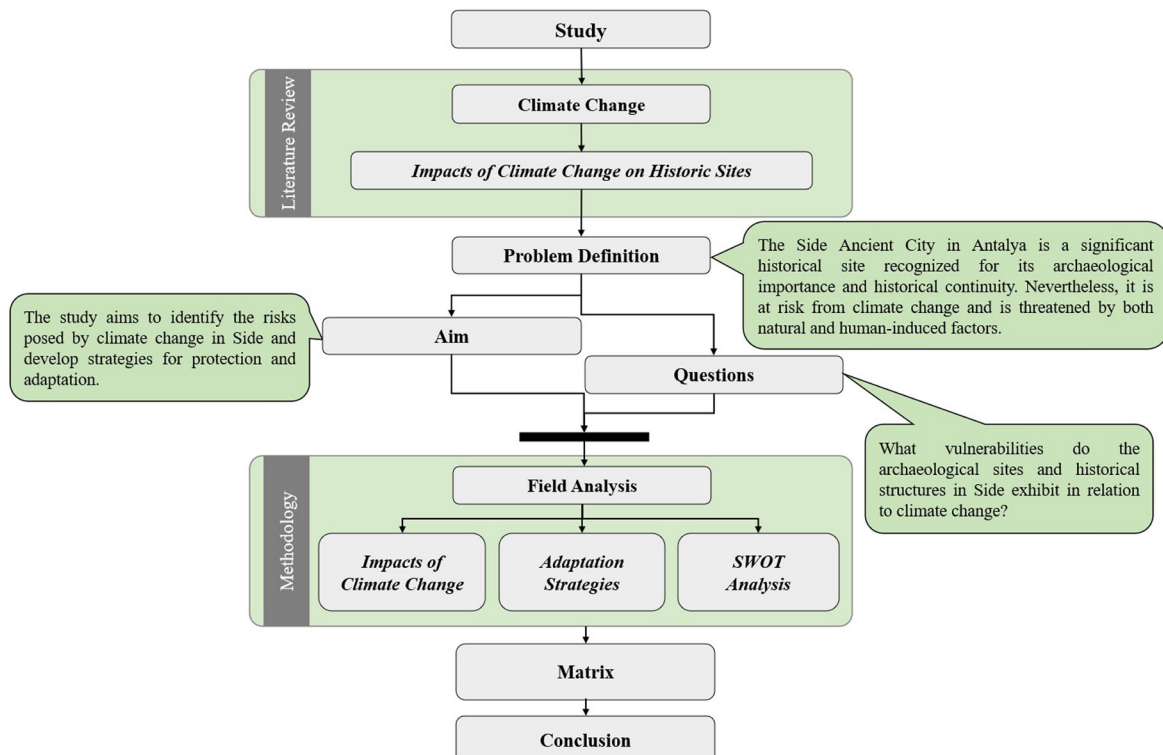
## 2. Climate change impacts on historic sites

Climate change has emerged as a critical issue with significant environmental and social repercussions, leading to an unprecedented rise in mean surface air temperatures over the past 50 years. This phenomenon impacts all facets of human and natural systems, including World Heritage sites. Ensuring the protection and sustainable management of these invaluable sites should be a priority for governments. The effects of climate change on cultural heritage are complex, involving interactions between natural, cultural, and social systems. Historical and archaeological sites are increasingly vulnerable to environmental changes, with climate change exacerbating their degradation through intensified physical, chemical, and biological

processes. Climate change increases the frequency and severity of extreme events like droughts, floods, and landslides, further threatening cultural heritage. Cultural heritage, encompassing historical structures, subsurface archaeological sites, cultural landscapes, and traditional lifestyles, often comprises entities and communities that are particularly susceptible to threats (Fatorić & Seekamp, 2017; A. J. Prieto et al., 2020). In this context, the impacts of climate change on cultural heritage can be categorized and analysed under several critical thematic areas: Sea Level Rise, Flooding and Coastal Erosion (Carbognin et al., 2010; Daly et al., 2022; García Sánchez et al., 2020; Maragno et al., 2023; Marzeion & Levermann, 2014; Reimann et al., 2018), Sea Acidification (Harkin et al., 2020; Willems & Schaik, 2017), Sea-Temperature Change (Harkin et al., 2020; Isaak et al., 2012; Willems & Schaik, 2017), Impacts on Architectural Buildings and Biodeterioration (Bienvenido-Huertas et al., 2021; Dias et al., 2023; Hedayatnia et al., 2021; Pires et al., 2022; B. Prieto et al., 2020; Sabbioni et al., 2010; Silva et al., 2020; Sitzia et

al., 2023), Soil Temperature (Asano et al., 2023; Bradford et al., 2019; Jackson et al., 2013; Menberg et al., 2014), Freeze-Thaw Cycle (Grossi et al., 2007; Sesana et al., 2018, 2021; UNESCO, 2007; Vyshkvarkova & Sukhonos, 2023), Salt weathering (Charlo, 2000; Menéndez, 2018; Ruiz-Agudo et al., 2011; Vyshkvarkova & Sukhonos, 2023), Extreme Weather Events (Sesana et al., 2018, 2021; UNESCO, 2007), Impact on Archaeological Sites (Daly, 2011; Heilen et al., 2018; Hollesen, 2022, 2023).

Gradual climate changes, such as shifts in temperature, precipitation, humidity, and wind intensity, contribute to the long-term degradation of cultural heritage materials by accelerating physical, chemical, and biological decay processes. Sudden events like floods, landslides, wildfires, and sea-level rise can cause immediate and severe damage or worsen existing deterioration (Sesana et al., 2021). Key strategies for protecting cultural heritage from climate change include securing adequate financial resources, improving knowledge of climate impacts, and effectively sharing this information. Engaging stakeholders, such as local communities and



**Figure 1.** Study framework.

decision-makers, is essential, alongside integrating climate change considerations into management plans. Practical measures include building protective infrastructure (e.g., coastal defences), relocating sites when necessary, and avoiding maladaptive practices. Additionally, developing materials compatible with historic environments, enhancing monitoring efforts, and digitally recording heritage for future preservation are recommended. The factors for implementing these adaptation strategies, as detailed in Figure 2, are categorized into six groups (Sesana et al., 2018).

Since the Paris Agreement, UNESCO has aimed to support countries in managing climate change impacts on cultural heritage. Countries should collaborate and share adaptive measures, with more developed nations helping less fortunate ones. Dialogue is needed not only between governments but also among heritage organizations, institutions, site managers, and academics. There is a gap in transferring international knowledge to local levels. Mainstreaming climate change in cultural heritage management requires raising awareness and engaging local communities. Regulations, guidelines, financial incentives, and further research on adaptive measures and risk preparedness are also essential.

### 3. Method

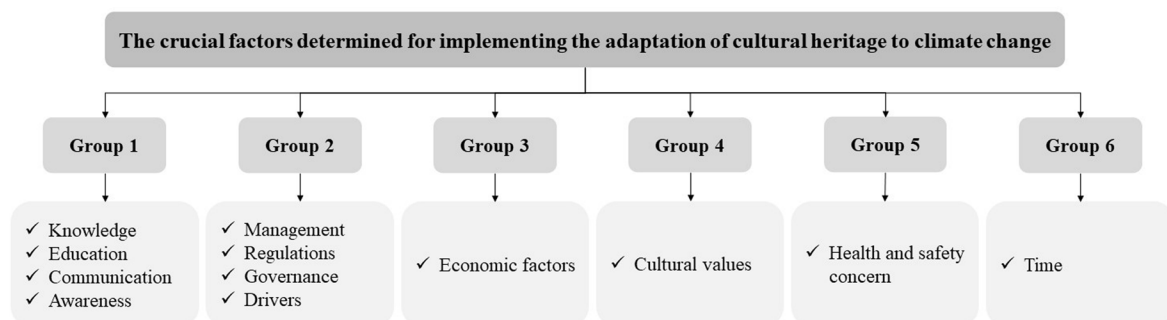
#### 3.1. Side Ancient City

The Mediterranean basin is a densely populated coastal area experiencing rapid demographic, social, economic, and environmental changes. Between 1960 and 2010, the urban population increased by 20%. Tourism also adds pressure, with Mediterranean

countries accounting for about one-third of global tourist arrivals in 2011, a number expected to grow to 637 million annually by 2025 (Wolff et al., 2018). In addition to local human activity, the region faces global environmental challenges, particularly sea-level rise and related hazards, which are anticipated to impact Mediterranean nations throughout the 21st century significantly (Anzidei et al., 2020; Wolff et al., 2018). The Side Ancient City, a significant cultural heritage site featuring monuments from ancient Greek, Roman, and Byzantine civilizations, is the focus of this study, which examines the impacts of climate change, particularly in the Mediterranean basin. This assessment is essential for protecting the city's cultural heritage and formulating strategies for conservation, sustainable tourism, and adaptive management. Additionally, it aids in policy development and contributes to global efforts to safeguard cultural heritage from climate-related risks. Due to its Mediterranean coastal location, Side exemplifies the climatic vulnerabilities common to many classical-period ancient cities, making it an effective case to demonstrate adaptation strategies applicable to similar heritage sites throughout Türkiye and the broader Mediterranean basin.

#### 3.2. Historical and cultural significance of the side

Asia Minor, a peninsular landmass covering approximately 756,103 square kilometres, constitutes a western subcontinent of Asia. Commonly referred to as Anatolia, this region encompasses a significant portion of present-day Türkiye.



**Figure 2.** The key factors for implementing the adaptation of cultural heritage to climate change.

During the Greek and Roman periods, Asia Minor was home to several prominent Greek cities, particularly within the central western coastal area known as Ionia. The Romans adopted the name “Asia Minor” shortly before the birth of Jesus, while earlier Greeks referred to the region simply as “Asia.” Following the decline of Mycenaean society in mainland Greece, the west coast of Asia Minor experienced a steady influx of Greek settlers. By 1000 B.C.E., Greeks of the Ionian ethnic group had established themselves in the region that came to be known as Ionia, with prominent city-states such as Miletus, Samos, Chios, and Ephesus. Greek colonization extended further during the great age of colonization (circa 750–550 B.C.E.), reaching the northern and southern coasts of Asia Minor. In the north, colonies such as Cyzicus on the Sea of Marmara and Sinope along the Black Sea coast were established by Miletus to secure control over trade routes. Key Greek cities on the southern coast included Phaselis, Perge, Aspendus, and Side, strategically positioned from west to east. The Greek settlements flourished due to their strategic positioning

along sea and caravan trade routes (Sacks, 2005; p.51). Figure 3 shows the location of the Side settlement in northern Asia Minor.

According to Figure 3, the ancient city of Side, one of Pamphylia’s most important port cities, is located in the south of the Asia Minor peninsula. Side is an Eastern Pamphylian city located between the Melas River and the Eurymedon River, closer to the Melas River. When examined etymologically, the name “Side” is found not only in the Pamphylia region but also in different regions such as Pontos, Thessalia, Lakonia, and Lycia. There are also areas in mainland Greece with names similar to Side. The name “Side” means Pomegranate in the local language (Alanyalı & Yurtsever, 2020; p.39). The exact foundation date of Side is not known. However, ancient writers mention that the city of Side was founded by the Cymeans who came from the Aeolia Region (Strabon, 2015; p.251). But, the decorated basalt crater, which was unearthed during excavations at the archaeological site and is thought to date back to the Late Hittite Period, is considered the oldest architectural remains of the

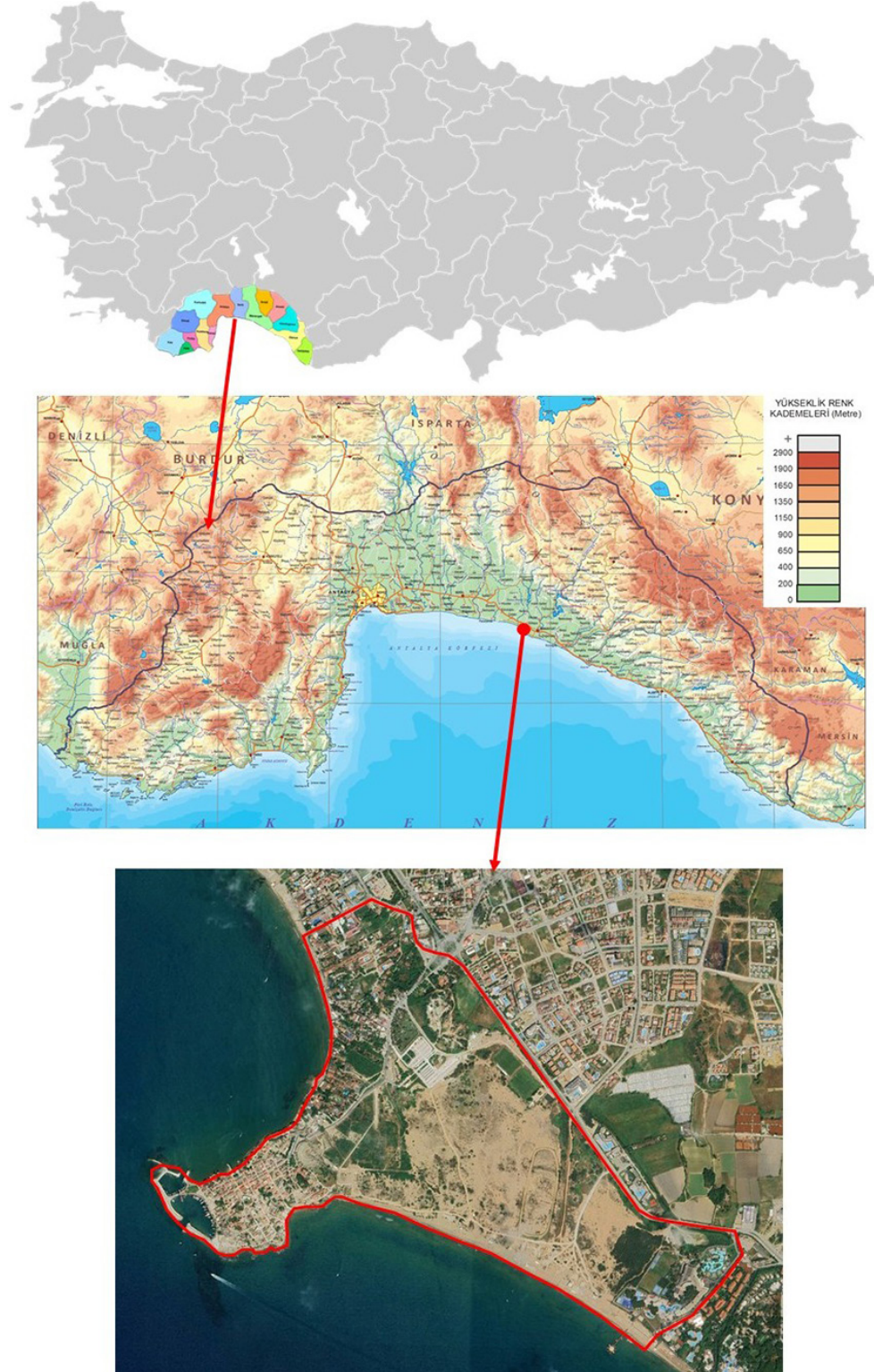


Figure 3. Location of the Side settlement in northern Asia Minor (Sacks, 2005; p.52).

city and dates the city's history back to the Late Hittite Period. However, ancient writers suggest a much earlier date for the city's foundation. According to Eusebius, the city of Side was founded in 1405 BC. (Alanyalı & Yurtsever, 2020; p.43). It is known that throughout history, there was no strong migration or colonial move-

ment to Side and that local elements were much stronger in the city (Alanyalı, 2011).

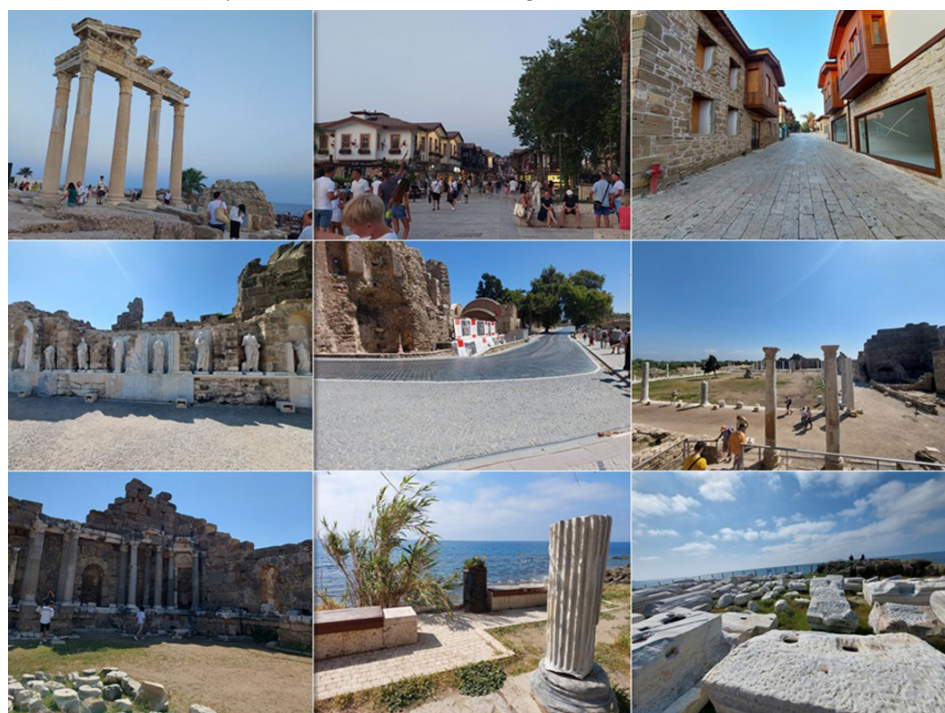
Mansel (2020) notes that Side experienced its first golden age during the Hellenistic period when it had an autonomous structure. The city's second golden age occurred between the 2nd and 3rd centuries AD. (Mansel, 2020).



**Figure 4.** Location of Side.

The city's last golden age was during the 5th and 6th centuries AD. During this period, Side became a bishopric center. It appears that Side was competing with Perge to become the religious center of the region at that time (Alanyalı & Yurtsever, 2020: p.53; Mansel, 2020). Side gained independence in the late Hellenistic period after Persian and Macedonian rule. It later became a Roman administrative center and a key naval base. The city flourished during the Early Byzantine period but declined in the 7th century due to Arab invasions (Altun, 2020; Elam, 2020). It was abandoned in the 13th century after the Seljuks took over the region. In the late 19th century, Turkish families from Crete resettled in Side, and the settlement was named Selimiye Village, later reverting to its ancient name (Altun, 2020). Settlement in Side resumed with the location of Cretan immigrants. Once a commercial, religious, and military hub that eventually became abandoned, Side was revived first as a center for scientific research and then as a tourist destination following archaeologist Arif Müfid Mansel's Side excavations in 1947 (Soykal Alanyalı, 2017). The Pamphylian city of Side has been a focus of scientific research since the 1940s, with significant archaeological work conducted by Mansel from 1947

to 1975. Key monuments include early Christian churches, temples, the Episcopal Palace, colonnaded streets, bath complexes, and fortification walls, indicating Side's prosperity until the Late Antique and early Byzantine periods. Recent findings suggest the bishop's complex included a basilica, baptistry, palace, three Martyria, and other structures, along with a garden area. Ongoing investigations, which began in the last ten years by excavation director Feriştah Alanyalı and her team, aim to explore the architectural history and functions of these structures and examine the potential relationship between the bishop's complex and adjacent areas. The project also prioritizes studying Side's urban integration during the Byzantine periods and conducting comparative analyses with similar episcopal sites in the Balkans, Greece, and Asia Minor (ÖAW, n.d.). The archaeological excavations carried out meticulously by the excavation director and her team set a good example in terms of conservation and also shed light on Side's past with important clues. The efforts in Side are considered valuable for implementing a comprehensive and participatory process in a complex area, serving as a model for other sites in Anatolia. Figure 4 shows the national, regional, and local location of Side.



**Figure 5.** Side Ancient City images (Leila Akbarishahabi, 2024).

Figure 4 illustrates the location and context of the Ancient City of Side through national, regional and local maps, highlighting its location in Antalya, its topographical sea-level coastal settlement and its urban and archaeological layout. Some images from Side Ancient City are shown in Figure 5.

### 3.3. Urbanization and conservation efforts of the side

When Side's urbanization process is examined, new structures have emerged rapidly in the region in the last 70 years. The most important factor that triggered this situation is tourism. The Figure 6 shows the structures of the ancient city of Side in recent years.

According to Figure 6, black areas represent buildings. The number of buildings increased significantly between 1953 and 2010. Obviously, the negative environmental impacts of this rapid construction are inevitable today. The conservation efforts of the Ancient City of Side began with the "Side and Surroundings Tourism Planning International Project Competition" organized by the Ministry of Tourism and Promotion in 1969. However, over time, the area's natural, historical, and coastal values attracted attention, leading to the city being opened to tourism (Büyüksural & Sağıroğlu Demirci, 2023). Side Ancient City changes resulted in chaotic urban sprawl, further exacerbated by the "Tourism Incentive Law" of the 1980s, which allowed for taller buildings and accelerated the construction of unauthorized concrete structures. These developments severely compromised the archaeological and histor-

ical fabric of the city (Çubuk, 2013). Side was registered as a 1st-degree archaeological site in 1990 to protect and ensure the continuity of its cultural heritage. However, as tourism demands grew, the city underwent rapid and unplanned changes and transformations. During this process, delays in conservation decisions resulted in the deterioration of cultural assets and illegal construction related to tourism continued (Büyüksural & Sağıroğlu Demirci, 2023). In the following years, Side's preservation efforts included how to integrate the Ottoman rural architectural heritage with the archaeological sites. After many revisions, the Side Ancient City Conservation Plan was approved in 2014. This project aimed to protect the traditional and ancient fabric together, prevent illegal construction, and involve the public in the preservation process. The project also focused on mapping the ancient city through excavations, protecting both tangible and intangible heritage, and enhancing public spaces (Altun, 2020). The 2014 conservation plan comprises two areas: an urban site + 3rd-degree archaeological sites and 1rd-degree archaeological site. In 2016, the Antalya Regional Board for the Protection of Cultural Assets decided to revise the plan based on detailed analyses such as mass, building height, and materials, prompting Manavgat Municipality to initiate plan implementations through the Ancient Side Urban Design Project. However, the area known as the Western Necropolis and Megalopolitans neighbourhood, initially designated as a 1st-degree archaeological site in the 2014 conservation plan, was updated to a 3rd-degree archaeo-



**Figure 6.** Urban development of Side between 1953 and 2010 (Güven Ulusoy, 2014: p.75).

logical site by decision no. 8268 dated 18.10.2018 from the Antalya Regional Board for the Protection of Cultural Assets. Consequently, in compliance with Law No. 2863, a separate planning process was initiated for this area, and the plan was approved in 2022. Finally, the latest revised version of the conservation plan was approved by the T. C. Ministry of Environment, Urbanization, and Climate Change in 2024. Figure 7 shows the plans of 2014 and 2024.

Figure 7 represents Conservation Plans from 2014 (left) and 2024 (right). There are some key differences between the two plans. The 2024 plan shows an expansion of the conservation areas compared to the 2014 plan in the north-eastern region. This area is marked with grey striped texture and named a “Sensitive Area to Be Strictly Protected”. However, in the 2014 plan, the northern part was a 1st degree archaeological site, while in the 2024 plan, this area was changed to a 3rd degree archaeological site and marked with a red striped texture. The area within the pink border in the 2014 plan and the blue border in the 2024 plan is an urban site and the 3rd degree archaeological site.

### 3.4. Climate change risks on the side

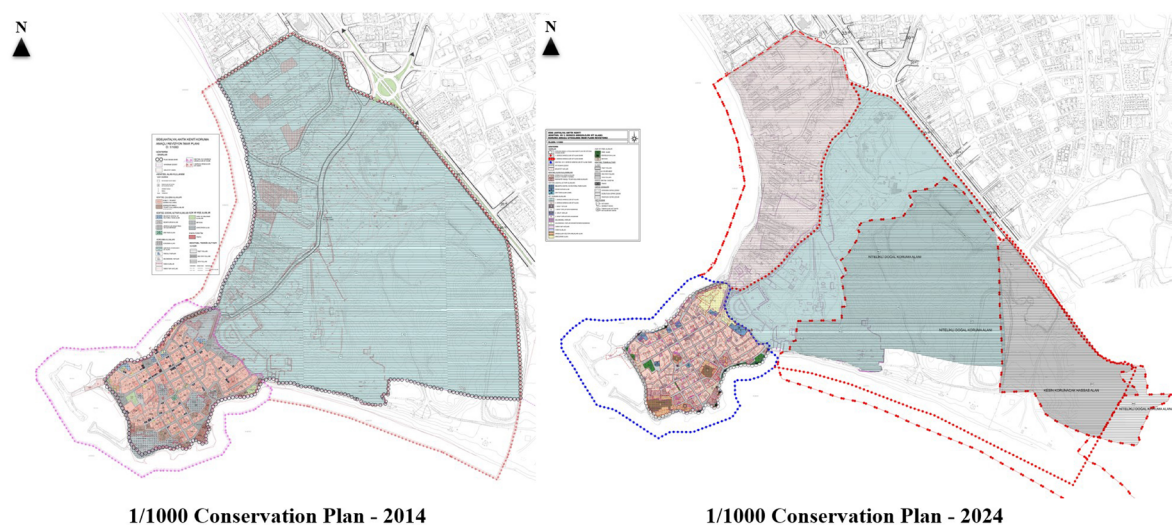
In the field analysis related to the impacts of climate change on cultural heritage, the current status of the site was examined and potential hazards such as air and soil temperature increases, erosion and water rise,

structural weaknesses such as material decay, and other related issues that may be caused by climate change were evaluated. Images of the Ancient City of Side in terms of climate change impacts are included in Figure 8.











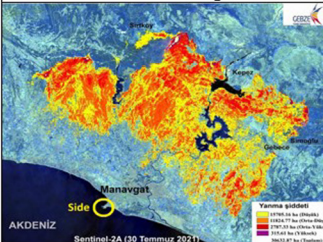

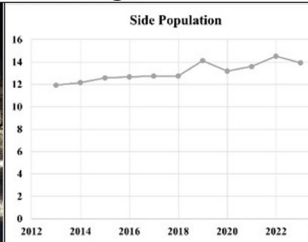
Upon examining Figure 8, various potential impacts of climate change on Side can be identified. These impacts are evaluated in 4 categories:

#### a. Physical Impacts on Structures

- **Temperature Fluctuations:** While the average temperature in Side was 17.1°C in 1979, it has increased to 18.5°C in 2023 (meteoblue, 2023a). Increased temperatures and more frequent heatwaves can cause materials such as stone, wood, and metal to expand and contract. This thermal stress leads to cracking, warping, and the weakening of structural integrity over time.
- **Freeze-Thaw Cycles:** In Side, temperatures normally range from 8°C to 32°C throughout the year, but in recent years temperatures have been below 4°C and above 37°C (MGM, n.d.). In Side, fluctuating temperatures around the freezing point can cause repeated freeze-thaw cycles, especially in porous materials such as stone. Water seeps into cracks, freezes and expands, leading to gradual deterioration.
- **Increased Precipitation and Flooding:** Higher rainfall and extreme weather events can lead to flooding, which threatens the founda-



**Figure 7.** Conservation Plans of 2014 and 2024.

Possible Impacts and Images			
<b>Physical Impacts on Structures</b>			
			
Temperature Fluctuations	Freeze-Thaw Cycles	Increased Precipitation and Flooding	Wind and Storm Surges
<b>Chemical and Biological Deterioration</b>			
			
Salt Crystallization	Air Pollution	Biological Growth	
<b>Impact on Archaeological Sites</b>			
			
Permafrost Thawing and Soil Temperature	Erosion and Desertification	Using Glass to Cover and Protect	
<b>Impact on Cultural Landscapes and Intangible Cultural Heritage</b>			
			
Fires (Photo: (GTÜ, 2021))	Changes in Seasonal Activities	Displacement of Communities	

**Figure 8.** Possible impacts and images.

tions of historic structures. Side Ancient City is located almost at the seaside. Water saturation can cause subsidence, erosion, and structural collapse in Side.

- Wind and Storm Surges: While the average wind speed of Türkiye is 1.9 m/s, the wind speed of the Antalya region is 3.36 m/s (MGM, n.d.). In some extreme cases, stronger storms and hurricanes can cause significant physical damage. Coastal erosion due to storm surges can wash away or destabilize sites located near the shoreline.
- Tornadoes: In the Mediterranean

region, which is vulnerable to the impacts of climate change, rising sea surface temperatures enhance atmospheric instability, thereby triggering and intensifying the development of severe storm cells and tornado-producing supercells. It is suggested that ongoing global warming will further increase sea surface temperatures values in the Mediterranean, potentially leading to a greater frequency and intensity of tornadoes in the future (Avolio & Miglietta, 2023; Gianfreda et al., 2005; Miglietta et al., 2017). Elevated sea surface temperatures

amplify atmospheric instability, heightening the likelihood of intense storms and tornadoes in Side.

#### *b. Chemical and Biological Deterioration*

- **Salt Crystallization:** Coastal sites are particularly vulnerable to salt crystallization, which is exacerbated by sea level rise and increased storm surges. In Side, in some historical structures, salt weathering was found on interior and exterior surfaces. Salt can penetrate into the porous materials and, upon crystallization, cause flaking and exfoliation of stone surfaces.
- **Air Pollution:** Climate change can exacerbate air pollution, particularly in urban areas. According to the 2022 Türkiye Air Pollution Report, the PM10 Annual Average Value ( $\mu\text{g}/\text{m}^3$ ) exceeds the WHO Annual Limit Value on 116 days of the year in the Manavgat district of Antalya (TMMOB, 2022). Increased levels of pollutants can accelerate the degradation of structure materials through chemical reactions, such as the formation of sulfuric acid, which corrodes stone and metal.
- **Biological Growth:** Warmer and wetter conditions favour the growth of biological organisms on structure surfaces. These organisms can cause staining, decay, and structural weakening, especially in organic materials like wood. Some biological organisms have been detected in Side historical structures.

#### *c. Impact on Archaeological Sites*

- **Permafrost Thawing and Soil Temperature:** The thawing of permafrost due to rising temperatures poses a risk to archaeological sites preserved in frozen ground. As the ground thaws, organic materials such as wood, bone, and textiles can rapidly decay upon exposure to air and microorganisms. No scientific research has been conducted on this subject in Side and therefore no data is available in this context. However, as an important archaeological site where excavations are still ongoing, it

seems likely that Side will face such a danger. Also, in Side Ancient City, soil temperature can rise up to 30°C (meteoblue, 2023b), this event may damage underground movable cultural heritage.

- **Erosion and Desertification:** Side has a Mediterranean climate. Summers are hot and dry, and winters are cold and rainy (MGM, n.d.). Increased desertification in arid regions and coastal erosion threaten to bury or wash away archaeological sites. Wind erosion can uncover and then destroy fragile remains, while soil erosion can lead to the loss of stratigraphic integrity, making it difficult to interpret the archaeological record.
- **Using Glass to Cover and Protect:** Using glass coverings to protect archaeological sites has some drawbacks. The enclosed space can trap heat, creating a greenhouse effect that potentially damages the remains through thermal stress. Moisture accumulation due to condensation can accelerate the decay of organic materials. Exposure to UV light through the glass may further degrade exposed materials.

#### *d. Impact on Cultural Landscapes and Intangible Cultural Heritage*

- **Fires:** In recent years, there have been very devastating fires in the Manavgat district where Side is located (28 July 2021 Manavgat Fire). Increased frequency and intensity of wildfires, driven by higher temperatures and prolonged dry periods, threaten historic sites located in forested areas. Fires can destroy wooden structures, damage stone buildings, and obliterate archaeological evidence. Additionally, fires in the surrounding area cause air pollution in the historic site.
- **Changes in Seasonal Activities:** Many cultural practices are tied to specific seasons or natural cycles, such as festivals, agricultural practices, and religious observances. Climate change can disrupt these cycles, leading to the loss or alteration of traditional cultural practices.

- **Displacement of Communities:** Climate change can force the displacement of communities due to rising sea levels, desertification, or other environmental changes. When communities are displaced, intangible cultural heritage, such as traditional knowledge, languages, and customs, is at risk of being lost.

### 3.5. SWOT analysis of the Side

The SWOT analysis is an effective and suitable approach for developing adaptation strategies to address the impacts of climate change. By examining strengths (existing policies, technologies, and institutional capacities), weaknesses (gaps in resources, knowledge, or infrastructure), opportunities (emerging technologies, funding programs, and collaborations), and threats (climate risks, political instability, or economic challenges), the analysis provides a comprehensive framework for evaluating an organization's or community's climate resilience. This method supports strategic decision-making by identifying key areas for resource allocation and improvement. In the context of this research on Side Ancient City, the SWOT analysis method was selected because it allows for a comprehensive assessment of the city's climate vulnerabilities and resilience capacity by systematically categorizing key factors. The SWOT analysis for Side was performed through a combination of literature review and field investigations. The strengths were identified based on historical, cultural, and archaeological assets and resilience features; weaknesses considered existing vulnerabilities such as infrastructure deficiencies and susceptibility of ancient materials to environmental stressors; opportunities focused on potential resources, partnerships, and educational initiatives; while threats covered climate-induced hazards, urbanization pressures, and socio-economic challenges. The main advantage of SWOT analysis within this research is its comprehensive approach to understanding and

addressing climate change impacts on heritage sites. By aligning adaptation strategies explicitly with identified SWOT components, the analysis helps prioritize and target interventions effectively, ensuring robust and adaptive management practices tailored specifically to Side and comparable historical coastal cities.

#### *SWOT (Strengths)*

- **Historical, Cultural and Archaeological Significance:** Side has a rich history involving multiple civilizations, including the Greeks, Lydians, Persians, Romans, Seljuks, and Ottomans. The city hosts a diverse range of ancient structures and artifacts, including Apollo and Athena Temples, Agoras, Ancient Theatre, Great Baths, Vespasian Fountains, and a well-preserved city Great Gate.
- **Architectural Features:** The Side Antique Theatre, with its Greek architectural style, is valuable in Anatolia due to its construction on a slope and use of vaults to support seating. This makes it an exceptional example of ancient engineering and design.
- **Financial Foundation:** Side Ancient City's strong financial foundation is driven by its status as a top tourist destination, attracting both government support and foreign investment. Additionally, local investors play a crucial role, contributing to the area's financial resilience and ensuring ongoing preservation and development efforts.
- **Strategic Location:** Located 80 km east of Antalya and 7 km southwest of Manavgat, Side is easily accessible to tourists visiting Türkiye's Mediterranean coast. Its coastal position also enhances its allure as a destination with both cultural and natural attractions. This situation also supports financial issues.
- **Adaptability of Structures:** Many of Side's ancient structures, such as stone-built temples, walls, and the theatre, have withstood centuries of weathering and climatic changes, showcasing a degree of resilience. This resilience can be

leveraged to promote Side as a site that has survived various natural challenges, appealing to visitors interested in history and climate studies.

- **Existing Research and Knowledge:** There is substantial historical and archaeological research on the materials and construction techniques used in Side, which can provide valuable insights into how these structures might withstand ongoing climate changes. This knowledge can inform current and future conservation efforts.
- **Archaeological Excavations:** In the archaeological site, excavations are carried out meticulously by the excavation director and her team with conservation concerns. This issue is important in terms of protection actions and cultural sustainability.

#### *SWOT (Weaknesses)*

- **Vulnerability to Natural Disasters:** Side has been historically affected by natural disasters, which have led to its decline and abandonment in various periods. The remaining structures are vulnerable to further damage from earthquakes, flooding, and other natural events.
- **Maintenance and Preservation Challenges:** The ancient structures and ruins require continuous maintenance and preservation efforts. Factors such as weathering, erosion, and potential vandalism pose ongoing challenges to the conservation of the site.
- **Exposure to Climate Risks:** The city is exposed to several climate-related risks, including increased temperatures, rising sea levels, and extreme weather events such as heavy rainfall and storms.
- **Vulnerability of Ancient Materials:** The building materials used in Side, such as stone and marble, are vulnerable to environmental changes. Acid rain, increased humidity, and temperature fluctuations can cause physical and chemical deterioration, leading to cracking, erosion, and weakening of the structures.
- **Limited Resources for Climate Adaptation:** There may be limited

financial and technical resources dedicated specifically to adapting and preserving the site in response to climate change. This lack of resources could hamper effective conservation strategies, leaving the site more susceptible to climate-related damage.

- **Information on Climate Change:** It has been determined that there are no training and information programs, especially for local people, tradesmen, and business owners, about the impacts of climate change caused by human activities.
- **Inadequate Modern Infrastructure for Climate Adaptation:** The current infrastructure around the ancient city may not be adequately equipped to handle the challenges posed by climate change. For instance, drainage systems may be insufficient to cope with increased rainfall, leading to water accumulation and potential flooding of the ruins. Similarly, there may be a lack of barriers or protective measures to prevent wind and water erosion in vulnerable areas.
- **Limited Financial and Human Resources:** Managing and maintaining a large, exposed archaeological site like Side requires significant financial investment and specialized skills. There may be insufficient funding dedicated specifically to climate adaptation strategies, and a lack of trained personnel to implement these measures. This financial and skill gap could limit the effectiveness of preservation efforts, especially in the face of escalating climate threats.
- **Lack of Tourism Activities Information:** There is no more information on the tourist capacity, the regular determination of the number of tourists arriving, and the direct and indirect environmental and financial impacts of tourism on Side.

#### *SWOT (Opportunities)*

- **Educational and Research Potential:** The site provides vast opportunities for archaeological research, studies in ancient history, and educational tours. Collaborations with academic institutions can be fos-

tered to enhance knowledge and preservation techniques.

- **Funding and Grants for Climate Resilience:** Increasing global awareness of climate change impacts on cultural heritage sites presents opportunities to secure international funding and grants aimed at enhancing climate resilience. Side could benefit from such funding to implement advanced conservation technologies and materials that can withstand changing climate conditions.
- **Climate Change Awareness and Education:** Side can serve as a case study for the impacts of climate change on cultural heritage, attracting academics, researchers, and tourists interested in climate studies. Educational programs and exhibitions about the effects of climate change on ancient structures could raise awareness and promote sustainable tourism practices.
- **Development of Climate-Resilient Tourism:** There is potential to develop climate-resilient tourism strategies, such as controlled access during extreme weather, improved drainage systems to manage water flow, and the use of protective shelters or coverings for vulnerable areas. This could mitigate some of the impacts of climate change while still allowing for tourist engagement.
- **International Collaboration and Funding:** Organizations such as UNESCO, the World Monuments Fund (WMF), and various NGOs are increasingly focused on protecting heritage sites from climate impacts. Side could benefit from these initiatives by applying for grants and participating in international conservation programs that provide both financial resources and technical expertise.
- **Development of Protective Infrastructure:** Opportunities exist for investing in protective infrastructure to mitigate climate change impacts. This includes installing modern drainage systems to manage increased rainfall, building sea walls or natural barriers to counter rising sea levels, shade Structures

and Windbreaks, and implementing climate-adaptive landscaping to prevent soil erosion. Such investments would not only preserve the site but also enhance visitor safety and accessibility.

#### *SWOT (Threats)*

- **Increased Frequency and Intensity of Extreme Weather Events:** Climate change is likely to increase the frequency and intensity of extreme weather events such as heavy rains, floods, and storms.
- **Rising Sea Levels and Coastal Erosion:** Rising sea levels due to climate change pose a direct threat to Side, particularly its coastal areas. As sea levels rise, the risk of coastal erosion increases, threatening the stability of nearby structures. Flooding could lead to the submersion of lower-lying parts of the city, causing irreversible damage to the ruins and potentially leading to the loss of valuable cultural artifacts.
- **Increased Frequency of Extreme Weather Events:** Climate change impacts could lead to further physical damage to the ruins through direct impact, flooding, or wind-driven erosion. For example, heavy rains could undermine the foundations of ancient structures, while high winds could cause more rapid erosion of exposed stone surfaces.
- **Temperature Fluctuations and Drought:** Higher temperatures and prolonged droughts can exacerbate the physical weathering of stone and other materials. Heat stress can cause expansion and contraction in building materials, leading to cracking and structural instability. Additionally, drought conditions can lead to increased soil erosion around foundational structures.
- **Urban Development:** Expansion of nearby urban areas or tourism-related development could threaten the integrity of the archaeological site, potentially leading to encroachment or loss of the historical context of the surroundings.
- **Tourist Pressure:** High volumes of tourists can cause physical wear and tear to the ruins. Unregulated tourism and inadequate visitor manage-

ment can lead to deterioration of the structures and the site's natural environment.

- **Political and Economic Instability:** Political instability or economic downturns in Türkiye could impact funding for the preservation of the site and reduce tourist numbers, which are vital for sustaining conservation efforts.
- **Competing Destinations:** There are many other ancient cities and heritage sites in Türkiye and around the Mediterranean that compete for tourists' attention. This competition can impact visitor numbers and the overall revenue generated from tourism.
- **Conflict Between Economic Interests and Conservation Concerns:** Economic interests often took precedence over conservation efforts.
- **Year-Round Tourism:** While year-round tourism activities have a

positive impact on the socio-economic revitalization of the region, this can lead to environmental and cultural degradation of Side and make the region more vulnerable to the impacts of climate change.

#### 4. Adaptation strategies

According to the impacts of climate change on Side and SWOT analysis, adaptation strategies were developed for the protection of Side in this section. Strategies focus on addressing material vulnerabilities with advanced technologies and reinforcing infrastructure. Opportunities from global awareness and new technologies can be utilized for innovative preservation methods, while threats like coastal erosion and wildfires are managed with proactive defences and adaptive design. This approach can integrate adaptation measures into preservation plans to protect

**Table 1.** Adaptation strategies.

Adaptation Strategies		
Implement Coastal Protection Measures	Sea Walls and Natural Barriers	To protect against rising sea levels and storm surges, it is essential to construct or reinforce sea walls. Additionally, implementing natural barriers, such as planting mangroves or building artificial reefs, can help reduce wave energy and minimize coastal erosion near the Apollon Temple and other coastal structures.
	Beach Nourishment	Regularly add sand or sediments to eroding beaches to maintain the shoreline and protect coastal ruins. This method can help mitigate the impacts of rising sea levels and coastal erosion on the city's coastal areas.
Improve Drainage and Water Management Systems	Enhanced Drainage Infrastructure	Install modern drainage systems throughout the site to manage increased rainfall and reduce flooding risks. These systems should include permeable surfaces, underground drainage channels, and retention basins to control water flow and prevent waterlogging around the ruins.
	Rainwater Harvesting and Management	Develop rainwater harvesting systems to capture and store rainwater, reducing runoff and providing a water source for landscape irrigation, especially during droughts. This would also prevent water from pooling around the ancient structures, reducing erosion and water damage.
Structural Reinforcement and Restoration	Use of Climate-Resilient Materials	In restoration projects, it is advisable to use modern materials that replicate the appearance of ancient stones while offering enhanced resistance to weathering and climate impacts. This approach may involve employing breathable, water-resistant mortars and stone consolidants designed to protect against moisture infiltration and freeze-thaw cycles.
	Regular Maintenance and Monitoring	Establish a comprehensive monitoring program to regularly assess the condition of the ruins and detect early signs of damage due to climate impacts. Implement preventive maintenance, such as sealing cracks and reinforcing weakened structures, to prevent further deterioration.
Protective Shelters and Coverings	Temporary or Permanent Shelters	Erect temporary or permanent protective shelters over particularly vulnerable ruins, such as the Temple of Apollon and other coastal structures. These shelters can help protect against direct rainfall, wind erosion, and intense sunlight, reducing the weathering process.
	Shade Structures and Windbreaks	Install shade structures or plant strategic vegetation to protect against extreme heat and wind. Vegetation can act as a natural windbreak, reducing wind speed and soil erosion, while shade structures can help prevent direct sun damage to delicate surfaces.
Enhanced Climate Monitoring and Early Warning Systems	Climate and Environmental Sensors	Deploy sensors around the site to monitor temperature, humidity, rainfall, and sea level changes in real-time. This data can help predict and prepare for extreme weather events, enabling timely protective measures, such as temporary closures or additional reinforcements.
	Early Warning Systems	Develop and implement early warning systems for extreme weather events such as storms or heatwaves. These systems can help manage visitor safety, allowing for timely evacuations or closures when necessary.
Landscape Management and Erosion Control	Erosion Control Techniques	Use erosion control measures such as terracing, planting native vegetation with deep root systems, and installing geotextiles to stabilize soil around archaeological features. This will help reduce the risk of soil erosion caused by heavy rainfall and wind.
	Sustainable Landscaping	Implement sustainable landscaping practices, including the use of drought-resistant plants and xeriscaping around the site. This can reduce water usage, prevent soil erosion, and enhance the natural protection of ruins.
Collaborations	National	During the strategy and policy-making process, securing support from state and local investors, fostering collaboration among various stakeholders, and implementing a public participatory process are essential components.
	International	Collaboration with organizations such as UNESCO, the World Monuments Fund (WMF), and various non-governmental organizations, along with participation in international conservation programs, could significantly benefit Side in this context.

Side's heritage from climate change impacts. Table 1 presents the strategies developed to protect the Side Ancient City against climate change impacts.

The adaptation strategies outlined for Side Ancient City provide a comprehensive framework for addressing the challenges posed by climate change while preserving its cultural heritage. The focus on coastal protection measures, such as constructing sea walls and implementing natural barriers, aims to mitigate the impacts of rising sea levels and storm surges, particularly around vulnerable structures like the Temple of Apollon. Beach nourishment is also highlighted as a critical approach to maintaining the shoreline, thus safeguarding archaeological sites from erosion. The strategies further emphasize the need to enhance drainage and water management systems. Installing modern drainage infrastructure and developing rainwater harvesting systems are essential for managing increased rainfall and reducing flooding risks. These measures not only protect the ruins but also improve the overall resilience of the site to climate impacts. Structural reinforcement through the use of climate-resilient materials is vital for restoration efforts. By employing modern materials that mimic ancient stones while providing better resistance to weathering, the integrity of historic structures can be preserved. Additionally, establishing a comprehensive monitoring program will allow for the early detection of damage, en-

surging timely interventions to prevent further deterioration. The implementation of protective shelters and shade structures will help shield particularly vulnerable ruins from direct exposure to harsh weather conditions, thereby reducing weathering effects. Enhanced climate monitoring and early warning systems are also crucial; deploying environmental sensors will provide real-time data to inform protective measures during extreme weather events. Landscape management strategies, including erosion control techniques and sustainable landscaping practices, will further support the site's resilience. These practices not only mitigate soil erosion but also promote the growth of native vegetation that can protect archaeological features. Finally, fostering national and international collaborations is essential for the successful implementation of these strategies. Engaging local investors, state agencies, and global organizations like UNESCO and the World Monuments Fund will ensure a comprehensive, multifaceted approach to conserving Side Ancient City, enhancing its ability to withstand the impacts of climate change while preserving its invaluable cultural heritage for future generations.

## 5. Results

This section presents a matrix that systematically illustrates the connections between climate impacts, SWOT components, and the corresponding adaptation strategies identified (Table 2).

**Table 2.** Matrix related to connections between climate impacts, SWOT components, and adaptation strategies.

Climate Change Impacts	Strengths	Weaknesses	Opportunities	Threats	Adaptation Strategies	National and International Collaborations
Rising Sea Levels & Coastal Erosion	Coastal appeal for tourism and cultural significance	Vulnerable to coastal erosion and sea level rise	Increased national and international funding for resilience	Loss of coastal structures and artifacts	Construct sea walls, natural barriers, and implement beach nourishment	<b>National:</b> Partner with Turkish Ministry of Culture and Tourism; <b>International:</b> Collaborate with UNESCO and World Monuments Fund (WMF) for funding and technical support
Temperature Fluctuations	Resilience of some historic materials	Vulnerable materials (e.g., stone) to thermal stress	Develop climate-resistant materials with historic appearance	Cracking, warping, and structural weakening due to expansion	Use climate-resilient materials, add shading structures, and install vegetation	<b>National:</b> Collaborate with universities for material innovation; <b>International:</b> Partner with International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) for best practices
Increased Precipitation and Flooding	Traditional water management knowledge	Inadequate modern drainage and water management systems	Opportunity to integrate sustainable water management	Foundation damage from waterlogging and soil saturation	Improve drainage systems, establish rainwater harvesting, and utilize permeable surfaces	<b>National:</b> Partner with local municipalities and agencies; <b>International:</b> Engage with the International Hydrology Program (UNESCO-IHP) for sustainable water management practices
Extreme Weather Events (Storms, Hurricanes)	Established resilience to past natural events	High exposure to storms due to coastal location	Leverage global climate awareness and funding	Potential destruction from high winds and storm	Erect windbreaks, strengthen structures, and develop early warning systems	<b>National:</b> Work with Turkish Disaster and Emergency Management Authority (AFAD); <b>International:</b> Seek support from UNESCO's World Heritage Risk Management Program
Air Pollution	Strong local and international awareness	Material degradation accelerated by pollution	Public-private partnerships for protective measures	Corrosion of stone, metal, and organic materials	Install air quality sensors, apply protective coatings, and establish clean air zones	<b>National:</b> Collaborate with Turkish Ministry of Environment, Urbanization and Climate Change; <b>International:</b> Partner with global air quality networks and ICCROM for protective technologies
Freeze-Thaw Cycles	Unique architectural techniques provide some resilience	Freeze-thaw damage to porous materials like stone	Research and funding opportunities for climate-resilient tech	Accelerated weathering and cracking of structures	Use breathable, water-resistant mortars, and conduct seasonal monitoring	<b>National:</b> Engage with preservation bodies for traditional techniques; <b>International:</b> Join European Union climate-resilient heritage research initiatives
Salt Crystallization	Presence of robust local materials that resist salt decay	Vulnerable to salt crystallization near coastal areas	Global awareness on protecting heritage from salt impacts	Flaking and exfoliation of stone and plaster surfaces	Apply salt-resistant treatments, create buffer zones, and monitor salinity levels	<b>National:</b> Collaborate with local preservation experts; <b>International:</b> Partner with heritage conservation councils such as Europa Nostra
Erosion and Desertification	Adaptive landscape with some natural windbreaks	Increased risk of desertification from regional climate	Opportunities for sustainable land and erosion management	Loss of soil stability around archaeological features	Implement erosion control techniques, use geotextiles, and plant deep-rooted vegetation	<b>National:</b> Partner with Turkey's General Directorate of Forestry; <b>International:</b> Participate in global erosion control programs through FAO, UNDP and UNEP
Biological Growth due to Humidity	Native vegetation can aid in natural humidity management	Biological growth on structures leading to material decay	Funding for biological research in preservation	Staining, decay, and weakening of structures from moss, algae	Regular cleaning protocols, use biocidal treatments, and control humidity through landscaping	<b>National:</b> Collaborate with Turkish botanical research centers; <b>International:</b> Partner with ICOMOS for international bio-conservation projects
Soil Temperature Increases	-	Risk of damage to subsurface archaeological features	Study soil-temperature effects on buried artifacts	Increased decay rates for organic materials in soil	Install soil temperature sensors, conduct controlled excavations, and adjust conservation techniques	<b>National:</b> Work with archaeological research institutes in Turkey; <b>International:</b> Consult with UNESCO and ICCROM on best preservation practices
Fire Risks (Wildfires)	Cultural significance may attract fire management support	Close proximity to high-risk wildfire zones	Increased funding and collaboration for fire prevention	Potential destruction of wooden or organic structures	Create firebreaks, use fire-resistant materials, and establish monitoring and early warning systems	<b>National:</b> Collaborate with Turkish Forestry Directorate for fire prevention; <b>International:</b> Seek support from UNESCO and ICOMOS for heritage-focused fire management strategies
Impact on Cultural and Intangible Heritage	Strong tradition of community and cultural practices	Climate change altering cultural practices and landscapes	Raise awareness of intangible heritage risks	Loss of traditional practices and intangible heritage	Develop adaptive programs for seasonal practices, and document intangible heritage through digital archives	<b>National:</b> Partner with Ministry of Culture and Tourism for documentation; <b>International:</b> Work with UNESCO's Intangible Cultural Heritage section for global support and guidance

The matrix presents a comprehensive approach to addressing climate change impacts on Side Ancient City, integrating strengths, weaknesses, opportunities, and threats into targeted adaptation strategies with relevant national and international collaborations. For each impact, the matrix aligns Side's strengths (such as established resilience in materials and historical appeal) with its vulnerabilities, such as the risk of erosion, flooding, or salt crystallization. Adaptation strategies are tailored to address these weaknesses while utilizing local knowledge and landscape features, such as using traditional water management techniques and resilient architectural methods. Collaborative efforts are strategically recommended based on Side's unique SWOT analysis, leveraging national partnerships (e.g., Türkiye Ministry of Culture and Tourism, universities, environmental agencies) to support local expertise, infrastructure, and resource mobilization. International partnerships (e.g., with UNESCO, ICCROM, ICOMOS, and World Monuments Fund) offer essential funding, technical expertise, and access to global heritage conservation practices. For instance, collaborating with UNESCO's World Heritage Risk Management Program can enhance resilience against extreme weather, while partnerships with ICCROM support material conservation under temperature fluctuations and air pollution conditions. Additionally, global air quality networks and conservation councils like Europa Nostra are engaged to address environmental threats like air pollution and erosion. In summary, this matrix strategically addresses each climate impact with targeted adaptation strategies, supported by relevant collaborations to enhance the resilience of Side Ancient City. The combined use of national and international resources strengthens Side's ability to preserve its cultural heritage against evolving climate threats.

## 6. Conclusion

Climate change increasingly threatens historic sites and cultural heritage globally, causing significant and growing risks. Side Ancient

City faces numerous challenges, particularly from environmental factors like coastal erosion, sea level rise, and extreme weather events, as well as human factors such as urban development and tourism pressures. Effective management and conservation strategies are critical to ensuring that Side's ancient heritage is preserved for future generations. Key factors for successful conservation and adaptation strategies include access to information, technical expertise, leadership, and stakeholder engagement. While the concepts of adaptation, adaptive capacity, and vulnerability are well established, there is still a need for more practical applications to reduce vulnerabilities to climate change. Successful adaptation requires integrating climate change considerations into broader decision-making frameworks and recognizing the role of social, economic, and political forces in shaping local vulnerabilities. The IPCC Sixth Assessment Report highlights that while cultural policies remain limited, integrating culture into policy and planning is crucial for developing sustainable and resilient cities (IPCC, 2022). Safeguarding cultural heritage, including historic buildings and archaeological sites, requires a multidisciplinary approach to address climate change and environmental risks. Heritage managers and non-experts need to understand the vulnerability of these assets. All findings related to cultural heritage vulnerability should be translated into practical guidelines for stakeholders, such as urban planners and conservationists, to prioritize protection efforts and improve the use of climate impact data.

Beyond its contributions to Side Ancient City, this study provides a replicable methodological framework for identifying climate risks and formulating effective adaptation strategies in culturally similar ancient sites across Türkiye and neighbouring regions. By applying the integrated SWOT-based analysis and strategic adaptation matrix proposed here, heritage managers and planners at other classical-period archaeological sites can proactively ad-

dress climate-related vulnerabilities. Thus, this research not only informs local conservation practices but also supports broader regional efforts aimed at safeguarding cultural heritage from the impacts of climate change.

## References

- Alanyalı, H. S. (2011). The Roman Pantheon of Side. *Anatolia*, 37, 75–92. <https://dergipark.org.tr/tr/pub/anatolia/issue/47620/601662>
- Alanyalı, H. S., & Yurtsever, A. (2020). Pamphylia bölgesi ve Side'nin tarihi coğrafyasına genel bir bakış. In M. E. Altınsapan & B. Y. O. Uçkan (Eds.), *Canan Parla Armağanı Sanat Tarihi, Arkeoloji, Tarih ve Filoloji Araştırmaları* (pp. 37–63). Doğu Kütüphanesi.
- Altun, A. O. (2020). Çok katmanlı kentlerde koruma: Side örneği. *Yerel Kimlik*, 64, 16–23. <https://online.fliph-tml5.com/fvgh/agmw/#p=25>
- Anzidei, M., Doumaz, F., Vecchio, A., Serpelloni, E., Pizzimenti, L., Civico, R., Greco, M., Martino, G., & Enei, F. (2020). Sea level rise scenario for 2100 a.D. in the heritage site of pyrgi (santa severa, italy). *Journal of Marine Science and Engineering*, 8(2), 1–18. <https://doi.org/10.3390/jmse8020064>
- Asano, J., Kojima, Y., Kato, C., & Kamiya, K. (2023). Climate change impacts on soil moisture and temperature in the plain and mountainous regions of Gifu Prefecture, Japan. *IOP Conference Series: Earth and Environmental Science*, 1165(1). <https://doi.org/10.1088/1755-1315/1165/1/012045>
- Avolio, E., & Miglietta, M. M. (2023). A Comparative analysis of two Mediterranean tornado hotspots. *Atmosphere*, 14(1). <https://doi.org/10.3390/atmos14010189>
- Bienvenido-Huertas, D., León-Muñoz, M., Martín-del-Río, J. J., & Rubio-Bellido, C. (2021). Analysis of climate change impact on the preservation of heritage elements in historic buildings with a deficient indoor microclimate in warm regions. *Building and Environment*, 200. <https://doi.org/10.1016/j.buildenv.2021.107959>
- Bonazza, A., & Sardella, A. (2023). Climate change and cultural heritage: methods and approaches for damage and risk assessment addressed to a practical application. In *Heritage* (Vol. 6, Issue 4, pp. 3578–3589). MDPI. <https://doi.org/10.3390/heritage6040190>
- Bradford, J. B., Schlaepfer, D. R., Lauenroth, W. K., Palmquist, K. A., Chambers, J. C., Maestas, J. D., & Campbell, S. B. (2019). Climate-driven shifts in soil temperature and moisture regimes suggest opportunities to enhance assessments of dryland resilience and resistance. *Frontiers in Ecology and Evolution*, 7(SEP). <https://doi.org/10.3389/fevo.2019.00358>
- Büyüksural, S. M., & Sağiroğlu Demirci, Ö. (2023). Kentsel arkeolojik sit alanı Side Antik Kenti'nde koruma ya yönelik uygulamaların değerlendirilmesi. *Online Journal of Art and Design*, 11(5), 365–381.
- Carbognin, L., Teatini, P., Tomasin, A., & Tosi, L. (2010). Global change and relative sea level rise at Venice: What impact in term of flooding. *Climate Dynamics*, 35(6), 1055–1063. <https://doi.org/10.1007/s00382-009-0617-5>
- Charlo, A. E. (2000). Salts in the deterioration of porous materials: an overview. *Journal of the American Institute for Conservation*, 39(3), 327–343.
- Çubuk, M. (2013). Turizmin rehlin aldığı Antik Kent ve Side Antik Limanının yat limanına dönüşümü üzerine. *Journal of Planning*, 23(1), 6–11. <https://doi.org/10.5505/planlama.2013.35220>
- Daly, C. (2011). Climate change and the conservation of archaeological sites: A review of impacts theory. In *Conservation and Management of Archaeological Sites* (Vol. 13, Issue 4, pp. 293–310). <https://doi.org/10.1179/175355212X13315728646058>
- Daly, P., Feener, R. M., Ishikawa, N., Mujah, I., Irawani, M., Hegyi, A., Banyai, K., Majewski, J., & Horton, B. (2022). Challenges of managing maritime cultural heritage in Asia in the face of climate change. *Climate*, 10(6). <https://doi.org/10.3390/cli10060079>
- Dias, L., Pires, V., Sitzia, F., Lisci, C., Candeias, A., Caldeira, A. T., & Mirão, J. (2023). Evaluating the biosusceptibility of natural stone as an supporting tool to prevent Cultural Heritage biodeterioration. *European Physical Journal Plus*, 138(6). <https://doi.org/10.1140/>

epjp/s13360-023-04185-w

Elam, N. (2020). Ecclesiastical personages of Side (Σίδη) of Pamphylia according to literary and sphragistic data. *ADALYA*, 23, 409–450.

Fatorić, S., & Seekamp, E. (2017). Are cultural heritage and resources threatened by climate change? A systematic literature review. *Climatic Change*, 142(1–2), 227–254. <https://doi.org/10.1007/s10584-017-1929-9>

García Sánchez, F., García Sánchez, H., & Ribalaygua, C. (2020). Cultural heritage and sea level rise threat: risk assessment of coastal fortifications in the Canary Islands. *Journal of Cultural Heritage*, 44, 211–217. <https://doi.org/10.1016/j.culher.2020.02.005>

Gianfreda, F., Miglietta, M. M., & Sansò, P. (2005). Tornadoes in Southern Apulia (Italy). *Natural Hazards*, 34(1), 71–89. <https://doi.org/10.1007/s11069-004-1966-3>

Grossi, C. M., Brimblecombe, P., & Harris, I. (2007). Predicting long term freeze-thaw risks on Europe built heritage and archaeological sites in a changing climate. *Science of the Total Environment*, 377(2–3), 273–281. <https://doi.org/10.1016/j.scitotenv.2007.02.014>

Güven Ulusoy, F. Ö. (2014). *Re-Integrating the Fragmented Context: Preservation and Presentation Of Side*. Middle East Technical University.

Harkin, D., Davies, M., Hyslop, E., Fluck, H., Wiggins, M., Merritt, O., Barker, O., Deery, L., McNeary, M., & Westley, R. (2020). Impacts of climate change on cultural heritage. *Marine Climate Change Impacts Partnership*, 16, 24–39.

Hedayatnia, H., Top, S., Caluwaerts, S., Kotova, L., Steeman, M., & Van Den Bossche, N. (2021). Evaluation of alar-0 and remo regional climate models over iran focusing on building material degradation criteria. *Buildings*, 11(8). <https://doi.org/10.3390/buildings11080376>

Heilen, M., Altschul, J. H., & Lüth, F. (2018). Modelling resource values and climate change impacts to set preservation and research priorities. *Conservation and Management of Archaeological Sites*, 20(4), 261–284. <https://doi.org/10.1080/13505033.2018.1545204>

Hollesen, J. (2022). Climate change

and the loss of archaeological sites and landscapes: a global perspective. *Antiquity*, 96(390), 1382–1395. <https://doi.org/10.15184/aqy.2022.113>

Hollesen, J. (2023). Climate change and the continued preservation of the arctic archaeological record. *Journal of Glacial Archaeology*, 6, 47–78. <https://doi.org/10.1558/jga.25620>

ICOMOS Climate Change and Heritage Working Group. (2019). *The future of our pasts: Engaging cultural heritage in climate action. Outline of Climate Change and Cultural Heritage*. <https://indd.adobe.com/view/a9a551e3-3b23-4127-99fd-a7a80d91a29e>

IPCC. (2022). Climate Change 2022: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the IPCC Sixth Assessment Report of the Intergovernmental Panel on Climate Change; Pötner, H. In *Working Group II Technical Support Unit* (Issue August).

IPCC. (2023). Summary for Policymakers. In The Core Writing Team, H. Lee, & J. Romero (Eds.), *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1–34). IPCC. <https://doi.org/10.59327/IPCC/AR6-9789291691647.001>

Isaak, D. J., Wollrab, S., Horan, D., & Chandler, G. (2012). Climate change effects on stream and river temperatures across the northwest U.S. from 1980-2009 and implications for salmonid fishes. *Climatic Change*, 113(2), 499–524. <https://doi.org/10.1007/s10584-011-0326-z>

Jackson, C. R., Mackay, J. D., & Bloomfield, J. P. (2013). *Changes in groundwater levels in the UK over the 21st century: an assessment of evidence of impacts from climate change* (A Climate Change Report Card for Water). <https://core.ac.uk/download/pdf/17201064.pdf>

Kapsomenakis, J., Douvis, C., Poupkou, A., Zerefos, S., Solomos, S., Stavraka, T., Melis, N. S., Kyriakidis, E., Kremlis, G., & Zerefos, C. (2023). Climate change threats to cultural and natural heritage UNESCO sites in the Mediterranean. *Environment, Development and Sustainability*, 25(12), 14519–14544. <https://doi.org/10.1007/>

s10668-022-02677-w

Mansel, A. M. (2020). *Side 1947 - 1966 yılları kazıları ve araştırmalarının sonuçları* (Second). Türk Tarih Kurumu.

Maragno, D., Pozzer, G., & dall'Omo, C. F. (2023). Supporting metropolitan Venice coastline climate adaptation. A multi-vulnerability and exposure assessment approach. *Environmental Impact Assessment Review*, 100. <https://doi.org/10.1016/j.eiar.2023.107097>

Marzeion, B., & Levermann, A. (2014). Loss of cultural world heritage and currently inhabited places to sea-level rise. *Environmental Research Letters*, 9(3). <https://doi.org/10.1088/1748-9326/9/3/034001>

Menberg, K., Blum, P., Kurylyk, B. L., & Bayer, P. (2014). Observed groundwater temperature response to recent climate change. *Hydrology and Earth System Sciences*, 18(11), 4453–4466. <https://doi.org/10.5194/hess-18-4453-2014>

Menéndez, B. (2018). Estimators of the impact of climate change in salt weathering of cultural heritage. *Geosciences (Switzerland)*, 8(11). <https://doi.org/10.3390/geosciences8110401>

meteoblue. (2023a). *Climate Change Side*. Meteoblue. [https://www.meteoblue.com/en/climate-change/side\\_public-of-türkiye\\_301238](https://www.meteoblue.com/en/climate-change/side_public-of-türkiye_301238)

meteoblue. (2023b). *Weather Maps*. Meteoblue. [https://www.meteoblue.com/tr/hava/haritasi/side\\_türkiye-cumhuriyeti\\_301238#coords=15.52/36.766329/31.391308&map=soil-Temperature~hourly~auto~0-10 cm down~none](https://www.meteoblue.com/tr/hava/haritasi/side_türkiye-cumhuriyeti_301238#coords=15.52/36.766329/31.391308&map=soil-Temperature~hourly~auto~0-10 cm down~none)

MGM. (n.d.). *Antalya-Manavgat*. MGM. <https://www.mgm.gov.tr/tahmin/il-ve-ilceler.aspx?il=Antalya&ilce=Manavgat>

Miglietta, M. M., Mazon, J., Motola, V., & Pasini, A. (2017). Effect of a positive Sea Surface Temperature anomaly on a Mediterranean tornadic supercell. *Scientific Reports*, 7(1). <https://doi.org/10.1038/s41598-017-13170-0>

ÖAW. (n.d.). *The Episcopal District of Side*. Austrian Archeological Institute. <https://doi.org/https://www.oear.ac.at/en/oeai/research/classical-studies/religious-studies/the-episcopal-district-of-side>

Pires, V., Amaral, P. M., Simão, J. A.

R., & Galhano, C. (2022). Experimental procedure for studying the degradation and alteration of limestone slabs applied on exterior cladding. *Environmental Earth Sciences*, 81(3). <https://doi.org/10.1007/s12665-022-10204-3>

Prieto, A. J., Verichev, K., Silva, A., & de Brito, J. (2020). On the impacts of climate change on the functional deterioration of heritage buildings in South Chile. *Building and Environment*, 183. <https://doi.org/10.1016/j.buildenv.2020.107138>

Prieto, B., Vázquez-Nion, D., Fuentes, E., & Durán-Román, A. G. (2020). Response of subaerial biofilms growing on stone-built cultural heritage to changing water regime and CO2 conditions. *International Biodeterioration and Biodegradation*, 148. <https://doi.org/10.1016/j.ibiod.2019.104882>

Reimann, L., Vafeidis, A. T., Brown, S., Hinkel, J., & Tol, R. S. J. (2018). Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. *Nature Communications*, 9(1). <https://doi.org/10.1038/s41467-018-06645-9>

Ruiz-Agudo, E., Lubelli, B., Sawdy, A., van Hees, R., Price, C., & Rodriguez-Navarro, C. (2011). An integrated methodology for salt damage assessment and remediation: The case of San Jerónimo Monastery (Granada, Spain). *Environmental Earth Sciences*, 63(7), 1475–1486. <https://doi.org/10.1007/s12665-010-0661-9>

Sabbioni, C., Brimblecombe, P., & Cassar, M. (2010). The atlas of climate change impact on European cultural heritage: scientific analysis and management strategies. In *Anthem Press* (Vol. 1, Issue November). <http://noahsark.isac.cnr.it/it%5Cnhttp://books.google.com/books?hl=en&lr=&id=aWbSMGbqUBgC&oi=fnd&p-g=PP6&dq=The+atlas+of+climate+change+impact+on+European+cultural+heritage++scientific+analysis+and+management+strategies&ots=Cb5Db-9>

Sacks, D. (2005). *Encyclopedia of the Ancient Greek World, Revised Edition*. Facts On File, Inc.

Sesana, E., Gagnon, A. S., Bertolin, C., & Hughes, J. (2018). Adapting cultural heritage to climate change risks:

- Perspectives of cultural heritage experts in Europe. *Geosciences (Switzerland)*, 8(8). <https://doi.org/10.3390/geosciences8080305>
- Sesana, E., Gagnon, A. S., Ciantelli, C., Cassar, J. A., & Hughes, J. J. (2021). Climate change impacts on cultural heritage: A literature review. In *Wiley Interdisciplinary Reviews: Climate Change* (Vol. 12, Issue 4). John Wiley and Sons Inc. <https://doi.org/10.1002/wcc.710>
- Silva, H. E., Coelho, G. B. A., & Henriques, F. M. A. (2020). Climate monitoring in World Heritage List buildings with low-cost data loggers: The case of the Jerónimos Monastery in Lisbon (Portugal). *Journal of Building Engineering*, 28. <https://doi.org/10.1016/j.jobbe.2019.101029>
- Sitzia, F., Lisci, C., Pires, V., Dias, L., Mirão, J., & Caldeira, A. T. (2023). Predicted dynamic of biodeterioration in cultural heritage stones due to climate changes in humid tropical regions—A case study on the *Rhodotorula* sp. Yeast. *Heritage*, 6(12), 7727–7741. <https://doi.org/10.3390/heritage6120406>
- Soykal Alanyalı, F. (2017). Side bir kentin kayboluşunun hikayesi. *Arkeoloji ve Sanat*, 155, 187–196.
- Strabon. (2015). *STRABON Antik anadolu coğrafyası (XII-XIII-XIV)* (N. Başgelen (ed.)). Arkeoloji ve Sanat Yayınları.
- TMMOB. (2022). *2022 Türkiye air pollution report, TMMOB Chamber of Environmental Engineers*. chrome-extension://efaidnbnmn-nnibpcajpcgclcfndmkaj/<https://icerik.cmo.org.tr/uploads/contents/2023-05-6-12-06-51-851419.pdf>
- UNESCO. (2007). *Climate Change and World Heritage*.
- Vyshkvarkova, E., & Sukhonos, O. (2023). Climate Change Impact on the Cultural Heritage Sites in the European Part of Russia over the Past 60 Years. *Climate*, 11(3). <https://doi.org/10.3390/cli11030050>
- Willems, W. J., & Schaik, H. P. V. (2017). *Water & Heritage*. Material, Conceptual and Spiritual Connections Sidestone Press. [https://www.ifugao-archaeological-project.org/uploads/6/4/4/7/6447606/acabado\\_&\\_martin\\_2015\\_-\\_between\\_pragmatism\\_and\\_cultural\\_context.pdf](https://www.ifugao-archaeological-project.org/uploads/6/4/4/7/6447606/acabado_&_martin_2015_-_between_pragmatism_and_cultural_context.pdf)
- Wolff, C., Vafeidis, A. T., Muis, S., Lincke, D., Satta, A., Lionello, P., Jimenez, J. A., Conte, D., & Hinkel, J. (2018). A Mediterranean coastal database for assessing the impacts of sea-level rise and associated hazards. *Scientific Data*, 5. <https://doi.org/10.1038/sdata.2018.44>