

Editorial Issue 2/2025

Water, Climate and World Heritage: Navigating Threat and Opportunity

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The frequency and intensity of weather extremes are rising globally due to anthropogenic climate change, the degradation of ecosystems' integrity, and the breach of six out of nine planetary boundaries over the last decades (Richardson et al. 2023). Water is central to understanding these changes and a critical focus for adaptation. According to the World Meteorological Organization (2021; cited in UNESCO 2025a), water-related hazards such as droughts, storms and floods have caused over 90 per cent of the world's major disasters since 1970, and have led to more than 2 million deaths and economic losses exceeding US\$3.6 trillion.

While today water is related to the most significant threats of a changing climate, it has always been a fundamental source of opportunity and a key factor in the rise of civilizations. This long-standing relationship between humans and nature has generated a wealth of sustainable water management practices. Some of the most outstanding examples of this water-culture nexus are protected as World Heritage properties under the 1972 World Heritage Convention. Examples include the Cultural Landscape of Bali Province: the Subak System in Indonesia, the Mill Network at Kinderdijk-Elshout in the Netherlands and the Persian Qanat in Iran.

Water connects natural and cultural elements of heritage with intangible practices. Water management is an inherent part of our cultural heritage; it is also an integral part of "natural" systems and landscapes. A focus on water challenges the current nature-culture dichotomy, a philosophical schism originating with Descartes that remains present within the institutional practices of UNESCO itself. A stronger focus on water-related aspects of cultural heritage can provide impetus for solutions to mitigate climate change and adapt to its consequences, providing a framework for re-evaluating the fractured human-nature relationship that the climate crisis represents.

Climate change was introduced as a scientific concept by Svante Arrhenius in the nineteenth century, yet UNESCO only recognized its potential impact on World Heritage properties in 2005 (World Heritage Committee 2005). In its *Policy Document on Climate Action for World Heritage* (2023), UNESCO affirms that "Climate change is one of the most significant and fastest growing threats to World Heritage properties." A recent assessment by UNESCO and the World Resources Institute (WRI) underscores the scale of the problem, showing that 73 per cent of World Heritage properties face high exposure to water-related hazards, including drought, water stress, and riverine or coastal flooding (UNESCO 2025a).

Direct impacts of climate change – and specifically water-system change – include structural damage and material decay caused by flooding, erosion and landslides; land loss and saltwater intrusion into aquifers from sea-level rise (e.g., in Everglades National Park, where drinking water supplies for nearby communities are at risk); and the destruction of terrestrial and marine heritage by wildfires and changing marine conditions (UNESCO 2025b). Indirect, cascading and systemic consequences that compromise the value, management and social context of heritage include both economic and non-economic losses. These include community displacement, reduced adaptive capacity and the loss of ecosystem services and materials needed to sustain specific practices and knowledge, such as the construction of traditional structures. They also affect traditional governance, cultural diversity, traditional knowledge systems, and archaeological evidence (UNFCCC 2024), potentially resulting in the degradation or loss of Outstanding Universal Value (OUV).

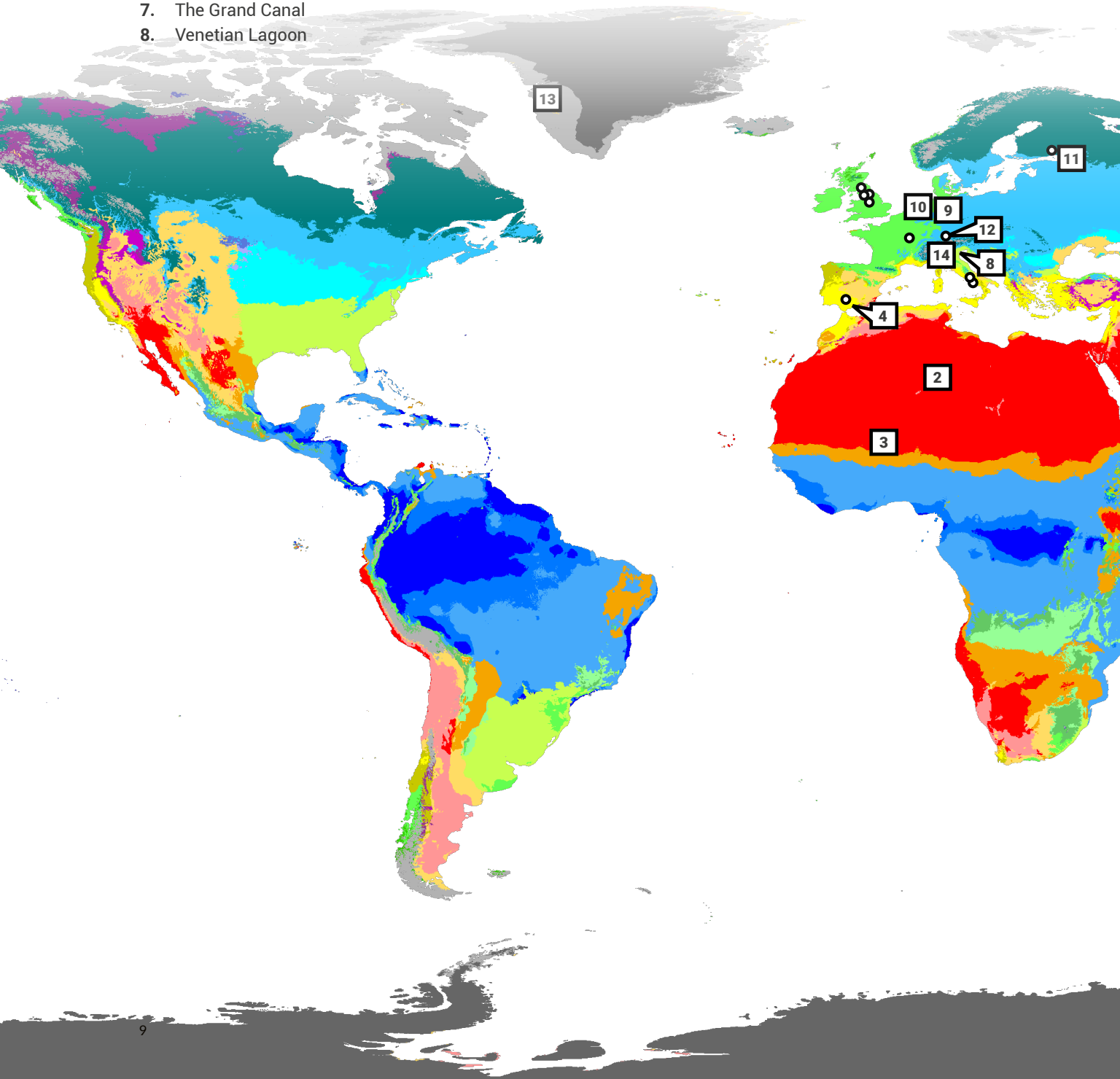
These challenges highlight the dual imperative of water management: safeguarding heritage sites shaped by water as sources of identity and inspiration for future generations, and protecting all heritage sites from water-related climate risks. Addressing these emerging threats requires sustainable approaches to water management and comprehensive strategies to support adaptation (Hein 2020; Mager 2024).

Sustainable water management is crucial for the preservation of World Heritage properties. Although water systems have historically been integral to many sites, this role has not always been fully recognized, leading in some cases to the loss of site-specific knowledge and to the introduction of unsustainable water management. Site managers, therefore, need to integrate water strategies into management plans. Recognizing heritage as a dynamic process influenced by social, economic and environmental factors is essential for sustainable development. However, UNESCO's *Policy Document on Climate Action for World Heritage* (2023), while emphasizing the importance of researching and documenting water management techniques to support climate science, does not explicitly refer to water management plans for individual properties.

As water-related climate variability intensifies, water management will become increasingly important for World Heritage properties. Further research, international collaboration and guidelines are needed to embed water strategies into site plans. A unified approach that bridges cultural and natural heritage is also necessary, given the deep interconnections between monument preservation and climate resilience.

This special issue of *Blue Papers* on “Water Management in World Heritage Properties at a Time of Climate Change” presents a global perspective on water heritage, bringing together 16 articles that explore World Heritage properties and a UNESCO Biosphere Reserve across diverse climatic zones. World Heritage properties are both highly vulnerable to climate change and vital sources of resilience. The contributions by heritage professionals and local custodians demonstrate that the preservation of these properties is not only a cultural concern but a fundamental component of sustainable climate adaptation (fig. 1).

1. Cultural Landscape of Bali Province: The Subak System as a Manifestation of the Tri Hita Karana Philosophy
2. Tassili n'Ajjer
3. Tomb of Askia
4. Sierra Nevada UNESCO Biosphere Reserve
5. Cultural Landscape of Honghe Hani Rice Terraces
6. Classical Gardens of Suzhou
7. The Grand Canal
8. Venetian Lagoon



9. Mines of Rammelsberg, Historic Town of Goslar and Upper Harz Water Management System
10. Seventeenth-Century Canal Ring Area of Amsterdam inside the Singelgracht
11. The Historic Center of St. Petersburg and Related Monuments
12. Water Management System of Augsburg
13. Ilulissat Icefjord
14. Prehistoric Pile Dwellings around the Alps
15. Selected UNESCO properties which include historic water mills across Europe (France, UK, Italy, Spain, Germany, Finland, Russia). Specific locations are marked with dots.

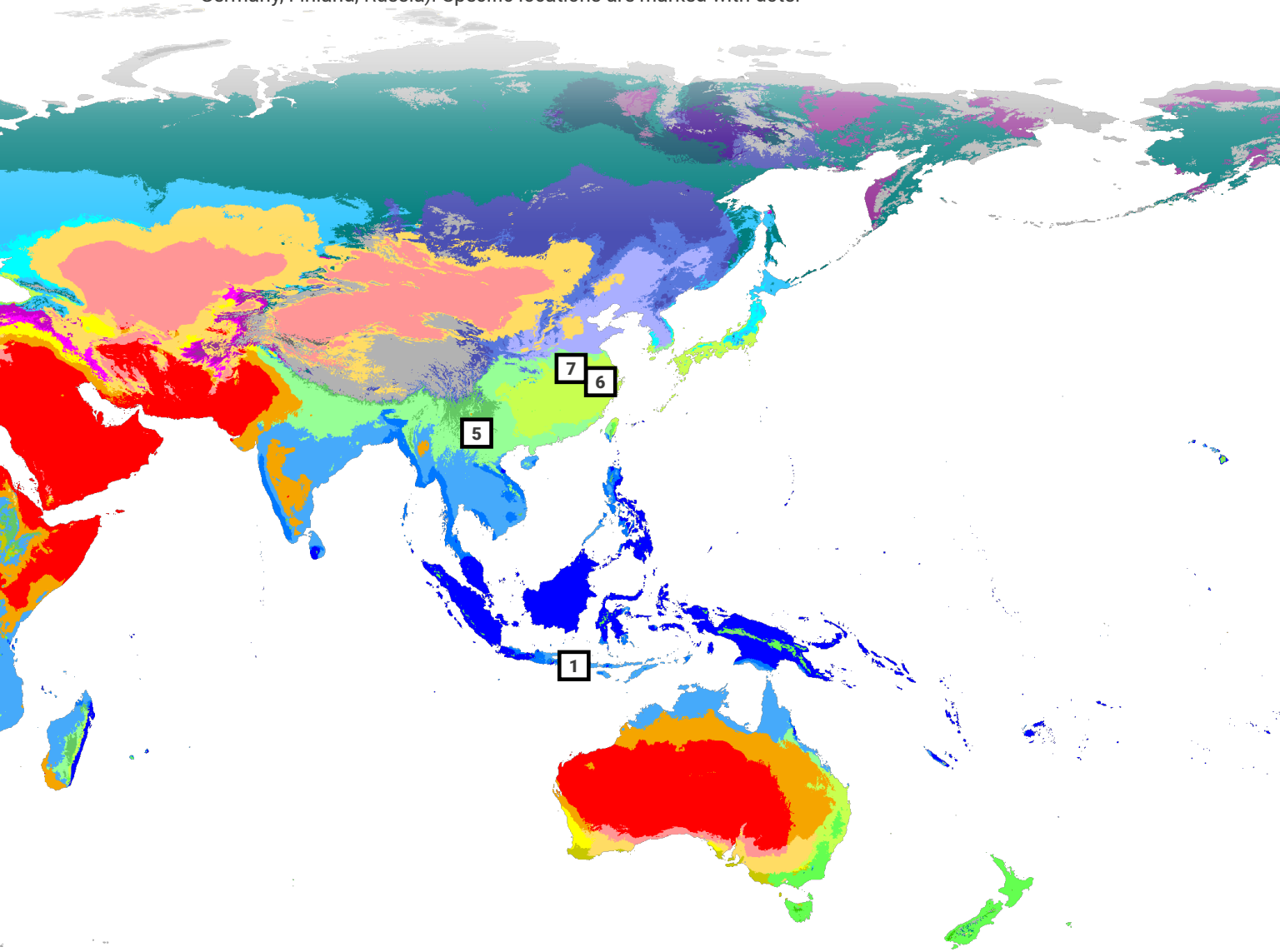


Fig. 1 All World Heritage properties and a UNESCO Biosphere Reserve that appear in this special issue are marked on the Köppen-Geiger Climate Classification Map, 1980–2016 (Authors: Beck, H.E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F. Source: Wikimedia Commons, CC BY-SA 4.0).

The impact of climate change on World Heritage properties has not been well reported or documented for a number of reasons, including reliance on self-reporting, lack of standardized monitoring methodologies and capacities, and the difficulty of attributing specific damage directly to climate change (UNESCO 2025b). Several articles gathered in this special issue of *Blue Papers* illustrate how climate change poses a direct threat to the World Heritage. **Bo Albrechtsen's** case study on the *Ilulissat Icefjord* demonstrates how thawing permafrost both erases important archaeological evidence and threatens modern Inuit infrastructure. **Sergey Gorbatenko** reveals that for the *Historic Center of St. Petersburg and Related Monuments*, the existential threat of flooding is compounded by a lack of integrated governance and legal frameworks. Similarly, **Mamadukou Samaké's** case study of the *Tomb of Askia* in Mali demonstrates how, in contexts of vulnerability, climate change acts as a threat multiplier, with flooding and desertification intrinsically linked to regional insecurity. **Amira Ghennaï** and **Said Madani** show how unprecedented rainfall is now destroying the prehistoric rock art of *Tassili n'Ajjer* that serves as a record of ancient climate shifts.

In the face of these threats, top-down governance models are proving inadequate, exposing a critical need for community-led and collaborative approaches. **Diana Rahman** demonstrates that centralized management is failing, and the future of the *Cultural Landscape of Bali Province* depends on genuine co-creation that empowers local communities as the primary agents of its adaptation to climate change. This governance challenge is equally clear in the analysis of the *Venetian Lagoon* by **Maria Chiara Tosi, Luca Velo, Michela Pace** and **Mette Juhl Jessen**, who explain a phase of administrative inertia and the pitfalls of singular technological solutions like the MoSE barriers. In response to such failures, **Tosi**, together with **Alessia Franzese** and **Mette Juhl Jessen**, presents the Wetland Contract for the Northern Lagoon of Venice as a practical model of participatory governance that fosters a "belonging community" to manage the lagoon as a commons. Similarly, **Ting Wang** argues that managing *Suzhou's Grand Canal* requires collaborative governance as much as technological monitoring to overcome jurisdictional fragmentation. A similar need for integrated governance is clear in **Manuela Armenat, Christian Bellak** and **Andreas Lange's** analysis of the *Upper Harz Water Management System*, which shows that managing a "living" World Heritage property requires integrated governance to balance historic functions with modern climate and safety demands. This call for a paradigm shift is echoed in **Luis José García-Pulido's** examination of Pampaneira, located in the *Sierra Nevada UNESCO Biosphere Reserve*, where a historical, community-managed hydraulic system proves to be an important bioclimatic regulator in adapting to aridification.

Ultimately, this issue reframes water heritage from a vulnerable asset into a source of essential knowledge for sustainability and climate resilience. **Maria Carmela Grano** shows how European watermills can be understood as dynamic infrastructures, emphasizing their potential for micro-hydropower and water regulation as catalysts for regenerative development. Similarly, **Christian Schaller** presents the *Water Management System of Augsburg* as a proven model in which a historical management plan successfully integrates heritage preservation with modern climate adaptation, offering a replicable blueprint for sustainable urban water governance. This view is expanded by **Cyril Dworsky** and **Barbara Fath**, who show how *Prehistoric Pile Dwellings* around the

Alps, tested for thousands of years, offer practical blueprints for modern climate-resistant construction amid rising sea levels. **Tianchen Dai** and **Carola Hein** examine the *Honghe Hani Rice Terraces*, noting that the future of this socio-ecological system depends on balancing the economic opportunities of modernization with the traditional community practices that sustain its ancient water system. **Yapeng Ou, Zhen Cai** and **Qingzhou Wu** find that the *Classical Gardens of Suzhou* have lost resilience due to their disconnection from the historic urban water network. The solution, they argue, is not just maintaining the gardens, but re-integrating them with the water network on which they depend. Completing this picture, **Carola Hein, Regina Klinger, Christel Voncken, Prapti Gupta** and **Vincent Baptist** argue that for Amsterdam's decaying quay walls, overcoming sectoral fragmentation through shared heritage narratives is key to transforming this historic infrastructure into a foundation for climate-adaptive and culturally continuous urban design.

Together, these contributions show that protecting water heritage is not about preserving a static past, but about sustaining dynamic systems of knowledge, practice and ecology that are essential for navigating climate uncertainty. They offer insights into pressing challenges and propose pathways to solutions for World Heritage properties and beyond. The lessons from these diverse locations converge on a single imperative: The path to resilience lies in integrating historical wisdom with collaborative, adaptive governance.

	Name	Location		Climate
1	Cultural Landscape of Bali Province: The Subak System as a Manifestation of the Tri Hita Karana Philosophy	Indonesia		(Af) Tropical Rainforest Climate
2	Tassili n'Ajjer	Algeria		(BWh) Hot desert climate
3	Tomb of Askia	Mali		(BWh) Hot desert climate
4	Sierra Nevada UNESCO Biosphere Reserve	Spain		(Csa) Mediterranean Climate
5	The Cultural Landscape of Honghe Hani Rice Terraces	China		(Cwa) Humid subtropical climate
6	Classical Gardens of Suzhou	China		(Cfa) Humid Subtropical Climate

Water-Related Climate Change Challenges and Other Challenges	Recommendations
<ul style="list-style-type: none"> • Water scarcity and shifting rainfall patterns due to climate change. • Competition for water between agriculture and tourism. • Other: Rapid tourism development and land conversion; disconnect between top-down heritage management and local community needs; restrictive World Heritage regulations hindering adaptation. 	<ul style="list-style-type: none"> • Integrate co-creation and local knowledge into heritage and water management strategies. • Support community-led adaptive practices, such as rotational irrigation and crop diversification. • Align conservation goals with local economic incentives and sustainable agriculture.
<ul style="list-style-type: none"> • Unprecedented intense rainfall and flash flooding. • Increased humidity and microclimatic changes degrading rock art. • Other: Vulnerability of rock surfaces and pigments; malpractices by tourists; need for updated legal frameworks and integrated conservation strategies. 	<ul style="list-style-type: none"> • Establish comprehensive climate and condition monitoring systems for the site. • Strengthen legal frameworks to explicitly address climate risks to heritage. • Integrate community engagement and traditional knowledge into conservation planning.
<ul style="list-style-type: none"> • Intense rainfall and catastrophic flooding of the Niger River. • Desertification and drought reducing water availability. • Other: Regional insecurity and armed conflict; Lack of emergency plans, funding, and reduced availability of traditional building materials. 	<ul style="list-style-type: none"> • Provide flexible funding for disaster preparedness and heritage-specific climate models. • Support local initiatives (e.g., building water collectors, community awareness). • Recognize that cultural heritage requires a higher level of protection than ordinary buildings.
<ul style="list-style-type: none"> • Reduced rainfall and snowfall, leading to decreased water availability. • Increased evaporation and rising temperatures. • Vanishing springs and reduced river flows. • Other: Overexploitation of water by commercial agriculture; breakdown of traditional management systems; abandonment of agricultural terraces; pressure from tourism. 	<ul style="list-style-type: none"> • Promote sustainable water management in heritage sites to mitigate climate change effects. • Implement active policies to support local actors in safeguarding water resources and maintaining system connectivity. • Learn from and apply historical knowledge of resilient, low-impact water systems.
<ul style="list-style-type: none"> • Increased frequency of droughts and floods. • Damage to irrigation canals and water conservancy facilities. • Degradation of the water-retaining forests. • Other: Rural outmigration and decline of traditional farming; pressure from tourism infrastructure; disruption of social structures and traditional water management practices. 	<ul style="list-style-type: none"> • Strengthen climate resilience by reinforcing irrigation infrastructure and integrating it with community life. • Establish an ecological compensation budget to support farmers and promote sustainable practices like rice-fish co-cropping. • Provide funding and support for youth entrepreneurship in heritage-related sectors.
<ul style="list-style-type: none"> • Increased flooding and waterlogging from heavy storms. • Degradation of water quality and aquatic ecology. • Disconnection from the historic urban water system reducing resilience. • Other: Fragmented “isolated management” between garden and water system authorities; high costs of artificial water purification; loss of waterways and groundwater connectivity from urban development. 	<ul style="list-style-type: none"> • Treat the gardens and the historic urban water system as a single organism and restore their symbiotic relationship holistically. • Ensure connectivity between gardens, rivers, lakes and wetlands to strengthen ecological exchange and flood regulation.

	Name	Location		Climate
7	The Grand Canal	China		(Cfa) Humid Subtropical Climate
8	Venice and its Lagoon	Italy		(Cfa) Humid subtropical climate
9	Mines of Rammelsberg, Historic Town of Goslar and Upper Harz Water Management System	Germany		(Cfb) Oceanic climate
10	Seventeenth-Century Canal Ring Area of Amsterdam inside the Singelgracht	Netherlands		(Cfb) Oceanic climate
11	The Historic Center of St. Petersburg and Related Monuments	Russia		(Dfb) Humid continental climate

Water-Related Climate Change Challenges and Other Challenges	Recommendations
<ul style="list-style-type: none"> • Riverbank erosion and degradation from storms, typhoons and floods. • Changes in precipitation affecting water levels and flows. • Slow-onset impacts like weathering and foundation settlement. • Other: Fragmented “Nine Dragons” governance across multiple departments; balancing active transport use with heritage preservation; integrating new monitoring technologies into management; lack of biodiversity monitoring. 	<ul style="list-style-type: none"> • Collaborate with private enterprise to adapt and localize monitoring technologies. • Expand the monitoring platform to include biodiversity conservation. • Integrate technical platforms with management reforms to create a comprehensive, multi-stakeholder governance model.
<ul style="list-style-type: none"> • Rising sea levels and intensifying storm surges causing frequent flooding (acqua alta). • Coastal erosion and degradation of salt marshes. • Ecological disruption and biodiversity loss. • Other: Fragmented and overlapping governance; administrative inertia; balancing mass tourism and depopulation; social fragility; conflicts between large-scale technical solutions (e.g., MoSE barriers) and ecological/community needs. 	<ul style="list-style-type: none"> • Establish unified, adaptive governance at a metropolitan level to harmonize regulations and projects. • Prioritize collaborative, bottom-up approaches in management. • Recognize the dynamic, amphibious nature of the lagoon as central to its heritage.
<ul style="list-style-type: none"> • Increased water scarcity affecting drinking water supply. • Increased risk of flooding and need for enhanced flood protection. • Increased sediment input and ecological pressure on water bodies from extreme weather events. • Other: Balancing hydraulic engineering and safety requirements with monument protection; financial constraints; managing multiple uses (tourism, energy, ecology) while preserving OUV. 	<ul style="list-style-type: none"> • Maintain constant, integrated management and communication between all stakeholders to find future-oriented compromises. • Clearly define the non-negotiable features of the site to preserve its OUV while allowing for necessary adaptation.
<ul style="list-style-type: none"> • Sea-level rise, salinization, and extreme weather threaten the city’s livability and the integrity of the World Heritage property. • Other: Lack of a shared value system amongst practitioners; Lack of standardized methods and a common vocabulary around heritage; Fragmented, difficult to access historical data. 	<ul style="list-style-type: none"> • Use heritage as a resource for sustainable, climate-adapted and circular design. • Make heritage data accessible and visual. • Use local heritage narratives for context.
<ul style="list-style-type: none"> • Sea-level rise and more frequent storm surge floods. • Projected expansion of flood zones that threatens coastal heritage. • Other: Rapid urbanization, high-rise construction, and land reclamation damaging the cultural landscape; Lack of a management plan, buffer zones, and weak legal protection for the World Heritage property. 	<ul style="list-style-type: none"> • Strengthen the Climate Adaptation Plan to explicitly protect cultural heritage. • Revise the Law on Protection Zones to include World Heritage concerns. • Establish buffer zones and create a management plan that addresses climate risks.

	Name	Location	Climate
12	Water Management System of Augsburg	Germany	(Dfb) Warm-summer humid continental climate
13	Ilulissat Icefjord	Greenland	(ET) Tundra climate
14	Prehistoric Pile Dwellings around the Alps	Switzerland, Germany, France, Italy, Austria, Slovenia	Diverse
15	Selected UNESCO sites which include historic water mills across Europe (France, UK, Italy, Spain, Germany, Finland, Russia)		Diverse

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Water-Related Climate Change Challenges and Other Challenges	Recommendations
<ul style="list-style-type: none"> • Water scarcity, flooding from heavy precipitation and high river levels, and ecological stress on the Lech River. • Other: Balancing heritage preservation with urban development and modern infrastructure needs; managing stress from tourism; coordinating multiple stakeholders with diverse interests. 	<ul style="list-style-type: none"> • Leverage historical water heritage for public awareness and cross-border dialogue. • Scale up local innovative solutions for global application.
<ul style="list-style-type: none"> • Coastal erosion from oceanic forces and permafrost thaw, leading to the loss of the Sermermiut archaeological site and cultural heritage. • Other: Balancing urban expansion and local community needs with World Heritage protection restrictions; managing increased tourism pressure; securing long-term funding for conservation. 	<ul style="list-style-type: none"> • Integrate local Inuit knowledge with scientific research in management. • Ensure local community involvement in decision-making and equitable benefit-sharing. • Secure sustained government funding for preservation.
<ul style="list-style-type: none"> • Flooding and rising water levels that threaten submerged cultural heritage. • Increased runoff and soil surface sealing in modern settlements. • Other: Lack of ratification of the 2001 UNESCO Convention (Austria, Germany); Need for specialized expertise in underwater archaeology and conservation. 	<ul style="list-style-type: none"> • Ratify and implement the 2001 UNESCO Convention on Underwater Cultural Heritage. • Establish permanent university programs for underwater/wetland archaeology. • Fund interdisciplinary research (archaeology, hydrology, climate science).
<ul style="list-style-type: none"> • Reduced river flows, sedimentation, floods, and droughts. Hydro-geological risks and slope instability. • Other: Tourism pressure and ecological conflicts (e.g., fish migration); Fragmented governance and undervaluation of non-UNESCO mills. 	<ul style="list-style-type: none"> • Integrate mills into Nature-Based Solutions for water retention and flood regulation. • Develop interoperable digital platforms for hydrological, cultural, and energy data. • Empower community-based governance and support miller associations.

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