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Cultural Heritage at Risk

Challenges of Adapting to Climate Change

Coordinated by:

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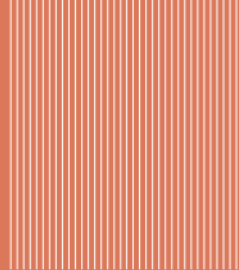
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ONE of the CSIC's functions is to inform, assist and advise public and private entities on science and technology, as stated in article 5 of its Articles of Association. As part of this function, the report *Cultural Heritage at Risk. Challenges of Adapting to Climate Change*, from the Science for Public Policy collection, is presented as a document aimed at public administrations, companies and society in general. It analyses how cultural heritage, one of the main values of today's society, is affected by the impact of climate change, aggravated, moreover, by growing anthropic pressure (demographic, economic, and industrial). It also considers the effects derived from the alteration and destruction of cultural heritage and presents the actions and lines of research being developed by the CSIC to face this challenge.

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Cultural Heritage in the Face of Climate Change

1.1.

**Social
relevance
of the problem**

CULTURAL heritage is a social value of the first order. Its study, protection and the proposal of sustainable solutions for its management constitute some of the most important challenges that our society has to face; as noted, among others, by the Faro Convention and the 2017 recommendation of the Committee of Ministers of the European Union (EU) on a common European data space for cultural heritage.

Threats to cultural heritage have two main origins: on the one hand, the direct effects of human activity in an industrialised and globalised world (e.g., urbanisation, large infrastructures, and intensive economic exploitation of natural resources); on the other hand, environmental agents and the effects of climate change on landscapes and cultural elements (e.g., relative sea level rise or extreme weather events).



Islote de la Cantera, Nueva Tabarca, partially flooded by the rising sea level (18th century mining works). / ANDRÉS DÍEZ HERRERO

Because of its social importance, cultural heritage has progressively become part of international discussions on the impact and effects of climate change. This is due, above all, to the growing awareness of its vulnerability and the irreversible consequences of its alteration and destruction for present-day human societies, as it is a non-renewable resource. These consequences include:

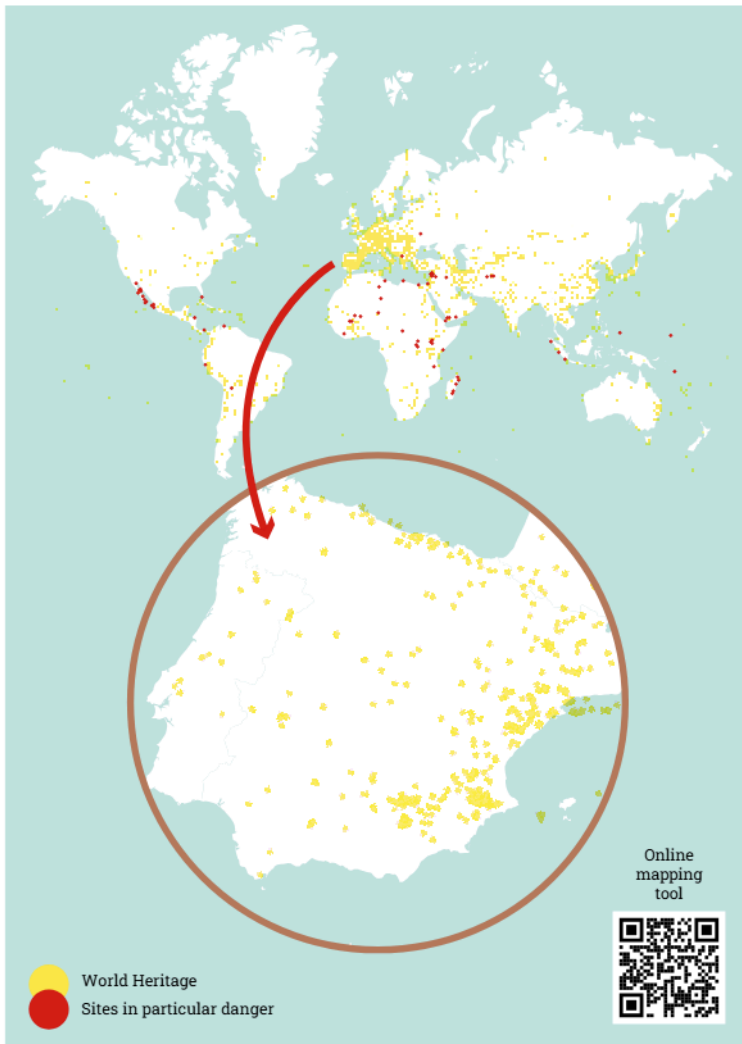
- The loss of social values, of traditional knowledge and uses, and of the capacity to learn from the past.
- The undermining of the sense of a collective identity and of belonging to a community.
- The negative impact on understanding others and its importance in education and social policies (e.g., integration and migration).
- The impact of the loss of heritage as a territorial economic resource.

This is therefore a global problem. However, it should be noted that these effects can have an uneven impact on cultural heritage depending on a number of factors, such as: the geographical and climatic characteristics of the different areas of the world; the political, legal, economic, and socio-cultural context of each region; the nature of the landscapes and cultural elements concerned; and the of heritage protection, education, and awareness policies.

According to the 2022 *White Paper II* of the International Council on Monuments and Sites (ICOMOS), since 1985, 89 World Heritage Sites have, been affected by climate change and have been included on the List of World Heritage in Danger; 22% of them are located in Europe. Of the 89 , currently around 50 are on the list.

With regard to the Mediterranean, according to the study "Climate Change Threats to Cultural and Natural Heritage UNESCO Sites in the Mediterranean", published in the journal *Environment, Development and Sustainability* in 2023, based on EURO-CORDEX simulations and IPCC (Intergovernmental Panel on Climate Change) emissions scenarios, most heritage sites are subject to an increase in threats from global warming and extreme phenomena. In the specific case of Spain, it will be particularly susceptible to the risk of extreme fires in its southern and central sectors. The report also highlights that regions south of the 40° N parallel will experience conditions typical of arid or semi-arid zones; that the number of days of extreme heat or precipitation

Figure 1 UNESCO map of World Heritage Sites



Source: Adapted from, Pasikowska-Schnass, M. (2024) The impact of climate change on cultural heritage. *EPRS. European Parliamentary Research Service*. Retrieved 17 December 2024, from [https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI\(2024\)762282](https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2024)762282)

per year will increase significantly; and that the sites at greatest risk are, in particular, those in coastal areas, issues aggravated by seismic risks. In some cases, there is a combination of confluent factors, with a multiplier effect due to climate change, inadequately planned urbanisation, and intensive exploitation of the environment and of certain resources.

An additional aspect with a high social impact is the realisation that it is not possible to protect all of the cultural heritage at risk. Many cultural elements disappear irreversibly today, sometimes before they can be studied by specialists and their existence brought to the attention of society. This is the case of certain archaeological remains located in particularly sensitive areas (such as coastal areas, unstable slopes or flood zones, subject to active erosive dynamics) that can be completely destroyed in a matter of hours, days or weeks. The time scale factor is relevant, as it is not always possible to identify a uniformity in the rate of alteration and destruction of cultural heritage, which makes case-by-case approaches necessary. Not all social agents—from administrations to the local community and the scientific community—accept in the same way the irreversibility of this destruction and the need to apply certain adaptive strategies. This leads to tensions and conflicts that can involve different sectors of society (for example, a local community refusing to relocate a property at risk of destruction, or the inability to adapt certain administrative procedures to speed up the urgent scientific study of a threatened heritage element).

Faced with this situation, a key element of reflection has to do with what we want to preserve and what we are able to preserve. Research must provide the necessary tools to identify, anticipate, analyse and prioritise the risks linked to cultural heritage and the actions that allow for its better understanding, preservation and dissemination.



The integration of heritage in the implementation of disaster risk reduction mechanisms is a reality that implies a remarkable amount of interdisciplinary research work, which, however, is still partially and incompletely addressed. The emergence of climate change means that the identification and documentation of heritage resources must be accompanied by risk studies, including complete and properly geo-referenced inventories, identification of hazards and their frequency, vulnerability analysis, adaptation and mitigation mechanisms, and post-disaster action protocols. Territorial contextualisation is therefore essential, as is the categorisation of the priority and severity of risks, according to the vulnerability and exposure of heritage resources.

There are also two fundamental reasons why the protection and management of cultural heritage in the face of climate change must be addressed in a decisive manner. On the one hand, the social importance of this heritage through the different values attributed to it. On the other hand, the active role it plays in addressing these challenges on the part of communities. This is therefore a global problem that affects society as a whole and requires dialogue between all sectors of society.

1.2.

Definitions and concepts

What do we understand by *cultural heritage*?

The concept of *cultural heritage* has been progressively enriched and encompasses more and more elements and resources. It can be defined as **the collective legacy of past generations, including both tangible and intangible elements, that a society identifies with and passes on to future generations, forming its unique cultural identity. It is a complex, ever-changing concept that is subject to social, technical, legal, and intellectual re-evaluations throughout history.**

The concept of *heritage* has changed from a monumental or object-centred content to a valuation that emphasises its historical and spatial context, with territory and landscape being essential. The recent definition of intangible cultural heritage has also been fundamental. This change of perspective implies abandoning eminently conservationist protection policies based on the fragmentation and isolation of objects or monuments, which, moreover, led to heritage being perceived as a burden on progress, in favour of other comprehensive and contextual policies, focused on the dynamic and changing nature of heritage resources.

Cultural heritage and natural heritage: unclear boundaries

The relevance of the spatial factor in the definition and protection of cultural heritage makes it necessary to overcome the classic dichotomy between cultural heritage and natural heritage, something already recognised by UNESCO in its 1972 World Cultural and Natural Heritage Convention. This is all the more necessary given that the risk of extreme events and progressive degradation is aggravated by recent social transformations: the abandonment of traditional land uses and rural depopulation, tourist overcrowding, etc. This makes it urgent to address climate change not only from environmental or ecological perspectives, but also considering social and humanistic disciplines.

Landscapes

The concept of **landscape** summarises this renewed vision of heritage and is an effective tool to propose solutions to the risk of climate change. If we follow the definition given in the National Cultural Landscape Plan of the Ministry of Culture, the cultural landscape is the result of the interaction over time of people and the natural environment, the expression of which is a territory perceived and valued for its cultural qualities, the product of a process and the support of the identity of a community. From this perspective, **the concepts of cultural heritage and landscape can be considered equivalent**, as has been argued in the framework of the European project CHeriScape: Cultural Heritage in Landscape. Landscape is a nexus between natural sciences, social sciences, humanities, and planning-related disciplines, and covers the whole territory (urban, rural, marine and natural regions), thus encompassing—not opposing—urban and monumental heritage as well as natural heritage.

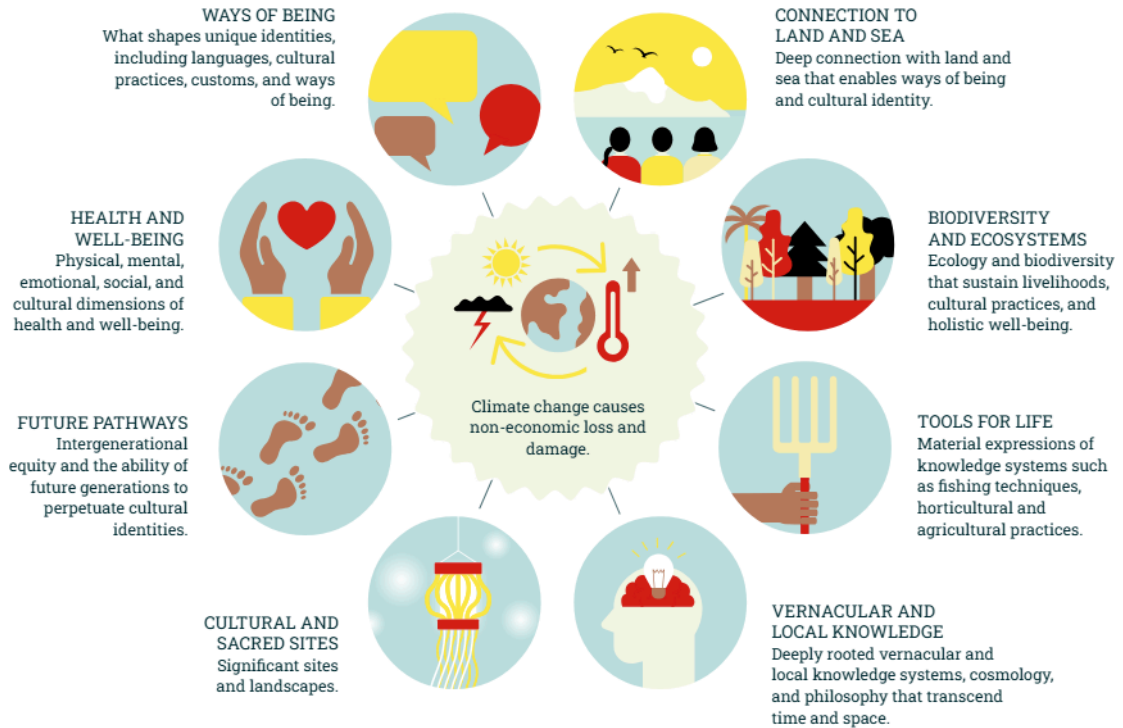
Intangible heritage

In this process of change described above, it has also been acknowledged that cultural heritage is not reduced to the material aspects of the past, but includes a whole series of intangible activities and processes (festivities, arts, knowledge, social practices, craft techniques...) that act to bind together the communities that share them: this is the intangible cultural heritage. Likewise, in the framework of this more complex and holistic vision, the interrelations between tangible and intangible heritage also become heritage.

Values of cultural heritage

The very values attributed to heritage depend on the cultural and social context, as already reflected in 1994 in the Nara Document on Authenticity. These values include the recognition of heritage itself and the collective attachment felt by different groups towards a place perceived as representative. Cultural heritage therefore plays a role in **building community identity, attachment to a place, social value, spiritual associations or social capital**. The loss of this socially valued cultural heritage is therefore unquantifiable and irreparable. A heritage community is made up of people who value specific aspects of a cultural heritage that they wish to preserve and pass on to future generations, within the framework of public action (Faro Convention). Various heritage stakeholders interact around this heritage, whether they are linked to the Administration, the private sector or society in general, each with their own knowledge, interests, demands, and needs, and with varying levels of participation in decision-making. In this regard, the notion of *cultural ecosystem* has become widespread to describe the field of culture as a dynamic environment in which agents, communities, heritage and natural resources interact with open, complex and changing interrelationships; various elements emerge, others survive and many others disappear, and this dynamic vision is crucial in decision-making.

In this context, it **becomes clear that the value of cultural heritage should not be reduced to economic quantification**, although its relevance in this sense is remarkable. Its contribution to the economy has many dimensions, and it is difficult to quantify because it is only indirectly taken into account by the measures and statistics (archaeological enterprises, restoration, cultural industries, rehabilitation of immovable property, and tourism). According to the results of the Ministry of Culture's Satellite Account of Culture in Spain, Spanish culture accounts for 2.2% of GDP (gross domestic product), of which heritage, archives and libraries account for 6.7%. For its part, another major industry at the national level is cultural tourism. While tourism has recently accounted for 11.6% of GDP, around 20% is related to culture (both

Figure 2 Non-economic damage caused by damage to cultural heritage

Source: adapted from McNamara, K. E., Westoby, R., Clissold, R., & Chandra, A. (2021). Understanding and responding to climate-driven non-economic loss and damage in the Pacific Islands. *Climate Risk Management*, 33, 100336. <https://doi.org/10.1016/j.crm.2021.100336>

for foreign tourists, with 22.6%, and national tourists, with 18.4%), according to data for the year 2022 from the Instituto Nacional de Estadística (INE), [National Statistics Institute].

Spain currently has more than 16,000 properties listed in the Register of Assets of Cultural Value, i.e., with the highest category of legal protection, including 50 World Heritage Sites. It is the second country in the world, and the first in Europe, in terms of the number of properties recorded on UNESCO's heritage lists.

Figure 3 Map of the Spanish National Atlas of World Heritage (ANE)



Source: Adapted from the UNESCO World Heritage Convention, the National Atlas of Spain and the Social Observatory of La Caixa.

Risk, vulnerability, and resilience

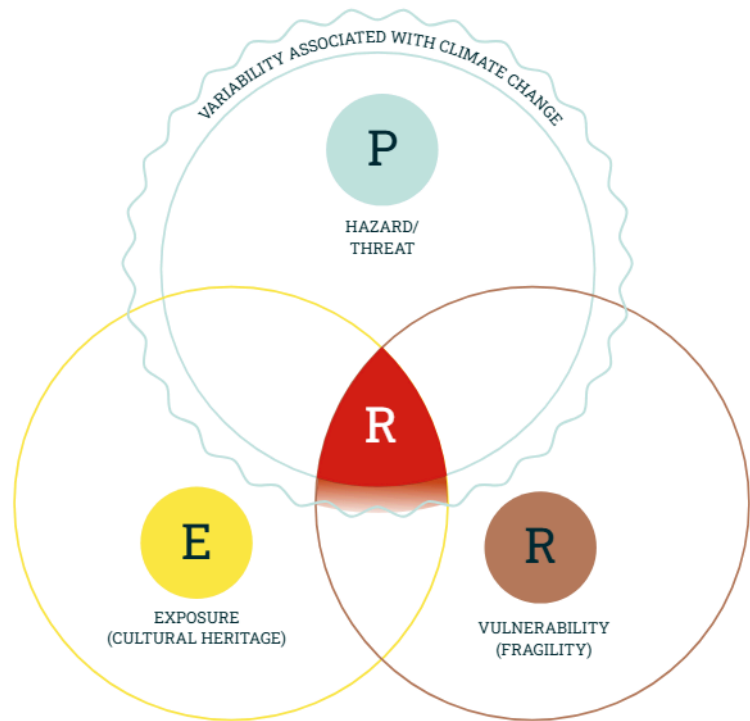
Although, from a scientific and technical point of view, the conceptual bases have been long established and agreed upon internationally (by organisations such as the United Nations), there is enormous confusion in public opinion and in some areas of management regarding the basic terms related to the risks affecting cultural heritage, their analysis, and mitigation.

In order to clarify them, they are precisely described below.

A **risk is a potential situation**, which has not yet occurred but may occur in the future, in which changes in the condition or value of certain tangible or intangible elements, usually damage or loss, to people, material goods, communications, infrastructure or services, may occur. Risk is not, therefore, as one might think, a flood or a volcanic eruption that has occurred or is occurring in a certain place and that affects a heritage element; that would be an event and, if resulting in damage and losses, it could be qualified as a disaster or a catastrophe, according to different scales and intervals.

Therefore, for risk to exist, in addition to the potential existence of a dangerous phenomenon (threat or hazard), there must be an element exposed to that hazard and it must also be vulnerable, i.e., fragile, to the damaging effects of the phenomenon. Thus, the concept of *heritage at risk* refers to the potential for an event or process to affect the spatial and temporal relationships that constitute cultural heritage.

Figure 4 Relationships between the components of risk (R) for cultural heritage in the context of climate change: hazard/threat (P), exposure (E), and vulnerability (V); and the variability introduced by climate change, primarily (but not exclusively) in terms of danger and associated risk



OWN ELABORATION

Hazardous phenomena or processes that generate risk situations have traditionally been classified according to their genesis. They are natural when the phenomenon or process is part of the dynamics of nature, especially the functioning of terrestrial systems. They are considered artificial or anthropic when humans are the cause or triggering factor of the phenomenon

or process (technological, financial, occupational or war-related). Finally, they are known as *induced risks* when they are natural phenomena in which humans interact by triggering, accelerating or increasing the effects and potential damage (e.g., in the case of forest fires).

In turn, **natural hazards**, perhaps those most closely related to the effects of climate change, are usually subdivided according to the Earth system they affect and the discipline that studies them: geological or geophysical, in the geosphere; atmospheric or meteorological, in the atmosphere; hydrological or hydrological, in the hydrosphere; biotic or biological, in the biosphere; and extra-terrestrial, when they come from outside our planet, such as meteorites or solar storms. Many of them, due to their conditioning or triggering factors, are clearly related in their frequency and magnitude to the effects of climate and global change.

The **analysis of risk to cultural heritage requires several methodological steps:**

1. Study of the hazards or threats, with examination of their severity (speed, draught, temperature, volume, and materials), their spatial-temporal dimension (area affected and duration of effects) and frequency or periodicity (usually expressed by the return period or the probability of occurrence and exceedance).
2. Evaluation of the exposed elements, in this case, the cultural heritage, in accordance with the inventory and cataloguing criteria specific to its type, with special emphasis on its cultural and social valuation and significance.
3. Assessment of heritage element vulnerability, both intrinsic (type, materials, and dimensions) and extrinsic (context, accessibility, evacuation, and transfer), which generate magnitude-damage or potential impact functions and vulnerability matrices.

4. Integration of risks, by overlaying the three previous analyses in space (mapping) and in time, to obtain a quantitative or qualitative estimate of the potential damage or impact, both for the current situation and for different foreseen scenarios of climate change and its influence on hazard, exposure, and vulnerability.

Once the risk to heritage has been analysed, if the potential damage in climate change scenarios proves unacceptable, a risk management plan should be drawn up, allowing for the selection, design, and sizing of mitigation measures, which can be predictive, preventive, and corrective. Before adopting any of them, it is advisable to analyse the **resilience** of the heritage element and its territorial and socio-economic context, i.e., the **capacity of this natural and cultural system to recover and return to normality existing before the potentially damaging event**.



Predictive measures for phenomena whose frequency and magnitude may be related to climate change particularly include meteorological (such as Meteoalerta) and hydrological (such as the SAIH [Automatic Hydrological Information System]) early warning systems, and monitoring systems for geodynamic and biotic phenomena. Preventive measures have classically been classified as structural—with the construction of protection works or actions on exposure and hazard—and non-structural—such as land and urban planning, civil protection, insurance systems, risk education and increasing the social risk awareness—. Finally, mid-event, corrective or post-event measures include economic aid, tax benefits, declaring catastrophic zones or development plans.

1.3.

Diagnosis

How does climate change affect cultural heritage?

The effects of climate change on cultural heritage are manifold, depending on the nature and intensity of the disturbance factors and the characteristics of the landscapes and cultural elements affected. However, as noted at the beginning of this report, we must not forget that these factors associated with climate change are compounded by anthropogenic action, socio-economic conditions, and other environmental agents, which also affect the integrity of cultural heritage (e.g., biological erosion due to the presence of animal, plant, and fungal species). It is important to bear in mind this multiplicity of disturbance agents in any action or policy aimed at studying and safeguarding cultural heritage affected by climate change.

In general, the alteration, erosion, and eventual destruction of cultural heritage is the result of the combined action of several factors over a longer or shorter period of time. However, a single event can sometimes cause the same alteration and destruction (such as, for example, a storm or a flood). We are, therefore, faced with a two-stage rate of impact: that of the progressive alteration (low or medium intensity and continuous over time), and that of the singular event (high intensity and concentrated over time).

These two scales are not self-excluding. A cultural element that has already been undergoing progressive alteration may eventually be destroyed by a high-intensity event and, conversely, a high-intensity event may initiate a process of progressive alteration in a cultural element that, until now, had remained stable.

Figure 5 Types of hazards to cultural heritage

NATURAL					
GEOTECTONIC OR GEOLOGICAL					
		Severity	Frequency	Dimension	
INTERNAL	Volcanism				
	Eruptions and explosions	●	●	●	
	Derived (lahars)	●	●	▲	
	Seismicity				
	Earthquakes	●	●	●	
	Sequakes / tsunamis	●	●	▲	
	Salt tectonics and diapirism	●	●	●	
EXTERNAL	Land movements				
	Rapid: landslides, mudslides and debris flows	▼	▲▼	▲▼	
	Slow: Flows, soil creep and subsidence	▼	▲	▲	
	Flash floods	▲▼	▲▼	▲▼	
	Glacial and periglacial	▼	▼	▼	
	Coastal and littoral	▲▼	▲▼	▲	
	Deep-sea	●	●	●	
	Aeolian (wind-driven)	▲	▲	▲	
	Karstification	▼	▲▼	▼	
	Clay expansivity	▼	▲▼	▼	
GEOCHEMICAL	Asbestos	●	●	●	
	Gas emissions				
	Hydrocarbons	▲	▲	▲	
	Radon	●	●	▲	
	Radioactivity	●	●	●	
ATMOSPHERIC OR METEOROLOGICAL					
THERMAL	Cold waves	▼	▼	▼	
	Heatwaves	▲	▲	▲	
HYDROMETEORS	Maximum precipitation	▲▼	▲▼	▲▼	
	Minimum precipitation	▲	▲	▲	
	Snowfalls / hoarfrost	▼	▼	▼	
	Hail / sleet	●	▲	▲	
AEOLIAN	Gusts and squalls	●	▲	▲	
	Tornadoes / waterspouts	●	▲	▲	
	Hurricanes / typhoons	●	▲	▲	
OTHER METEORS	Lightning	●	▲	▲	
	Thunder	●	▲	▲	
	Tidal bores and meteotsunamis	●	▲	▲	
BIOTIC OR BIOLOGICAL					
INCREASES IN FLOW/LEVEL		Severity	Frequency	Dimension	
	Sea level rise	▲	▲	▲	
	Coastal flooding	▲	▲	▲	
	Inland flooding	▲▼	▲▼	▲▼	
DROUGHTS	River low flows	▲	▲	▲	
	Wetland desiccation	▲	▲	▲	
	Groundwater decline	▲	▲	▲	
BIOTIC OR BIOLOGICAL					
PLAGUES		Severity	Frequency	Dimension	
	Botanical	▲	▲	▲	
	Zoological	▲	▲	▲	
	Epidemics and pandemics	▲	▲	▲	
INDUCED					
FIRES		Severity	Frequency	Dimension	
	Rural and forest	▲	▲	▲	
	Urban	▲	▲	▲	
ANTHROPOGENIC					
TECHNICAL OR TECHNOLOGICAL					
TECHNICAL/ PROFESSIONAL		Severity	Frequency	Dimension	
	Negligence and breakdowns	●	●	●	
	Lack of maintenance	●	●	●	
	Occupational	●	▲	●	
TECHNOLOGICAL		Severity	Frequency	Dimension	
	Industrial	●	●	●	
	Traffic	●	●	●	
	Energy-related	●	▲	●	
ETHOLOGICAL					
WARLIKE		Severity	Frequency	Dimension	
	Vandalism	●	●	●	
	Terrorism / sabotage	●	●	●	
	Wars	●	▲	▲	
PSYCHOPATHIC		Severity	Frequency	Dimension	
		●	▲	▲	
		●	●	●	

▲ Increase ● Equal ▼ Decrease

OWN ELABORATION

How does heritage contribute to the fight against climate change?

The relationship between cultural heritage and climate change is complex, as cultural heritage is not only affected by climate change, but is also a resource for climate change adaptation and mitigation. This is evident in several respects:

1. Cultural heritage provides historical information on how human societies have adapted to their environments and to changing climatic conditions that have occurred over time, in different parts of the world. It is an archive of information on consecutive successes or failures in the society-environment relationship, key to understanding climate change and its effects on societies, and making decisions for the future.
2. Cultural heritage also provides information on traditional materials and techniques for the use of natural resources, water and land management, and agricultural and livestock practices, which have proven over time to be effective in responding to changing climatic conditions. It also makes it possible to identify which practices are inadequate or unsuccessful for such adaptation.
3. For intangible heritage, vernacular knowledge on the local management of natural or productive spaces has a recognised value in climate change adaptation strategies.
4. Linked to the point above, cultural heritage contributes to the circular economy through the preservation and reuse of spaces and buildings or through sustainable urban space and territorial management practices. For example, it has been recognised that historic buildings can contribute to this adaptation process through decarbonisation based on their insulation and space management mechanisms against cold and heat.



5. Cultural heritage, as noted above, plays a role in building feelings of identity between different groups. It can therefore promote social cohesion and resilience, which are key to responding to change and natural disasters.
6. Heritage sites and museums disseminate scientific information on climate change, which helps to raise awareness and promote action among their visitors. For example, the paleoenvironmental and geoarchaeological record generates in-depth information on paleoclimates and their relevance to long-term modelling. In this way, heritage forms a link between scientific knowledge and society. It is therefore a significant source of information for the design of effective and fair climate change adaptation and mitigation measures, and a resource for promoting knowledge, action and creativity in general.

1.4.

Sizing up the problem: from global to regional scale

IN a context of global challenges (UN Sustainable Development Goals), it is important to note that the discussion on cultural heritage and its value to society has recently been included in the debate on the impact of climate change, generally from a perspective of conservation and without considering its potential to be part of a solution.

The threat posed by climate change to cultural heritage was identified by UNESCO in relation to World Heritage in 2006. However, as noted in ICOMOS *White Paper II*, the inclusion of cultural heritage in the UN IPCC reports is haphazard and superficial, and does not capture the wide diversity of heritage types and risks posed by climate change. Moreover, the impacts or risks identified are often described qualitatively, in a non-specific manner, and are only sporadically quantified. **These shortcomings are serious, as the IPCC reports are considered the most comprehensive compendium of climate-related science available.**

The necessary involvement of the human and social sciences in climate change studies has been the subject of several ICOMOS initiatives, aimed at trying to converge with IPCC terminology and general schemes of analysis. IPCC *White Papers I, II, and III*, published in 2022, further developed the specificity of social approaches as necessary tools for climate change adaptation and mitigation. **Despite the fact that climate change is considered to be aggravated by the action of societies on the environment, and that there is consensus that possible solutions involve social and cultural changes, the funding of social approaches to understanding the phenomenon is very low**, as opposed to natural sciences. According to a 2020 ICOMOS study on climate change research funding, between 1990 and 2018, **natural and technical science received 770% more funding than social science for research on climate change issues**. Also, only 0.12% of all research funding was spent in social sciences on mitigating the impact of climate change.

Two key ideas are promoted in these reports. On the one hand, it is pointed out that the concept of *heritage* includes the cultural and the natural, the tangible and the intangible; highly relevant in this respect is the assertion that the barriers to recognising cultural and natural heritage as inseparable are not due to scien-

tific uncertainty, but rather to a lack of political understanding. On the other hand, the need for holistic and inclusive approaches is promoted. This goes beyond inter- or multi-disciplinarity or the joint work of different actors (politicians, scientists, other social and economic actors...) or citizen science in relation to heritage, and points towards the recognition of different knowledge systems.

Another key aspect of climate change initiatives at the international level relates to the response to climate disasters, which are becoming more intense and more frequent. The international reference framework is the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR), the current global agreement on disaster risk reduction (DRR). It asserts that effective disaster risk management contributes to sustainable development. Cultural heritage is included among the assets to be protected and encouraged to be resilient. Closer collaboration between the public and private sectors and civil society organisations, as well as the academic community and scientific and research institutions, is considered essential. In this regard, in 2020, the UNESCO General Assembly adopted a document on principles and modalities for the protection of intangible heritage in the event of emergencies.

Other bodies and initiatives have also addressed the relationship between cultural heritage and climate change. This is the case of ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property) and the Climate Heritage Network, launched in 2019. This network aims to increase the quantity and quality of climate actions based on cultural approaches and to transform climate policy by promoting the integration of culture and heritage in public decision-making.

At the European level, various regulations, guidelines and initiatives have been promoted in recent years that are relevant to understanding and tackling the problem. In this respect, the first decades of the 21st century are serving as an important turning point, when the European Landscape Convention, the European Green Deal, and the New European Bauhaus have been approved by the EU, the Council of Europe and other transnational institutions.

Similarly, the EU Mission on Adaptation to Climate Change has recently joined the efforts to build resilience to the impacts of climate change. In addition to these initiatives, which encompass different aspects of society, a number of specific documents have been published on cultural heritage and climate change, such as the white paper *Cultural Heritage and Climate Change: New Challenges and Perspectives for Research: New Challenges and Perspectives for Research*, jointly promoted by the Joint Programming Initiative on Climate Observation (JPI Climate) and the Joint Programming Initiative on Cultural Heritage and Global Change (JPI CH) from the Council of Europe, in whose preparation CSIC has played an active role.

Some European initiatives focus on the integration of heritage into disaster management and resource management protocols, such as PROCULTHER (Protecting Cultural Heritage from the Consequences of Disasters) or the STORM (Safeguarding Cultural Heritage through Technical and Organisational Resources Management), and HYPERION (adoption of solutions for hydrogen uptake in European regions) projects.

Among the neighbouring countries, the United Kingdom was a pioneer in discussing the effects of climate change on cultural heritage. For its part, Scotland acted as one of the main drivers of this dynamic, with the emergence of research groups in the 1990s, which generated a debate that has resulted in various actions and regulations. Since 2009, the country has had a Climate Change Act, under which various regulations have been developed. Currently, and under the responsibility of Historic Environment Scotland, the Climate Action Plan (2020-25) is active, one of the main pillars of which is the protection of cultural heritage and landscape. Other countries such as Italy and France have also included cultural heritage in their climate plans, albeit to varying degrees. Since 2014, Italy has had a National Plan for Adaptation to Climate Change (PNACC) that includes cultural heritage among the various sectors at risk taken into consideration.

In the case of France, the implementation of the third PNACC is expected; according to several specialists, this plan should make progress in terms of heritage protection, as the second plan (2018-2022) integrated the problem of cultural heritage at a descriptive level and without concretely addressing the implementation of solutions.

In the case of Spain, although Law 7/2021 of 20 May on Climate Change and Energy Transition only refers to natural heritage, there are different plans, programmes and regulations referring to climate change, its effects, mitigation and adaptation measures, as well as civil protection legislation and planning, which take into account the risks to cultural heritage. Among others, the Integrated National Energy and Climate Plan (PNIEC) 2021-2030 underlines the interdisciplinarity required by the climate challenge, specifically citing the conservation of cultural heritage and the necessary contributions of social sciences and humanities.

In turn, our National Plan for Adaptation to Climate Change (PNACC) 2021-2030 has a specific section listing the objectives by areas of work dedicated to cultural heritage, which includes five areas of interest:

- Identifying the elements of Spanish cultural heritage most vulnerable to climate change and defining possible adaptation strategies.
- Incorporating climate change observations and projections into cultural heritage conservation plans (including the National Cultural Landscape Plan).
- Collecting and transferring vernacular knowledge useful for climate change adaptation.
- Promoting cultural tourism adapted to climate change and low carbon emissions.
- Promoting international cooperation in the transfer of knowledge to protect cultural and architectural heritage from climate change.

In turn, annex I of the PNACC presents a line of action for integrating the risks derived from climate change into the conservation of cultural heritage, with two components:

- Identification of the main risks and elements of Spanish cultural heritage that are most vulnerable to climate change and design of possible adaptation strategies.
- Incorporation of the climate change variable into the preventive conservation plans for cultural heritage drawn up by the Directorate General for Cultural Heritage and Fine Arts (including cultural landscape conservation plans) and in the Emergency and Risk Management plans, including observations and projections of climate change in cultural heritage conservation plans.

Other lines of action also refer to cultural heritage in the face of climate change, such as the promotion of climate-conscious, climate-smart and low-carbon cultural tourism, as well as numerous other references to cultural heritage in matrices of relationships with other areas of adaptation work. However, so far, cultural heritage has not been included in the Spanish Plans to Promote the Environment (PIMA), especially in PIMA Adapta, which aims to implement projects that reduce vulnerability to the effects of climate change, anticipating the expected impact.

For its part, the National Plan for Emergencies and Risk Management in Cultural Heritage, drawn up in 2015 by the former Ministry of Education, Culture and Sport, contains only one indirect reference to the effects of climate change on cultural heritage: the 2009 general recommendation on the protection of cultural heritage in the face of climate change, derived from the European and Mediterranean Major Hazards Agreement.



In turn, the Ministry of the Interior's Basic Civil Protection Standard of 2023 incorporates self-protection actions into general civil protection planning and provides for a specific Basic Planning Guideline which, as a minimum standard, fully includes this important chapter of society's actions in the general scheme for the protection of people, animals, property, the environment, and historical, artistic and cultural heritage. For this reason, the catalogue of risks subject to planning includes those which, due to their frequency, duration, and territorial scope, have the greatest impact on historical, artistic and cultural heritage, as well as basic measures for the protection of this heritage. Without, however, any explicit reference to the effects of climate change.

Finally, the management plans for some natural hazards potentially affected by climate change do include an analysis of the effects on cultural heritage. This is the case of the flood risk management plans (PGRI), which aim to reduce risk by reducing the danger to human health, economic activities, cultural heritage, and the environment in flood-prone areas, taking into account the foreseeable effects of climate change. In fact, the second development cycle of the European Commission's Floods Directive on the assessment and management of flood risk, published in 2007, already includes pilot programmes for adapting cultural heritage elements to climate change, such as the Royal Mint in Segovia, a historic 16th century industrial building affected by frequent flooding.

Due to the powers assumed, the various **autonomous communities** have included adaptation to climate change in their regulations and, fundamentally, in their strategies. However, not all regions include cultural heritage in their agenda. Those that do are the Canary Islands with their Climate Action Strategy, containing very specific references, the Basque Country's Climate Change Strategy 2050 and the Aragonese Climate Change Strategy (EACC) - Horizon 2030. The Community of Madrid, in its Energy, Climate and Air Strategy 2023-2030, although not mentioning cultural heritage as such, it does address it in a cross-cutting manner in certain lines of action. The Andalusian Climate Action Plan (PAAC) 2021-2030 also generically considers the implementation of measures to prevent the impacts of climate change, with reference to historical heritage, in urban and land-use planning actions. For its part, the Galician Climate Change and Energy Strategy 2050 only mentions cultural heritage linked to the maritime and fishing world when citing the vulnerability and impact of climate change in connection with tourism. Similarly, the Climate Change Strategy of Castilla-La Mancha, Horizons 2020-2030, only mentions cultural heritage when referring to increasing resilience to climate change in tourism. As for the Balearic Islands, neither the Balearic Climate Change Strategy 2013-2020 nor the subsequent Law 10/2019 on Climate Change and Energy Transition cover it under any section. Nor does the Valencian Climate Change and Energy Strategy 2030 include specific actions with regard to cultural heritage, which is very necessary especially as it concerns, for example, the important representation of Levantine rock art, which is very vulnerable due to its exposure, in this territory. Similarly, there is no allusion in either Law 16/2017, on Climate Change, or in the Strategic Reference Framework for Adaptation to Climate Change for the 2030 Horizon, of Catalonia, although both mention natural heritage on several occasions. Nor is cultural heritage included in the Regional Climate Change Strategy of Castilla y León 2009-2012-2020.

Thus, the Autonomous Communities have a long way to go to explicitly incorporate cultural heritage in their climate change regulations and strategies.



Royal Mint of Segovia
(16TH century) flooded by sudden snow
melt in 2024. / ANDRÉS DÍEZ HERRERO

two



Cultural Heritage at Risk: CSIC's Contributions to the Challenges of Mitigating and Adapting to Climate Change

THE preservation of cultural heritage at risk is one of the main challenges facing society today, regardless of the nature of the threats. Unlike natural species and ecosystems, cultural heritage has no intrinsic adaptive capacity: it cannot react to change, it cannot move or regenerate itself. This means that strategies to mitigate these changes must be induced by human action, with actions to minimise and manage the potential impacts to which it may be subjected. How do we study and assess the alteration of cultural heritage? What tools are available to do so? How can we prevent damage? How do we prioritise interventions? Decision-making is therefore an essential issue for the future of a cultural element or property. In this decision-making process, the work of scientific and technical research is fundamental, as it provides the tools, data and reflections that allow us to assess which are the most appropriate and sustainable options for tackling the problem.

Along these lines, the CSIC has published a series of *White Papers entitled Scientific Challenges 2030*. Although the problem of cultural heritage in the face of climate change has not been the subject of a specific volume, several of them directly or indirectly integrate elements that are relevant to its understanding. This is particularly the case of issues 1 (*New foundations for a sustainable global society*), 7 (*Global change*), 13 (*Oceans*), and 14 (*Dynamic Earth*). The CSIC has also implemented different interdisciplinary thematic platforms (ITPs) and connections (Connections/HUBs) that coordinate research groups and teams. Some of them are related to both cultural heritage and climate change, such as PTI-PAIS (Patrimonio Abierto: Investigación y Sociedad [Open Heritage: Research and Society]), PTI+Clima, Conexión Geociencias [Geosciences Hub], and Conexión-Arqueología/Archaeology Hub.

Thus, we can summarise the CSIC's contributions in relation to the study of heritage in the face of climate change in three main blocks: those that have to do with a historical perspective, those that propose an analysis from the present, and those that reflect on future scenarios and strategies for dealing with them.

2.1.

Lessons from the past for understanding the relationship between heritage and climate change

KNOWLEDGE of the past is fundamental for understanding the present and managing the future in terms of sustainability. For decades, the CSIC has demonstrated an enormous research potential in **studies on landscapes and their recognition as heritage**, promoted from the field of archaeology, but with a primarily multidisciplinary basis. In fact, the CSIC is among the pioneers in Spanish and international research in this field. In parallel to the development of the content of the concept of *cultural heritage*, the framework of archaeological research has also expanded from objects to their contexts, and from a conception of space as the setting for community activities to consider it as the materialisation of social relations.

CSIC's **contribution** of landscape archaeology to the understanding of climate change is based on the following pillars:

- The production of comprehensive documentary records that provide insight into different periods of climate change throughout history and their impact on societies.
- The documentation of different forms of relationship between societies and the environment, which shows the diversity of solutions, and the fact that these respond to the specific circumstances of each historical moment.
- The realisation, through the dynamics of landscapes, that we live in permanent change, that the forms of interaction with the environment have been many and very different, and that current circumstances are not the result of blind forces that move history, but of past decision-making within specific social contexts.
- The generation of community and sustainable resources, especially in rural areas, is based on the assumption that the landscape is a living and changing reality. For this reason, the CSIC actively converges with regional and local governments, which are responsible for heritage management, and with local communities, associations, entrepreneurs and other actors involved in heritage conservation.



- The development of truthful narratives aimed at encouraging the critical and imaginative participation of citizens in heritage protection actions and decision-making towards a sustainable future.

Topographic survey with airborne LiDAR at the Roman site of Monte Cido (O Courel, Lugo). / BRAIS X. CURRÁS

Research questions about the past have generated **multidisciplinary approaches** involving the application of techniques from the human, social, natural and physical sciences (geomatics, geoarchaeology, and palaeoenvironment, among others). Apart from excavation and field survey, the traditional methods of the archaeological discipline, the CSIC is a pioneer in the use of geospatial technologies (geographic information systems, GIS-; and global positioning systems GPS; spatial data infrastructures IDE), that include non-invasive analysis techniques, such as LiDAR data, which are obtained by means of drones, or geophysical survey techniques.



Bronze Age cist on the islet of
Guidoiro Areoso (Pontevedra),
affected by relative sea level rise.
/ ELÍAS LÓPEZ-ROMERO

In this line, the CSIC pays special attention to the value of **non-invasive methods** for the large-scale recording of archaeological elements in the landscape, seeking points of connection with other disciplines related to the management, custody and exploitation of the landscape, especially with agronomy and precision agriculture. Climate change is impacting on the balance and conservation of cultural landscapes in rural areas, where they have to coexist with economic exploitation and heritage preservation. The development of non-invasive methods provides the means to obtain a good knowledge of the heritage of these fragile areas and facilitates land-use planning and management. This allows an interdisciplinary approach to existing problems, from overexploitation, erosion, and soil loss to the silent destruction of the material evidence of past rural lifestyles by the im-

part of today's technified agriculture, which is being analysed by, among others, the Instituto de Arqueología de Mérida (IAM, CSIC-Junta de Extremadura) [Institute of Archaeology of Merida], and the Centro de Investigaciones sobre Desertificación (CIDE, CSIC-UV-Generalitat Valenciana) [Centre for Research on Desertification].

On the other hand, the CSIC carries out important research related to **environmental archaeology, human ecology, palaeoeconomics, and archaeobiology**. To this end, analyses are carried out on plant or animal macro-remains (for example, seeds, charcoal, and bones found in archaeological contexts) and plant micro-remains (such as pollens, mineralised cells, starches or different carbonised plant tissues) retrieved both in archaeological contexts and in their environment, or in the artefacts used to prepare and consume food; all of this through the analysis of residues and traces of use of ceramic surfaces and even in the remains of calcified dental plaque from ancient teeth. Important reference collections at the Instituto de Historia (IH, CSIC) [Institute of History] and the Institución Milá y Fontanals de Investigación en Humanidades (IMF, CSIC) [Milà i Fontanals Humanities Research Institution] are available for this research. With an environmental archaeological approach, the IH studies the palaeoenvironmental evolution during the Pleistocene and Holocene, as well as the impact of anthropogenic activities, climate variability on the landscape and vegetation dynamics; patterns of resilience and vulnerability of ecological systems (extinctions, latitudinal/longitudinal shifts of vegetation, etc.) and social systems (collapse and modification of the palaeoeconomic system) to climate variability and abrupt climatic changes are identified.

Analyses of bones or teeth isotopes are also used to study both the diet and mobility of past populations. To put it very simply: different environmental conditions leave an imprint on the isotopic configuration (the type of atoms—isotopes—of certain components such as oxygen, nitrogen, carbon or hydrogen) in living organisms. This information can be extracted from the preserved skeletal remains and compared with that of other sites and current environmental conditions. From this, it is possible

to identify changes in the climate (greater or lesser humidity or aridity, among others) and, for example, how livestock herds have adapted to the new environmental conditions. In this regard, archaeogenetic and genomic studies are becoming increasingly relevant in the context of archaeobiology, as currently being undertaken at the IMF.

Some CSIC research lines are also being developed from a **historical and geological chronological perspective**, in institutes and centres such as the Instituto Geológico y Minero de España (IGME, CSIC) [Spanish Geological and Mining Institute], the Museo Nacional de Ciencias Naturales (MNCN, CSIC) [National Museum of Natural Sciences], the Instituto Pirenaico de Ecología (IPE, CSIC) [Pyrenean Institute of Ecology], and the Instituto Andaluz de Ciencias de la Tierra (IACT, CSIC-UGR) [Andalusian Institute of Earth Sciences]. These lines use past data sources recorded in natural elements (rocks, sediments, landforms, ice, vegetation, and even fauna) and in the cultural heritage itself (building structures, materials) to study the incidence of extreme events in the past (floods, storms, cold spells and heat waves) under different climatic contexts, both warm periods (Minoan, Roman or late medieval) and cold ones (Hellenistic, early medieval or Little Ice Age). In this way, it is possible to observe the frequency, magnitude and impact on heritage of hazards in past climates and to seek analogies with current and future climate change scenarios. In turn, it is possible to see how heritage elements have behaved and responded to different climatic periods and their extreme events, from which we can extract recommendations for the preventive conservation of cultural heritage.

Inter- and trans-disciplinary specialities such as dendrogeomorphology, palaeohydrology, glaciology, archaeoseismology, speleoseismology, palaeoseismology or lichenometry allow us to extract patterns of changes in active processes with the climate of past times, look for equivalents to current global warming (Roman or late medieval Warm Periods) and project them towards the foreseeable dangers and risks to cultural heritage in the future. There are even projects developed by the CSIC (IGME) that combine these studies of natural records with historical research on traditional measures for adapting to climate

change based on nature, through the temporary retention of water in periods of its availability, for subsequent use in temporary periods of shortage. An example of this is the so-called *sowing and harvesting of water* in various areas of Spain and South America.

The CSIC carries out research on historical periods that are key to understanding the **relationship between societies and the environment over the centuries**. Apart from the important documentation generated about the past, these studies allow us to identify the economic and social mentalities with which people have constructed their relationship with resources and their ways of organising production. Some were sustainable, others were predatory, and the vast majority, in any case, differ from today's ways of life. The connection between these diverse forms of resource management and the different climatic changes that have occurred historically is relevant for the definition of current strategies to address the problem. This knowledge also helps to avoid, or at least discuss, environmental determinism in both past and present cases. In the framework of **human origins**, new research approaches based on biogeography and adaptive behaviours are being applied at the IH to understand the complex processes of colonisation by pre-modern humans throughout the Old World. Research analyses the different evolutionary pathways followed by hominins who shared a biological and cultural background, but took routes with different climatic and biogeographical conditions. This research is carried out at sites in Tanzania, Spain and China.

A particularly relevant period is the **transformation of hunter-gatherer societies into stable agricultural societies** during the Neolithic period, which gave rise to a new way for societies to relate to animals and plants. The CSIC, mainly through the IMF, carries out projects aimed at understanding why agriculture began, what changes it brought about and what the relationship with plants was like before domestication. Research is carried out both in Spain, for example in mountain areas such as the Central Pyrenees, and in regions where this phenomenon is documented for the first time (Israel, the highlands of Jordan, southeast Turkey and China) or in parts of the New World where the processes followed their own courses (Chile).

The transition from hunter-gatherer to agricultural societies, and the interactions between hunter-gatherers and early farmers during the Last Glacial Maximum to the Early Holocene in the Eastern Mediterranean are key processes for understanding possible socio-ecological responses to current climatic instability. Several of these studies focus on arid regions, such as the Negev and Sinai deserts (Near East) or the Atacama Desert (South America), where the role of plants in land management by hunter-gatherers is analysed.

Other periods of history widely studied by CSIC research groups involve a **systematic exploitation of the environment and natural resources**, but in accordance with very different ways of organising production and economic objectives unlike those of today. The relationship between human groups and the environment has never been neutral, although changes in the scale of these impacts are clearly visible in history. Above certain thresholds of social development, a model that does not produce lasting, often irreversible effects is historically unlikely, although nothing compares to the modern post-industrial world. Iron Age territory and landscape studies the carried out mainly at the IH, the IAM and the Instituto de Ciencias del Patrimonio (INCIPIT, CSIC) [Institute of Heritage Sciences] have had a fundamental point of reference in the notion of *peasant economy*. In fact, the CSIC is a pioneer in the theoretical definition and archaeological analysis of the forms of peasant organisation in the societies of recent prehistory and protohistory. The notion of *peasantry* implies forms of social organisation based on communities and domestic units that control access to land and agricultural production, according to two central parameters: the tendency to underproduce and the minimisation of risks. These are strategies that avoid maximising production and producing more surplus than is necessary to meet social obligations or, where appropriate, taxation. These societies have a clear environmental impact, for example through deforestation, but often allow for a balanced relationship between population and resources. The CSIC is also a trendsetter in the study of soil and water conservation systems, such as cultivation terraces and palaeosoils, from pre-Roman, Roman and medieval times, at centres such as the IH, INCIPIT, IPE and CIDE.



Roman salt pans of
Guilheta (Esposende,
Portugal). / BRAIS X. CURRÁS

The Roman conquest is a paradigmatic case study of **large-scale anthropogenic effects** on environmental conditions in a pre-industrial context. Mention should also be made of the gold mining areas in the northwest and west of the Iberian Peninsula, which have been studied by the IH. Although they are the result of the imperial domination of a society based on a market economy, the Hispanic gold mines cannot be understood only in terms of economic factors, but above all in terms of political ones. In fact, if they have been so excellently preserved, it is because their exploitation is not profitable from a modern capitalist point of view. The constant supply of gold was necessary for the viability of the monetary system and was profitable because the construction of hydraulic infrastructures and the cost of labour depended on an administrative system that drained resources to the state in the form of taxation and regardless of economic reasoning. The mining hydraulic structures themselves (canals and water reservoirs), in addition to being an example of forms of water management for non-food uses, have generated a very useful record for palaeoenvironmental studies. The same type of record in natural deposits such as ice, lakes and peat bogs in Europe and Greenland is of great interest for studying the polluting effects of mining and metallurgical activity in relation to climate change over the last millennia. The CSIC is tackling these problems in different Spanish and European mining areas, such as in the northwest of the Iberian Peninsula and Cartagena (Murcia), or in the Bessa (northern Italy).



The CSIC has also contributed to the understanding of the relationships between society, the environment and climate change during medieval, modern and contemporary times. Research is being carried out at the IH to explore the diversity of plant species used by the Christian, Islamic, and Jewish communities in medieval times and their adaptation and management; it also attempts to document the arrival and origin of new species and varieties such as citrus fruits, rice, and spices. The Escuela de Estudios Árabes (EEA, CSIC) [School of Arabic Studies] examines Islamic agricultural landscapes. And INCIPIT has addressed the period between the decline of feudalism and the spread of modernity and capitalism, with approaches aimed at understanding the cultural and socio-environmental processes involved in the formation of current rural landscapes in the northwest Iberian Peninsula. This is highly relevant for understanding how the environment has been managed throughout different climatic stages and their transitions.

2.2.

Approach from the present: the state of cultural heritage and the impact factors

A number of methods and techniques make it possible to address, from the present, the state of cultural heritage and the factors affecting it. These methods draw on climate databases and derived products provided by the centres participating in PTI+ Clima. The CSIC is directly involved in the **research and application of physical-chemical, mineralogical-petrological and material science analyses** for the characterisation, monitoring, conservation, and restoration of cultural heritage ensembles and elements. The work in this is highly diverse, including studying the causes and degree of impact by climatic variables on architecture, objects and materials, whether of organic or inorganic origin. Such approaches can focus directly on the object or element affected (such as the ornamental rocks of a monument), on the surroundings or environment in which it is located (e.g., differential alteration of the rocks depending on the orientation of the heritage element due to the degree of humidity or the incidence of sunlight) or on a combination of both.

An increasing amount of work in this area involves the use of non-destructive techniques to assess the deterioration of cultural heritage and to inform the most appropriate strategies for its protection. These techniques make it possible to determine the composition and mechanical characteristics of the materials, as well as the alteration factors, without affecting the integrity of the element under study. Various CSIC teams and infrastructures are currently working on the use and development of these technologies. These include the use of imaging techniques (such as tomography and ground-penetrating radar) and elemental physical and chemical, geochemical, mineralogical, petrological, biochemical, etc., analysis (e.g., X-ray fluorescence, ultrasound or porosimetry, among others).

The CSIC is at the forefront of research and the use of **new technologies in the conservation of cultural heritage in the face of the effects of climate change**. A novel field in this regard has to do with the use of nanotechnology for conservation and restoration treatments. Thus, the Instituto de Geociencias (IGEO, CSIC-UCM) [Institute of Geosciences] is working on the study of heritage stone materials, while new treatment techniques, such as electro-kinetic techniques, are being evaluated. Non-destructive procedures are essential to determine the petrophysical characteristics of the geomaterials used in heritage, to determine their degree of deterioration and to establish the urgency and guidelines for the interventions to be carried out. They are also necessary for the selection of the conservation and protection techniques to be implemented; because the extreme meteorological events caused by climate change affect the conservation of heritage and will generate a different behaviour to its resistance to deterioration, giving rise to new pathologies that were not previously present.

Similarly, research groups from the Instituto de Química Física Blas Cabrera (IQF, CSIC) [Blas Cabrera Institute of Physical Chemistry] are working on laser-based methods and techniques based to prevent, minimise and monitor the environmental effects of climate change on materials. This aims to better understand heritage objects and their degradation processes using state-of-the-art non-invasive laser-based technologies and innovative conservation approaches focusing on laser-based cleaning of tangible heritage. Likewise, centres such as INCIPIT applies and optimises advanced imaging techniques (multi-band technical photography, multi- and hyperspectral imaging, XRF scanning...) for the digital recovery of artistic, archaeological and documentary heritage in some cases deteriorated by climate change-related events and processes, such as fires, floods or bio-deterioration. The imaging techniques studied have made it possible, for example, to recover the legibility of texts in historical documents on paper and parchment affected by damp stains, ink fading or smoke deposition, among other causes.



In situ characterisation using portable X-ray fluorescence equipment of the conglomerate ashlar of Espejón (Soria), used in the Renaissance doorway of the palace of the Counts of Miranda (Peñaranda de Duero, Burgos). / VIRGINIA GARCÍA-ENTERO

In some CSIC centres (such as the IGME), a particularly novel approach is being developed to analyse the environmental factors that deteriorate stone in heritage. This approach takes into account the intensity and directionality of these factors in order to estimate their future evolution in the context of climate change. There is directionality in the alteration and erosion of built heritage, and it is precisely the most aggressive environmental events that show the most marked directionality. Climate change is increasing the intensity and frequency of these events, expanding the uneven vulnerability of certain façades or elements.

The use of **digital techniques and process automation** also enables the analysis of ensembles and materials affected by climate change. In this line, a number of CSIC teams and projects apply digital photogrammetry, 3D recording and analysis (using, for example, handheld lasers or terrestrial laser scanners), and are generating augmented reality tools with a view to conservation and dissemination.

The IAM and INCIPIT have been working for some time on the study of the archaeological heritage of coastal areas threatened by the relative rise in sea level, the effects of storms and the erosion of dunes and cliffs. The 3D recording and monitoring of site erosion provides accurate digital twins and contributes to decision-making for research, management and intervention on threatened sites (e.g., analysis of erosion in a given area by comparing 3D models obtained at different times).

As a transversal approach, the CSIC is applying deep *learning* and artificial intelligence techniques with the aim of improving the interpretation of the diagnosis and the results of the data generated. Some projects, such as those of the Instituto de Tecnologías Físicas y de la Información Leonardo Torres Quevedo (ITEFI, CSIC) [Leonardo Torres Quevedo Institute for Physical and Information Technologies], which use the latest advances in mechatronics and deep learning to optimise the information obtained from tomographic images from non-destructive techniques, such as acoustic transmission and ground-penetrating



radar (GPR), in order to facilitate the structural diagnosis of typical elements in historical heritage buildings. They are also researching on flexible and automated inspection systems that, together with a deep learning-based methodology, will make it possible to obtain the maximum information on heritage building elements and thus be able to assess their resilience to climate change. One of the main objectives of these projects is to develop non-destructive inspection tools and methods that are useful for professionals in the field of restoring heritage buildings and to mainstream these structural diagnosis techniques.

3D registration by means of
a terrestrial laser scanner
of the megalithic monument
M4 of Guidoiro Areoso
(Pontevedra). / ELÍAS LÓPEZ-
ROMERO.

Another AI application at the CSIC aims to numerically study the propagation of elastic waves in historical masonry elements. The goal is to facilitate the interpretation of results obtained from on-site non-destructive testing and improve our ability to perform structural diagnosis. This makes it possible to detect and classify the internal characteristics of masonry elements that are being affected by environmental factors associated, among other variables, with climate change.

Other projects, such as those directed by the IGME, apply *machine learning* tools for the automatic classification of ground motion data derived from InSAR (interferometric synthetic aperture radar) information, with which to draw up ground motion susceptibility maps for possible locations of heritage elements. A direct link has been found between the increased likelihood of ground movement and climate change because the intensification in extreme events, such as hydrological droughts, leads to more groundwater exploitation, more likelihood of subsidence in certain aquifers and more torrential events, which generate a higher frequency of landslides. In turn, these slopes may house heritage elements, such as cultivation terraces, huts, wells, waterwheels, and dry-stone ice houses, a construction technique declared Intangible Heritage of Humanity by UNESCO in 2018 and studied by the CIDE, IH, INCIPIT and IPE centres.

The CSIC also leads or participates in projects that analyse the **cultural heritage** that has remained **submerged** under the waters of reservoirs for decades, and which, recently, is undergoing processes of total or partial cyclical emersion, which causes the acceleration of its deterioration. It is a type of heritage that has not been scientifically addressed until now, as has been the case with submerged cultural heritage in marine environments and even on coasts, subjected to rises and falls in sea level. The long and intense droughts of recent years and the overexploitation of water resources are directly responsible for the enormous drops in the water level of reservoirs during dry periods, while in wet periods, the water level rises to the point of re-submerging the

previously submerged cultural heritage. In many cases, such sharp oscillations occur on an annual basis. Thanks to these CSIC projects, in which the IGEO and the IGME, among other centres, are involved, a new type of cultural heritage has been recognised, often not even inventoried and, of course, not subject to any protection formula due to its impossibility in most cases. Its pattern of deterioration is different from that of subaerial, underwater or buried environments, and the risks to which it is subjected, the factors, causes, processes, and forms of alteration have been identified, as well as the most appropriate techniques for its monitoring. A similar case is that of lakes, ponds and marshes that contain cultural heritage elements subject to fluctuations in the water table and its natural resources, as a consequence of climate change and human action. An emblematic example is the site of La Draga, in Banyoles (Girona), which has been studied for years by the IMF.

Various centres (MNCN, IGEO and IACT, among others) and multidisciplinary research projects are focusing on other unique environments, with undeniable heritage interest, such as the **underground space**, in general, and caves, in particular. The aim is to attempt to solve the environmental problems caused by climate change inside these spaces, visible in the atmosphere, and the materials that are currently forming in them (speleothems and deposits), which impact on the cultural heritage they contain. CSIC research provides tools and information that can be used to establish specific guidelines and controls in order to avoid or minimise environmental modifications in these areas and to maintain the necessary balance to make them sustainable spots. These areas are considered authentic natural laboratories and are affected by any activity carried out both in the interior, where the formation and transformation of minerals takes place, and in the outer area of influence. More specifically, the MNCN has extensive experience in the conservation of heritage in underground environments, both natural (caves with cave art in Cantabria such as Altamira, the caves of Mount Castillo, La Garma, etc.) and anthropic (necropolis of Carmona [Seville], catacombs

in Rome, the Thyssen Museum in Malaga, etc.). The research addresses different aspects; on the one hand, environmental monitoring, with stations for measuring various parameters, such as temperature, humidity, wind, pressure and the concentration of tracer gases, such as carbon dioxide, methane, and radon (Radon-222 isotope), as well as particles in suspension, and portable gas and water sensors and analysers. In addition, research characterises the substrates and seepage water from a mineralogical, geochemical, and petrophysical point of view. It also takes into account geomicrobiological aspects in relation to the interaction between micro-organisms and the diverse existing substrates: sediments, rocks, building materials, etc., by means of early detection of the proliferation of micro-organisms. Finally, the impact of visitors on subterranean environments is evaluated and strategies are designed to minimise the harmful effects.

Finally, the **importance of research networks, collaborations, and participation in international consortiums and platforms** that have a direct or indirect impact on the contemporary study of the effects of climate change on heritage should be noted. The CSIC's participation in the European Research Infrastructure for Heritage Sciences (E-RIHS), in the Alliance for Research on Cultural Heritage in Europe (ARCHE; with the IQF and the Centro Nacional de Investigaciones Metalúrgicas—CENIM, CSIC—[National Centre for Metallurgical Research]), or in the European Synchrotron Radiation Facility (ESRF; with the Instituto de Ciencia de Materiales de Madrid—ICMM, CSIC—[Institute of Materials Science of Madrid]) should also be highlighted.

2.3.

Future scenarios: from adaptation and mitigation to the social value of heritage

IN terms of **the future impacts of climate change scenarios on heritage**, the research carried out by various CSIC centres ranges from global, continental and regional scales to focus on a single unique heritage element. One example is the participation of CSIC (MNCN) researchers in the IPCC, which issues reports of the impact on the frequency and magnitude of extreme events (floods) and their effects, including those on heritage. The prediction of global change impacts on groundwater and naval water resources in protected natural spaces, such as wetlands and mountain areas, through projects led by the IPE and the IGME, in turn predict the effects on landscapes and other cultural heritage elements of these territories. They also allow predictive models of the environmental response to climate change in underground environments (MNCN) to optimise conservation measures for the heritage they are home to, such as the future evolution of unique heritage elements like the Altamira cave (Cantabria) with time horizons of up to a century.

CSIC is fully committed to these issues and is involved in initiatives at all levels, especially at the **European level**, where it participates in and leads projects in the framework of European Cooperation in Science and Technology (COST) actions and Joint Programming Initiatives/ JPI-JHEP. The role played in the preparation of documents such as the Statement Social Archaeology of Climate Change, promoted by the European Association of Archaeologists (EAA) and the Society for American Archaeology (SAA), is of special relevance due to its social and heritage nature.

At present, both the tangible and intangible heritage of Mediterranean agricultural systems (cultural wealth associated with the management of pastureland, orchards, drylands, mountain farming, etc.) is of great value. For this reason, the CSIC, through 16 centres covering different disciplines, is participating in the European Joint Programme - EJP SOIL, focused on sustainable and climate-smart management of agricultural soils. This initiative includes the analysis of the know-how and long-standing practices related to sustainable agricultural soil management, which promote its healthiness and its effects on climate change mitigation. It also takes into account the consequences that climate change scenarios may have on these management

The infographic illustrates the historical and projected CO₂ concentrations. The top section shows a person's head with arrows indicating CO₂ exchange, and two clouds labeled CO₂ with a snowflake and a sun icon respectively. The bottom section is a line graph showing CO₂ concentration in ppm from 1960 to 2100. The graph includes historical data (black line), in situ measurements (red line), and various predictions (blue, green, and orange lines). A legend at the bottom explains the data series.

Legend:

- Predicciones (concentración distribuida de forma equitativa)
- Predicciones (concentración distribuida de manera realista)
- Predicciones (sin visitantes)
- Mediciones *in situ*

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practices (among others, drought or high-intensity hourly rainfall problems, and irrigation-related knowledge and constructions). In addition, the effectiveness of public policies, both at the macro and micro-policy levels, is assessed and the inclusion of all stakeholders is promoted.

The INCIPIT and IAM are also innovators in Spain in the qualitative and **quantitative assessment of threats to cultural heritage** under anthropogenic pressure and the effects of climate change. In collaboration with international research centres, these CSIC groups have applied different tools in order to observe the variables that affect heritage and obtain numerical values of its vulnerability, which can be analysed at different levels. The results obtained are a powerful tool for communication and decision-making on the measures to be implemented in the short, medium, and long term in threatened sites.

From a theoretical-methodological perspective, the CSIC promotes research projects applied to the design of heritage impact assessment methodologies, aimed at renewable energy production facilities (essentially wind and photovoltaic energy), relevant for climate change management. This is a long-established line of work at INCIPIT, an institute that continues to be a benchmark in the field.

From a historical perspective, by **enhancing the heritage value of cultural landscapes**, problems that are aggravated by climate change can be addressed. In the case of the ancient mining landscapes of north-western Spain, studied by the IH (Las Médulas [León], a UNESCO World Heritage site since 1997), their conversion into heritage resources has made it possible to diversify local sources of wealth, in the context of the recent weakening of the mining industries and the abandonment of traditional land use in rural areas. Within the framework of a project of the Interreg VI-B Sudoe 2021-2027 programme, the INCIPIT is tackling the crisis in south-west European mountain areas (with serious problems of ageing and depopulation) by enhancing the value of the heritage associated with their cultural landscapes. This social innovation tool offers new development opportunities to mountain communities, improving their quality of life, territorial cohesion and the development of new economic resources.



Fort Louis (18th century) on the island of Saint-Martin (French West Indies), affected by atmospheric agents. / ELÍAS LÓPEZ-ROMERO

In relation to depopulation and the loss of woodland and landscape value in areas with severe ageing and exodus problems, the IH and the IPE are studying how the restoration of abandoned villages helps to stabilise the population and has a positive impact on the sustainable economic and social development of depopulated areas. This provides the scientific evidence needed to support informed decision-making for a successful, fair, and sustainable ecological transition that helps to halt rural depopulation. These communities are guardians of the cultural heritage that is threatened by climate change. For its part, the EEA is carrying out a project for the rehabilitation of agricultural areas in connection with the *almunias*, aristocratic agricultural estates located on the outskirts of Mediterranean medieval cities. Although most of these estates have disappeared, many of their farmland areas and hydraulic infrastructures have survived and are still in use, forming part of the so-called *urban green belts*. Their identification leads to the acknowledgement of the historical value of these traditional farming areas, with their irrigation ditches, pools, waterwheels, etc. This guarantees their conservation, restoration, and enhancement, and contributes to the appropriate and sustainable management of historic urban environments in Southern Europe and North Africa, which are particularly sensitive to the risks of climate change.

With regard to landscape management, IMF's archaeobiology genetic studies are fundamental to understanding the geographical and temporal dynamics that have shaped the genomic composition of today's Iberian sheep in all their diversity. Information on the origins, evolutionary trajectories, and historical improvement will be helpful for policies related to the management and conservation of Iberian breeds. Public policies have a high impact on livestock farming, so historical sequences of data beyond 1950 should be included, in order to make more solid productivity and sustainability models, which also take into account the ecological particularities and the level of population density of each area.

Studies on **intangible heritage** are also important. The Mediterranean diet, included on the UNESCO list since 2013, has been the focus of several transfer and dissemination initiatives, in centres such as the IH and the IMF, which aim to promote the consumption and enhancement of traditional plant foods (legumes and whole grains), as well as to emphasise their benefits for human health and the environment.

In terms of intangible heritage, the INCIPIT chairs projects to analyse, at a local level, the responsibilities, expectations, obligations, and returns involved in heritage processes. One of the case studies focuses on shellfish gatherers and their role as drivers of heritage definition and sustainability in the Galician estuaries, in relation to anthropic action and the environmental changes expected in the near future. The INCIPIT has also participated in projects for the characterisation of the social risk associated with the uses of heritage (such as, for example, the Altamira Social Value initiative), which are directly related to changes in tourism dynamics and, directly or indirectly, to the impact of climate change on the latter. This research sets a guideline for the transfer and exchange of knowledge between academia and public administration, which takes the form of collaboration in the design of public policies for the management of heritage assets.



In short, **the CSIC is directly involved in all aspects that are currently at the forefront of scientific and technical research, theoretical positioning, methodological development, and the value and social impact of cultural heritage in relation to climate change.** The actions carried out cover local, regional, national, and international scopes, and encompass the entire chronological range of the relationship between human societies and the environment, from prehistoric times to the present day. The CSIC's work is characterised by a high degree of interdisciplinarity, something which, thanks to the initiatives, connections, and platforms being implemented by the institution, will be further enhanced in the coming years.

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Conclusions and Recommendations

Conclusions



Cultural heritage/landscape is an active part of social relations and quality of life, and its loss is irreparable. Changes in climate, including the current climate, have environmental effects that may be harmful to it. Future scenarios and short- and medium-term predictions point to an increase in the frequency and magnitude of extreme events in certain parts of the planet, including Spain. Therefore, the study of the interaction between climate, human communities, and cultural heritage is essential for adapting the relationship to the problems posed by climate change and the mitigation of its harmful effects.



Importantly, we should overcome the belief that cultural heritage/landscape is as a passive subject of climate change and consider how its study can provide knowledge in order to adapt to climate change. Possible actions should consider an **open concept of cultural heritage/landscape** that accounts for the processes of change and avoids its fossilisation. Heritage provides historical information on how human societies have adapted to their environments and to changing climatic conditions; it provides information on traditional materials and techniques that have proven effective in responding to these conditions; it participates in the circular economy through the preservation and reuse of spaces and build-

ings or through sustainable urban space and land management practices; it plays a role in the construction of feelings of identity, promoting social cohesion and resilience, key elements for responding to natural changes and disasters; and it constitutes a significant source of information for the design of effective and fair adaptation and mitigation measures in the face of climate change. In addition, vernacular knowledge on local management of natural or productive spaces has a recognised value in climate change adaptation strategies.



Climate change highlights the fragility of the balance between the different interests that intersect, almost always in conflict, in the management and enjoyment of these heritage resources, and this requires adaptations and changes in cultural landscape management systems, taking into account multiple factors such as land ownership and use, heritage treatment, the direct or indirect uses of these assets (economic, social, etc.), physical intervention on heritage, the symbolic/identity uses of cultural heritage, and heritage governance.

Recommendations

Recommendations for policy-makers:



Acknowledging the problem. The difficulties of managing a complex set of assets and the need for interaction between the different government levels and areas should be considered. In this respect, the weight of the autonomous communities is enormous, since they have assumed the powers over cultural heritage and almost all of them have drafted their own protection legislation. It is essential to insist on the regional level and to reinforce the interlocution between administrations. It is at this level that problems and changes are detected and where the measures adopted must be implemented. It is crucial in terms of prevention, anticipation, and foresight.



Increasing the regulatory and legislative effort. Cultural heritage is currently unprotected against the risks of climate change, while it is poorly provided for in legislation and risk management plans. Although almost all the autonomous communities have their own action plans against climate change, very few cover cultural heritage or merely include it in their strategies, without implementation through plans and regulations, and therefore there is no specific budget in their annual expenditure forecasts. Therefore, in the face of extraordinary events, sectoral policy allocations must be used. Although cultural heritage involves multiple economic sectors, tourism has traditional-

ly been seen as a particularly relevant source of wealth for Spain. However, heritage issues cannot remain exclusively linked to this economic sector in public policies and protection plans, nor solely focused on heritage management. The social value of heritage needs to be recognised, as well as its role in improving the living conditions of citizens. It is also essential to ensure compliance with the regulations already in force, through the inspection and monitoring of plans, programmes, and projects.



Having an in-depth knowledge of the various sources of funding. It is essential to promote the participation and attraction of international funds (global, European and bilateral) by public administrations by creating information and advice offices (especially at local and regional level) and reducing the bureaucratic procedures for applying for, obtaining, monitoring and justifying the support.



Increasing investment in research and training. An economic boost is needed to address social and environmental issues on a truly multidisciplinary basis. To this end, it is essential to allocate staff and resources to the offices and centres providing advice to the scientific community to apply for and develop projects and plans, such as offices for the transfer of research results.



Floods caused by the flooding associated with the isolated depression at high levels of 29 October 2024 in the parish church of San Jorge Mártir in Paiporta (Valencia) / BIEL ALIÑO PARA LA AGENCIA EFE



Sign of closure during the floods in the cloister of San Juan de Duero (Soria). / ANDRÉS DÍEZ HERRERO



Encouraging the creation of networks. These are vital in order to develop multidisciplinary lines of work, sharing resources and avoiding the atomisation of science. The Spanish R&D&I system, and in particular the CSIC, currently has internationally renowned individuals, research groups and centres engaged in the holistic and multidisciplinary research into cultural heritage and the effects of climate change.



Developing a collaborative system of indicators. This is key to establishing thresholds and intervals for the prioritisation of problems, the prioritisation of actions and an early warning system in terms of impact on heritage. These indicators will enable medium- and long-term trend assessments to make preventive conservation strategies more objective and aid decision-making.



Creating and maintaining geo-referenced databases of past events. It is important that these data related to climatic changes that have affected heritage (floods, fires, land movements, droughts, etc.) are recorded so that they can help to understand how societies have adapted and mitigated their effects, in order to prevent future events associated with current climate change.



Generating true risk maps. It is critical that the maps are based on interdisciplinary scientific evidence in order to justifiably prioritise the allocation of resources. The current lack of basic information is alarming, not only for threatened heritage, but for heritage in general. There is a lack of inventory, documentation and management plans for a part of the threatened heritage (e.g., submerged heritage in reservoirs, underground and coastal heritage, subject to rapid emergence and disappearance; mountain heritage, highly sensitive to the neglect of management practices with an impact on erosion processes, forest preservation activities, loss of transhumance routes, etc.).



Designing a monitoring framework and promoting preventive conservation measures. It would be advisable to adapt measures against climate change to the reality of the environment of exposure. To this end, regionalised information on environmental aggressiveness and directionality is proposed; and further, to prepare specific vulnerability studies on strategic heritage elements of maximum interest (open and available to society); to create methodological guides for their adaptation to local cases; and, finally, to promote the availability of quality climate data prior to the design of preventive conservation measures.



Bearing in mind that the actions of all political-administrative levels must account for European regulations and international reference frameworks. European documents and recommendations, such as the European Landscape Convention, should serve as a starting point and minimum content for national, regional and local legislation and guidelines. Furthermore, the National Landscape Plan and the National Plan for Adaptation to Climate Change (PNACC) 2021-2030 are equally necessary to serve as a mandatory framework for other sectoral legislation.

Recommendations for businesses:



Encouraging science-business collaboration for the development of methodologies and techniques. Certain sectors are particularly relevant, such as those related to architecture and urban planning, land use planning, tourism, and cultural industries, and therefore specific funding calls could be promoted.



Incorporating departments, teams and staff in the field of multidisciplinary research on cultural heritage and risks posed by climate change, in order to improve the data sources, methodologies, and products available to their clients in these novel areas with a major future market.



Promoting communication, dialogue and permeability between research, policy, management, and society. Not only should channels for such communication be created, but also technical and administrative procedures should be improved to minimise the effects of poor coordination and communication.



Promoting a long-term approach. We need to take into account the sometimes-delayed effects on heritage, such as changes in the intensity of extreme events (sixth generation fires or the extent of cold drops) and the acceleration of rural exodus.



Investing in real applied research developments, additional and alternative to those of the public sector, which contribute to the Spanish National R&D&I system as a private initiative, as is the case in many European countries.



Encouraging and enhancing companies that introduce specialised scientific-technical staff and specific tools for the study of cultural heritage in the face of climate change.

Recommendations for society:



Raising awareness on the extent of the problem for cultural heritage and to the same degree as has been achieved in relation to the effects of climate change on ecosystems and plant and animal species.



Recognising society itself, both collectively and individually, **as part of the solution**, and becoming more actively involved in understanding and defending cultural heritage in relation to climate change.



Promoting bottom-up initiatives and processes, based on **active social mobilisation and participation**, as they are key to heritage conservation in the face of climate change threats, as well as the public reporting of problems. The transfer and adaptation to cultural heritage of successful experiences in the field of natural heritage (such as *Sponsor a tree*, *Sponsor an animal* or *Sponsor a rock*) can engage society in detecting and finding solutions to heritage problems in the face of climate change.

Recommendations for the scientific community:



Developing and applying a multidisciplinary approach to solving societal problems. The impacts of current and future climate change on heritage can only be understood from physical-chemical, geological, biological, archaeological, and historical perspectives, which provide an overview with sufficient time span to ensure that numerical models for simulating and predicting future climate can be calibrated and validated based on real, objective observations. Disciplines such as archaeology, history, and geology, which have generally been neglected in these discussions, must play a role in addressing the current challenges and not just provide content for tourism, leisure or cultural industries.



Promoting interoperability and ease of identification and joint use of data generated for the monitoring and management of cultural heritage. The development of common procedures and best practices, including patents and utility models, should be promoted to ensure the quality of the record analysed. New data sources and methods of analysis, and physical-chemical treatments of cultural heritage and its context within the limits of knowledge should also be encouraged. To this end, public-private consortia of research teams and groups need to be formed that can apply for grants in calls for innovative ideas and proof of concept.



Promoting closer dialogue on heritage and climate change **between the scientific community and the media and content creators**, while scientists need to improve their skills in the use of social networks, audio-visual platforms, and other digital communication tools.



Fostering education, outreach and awareness-raising on the importance of cultural heritage and its vulnerability to climate change, at different educational stages and for different types of audiences, as well as **enhancing citizen collaboration** in the documentation and protection of threatened heritage. This would contribute to improving social cohesion around the notion of the *common good*, as well as the resilience of society, which is essential to cope with change.

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List of Centres



CENTRE	WEB PAGE	E-MAIL
Centro de Investigaciones sobre Desertificación (CIDE, CSIC-Universitat de València, Generalitat Valenciana)	www.uv.es/uvweb/centro-investigacion-desertificacion/es/centro-investigaciones-desertificacion-1285894590702.html	direccion.cide@csic.es
Centro Nacional de Investigaciones Metalúrgicas (CENIM, CSIC)	www.cenim.csic.es/	direccion.cenim@csic.es
Escuela de Estudios Árabes (EEA, CSIC)	www.eea.csic.es/	direccion.eea@csic.es
Institución Milá y Fontanals de Investigación en Humanidades (IMF, CSIC)	www.imf.csic.es/	direccion.imf@csic.es
Instituto Andaluz de Ciencias de la Tierra (IACT, CSIC-Universidad de Granada)	www.iact.csic.es/	direccion.iact@csic.es
Instituto de Arqueología de Mérida (IAM, CSIC-Junta de Extremadura)	www.iam.csic.es/	direccion.iam@csic.es
Instituto de Ciencia de Materiales de Madrid (ICMM, CSIC)	www.icmm.csic.es/	direccion.icmm@csic.es
Instituto de Ciencias del Patrimonio (INCIPIT, CSIC)	www.incipit.csic.es/	direccion.incipit@csic.es
Instituto de Geociencias (IGEO, CSIC-UCM)	igeo.ucm-csic.es/	direccion.igeo@csic.es
Instituto de Historia (IH, CSIC)	ih.csic.es/es	direccion.ih@csic.es



CENTRE	WEB PAGE	E-MAIL
Instituto de Química Física Blas Cabrera (IQF, CSIC)	www.iqf.csic.es/es/	direccion.iqf@csic.es
Instituto de Tecnologías Físicas y de La Información Leonardo Torres Quevedo (ITEFI, CSIC)	www.itefi.csic.es/es	direccion.itefi@csic.es
Instituto Geológico y Minero de España (IGME, CSIC)	web.igme.es/	direccion.igme@csic.es
Instituto Pirenaico de Ecología (IPE, CSIC)	www.ipe.csic.es/	direccion.ipe@csic.es
Museo Nacional de Ciencias Naturales (MNCN, CSIC)	www.mncn.csic.es/es	direccion.mncn@csic.es

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Further Information



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Conexión-Arqueología / ArchaeologyHub – Consejo Superior de Investigaciones Científicas (CSIC).



Conexión Geociencias – Consejo Superior de Investigaciones Científicas (CSIC).



CHeriScape: Cultural Heritage in Landscape.



Consejo Superior de Investigaciones Científicas (CSIC).
White Papers Scientific Challenges 2030.



CSIC Interdisciplinary Thematic Platform for Climate and Climate Services,
PTI+ Climate.



CSIC Interdisciplinary Thematic Platform, Open Heritage:
Research and Society.



Intergovernmental Panel on Climate Change (IPCC).



International Centre for the Study of the Preservation and Restoration of Cultural Property (ICRROM). *Net Zero: Heritage for Climate Action*.



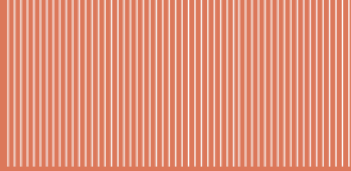
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Science for Public Policy



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