CLIMATE CHANGE IN MEDITERRANEAN WORLD HERITAGE CITIES

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S H O R T   S U M M A R Y

Climate change: a significant threat for Mediterranean World Heritage Cities

World Heritage Cities in the Mediterranean region are threatened by significant climate hazards, including extreme temperature fluctuations, heatwaves and flooding. More than half of the World Heritage Cities in the region will face at least two types of climate threats by the end of the twenty-first century, with multiple hazards expected to compound and amplify. Sea-level rise will impact all coastal World Heritage Cities in the region.

Against this backdrop, a unique study was conducted on 114 UNESCO World Heritage Cities in the Mediterranean region. Combining qualitative analysis of reports from cities and settlements and Earth observation data, the study provides both Earth system models and regional climate models to prepare for future climate risks.

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OF WORLD HERITAGE CITIES

already experience at least one climate hazards

It is also crucial to address the direct economic and non-economic losses to World Heritage Cities. To this end, a wide range of actions is required, from international policies to national and local strategies. Regular monitoring is key, as is the integration of cultural heritage into climate action plans and policies at all governmental levels. **Better planning allows cities to harness resilience, adaptation and mitigation offered by their cultural heritage.**

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"Since wars begin in the minds of men and women, it is in the minds of men and women that the defences of peace must be constructed."

CLIMATE CHANGE IN MEDITERRANEAN WORLD HERITAGE CITIES

FOREWORD

Climate change presents an unprecedented challenge and the most significant threat to the world's invaluable cultural and natural heritage. As one of the world's most vulnerable and exposed regions, the Mediterranean is increasingly threatened by the impacts of climate change. With its unique environment and rich, layered histories, the region is home to cultural and natural heritage of global significance, including nearly 300 cultural sites inscribed on the UNESCO World Heritage List. These sites, and the cities that house them, represent humanity's collective story, embodying the rich diversity of cultures and traditions shaped by millennia of interaction and exchange. This report highlights the profound challenges faced by Mediterranean World Heritage cities, iconic places that stand as testaments to human ingenuity, artistry and resilience.

Rising sea levels, extreme weather events and shifting climate patterns jeopardize cities' physical integrity, cultural identity and socio-economic stability. As the pace of climate change accelerates, irreplaceable cultural treasures face the risk of irreversible loss and damage, impacting local communities and humanity as a whole.

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UNESCO has been at the forefront of responding to the threats of climate change to cultural and natural heritage. From the UNESCO World Conference on Cultural Policies and Sustainable Development – MONDIACULT 2022, to contributing as Knowledge Partner for the Group of Twenty (G20) and the Group of Seven (G7), as well as Lead Knowledge Partner for the Group of Friends of Culture-Based Climate Action, established at COP 28, UNESCO has played a key role in integrating cultural heritage into global climate action. The recent adoption of the 'Pact for the Future' by the General Assembly of the United Nations further highlights culture's vital role in sustainable development and climate action.

UNESCO has led the development of high-level guidance for climate action for cultural and natural heritage with initiatives including the Policy Document on Climate Action for World Heritage adopted by the General Assembly of States Parties to the World Heritage Convention (196 States) in 2023, and the Guidance Note on Climate Action for living heritage, endorsed by the Intergovernmental Committee for the Safeguarding of the Intangible Cultural Heritage in 2024. Additionally, UNESCO reports such as World Heritage forests: Carbon sinks under pressure; UNESCO Marine World Heritage: Custodians of the globe's blue carbon assets; and World Heritage Glaciers: Sentinels of climate change, provide insights into the impact of climate change on diverse natural heritage.Most recently, UNESCO led the sections on cultural heritage for the recently released UNFCCC report on Non-Economic Losses: Featuring loss of territory and habitability, ecosystem services and biodiversity, and cultural heritage, outlining for the first time the significance of the loss of cultural heritage and actions to enhance resilience of the cultural heritage, as well as the communities who are impacted by such losses.

This report on Mediterranean World Heritage cities, a pathbreaking study of 114 World Heritage cities in the Mediterranean region, provides evidence of the impacts of climate change on urban heritage as well as the role of urban heritage in countering it. It underscores the immediate need for action while emphasizing the long-term importance of safeguarding urban heritage to ensure resilience in the face of climate change.

This report is an urgent call to action, reminding us that safeguarding our heritage goes beyond preserving the tangible remains of our past; it is also about ensuring their survival in the face of growing global challenges. It is a commitment to building a resilient and inclusive future that honours the richness of the world's cultural diversity.

As readers engage with this important report, I hope it inspires both reflection and action to protect these irreplaceable legacies in an era of catastrophic environmental change, ensuring that their value endures for generations to come.

Ernesto Ottone
Assistant Director General for Culture

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CONTENTS

LIST OF ABBREVIATIONS

CRIDA – Climate risk informed decision analysis

EGMS – European Ground Motion Service

ESL – Extreme sea level

ESM – Earth system models

EO – Earth observation

G7 – Group of Seven

G20 – Group of 20

GDP – Gross domestic product

GHG – Greenhouse gas

GNSS – Global navigation satellite system

GPR – Ground penetrating radar

HUL – Historic Urban Landscape

ICCROM – International Centre for the Study of the Preservation and Restoration of Cultural Property

ICH – Intangible Cultural Heritage

ICOMOS – International Council on Monuments and Sites

ICSM-CHC – International Co-Sponsored Meeting on Culture, Heritage and Climate Change

ICT – Information and communication technology

IPCC – Intergovernmental Panel on Climate Change

IUCN – International Union for Conservation of Nature

LISCOAST – Large Scale Integrated Sea-level and Coastal Assessment Tool

NbS – Nature-based solutions

NELS – Non-Economic losses

OUV – Outstanding Universal Value

RCM – Regional climate models

RCP – Representative concentration pathways

UAV – Unmanned aerial vehicle

UNESCO – United Nations Educational, Scientific and Cultural Organization

UNFCCC – United Nations Framework Convention on Climate Change

GLOSSARY

Adaptation is the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (IPCC, 2023*a*).

Climate hazards/threats are physical events or changes in the climate that may cause harm (IPCC, 2023*a*). They can be extreme or rapid onset events like floods, wildfires and storms, or slow onset events or gradual variations like sea-level rise, ocean acidification and desertification. In this paper, we use hazards to mean observed past events and threats to mean potential future events.

Climate forcing is the change in radiative flux due to a change in a driver of climate change, such as greenhouse gas concentrations or the output of the sun. In other words, it is what happens when the amount of energy that enters Earth's atmosphere is different from the amount of energy leaving the atmosphere (European Environment Agency, n.d.).

Climate impact is the actual consequence or effect that results from climate hazards and their associated risks (IPCC, 2023*a*).

Climate index is a synthesized measure derived from multiple climate variables and used to represent broader climatic patterns or trends.

Climate risks are the potential for adverse consequences for human and/or natural systems. They arise from interactions between climate threats and the vulnerability and exposure of human and/or natural systems (IPCC, 2023*a*).

Climate variable refers to individual measurable factors that describe the state of the climate, such as temperature, precipitation and humidity.

GIS stands for geographic information system, a technology used for capturing, storing, analysing and managing geographic (spatial) data.

Mitigation is any human intervention intended to reduce emissions or enhance the sinks of greenhouse gases (IPCC, 2023*a*).

Outstanding Universal Value means cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity.

Periodic reporting is a key conservation monitoring process under the World Heritage Convention, wherein States Parties submit reports to the World Heritage Committee every eight years or so, providing updates on the implementation of the Convention within their territories, at both national and site levels.

RCP4.5 is a moderate or 'intermediate' scenario that projects future greenhouse gas concentrations in which climate forcing is stabilized after the twenty-first century at 4.5 W/m^2 (EURO-CORDEX, n.d.).

RCP8.5 is the most pessimistic scenario characterized by continual emissions increase and rising climate forcing passing 8.5 W/m^2 at the end of the twenty-first century (EURO-CORDEX, n.d.).

State of conservation refers to the condition and preservation status of World Heritage properties, including the threats they have faced or are currently facing, as monitored and reported through the comprehensive statutory Reactive Monitoring process and related decisions by the World Heritage Committee. All data collected through this process is accessible through the UNESCO World Heritage Centre's State of conservation Information System.

EXECUTIVE SUMMARY

This timely report addresses important intersecting concerns around impacts of climate change on cultural heritage, the Mediterranean region as a global climate hotspot, and cities as significant sources of greenhouse gas emissions as well as of climate action, through a study of 114 historic cities and settlements (Appendix 1) in the Mediterranean region inscribed on the UNESCO World Heritage List. Considering an inclusive approach using diverse knowledge systems to better understand the threats and impacts of climate change, the study uses three different methodologies to analyse and identify threats and subregional variations within the Mediterranean region. The study includes a qualitative overview of observed and reported current climate change-related hazards across inscribed World Heritage Cities and settlements in the Mediterranean region during the Third Cycle of Periodic Reporting (2018–2024) to UNESCO World Heritage Centre; climate model projections of threats to World Heritage Cities based on Earth observation (EO) as well as an ensemble of Earth system models (ESMs) and Regional climate models (RCMs) for projecting future scenarios in the Mediterranean region by the end of the twenty-first century. Finally, spatial mapping is used to analyse geographical patterns in detail across the Mediterranean subregions.

The key findings regarding the current scenario are based on recent reporting by the World Heritage Cities in the Mediterranean region on their experienced climate hazards. Nearly two-thirds (59%) of World Heritage Cities in the Mediterranean region report already experiencing at least one climate hazard, while nearly one-fifth (18%) of the World Heritage Cities reporting facing three or more climate hazards. 32% of Mediterranean World Heritage Cities report experiencing extreme temperature fluctuations, nearly a third (28%) report experiencing flooding, and a quarter report experiencing storms (25%) and drought (24%). Coastal areas face equal risks from flooding and storms (27%), while temperature changes (37%) and drought (32%) are the most significant hazard for inland cities. World Heritage Cities in the north-western and western subregions of the Mediterranean report the highest number of climate hazards with nearly three-quarters of the World Heritage Cities experiencing at least one such hazard. Flooding is the most frequently reported climate hazard across the north-western, north-central and southern subregions, with 63% in the north-central subregion and 50% reporting floods in the north-western subregion. Meanwhile, the western and central subregions primarily report temperature changes, while the eastern subregion experiences a mix of storms and temperature changes.

The key findings regarding the future scenario for World Heritage Cities in the Mediterranean region by the end of the twenty-first century under the pessimistic projection (RCP8.5) are based on Earth observation and an ensemble of Earth system models. It is projected that more than half (51%) of the World Heritage Cities in the region will face at least two climate threats and their potential impacts by the end of this century. World Heritage Cities in the north-western, north-central, western and eastern subregions will be the most vulnerable ones to the impacts of extreme weather events. A west-to-east pattern towards the eastern Mediterranean indicates the increasing number of threats going eastward that compound and amplify the potential impacts of any one threat. North-western, central and north-central subregions are projected to be heavily impacted by flooding while the western, southern and eastern parts of the region are projected to have reduced precipitation leading to drought-like conditions. Extreme heat conditions are most significantly projected for the eastern subregion of the Mediterranean. All World Heritage Cities in the north-west and north-central subregions of the Mediterranean region will face at least two threats with the majority in the north-central subregion facing three threats. 63% of World Heritage Cities in the western subregion of the Mediterranean region will face at least two threats. Most World Heritage Cities in the central (73%) and southern (63%) subregions of the Mediterranean are projected to face at least one threat. Furthermore, sea-level rise is estimated to be in the range of 0.5 m to 0.67 m, posing an additional threat to all coastal World Heritage Cities in the region.

The predicted future scenario highlights what is already being experienced at many World Heritage Cities, with the predictions showing it will only get worse. Currently, a majority of World Heritage Cities report experiencing one hazard; however, the prediction for the future is that a majority of the World Heritage Cities in the region will face two or more hazards. The geographical distribution of future threats and their potential impacts are predicted to remain almost identical to those being currently observed, where flooding in the north-western and north-central subregions are and will remain the main threat in the future, while the western and central subregions will continue to be threatened mainly from drought and extreme heat.

Based on recent experiences in several regions, we can conclude that along with the increased number of threats these cities will face, their intensity and the scale of their impacts will also increase, greatly escalating the likelihood of significant loss and damage to valuable heritage. The projected severity of the flooding events will increase over time for the majority of the World Heritage Cities, followed by increasingly severe drought conditions and extreme heat events. Experiencing multiple hazards on top of one another results in compounded and amplified impacts. Furthermore, the loss and damage to biodiversity, ecosystem services and territory in addition to those to cultural heritage in World Heritage Cities results in cascading effects that further amplify the negative impacts (see UNFCCC, 2024*a*) as well as the vulnerability of the World Heritage Cities and their valuable cultural heritage.

The negative impact of the climate hazards on World Heritage Cities may range from direct economic losses due to loss of valuable structures, property and goods, historic fabric, infrastructure, related loss of livelihoods for the local communities, and tourism revenues to the non-economic losses (NELS) of climate change with regard to cultural heritage, including potential loss and damage to the OUV of properties inscribed on the World Heritage List. These losses also encompass the erosion of cultural knowledge – particularly on natural ecosystems – reducing the ability to adapt to environmental changes. As local resources and knowledge are lost, communities face challenges in meeting their socio-economic development needs. Anticipated shortages in water and food will disrupt traditional ways of life, and further compromise the ability of communities to protect and manage their heritage, both tangible and intangible (UNFCCC, 2024*a*). While the loss of cultural heritage has immediate impacts on local communities, it also affects humanity as a whole, particularly when the heritage is part of the OUV.

Moreover, the loss of cultural heritage in World Heritage Cities from climate hazards will likely result in different types of losses of cultural heritage, such as diminished cultural diversity, the loss of important archaeological sites and historical evidence for future generations, traditional knowledge systems, sources of inspiration and creativity, and diminished cultural rights and right of access to culture, alongside a broader loss of cultural identity and diminished resilience of communities (ICOMOS, 2019; UNFCCC, 2024*a*).

The loss of cultural heritage also contributes to loss of cultural diversity that impairs inclusive sustainable development. As cultural heritage has many different and overlapping values, a single loss of such tangible heritage may result in multiple interconnected losses of cultural heritage that together lead to a much more significant loss than is apparent by only the loss of a single structure or monument. Cultural or symbolic values derived from heritage's historical and social significance can also be lost. Cultural skills, craftsmanship, and traditional knowledge related to construction techniques can be lost or forgotten if a tangible heritage site is lost or abandoned through climate-driven population displacement, cultural erosion, decreasing access to traditional materials, and changing local climatic needs.

While vulnerable to impacts of climate change, World Heritage Cities are also valuable assets for mitigation and adaptation strategies, offering opportunities through the reuse of existing buildings, including heritage structures, and adaptation of traditional building techniques and planning solutions to optimize climate conditions. These cities, with their walkable neighborhoods, compact designs, and green spaces, depending on historical context, typically have lower energy consumption and greenhouse gas emissions compared to new developments. Historic cities are immense repositories of traditional knowledge, accumulated over centuries, which can inspire environmentally regenerative and low-energy construction, retrofitting without maladaptation, and the conservation and reuse of existing buildings, especially in developed areas.

Earth observation technologies can be further used to improve planning and gathering knowledge. They enable continuous monitoring of cities, which helps in assessing environmental and climate conditions and aids in detecting potential changes and threats. In this way, EO can help in developing effective mitigation and adaptation strategies and enhancing the level of preparedness.

Responding to the risks and impacts of climate change on World Heritage Cities requires a wide range of actions, from international policies to national and local strategies. International agreements must urgently recognize the vulnerability of cultural heritage to climate change and emphasize its role as a resource for climate resilience and adaptation, especially in World Heritage Cities integrating cultural heritage into Climate Action Plans (CAP) and policies at all governmental levels. The UNESCO 1972 Convention for the Protection of the World's Cultural and Natural Heritage (World Heritage Convention) (UNESCO, 1972), and the UNESCO HUL Recommendation (UNESCO, 2011), provide a strong foundation for protecting urban heritage in historic cities and settlements, both those inscribed on the World Heritage List as well as those that are not. The UNESCO 2023 Policy Document on Climate Action for World Heritage offers a guiding framework (UNESCO, 2023*b*) to assist State Parties with the implementation of comprehensive climate action, including mitigation and adaptation measures, resilience building, innovation and research.

Going forward, the actual direct and indirect impacts on each World Heritage City need to be carefully monitored and assessed regularly. Other recommended actions include advancing climate change mitigation and adaptation actions in line with the World Heritage Convention; integrating cultural heritage protection into national and local adaptation plans and policies; leading and catalysing transformative change with World Heritage towards making World Heritage properties carbon neutral, more resilient, and better adapted to a changing climate; building capacities and raising awareness among all stakeholders; reducing the risk of climate-related extreme events and disasters, including slow-onset events, and enhancing climate resilience of cultural resources as well as of local communities.

The World Heritage Cities in this study represent only a fraction of the broader challenges likely faced by numerous other cities and settlements in the region. While this study focuses on the Mediterranean region, the lessons for actions to respond to the losses due to the climate impacts in this region could be extended to World Heritage Cities as well as other historic cities and settlements in other regions.

1 THE CONTEXT OF THE WORLD HERITAGE CITIES IN THE MEDITERRANEAN REGION

The Mediterranean region[1] is a distinctive geographical area that encompasses countries from European, Asian and African continents surrounding the Mediterranean Basin, with a unique environmental, climatic and historical identity, rich in cultural and natural heritage of global significance. With its dense population, the region holds significant geographical and geopolitical influence. The Mediterranean region is home to around 300 cultural sites inscribed on the UNESCO World Heritage List for their Outstanding Universal Value (OUV), with historic cities and settlements accounting for almost half of them.[2]

The IPCC's Sixth Assessment Report (Ali et al., 2022) identified the Mediterranean region as predominantly vulnerable to climate change-related impacts of warming, notably prolonged and stronger heat waves, increased drought in an already dry climate and risk of coastal flooding, with southern and eastern countries being generally more vulnerable than countries in the north. The record-breaking temperatures of recent years are evidence of this, with 2023 being the hottest year globally and June 2024 being the 13th consecutive month with record high temperatures (Copernicus, 2024). The Mediterranean is considered a prominent 'climate change hotspot' due to high regional vulnerability and exposure, impacting natural systems and socio-economic sectors (Zittis et al., 2022). The Mediterranean region's annual mean temperatures on land and sea are already 1.5°C higher than during pre-industrial times (Ali et al., 2022). According to the First Mediterranean Assessment Report, the average regional warming in the twenty-first century will exceed the global mean value by 20% annually and 50% during the summer (MedECC, 2020*a*).

The ongoing Seventh IPCC Assessment Report, AR7, includes a Special Report on Climate Change and Cities. The agreed outline identifies cities 'as hotspots of effects of hazards and emissions, losses and damages, vulnerabilities, exposure and impacts, while also being key climate actors' (IPCC, 2024, p.3). Cities interact with climate change in three ways:

1. Cities are increasingly vulnerable to climate hazards, which are further compounded by rapid urbanization and a lack of climate sensitive planning (Dodman et al., 2022), both of which are present in the Mediterranean, where the urban population has increased from 152 million to 315 million between 1970 and 2010 alone (UNEP/MAP, 2012; García-Nieto et al., 2018). In 2018, the population of the countries bordering the Mediterranean Sea was approximately 512 million, accounting for 6.7% of the global population (UNEP/MAP and Plan Bleu, 2020). Unplanned rapid urbanization is a major driver of risk, especially in situations where cities expanding into land prone to coastal flooding, or into areas with inadequate water supply for the growing population (Dodman et al., 2022).

2. Cities are responsible for an estimated 70% of global carbon dioxide (CO2) emissions, thus, they have a crucial role to play in reducing emissions and implementing mitigation actions (Dodman et al., 2022).

3. Cities have a central role to play in solutions to enhance climate resilience and adaptation. Cities can be transformed to be climate-resilient both by innovative technologies and infrastructure as well as those rooted in heritage and local and traditional knowledges. Governance capacity, financial support and the legacy of past urban infrastructure influence how cities and settlements are able to adapt (Dodman et al., 2022). Cultural heritage in cities is, on the one hand, more vulnerable to loss and damage and on the other, contributes significantly to solutions. As socially constructed entities, cities are arguably one of humanities greatest inventions for crafting solutions for the future (Morel et al., 2022).

[1] For the purposes of this study, the 'Mediterranean region' or the 'Mediterranean' includes countries surrounding the Mediterranean Basin and Portugal. While Portugal's coast is not directly located in the Mediterranean Basin, this country is traditionally included in other studies regarding the region, including IPCC studies.

[2] The criteria for World Heritage Cities used for the purposes of this study are those used for the Thematic Programme of the World Heritage Cities Programme of the UNESCO World Heritage Centre.

In the context of heritage protection, the 1972 UNESCO Convention on the Protection of the World's Cultural and Natural Heritage (World Heritage Convention) (UNESCO, 1972) is one of the most widely recognized cultural heritage instruments globally, ratified by 196 States Parties. Governed by the intergovernmental World Heritage Committee and the General Assembly of States Parties, it establishes a framework for international cooperation in safeguarding natural and cultural heritage properties with OUV, whose importance transcends all national and geographical boundaries.

According to UNESCO, cultural heritage broadly includes our legacy from the past, what we live with today and what we pass on to future generations. Cultural heritage includes artefacts, monuments, groups of buildings and sites and museums, all of which hold a diversity of values, including symbolic, historic, artistic, aesthetic, ethnological or anthropological, scientific and social significance. It includes tangible heritage (movable, immovable and underwater) and Intangible Cultural Heritage (ICH) embedded into cultural and natural heritage artefacts, sites or monuments (UNESCO 1972, 1978, 2001, 2003, 2023*a*).[3]

Urban heritage from the perspective of the UNESCO 2011 Recommendation on the Historic Urban Landscape (UNESCO, 2011) (HUL Recommendation) includes urban areas formed as a result of the interrelationships between the built, the natural and the local communities that inhabit a historic layering of cultural and natural values and attributes which includes the area's geographical and natural features, its built environment (both historic and contemporary), its infrastructures above and below ground, its open spaces and gardens, its land-use patterns and spatial organization, perceptions and visual relationships, as well as all other elements of the urban structure. It also includes social and cultural practices and values, economic processes and the intangible dimensions of heritage as related to diversity and identity (UNESCO, 2011).

States Parties reporting to UNESCO indicate that more than half of the World Heritage Cities across the Mediterranean region report experiencing impacts related to climate change.[4] The most recent IPCC report (IPCC, 2023b) and other existing studies (García-Nieto et al., 2018; Reimann et al., 2018; UNEP/MAP and Plan Bleu, 2020; Ferreira et al., 2022; Kapsomenakis et al., 2023; MedECC, forthcoming) identify physical damage to heritage assets, potential loss of key attributes expressing the OUV of such assets and decreased ability to address socio-economic development needs of local communities.

This study focuses on historic cities and settlements inscribed on the UNESCO World Heritage List, included in the UNESCO World Heritage Cities Programme, a thematic programme of the World Heritage Convention for which UNESCO is the secretariat. The international recognition of World Heritage Cities enables them to serve as valuable case studies of the impacts of climate change and also to explore good practices for mitigation and adaptation strategies integrated with the conservation of urban heritage. Furthermore, understanding the effects of climate change on these iconic, well-recognized and cherished historic cities and settlements can raise public awareness about the broader impacts of climate change on cultural heritage and the importance of protecting cultural heritage for current and future generations, and for its active role and contribution to climate action.

The international community has recognized the challenges regarding climate change's impacts on cities and their cultural assets (including their natural heritage values) and in response, several policy frameworks have

[3] The UNESCO World Heritage Convention (UNESCO, 1972) also includes natural heritage, mixed heritage and cultural landscapes. Tangible immovable heritage includes archaeological sites and individual monuments, historic cities, vernacular settlements, cultural landscapes. Intangible cultural heritage (UNESCO, 2003) includes traditions or living expressions inherited from our ancestors and passed on to our descendants, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe, or the knowledge and skills to produce traditional crafts.

[4] Based on data interpretation from the Third Cycle of Periodic Reporting exercise conducted by UNESCO for the period 2018–2024. World Heritage Cities are those properties inscribed on the UNESCO World Heritage List that are included in the World Heritage Cities Programme of the UNESCO World Heritage Centre.

been developed. The UNESCO Policy Document on Climate Action for World Heritage ('Policy Document') was adopted in 2023 by the 195 States Parties to the 1972 World Heritage Convention (UNESCO, 2023*b*) gathered in General Assembly. In 2022, The Declaration of the UNESCO World Conference on Cultural Policies and Sustainable Development – MONDIACULT 2022, reaffirmed culture as a 'global public good' and stressed the importance of integrating cultural heritage and creativity into international discussions on climate change (UNESCO, 2022*a*). At the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in 2016, the New Urban Agenda was adopted and serves to guide sustainable urban development and emphasize the need to build resilience and adapt to the risks of climate change in cities (UN, 2017). Adopted by UN Member States in 2015, the Sendai Framework for Disaster Risk Reduction 2015–2030 focuses on reducing disaster risk, including the risks posed by climate change, while emphasizing the importance of protecting cultural heritage (UNDRR, 2015). The 2030 Agenda, particularly through Sustainable Development Goal 11, aims to make cities and human settlements inclusive, safe, resilient and sustainable, with Goal 11.4 specifically focusing on strengthening efforts to protect and safeguard the world's cultural and natural heritage (UN, 2015). The HUL Recommendation adopted by 194 Member States (UNESCO, 2011), also emphasizes integrating the conservation of urban heritage with climate action. As part of this, climate change-related questions were included in the Third Member State Consultation on the Implementation of the HUL. It is significant also to note that an IPCC Special Report on Climate Change and Cities (IPCC, n.d.) is under preparation. This report is based on proposals made during the 43rd Session in 2016, to which an IPCC co-sponsored meeting contributed and its outline was approved during the 61st Session in July 2024.

1.1 METHODOLOGY AND APPROACH

This study focuses on 114 historic cities and settlements (Appendix 1)[5] in the Mediterranean region inscribed on the UNESCO World Heritage List, 41 of which are coastal. These cities represent the region's diverse climatic conditions and environments, which expose them to varying threats and risks to heritage protection. The study combines three different approaches to analyse climate impacts and identify key patterns and subregional variations across the World Heritage Cities in the Mediterranean:

1. A qualitative overview of observed and reported current climate change-related hazards reported across inscribed World Heritage Cities and settlements in the Mediterranean region.

2. The use of climate model projections of both short- and long-term threats to the historic cities, which is based on historic data collection and Earth observation (EO).

3. Spatial mapping by the authors to analyse patterns in detail across subregions within the Mediterranean region.

The World Heritage Cities in the Mediterranean are considered in the following six subregions based on their common climate characteristics and expected climate pressures (Appendix 3) in each subregion of the Mediterranean region:

[5] Some properties are archaeological sites embedded within the context of cities.

1. **North-western:** including northern and central-eastern parts of France;
2. **North-central:** Albania, Bosnia and Herzegovina, Croatia, Montenegro and Slovenia;
3. **Western:** Southern and south-western parts of France, Portugal[6] and Spain;
4. **Central:** Holy See, Italy, Malta, San Marino and one site in Tunisia;
5. **Southern:** Algeria, Egypt, Libya, Morocco and Tunisia;
6. **Eastern:** Cyprus, Greece, Israel, Lebanon, the State of Palestine, Syrian Arab Republic and Türkiye.[7]

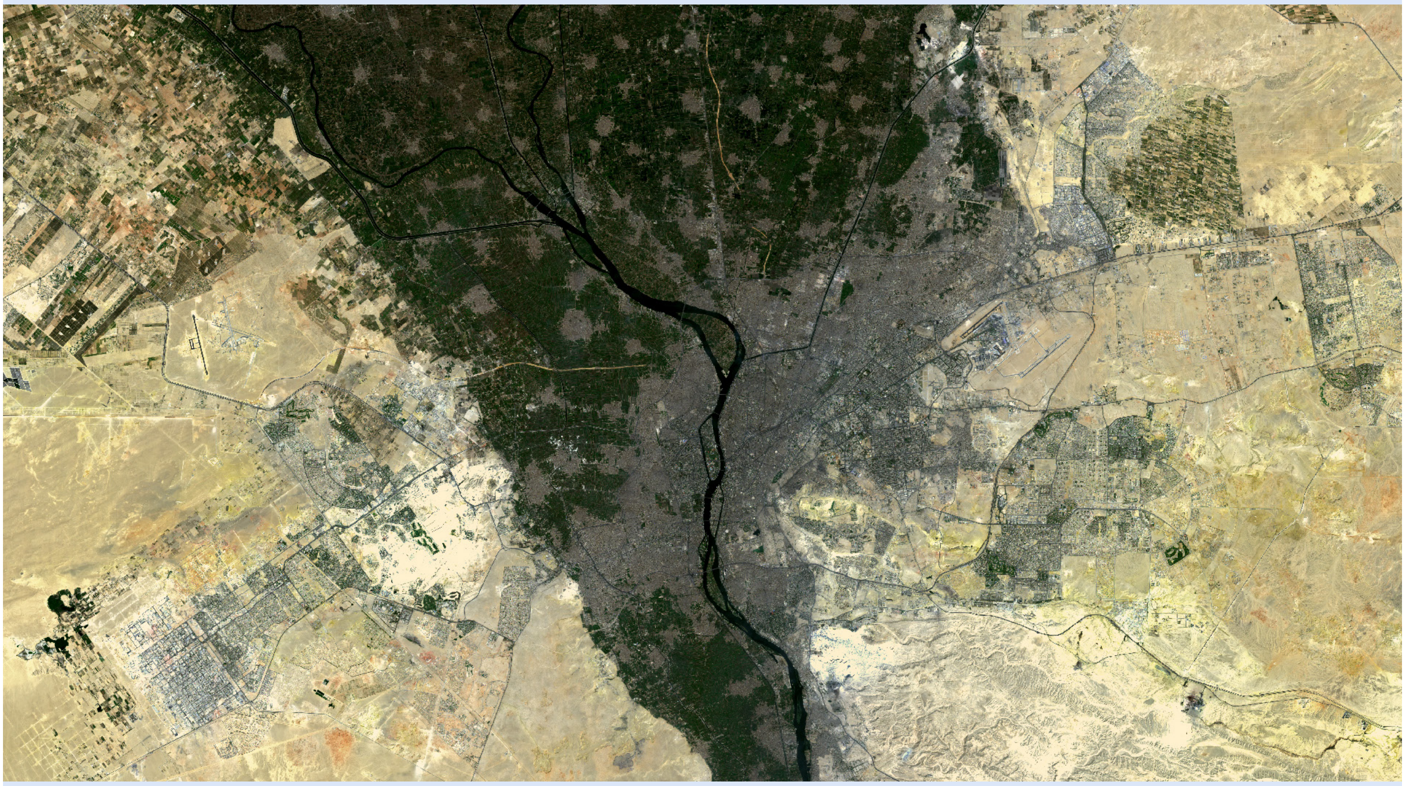
The study also demonstrates the various ways that EO can be applied to map and monitor the impacts of climate change on World Heritage Cities to inform decisions both to protect the cultural heritage assets and local communities, and to support mitigation and adaptation actions to increase the resilience both of the cultural heritage assets and local communities.

The 2023 Policy Document provides the overall framework for the analysis. The categories of threats considered are those identified through the UNESCO World Heritage Reactive Monitoring process (e.g. reporting on the state of conservation of inscribed sites) and the Third Cycle of Periodic Reporting Exercise. The qualitative analysis of observed and reported current climate change-related hazards are based on information regarding threats/events provided by national and local authorities to UNESCO World Heritage Centre in the Third Cycle of Periodic Reporting exercise (2018–2024). Qualitative reviews of local strategies and solutions towards mitigation and adaptation to the impacts of climate change are also based on reports of local efforts at World Heritage Cities. The modelling of future climate change conditions under moderate and pessimistic greenhouse gas (GHG) emissions scenarios is used to identify environmental changes to the historic city or settlement, such as in temperature, humidity and other climate variables important for cultural heritage preservation and to track and map their potential impacts (Box 1). Finally, spatial mapping and GIS analysis offers detailed and geographically disaggregated insights into climate trends and impacts.

The following subsection focuses on the current climate change trends in the Mediterranean, with examples of climate impacts in and around World Heritage Cities based on qualitative analysis of the reporting from States Parties, supported by case studies and examples of climate change impacts across the region. Section 2 examines current climate hazards on World Heritage Cities in the Mediterranean, drawing on the Third Cycle of Periodic Reporting (2018–2024) by the States Parties. Section 3 explores future scenarios of climate impacts on World Heritage Cities in the Mediterranean, based on climate models. Section 4 discusses the significance of the loss of cultural heritage, including insights from the state of conservation reports by the States Parties, the Consolidated Results of the Implementation of the 2011 Recommendation on the Historic Urban Landscape (UNESCO, 2023*c*), and a review of literature on managing historic cities for resilience and sustainable development. Section 5 outlines actions to prevent or reduce the loss and damage to cultural heritage, including policies and international agreements, as well as mitigation and adaptation strategies and best practice examples. The final section reflects on future steps to address these challenges.

[6] While Portugal is not directly positioned by the coast of the Mediterranean Sea, it is included in studies on the climate change impacts in the Mediterranean region, including the reports by IPCC (Intergovernmental Panel on Climate Change).
[7] The designations employed and the presentation of material do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

BOX 1 | APPLYING EARTH OBSERVATION (EO) TO SAFEGUARD CULTURAL HERITAGE



This image from the Copernicus Programme shows Cairo, Egypt in 2015, with its imposing urban sprawl on both banks of the river Nile. The pyramids and the necropolis of Giza have been effectively incorporated into the city. © Copernicus Sentinel data (2015)/ESA.

Earth observation (EO) is widely used to monitor changes in the urban environment and is highly effective for developing tailored mitigation and adaptation strategies to protect cultural heritage from climate change hazards and impacts (Xiao et al., 2020). EO can be applied to detect or monitor urban emissions, urban sprawl, land use and change, air pollution, subsidence near cultural heritage sites and other impacts from climate change or urbanization. This makes EO a valuable tool for risk assessment and the design of preventive measures for safeguarding cultural heritage. Recently, EO has been used for risk assessment caused by climate-induced extreme hazards on cultural and natural heritage sites (drought, flood, heavy rain) in combination with regional climate modelling (Bonazza and Sardella, 2023; Canesi et al., 2024). Moreover, EO has been successfully applied in archaeological practices, such as the systematic detection of cultural heritage sites, managing disaster risks related to geohazards, as well as the investigation of environmental factors (i.e. land use/land cover changes, deterioration of materials and structures) (Cerra et al., 2016; Agapiou et al., 2020; Prodromou et al., 2023; Themistocleous, 2023; Masini et al., 2023).

Techniques such as ground penetrating radars (GPR), global navigation satellite systems (GNSS), unmanned aerial vehicles (UAV), combined with artificial intelligence, machine and deep learning, enhance monitoring capabilities for both cultural and natural heritage. The integration and use of these technologies are critical for producing high-quality products for heritage preservation (European Space Agency, n.d.).

EO-derived information can bridge the gap between climate change and cultural heritage communities and provide a framework for creating collaborative, multidisciplinary, inclusive and multigovernmental strategies to address climate change impacts on urban cultural heritage (Bonazza et al., 2022).

1.2 REVIEW OF EXISTING STUDIES ON CLIMATE CHANGE IN THE MEDITERRANEAN AND ITS IMPACTS ON CULTURAL HERITAGE

Over a third of the World Heritage Cities in the Mediterranean are in coastal areas. At the same time, a third of the Mediterranean population (about 150 million people) currently lives close to the sea (MedECC, 2020*b*; Plan Bleu, 2018) and is exposed to climate-related impacts such as sea-level rise through flooding, coastal erosion, altering of extreme waves and storm surges frequency (Toimil et al., 2023), as well as saltwater intrusion into coastal aquifers (Cazenave and Cozannet, 2014). A 2018 study (Reimann et al., 2018) highlighted that, of 49 cultural World Heritage properties in low-lying coastal areas of the Mediterranean, 37 were at risk from a 100-year flood already in 2018, highlighting the importance for devising suitable local strategies for adaptation for each World Heritage property. The IPCC report projects further sea-level rise in the Mediterranean over the coming decades and centuries (Ali et al., 2022). By the year 2100, 47 of the 49 UNESCO sites are projected to be at risk from coastal flooding or erosion (Reimann et al., 2018). Over time, impacts from sea-level rise are projected to lead to permanent flooding, shoreline retreat and erosion of sandy beaches, impacting the recreation and tourism industry (Ali et al., 2022). The small tidal range and steep topography in the coastal areas of the Mediterranean influenced ancient and current settlements to be located directly at the waterfront and hardly above sea level (Reimann et al., 2018). Venice and its Lagoon, a World Heritage City, serves as a particularly illustrative example (Box 2) of potential future scenarios across other low-lying areas in the Mediterranean region.

The historic centre of Marrakesh, Morocco, features intricate water supply systems, public fountains and gardens like the Menara and Agdal gardens, showcasing the importance of water management in Islamic urban design and landscaping. © marcin jucha/Shutterstock.com*

The Moorish complex of Alhambra, Generalife and Albayzín in Granada, Spain, includes the Generalife Gardens with intricate water features like fountains, ponds and water channels. The gardens exemplify the sophisticated hydraulic systems and water management of the Moorish civilization. © Paradise at risk/Shutterstock.com*

Wildfires in and around historic cities also have a significant impact. Several countries in the region, including Albania, Croatia, Greece, Italy, Portugal, Spain and Türkiye, have been affected by disastrous wildfires in recent years. The threat to cultural heritage sites is particularly important in southern European countries, where most cultural heritage and archaeological sites are covered with vegetation or situated close to forests and other flammable vegetation and are therefore exposed to high wildfire hazards (Mallinis et al., 2016). In Córdoba (Spain) for instance, fire suppression costs have increased by 66–87% in the last decade (Molina et al., 2019). While wildfires directly threaten historic districts and their cultural assets with destruction, they pose an equal risk to people via population displacement in and around World Heritage Cities and the destruction of surrounding ecosystems that support traditional occupations and related cultural practices, resulting in a cascading effect of cultural losses. Post-fire effects, such as rains increasing sedimentation and debris flows, pose further risks to cultural heritage sites, as was observed in the aftermath of the 2021 Navalacruz wildfire in central Spain, which affected up to 60 cultural heritage sites, with damage extending to the burial of entire archaeological sites (Ortega-Becerril et al., 2024).

A burnt forest after a wildfire near Olympia on the Peloponnese peninsula, Greece. © Matyas Rehak/Shutterstock.com*

BOX 2 | CLIMATE CHANGE IMPACTS ON WORLD HERITAGE CITIES

Venice and its Lagoon, Italy
Inscribed on 1987 on the World Heritage List.

Venice is dramatically impacted by climate change and has been sinking at a rate of about 10 cm per century due to natural subsidence – the rise of water level caused by delta propagation and the compactness of sediments. However, it sank an additional 10 cm in the twentieth century because of neighbouring industries' pumping of groundwater from deep aquifers. By the time this process concluded in the 1970s, the damage was irreversible. The combination of such human actions, historical and morphological changes in the lagoon and global sea-level changes has resulted in a net rise in the sea level in Venice (Carbognin et al., 2009). The city is at risk of sinking due to the combined actions of sea-level rise and local land subsidence (Camuffo, 2021; Lionello, Nicholls et al., 2021).

The frequency of flooding and damage to the city has increased significantly in recent decades: besides the 1966 tide with a height of 194 cm, two of the highest tides of the past century have occurred in the past five years (Lionello, Barriopedro et al., 2021; UNESCO, 2022*b*). In November 2019, the city was hit by an exceptionally high tide, reaching the level of 1.87 m, the second highest in history after 1966, causing enormous damage to the city, the smaller islands, the coasts, several municipalities and their residents and economic activities. Public buildings, the Basilica of San Marco and all the historical and artistic heritage, museums, schools, houses, shops and crafts were devastated by high water and the force of the wind.[8] In November 2022, a tide with a peak height of 2.09 m, the highest level ever recorded, occurred. The closure of the MOSE (Modulo Sperimentale Elettromeccanico) mobile tide barriers prevented catastrophic flooding of the city, but the increasing frequency and magnitude of high tides necessitates further adaptation (UNESCO, 2022*b*).

To cope with these and other threats, the city of Venice is implementing various adaptation measures, besides the MOSE mobile tide barriers. These include raising embankments, securing specific sites like the Basilica of San Marco, developing a Civil Protection Plan for heat waves and a Tide Forecasting Centre to alarm the population and a Water Plan for the mainland.

Streets in Venice, Italy, flooded in November, 2019. © Mclein/Shutterstock.com*

[8] Information gathered from analysis of the Online Survey of the Third Member States Consultation on the 2011 Recommendation on the Historic Urban Landscape.

2 CURRENT REPORTING OF CLIMATE HAZARDS ON MEDITERRANEAN WORLD HERITAGE CITIES

2.1 METHODOLOGY OF THE ANALYSIS

During the Third Cycle of Periodic Reporting (2018–2024), States Parties reported to the UNESCO World Heritage Centre on matters relevant to the state of conservation of their World Heritage properties, including factors that threatened to impact the OUV of the property. The 114 World Heritage Cities in the Mediterranean region in this study (Appendix 1) reported experiencing several climate change-related hazards that put their invaluable heritage at risk. These include storms, flooding, drought, desertification, changes to oceanic water and temperature changes.[9] The States Parties reported on factors related to 'Climate Change and severe weather events' that had impacted the properties during the period of reporting.

2.1.1 LIMITATIONS OF THIS ANALYSIS

For this study, the climate hazards considered are based on the analysis of the results of the Third Cycle of Periodic Reporting (2018–2024). The Periodic Reporting Exercise was based on responses to a questionnaire sent by UNESCO. Although the UNESCO World Heritage Centre, together with the Advisory Bodies and the UNESCO Category 2 Centres, provides a significant amount of capacity-building and support to the national and local authorities to complete the questionnaire, the responses provided are 'self-reporting' and not verified by experts. The responses to the questions regarding climate change were multiple choice, where the choices presented were limited to and aligned with those in the World Heritage Reactive Monitoring Process. Hence, the study assumes that threats or events would not be selected in the multiple choice unless a World Heritage City had in fact experienced them. The questionnaire for the Third Cycle of Periodic Reporting offered a choice of a limited number of climate-related hazards for the respondents to select with reference to 'Climate change and severe weather events'. Those are therefore the only hazards analysed in this study.[10] Two other groups of factors in the questionnaire, with some factors related to climate issues or natural hazards, not included in this paper are 'Local conditions affecting the physical fabric' and 'Sudden ecological and or geological events'.[11] For example, wildfires and erosion, though also climate-related hazards, have not been considered in the analysis,[12] since their relation to climate change could be open to interpretation. The focus of this study was on factors that were clearly reported as stemming from climate change and had a correlation with the factors examined in the climate modelling. The study also assumes that the respondents would have only reported actual climate-related hazards, events which occurred and resulted in significant exposure to the World Heritage City if these hazards were reported in the Third Cycle of Periodic Reporting. Thus, this study is premised on this expected level of understanding and consistency among States Parties in their reporting on climate change-related hazards. As the responses are based on observed events and their possible impacts, it would be expected that national and local authorities would be more likely to report regarding rapid-onset events rather than the slow-onset ones. Moreover, the area of the World Heritage property may only be a small part of the whole city or settlement and hence may not capture the experience of the whole city or settlement. The study discusses climate change-related hazards as having exposure and possible impacts across the World Heritage Cities as a whole and does not assess the intensity or frequency of climate hazards, nor the specific impacts on the OUV of each World Heritage property, or the extent of loss or damage to them. Such assessments would have to be systematically carried out and data gathered for each of the properties before they could be analysed.

[9] The climate-related impacts being experienced by World Heritage Cities is based on the list of factors affecting the OUV of World Heritage properties that was established within the framework of the revision of the questionnaire of the UNESCO Periodic Reporting exercise in 2008 following a two-year consultation process with experts in both fields of natural and cultural heritage and approved by the World Heritage Committee. Climate change is identified as a one of 14 primary factors affecting the state of conservation of World Heritage properties and includes seven secondary factors which this study refers to. See https://whc.unesco.org/en/factors/ for further details.

[10] The responses from the subcategory of 'Other climate change impacts' in the questionnaire has been omitted from this study, due to a low number of responses and lack of a clear and consistent understanding of climate-related impacts among the respondents.

[11] These two categories were not included as the respondents had not responded consistently in the context of climate change.

[12] As the data is based on States Parties' reporting of climate hazards, it cannot be assured that the reporting encompasses all the experienced climate hazards, or that the hazards experienced are directly correlated to climate change. The reporting exercise focuses on identifying and reporting single climate hazards, yet as climate hazards often overlap, it might be prudent to adopt a multi-hazard approach in the future.

Further studies in each city are needed to assess the intensity of these events, the level of exposure (the city's area exposed to the climate change event), the effectiveness of existing infrastructure and the effectiveness of the mitigation and adaptation strategies in reducing vulnerability, and the actual and potential damage to World Heritage Cities.

2.2 ANALYSIS AND MAPPING OF RESULTS

Spatial analysis and mapping shows that the number of reported hazards varies across these World Heritage Cities, from cities reporting no climate change-related impacts to cities reporting impacts from three or more climate hazards (Figure 1).

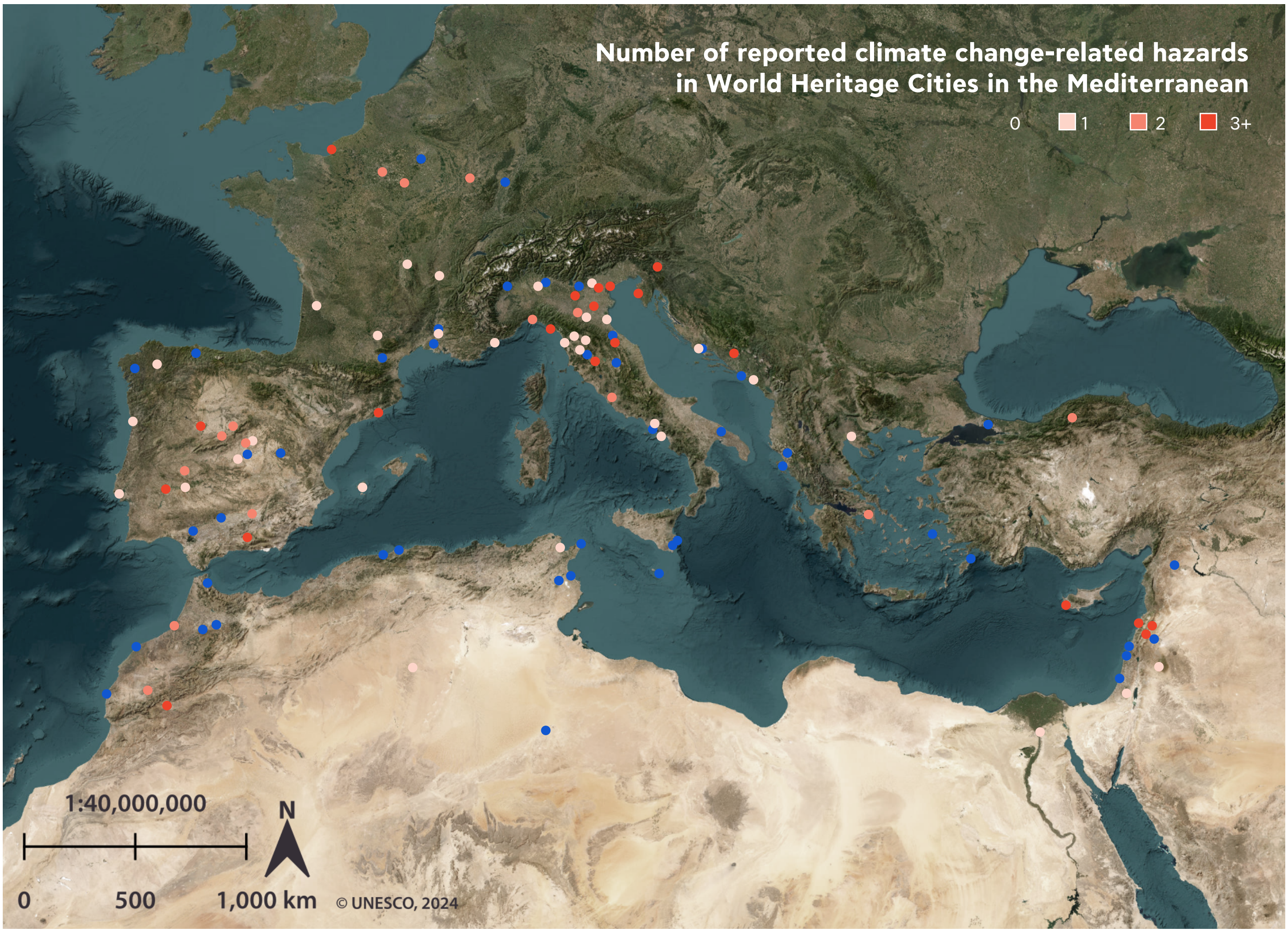


Figure 1. Number of reported climate change-related hazards in World Heritage Cities in the Mediterranean region. Image generated based on interpretation of the Third Cycle of the Periodic Reporting exercise 2018–2024.

NEARLY TWO-THIRDS (59%) OF WORLD HERITAGE CITIES IN THE MEDITERRANEAN REGION HAVE ALREADY BEEN EXPERIENCING CLIMATE CHANGE-RELATED HAZARDS (FIGURE 2).

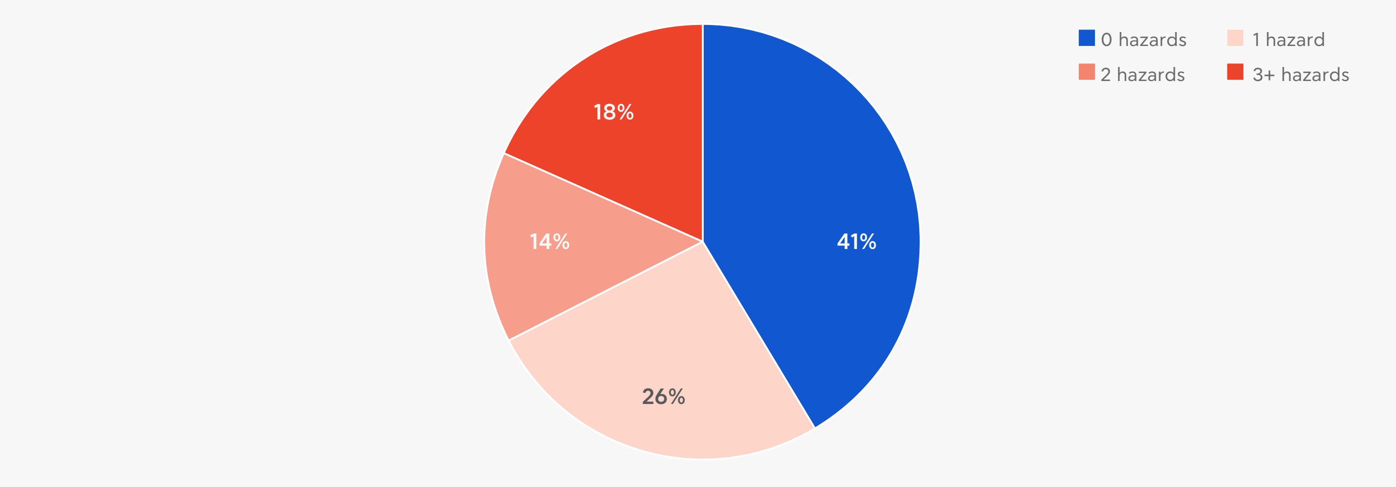


Figure 2. The overview of World Heritage Cities in the Mediterranean region by the percentage of climate hazards across all clusters. Image generated based on interpretation of the Third Cycle of the Periodic Reporting exercise 2018–2024.

At least one climate hazard was reported by 51% of all coastal cities and 63% of all inland cities. There is a wide range of climate change-related hazards that have been reported as experienced by the World Heritage Cities – 33% experience temperature changes,[13] nearly a third (28%) experience flooding and a quarter experience storms (25%) and drought (24%) (Figure 3). Although only 4% of World Heritage Cities reported changes to oceanic waters and 2% reported desertification, the lower occurrence of the latter two may be associated with their less visible and measurable impacts for monitoring on urban heritage properties as compared to natural heritage.

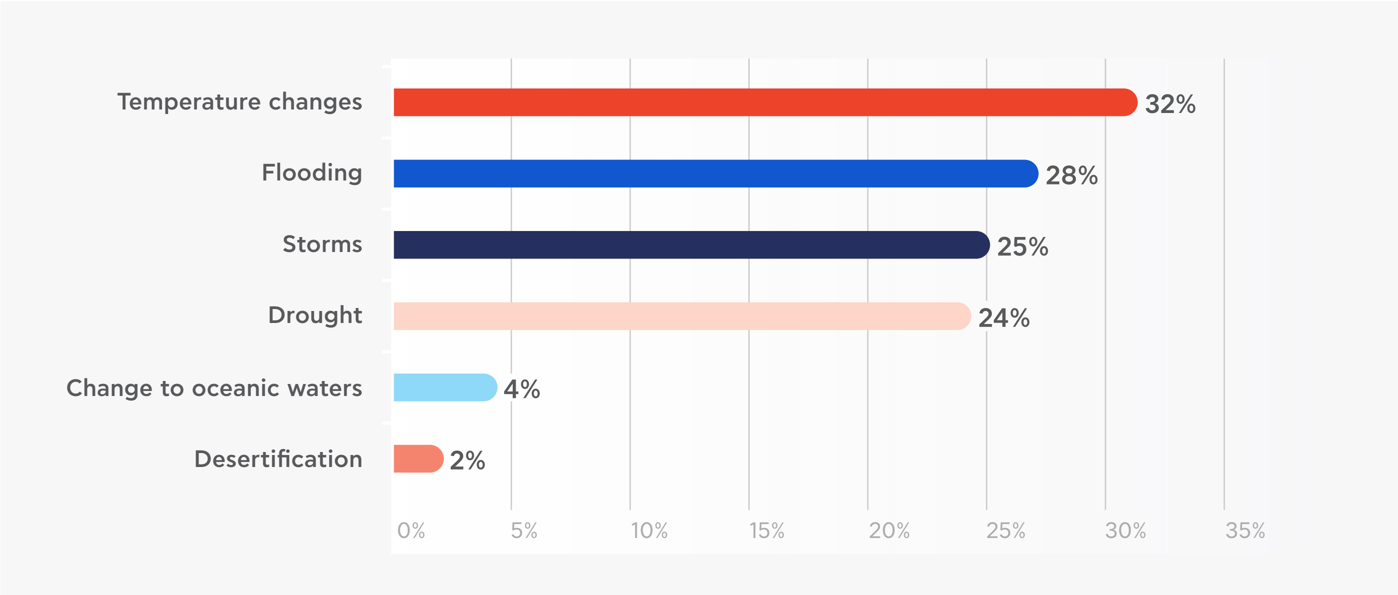


Figure 3. Overview of World Heritage Cities in the Mediterranean region by the type of climate hazards across all clusters. Note that some cities report more than one impact. Image generated based on interpretation of the Third Cycle of the Periodic Reporting exercise 2018–2024.

[13] The subcategory 'Temperature changes' presents data from the subcategory 'Temperature change' in the Periodic Reporting questionnaire. It has been interpreted during capacity-building sessions as implying extreme temperature fluctuations, including heatwaves, hence, this is the sense in which the responses have been interpreted.

While the direct impacts of changes to oceanic waters and desertification may be on areas adjacent to urban settlements, such as agricultural land, forests, pastures, bays and the sea's inner shelf region, rather than having a direct impact on World Heritage Cities, studies confirm the increasing frequency of these events across the Mediterranean region (Mirzabaev et al., 2019) and their indirect impacts on the region, with far-reaching consequences beyond the directly affected areas. The changes to oceanic waters indirectly impact historic cities through seawater acidification, by which calcium carbonate structures like coral reefs and shellfish beds can be degraded or disappear. Without this natural protective barrier, coastal cities are more vulnerable to flooding and impacts of rising sea level, as well as vulnerabilities to fisheries production decreasing food security and increasing unemployment (Hoegh-Guldberg et al., 2017). In addition, sea-level rise is exacerbated by expansion of seawater as it warms (NASA, n.d.; Copernicus, n.d.), increasing the risk of flooding and permanent inundation for World Heritage Cities located along coastlines, threatening infrastructure, cultural heritage sites and residential areas. This reflects the concern that slow-onset events need systematic monitoring to ensure that threats posed by them to the World Heritage Cities could be averted, minimized and addressed.[14]

Comparing hazards between coastal and inland cities, we see that inland cities consider temperature changes to be the top hazard, reported by 37% of cities, followed closely by drought, reported by 32%. Meanwhile coastal cities face bigger risks from flooding and storms, with 27% of coastal cities reporting them as hazards, alongside temperature changes which are also reported as a hazard by 27% of coastal cities. However, these results do not account for other hazards, such as sea-level rise, which significantly impacts coastal settlements through aggravating coastal erosion, extreme marine flooding, or saltwater intrusion in coastal aquifers, as these other hazards were not part of the Periodic Reporting exercise.

[14] For example, Byblos, in Lebanon, has reported landslides and Byblos and Tyre in Lebanon and Rabat, in Morocco, have reported 'erosion or siltation'. As these sites are located on the coast, the reported events may be related to rising sea-level and climate change but have not been included in the analysis.

2.2.1 ANALYSIS AND MAPPING OF CURRENT CLIMATE IMPACTS ON WORLD HERITAGE CITIES BY SUBREGIONS WITHIN THE MEDITERRANEAN REGION

Below is a spatial analysis and mapping showing all World Heritage Cities in the Mediterranean region in this study, colour-coded by the number of climate change-related hazards already being experienced (and reported). The spatial analysis that presents the World Heritage Cities by subregions according to their shared common climate characteristics shows the subregional variations between the World Heritage Cities in the Mediterranean region which have been most vulnerable to climate hazards in recent years and the reported hazards they have been facing in recent years (Figure 4).

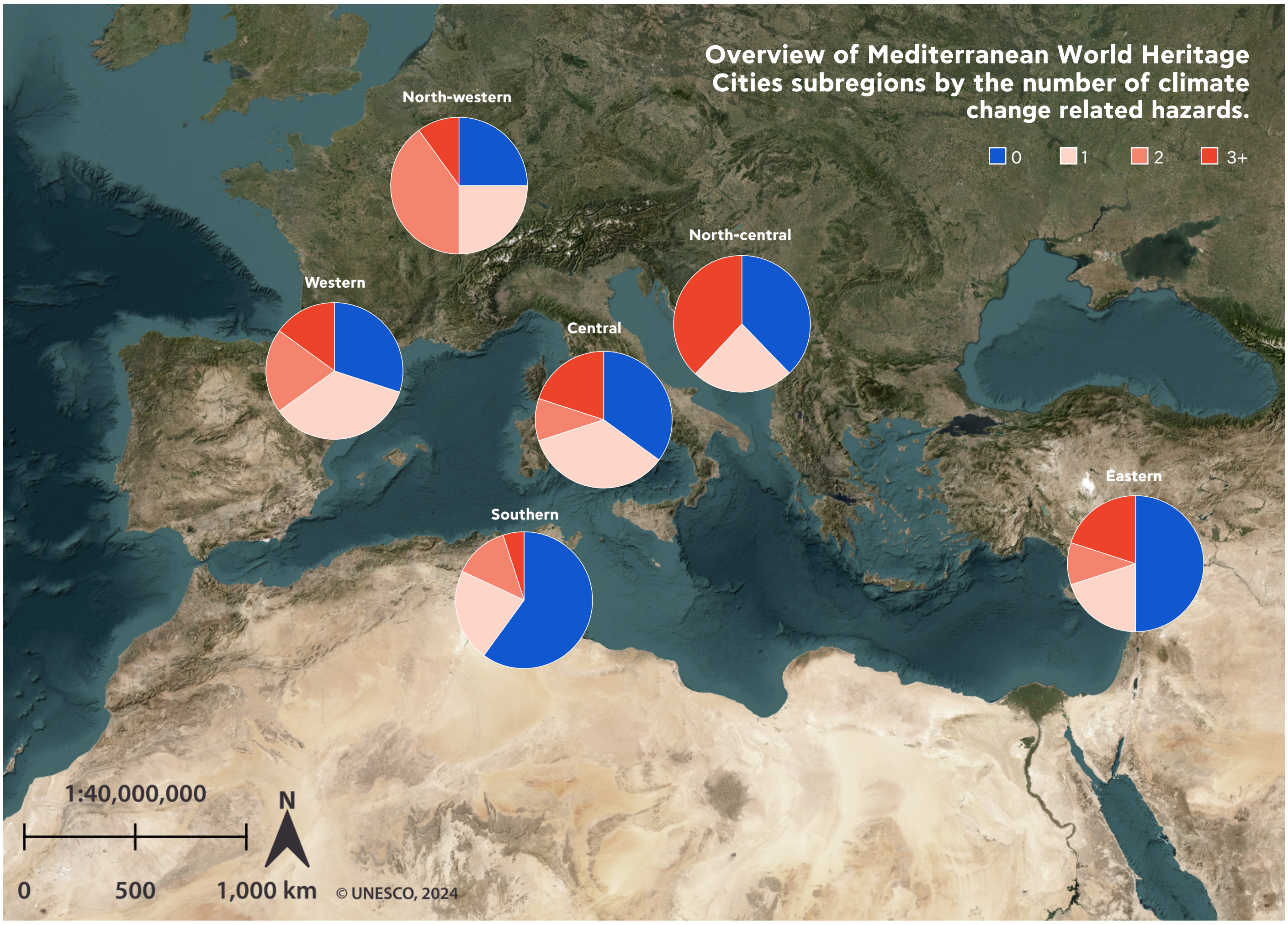


Figure 4. Overview of Mediterranean World Heritage Cities by subregion showing the number of climate change-related hazards. Image generated based on interpretation of the Third Cycle of the Periodic Reporting Exercise 2018–2024.

World Heritage Cities in the north-western and western Mediterranean report experiencing the highest number of climate change-related hazards. Nearly three-quarters of the World Heritage Cities of the western and north-western subregions are already experiencing at least one climate change-related hazard (Figure 4).

While reports suggest that cities in the southern Mediterranean subregion experience the fewest climate hazards, this may actually reflect inadequate or inconsistent reporting, insufficient data, or limited monitoring.

In further detail, among the six subregions, the north-western and western have reported experiencing the highest number of climate hazards, with at least one impact experienced in 75% and 68% of the cities in each subregion, respectively (Figure 5). However, taking into consideration the concentration of hazards with cities experiencing three or more climate change hazards, the north-central (37.5%), central (21%) and eastern subregions (22%) showcase the highest rates. The lowest percentage of cities reporting at least one of the six considered hazards was reported in the southern subregion (38%), which is also the subregion with the lowest percentage (6%) of cities facing three or more hazards.

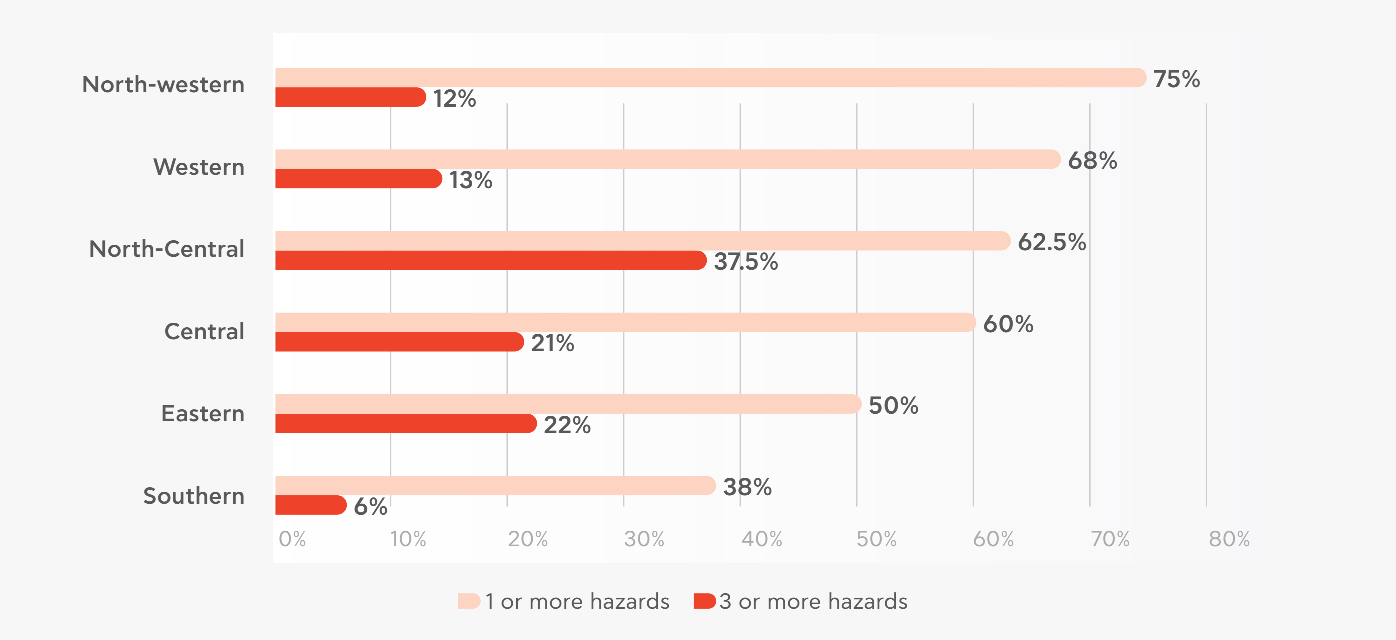


Figure 5. Percentage of Mediterranean World Heritage Cities experiencing at least one and three or more climate change-related hazards in each subregion. Image generated based on interpretation of the Third Cycle of the Periodic Reporting exercise 2018–2024

For the Mediterranean region as a whole, flooding was the most frequently reported climate hazard across the north-western, north-central and southern subregions of the Mediterranean region with 50% of World Heritage Cities reporting floods in the north-western and 63% in the north-central region. While the western and central subregions most frequently reported temperature changes, the eastern subregion reported experiencing a combination of storms and temperature changes.[15]

[15] For details on hazards for a specific subregion, please refer to Appendix 2.

2.3 KEY FINDINGS

- Nearly two-thirds (59%) of World Heritage Cities in the Mediterranean region report already experiencing at least one climate hazard, while nearly one-fifth (18%) of the World Heritage Cities reporting facing three or more climate hazards.
- 32% of Mediterranean World Heritage Cities report experiencing temperature changes, nearly a third (28%) report experiencing flooding and a quarter report experiencing storms (25%) and drought (24%).
- Only 4% of World Heritage Cities reported changes to oceanic waters and 2% reported desertification, which may be due to the less visible and measurable impacts, such as coral reef bleaching and wildfires, on urban heritage properties as compared to natural heritage. It may also be due to the challenges of monitoring and reporting slow-onset events.
- Temperature changes are the most prominently reported hazard for coastal and inland cities. This hazard is more common in inland cities (37%) than in coastal cities (27%). Coastal areas face equal risks from flooding and storms (27%), while drought (32%) is the second most significant hazard for inland cities, following temperature changes.
- World Heritage Cities in the north-western and western subregions of the Mediterranean report the highest number of climate hazards with nearly three-quarters of these experiencing at least one such hazard.
- Flooding is the most frequently reported climate hazard across the north-western, north-central and southern subregions of the Mediterranean, with 50% of cities reporting floods in the north-western and 63% in the north-central subregion. Meanwhile, the western and central subregions primarily report temperature changes, while the eastern subregion experiences a mix of storms and temperature changes.
- While reports suggest that cities in the southern Mediterranean subregion experience the fewest climate hazards, this may in fact be related to inadequate or inconsistent reporting, limited data, or a lack of monitoring. It may also be that some are experiencing different types of hazards not included in the multiple choice offered to them in the questionnaire.

3 FUTURE CLIMATE SCENARIOS AND INDUCED IMPACTS ON MEDITERRANEAN WORLD HERITAGE CITIES

3.1 METHODOLOGY OF THE ANALYSIS

An ensemble of Earth system models[16] (ESMs) and regional climate models[17] (RCMs) was used to project the change of climate variables and extreme climate indices important for cultural heritage protection in the Mediterranean region. These simulations are part of the EURO-CORDEX[18] programme and calculations were made for three periods, corresponding to the standard 30-year time periods utilized in climate modelling and for two climate scenarios. The future periods span the years 2031–2060 (near future) and 2071–2100 (distant future) and they are based on the IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5 greenhouse emissions scenarios. The results are presented in comparison to the reference period, 1971–2000. For the purposes of this paper, the worst case scenario (RCP8.5) for the distant future was selected, as a realistic alarm to the worst impacts already being faced in many parts of the world.

Variables like air temperature, relative humidity and precipitation, as well as the following climate indices, representative of specific climate change-related potential impacts and common usage in the literature (e.g. Brimblecombe et al., 2010; Sardella et al., 2020; Bonazza et al., 2021; Bonazza and Sardella, 2023; Kapsomenakis et al., 2023; Kotova et al., 2023), are utilized in the following categories: 'Days with extreme heat', 'Consecutive dry days', 'Days with extreme precipitation' and 'Consecutive 5-day precipitation' (Appendix 3). The mean sea-level rise was also calculated for coastal Mediterranean World Heritage Cities, using the Extreme Sea Level (ESL) RCP 8.5 dataset of the Large Scale Integrated Sea-level and Coastal Assessment Tool (LISCOAST) programme, developed by the Joint Research Center (JRC, 2020). It is noted that air pollution, acid rain and other anthropogenic threats are not part of the scope of the paper, though they are permanently influencing cultural heritage and are interlinked with meteorology.

3.1.1 LIMITATIONS OF THIS ANALYSIS

Climate models are important tools for simulating climate and there is considerable confidence that they are able to provide credible quantitative estimates of future climate change. However, the use of climate models in this analysis comes with a number of limitations (e.g. CCSP, 2008) that should be considered when interpreting the results and the conclusions, which lie beyond physical process understanding. Part of the limitations are related to the spatial resolution of the global and regional models that were deployed, given the fact that confidence in the changes projected decreases at smaller scales and especially at urban, local-scale climate change. The spatial resolution issue is also relevant due to the mismatch with the scale of impact-relevant climate features, which in this analysis drives the direction of conclusions. In this context, the deployment of climate model results to project and assess impact requires significant caution, e.g. one cannot safely infer that days with extreme precipitation will necessarily result in flooding, unless local analysis on several other aspects [e.g. runoff, imperviousness, urban infrastructure status, etc.] is also taken into account.

In general, using the direct output of climate models is well established, as it represents a physically consistent picture of future climate, including changes in variability and the occurrence of extreme events. For the assessment of change, a simplistic method requiring only mean changes in variables (e.g. temperature and precipitation) and indices has been applied to estimate impacts, which however is very popular in the literature, though there are more sophisticated methods that consider the entire distribution of daily or monthly values of the variables. In this analysis, the simple approach has been mostly deployed. The use of climate models to assess economic, social and environmental impacts is becoming more sophisticated, albeit slowly. Simple

[16] Earth system models (ESMs) integrate the interactions of atmosphere, ocean, land, ice and biosphere to estimate the state of regional and global climate under a wide variety of conditions (Heavens et al., 2013).

[17] Numerical models that simulate the climate of geographic regions typically cover a few thousand square kilometres to a continent (Leung, 2012).

[18] The EURO-CORDEX programme provides regional climate projections for Europe at general resolution of 0.44 degrees (EUR-44, ~50 km) and a finer resolution of 0.11 degrees (EUR-11, ~12 km). The simulations consider the global climate simulations from the CMIP5 long-term experiments up to the year 2100 using greenhouse gas emission scenarios (Representative Concentration Pathways, RCPs) (EURO-CORDEX, n.d.).

methods requiring only mean changes in temperature and precipitation to estimate impacts remain popular, but an increasing number of studies are using more detailed information, such as the entire distribution of daily or monthly values and extreme outcomes.

3.2 ANALYSIS AND MAPPING OF RESULTS

For all Mediterranean World Heritage Cities included in the study (Table 1), average temperatures are projected to rise by up to 4.1 °C – considerably higher than that aimed for in the Paris Agreement adopted under the UNFCCC. The increasing temperatures and their effects are more evident during the second half of the twenty-first century (Table 1). The same cities are additionally projected to become drier and more prone to floods and droughts. Extreme heat days, defined as the number of days with temperature higher than the 95th percentile of the reference period, are expected to increase by up to 58 more days per year, implying overall higher temperatures and more prolonged heatwaves. The eastern subregion of the Mediterranean shows the largest increase in temperature (4.3 °C) and stands out as having the highest number of 'Days with extreme heat' (70 days per year). Furthermore, increasingly lower precipitation is projected with 'Consecutive dry days', reaching 15 days. The southern subregion is likely to experience almost double that (29 days) resulting in more severe drought conditions. Increasing flood probability ('Days with extreme precipitation' and 'Consecutive 5-day precipitation' as a proxy) across the entire region, with peaks in the north-western, north-central and central subregions.

Table 1. Average projected change (indicating either an increase or decrease) of the climate variables (temperature, relative humidity and precipitation) and indices (Consecutive dry days, Days with extreme heat, Days with extreme precipitation, Consecutive 5-day precipitation) for all subregions (under RCP8.5 for the period 2071–2100 relative to the reference period, 1971–2000)

Subregion	**Temperature** (°C)	**Relative humidity** (%)	**Precipitation** (mm)	**Consecutive dry days** (days)	**Days with extreme heat** (days/year)	**Days with extreme precipitation** (days/year)	**Consecutive 5-day precipitation** (days/year)
Total	**4.1**	**–2.4**	**–0.2**	**15**	**58**	**1**	**5.2**
North-western	3.6	–1.2	0.1	4	40	3	11.4
North-central	4.1	–2.0	0.0	8	60	2	17.1
Western	4.1	–3.5	-0.3	18	55	0	3.9
Central	4.1	–1.9	-0.1	8	56	1	12.4
Southern	4.1	–2.2	-0.3	29	58	–1	–8.7
Eastern	4.3	–2.0	-0.2	18	70	0	–1.5

Based on climate projections, by the end of the twenty-first century, 40% of the selected World Heritage Cities will face one climate change-relevant threat and thus potential impacts, half (51%) of the cities will be challenged by at least two threats, in parallel, while an additional 8% will come up against three potential threats (Figure 6). It is highlighted that once more than one threat is present at a city, it is highly possible that different impacts may be amplified or accelerated, in a cumulative manner.

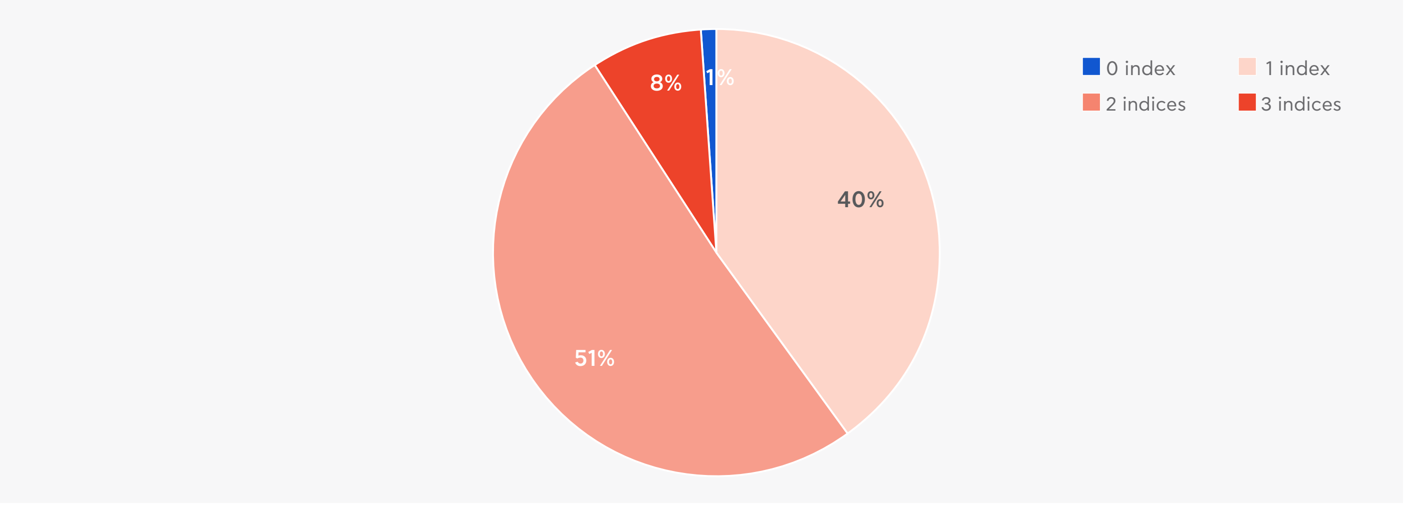


Figure 6. Percentage of World Heritage Cities with climate indices values exceeding the average of the Mediterranean region (under RCP8.5 for the period 2071–2100). Once an index value exceeds the average change value, it is assumed to be a considerable indication of potential imposed future impact at the city. © GGO

Looking at individual indices, 'Consecutive 5-day precipitation' values above average occur in 57% of all World Heritage Cities in the Mediterranean region, while the percentages for 'Consecutive dry days' (47% of all cities) and 'Days with extreme heat', are 47% and 45%, respectively. 'Days with extreme precipitation' above average occur in 18% of the World Heritage Cities (Figure 7).

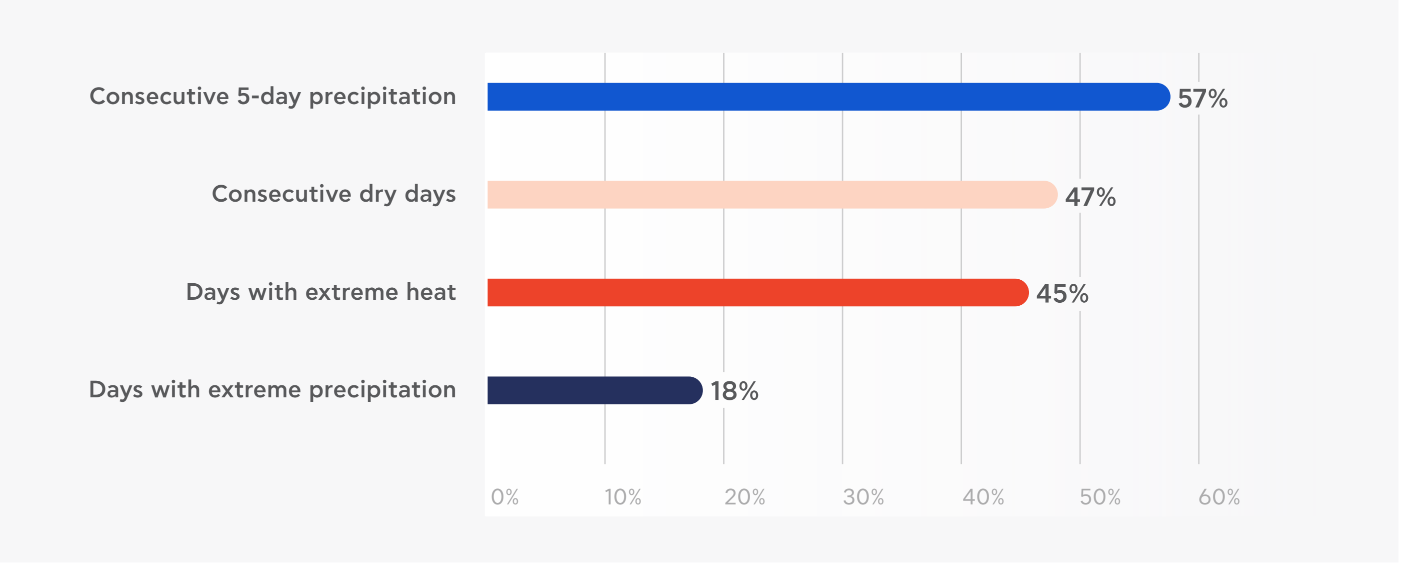


Figure 7. The percentages of all World Heritage Cities being influenced by the projected indices, under the RCP8.5 emission scenario. Indices are correlated with climate threats. © GGO

While Figures 6 and 7 show how many World Heritage Cities will be challenged by individual or multiple threats and potential impacts, on the assumption than any change of an index above the average change will have an impact on the city, it incorporates no information on how statistically extreme the potential changes may be. For this, a more sophisticated scoring approach has been also applied, based on percentile distribution of the indices change, to characterize potential impacts on a scale from very low to very high (Appendix 4). This allows for a deeper understanding of the necessity for action, both in terms of impact type and geographical distribution.

A consistent outcome is that the score for both 'Days with extreme precipitation' and 'Consecutive 5-day precipitation' denotes 'Very high' and 'High' values in the north-western, north-central and central subregions, while there appears to be no such classification for 'Consecutive dry days' and 'Days with extreme heat'. This highlights that such an analysis enables identification of geographical patterns and hot spots for different threats versus more homogeneous distribution of potential impacts across all subregions.

Coastal World Heritage Cities will additionally be facing the risk of sea-level rise. Data (JRC, 2020) for sea-level rise projections is available in 25 of the 41 coastal World Heritage Cities and the estimate is that the sea-level rise will be in the range of 0.5 m to 0.67 m, with values in the higher end falling over the central part of the Mediterranean region (Figure 8).

These cities will probably become extremely vulnerable to coastal flooding as well as surges in coming years.

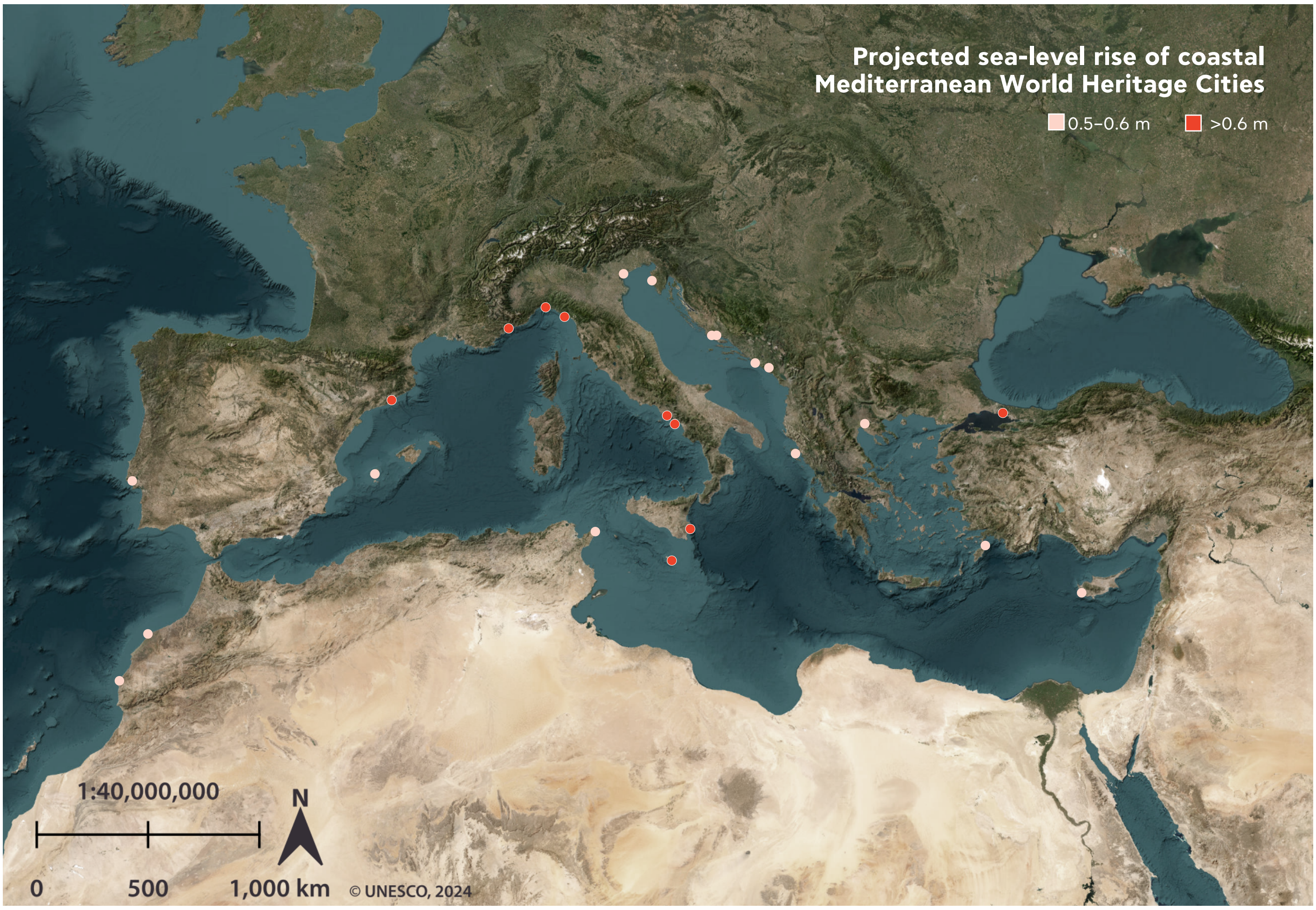


Figure 8. Projected sea-level rise at 25 coastal World Heritage Cities in the Mediterranean region for which data is available. © GGO

3.2.1 ANALYSIS AND MAPPING OF CLIMATE CHANGE IMPACTS ON WORLD HERITAGE CITIES BY SUBREGIONS WITHIN THE MEDITERRANEAN REGION

As already mentioned, more than half of the selected World Heritage Cities will face at least two climate change-relevant threats and thus potential impacts, in parallel. The relevant spatial analysis demonstrates the distribution of multiple impacts per subregion (Figure 9).

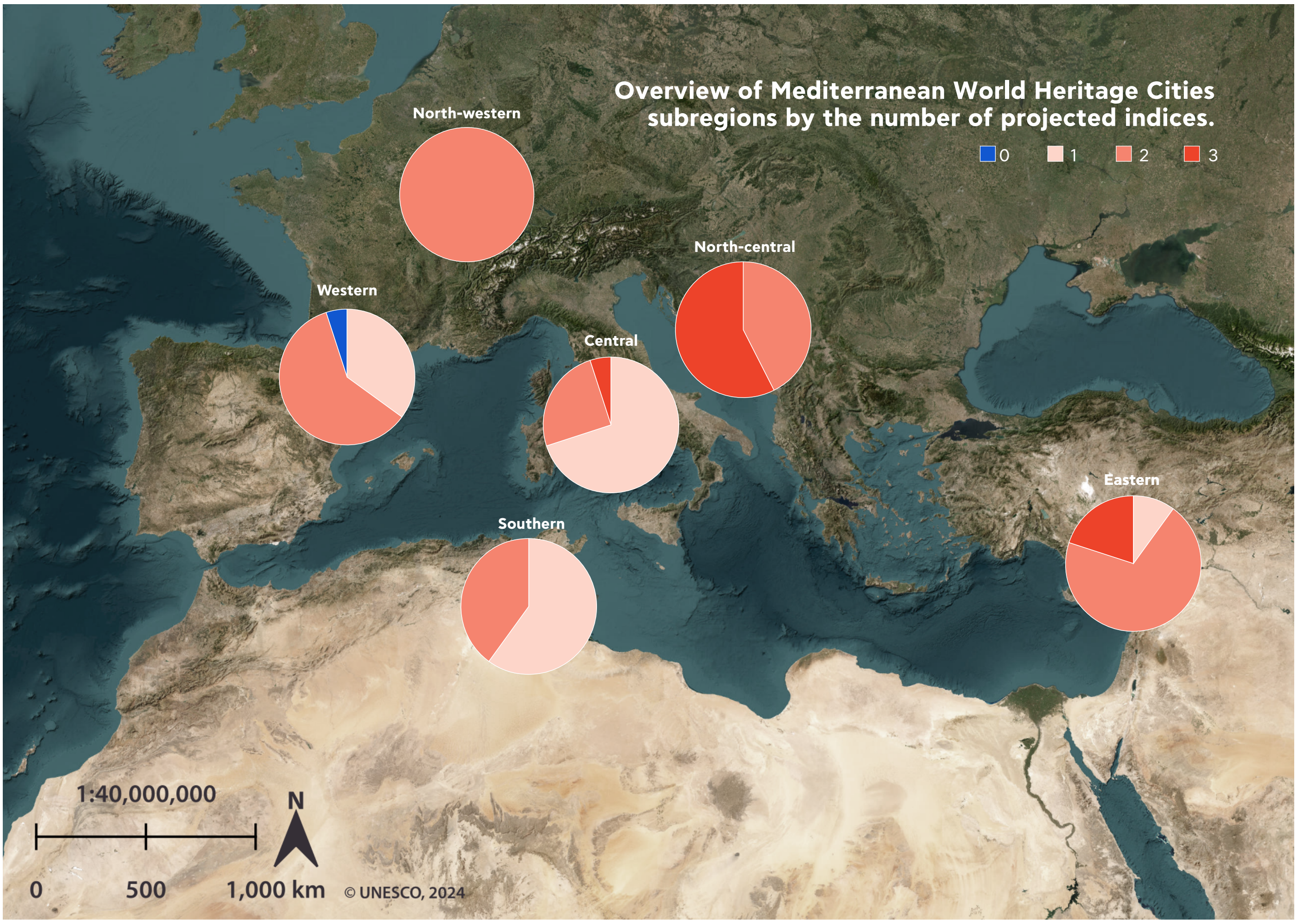


Figure 9. Clustering of Mediterranean World Heritage Cities per subregion, with respect to the number of indices with values above the average change (under RCP8.5 for the period 2071–2100). © GGO

A west-to-east pattern is discerned with the north-central and eastern subregions showing up to three simultaneous threats from 'dominant' to 'very significant', respectively. Specifically, more than half (56%) of the World Heritage Cities in the north-central subregion and one-fifth (20%) in the eastern subregion will face at least three threats. In the north-western and western subregions, the co-existence of two threats is dominant, with 100% and 63% occurrence in the World Heritage Cities. Finally, in the central and southern subregions, mostly one threat is projected, at 73% and 63%, respectively.

Focusing on the types of climate change threats and thus related impacts in the World Heritage Cities in the six subregions, in the north-western, north-central and central subregions the indices that correspond to the risk of flooding are dominant, while in more than half of the World Heritage Cities in the western, southern and eastern subregions, the indices that correspond to drought and extreme heat prevail (Figure 10).

It should be noted that this analysis does not aim to highlight the most threatened subregions in terms of absolute numbers of World Heritage Cities; rather, it aims to classify the different threats each subregion is facing in a comparable manner, for decision-making and prioritization at the subregion level.

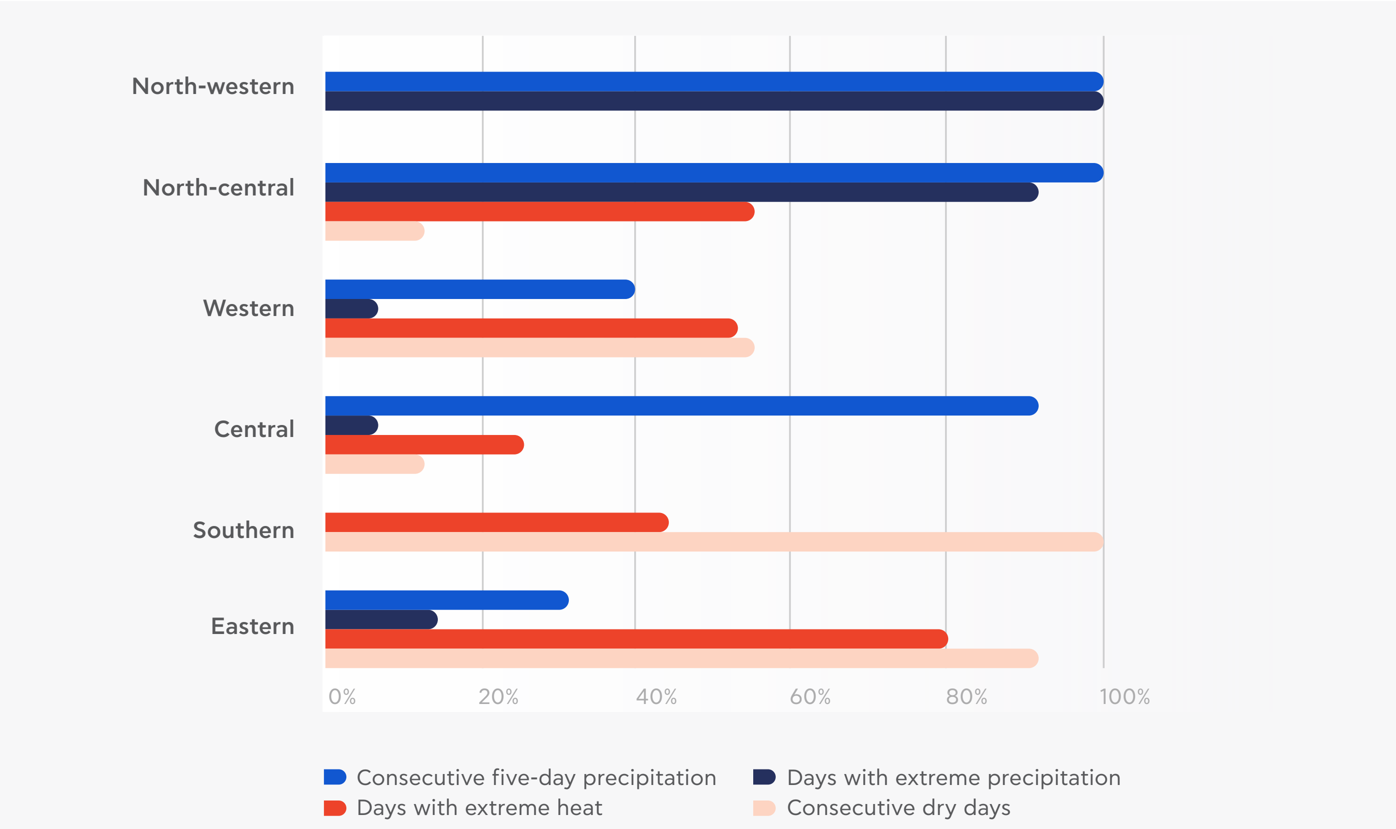


Figure 10. Percentage of World Heritage Cities within the subregion with climate indices values exceeding the average for the Mediterranean region (under RCP8.5 for the period 2071–2100). © GGO

3.3 KEY FINDINGS

By the end of the twenty-first century and under RCP8.5:

- More than half (51%) of the selected World Heritage Cities will face at least two climate change-related threats and thus potential impacts, in parallel, with unforeseen amplification effects.
- Sea-level rise is estimated to be in the range of 0.5 m to 0.67 m, posing an additional threat to all coastal World Heritage Cities in the region, with a greater rise in the central part of the Mediterranean Basin.
- A discernible west-to-east pattern is revealed, as towards the eastern Mediterranean, the increasing number of threats compound and amplify the potential impacts of any one threat.
- All World Heritage Cities in the north-west and north-central subregions of the Mediterranean region will face at least two threats with the majority in the north-central subregion facing three threats. 63% of World Heritage Cities in the western subregion of the Mediterranean region will face at least two threats. Most World Heritage Cities in the central (73%) and southern (63%) subregions of the Mediterranean are projected to face at least one threat.
- North-western, central and north-central subregions are projected to be heavily impacted by flooding, while the western, southern and eastern parts of the region are projected to have reduced precipitation leading to drought-like conditions. Extreme heat conditions are most significantly projected for the eastern subregion of the Mediterranean.

4 SIGNIFICANCE OF THE LOSS OF CULTURAL HERITAGE FOR WORLD HERITAGE CITIES

4.1 ECONOMIC LOSSES DUE TO LOSS AND DAMAGE TO CULTURAL HERITAGE

Loss of heritage in historic cities has a direct economic impact due to the loss of valuable structures, property and goods, historic fabric, infrastructure, related loss of livelihoods for the local communities and tourism revenues. These economic losses can result in impoverishment for vulnerable communities, deepening existing inequalities or giving rise to new forms of disparity. Related impacts to the management of water and loss of biodiversity and ecosystem services, degradation of land and marine ecosystems, as well as loss of territory compound these economic losses.

The most immediate economic impact is from the loss of property and goods, and damage to infrastructure, including transport, due to floods, storm surges, hurricanes, intense rainfall, drought and heatwaves. This might include impacts on energy infrastructure such as dams and reservoirs (IPCC, 2023*b*).

Cultural heritage provides livelihood opportunities for the local communities in World Heritage Cities (Labadi et al., 2021). The loss of cultural heritage is first and foremost a loss of built fabric, land, including agricultural land, infrastructure, the intangible heritage bound up with them and the associated economic losses. Cultural heritage is a source of key livelihoods from a range of traditional practices, ranging from crafts and artisanal trades to fishing, agriculture and the extraction of agriproducts and foods. The loss and damage of cultural heritage sites will additionally raise the costs of their conservation and recovery and reduce tourist interest. All these directly impact local economies and livelihoods. Sea-level rise alters coastal ecosystems such as coral reefs, affecting fisheries and other resources upon which communities have traditionally relied. Many livelihoods are based on ancestral knowledge of local marine environments, which will be rendered ineffective if ecosystems shift or collapse due to sea-level rise (ICOMOS, 2019). Impacted cities and settlements must find ways to rebuild in the same place, where the sea-level rise is somewhat slower, or rebuild in other places, wherein communities must be displaced and moved due to the rising waters. Impacts on water, food production and health would impact local communities and their abilities to protect and care for their cultural heritage. Economic losses also result from the inability to organize cultural events or festivals, or from the lack of availability of natural resources for artisanal products emblematic of the region.

Cultural heritage tourism contributes significantly to creating jobs and attracting investment and local businesses. Depending on the location and the value of the cultural heritage, tourism may be a dominant economic source contributing significantly to the national GDP. Coastal regions often rely on cultural heritage tourism as a significant source of income. Frequent or permanent flooding, shoreline retreat and erosion of sandy beaches impacts the recreation and the tourism industry. Due to its rich and stunning natural and cultural heritage, the Mediterranean region is the world's leading tourist destination (Ali et al., 2022), accounting for one-third of global tourism (WWF, 2017), making it a vital element of the region's economy. World Heritage Cities are major attractions for cultural tourism, drawing local and international visitors. In 2015, employment generated by tourism reached 11.5% in the Mediterranean economies at large (Fosse et al., 2021). Consequently, the increase in intensity and frequency of extreme weather events, growing difficulty in accessing resources and decreased comfort in Mediterranean cities can significantly impact local economies, businesses and people's lives which currently rely on the tourism industry (e.g. small businesses, maritime transport, entertainment and trade). However, the IPCC notes that multiple studies project decreasing tourism in the Mediterranean region as well as greater risks for sustaining tourists due to the impacts of rising temperatures on health, water and food production. These shocks may also be accompanied by displacements that pose additional challenges to the economy.

The direct impacts of climate change on World Heritage Cities include damage to historic buildings and structures due to an increase of slow variations of climate and pollution parameters (i.e. temperature, relative humidity, precipitation) and in the frequency of extreme climate events, such as extreme heat, drought, wildfires heavy precipitation and coastal and pluvial flooding, all of which accelerate deterioration processes, threatening cultural monuments' structural stability (Bonazza, Messina et al., 2009; Bonazza, Sabbioni et al., 2009; ICOMOS-ISCS, 2008; Doehne and Price, 2010; Grossi et al., 2011; Sesana et al., 2021; Ruedrich et al., 2011; Gómez-Bolea et al., 2012; Brimblecombe, 2013; Falk and Hagsten, 2023). Even minor climate alterations can lead to severe deterioration processes, causing irreversible impacts on material surfaces and structures on a micro level. This consequently increases the costs and time required to maintain and restore historical structures and city centres. The loss of visual integrity and coherence affects the local businesses, residents occupying historic buildings and disrupts local communities, economies and the overall character of historic neighbourhoods. Many historical buildings were constructed using traditional materials and techniques that may become increasingly difficult to replicate or maintain as weathering progresses, with changes in temperature and precipitation already affecting some of the most iconic assets in World Heritage Cities with valuable archaeological sites.

This Copernicus Sentinel-2 image shows the scale of the flooding in Valencia, Spain, in October 2024 and the drastic transformation of the landscape. Contains modified Copernicus Sentinel data (2024), processed by ESA.

4.2 NON-ECONOMIC IMPACT OF LOSS AND DAMAGE TO CULTURAL HERITAGE

Properties inscribed on the UNESCO World Heritage List are inscribed for their OUV that must be protected, including its conditions of authenticity and integrity. The OUV goes beyond national or regional significance to being of value for all of humanity, and must be preserved for future generations. Thus, any loss or damage to such properties is a loss to humanity for generations to come.

The UNFCCC Expert Group on Non-Economic Losses, functioning under the Executive Committee of the Warsaw International Mechanism on Loss and Damage related to Climate Change Impacts, has identified cultural heritage as one of the three significant types of Non-Economic Losses (NELS), together with loss of biodiversity and ecosystem services as well as territory. UNESCO, as the cultural heritage lead for the UNFCCC Technical Paper on Non-Economic Losses, has also identified the NELs due to climate change with regard to cultural heritage, (used broadly to include natural and mixed World Heritage properties). Primarily, these are losses or damage to invaluable cultural heritage assets, including properties inscribed on the UNESCO World Heritage List for their OUV, but also loss of cultural knowledge of the environment, such as decreased adaptive ability as local knowledge and resources are lost, and decreased ability to address socio-economic development needs.

When the situation results in the displacement of local communities or shortages in resources such as water and food, this further disturbs traditional ways of life and the ability of communities to protect and manage their tangible and intangible heritage (UNFCCC, 2024*a*). Moreover, the loss of cultural heritage in World Heritage Cities from climate hazards will likely result in different types of loss of cultural heritage, such as diminished cultural diversity, loss of important archaeological sites and historical evidence for future generations, traditional knowledge systems, sources of inspiration and creativity, and diminished cultural rights and right of access to culture, alongside a broader loss of cultural identity and diminished resilience of communities (ICOMOS, 2019; UNFCCC, 2024*a*). The 2023 Policy Document on Climate Action for World Heritage (UNESCO, 2023*b*) also includes discussions of loss, stating that 'loss of livelihoods of communities living in and around the sites may also impact their livelihood, knowledge systems and their capacity to maintain the site. In addition, local knowledge and wisdom and traditional practice represent different knowledge system that are key source of information to inform mitigation and adaptation options needed to prepare communities for future climate risks'.

World Heritage Cities are equally at risk of cumulative and cascading effects of climate change (Ali et al., 2022) that indirectly threaten the historical significance of these sites, as well as their populations and their everyday life (Box 3). Culture is inextricably linked to a sense of place (Pearson et al., 2021). Various urban attributes in historic urban areas, such as public squares, markets, courtyards, places of worship and informal places of gathering, are places for living heritage practices and enable the transmission of ICH to future generations. Loss or damage to the physical setting in which these intangible elements exist puts at risk values and traditions associated with these places and threatens their continuity.

Losing distinctive heritage in World Heritage Cities can broaden to include the loss of a sense of place and the diminished ability of a community to express its cultural identity that depends on the value of the cultural heritage. Thus, this may include the loss of distinctive forms and expressions of identity, the loss of accumulated cultural and environmental knowledge, skills related to local resources and livelihoods, the loss of traditional forms of governance systems, inspiration and innovation, diminished food and water security and loss of adaptive capacity and resilience of communities, including resilience to disasters (Box 4). These are frequently experienced as multiple and overlapping losses. The loss of cultural heritage may disproportionately impact the most vulnerable communities including marginalized groups and certain Indigenous Peoples, thereby exacerbating existing inequalities or creating new ones (UNFCCC, 2024*a*).

While the loss of cultural heritage most immediately impacts the local communities of the World Heritage Cities, values are plural and can exist at different scales. Hence, depending on the value of the cultural heritage, as well as the extent and significance of its loss, local, national and global communities may also be impacted – and as World Heritage properties recognized for their universal value to all of humanity, their loss and damage impacts all of humanity. Furthermore, the loss of cultural heritage is interlinked with loss of territory, biodiversity and ecosystem losses, as well as the loss of indigenous knowledge and the loss of social/cultural identity. The loss of cultural heritage also contributes to loss of cultural diversity that impairs inclusive sustainable development.

As cultural heritage has many different and overlapping values, a single loss of such tangible heritage may result in multiple interconnected losses of cultural heritage that together lead to a much more significant loss than that of a single structure or monument. Heritage sites may have multiple types of heritage associated with them that are also lost. For example, a historic monument may be an outstanding monument of artistic value, but it may also have traditional houses around it that are part of its context or setting that respond to peoples' ways of life, as well as artisanal crafts, music, festivals, processions and other associated intangible heritage practices. There may also be archaeological excavations and material associated with it, as well as art, objects and artefacts of high value. Thus, the losses are further compounded for the local communities in the present as well as for future generations. Such compounding losses can include historical knowledge and traditional crafts, the social value of heritage, a source of inspiration and innovation, a diminished sense of place and identity and a resulting diminution of social cohesion and community resilience (UNFCCC, 2024*a*).

Cultural or symbolic values derived from heritage's historical and social significance can also be lost. Cultural skills, crafts and traditional knowledge related to construction techniques can be lost or forgotten if a tangible heritage site is lost or abandoned through climate-driven population displacement, cultural erosion, decreasing access to traditional materials and changing local climatic needs. Loss of cultural heritage can also result in loss of associated social value, including governance systems. Loss of traditional management and ownership of heritage and ability to care for it not only concerns cultural heritage, but also many communities living in and around World Heritage sites (UNFCCC, 2024*a*).

Historical cities often serve as places of creativity and sources of inspiration and innovation. Losing heritage of significant artistic value that involved a high level of artistic accomplishment or represented a singular innovation can be as much a loss for local communities as for the global community in terms of artistic inspiration and innovation (UNFCCC, 2024*a*). The loss of objects or practices imbued with cultural significance can also threaten the sort of social coordination that holds up resilient communities by disrupting values or the identity connected with them. At the same time, a wealth of traditional knowledge and intangible heritage practices help to bolster the resilience of communities in coping with natural disasters and adapting to climate change. Losing such heritage therefore impacts the resilience of communities (UNFCCC, 2024*a*).

BOX 3 | CLIMATE CHANGE IMPACTS ON WORLD HERITAGE CITIES

Ksar of Ait-Ben-Haddou, Morocco
Inscribed in 1987 on the World Heritage List.

The ksar is a cluster of earthen buildings surrounded by high defensive walls reinforced by corner towers. Ait-Ben-Haddou is a striking example of this architectural style prevalent in southern Morocco. These earthen constructions are perfectly adapted to the local climatic conditions and can be observed dating back to the seventeenth century in the valleys of Dra, Todgha, Dadès and Souss.

The Ksar of Ait-Ben-Haddou is affected by the impacts of storms, drought and flood events. The floods in 2014 led to the partial disintegration of the property (UNESCO, 2021). Through the past several decades, observed trends have shown more erratic rainfall and an overall decline in precipitation (World Bank, 2021), which is likely to further decrease between 10% and 20% until the year 2050 (Schilling et al., 2012; World Bank, 2021). Morocco has been experiencing a shift in seasonal rainfall patterns towards longer and more intense seasonal rain events, which often cause flooding, but with substantial reductions in rainfall during the rest of the year (World Bank, 2021). Drought frequencies have also risen from one event every ten years at the beginning of the twentieth century to five or six events every ten years at the beginning of the twenty-first century (El Khatri and El Hairech, 2014).

Among the factors affecting the property and related to the increasing vulnerability of the area is the changing valuing of heritage by society, resulting in partial abandonment of the property (UNESCO, 2021) and overall migration to regions less exposed to climate change impacts. The earthen buildings are very vulnerable due to lack of maintenance and repair resulting from the abandonment of the ksar by its inhabitants.

The fortified city, or ksar, of Aït Ben Haddou, Morocco, in the early morning light before the sun appears above the horizon. © Tom Camp/Shutterstock.com*

BOX 4 | CLIMATE CHANGE IMPACTS ON WORLD HERITAGE CITIES

M'Zab Valley, Algeria
Inscribed in 1982 on the World Heritage List.

600 km south of Algiers, Algeria, the small M'Zab Valley is home to a unique collection of sites. Ancient traces of dwellings are seen on the plateaus and rocky escarpments bordering this valley, regularly occupied as far back as the early part of the eleventh century (UNESCO, n.d.a). In October 2008, the M'Zab Valley – and its five fortified ksour (El Atteuf, Bou Noura, Beni Isguen, Melika and Ghardaïa) – experienced an extreme flash flood event, with water depths exceeding 8 m. The strong torrential rains caused the rivers in the region to overflow, destroying hundreds of houses in the historic town and a neighbouring oasis. This catastrophic flood resulted in 50 fatalities and left thousands homeless (Boutaghane et al., 2021). The damage was exacerbated by the lack of water distribution system maintenance, non-compliance with the existing traditional canalization systems, and unregulated construction activity in the valley that had replaced formerly temporary dwellings in areas historically prone to flooding (about every 25 years).

In dry regions like the Sahara, rain is rare, but sudden and destructive floods appear in the seasons of autumn and spring. Two or three times a year, the rain can produce a high quantity of water (Khelifa and Remini, 2019). Climate change is increasing the frequency and intensity of extreme weather events, including heavy precipitation and pluvial flooding in the Saharan region (IPCC, 2021), resulting in the expected increase of frequency and severity of the flood events, with periodic overflows becoming increasingly frequent. To address these issues, there is a significant need to enhance the risk preparedness of the water distribution system in the M'Zab Valley. Recent initiatives have incorporated the relevant traditional knowledge in water management, which has been put in place to guard against future flooding and align with water storage, distribution and evacuation needs – the key areas for action.

View across the M'Zab Valley, Algeria. Dan Sloan/Flickr.com

5 ACTIONS TO RESPOND TO CLIMATE CHANGE RISKS AND IMPACTS IN WORLD HERITAGE CITIES

5.1 ENHANCING RESILIENCE AND PROTECTION OF CULTURAL HERITAGE

International agreements and agendas on climate urgently need to recognize the threats to cultural heritage due to the slow-onset and rapid-onset climate change-related events, as well as mainstream the importance of cultural heritage as a resource for climate resilience and adaptation solutions, in particular in historic cities and settlements. As the 2024 G7 Ministerial Declaration of the Ministers of Culture states, 'We will leverage current efforts to mainstream cultural considerations in the international climate agenda…' (G7, 2024). The G20 Culture Working Group also made significant commitments in the field of culture and climate in 2023 (G20, 2023). Furthermore, the 2024 Salvador da Bahia Declaration of the G20 Ministers of Culture calls for 'within our national contexts and international cooperation, broad, transparent, and inclusive engagement to integrate considerations relating to cultural heritage, arts, and creative industries into national climate adaptation and mitigation strategies, in line with national priorities and competencies, in view of the urgent need to promote a strengthened global action to address the challenges posed by climate change to culture' (G20,2024).

Actions are also needed to regularly assess and monitor climate change impacts on cultural heritage in historic cities and settlements. The 2022 report Strengthening Cultural Heritage Resilience for Climate Change by the EU Open Method of Coordination expert group of Member States stresses that only 7 out of the 28 participating countries have plans of adaptation to climate change containing measures specifically addressed to the safeguarding of cultural heritage (European Commission, 2022).

Yet protection and safeguarding of cultural heritage is itself a significant climate action. Integrating cultural heritage in climate plans and policies at all levels from the national to the local is essential. Reinforcing cultural resilience is urgent, including inventorying that ensures the full engagement of local communities and Indigenous peoples as well as other stakeholders in the processes. The Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR, 2015), for instance, includes the protection of cultural heritage and the promotion of the 'cultural resilience' of people, communities and countries, inviting a better understanding of the impacts of disasters on cultural heritage, and promoting the protection of cultural institutions. Climate plans, policies and strategies need to similarly integrate and mainstream cultural heritage.

UNESCO, as the only UN agency with a mandate on culture, is addressing the loss of cultural heritage through a variety of actions, ranging from its own international culture-related conventions to integrating culture within other important instruments, carrying out studies, developing tools, providing technical assistance on the ground and emergency assistance where possible.

In September 2024, the Heads of States and Governments of the UN General Assembly placed culture at the heart of their response to the strategic challenges of our century in the 'Pact for the Future', especially under Action 11 that calls to 'integrate culture into economic, social and environmental development policies and strategies and ensure adequate public investment in the protection and promotion of culture'.This followed the direction of the UNESCO World Conference on Cultural Policies and Sustainable Development (MONDIACULT 2022), hosted by Mexico, to integrate cultural heritage and creativity into international discussions on climate change. Organized as part of the thematic initiatives under the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage, as established by its Intergovernmental Committee, UNESCO has launched a reflection on the relationship between safeguarding ICH and climate change. As a Knowledge Partner, UNESCO supports the Group of Friends of Culture-Based Climate Action that intends to strengthen the momentum on culture and climate action in various global and regional forums by building consensus through coordinated and inclusive dialogue and action across membership and other relevant stakeholders. The UAE Framework for Global Climate Resilience, which had been adopted at COP28 to guide the achievement of the global goal on adaptation, has an explicit target regarding cultural heritage, which is also reiterated as part of the global stocktake (UNFCCC, 2024*b*).

UNESCO also contributes to the UAE-Belem Workplan for the development of Indicators for the Global Goals for Adaptation, including with the UNESCO Culture|2030 Indicators framework (UNESCO, n.d.b).

Recognizing the synergies between culture and other policy areas and considering the impact of culture, cultural heritage and the creative economy on the economic, social and environmental dimensions of development, culture was integrated into the G20 Summit in 2020 and consolidated as a dedicated Culture Working Group as of 2021. The Ministers of Culture of the G20 adopted the Rome Declaration of the G20 Culture Ministers, which recognizes culture's role and its potential in leading to solutions to address climate change (G20, 2021). The 2024 G20 summit in Brazil addressed the issue of climate change and sustainable development. Most recently, the Salvador de Bahía Declaration, issued at the meeting of Ministers of Culture on the margins of the G20, the Ministers emphasized that culture, recognized as a common good of humanity and a universal right, drives innovative, cohesive and resilient societies while directly contributing to the achievement of the Sustainable Development Goals (SDGs) and highlighted the role of cultural knowledge in climate adaptation and mitigation, as well as the protection of cultural heritage as a key element in strengthening climate resilience (G20, Ministers of Culture 2024). On their side, the G7 countries also adopted the Ministerial Declaration of the Ministers of Culture, stating their commitment to foster mitigation and adaptation strategies and actions and to improve the resilience of cultural heritage against climate change (G7, 2024). The Inter-Agency Platform on Culture for Sustainable Development (IPCSD) was launched by UNESCO in 2021 to foster structured dialogue and cooperation on culture and sustainable development. The Platform is intended as a jointly owned community of practice, bringing together some 30 international and regional bodies, including UN agencies, regional or subregional intergovernmental organizations, as well as development banks. UNEP and UNFCCC are active members of the Platform, particularly as regards the role of culture for the environment. The UNESCO 1972 Convention for the Protection of the World's Cultural and Natural Heritage (World Heritage Convention) (UNESCO, 1972), which is universally ratified by 196 States Parties, and the UNESCO HUL Recommendation (UNESCO, 2011), adopted by 194 Member States of UNESCO, provide a sound basis for protecting the urban heritage in historic cities and settlements inscribed on the World Heritage List, as well as those that are not.

The UNESCO 2023 Policy Document on Climate Action for World Heritage, adopted by the 195 States Parties of the 1972 World Heritage Convention gathered in General Assembly, is a guiding document (UNESCO, 2023*b*) to assist States Parties with the implementation of comprehensive climate action, including mitigation and adaptation measures, resilience building, innovation and research. It provides a pathway to utilize synergies between the World Heritage Convention, the UNFCCC and other multilateral agreements. Its outcome-oriented policy framework aids in the development of goals and targets at national and heritage site levels, the updating of national heritage management tools and action plans and the facilitating of continuous monitoring of the implementation and review of this Policy Document. The Policy Document is also intended to be of relevance to all stakeholders and rights holders, including Indigenous peoples and local communities, civil society and the private sector. The long-term vision of the Policy Document is that each State Party understands the current and future potential impacts of climate change on World Heritage properties situated on their territory and undertakes climate action in an effective, ambitious, cooperative and active way. A comprehensive toolkit is currently under development together with UNESCO, ICCROM, IUCN and ICOMOS to support capacity-building, assessment and awareness-raising.

Aerial view of the Old Town of Ghadamès, Libya. The town faces damage and collapses of traditional buildings due to ever more intense precipitation events. Mohamed Alazrak/Wikimedia Commons

A collaboration since 2021 between ICOMOS, UNESCO and IPCC resulted in the Global Research and Action Agenda on Culture, Heritage and Climate Change that was launched in April 2023. The report (Morel et al., 2022) and its associated white papers (Orlove et al., 2022; Shepherd et al., 2022; Simpson et al., 2022) explore the synergies between culture, heritage and climate change. The report contains key messages to promote further engagement in climate action across these domains and represents a milestone partnership towards the full integration of culture in international climate action. The scientific outcomes of this International Co-Sponsored Meeting on Culture, Heritage and Climate Change (ICSM-CHC) concluded that recognizing the impacts of climate change on culture and heritage is important to enable governments, businesses and communities to leverage culture's contribution for a climate-resilient future and a sustainable response to climate change. A better understanding of culture and heritage and the past can inform ideas of growth, sustainability and development, have implications for green transformation, and provide opportunities to introduce, develop and enhance adaptation approaches and strategies rooted in and informed by culture and heritage.

The UNESCO World Heritage Cities Programme (UNESCO, n.d.c) is one of the six thematic programmes approved and monitored by the World Heritage Committee. The programme provides a framework for urban heritage conservation and informs new approaches and methodologies to that end. It also provides technical assistance to States Parties for the implementation of the UNESCO 2011 Recommendation on the Historic Urban Landscape (UNESCO, 2011); its principles and approach form the framework and serve as the tool for urban heritage conservation in World Heritage Cities. Following the Decisions of the Executive Board, this has been aligned with the World Heritage Sustainable Development Policy (UNESCO, 2015), the UN 2030 Agenda for Sustainable Development (UN, 2015) and the New Urban Agenda (UN, 2017) as well as climate action to inform the framework, methodology and activities of the Cities Programme. This alignment and integration of urban heritage with climate considerations is evident in the publication Urban Heritage for Resilience (UNESCO, 2023*c*) that is the consolidated report on the Third Member State Consultation on the Implementation of the HUL

Recommendation. The HUL Recommendation advocates the integration of the natural features with built form and local communities. From this perspective, the World Heritage Canopy and the Urban Heritage Atlas are two UNESCO tools to support the implementation as well as capacity-building towards sustainable development and climate action for World Heritage Cities.

5.2 REDUCING VULNERABILITIES

The impact of the hazards on World Heritage Cities, resulting in a range of economic and non-economic losses and damage, including the loss of cultural heritage, depends on the frequency and intensity of exposure to hazards, the complexity and cascading impacts of the hazards, including multihazard components, as well as the vulnerability of the cities and their cultural heritage.

The IPCC Outline of the Special Report on Climate Change and Cities (IPCC, 2024) identifies the link between sustainable development and climate resilience. From early warning systems to governance and community awareness, from options for spatial planning and energy (heating, cooling, electricity) to existing and new buildings and infrastructure, mobility and transport, water, land, food and behavioural change, spatial and strategic urban planning has a significant role to play in reducing vulnerabilities and enhancing resilience. Cultural heritage protection must be integrated in such planning efforts – and for World Heritage Cities, their OUV must be integrated in the planning and design of their resilience actions. The Management Plans for World Heritage must be integrated with the strategies to reduce vulnerabilities and enhance resilience.

The IPCC's Global Research and Action Agenda on Cities and Climate Change Science (IPCC, 2019) identified that cities have the potential to be major catalysts of change in the implementation of recent international agreements such as the Paris Agreement (UNFCCC, 2016), the UN 2030 Agenda for Sustainable Development (UN, 2015), the New Urban Agenda (UN, 2017) and the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR, 2015), and that actions to address climate change through mitigation and adaptation at the city level will make crucial contributions to the national efforts aimed at fulfilling international commitments. The IPCC Outline (IPCC, 2024) has also highlighted the importance of understanding and learning from the past to better understand current and future global and city-specific climate trends.

The IPCC's Global Research and Action Agenda on Cities and Climate Change Science (IPCC, 2019) has also observed the need for exploration of low-carbon and environmentally friendly infrastructure options that go beyond traditionally dominant grey infrastructure for transformational climate solutions in developed and rapidly developing urban areas, and that blue/green infrastructure such as open spaces, parks, indigenous biodiversity and bodies of water have a wide array of economic, social and environmental benefits, including greatly improving urban form and enhancing the effectiveness and/or reducing demand on other infrastructure sectors.

5.3 MITIGATION AND ADAPTATION

Cities and settlements are critical for achieving emissions reductions and advancing climate-resilient development. Similarly, the integration of culture into urban policy and planning is critical to developing sustainable and resilient cities (Dodman et al., 2022). Key elements in cities' urban fabric for mitigation and adaptation include considering the design and planning of infrastructure, achieving a compact urban form through appropriate land use, a mixed-use design of urban spaces and supporting active mobility and/or public transport (IPCC, 2023*b*).

Historic cities, including World Heritage Cities, have exhibited such urban elements for centuries. Urban heritage is therefore a crucial resource in climate action. Historic centres are characterized by compact, human-scaled designs, with a mixed use of buildings that combine jobs and housing in the same location, thus reducing the need for long-distance travel, resulting in lower energy consumption and greenhouse gas emissions compared to sprawling suburban developments. Urban climate mitigation and adaptation strategies also include adapting traditional building techniques and planning solutions to optimize climate conditions in historical cities, alongside the incorporation of nature-based solutions (NbS) or nature-positive solutions into spatial planning. Efficient design, construction, retrofitting and use of buildings, reducing their energy and material consumption and substituting building materials, are important climate actions (Labadi et al., 2021).

Historic old town of Trogir, Croatia, showcasing a compact, mixed-use and walkable urban form. © OPIS Zagreb/Shutterstock.com*

World Heritage Cities are immense repositories of traditional knowledge accumulated over millennia. Historic buildings and sites showcase traditional building materials and techniques that prioritize local resources, artisanship and climate responsiveness. They are demonstrative of how to build with low-carbon, local, natural, repairable materials, how to build to maximize passive performance and human comfort (Box 5) and how to use buildings in ways that optimize energy use, all of which reduce a building's carbon footprint. Historic cities can serve as inspirations for environmentally regenerative and low-energy new construction and retrofitting without maladaptation by conserving and reusing existing buildings (Labadi et al., 2021). This also respects the local values, history and culture of the people who inhabit historical urban spaces, in turn maintaining their connection to their environment, preserving their sense of place and helping foster a cultural identity (Box 6). Furthermore, historic cities and settlements reflect traditional and local environmental knowledge of place including geography, water and land management and resource extraction. This knowledge offers vital lessons for resilience as well as adaptation and mitigation strategies.

BOX 5 | INSPIRATIONS FROM A WORLD HERITAGE CITY

Medina of Tunis, Tunisia
Inscribed in 1979 on the World Heritage List.

The traditional dwelling in the medina is the courtyard house. This is a common model for domestic architecture in North Africa and the Middle East. The Medina of Tunis courtyard houses follow a similar typology to other historical Islamic cities, adapted to local traditions, construction materials and environmental factors. Their plan is introverted, with rooms looking towards the central open space, which provides privacy and comfort and serves a passive cooling function.

Cross-section of traditional Dar El Haddad courtyard house. © UNESCO / Carlota Marijuan Rodriguez, based on 1967 drawings by the Institut National d'Archeologie et Arts, kept at the UNESCO Archives.

BOX 6 | INSPIRATIONS FROM A WORLD HERITAGE CITY

The works of Jože Plečnik in Ljubljana, Slovenia – Human-centred urban design
Inscribed in 2021 on the World Heritage List.

The urban design of 'Plečnik's Ljubljana' is based on the architect's profoundly human vision for the city, based on an architectural dialogue with the older city while serving the needs of emerging modern twentieth-century society.

Implemented during the interwar period, a series of public spaces and public institutions were sensitively integrated into the pre-existing urban, natural and cultural context. Based on a harmonic relationship between the built cityscape and its natural features, the historical city centre was interpreted and developed in the context of existing buildings and spaces and tailored to suit the inhabitants. The World Heritage property provides an example of how historical context can be respected, acknowledged and combined with the needs of a modern society, while also aligning with the principles of a sustainable, resilient city, such as a human-centred walkable design, integrated within a matrix of the city's natural features.

Cobblers' Bridge in Ljubljana, Slovenia. © Museum and Galleries of Ljubljana/Matevž Paternoster *

The potential for mitigation and adaptation varies significantly across the Mediterranean, with north-western countries exhibiting stronger potential than countries in the south and east (Ali et al., 2022). Planning is a vital factor in building climate resilience (European Commission, 2022), as it enables communities to anticipate risks, allocate resources efficiently and implement sustainable strategies to reduce emissions and adopt sustainable adaptation practices against the impacts of climate change (Box 7). According to reporting in the Third Member State Consultation on the Implementation of the HUL Recommendation (UNESCO, 2023*c*), only around half of the reporting cities and settlements globally mention having strategies in place to diminish the impact of climate change on urban heritage. Considering a similar trend for the Mediterranean region, there is significant room for improvement in terms of planning, learning and sharing knowledge. The use of technology can play a significant role. In order to better understand future climate trends, there is a need for high-quality data, which can be provided by EO programmes, such as the Copernicus Programme. Partnerships between governmental or intergovernmental organizations and data-providing institutions can serve to effectively support mitigation and adaptation efforts by making available to the largest number of stakeholders the wealth of EO data (Copernicus, 2022). An example of a successful framework for such cooperation is the Urban Heritage Climate Observatory (UHCO) that provides a forum for relevant partners from the EO and cultural heritage disciplines to share knowledge, methodologies and data to benefit World Heritage Cities and urban heritage (UHCO, 2021). EO technologies, for example, enable continuous monitoring of cities, which helps in assessing environmental and climate conditions and aids in detecting potential changes and threats (Box 8). In this way, EO can help in developing effective mitigation and adaptation strategies and enhancing the level of preparedness. In the case of World Heritage Cities, EO can contribute to better documentation of the cultural heritage's state of preservation, which is of paramount importance for the design of effective and sustainable conservation measures prioritizing the sites with limited capacities for facing the pressures imposed by anthropogenic climate change.

BOX 7 | BUILDING CLIMATE RESILIENCE OF CULTURAL HERITAGE USING CRIDA

Integrating climate change considerations into water resources planning is increasingly important due to the impact of climate change on water-related disasters and water security.

The Climate Risk Informed Decision Analysis (CRIDA) approach can be applied to address disaster risk reduction, urban water security and to promote nature-based solutions. As a tool, CRIDA provides a step-by-step framework to identify potential water security risks and develop adaptation pathways for climate hazards connected to water. A participatory and bottom-up approach, CRIDA offers a step-by-step process to address challenges in sustainable water management.

To effectively address not just threats to urban heritage, but also the opportunities and potential to assist in mitigation and adaptation, it is necessary for such strategies to integrate knowledge of and from historic urban areas and their tangible and intangible heritage. Significant efforts are therefore needed to support historic cities and settlements to document and map traditional practices related to climate adaptation measures that are being practised or used to be practised in their city/settlement (UNESCO, 2023*c*). Furthermore, support is necessary for translating national-level laws and policies into implementable regulations and guidelines at the local level.

World Heritage Cities could serve as observatories and models of good practice, exemplifying sustainable mitigation and adaptation techniques and projects, while at the same time promoting sustainable social and economic development through innovative management, financing models and capacity-building activities in the communities. As Morel et al. (2022) noted, 'Culture and heritage are keys to understanding the spatial dimensions of cities and the interplay of this with circular economies; mobility and walkability; local self-sufficiency; gastronomy and healthy living'. Furthermore, heritage methodologies and culturally sensitive approaches have the potential to achieve more equitable inclusion of diverse individuals and communities in adaptation and mitigation decision-making processes at urban scales (Morel et al, 2022).

BOX 8 | EARTH OBSERVATION FOR CULTURAL HERITAGE

Earth observation products and current data can support knowledge of the environmental context and evaluate specific risks to heritage sites. For example, the European Ground Motion Service (EGMS) from the Copernicus Land Monitoring Service is a valuable tool for providing information of high relevance for the monitoring of ground subsidence in and around cultural heritage sites.

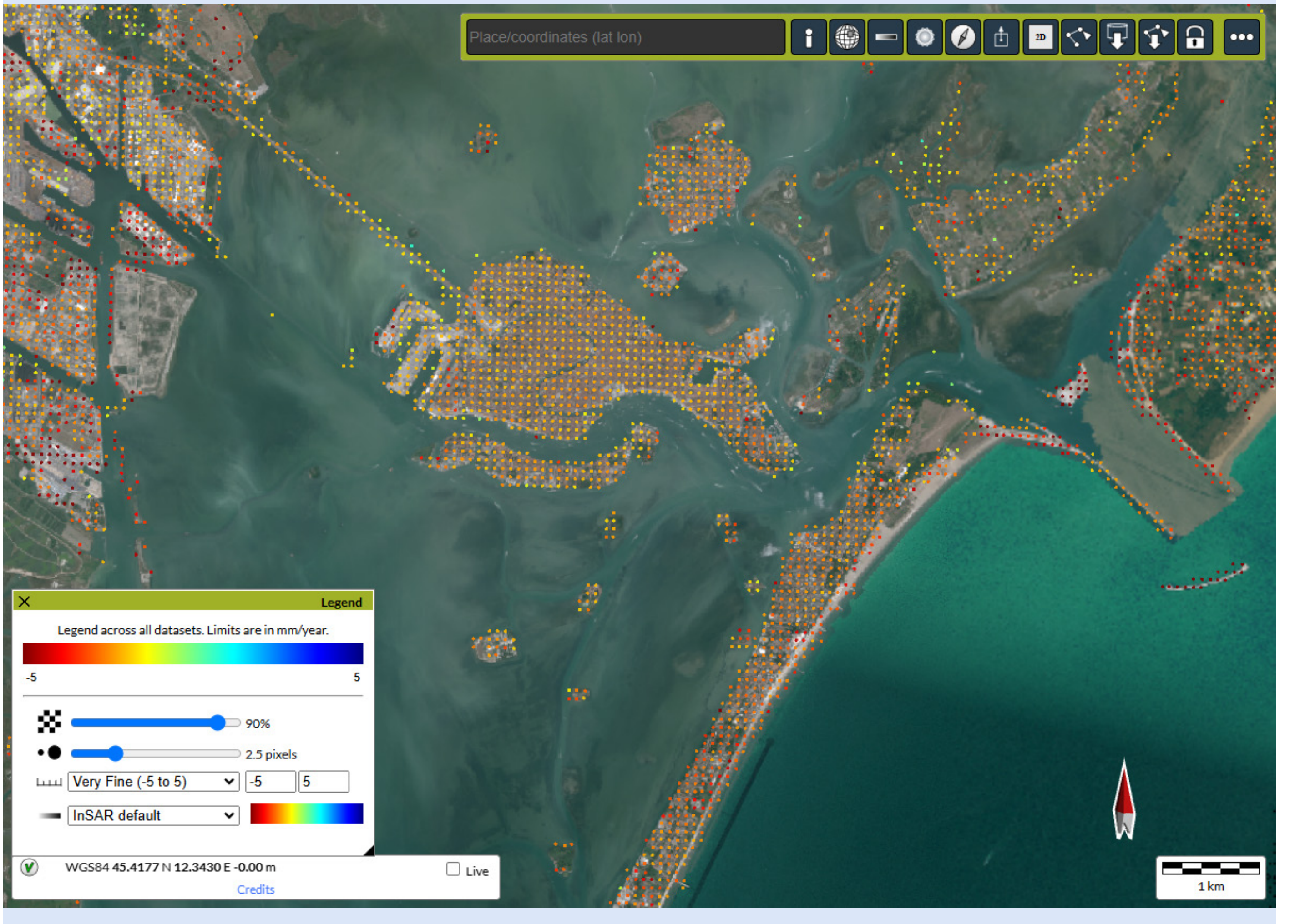


Image retrieved from the EGMS web portal, showing data points that indicate ground subsidence in areas of Venice, Italy. *Source:* Copernicus Land Monitoring Service/European Environment Agency

6 CONCLUSIONS AND WAYS FORWARD

6.1 CONCLUSIONS

6.1.1 CURRENT REPORTING OF CLIMATE HAZARDS ON THE WORLD HERITAGE CITIES IN THE MEDITERRANEAN REGION

- Nearly two-thirds (59%) of World Heritage Cities in the Mediterranean region report already experiencing at least one climate hazard, while nearly one-fifth (18%) of the World Heritage Cities reporting facing three or more climate hazards.
- 32% of Mediterranean World Heritage Cities report experiencing temperature changes, nearly a third (28%) report experiencing flooding and a quarter report experiencing storms (25%) and drought (24%).
- Only 4% of World Heritage Cities reported changes to oceanic waters and 2% reported desertification, which may be due to the less visible and measurable impacts, such as coral reef bleaching and wildfires, on urban heritage properties as compared to natural heritage. It may also be due to the challenges of monitoring and reporting slow-onset events.
- Temperature changes are the most prominently reported hazard for coastal and inland cities. This impact is more common in inland cities (37%) than in coastal cities (27%). Coastal areas face equal risks from flooding and storms (27%), while drought (32%) is the second most significant hazard for inland cities, following temperature changes.
- World Heritage Cities in the north-western and western subregions of the Mediterranean report the highest number of climate hazards, with nearly three-quarters of these experiencing at least one such hazard.
- In the World Heritage Cities of the Mediterranean, flooding is the most frequently reported climate hazard across the north-western, north-central and southern subregions, with 50% of cities reporting floods in the north-western and 63% in the north-central subregion. Meanwhile, the western and central subregions primarily report temperature changes, while the eastern subregion experiences a mix of storms and temperature changes.
- While reports suggest that cities in the southern Mediterranean subregion experience the fewest climate hazards, this may in fact be related to inadequate or inconsistent reporting, limited data, or a lack of monitoring. It may also be that some are experiencing different types of hazards not included in the multiple choice offered to them in the questionnaire.

6.1.2 FUTURE SCENARIOS OF CLIMATE IMPACTS ON THE WORLD HERITAGE CITIES IN THE MEDITERRANEAN REGION

By the end of the twenty-first century and under RCP8.5:

- More than half (51%) of the selected World Heritage Cities will face at least two climate threats and thus potential impacts, in parallel, with unforeseen cumulative effects.
- World Heritage Cities in the north-western, north-central, western and eastern subregions will be the most vulnerable ones to the impacts of extreme events.
- The projected severity of the flooding events will increase over time for the majority of the World Heritage Cities, followed by increasingly reduced annual precipitation (drought conditions) and extreme heat events. A discernible west-to-east pattern is revealed, as towards the eastern Mediterranean, the increasing number of threats compound and amplify the potential impacts of any one threat.
- All World Heritage Cities in the north-west and north-central subregions of the Mediterranean region will face at least two threats, with the majority in the north-central subregion facing three threats. 63% of World Heritage Cities in the western subregion of the Mediterranean region will face at least two threats. Most World Heritage Cities in the central (73%) and southern (63%) subregions of the Mediterranean are projected to face at least one threat.
- North-western, central and north-central subregions are projected to be heavily impacted by flooding,

while the western, southern and eastern parts of the region are projected to have reduced precipitation leading to drought-like conditions. Extreme heat conditions are most significantly projected for the eastern subregion of the Mediterranean.

- Furthermore, sea-level rise is estimated to be in the range of 0.5 m to 0.67 m, posing an additional threat to all coastal World Heritage Cities in the region, with a greater rise in the central part of the Mediterranean Basin.

It is significant to note that what has been predicted in the 'worst-case' future scenario (RCP8.5) for 2100 is already being experienced at many World Heritage Cities, with the projections showing it will only get worse. The geographical distribution of threats and their potential impacts predicted for the future will mostly remain the same as those already observed in the current scenario. Flooding in the north-western and north-central subregions will still be the main threat. The western and central subregions will still be threatened mainly from drought and extreme heat. Presently, a majority of the analysed World Heritage Cities face one hazard; however, the prediction for the future is that a majority of the World Heritage Cities in the region will face two or more hazards. This study does not map the intensity or frequency of the events; however, based on recent experiences in several regions, we can conclude that along with the increased number of threats these cities will face, their intensity and the scale of their impacts will also increase. Such exposure to multiple hazards greatly escalates the likelihood of significant negative impacts to their valuable heritage. Furthermore, multiple hazards result in compounded impacts and cascading effects from the loss and damage to the biodiversity and ecosystem services as well as territory, in addition to the compounded losses to the cultural heritage of the World Heritage City (see UNFCCC, 2024*a*).

6.1.3 SIGNIFICANCE OF THE LOSS OF CULTURAL HERITAGE IN WORLD HERITAGE CITIES AND ACTIONS TO RESPOND

Properties on the UNESCO World Heritage List are inscribed for their OUV that must be protected, including its conditions of authenticity and integrity. The OUV goes beyond national or regional significance to being of value for all of humanity and must be preserved for future generations. Thus, any loss or damage to such properties is a loss to humanity for generations to come.

Loss of heritage in historic cities has a direct economic impact due to the loss of valuable structures, historic fabric and related loss of livelihoods for the local communities. This is compounded by related impacts to the management of water and loss of biodiversity and ecosystem services, degradation of land and marine ecosystems, as well as reductions in territory.

The loss of cultural heritage is first and foremost a loss of built fabric, land (including agricultural land), infrastructure, the intangible heritage bound up with them and the associated economic losses. Cities and settlements that are impacted must find ways to enhance resilience or rebuild in the same place where communities are displaced and moved due to rising waters. The increasing intensity and frequency of extreme weather events, along with reduced access to resources and declining comfort in Mediterranean cities can threaten local economies, businesses and people's lives, particularly those reliant on tourism (e.g. small businesses, maritime transport, entertainment and trade). These economic losses can result in impoverishment for vulnerable communities, deepening existing inequalities or giving rise to new forms of disparity.

NELs of climate change with regard to cultural heritage include the loss or damage to invaluable cultural heritage assets, such as potential loss and damage to the OUV of properties inscribed on the UNESCO World Heritage

List. These losses also encompass the erosion of cultural knowledge – particularly on natural ecosystems – reducing the ability to adapt to environmental changes. As local resources and knowledge are lost, communities face challenges in meeting their socio-economic development needs. Anticipated shortages in water and food will disrupt traditional ways of life and further compromise the ability of communities to protect and manage their heritage, both tangible and intangible (UNFCCC, 2024*a*). While the loss of cultural heritage has immediate impacts on local communities, it also affects humanity as a whole, particularly when the heritage is part of the OUV. Such losses also contribute to a decline in cultural diversity, undermining inclusive sustainable development.

Responding to the risks and impacts of climate change on World Heritage Cities requires a wide range of actions, from international policies to national and local strategies and integrated policies and measures. International agreements must urgently recognize the vulnerability of cultural heritage to climate change and emphasize its role as a resource for climate resilience and adaptation, especially in World Heritage Cities. Protecting and safeguarding cultural heritage is itself a significant climate action. Regular assessment and monitoring, as well as integrating cultural heritage into Climate Action Plans (CAP) and policies at all governmental levels, from the national to the local, is essential. The UNESCO 1972 Convention for the Protection of the World's Cultural and Natural Heritage (World Heritage Convention) (UNESCO, 1972) and the UNESCO HUL Recommendation (UNESCO, 2011) provide a strong foundation for protecting urban heritage in historic cities and settlements, both those inscribed on the World Heritage List and those that are not. The UNESCO 2023 Policy Document on Climate Action for World Heritage offers a guiding framework (UNESCO, 2023*b*) to assist States Parties with the implementation of comprehensive climate action, including mitigation and adaptation measures, resilience building, innovation and research.

World Heritage Cities are also valuable assets for mitigation and adaptation strategies, offering opportunities through the reuse of existing buildings, including heritage structures and adaptation of traditional building techniques and planning solutions to optimize climate conditions in historic cities, and sustainable safeguarding and management of tangible and intangible cultural heritage. These cities, with their walkable neighbourhoods, compact designs and green spaces, depending on historical context, typically have lower energy consumption and greenhouse gas emissions compared to new developments. Historic cities are immense repositories of traditional knowledge, accumulated over centuries, which can inspire environmentally regenerative and low-energy construction, retrofitting without maladaptation and the conservation and reuse of existing buildings, especially in developed areas. Furthermore, historic cities and settlements reflect traditional and local environmental knowledge of place, including geography, water and land management and resource extraction. This knowledge offers vital lessons for resilience and effective adaptation and mitigation strategies.

6.2 WAYS FORWARD

The World Heritage properties represent some of the world's most outstanding cultural and natural heritage. They are inscribed on the UNESCO World Heritage List for their OUV, a value so great as to be of significance to all humanity, which must be protected and transmitted to future generations. As such, the 196 States Parties to the Convention commit to protecting heritage in their territories, but are specifically obliged to ensure the protection of the OUV of the properties on the World Heritage List. This is equally true for World Heritage Cities. While this study has looked at the hazards, threats and potential impacts of climate change on World Heritage Cities in the Mediterranean, the actual impacts, direct and indirect, on each city and its World Heritage property need to be carefully monitored and assessed. Furthermore, the actual impacts of such hazards and climate change-related events, of both rapid and slow onset, on the OUV of each World Heritage property, need to be monitored and assessed with a view to averting, minimizing and addressing loss and damage.

Beyond the 114 World Heritage Cities included in this study, of the 952 cultural heritage properties inscribed on the World Heritage list, nearly 70% are in urban areas (UNESCO, n.d.d). The World Heritage Cities in this study represent only a fraction of the broader challenges likely faced by numerous other cities and settlements in the region. While the climate data for this study is modelled to project the future for World Heritage Cities in the Mediterranean region, the lessons for actions to respond to the losses due to the climate impacts in this region could be extended to historic cities and settlements in other regions as well.

The proposed actions outlined below align with UNESCO policies and instruments adopted by the Member States of UNESCO, the 2023 Policy Document on Climate Action for World Heritage (UNESCO, 2023*b*), the 1972 Convention on the Protection of the World's Cultural and Natural Heritage (UNESCO, 1972), the 2011 Recommendation on the Historic Urban Landscape (UNESCO, 2011), the UNFCCC 2024 Technical Paper on Non-Economic Losses (UNFCCC, 2024*a*), the UNESCO-ICOMOS Global Research and Action Agenda on Culture, Heritage and Climate Change (Morel et al., 2022) and the Kunming-Montreal Global Biodiversity Framework (CBD, 2022)

1. **Monitoring and assessing risks:** Regularly monitoring and assessing climate risks and vulnerabilities, as well as loss and damage to the value of World Heritage properties in urban areas, and more broadly to cultural heritage in historic cities and settlements, using diversity of knowledge systems and disciplines combining scientific research and data, including innovative tools such as Earth observation and tailored applications of climate modelling, together with alternative forms of knowledge and documentation such as visualization, mapping and storytelling, to integrate traditional and indigenous knowledge systems that actively engage local communities. Regularly reporting through the UNESCO World Heritage Periodic Reporting exercise and the implementation of the UNESCO Culture|2030 Indicators. Considering actions to assess the impact of damage to cultural heritage on livelihoods dependent on heritage-related activities, to inform integrated strategies for mitigation and resilience.

2. **Comprehensive vulnerability and risk evaluation:** Fostering the development and use of a commonly agreed methodology for vulnerability evaluation of cultural heritage categories in historic cities, which, once integrated with climate hazard analysis, allows for a comprehensive understanding of the associated risks.

3. **Climate adaptation and heritage protection:** Advancing necessary climate change adaptation actions to avert, minimize and respond to climate impacts on heritage values. For World Heritage properties, this should align with the World Heritage Convention and its purpose to conserve, present and transmit Outstanding Universal Value of the property, rather than a broad agreement to proceed with all possible adaptation measures. Adaptation strategies should also address losses to intangible heritage and creative industries associated with these sites, to avoid deepening social and economic inequalities.

4. **Integrating heritage into policy and planning:** Integrating cultural heritage protection into national and local adaptation plans and policies, including connections with social integration policies, and mainstreaming World Heritage properties as valuable repositories of good practices for adaptation solutions that enhance resilience of heritage values and local communities. Urban planning strategies should also incorporate heritage considerations, integrate adaptive measures and draw lessons from their urban heritage.

5. **Advancing mitigation strategies:** Advocating and advancing mitigation strategies by aligning the management of historic cities and settlements with the implementation of strategies that reduce greenhouse gas emissions, informed by diverse knowledge systems and practices, including traditional knowledge

and Indigenous peoples and including associated living heritage elements. As the IPCC (Dodman et al., 2022) has indicated, transitions in energy, land use, urban areas, infrastructure (including transport and buildings) and industrial systems, among others, requires significant greenhouse gas emissions management, including reductions, removals, reuse and recycling in all sectors, including manufacturing, transport, tourism, construction and infrastructure development, forestry, health, water management and agriculture

6. **Leading transformative change:** Leading and catalysing transformative change with World Heritage exemplified by decisions that contribute towards making World Heritage properties carbon neutral, as far as possible, and more resilient and better adapted to a changing climate, while safeguarding their Outstanding Universal Value. By acting as exemplars of climate action, World Heritage properties may serve as catalysts for change in the wider policy, economic, environment and social sectors for the benefit of present and future generations. World Heritage properties can embrace transformative change to exemplify the change the world needs (UNESCO, 2023*b*). Solutions for safeguarding the properties can only be found if they are connected to spatial, social and cultural transformations beyond the borders of a World Heritage property. Transformative change should also prioritize equitable outcomes, ensuring that those who depend on heritage for their livelihoods are supported in the face of climate challenges

7. **Capacity building and knowledge sharing:** Building capacities and raising awareness among all stakeholders, drawing on resources such as the Climate Action Toolkit under development by UNESCO, ICCROM, IUCN and ICOMOS; sharing knowledge, including innovative and best practices, via platforms like the UNESCO World Heritage Canopy and the IUCN Panorama Nature Culture Community. All relevant stakeholders and rights holders at all levels should work together in a spirit of global partnership, inclusion and solidarity. This should include strategies to address the economic and social vulnerabilities of communities that rely on heritage-related industries.

8. **Enhancing resilience to extreme events:** Reducing the risk of climate-related extreme events and disasters, including slow-onset events. Enhancing climate resilience for historic cities and settlements by enhancing the resilience of cultural resources and strengthening the resilience of local communities. This also requires thorough documentation, monitoring and protection of all cultural heritage values and elements tools, such as the UNESCO Urban Heritage Atlas. Resilience measures must also address the economic losses experienced by communities whose livelihoods are tied to cultural heritage.

9. **Integrated urban development for climate action:** Reducing vulnerabilities in historic cities and settlements by advancing the UN 2030 Agenda for Sustainable Development, integrating cultural heritage in spatial and strategic urban planning, blue/green and grey infrastructure development, transport, land use and energy. Actions to address climate change at the city level will make crucial contributions to national efforts aimed at fulfilling international commitments. Emphasizing equitable urban development ensures that economic opportunities tied to cultural heritage are preserved and expanded for all.

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APPENDIX 1

Table A1. List of World Heritage Cities included in the study, divided by their respective subregions.

North-western subregion	**8**
France	**8**
	Cathedral of Notre-Dame, Former Abbey of Saint-Rémi and Palace of Tau, Reims
	Historic Site of Lyon
	Le Havre, the City Rebuilt by Auguste Perret
	Paris, Banks of the Seine
	Place Stanislas, Place de la Carrière and Place d'Alliance in Nancy
	Provins, Town of Medieval Fairs
	Strasbourg, Grande-Île and Neustadt
	The Great Spa Towns of Europe (France)
North-central subregion	**8**
Albania	1
	Historic Centres of Berat and Gjirokastra
Bosnia and Herzegovina	1
	Old Bridge Area of the Old City of Mostar
Croatia	4
	Episcopal Complex of the Euphrasian Basilica in the Historic Centre of Poreč
	Historic City of Trogir
	Historical Complex of Split with the Palace of Diocletian
	Old City of Dubrovnik
Montenegro	1
	Natural and Culturo-Historical Region of Kotor
Slovenia	1
	The works of Jože Plečnik in Ljubljana – Human Centred Urban Design
Western subregion	**31**
France	**7**
	Arles, Roman and Romanesque Monuments
	Bordeaux, Port of the Moon
	Episcopal City of Albi
	Historic Centre of Avignon: Papal Palace, Episcopal Ensemble and Avignon Bridge
	Historic Fortified City of Carcassonne

	Nice, Winter Resort Town of the Riviera
	Roman Theatre and its Surroundings and the 'Triumphal Arch' of Orange
Portugal	**4**
	Garrison Border Town of Elvas and its Fortifications
	Historic Centre of Évora
	Historic Centre of Oporto, Luiz I Bridge and Monastery of Serra do Pilar
	Monastery of the Hieronymites and Tower of Belém in Lisbon
Spain	20
	Alhambra, Generalife and Albayzín, Granada
	Aranjuez Cultural Landscape
	Archaeological Ensemble of Mérida
	Cathedral, Alcázar and Archivo de Indias in Seville
	Historic Centre of Cordoba
	Historic City of Toledo
	Historic Walled Town of Cuenca
	Monuments of Oviedo and the Kingdom of the Asturias
	Old Town of Ávila with its Extra-Muros Churches
	Old Town of Cáceres
	Old Town of Segovia and its Aqueduct
	Palau de la Música Catalana and Hospital de Sant Pau, Barcelona
	Paseo del Prado and Buen Retiro, a landscape of Arts and Sciences
	Renaissance Monumental Ensembles of Úbeda and Baeza
	Roman Walls of Lugo
	Santiago de Compostela (Old Town)
	Ibiza
	Works of Antoni Gaudí, Barcelona
	Old City of Salamanca
	University and Historic Precinct of Alcalá de Henares

Central subregion	33
Holy See	2
	Vatican City
	Historic Centre of Rome, the Properties of the Holy See in that City Enjoying Extraterritorial Rights and San Paolo Fuori le Mura
Italy	28
	18th-Century Royal Palace at Caserta with the Park, the Aqueduct of Vanvitelli and the San Leucio Complex
	Assisi, the Basilica of San Francesco and Other Franciscan Sites
	Botanical Garden (Orto Botanico), Padua
	Cathedral, Torre Civica and Piazza Grande, Modena
	Church and Dominican Convent of Santa Maria delle Grazie with 'The Last Supper' by Leonardo da Vinci
	City of Verona
	Costiera Amalfitana
	Crespi d'Adda
	Early Christian Monuments of Ravenna
	Ferrara, City of the Renaissance and its Po Delta
	Genoa: Le Strade Nuove and the system of the Palazzi dei Rolli
	Historic Centre of Florence
	Historic Centre of Naples
	Historic Centre of Siena
	Historic Centre of Urbino
	Ivrea, industrial city of the 20th century
	Late Baroque Towns of the Val di Noto (South-Eastern Sicily)
	Mantua and Sabbioneta
	Piazza del Duomo, Pisa
	Portovenere, Cinque Terre and the Islands (Palmaria, Tino and Tinetto)
	Syracuse and the Rocky Necropolis of Pantalica
	The Porticoes of Bologna
	The Trulli of Alberobello
	Historic Centre of San Gimignano
	City of Vicenza and the Palladian Villas of the Veneto
	Historic Centre of the City of Pienza

	Venice and its Lagoon
	The Great Spa Towns of Europe (Italy)
Malta	1
	City of Valletta
San Marino	1
	San Marino Historic Centre and Mount Titano
Tunisia	1
	Punic Town of Kerkuane and its Necropolis
Southern subregion	16
Algeria	3
	Kasbah of Algiers
	M'Zab Valley
	Tipasa
Egypt	1
	Historic Cairo
Libya	1
	Old Town of Ghadamès
Morocco	8
	Ksar of Ait-Ben-Haddou
	Medina of Essaouira (formerly Mogador)
	Medina of Fez
	Medina of Marrakesh
	Medina of Tétouan (formerly known as Titawin)
	Portuguese City of Mazagan (El Jadida)
	Historic City of Meknes
	Rabat, Modern Capital and Historic City: a Shared Heritage
Tunisia	3
	Kairouan
	Medina of Sousse
	Medina of Tunis

Eastern subregion	18
Cyprus	1
	Paphos
Greece	5
	Acropolis, Athens
	Medieval City of Rhodes
	Old Town of Corfu
	Paleochristian and Byzantine Monuments of Thessalonika
	The Historic Centre (Chorá) with the Monastery of Saint-John the Theologian and the Cave of the Apocalypse on the Island of Pátmos
Israel	2
	Old City of Acre
	White City of Tel-Aviv – the Modern Movement
Lebanon	4
	Anjar
	Baalbek
	Byblos
	Tyre
State of Palestine	1
	Hebron/Al-Khalil Old Town
Syrian Arab Republic	3
	Ancient City of Aleppo
	Ancient City of Bosra
	Ancient City of Damascus
Türkiye	2
	City of Safranbolu
	Historic Areas of Istanbul

Notes: For the Earth observation analysis in Section 3.2, it should be noted that we utilize a total of 116 Mediterranean World Heritage Cities. This is due to the fact that some World Heritage properties are listed together as one site; however, the cities that make up the property are geographically far apart and therefore need to be separate in order to extract the climate data. For example, the data used in future climate modelling for the historic centres of Berat and Gjirokastra in Albania have been considered separately for the town of Berat and the town of Gjirokastra, due to the significant distance between the two towns (100 km) and differences in data available in each of the cities. The same goes for the sites in the City of Safranbolu in Türkiye.

Two World Heritage Cities, namely the Central Zone of the Town of Angra do Heroismo in the Azores, in the Azores Islands, Portugal, and San Cristóbal de La Laguna in the Canary Islands, Spain, due to their geographical distance and differing climatic conditions.

While Portugal's coast is not directly located in the Mediterranean Basin, traditionally this country is included in other studies regarding the region.

APPENDIX 2

North-western subregion

A significant portion of cities in the north-western subregion face climate change hazards, with 75% experiencing at least one hazard and 12.5% facing three or more hazards simultaneously. However, 25% of cities in the north-west reported no hazards during the reporting period. The north-western subregion appears severely impacted by flooding, with half (50%) of the World Heritage Cities reporting this hazard.

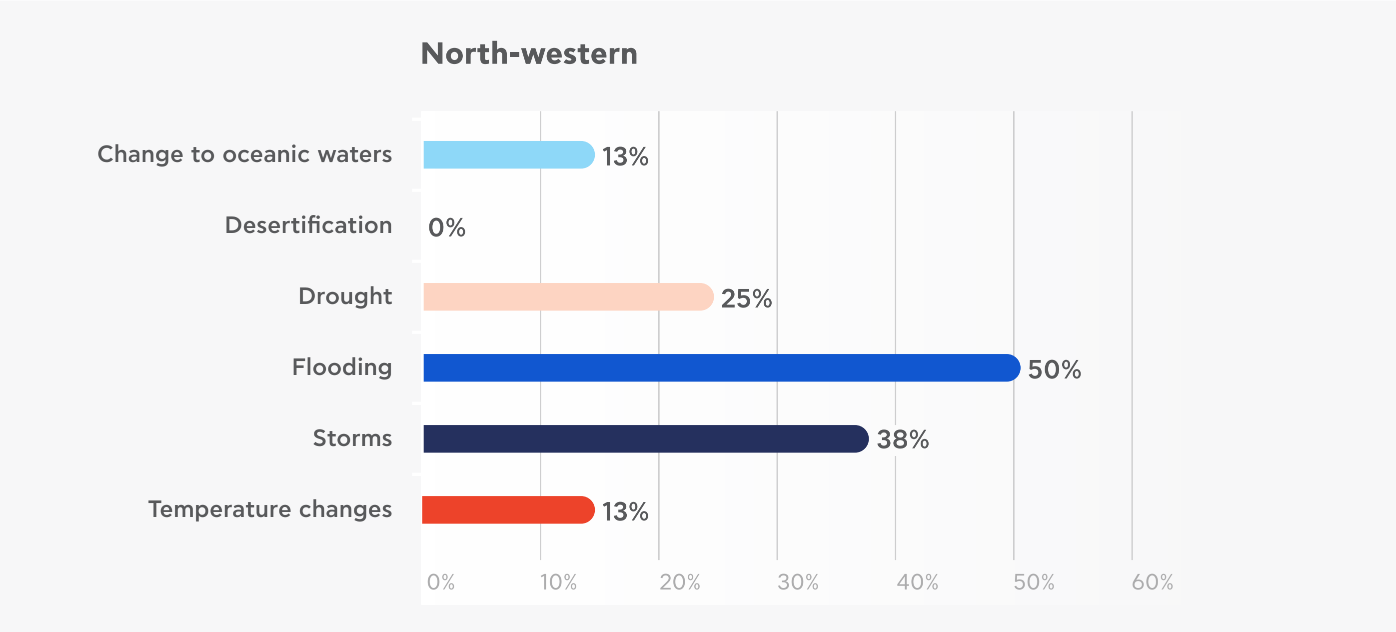

Figure A1. Climate hazards facing the north-western subregion.

North-central subregion

More than half of the cities in the north-central subregion (62.5%) report experiencing at least one hazard and more than a third (37.5%) face three or more hazards simultaneously. However, the same proportion reports no hazards at all. Almost two-thirds (63%) of cities report being impacted by flooding.

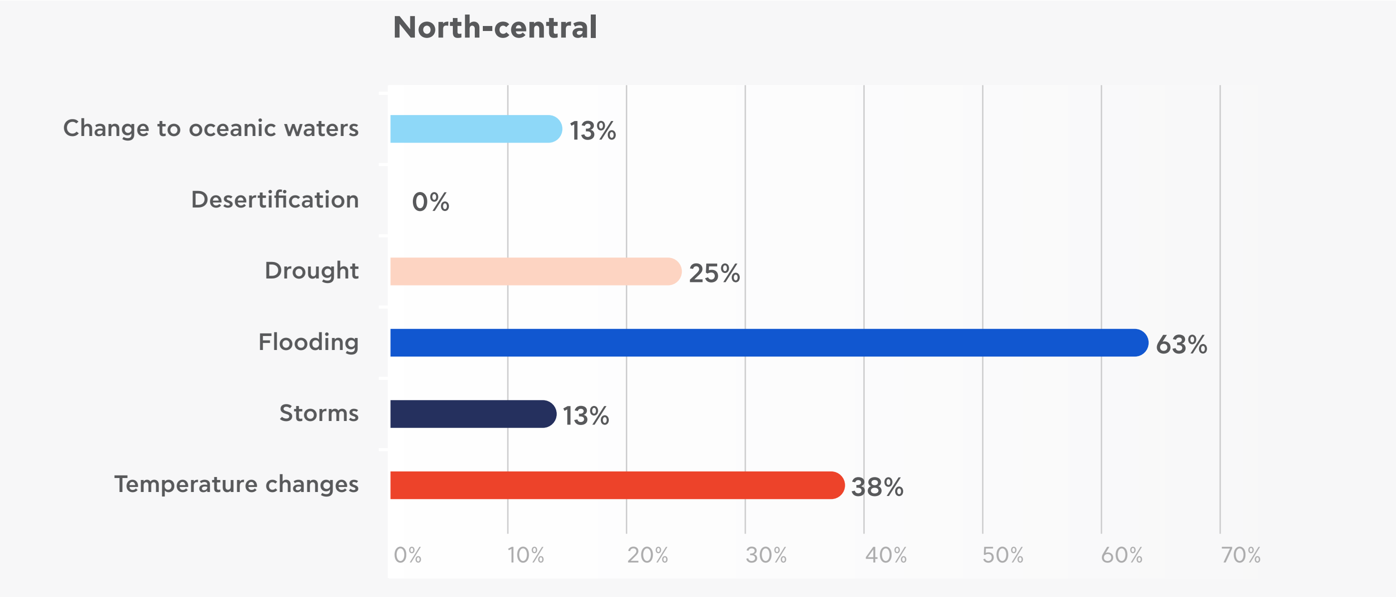

Figure A2. Climate hazards facing the north-central subregion.

Western subregion

More than two-thirds (68%) of the cities in the western subregion report experiencing at least one hazard and 16% face three or more hazards simultaneously, with 32% reporting no hazards at all. The most reported hazard, for 39% of cities, is temperature changes.

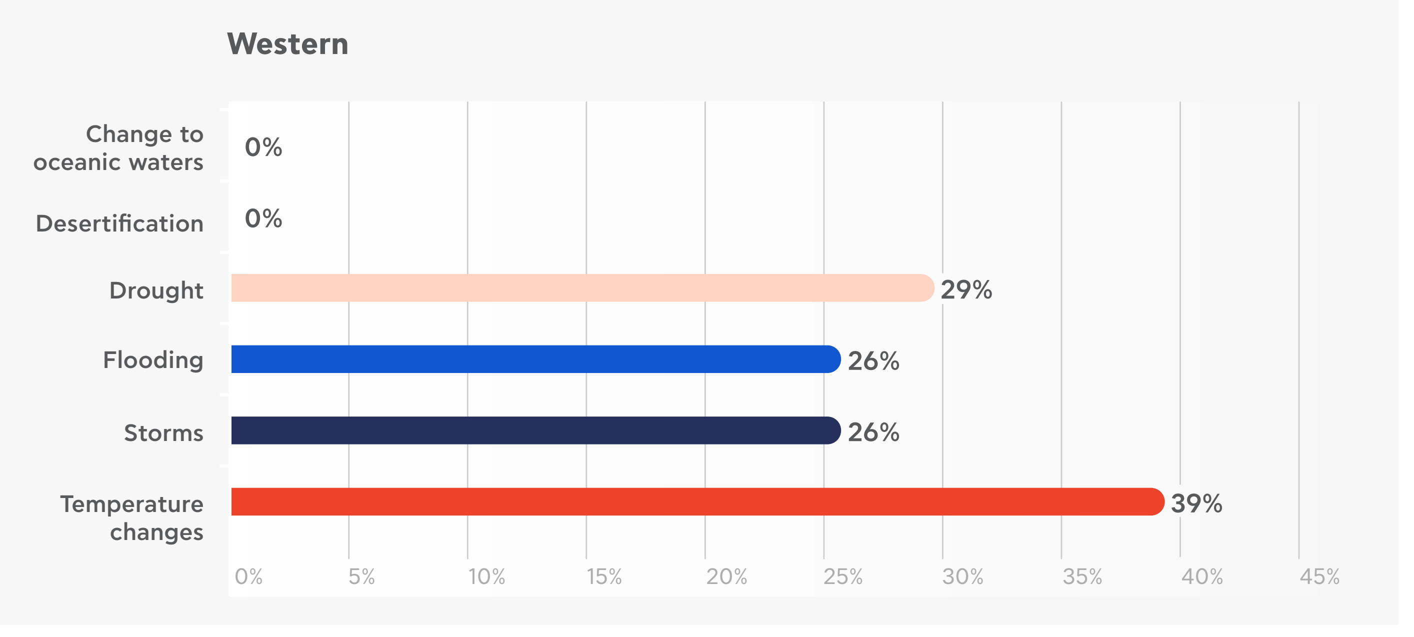

Figure A3. Climate hazards facing the western subregion.

Central subregion

Similarly to the western subregion, over half of the cities in the central subregion (60%) report experiencing at least one hazard and a quarter (24%) face three or more hazards simultaneously, with 40% reporting zero hazards. The most reported hazards are temperature changes (39% of cities), identical to the western subregion.

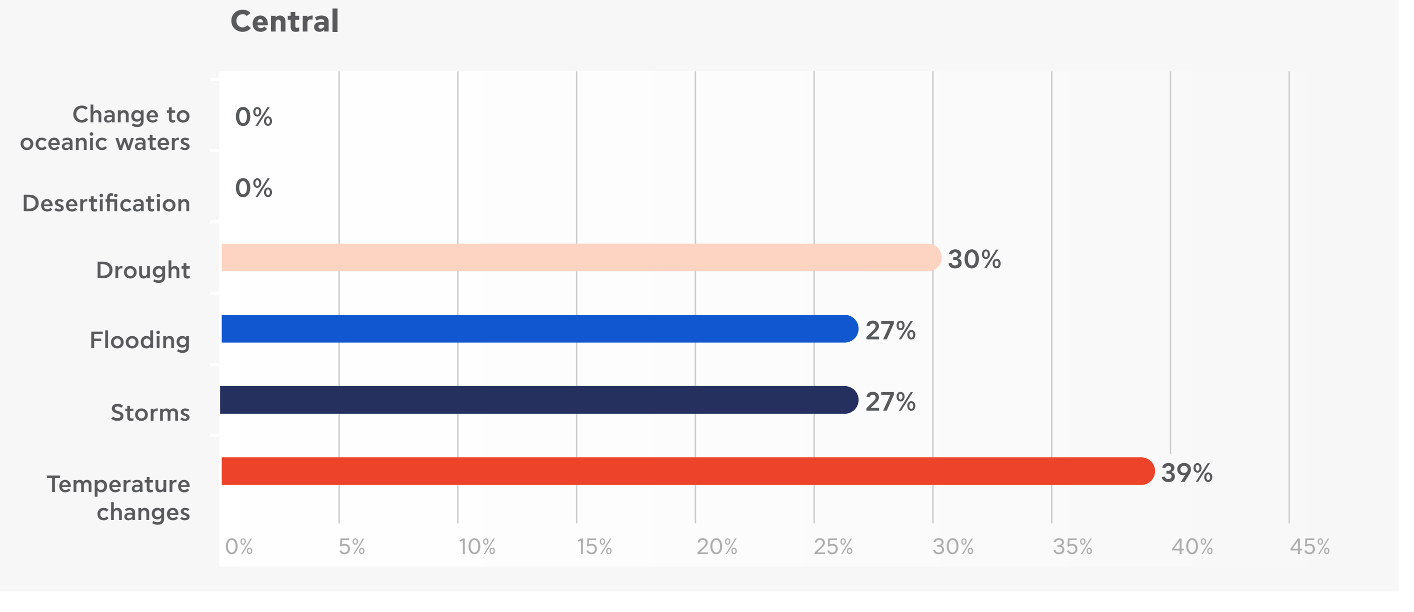

Figure A4. Climate hazards facing the central subregion.

Southern subregion
One-third of cities in the southern subregion (37.5%) report experiencing at least one hazard, with only 6% facing three or more hazards. Over half (62.5%) of cities report no hazards. The most reported hazard, for 25% of cities, is flooding.

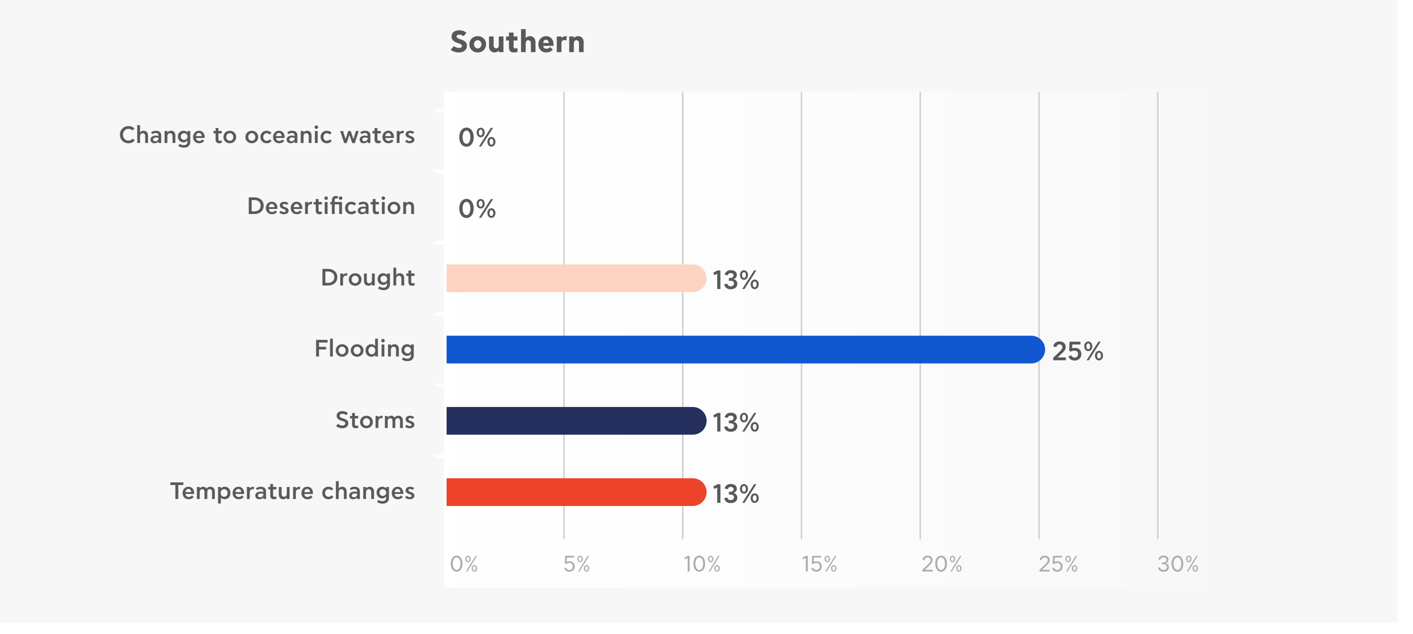

Figure A5. Climate hazards facing the southern subregion.

Eastern subregion
Half of the cities in the eastern subregion (50%) report experiencing at least one hazard and 22% face three or more hazards, with 50% of cities reporting no hazards. The most reported hazards are temperature changes and storms, with all other reported hazards following an equal distribution.

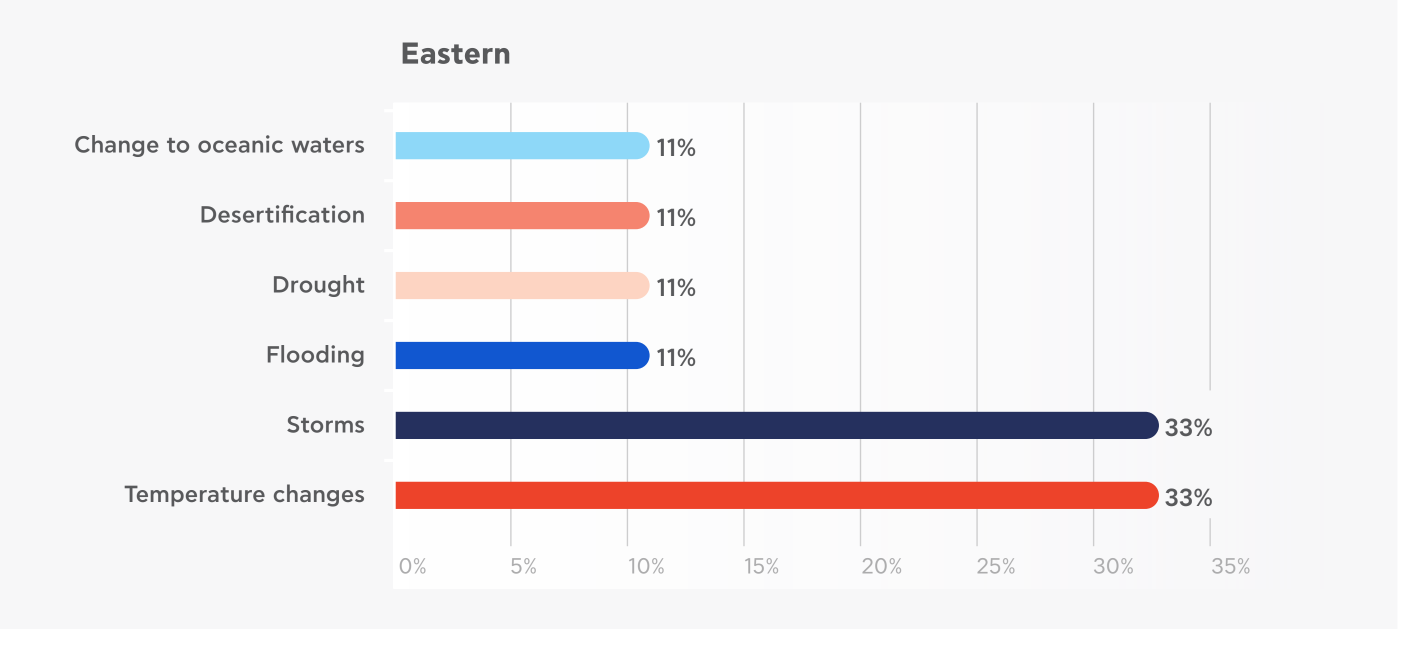

Figure A6. Climate hazards facing the north-central subregion.

APPENDIX 3

Table A2. Definitions of extreme climate indices

Index	Definition	Unit
Days with extreme heat (Tx95p)	Days with maximum temperature greater than the 95th percentile of the time period 1971–2000	days/year
Consecutive dry days (CDD)	Maximum length of a dry spell in a year, that is, the maximum number in a year of consecutive dry days with a daily precipitation smaller than 1 mm/days	days
Days with extreme precipitation (prDays-95p)	Daily precipitation amount on a wet day (P>1mm) greater than the 95th percentile of the time period 1971–2000	days/year
Consecutive 5-day precipitation (Rx5 day)	Highest 5-day precipitation amount. Yearly maximum of cumulated precipitation over consecutive 5-day periods.	mm

Note: The definitions employed are based on the collaborative climate community project Climdex, led by the University of New South Wales in Sydney, Australia (Climdex, n.d.) and the study by Bonazza and Sardella (2023).

APPENDIX 4

As defining thresholds related to potential impacts on cultural heritage is challenging, a 5-level scale ranging from very low to very high was utilized to highlight and prioritize the climate parameters that are projected to be the most relevant and impactful in the Mediterranean region (Table 3). This scale helps the prioritization of the climate parameters that are projected to have the most significant impacts and is based on a percentile ranking scoring, in which values within the range are scored from 0% (for the lowest value) to 100% (for the highest value). This scale offers a proportional assessment of the likelihood that each parameter will affect World Heritage Cities. This approach supports policy-makers to identify and prioritize climate related threats per subregion. Thus, it provides deeper assessment capabilities for the parameters that are proportionally more likely to cause impacts, compared to simply looking at the above average values (as described in Section 3.2).

Table A3. Scale-based analysis of climate all climate parameters per subregion highlighting the regions with the most impactful projections

Subregion	Temperature	Relative humidity	Precipitation	Consecutive dry days	Days with extreme heat	Days with extreme precipitation	Consecutive 5-days precipitation
North-western	L	H	VH	VL	VL	VH	H
North-central	M	H	H	VL	M	H	VH
Western	M	L	M	L	L	L	H
Central	M	H	H	VL	L	M	VH
Southern	M	M	M	M	M	VL	L
Eastern	H	H	M	L	M	L	M

Note: VL – very low; L – low; M – medium; H – high; VH – very high.

ON THE PROJECT/COLLABORATION

The UHCO (Urban Heritage Climate Observatory) Pilot Initiative is a collaborative effort between UNESCO's World Heritage Centre (WHC) and the Greek GEO Office (GGO) within the frame of the Work Programme of the Group on Earth Observations (GEO). The primary goal of this initiative is to inform and support the implementation of mitigation and adaptation strategies that can protect urban cultural heritage from the risks and impacts of climate change. The initiative focuses on exploiting Earth observations (EO) technology to enhance the resilience of World Heritage Cities against disasters stemming from climate change. The UHCO Pilot Initiative aims to serve as a crucial link between the main global policy frameworks and the activities coordinated through GEO.

This report addresses important concerns around the impacts of climate change on cultural heritage. A study of 114 historic cities and settlements in the Mediterranean region, inscribed on the UNESCO World Heritage List, reveals alarming trends: nearly two-thirds of World Heritage cities in the Mediterranean region report having experienced at least one climate hazard already, while nearly one-fifth of the World Heritage cities indicate facing three or more climate hazards. Projections show that more than half of the selected World Heritage cities will face at least two climate threats and their potential impacts, together with unforeseen cumulative effects.

World Heritage properties represent some of the world's most outstanding cultural and natural heritage. They are inscribed on the UNESCO World Heritage List for their Outstanding Universal Value (OUV), a value so great as to be of significance to all humanity, which must be protected and transmitted to future generations. The Mediterranean region is home to around 300 cultural sites inscribed on the UNESCO World Heritage List, with historic cities and settlements accounting for almost half of them. Mediterranean region is very vulnerable to climate change-related impacts of warming, increased drought in an already dry climate and risk of coastal flooding.

The losses and damages from climate change to cultural heritage impacts a wide range of invaluable cultural heritage assets, from the erosion of cultural knowledge reducing the ability to adapt to environmental changes to the loss of cultural diversity that impairs inclusive sustainable development. However, the cultural heritage of World Heritage cities is also a valuable resource for mitigation and adaptation strategies, offering opportunities through the reuse of existing buildings, including heritage structures and adaptation of traditional building techniques and planning solutions to optimize climate conditions in historic cities, and sustainable safeguarding and management of tangible and intangible cultural heritage as reported in this unique study.

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