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Climate Change Adaptation and Historic Settlements: Evidence from the Old Town of Corfu

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Abstract

The Old Town of Corfu is an excellent example of a historic town and a World Heritage Site, distinguished by its authentic and unique character, as reflected in its Venetian-era fortifications and extensive historic building stock. Simultaneously, the Old Town of Corfu is also a vibrant modern city vulnerable to various pressures, including climate change. This paper aims to evaluate the effects of climate change on this modern city monument, assess its vulnerability using the Intergovernmental Panel on Climate Change's methodology, and develop a comprehensive set of adaptation proposals. The methodology of this paper is based on the analysis of climate data for the Old Town of Corfu, from which the assessment of the extreme weather events and climate changes that pose the greatest threat to the Old Town and the assessment of its vulnerability to these threats are derived. The dense geometrical characteristics of the city's structure, the intense pathology observed in the materials and structures of the historic building stock, problems in the existing electromechanical infrastructure, and the poor management of issues such as increased tourism and heavy traffic congestion are the primary factors that make the Old Town of Corfu vulnerable to the effects of climate change.

Keywords

Historic Settlements, Archaeological Site, Vulnerability, Climate Change, Adaptation Strategy

1. Introduction

According to the Sixth Assessment Report of the Intergovernmental Panel on

Climate Change (IPCC), climate change impacts every inhabited region. There is convincing evidence that anthropogenic emissions and human influence are the primary causes of extreme weather events like heavy rainfall, droughts, abrupt temperature changes, sea-level rise, and wildfires (IPCC, 2021). It is anticipated that the continued increase in greenhouse gas emissions will contribute to the climate crisis and global warming, and thus the occurrence of these phenomena (IPCC, 2021).

The components of cultural heritage and the values they represent are anticipated to be significantly impacted by the anticipated impacts of climate change (Daly et al., 2010). Cultural heritage refers to archaeological sites, historic sites, museum collections, monuments, historic towns, and settlements, along with their broader environment and social context, particularly in the case of inhabited housing areas. Individual monuments and museum collections are also considered in their broader context as cultural heritage elements.

The intensity of the effects of climate change varies based on the range of climatic parameters causing it and the rate at which these effects occur in various locations. Extreme events, such as heavy rainfall, wildfires, and storms, pose risks that are both severe and readily apparent (Cassar, 2016). The risk is that a cultural heritage asset will experience indirect but real and significant changes in its condition due to constantly changing environmental conditions (such as material deterioration) (UNESCO, 2008).

There has been a notable rise in scholarly articles focusing on integrating cultural heritage into strategies aimed at adaptation and mitigation. Fatoric & Seekamp (2017) examined existing literature on the frameworks, tools, and methodologies employed in evaluating climate-related risks and vulnerabilities associated with diverse categories of cultural assets. Based on the findings of Orr et al. (2021), the primary challenges related to this undertaking encompass imprecise temporal data, unreliable references to the natural environment, a lack of international collaboration, and the need to disseminate knowledge regarding climate change and cultural heritage. Still, the number of studies investigating the impact of climate change on intangible heritage remains relatively limited compared to those focusing on individual structures or sites (Orr et al., 2021).

There has been a significant increase in research efforts focused on examining the impacts of climate change on World Heritage Sites. Sesana et al. (2020)'s study created a thorough manual to assist World Heritage Site (WHS) administrators in assessing climate change risks and their potential effects on WHS management. The objective of this guide is to understand the potential effects of climate change on the characteristics of a site that contribute to its Outstanding Universal Value (OUV). It aims to establish a framework for incorporating site-specific climate change impacts into management strategies, offer guidance on evaluating the risk to the site's OUV, and provide recommendations for identifying the potential impacts of climate change on the site's OUV. In a related endeavor, the United Nations Educational, Scientific, and Cultural Organisation

(UNESCO) implemented a framework aimed at safeguarding the World Heritage Sites' resilience against climate change, thereby ensuring the preservation of their Outstanding Universal Value (OUV). In a study conducted by Sabbioni et al. (2008), it was determined that forthcoming investigations about the intersection of climate change and cultural heritage should prioritise the development of models and projections that offer a detailed analysis of climate changes specifically affecting heritage sites, both in terms of spatial and temporal resolution.

Additionally, there is a need to enhance comprehension of the susceptibility of heritage materials to climate-related factors and to evaluate the future consequences of such impacts. Furthermore, it is crucial to establish effective monitoring systems that can track changes in heritage sites, particularly over extended periods. The present study builds upon the prior research conducted by Maistrou et al. (2021, 2022a, 2022b, 2023) and Lazoglou (2022a, 2022b); Dandoulaki et al. (2023) and Lazoglou & Serraos (2021) in the fields of spatial planning, cultural heritage, and climate change adaptation.

This paper aims to evaluate the anticipated effects of climate change on the Old Town of Corfu and to develop a set of proposals for its adaptation to climate change.

In order to assess the climate change risks to which a historic city, such as the Old Town of Corfu, is exposed and to identify potential mitigation strategies, its vulnerability must be examined. In its Third Assessment Report published in 2001 (IPCC, 2001), the IPCC established vulnerability assessment as a method for risk analysis. In this paper, this methodology is used. According to the IPCC (IPCC, 2001), vulnerability assessment is a crucial prerequisite for developing methods to reduce the effects of climate change on all human activity sectors. This approach has an advantage over traditional risk analysis because it does not rely solely on assessing the system's exposure and sensitivity to one or more risks. In addition, it considers its capacity to adapt to new circumstances and regain equilibrium within them.

The methodology of the present paper consists of three consecutive steps, beginning with the analysis of climate data for the Old Town of Corfu based on the periodic climate model RACMO22e-MOHC, followed by the estimated climate changes for the periods 2031-2060 and 2069-2098, and concluding with the analysis of climate emission scenario data for RCP2.6, RCP4.5, and RCP8.5. This analysis is followed by evaluating the extreme weather events and climate changes that pose the greatest dangers to the Old Town and determining its vulnerability.

The second chapter of the paper describes the Old Town of Corfu's primary characteristics, focusing on its institutional protection framework. The Greek Ministry of Culture and Sports and the Greek Ministry of Environment and Energy have issued numerous decrees classifying the Old Town of Corfu as an archaeological site, historic site, and traditional settlement respectively, while it was also inscribed on the UNESCO World Heritage Site List in 2007, following an ICOMOS recommendation. In addition, the structure and infrastructure of the urban fabric, as well as the materials and structures of the historic building stock, are examined. The third chapter describes the methodology used to assess and evaluate the extreme weather phenomena that threaten the Old Town of Corfu and calculate its vulnerability. The fourth chapter presents the results of the research in terms of extreme weather events. The fifth chapter describes a series of illustrative actions that could contribute to the city's adaptation to the most severe climate changes anticipated to impact it by 2098. The paper draws conclusions that can be generalized to historic urban centers based on the critical points that emerged from applying the methodology to the Old Town of Corfu.

2. Study Area: The Old Town of Corfu

The Old Town of Corfu, the island's and the Ionian Islands' capital, is located on the island's central east coast. It is a modern, vibrant city with a significant architectural heritage of Western influences preserved and is a World Heritage Site (**Map 1**, **Figure 1**). The Old Town of Corfu has been at the crossroads of people and cultures. It has undergone numerous administrations, the most notable being that of the Venetians (15th-18th century), who used it as a gateway to the Adriatic Sea. Corfu became a semi-autonomous state, known as Eptanissos Politeia, between the two periods of French rule (1797-99 and 1807-14). It then

Map 1. Geographical location of the old town of Corfu. Source: Google Maps.

Figure 1. View of the Old Town from the north. Source: photographic material of the IRC-Hermes project recording (IRC-Hermes, 2021).

passed into the hands of the English for fifty years (1814) before joining the Greek state (1864).

The Old Town of Corfu is 295 acres, first inhabited in 1000 BC. It developed gradually outside the fortifications of the original medieval settlement of the 6th century, which occupied the peninsula of the Old Fortress and was recognized as the city's center by the end of the 16th century (Map 2). On the hill of St. Mark's to the west, the New Fortress was installed into the enclosure works surrounding the new town. The Old Town of Corfu is a fortified Mediterranean port with an urban and port complex distinguished for its high integrity and authenticity.

The fortifications with the Old and the New Fortress constitute a large-scale technical project constructed to support the critical maritime and strategic role that Corfu played in protecting the interests of the Galician Republic of Venice but also to promote its moral authority and grandeur. It is a monument of military architecture of the highest importance, the effectiveness of which was demonstrated by the successive repulsions of Turkish attacks. The importance of the Corfu fortifications in the history of defensive architecture is immense. Both technically and aesthetically, they are one of the most brilliant examples that survive, not only in Greece but also in the entire Eastern Mediterranean. Moreover, Venetian Corfu's fortifications also influenced the urban ensemble's development (Municipality of Corfu et al., 2005). The urban ensemble developed within the boundaries of land and sea. Delimited by the perimeter fortifications, it brings together all the features of urban planning that characterize the fortified cities of the West. At the same time, it is an excellent example of the organization of a town concerning its defense. The urban framework, combined with the dense, multi-storey structure and the morphology of the buildings, which assimilate the characteristics of a timeless cultural process, together create a unique entity of international value and particular importance in the history of architecture and urban planning (Municipality of Corfu et al., 2005).

The Old Town of Corfu is a case study vulnerable to multiple pressures related to climate change. The demands and needs of modern lifestyles, rapid tourism development, mobility issues, sensitivities, and the unique cultural characteristics of the area are some of the challenges that need to be addressed individually and in conjunction with anticipated extreme weather events (CulturePolis, 2014).

It was chosen based on its geographic location, monumental character, national and international significance, and estimated vulnerability based on the known past.

2.1. Legal Framework

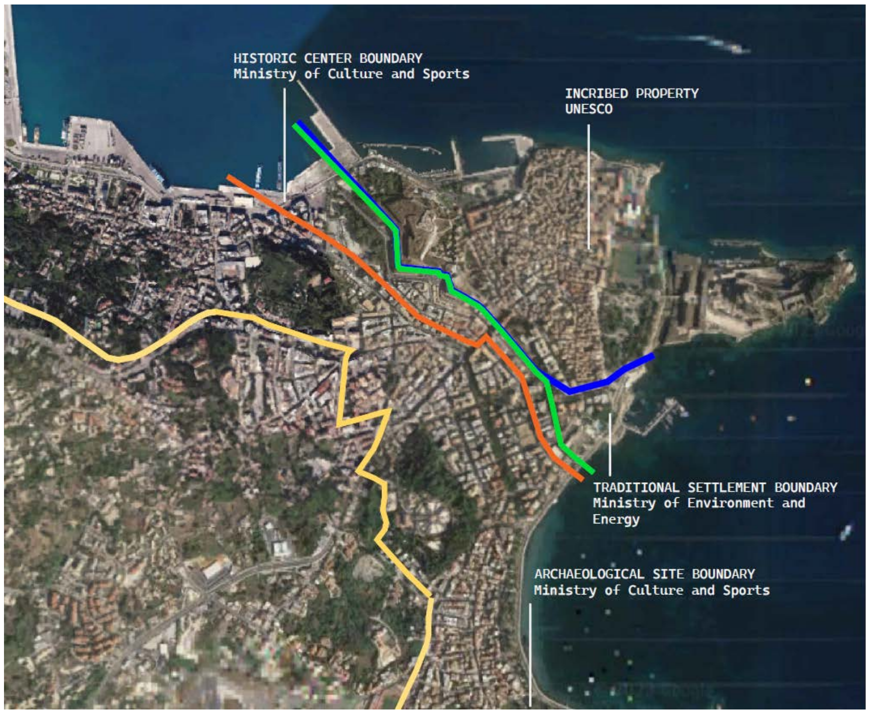
The protection of the Old Town of Corfu and its fortifications falls under the authority of the Greek Ministry of Culture and Sports, with the Directorate of Byzantine and Post-Byzantine Antiquities serving as the central service and the Ephorate of Corfu Antiquities serving as the regional service. The protection status is based on a series of Ministerial Decisions based on the provisions of the Archaeological Law, while the competent bodies of the Ministry of Culture examine every project carried out in the Old Town.

The Service for Modern Monuments and Technical Works of Epirus, Northern Ionian, and Western Macedonia is responsible for monuments dating after 1830. The old Town is declared "Historic Site" and "Archaeological Site" by the Greek Ministry of Culture. In addition, the Old Town was declared a Traditional Settlement by Presidential Decree in 1980 (Government Gazette 274/D/5 May 1980). The cultural significance of the Old Town's monumental complex and its fortifications led to its inscription on the UNESCO World Heritage List in July 2007 via decision 31 COM 8 B.40. It was inscribed according to criterion (iv), namely that the urban and port complex of Corfu, which is dominated by forts of Venetian origin, is an architectural example of exceptional universal value, characterized by authenticity and integrity. Moreover, for the Old Town of Corfu, the Management Plan 2006-2012 was developed in 2005 and is currently under revision. **Map 2** depicts the general boundaries of the aforementioned land claims.

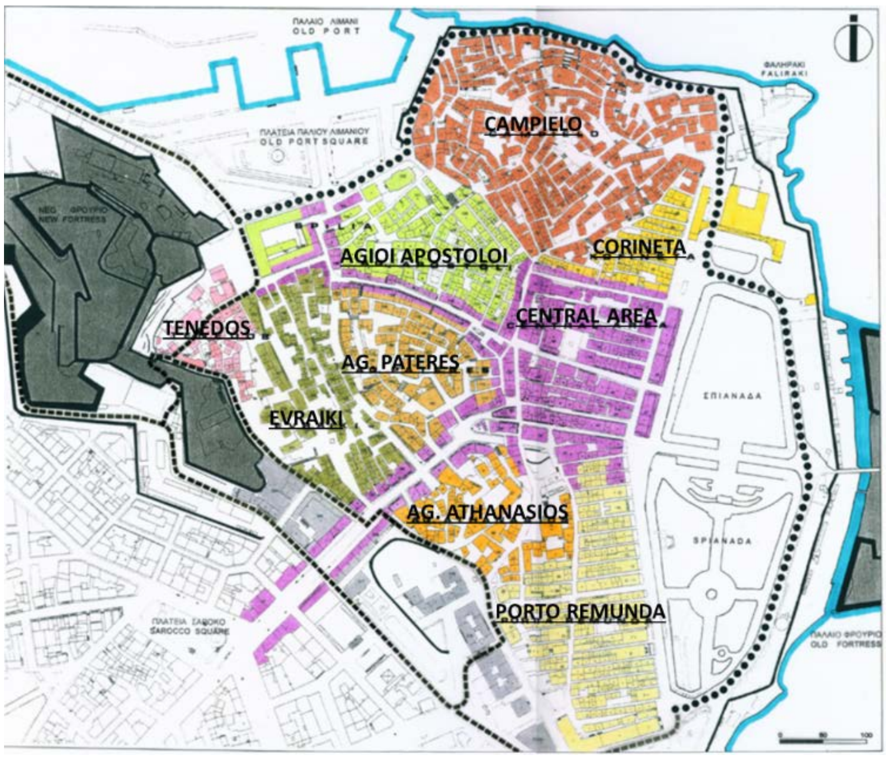
Map 2 illustrates the boundaries of the Ministry of Culture's (orange and yellow), and the Ministry of Environment and Energy (green) and UNESCO's land (blue) (yellow).

2.2. Urban Structure

The Old Town of Corfu is developed more organically than by plan. Ten districts are subdivided into Kabiello, Agioi Pateres, and Agios Athanasios, whose names are derived from the three hills on which the Old Town is built (**Map 3**). Each district has a small square in the middle that serves as its only open space and is home to a church and a tall bell tower, from which it typically derives its name. The cantounia streets are narrow and winding, with stairs leading uphill, vaulted covered passageways, and small squares where two or three roads intersect (discrete and triple streets). In contrast, the first blocks approaching Spianada have a



Map 2. Map, showing the set of sermons for the Old Town. Source: (ELLET, 2022).



Map 3. Map of the city with its neighbourhoods, Old and New fortresses and gates. Source: (Corfu History, 2023). Edited by (ELLET, 2022).

strict, radial layout with the fortress at the center for defensive purposes.

The Spianada Square is the most significant open space in the Old Town of

Corfu overall. In addition to the square of the Old Harbor, the Town Hall Square and Heroes' Square are also important public spaces in the Old Town. Within the community, there are no other square-shaped open areas. All of the small squares, which resemble squares more than anything else, are remnants of the medieval organization of the Old Town and can be found spread throughout the older districts, at road intersections, and near churches and mansions.

The Old Town of Corfu is home to various land uses, ranging from residential and commercial to administrative, educational, commercial, and cultural. In recent years, the tourism and leisure function (tourist trade, shops, cafés) has steadily expanded, occupying a significant portion of the city, with only a few neighborhoods hosting pure residential land uses. As a result, issues such as noise, traffic congestion, overcrowding, and increased energy, power, and waste collection needs are reflected in the city's daily operations.

According to available data, the average daily number of visitors during the peak summer season between 2016 and 2019 was 3.276 domestic and 676 international arrivals at the port of Corfu and 583 domestic and 8.933 international arrivals at the airport (SUMP, 2022). The presence of cruise passengers in an Old Town amplifies the preceding. As a result, they create difficulties for the daily operation of the town: noise, traffic congestion, and overcrowding on the streets, changing the local identity and causing problems for the residents. In addition, the intensity of these operations increases the demand for energy, food, and waste removal, which exceeds the city's carrying capacity.

Map 4 details the Old Town's street and open space network, the roads with the highest tourist traffic, and some non-residential primary uses that extend throughout the city's neighborhoods.

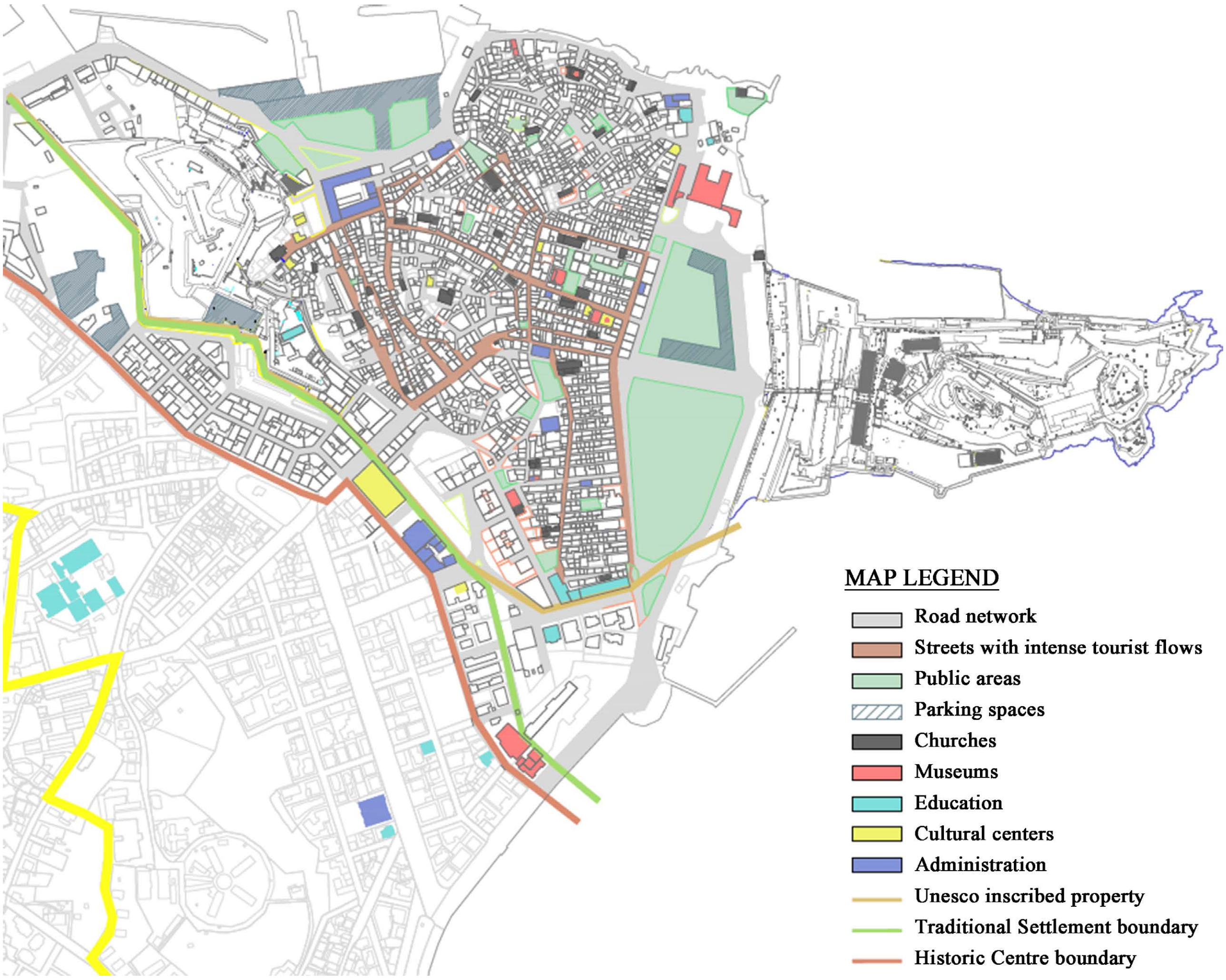
2.3. Building Materials and Structures

The Old Town's structure and buildings are inextricably linked to its history (socioeconomic conditions, know-how, etc., per historical period: Venetian rule, English rule, Ionian State, Modern Greek state) (Maravelaki, 2022).

Most Old Town structures are made of load-bearing masonry and wooden roofs with tiles. The lower floors are constructed of stones, while the upper floors are made of clay bricks. Also built with clay blocks were relief arches, vaulted structures, and cornices. The walls were permanently covered with plaster. In later interventions at the turn of the 20th century, additional materials, including cast iron, steel, cement mortars, and reinforced concrete, were observed (Maravelaki, 2022).

Carved masonry is only used in specific areas of structures for structural and/or decorative purposes (see corner shaping, construction of cornices, and arched wall frames (Maravelaki, 2022)). In some Venetian structures, low-quality, mixed clay brick and quarry stone masonry can be observed. There are also numerous walls constructed with lime mortar.

Neoclassicism had an influence on the houses built during the Anglo-Saxon era. The manner in which they were constructed complied with specific regulations.



Map 4. Street system, open spaces and other uses in the Old Town of Corfu. Map source: (NTUA, 2021). Application to the Old and the New Fortress of the Old Town of Corfu. Source: (ELLET, 2022).

In general, the dwellings were of the multi-story variety and were taller than those of the Venetian era, while new housing demands led to the addition of up to three stories to older structures. The increase in openings and the increased use of carved masonry on ground floors are additional characteristics of the architecture of this period (Maravelaki, 2022).

2.4. Vegetation

The majority of the Old Town's vegetation is located in the Old and New Fortress, a region west of the New Fortress, and in Spianada; however, there are also green islands scattered throughout the Old Town, which offer limited climate comfort (Kokkoris, 2022).

The dominant vegetation is a composition of native and alien species. Most species, such as palms and bougainvilleas, are well adapted to the area and are a vital element of the landscape, having been present since the distant past. **Map 5** shows the vegetation cover of shrub and/or tree species (Kokkoris, 2022).

Map 5. Vegetation map of shrub and/or tree species, in the Old Town of Corfu and the two fortresses (1: New Fortress, 2: Old Fortress). Source: (Kokkoris, 2022).

The Old Fortress is dominated by well-maintained and low areas of herbaceous vegetation, with scattered trees and shrubs of varying ages and sizes also present. Additionally, the New Fortress is dominated by low-growing herbaceous vegetation. However, unlike the Old Fortress, areas in the upper elevations require clearing and shaping of vegetation (Kokkoris, 2022).

The area with the most developed vegetation is a small island west of the New Fortress, adjacent to Captain Spyridon Vlaikos Street. On this island, the vegetation is a mixture of natural and anthropogenic units, with cypress dominating and olive trees and eucalyptus also recorded. Simultaneously, significant areas are also covered by the alien and highly invasive Ailanthus altissima (Aeilanthus, Stinkwort).

2.5. Infrastructure

2.5.1. Electro-Mechanical Infrastructure

In order to comprehend the city's potential and issues, the supporting electromechanical (E/M) infrastructure, road and traffic infrastructure, and parking options were documented.

The municipal underground, pressurized water supply network provides the water supply. Typical urban water supply network issues, including age and section leaks, plague the network. The natural water source from which the Old Town of Corfu receives its water does not exhibit any quality degradation. Nonetheless, a central issue identified is the seasonal water shortage on certain summer days, necessitating identifying alternative sources (Maistros, 2022).

With connections to the municipal underground pancreatic drainage system in the same pipelines, rainwater is used to ensure the drainage of urban wastewater. Generally, the pan-tributary network cannot be implemented in an Old Town like Corfu. The Old Town of Corfu is an exception, as the construction of the pan-European network dates back to the Venetian era. Due to the form and structure of the urban fabric, a separate installation is not possible (see paragraph 1). This issue has been addressed with a hybrid system, where part of the runoff is served by the pan-tributary network (part of the Old Town) and part by a separate system (the remainder of the urban fabric of Corfu Town) (Maistros, 2022).

Various methods, including overhead and wall-mounted networks and, in some cases, underground networks, supply electricity. The Medium Voltage network and a portion of the Low Voltage network are buried, whereas the electricity consumption meters are wall-mounted and supplied overhead from building to building. In addition to these networks, the municipal and festive lighting network, wired telecommunications networks, and relics of the first period of electrification coexist. Overall, the multiple changes to the networks (additions, removals, route changes, cable cross-section changes, etc.), particularly in the case of wall-mounted networks, combined with the age of the coatings, have caused a multitude of facade deterioration (see holes, disintegration) (Maistros, 2022).

Regarding the existing heating-cooling systems, approximately 54% of the households are heated with gas heaters or electric stoves, while 33% are heated with electric radiators or heaters. In contrast, using air conditioners (approximately 13%) has become more prevalent in recent years. The heating systems utilized in the Old Town of Corfu consume a significant portion of the allocated energy resources (Maistros, 2022). This is an important parameter since climate change influences and significantly affects it (IPCC, 2022).

2.5.2. Transportation Infrastructure

Regarding the road network of the Old Town, there are 1) important roads that connect or delimit Old Town neighborhoods, 2) axes, usually through-roads, leading to the gates of the Venetian enclosure or important sites (such as critical public buildings, churches, and important open public spaces), and 3) secondary roads or "cantons"or "camtounia" of extremely limited width (up to 1 m). Due to the historicity of the settlement's composition and topography, many roads, including major thoroughfares, continue with steps and ramps, while others pass through vaulted passageways (Kalantzopoulou, 2022).

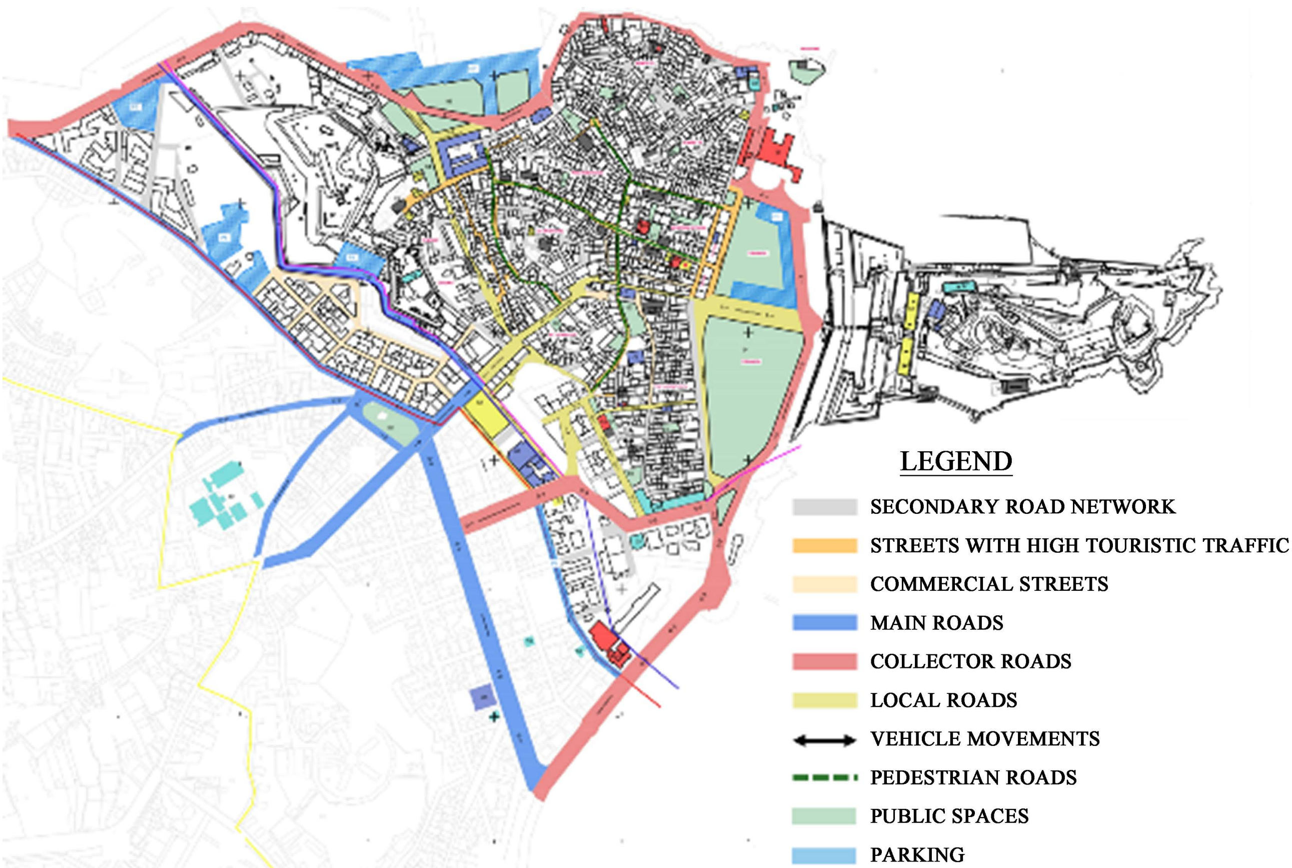
The traffic operation of the Old Town is hampered by a number of factors, including the limited geometric characteristics of the historic part of the city, the absence of fixed-route vehicles, the number of uses concentrated in the Old Town (hyperlocal administrative, educational, commercial, and cultural uses), the lack of a bypass axis, and the volume of through traffic (**Map 6**). In addition, tourist buses are generally parked in the Spianada neighborhood and connected to the port and airport. Large tourist tour vehicles are also a significant burden for the Old Town of Corfu (Kalantzopoulou, 2022).

Parking is permitted in organized areas, such as Spianada and the old port, whereas parking along the main arteries and peripheral axis is prohibited. Parking is generally free, as there is no controlled parking system or parking enforcement (Kalantzopoulou, 2022).

Urban buses (12 in winter, 14 in summer) and intercity buses (35 in total) provide public transportation (SUMP, 2022).

3. Methodology

The methodology used to assess the effects of climate change on the Old Town of Corfu in order to formulate an adaptation plan with actions focusing on its



Map 6. The traffic function of the Old Town of Corfu. Map source: (NTUA, 2021). Application to the Old and the New Fortress of the Old Town of Corfu. Source: (ELLET, 2022).

protection and sustainable management consists of three steps (Figure 2).

In the first step, the parameters of the climate data for the Old Town of Corfu are analyzed using the periodic climate model RACMO22e-MOHC. Estimated climate changes are calculated for 2031-2060 and 2069-2098, while the data and climate change analysis is repeated for three climate emission scenarios RCP2.6, RCP4.5 and RCP8.5.

In the second step, the impact of climate change on the Old Town, as determined in the first step of the methodology, is evaluated for the periods 2031-2060

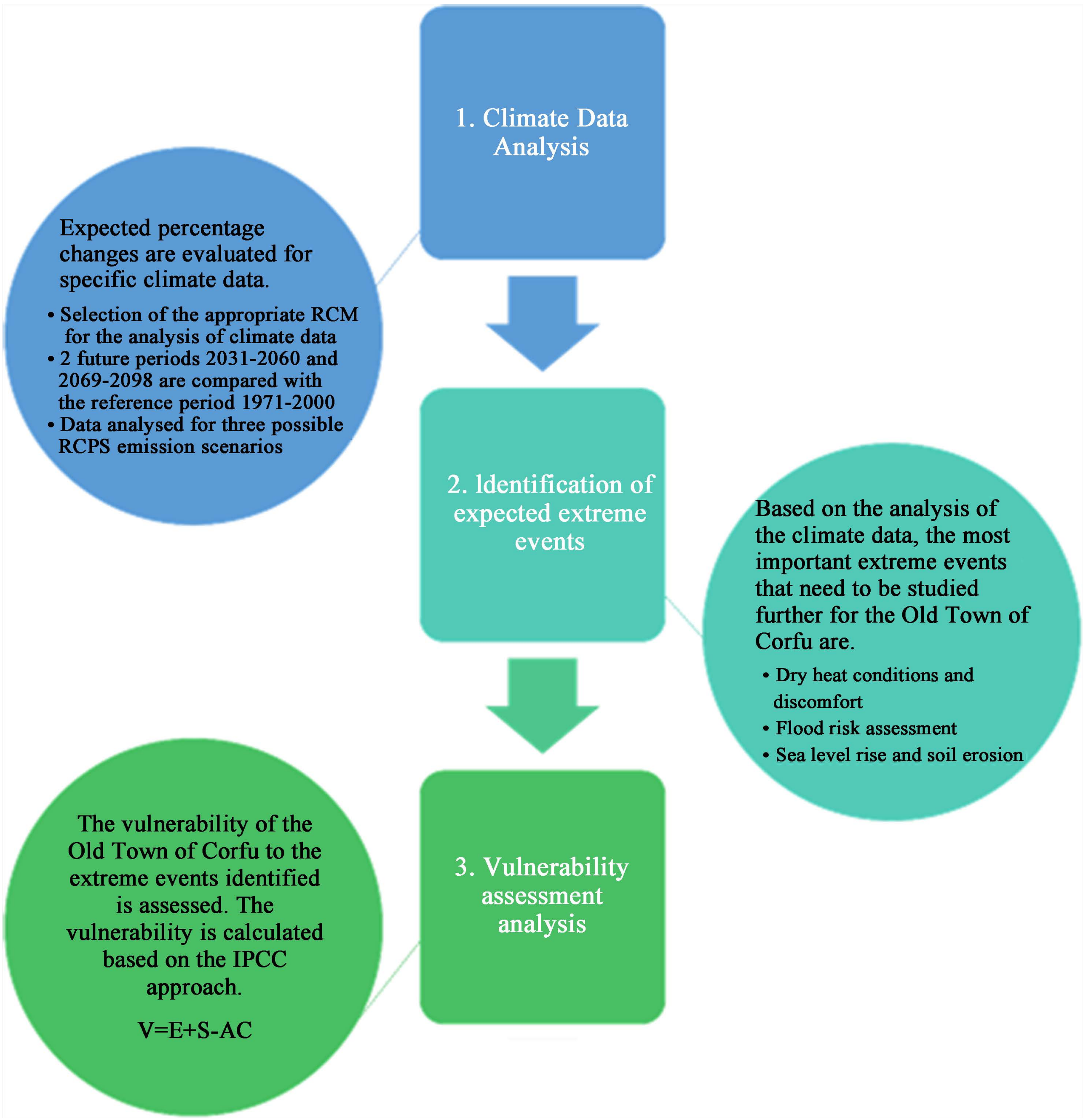


Figure 2. The methodological approach followed to assess the impacts of climate change on the Old Town of Corfu. Source: (ELLET, 2022).

and 2069-2098. Moreover, extreme weather phenomena that have already been observed are documented, as they all pose significant threats to the Old Town of Corfu.

The third step calculates the vulnerability of Corfu Old Town to the most critical threats identified in the second step. It is projected to evolve significantly by 2098, based on the methodology outlined in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001).

3.1. Identification and Evaluation of Potential Risks from Climate Change and Expected Extreme Events in the Old Town of Corfu

Numerous climate variables and indicators were analyzed to assess potential risks and extreme events related to climate change in the Old Town of Corfu, corresponding to those tested in the IPCC assessment reports (IPCC, 1990, 1995, 2001, 2007, 2014, 2022). The National Observatory of Athens (NOA) provided time series data in the form of climate variables and indicators for the Old Town of Corfu. The original data were retrieved from 2 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 (2069-2098) 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 RACMO22E regional climate model of the Royal Netherlands Meteorological Institute (KNMI) driven by the HadGEM-ES global climate model of the Met Office Hadley Centre (RACMO22e-MOHC) with a spatial resolution of 12 km (0.11˚).

The climate projections were based on the climate emission scenarios RCP2.6, RCP4.5, and RCP8.5. More specifically, 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) that seeks to keep global warming below 2oC above pre-industrial levels, two intermediate scenarios (RCP4.5 and RCP 6.0), and a scenario with extremely high GHG emissions (RCP8.5) (**Figure 3**).

For the case study of the Old Town of Corfu, three RCPs were examined, specifically the severe mitigation scenario RCP2.6, one of the two intermediate scenarios, namely RCP4.5, and the extremely high GHG emissions scenario RCP8.5.

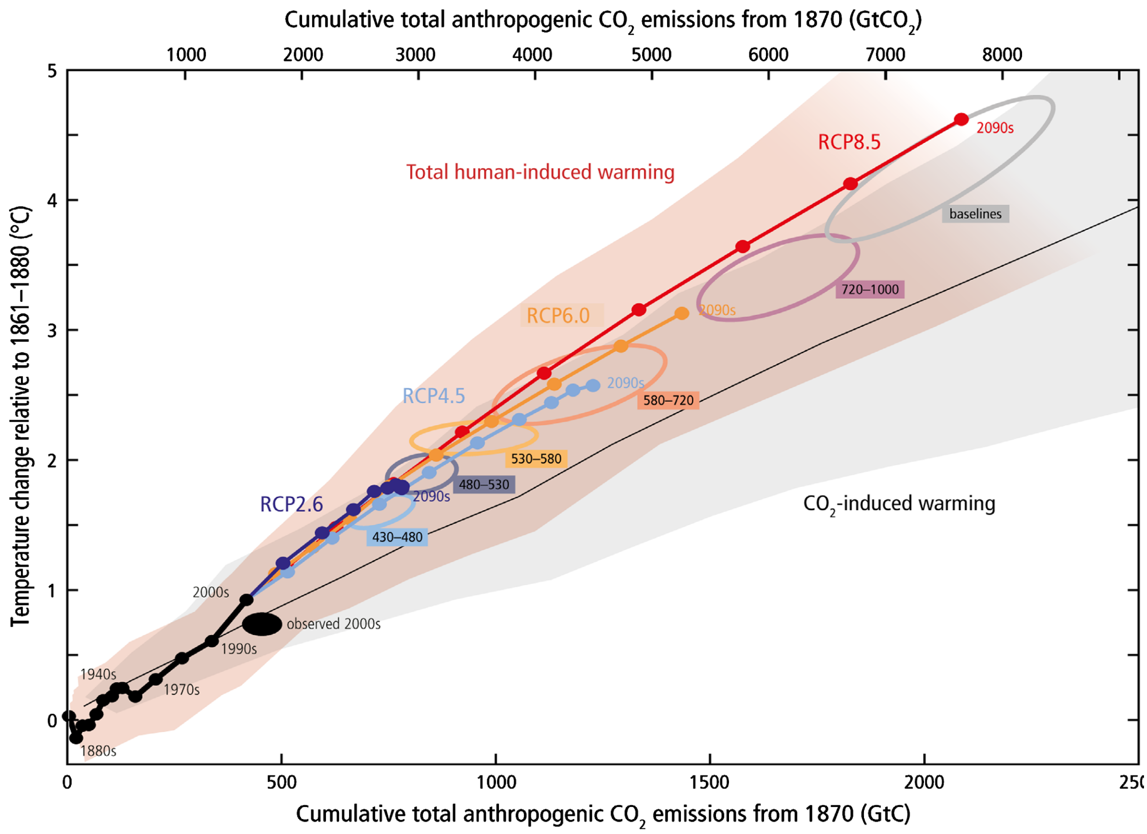


Figure 3. Global mean surface temperature increase as a function of cumulative total global carbon dioxide (CO_2) emissions from various lines of evidence. Multi-model results from a hierarchy of climate carbon-cycle models for each RCP until 2100 are shown (colored lines). Model results over the historical period (1860-2010) are indicated in black. The colored plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP8.5. Dots indicate decadal averages, with selected decades labeled. Ellipses show total anthropogenic warming in 2100 versus cumulative CO_2 emissions from 1870 to 2100 from a simple climate model (median climate response). Temperature values are always relative to the 1861-1880 period, and emissions have been cumulative since 1870. Black-filled ellipse shows observed emissions to 2005 and observed temperatures in 2000-2009 with associated uncertainties. Source: (IPCC, 2014).

The statistical significance of the differences between the values obtained for the reference period and those for the two future periods and the three emission scenarios was determined using the z-test. The null hypothesis Ho that the difference between the means of the two samples is not statistically significant was tested for each sample. When the result was z critical two-tail z and P (Z = z) 0.05 at a confidence level of 95%, it indicated that Ho was invalid and that the differences between the samples compared were statistically significant. In this way, the statistically significant expected climate changes up to 2098 for the Old Town of Corfu were documented.

Analysing climate data and investigating the most significant climate changes and risks can be replicated at other sites.

The largest proportion of statistically significant climate changes relative to the baseline period was associated with the impending rise in temperature and discomfort. Precipitation remains relatively stable in all three emission scenarios (see **Table 1**).

Table 1. Expected percentage changes for the climate parameters according to the different RCPs. Source: (ELLET, 2022).

PR 1971-2001	Rcp2.6 2031-2060	Rcp2.6 2069-2098	Rcp4.5 2031-2060	Rcp4.5 2069-2098	Rpc8.5 2031-2060	Rpc8.5 2069-2098
Expected change in average temperature **Tmean**, compared to the reference period	13%	13%	14%	18%	16%	31%
Expeceted change in discomfort levels **TR20**, compared to the refenece period	67%	63%	70%	92%	85%	138%
Expeceted change in relative humidity **RH**, compared to the refenece period	−1%	−1%	−2%	−2%	−2%	−4%
Expected change in Precipitation **PR**, compared to the reference period	8%	4%	7%	0%	3%	−3%
Expected change in daily $\mathbf{T_{max}}$-$\mathbf{T_{min}}$, compared to the reference period	−5%	−5%	−5%	−6%	−5%	−8%
Expected change in **FWI** index, compared to the reference period	11%	8%	14%	15%	15%	27%

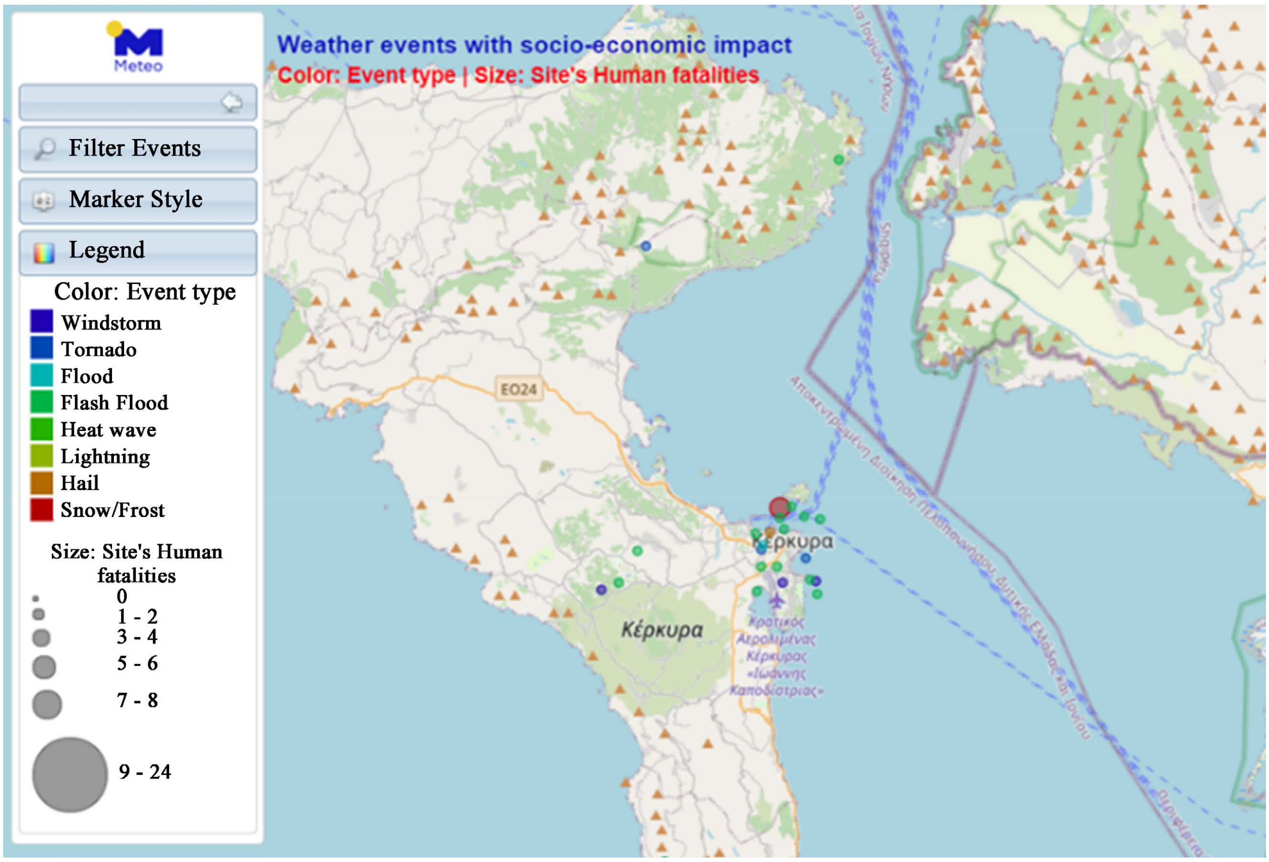
Table 1 shows that the temperature is projected to increase by up to 30%, with RCP8.5 predicting the highest values. Discomfort levels are anticipated to increase by up to 138% above the 1971-2000 reference period. Relative humidity (RH) is expected to remain nearly constant, with a slight, non-statistically significant decrease. Expected precipitation is projected to follow a similar trend, which is expected to change statistically significantly in 2069-2098. It is highlighted, however, that the severity of the flood risk in the Old Town is uncertain, firstly because Corfu is one of the areas in Greece with the highest annual precipitation and secondly because the available rainfall data were available on a daily scale and not an hourly scale. Therefore, it was impossible to calculate the intensity of rainfall, which is frequently a key factor in urban flooding. The difference between the daily maximum and minimum temperatures is anticipated to decrease. However, it is still regulated because it is a significant factor in the deterioration of historic building materials. The forest fire hazard index (FWI) is anticipated to increase, although the values for the two future periods in all three emission scenarios are low overall.

Overall, the analysis showed that the city's most significant risks are dry heat conditions and levels of discomfort for residents and visitors, as statistically significant increases in temperature and tropical nights (TP20) are expected by 2069-2098. In addition, it was decided to assess flood risk and investigate which areas are most at risk of a flood event because, in the past, precipitation has repeatedly caused damage in the city.

Further, since Corfu Old Town is a coastal town, additional information was collected on the risks that could affect or are about to affect the coastal zone (Old Fortress area). During the development of the final adaptation plan, it was noted that the area surrounding the Old Fortress had experienced strong tornadoes, and flash floods, thirteen in 2021 around Corfu, some of which had a significant social and economic impact (Map 7).

Although no data indicate whether their frequency or intensity will increase over time, they were included in the list of hazardous events for which adaptation measures were suggested. The possibility of soil erosion along the coastline and the risk of sea level rise were also evaluated based on the available data.

The seismic risk, which exists for the whole of Greece and has occurred several times in the Ionian Islands, except for Corfu, although not directly related to climate change, must be taken into account in any proposal to address the impacts of climate change, as (a) the state of preservation of the materials and structures of monuments is crucial for the flawless response of buildings to earthquakes, and (b) the state of the electro-mechanical infrastructure and the functioning of the emergency management system is crucial for the effective response of emergency services. It is noted that earthquakes are generally unpredictable, and the timing, magnitude, duration, and exact location of this phenomenon cannot be assumed with certainty. The criticality of this phenomenon is highlighted, given that the devastating earthquakes of 1953 almost destroyed the other two neighbouring historic major cities of the Ionian Islands, namely Zakynthos and Kefalonia (Municipality of Corfu et al., 2005).



Map 7. Climate phenomena in the area of the Old Town of Corfu with strong socio-economic impact. Source: Meteo (2023).

3.2. Identification of Extreme Weather Events

3.2.1. Dry Heat Conditions and Discomfort

The data for the indicator 'number of consecutive days with precipitation less than 1 mm or PRm' were utilized to further document and integrate drought data into the study area's location. Using Geographic Information Systems, the results were mapped to corresponding thematic maps for comparison (Kokkoris, 2022). Similarly, the "tropical nights" indicator was analyzed to assess discomfort further, and the resulting comparative charts are shown.

3.2.2. Floods

Corfu is one of the Greek areas with the highest average annual precipitation exceeding 1.200 mm between 1.950 and 2020 (Varlas et al., 2022). According to statistical data, the average annual precipitation for the reference period (1971-2004) was approximately 1438 millimeters, while similar values are observed in the climate scenarios, except for the RCP2.6 and RCP4.5 scenarios for the period 2031-2060, which show slightly higher precipitation (1.532 and 1.531 millimeters, respectively). Kourgialas & Karatzas (2011)'s methodology was used to assess the flood risk areas of the study area. Based on this methodology, the flood hazard map was generated by integrating multi-criteria analysis with GIS software using maps with a specific canvas size of approximately 1 m (Dimitriou, 2022).

Six sub-maps were created for each of the six primary factors contributing to flood development: flow accumulation, slope, land use, rainfall intensity, geology, and elevation. Each factor's influence was assigned to one of five risk categories: very high, high, moderate, low, and very low. The risk classes for numerical factors (flow accumulation, slope, altitude, and rainfall intensity) were determined using Jenk's Natural Breaks method. In contrast, the risk classification for non-numerical factors (geology and land use) was determined using subjective criteria based on their influence on flooding processes. Each factor was assigned a weighting factor based on their impact on river basin flooding processes. After algebraic aggregation of each weighted factor, the final flood risk map was generated (Gemitzi et al., 2006; Dimitriou, 2022):

$$S = \sum_{1}^{i} w_i x_i$$

where,

S: the risk weighted index,

w_i: the weight of factor i,

x_i: the relative importance of factor i.

3.2.3. Sea Level Rise and Soil Erosion

The literature was reviewed to assess the risk of sea level rise and soil erosion since no data were available for analysis as in other risk cases. A set of studies, publications, and maps were studied (Copernicus, 2023; EEA, 2023; Plan Bleu, 2023; Reimann et al., 2018; Wolff et al., 2018; UNEP/MAP, 2016; EEA, 2014), with the aim of understanding with as much certainty as possible the extent to which the above risks will increase due to climate change and affect the coastal frontage of Corfu Old Town.

Specifically, for sea level rise, the average value of sea level rise over 100 years for the study area was evaluated and compared to the literature (Copernicus, 2023; Reimann et al., 2018; Wolff et al., 2018; UNEP/MAP, 2016; EEA, 2014).

The value of the CRI-MED index, which takes into account, among other things, parameters related to climate risks (storms, drought, and sea level rise), tourist arrivals, landscape cover and form, and topographic features, was evaluated in the literature (Plan Bleu, 2023; Satta et al., 2015) to assess soil erosion. It is composed of three sub-indexes the Coastal Forcing Index, the Coastal Vulnerability Index, and the Coastal Exposure Index (Plan Bleu, 2023; Satta et al., 2015).

3.2.4. Tornadoes

Due to a lack of data, assessing the risk of tornadoes and floods caused by climate change was impossible. Nonetheless, it was included as a critical risk to be managed in the final adaptation proposal development.

3.2.5. Forest Fires

Using the Fire Weather Index (FWI), the forest fire risk was documented/identified and spatially attributed to assess the forest fire risk at the Old Town of Corfu location. The data for the FWI and the Extreme Forest Fire Risk Index (FWI>50) were analyzed. The FWI is comprised of five distinct sub-indices, which are categorized as follows (van Wagner, 1987):

- The Fine Fuel Moisture Code (FFMC), the Duff Moisture Code (DMC) and the input data the Drought Code (DC) which assess the moisture content of different type of fuels, and
- The Initial spread index (ISI), the Buildup Index (BUI) to estimate the intensity of possible fire.

For the risk assessment, correlations were made between 1971 and 2000 (reference period) and the following periods/climate scenarios: 1) 2031-2060, RCP26; 2) 2031-2060, RCP45; 3) 2031-2060, RCP85; 4) 2071-2100, RCP26; 5) 2071-2100, RCP45; 6) 2071-2100, RCP85. Using Geographic Information Systems, the outcomes were mapped against corresponding thematic maps.

It is noted that the risk of forest fire is directly dependent on the existing vegetation of the Old Town, which is currently mainly located in the Old and New Fortress, in an area west of the New Fortress and Spianada. There are also islands of greenery scattered throughout the Old Town, but these are not considered significant forest areas.

3.3. Vulnerability Assessment of the Old Town of Corfu

In order to assess the threats caused by climate change to which a system or cultural heritage site, such as the Old Town of Corfu, is exposed, its vulnerability should be assessed. Through this process, it is possible to identify the site's needs as efficiently as possible, propose an integrated adaptation strategy, and prioritize the measures.

After the publication of its Third Assessment Report in 2001, the IPCC introduced vulnerability assessment of a system to the impacts of climate change as a methodology for risk assessment (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 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 it 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):

$$V = (E + S) - AC, \tag{1}$$

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

For the evaluation of the impact of climate change on the Old Town of Corfu, an attempt was made to evaluate exposure, sensitivity, and adaptive capacity parameters using the above general formula.

3.3.1. Assessment of Exposure

The exposure of the Old Town of Corfu to extreme events was evaluated based on the degree to which it will be negatively impacted by the risks of increased dry and hot conditions and discomfort, flooding, sea level rise, and soil erosion as a result of its geographical location. The site's characteristics, including catchment area, topography, and land use, were evaluated.

3.3.2. Assessment of Sensitivity

The sensitivity of the Old Town of Corfu to extreme events was evaluated based on 1) its urban characteristics and how the built environment is organized; 2) the sensitivity of the building materials and structures; 3) the sensitivity of the (native and/or cultivated) vegetation.

3.3.3. Assessment of Adaptive Capacity

The adaptive capacity of the Old Town was evaluated by assessing the adequacy, conservation status, and suitability of a) the existing infrastructure (electromechanical, hydraulic, transport, etc.); b) the management practices of the Old Town (traffic, maintenance, and rehabilitation of the building stock, land use management, etc.) the uses of buildings and public space, as well as the management and operation of the historic district overall.

4. Results Regarding the Risk of Extreme Weather Events

Based on the methodology presented in Section 3.1, it can be concluded that increasing dry heat conditions and discomfort levels in the city, flooding, and sea level rise in the area of the Old Fortress are critical risks for the study area. Therefore, it was decided to further evaluate the likelihood of their occurrence. The relevant results, categorized by risk, are listed below.

4.1. Rise in Dry-Heat Conditions and Discomfort

According to the results of the spatial performance of the consecutive days of drought index (PR < 1 mm) for the study area, the following applies:

1) Reference period (1971-2000): The index value range for the reference period is from 54.10 consecutive dry days in the western part and the new Fort to 54.81 in the eastern part and the Old Fortress (**Map 8**).

2) Near future (2031-2060): the range of the change in the index price for the near future changes as follows:

a) 2.54 additional consecutive days for the RCP26 scenario,

b) 6.30 to 6.42 additional consecutive days for the RCP45 scenario; and

c) 2.14 to 2.16 additional consecutive days (in the western part and the new fortress) for the RCP85 scenario.

3) Far future (2071-2100): The range of the index value change for the far future is varied as follows:

a) 1.05 to 1.07 additional consecutive days for the RCP26 scenario,

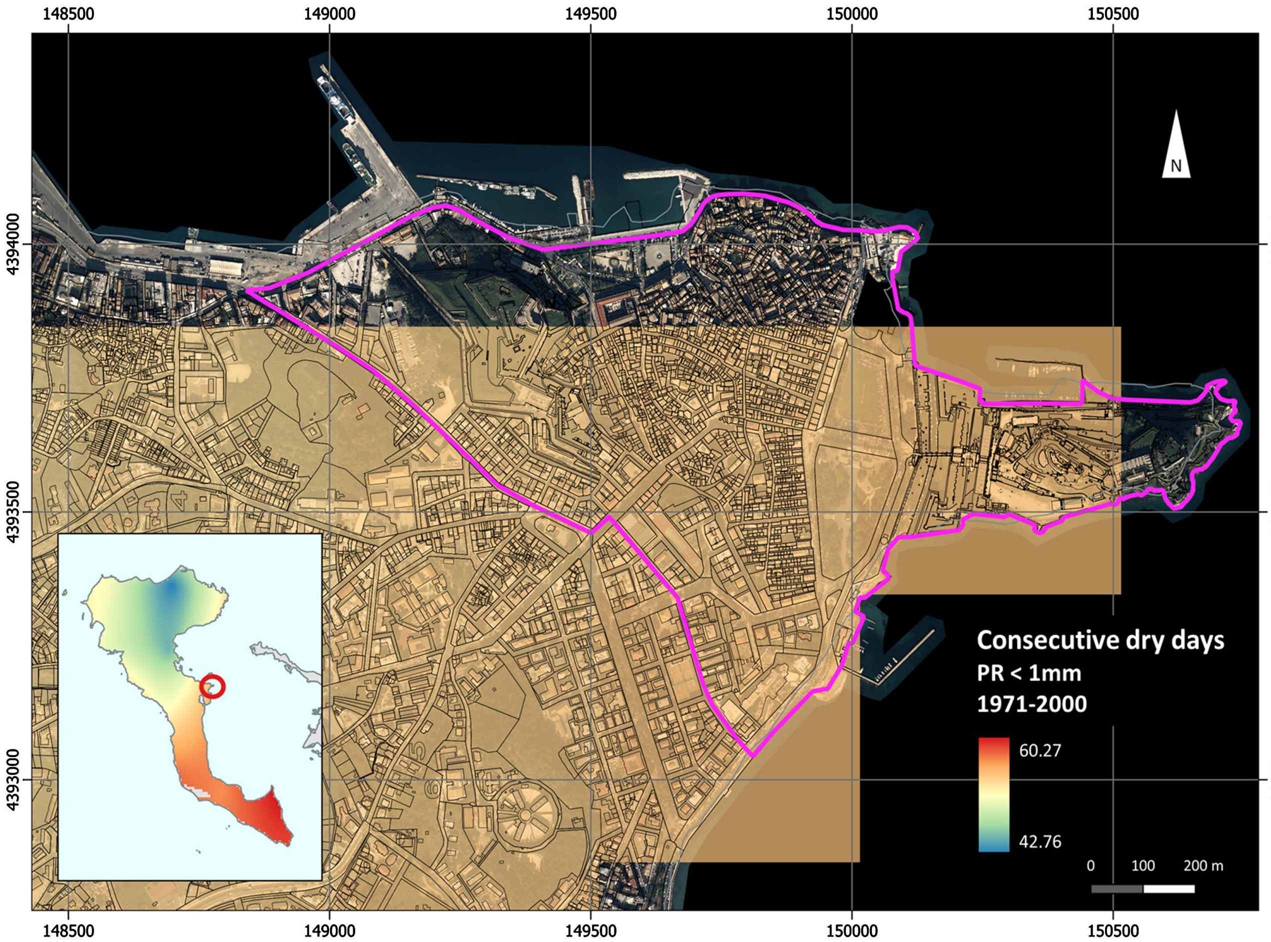
b) 4.57 to 4.61 additional consecutive days for the RCP45 scenario; and

c) 15.48 to 15.52 additional consecutive days for the RCP85 scenario.

In conclusion, a worsening of drought is expected in all climate scenarios, for the near and far future, with the worst-case scenario projected for the far future 2071-2100 and for RCP8.5, when the expected increase in drought days is in the order of 15 days (**Map 9**).

Regarding levels of discomfort, controlling for the Tropical Nights or T_{min} < 20˚C indicator, the following percentage distributions, by 30-year period, were obtained, as shown in the table.

As observed in **Figure 4**, compared to the 1971-2000 reference period, the increase in the proportion of tropical nights is statistically significant, with the highest values recorded under the adverse emissions scenario RCP8.5; in both RCP4.5 and RCP8.5, the proportion of days with high levels of discomfort is on the order of one-third or more of the days per year.



Map 8. Distribution of drought index, number of consecutive days of drought (PR < 1 mm), for the study area, for the reference period (1971-2000). Data source. Processing: (Kokkoris, 2022).

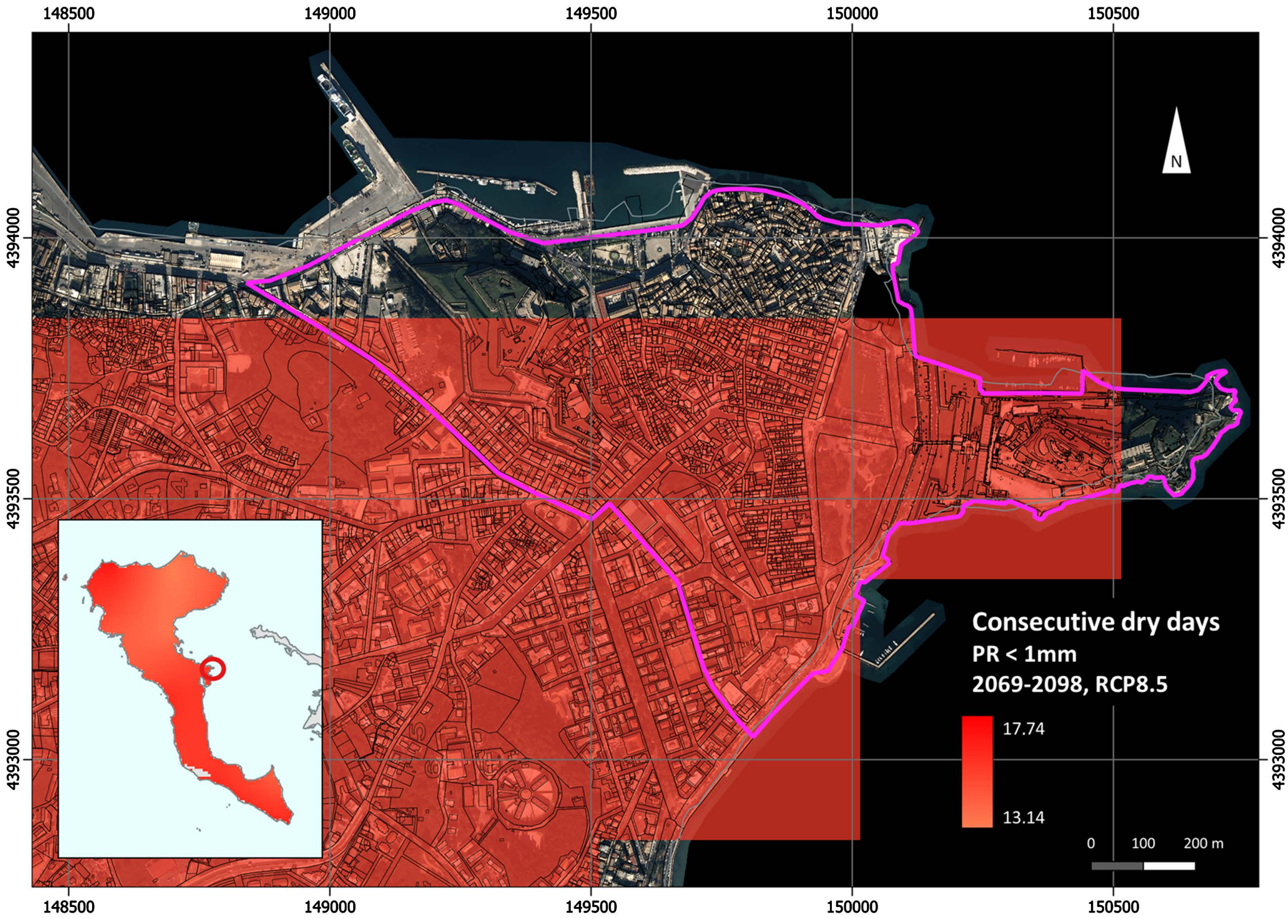
4.2. Areas Vulnerable to Flood Risk

Calculating the flood risk (see Section 3.2.2) resulted in the following risk map in case of high rainfall velocity (**Map 10**).

According to **Map 10**, the western part ("Spilia" area and port area) of Old Town, where most of the rainwater is concentrated due to the area's slopes, has a very high flood risk. High to extremely high flood risk is also present in parts of the coastal zone on the eastern front of the study area and in some of the Old Town's narrow alleys, which appear to have suboptimal stormwater discharge conditions. Spianada Square presents a moderate to high risk of flooding. Built on elevations with favorable slope and land cover conditions, the two fortifications pose a moderate to low and very low risk of flooding, respectively.

4.3. Areas Vulnerable to Sea Level Rise and Soil Erosion

Based on the literature review, as detailed in Section 3.1.3, it has been found that the Old Town of Corfu is among the historical areas of Greece with a relatively high risk of sea level rise (other areas include Pythagorion and Heraion of Samos, Delos, and the medieval town of Rhodes) (Reimann et al., 2018). Without



Map 9. Change in the average annual number of dry days (PR < 1 mm), relative to the reference period (1971-2000), for the study area of Corfu Old Town, in the case of RCP8.5 prevalence, for the distant future 2071-2100. Data source. Edited by (Kokkoris, 2022).

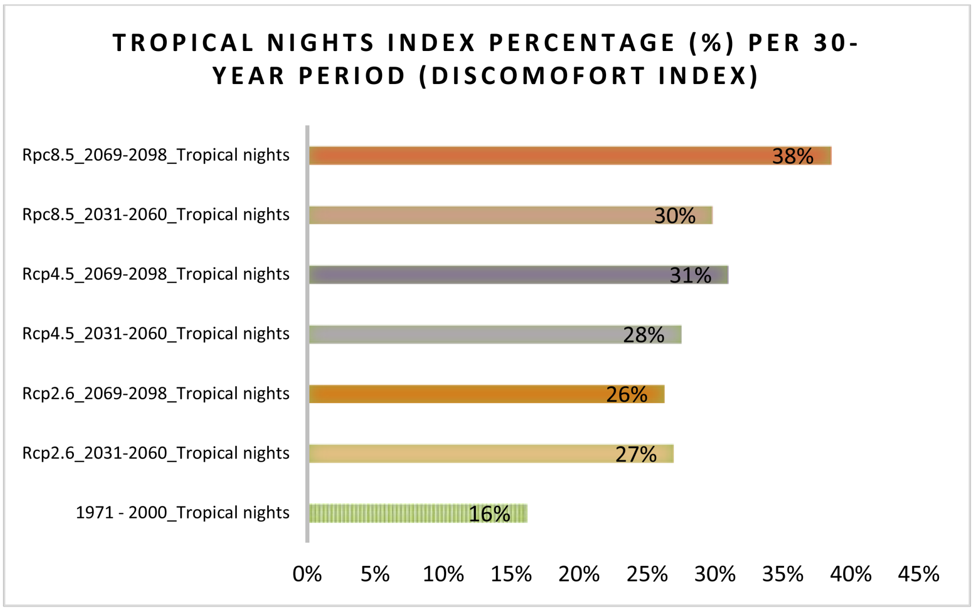
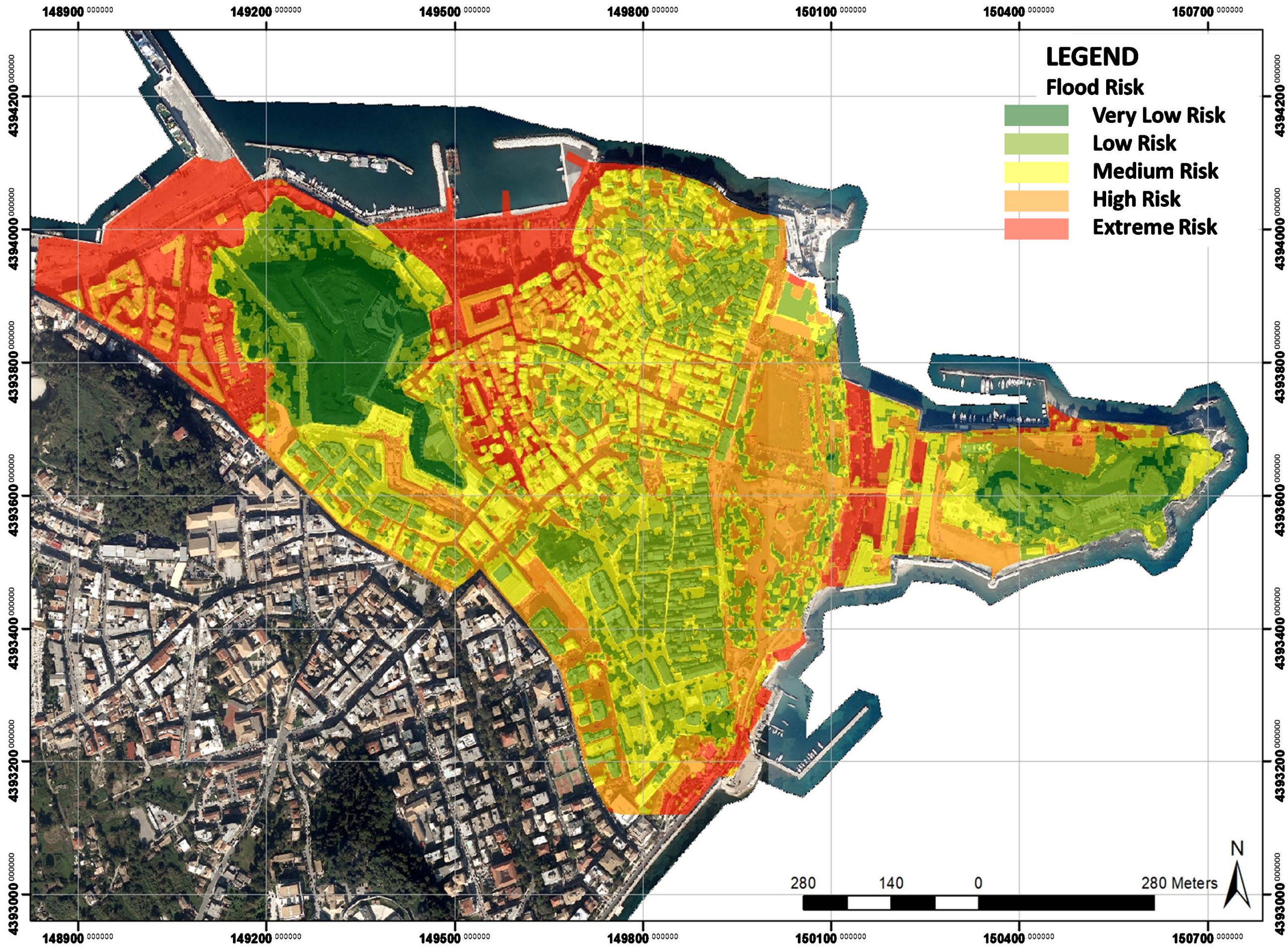


Figure 4. Comparison of the Tropical Nights (TR20) percentage per 30-year period, per emission scenario. Data source. Processing: (ELLET, 2022).



Map 10. Flood risk map, in case of high rainfall velocity. Data source. National Aeronautical Observatory of Athens, Greece. Source: (Dimitriou, 2022).

long-term policy planning to address the associated risks (flooding, coastal erosion), Greece's extensive coastline and population and infrastructure concentration in coastal areas make the risks and impacts of sea level rise substantial, even under optimistic scenarios of average sea level rise.

The Old Town of Corfu is located in a larger coastal area where sea level rise could reach 0.54 to 0.69 meters, as shown in **Figure 5**.

The most vulnerable areas to sea level rise, according to (Climate Central, 2023), are the western area of the Old Town ("Spilia" area and port) and part (central and eastern) of the Old Fortress.

Regarding soil erosion, and based on the CRI-Med index, the Coastal Risk Index for the Old Town of Corfu is calculated as "low" to "medium" (Copernicus, 2023).

4.4. Other Hazards and Their Impacts

It is also prudent to consider the possibility of tornadoes originating from the ocean, especially near the Old Fortress (see **Map 6**). Data needs to be produced on their trend and degree of evolution due to climate change; however, this is

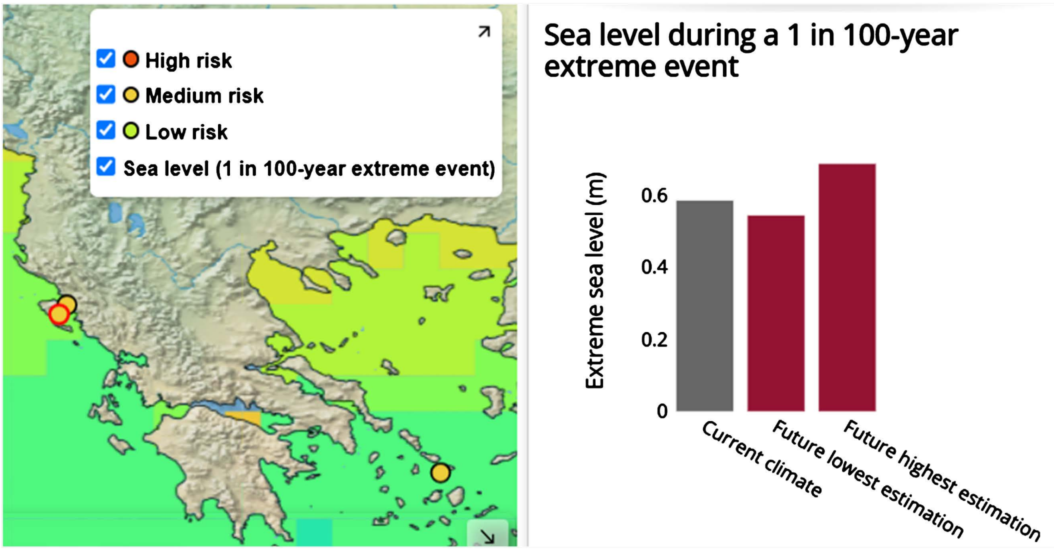


Figure 5. Mean Sea level during a 1 in 100-year extreme event for the case study of the Old Town of Corfu. Source: (Copernicus, 2023).

believed to be investigated further. During the event, workers and visitors at the Old Fortress site are in danger, as are the poorly maintained building structures.

Due to the nature of the vegetation, the risk of forest fire (Section 3.2.5) was deemed low, subject to the risk of fire occurring due to high temperatures and fuel being burned on the ground.

5. Assessment of the Vulnerability of the Old Town of Corfu

After assessing the likelihood of extreme events of temperature rise and increased distress, flooding and sea level rise, and soil erosion, an attempt is made to determine the city's overall vulnerability to these occurrences. The methodology presented in Section 3.2 was used to evaluate the IPCC-defined parameters of exposure, sensitivity, and adaptive capacity.

5.1. Exposure of the Site to Climate Change Impacts Due to Location

Overall, the Old Town of Corfu is moderately to highly exposed to the extreme risks of increased dry heat days, rapid rainfall, tornadoes, rising seas, and soil erosion due to its location and topographic characteristics. Some parts of the Old Town are estimated to be especially vulnerable (see 4.2), considering a flood's geographical, geological, and topographical characteristics.

Compared to other Mediterranean coastal areas, the risk of soil erosion is low to moderate (see 4.3).

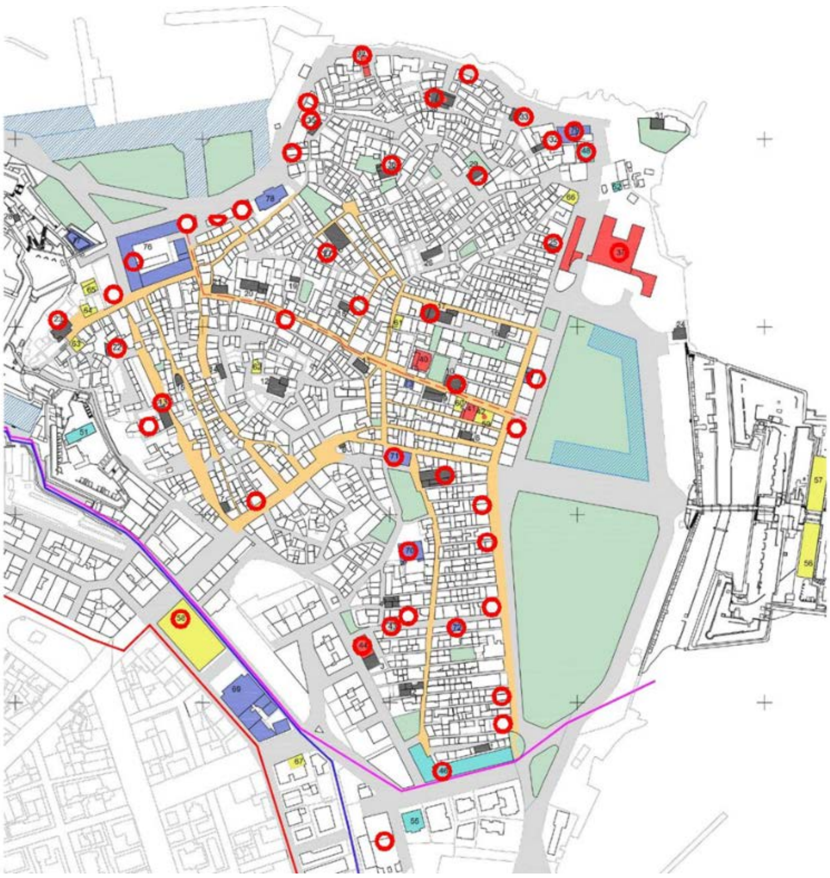
5.2. Sensitivity Due to Urban Structure and Land-Uses

The city's sensitivity against extreme events is considered high due to its urban organization and specific geometric characteristics in conjunction with the city's functions. The density of urban space, the narrow streets, and the lack of open spaces, combined with the multifunctional nature of the city, the intense tourist traffic, particularly in the summer months, and the occupation of the public space, make it difficult to evacuate crowds immediately or provide rescue services with timely access, making the Old Town prone to extreme events. Moreover, in addition to the city's high population density, the height of the historic buildings needs to be considered, which further impedes the access of a typical fire engine or municipal crane. Generally, the most vulnerable areas, such as Kabiello, Kofineta, and Aghios Pateres, are the most vulnerable.

5.3. Sensitivity of Materials and Building Structures to the Impacts of Climate Change

In order to evaluate the sensitivity of materials and structures of the historic buildings, the existing pathology and degree of individual deterioration in a selection of city-wide landmark buildings were examined. The principal pathologies caused mainly by precipitation and rising humidity but also by sudden temperature changes: acupuncture, blistering, biological damage, black crusts, powdering, loss of materials (in the coating, in the grout, or stone sections), corrosion, oxidation of metal elements, and wood rot. In addition, the following were observed. The tested structures are depicted on **Map 11** (Maravelaki, 2022).

By evaluating the existing pathology of the building materials and structures,

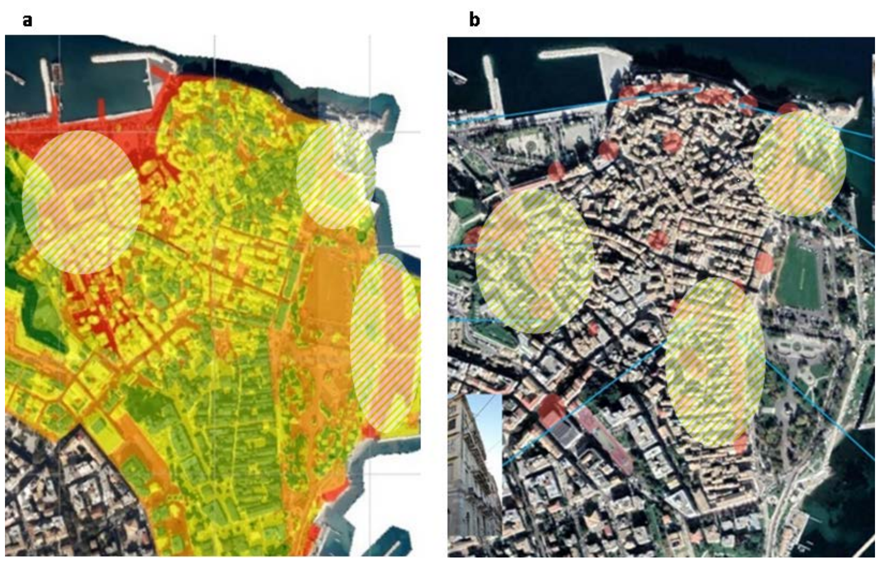


Map 11. Overall inventory of the buildings checked. Source: (Maravelaki, 2022).

it was concluded that the historic building stock is already quite vulnerable to intense climatic phenomena. The situation is anticipated to worsen as the frequency of such occurrences increases. Based on the analysis, it was determined that the areas with the greatest vulnerability are those facing the coastal front (already concentrating a large amount of damage, primarily biological), the Jewish area (a burdened area, with intense damage to materials, such as moisture, biological deterioration, and detachments), and overall the areas with denser building and thus the absence of sunlight (see **Map 12**) (Maravelaki, 2022).

The maps show the locations where the most significant sensitivity of materials (**Map 13(a)**) and structures are mainly identified, which coincide with locations at high risk in a flood event (**Map 13(b)**).

Map 12. The areas with the highest sensitivity of materials and structures to the effects of climate change are marked. Source: (Maravelaki, 2022).



Map 13. The areas (a) with the highest risk in case of a flood event and (b) with the highest sensitivity of materials and structures to the impacts of climate change are marked. Source: (Dimitriou, 2022; Maravelaki, 2022).

5.4. Sensitivity of Vegetation to the Impacts of Climate Change

The analysis revealed that the Old Town's vegetation and flora are well adapted to their environment and are relatively insensitive to climate change. Some eucalyptus individuals adjacent to the ocean and exposed to strong winds were found to be at greater risk, except for "invasive" species, invasive plant species are not considered a threat. Particularly for the species Ailanthus altissima (Ailanthus altissima), it was determined that it has already occupied a significant portion of the natural vegetation's living space, thereby diminishing its resilience and that it can reproduce and grow quickly and rapidly even in locations with adverse conditions (e.g., sidewalk cracks, urban soil pockets, etc.). Even though this is not directly related to climate change, it has been accounted for in the final adaptation plan because it may significantly alter the city's character (Kokkoris, 2022).

5.5. Adaptability of the Old Town of Corfu Site due to Infrastructure. Management Practices and the Institutional Framework

In light of the Old Town's existing infrastructure and management practices, it was found that the city's capacity to adapt to climate change, minimize potential damages, and cope with and recover from its potential impacts is limited.

1) It was determined that the city's existing electromechanical infrastructure needs to be upgraded to achieve the desired level of resilience against extreme events. The analysis revealed that cooling-heating systems, fire protection systems, and the above-ground electricity network could act as fire starters or contribute to the spread of a potential fire. In addition, the adequacy of the rainwater drainage system needs to be further ensured (Maistros, 2022).

2) Regarding the city's road/transport infrastructure and traffic operation, it has been found that several significant improvements are required to enhance the city's ability to respond to and manage a catastrophic event promptly. This is due to a combination of factors, including the city's unique geometric characteristics, the occupation of public space and dense building density, and the high volume of visitors (Kalantzopoulou, 2022).

3) Existing management practices were considered for review and revision, emphasizing increasing the city's adaptability. Managing the city's visitors, parking uses extending into the public space, and daily traffic is crucial (Kalantzopoulou, 2022).

3) To the extent that the institutional framework for the protection, including the measures and actions required for addressing the risks of climate change, is deemed adequate. There is, however, the need for an updated Management Plan and the assurance that its proposed guidelines will be implemented.

6. Expected Risks and Vulnerability of the Old Town of Corfu

Based on the analysis of individual potential risks (see Section 4), the following figure was created to illustrate the likelihood of climate-related extreme events. The degree of risk is 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 6, the risk of drought and increased levels of discomfort is exceptionally high, particularly if RCP8.5 holds for both future periods. As discussed in Section 4.2, the risk of flooding remains stable but is significant in specific areas of the city. In the case of RCP8.5 prevalence, sea level rise is a significant additional risk. In conclusion, the literature review revealed that the risk of soil erosion is low to moderate.

Concerning the Old Town of Corfu's vulnerability, the analysis revealed that it is especially vulnerable to these risks and climate change-related extreme events due to several structural and functional issues. Specifically, the dense geometric features of the city's structure, the severe deterioration observed in materials and structures of the historic building stock, the inadequate electromechanical infrastructure, and the poor management of issues such as increased tourism or heavy traffic congestion are the primary factors that worsen the Old Town's vulnerability. The Old Town's current management plan dates back to 2005, combined with the fact that the Urban Planning Study of the Old Town still needs to be completed, are negative factors in the city's response to the risks of climate change.

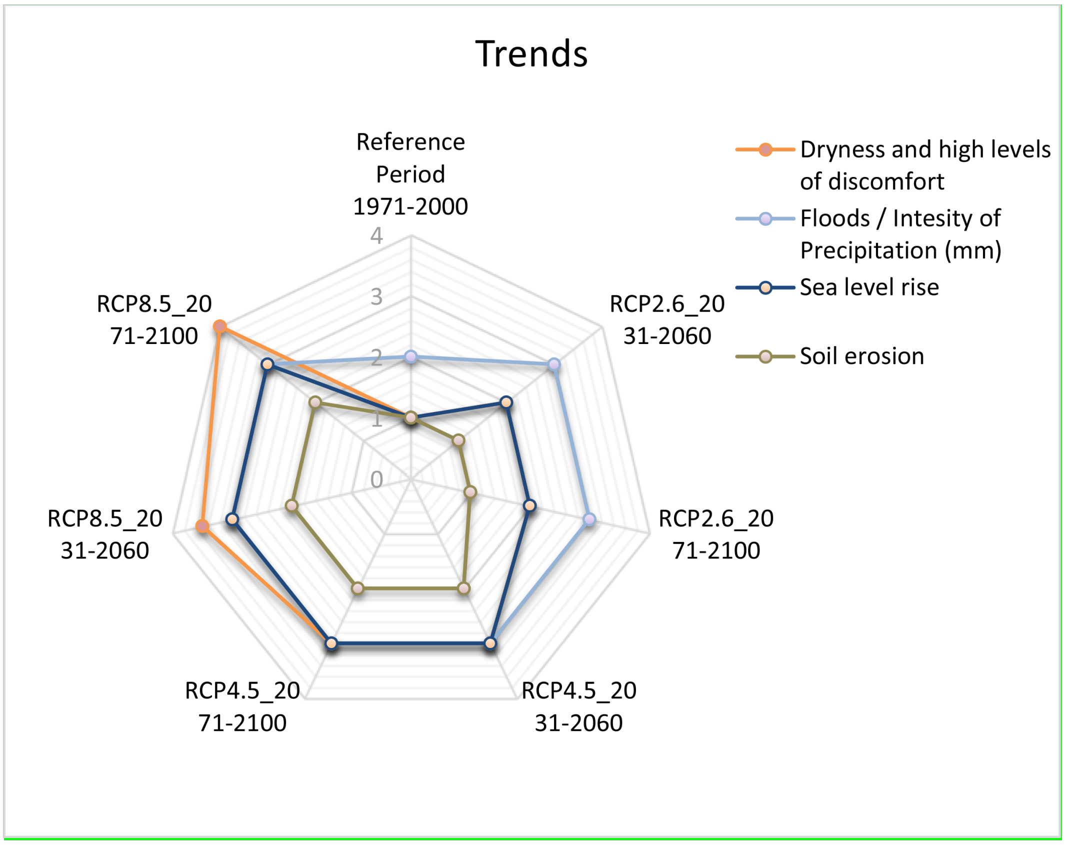


Figure 6. Degree of risk of extreme events in the Old Town of Corfu, due to climate change, depending on the emission scenarios. Source: (ELLET, 2022).

Figure 7 summarizes the results regarding the exposure of the Old Town to the impacts of climate change due to its location, the sensitivity due to its urban organization and its particular geometric characteristics, the materials and structures of the building stock and vegetation, and the adaptive capacity of the Old Town based on the adequacy of the existing infrastructure, the management practices implemented, and the institutional framework of protection. Depending on the considered parameter, the values were formulated based on the estimated degree of risk to which the Old Town was exposed to climate change's anticipated effects. The qualitative scale ranges from 1 to 4, with 1 indicating a low risk of occurrence, 2 indicating a moderate risk of occurrence, 3 indicating a moderate to high risk, and 4 indicating a high risk of occurrence.

At a general level, as illustrated in Figure 7, the analysis revealed that the Old Town of Corfu is particularly vulnerable to the above-mentioned risks and extreme events related to climate change (see Figure 6) for various issues mainly related to the functioning and structure of the town. More specifically, the dense geometric characteristics of the Old Town's structure, the intense pathology

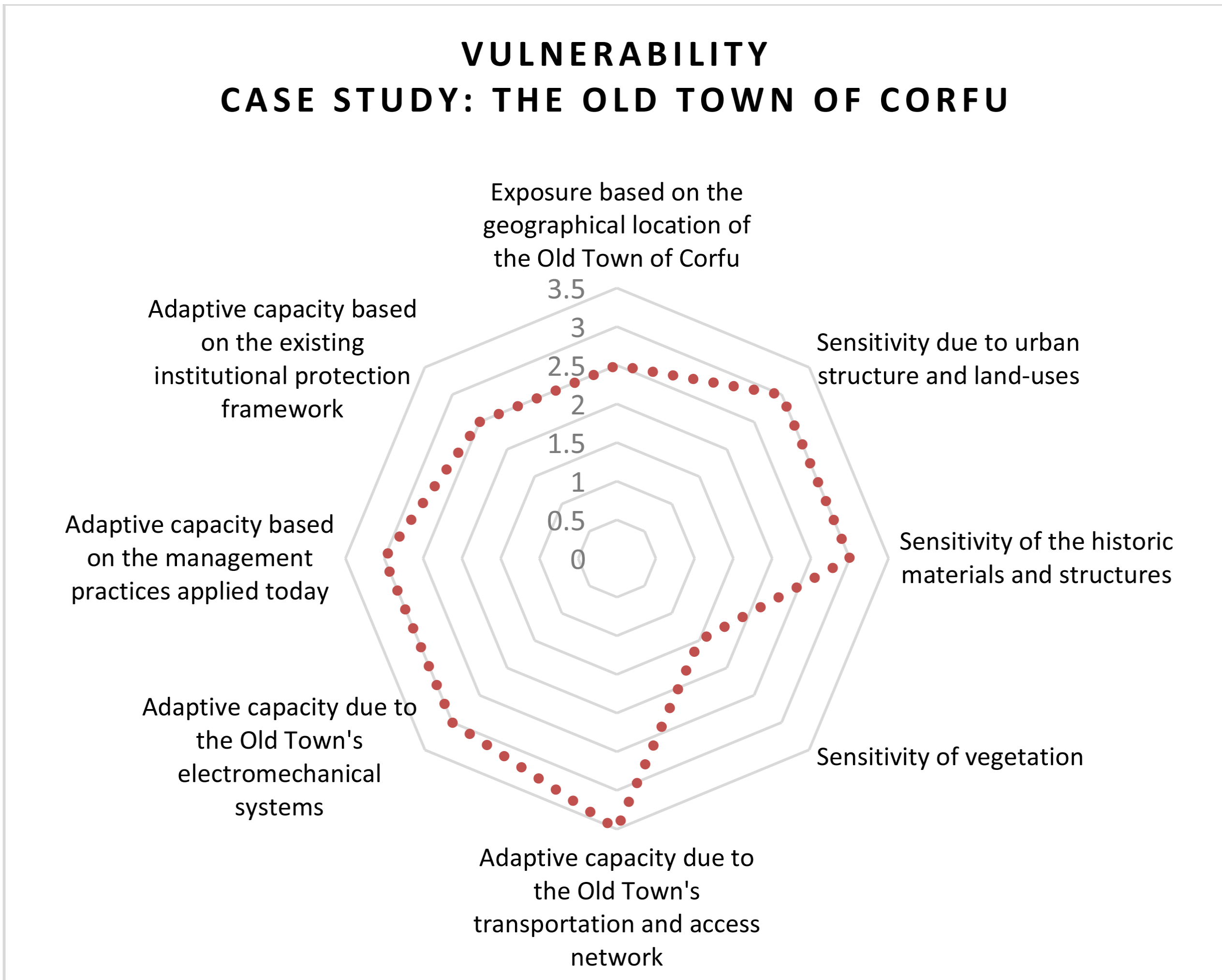


Figure 7. Vulnerability Assessment Analysis of the case study of the Old Town of Corfu. Source: (ELLET, 2022).

observed in the materials and structures of the historic building stock, specific problems, and deficiencies in the electromechanical infrastructure and poor management of issues such as increased tourism and intense traffic congestion, are the main parameters that exacerbate the vulnerability of the Old Town to climate change. The age of the management plan (2005) and its incomplete implementation are additional negative factors in managing climate change risks.

Based on the analysis of the individual potential risks and the assessment of the vulnerability of Corfu Old Town and aiming at enhancing its resilience to the expected impacts of climate change, a comprehensive strategic adaptation plan can be developed. The plan could be structured along the following axes.

Adaptation to climate change measures: Several proposals were formulated to enhance resilience and improve the site's functionality.

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

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

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

Spatial Monitoring System: A series of proposals were formulated to understand better the relevant effects of climate change on the materials and structures of the monuments of the archaeological site and monitor the effectiveness of any measure taken.

The series of proposals for the integrated management of traffic organization and operation is a crucial action of a strategic adaptation plan that can contribute to the more effective adaptation of the Old Town of Corfu against the effects of climate change. According to the analysis, this is one of the most critical issues, w significantly impacting Corfu Old Town's vulnerability. Main proposals include the complete removal of cars and motorcycles from the Old Town (especially within the perimeter of the UNESCO Site) for non-residents and the complete prohibition of parking around the perimeter of the UNESCO Site, except for the streets Republic, Fighters of Polytechnic, El. Venizelos and the area of Pl. controlled parking spaces can be designated (possibly for residents only). In addition, it is suggested that public parking spaces be provided outside the Old Town's perimeter. Another proposal would restrict the movement of large tourist vehicles throughout the Old Town to increase the network's traffic capacity during peak hours. To deal with extreme events, it is proposed to map, delineate, and mark all necessary transit routes for emergency services and create rescue-evacuation plans for every urban unit. In addition, the need for priority- and name-based discretionary protection of these corridors within the framework of the Urban Regulation is recognized. Combined, it is suggested that public transportation be promoted and improved so that it becomes the primary mode of access to the Old Town (fleet consolidation, increased frequency, etc.)

and that the infrastructure for cycling is improved.

Equally important is strengthening the city's electromechanical infrastructure, which has been identified as requiring improvement so that the Old Town can withstand extreme events. The principal proposals could include the construction of a desalination project as a supplementary source of water supply for Corfu, the use of heat pumps for cooling and heating homes, which the appropriate financial incentives should accompany due to their high cost, and the restoration of the dependability of external electricity distribution networks.

The "Spilia" area, the eastern coastal front, and, to a lesser extent, the Spianada area have been identified as particularly vulnerable in the event of a flood. It is recommended that the flood protection infrastructure be strengthened, emphasizing load transfer from these sections. Two of the proposals involve either the placement of collector drains and/or ditches, with the goal of controlled removal of a portion of the water flowing towards the aforementioned vulnerable areas, or the expansion of the drainage capacity of stormwater drains in low-lying, elevation zones where manhole overflows are observed.

Strengthening fire protection infrastructure is necessary to reduce the risk of fires. Although forest fire is not a significant threat to the city, it is recommended that additional fire hydrants be installed and that the existing equipment be upgraded with portable fire pumps, fire trucks, and special ladders.

The Old Town of Corfu's unique and valuable building stock necessitates a comprehensive program to protect and enhance its resilience against climate change (see changes in temperature, precipitation, and humidity). The situation is anticipated to worsen as the frequency of such occurrences increases. 1) cleaning of masonry and decorative elements; 2) restoration of masonry with compatible materials and protection of wooden and metal elements; 3) thermal insulation of buildings with natural products; 4) fixing and waterproofing of exposed stones and ceramics; 5) application of self-cleaning membranes. According to the type of wear, material, etc., a detailed list of recommended products or methods must be compiled for each direction.

Regarding the flora, it is recommended that the expansion of the invasive, alien flora species be recorded and systematically monitored, as it has the potential to alter significantly, within a few years, the physiognomy of the Old Town, the landscape, and thus the Old Town as a whole.

At the level of the institutional framework, it is believed that the following actions could make a decisive contribution to the Management Plan of the Old Town to preserve its unique identity despite the pressures it faces, i., the formulation of an integrated visitor management plan with indicators that will record trends in behavior, movements, needs, preferences, and carrying capacity; ii. the implementation of a monitoring and evaluation system for protecting the Old Town from the effects of climate change; iii. the introduction of a reward card for those visiting the Old Town by public transport, on foot, or by bicycle (e.g., a points system providing discounts on tickets to cultural sites, a network of tourism or other businesses, etc.).

Other proposals include the preparation of a fire prevention plan, which includes the maintenance and pruning of vegetation and the systematic cleaning of the underpass of all yards from vegetation and trash, the installation of an early warning system, which includes automatic weather stations and water level and water supply sensors, and the blocking of areas from motor vehicle traffic to facilitate unimpeded access for rescue vehicles.

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 actions and workshops focusing on issues such as discouraging the use of private cars and promoting soft modes of transportation, promoting alternative forms of tourism, and informing owners on methods and techniques for the proper maintenance and restoration of their buildings, encouraging voluntary actions such as "cleaning up the neighborhood", and most importantly, promoting participatory decision-making processes in the municipality.

To continuously monitor the implementation of these actions and the impacts and predict the risks associated with climate change, it is deemed necessary to develop a data observatory and evaluate the efficacy of the measures taken to manage them. Indicatively, the Observatory could collect data regarding the carrying capacity of the site, i.e., the regular determination of its resistance levels in distinct areas of interest (see infrastructure, environment, material and intangible cultural heritage, society), visitation (see traffic, preferences, length of stay, loads per monument), and the needs and issues of the locals. Also recommended is the collection of data per case of action taken to adapt the Old Town to climate change, as well as the recording of data such as implementation times, acceptance, and effectiveness. The aforementioned information is useful for preserving the cultural asset and the city's development planning regarding sustainability, viability, and climate change resilience.

7. Conclusion

This paper analyses the effects of climate change on the Old Town of Corfu and proposes several adaptation strategies. These measures will ensure that the Old Town can adapt to the effects of climate change and that its management will remain viable.

The Old Town of Corfu case study is a remarkable architectural example of universal significance in its authenticity and simplicity. Since it is both a modern city and a World Heritage Site, it is more vulnerable to various stresses, including climate change, than most other locations. Individually and in conjunction with the anticipated occurrence of extreme weather events, the requirements and prerequisites of the current way of life, the rapid development of tourism, mobility concerns, and the sensitivity and particularities of the cultural value itself are among the obstacles that must be managed. The above pressures are dynamic and evolving and require constant monitoring. The current management plan for the Old Town of Corfu dates back to 2005 and is considered a significant area for improvement in the effective management and protection of this UNESCO World Heritage Site. Therefore, the need for an immediate revision of the current management plan is underlined to ensure a balance between the objectives of protection and conservation of the cultural assets and the objectives of sustainable development and multi-crisis management.

Generally, for the historic cities of Greece with the same characteristics and sensitivities as the Old Town of Corfu, it is necessary to develop and regularly revise integrated Management Plans to maintain their distinct identities despite the pressures they face and manage the anticipated effects of climate change. This is required to address the consequences. Utilizing international protection principles and exchanging relevant experiences may facilitate formulating of more effective policies.

Throughout the entirety of this paper's preparation, three significant concerns have emerged.

The first cause for concern is the difficulty of collecting data on the current state and other potential pressures (visitors, traffic, etc.) affecting historic cities and cultural heritage more broadly in Greece. This is because the situation is challenging to evaluate. Therefore, formulating effective policies necessitates continuous monitoring and recording of the condition of cultural assets and the conservation and/or restoration interventions implemented on them in a database accessible to all administrative and scientific stakeholders.

The second concern is that it may be difficult to distinguish between the hazards of climate change and those of a particular cultural site. This is especially true in an evolving historic city with a substantial architectural heritage. Extreme weather events and changes are inextricably linked to the current condition of a site, including its level of conservation, urban layout, land uses, infrastructure, and management methods. Therefore, both issues must be researched and addressed simultaneously. They urge a multidisciplinary approach to their study.

The third issue of concern is the site's transition to a new management system, necessitating collaboration between numerous services and institutions. This issue relates to the necessity of developing an integrated and comprehensive management plan that, when implemented, will safeguard the cultural heritage site against all types of pressures and threats. Maintaining and repairing the historic building stock in addition to protecting cultural resources and their natural environments, ensuring the better and safer operation of infrastructure, traffic, transport, and electromechanical systems, and ensuring the better and safer operation of all of these systems must be accomplished simultaneously and with the assistance of the appropriate individuals.

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Conflicts of Interest

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

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