The impact of climate change on cultural heritage: evidence and response

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Abstract

This paper presents the first broad-based research on the impact of climate change on historic buildings, buried archaeology, parks and gardens. Research coincided with the publication of the UKCIP02 climate change scenarios and other studies assessing regional climate change and the impact on nature conservation and gardens. The methodology consisted of an assessment of climate change and adaptation literature, a questionnaire, site visits, regional and policy workshops. It conflated evidence from climate and heritage specialists, pointing to physical changes in cultural heritage and concluding with several policy recommendations.

Keywords

climate change, historic buildings, buried archaeology, parks, gardens, methodology, policy

Introduction

Archaeological sites and some buildings have survived at least two periods of global warming (around 1500–1200 BC and 800–1200 AD) and intervening cold periods. With international scientific evidence mounting and the reliability of future climate predictions increasing, in 2002 English Heritage commissioned research to gather evidence on climate change as a possible cause of environmental instability of cultural heritage and to inform present and future planning (Cassar 2005).

Climate change modelling and prediction

Climate change predictions are based on climate models which are constructed from studies of the current climate system, including atmosphere, ocean, land surface, cryosphere and biosphere, and the factors that influence it such as greenhouse gas emissions and future socio-economic patterns of land use. A climate model is a mathematical formulation of the effects of all the key processes operating in the climate system and the effectiveness of any particular model is assessed by seeing how well it reproduces past climate behaviour. Additionally, extrapolating the models to future climates incorporates not only the scientific uncertainties inherent in modelling complex weather systems, it implies that the broad operation of the climate system will remain constant and not undergo dramatic shifts and the much less quantifiable uncertainties in future emissions and land use. Advanced global models typically have a coarse resolution (a few hundred kilometres) which does not allow for useful local climate change projections where local weather is heavily influenced by local topography and land use.

More detailed regional climate models (RCMs) are constructed for limited areas and shorter time periods. The United Kingdom's Meteorological Office supports the Hadley Centre for Climate Prediction and Research, which has several such regional climate models. This study used the UKCIP02 projections (Hulme et al. 2002) from the output of the regional climate model, HadRM3 whose resolution is 50 km over Europe, with the model run over the periods 1961–90 and 2070–99 for a range of emission scenarios. The confidence levels in the key predictions are qualitative because they are based on expert understanding of complex science, observed data, the ability to predict and the consistency of the model (Table 1).

Focussing on the high confidence projections for 2080, the United Kingdom is likely to experience a rise in temperature, an increase in variability leading to some very warm years, and an increase in wetter winters everywhere; greater contrast between summer and winter seasons and a decrease in soil moisture levels in summer and autumn in southeast England; increased regional differences in sea level rises and a significant decrease in snowfalls everywhere.

To manage a wide array of climatic variables and heritage types in an integrated research project is a huge challenge. A decision was made to concentrate on two specific contrasting regions, the northwest and the southeast of England. Both had already been extensively studied by Cranfield University's RegIS project (Holman et al. 2001) which was the only published integrated assessment of climate change impacts in the UK and was therefore of unique importance.

Table 1. Summary statements of UK weather changes and relative confidence levels for the UKCIP02 climate change scenarios

Key predictions	Confidence level
Temperature:	
Annual warming by the 2080s of 1–5 °C, depending on region	High
Greater summer warming in the southeast than the northwest of England	High
Variability: years as warm as 1999 becoming very common	High
Greater warming in summer and autumn than in winter and spring	Low
Greater day-time than night-time warming in summer	Low
Summer and autumn temperatures become more variable	Low
Precipitation:	
Generally wetter winters for the whole United Kingdom	High
Greater contrast between summer (drier) and winter (wetter) seasons	High
Snowfalls decrease significantly everywhere	High
Substantially drier summers for the whole United Kingdom	Medium
Variability: summers as dry as 1995 become very common	Medium
Winter and spring precipitation becomes more variable	Low
Storminess:	
Winter depressions become more frequent, including the deepest ones	Low
Humidity:	
Specific humidity increases throughout the year	High
Relative humidity decreases in summer	Medium
Soil moisture levels:	
Decrease in summer and autumn in southeast England	High
Increase in winter and spring in northwest England	Medium
Sea level rise:	
Continuation of historic trends in vertical land movements introduces significant regional differences in relative sea level rises around the United Kingdom	High
Storm surge: for some coastal locations and some scenarios, return periods will reduce an order of magnitude by the 2080s	Medium
Changes in storminess, sea level and land movement mean that storm surge heights will increase by the greatest amount off southeast England	Low
Solar radiation:	
Reduction in summer and autumn cloud, especially in the south, and increase in radiation	Low

Methodology

The risks inherent in gathering and interpreting observed evidence made it essential to design a methodology that allowed access to a diverse range of sources, so that data could be verified before being accepted as evidence. The methodology made empirical evidence more robust by cross-checking different types of data.

Project teamwork

A multidisciplinary team of investigators was assembled including conservators, building physicists, archaeologists and a climate modeller.[1] The widest possible list of likely climate-related problems for cultural heritage was brought together, the UKCIP02 climate change scenarios (Hulme et al. 2002) were evaluated and the variables most likely to impact on cultural heritage in the two study areas were selected.

Questionnaire

The purpose of the questionnaire was to gather data but also to be an information source for the recipients. It was constructed around 18 central questions, one for each issue of concern identified by the project team, namely seasonal and diurnal temperature changes, seasonal and extreme rainfall, sea level rise, storm surge, river flooding, water runoff and erosion, soil moisture content, water table height and chemistry, relative humidity, wind, solar radiation and cloud cover, lightning and fire risk, plant physiology and distribution, pest and diseases, human comfort and health and safety. Each question was accompanied by a text synopsis of the climate change impact projected for that issue, using predictions from the UKCIP02 climate change scenarios (Hulme et al. 2002) and the RegIS project (Holman et al. 2001) and comparing the projections for 2080 with the baseline years of 1961–90 making it possible to see the likely degree of future change. The questionnaire was circulated widely to national, regional and local scientific and heritage experts, and local site managers requesting evidence of links between climate change and its impact on cultural heritage, the likely future effect on heritage of current climate change predictions and the planning and preparation that would be needed to ensure a timely management response.

Site visits

The questionnaire was followed by visits to 17 buildings, archaeological sites, parks and gardens with contrasting climates, flood risk, accessibility, urbanization, types of buildings, archaeology and gardens.[2] The choice was made in consultation with regional and local heritage experts, managers, advisers and custodians. The visits were intended to see and hear at first hand the climate change threats to the sites, to examine examples of damage attributed to climate change and to discuss how these were impacting on local stewardship decisions.

Regional workshops

Two regional workshops were organized in Cambridge and Manchester, representing two areas affected differently by climate change. Regional experts and managers discussed the questionnaire and site visit data, future protection plans and likely conflict over the different ways in which heritage might respond to climate change. On the basis of the cross-referred evidence from the questionnaire, site visits and workshops, the original list of climate-related problems was distilled into five issues central to the cultural heritage, namely: temperature (maximum temperatures rising markedly); soil moisture (levels dropping markedly and summer drought); extreme rainfall and high winds (torrential rainfall becoming common and damaging winds probably becoming common); river flooding (floods increasing in frequency and severity); and coastal flooding (sea levels rises and storm surge exacerbating coastal flooding and loss).

Policy makers' workshop

A policy makers' workshop met to discuss and prioritize the five issues. Maps overlaid the locations of vulnerable sites and their susceptibility to patterns of local climate change produced from regional climate models (Cassar 2005). They helped make complex risk data accessible and provided a direct and effective means of perceiving the overall scale of climate change problems and the risks to individual sites (Figures 1 and 2). The policy makers' workshop distilled several recommendations as well as some general conclusions on how cultural heritage could adapt to a changing climate.

Evidence of threat and observed changes to cultural heritage

This evidence was based on specific observations by heritage managers of changes attributed to climate change and on experience, knowledge and understanding of the sites in their care. The climate change factors identified as the greatest threat to cultural heritage were reached by consensus and almost all heritage managers had already noticed progressive changes in the climate patterns of their sites and associated increases in deterioration.

Buildings and their contents

The inability of historic rainwater disposal systems to handle torrential or wind-driven rain was highlighted as a contributory factor in the wetting of walls. Solar radiation drives moisture and salts inside walls leading to damp and the risk of efflorescence on internal surfaces. The problems of river flooding necessitating extensive repairs to buildings and the risk of disturbance to buried archaeology of improvements to drainage systems to cope with flood risks were emphasized. Audley End House, a historic property with gardens in south east England, was

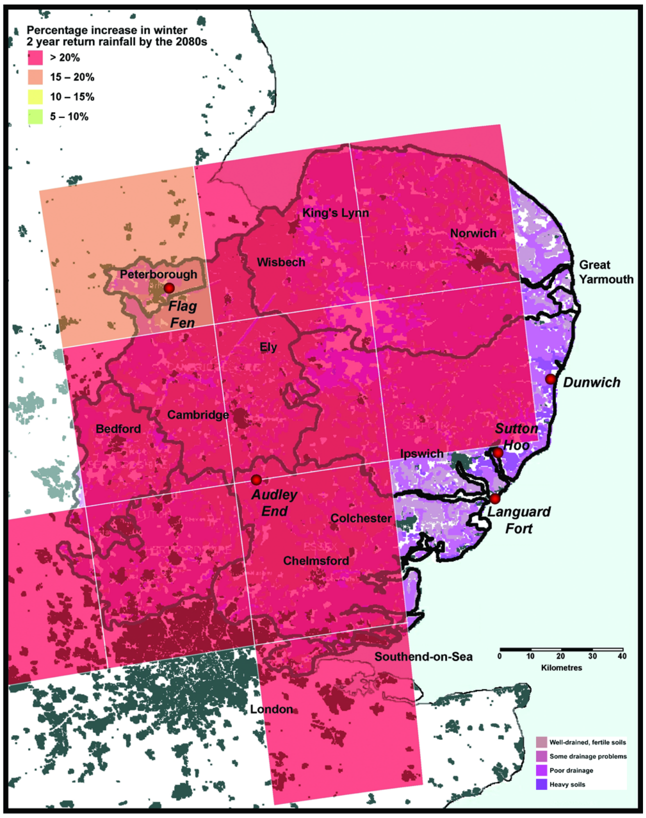

Figure 1. UKCIP02 high confidence prediction of torrential rain in the east of England superimposed on visited sites

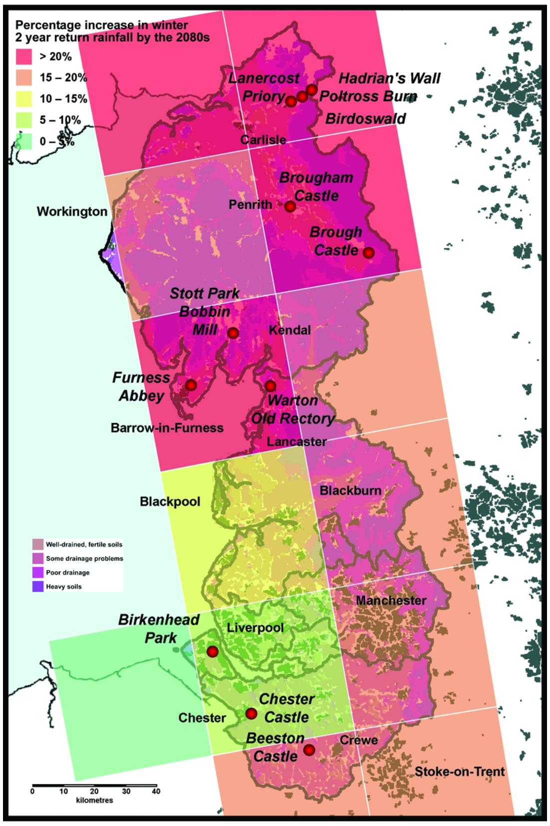

Figure 2. UKCIP02 high confidence prediction of torrential rain in the northwest of England superimposed on visited sites

highlighted as an example where there have been problems with rainwater disposal, damp penetration, damage to decorative plasterwork and river flooding of the gardens. Although the UKCIP02 climate change scenarios have a low confidence level for predictions of storminess and high winds, these issues were flagged up as problems already being experienced with historic roofs, windows, awnings, verandas, large trees close to buildings, ruins and excavated archaeology. The high confidence level predicting a decrease in soil moisture levels also puts buildings at risk from subsidence. The increased erosion of the ruins of Furness Abbey on the Cumbrian peninsula in the northwest of England was linked to wind throw, increased storminess and gales, whereas coastal loss in south east England continues to affect the medieval town of Dunwich, which has virtually disappeared into the sea. Predicted changes in temperature and relative humidity were considered to be small and gradual enough for vulnerable materials to accommodate them. However, concern was expressed over the indirect future effect of these changes, namely increased demand for mechanical cooling in summer, requiring meticulous environmental monitoring of conditions and a set of baseline values. Evidence of the change in distribution of existing pest species across the United Kingdom and the introduction of new pest species suggest that isolated opportunities alone cannot account for these changes in the past decade.

Buried archaeology

Changes in soil moisture and chemistry were unanimously considered a threat to preservation in situ as baseline knowledge of the effect of changes in soil chemistry on preservation is poorly understood, for example the loss of certain data types only preserved in waterlogged/anaerobic/anoxic conditions, the loss of archaeology presently preserved close of the ground surface and the effect on the archaeological record of the drying of soil causing the loss of stratigraphic integrity. The increase in sea level and storminess is a danger for many sites vulnerable to erosion such as the Sutton Hoo barrow site because of the disturbance of the metastable equilibrium between artifacts and soil. On the other hand, in areas that lie below sea level, such as the Fenland area in south east England where many prehistoric and Roman fenland sites were built and decayed under tidal influence, flood risk alleviation schemes could cause more damage to buried archaeology than flooding, though the occurrence of torrential rain would cause erosion. Changes in plant physiology and distribution were of concern for a variety of reasons: drought causing loss of vegetation exacerbating erosion, deep root penetration damaging structures causing subsidence and sediment boundaries and changes in vegetation cover affecting the survival of artifacts and ecofacts.

Parks and gardens

The effect of climate change on parks and gardens has been documented elsewhere (Bisgrove and Hadley 2002). The evidence from this research confirmed that many factors that affect buildings and archaeology also affect historic parks and gardens. Wind and rainfall are a key concern. Mature tree specimens are particularly susceptible to wind damage. Storms have already damaged or destroyed many historic landscapes, but there is concern that in the future climate change can make identical replacements difficult to grow. Excessive rainfall has caused trees to become unstable and to topple during gales, while the planting that can cope successfully with dry summer conditions is at risk from waterlogged soils in winter. The predicted rise in temperature could see a dramatic change in the appearance of the English landscape where daffodils and apples need frost to germinate or set seed. Warmer temperatures have already increased the risk from pests such as the year-round presence of Canada geese at Birkenhead Park in northwest England destroying grassed areas. Changes in the chemistry and height of water tables would affect water supplies to ornamental lakes, fountains and other water features, whereas the after-effects of high tides and river flooding can be exacerbated by salinity of the flood water as for example at Westbury Court Garden on the River Severn in the west of England where yew hedges hundreds of years old are at risk.

Strategies for adapting cultural heritage to climate change

Planning time-scales

Convincing policy makers to include climate change impacts in planning and moreover cultural heritage can be difficult. The questionnaire revealed, and the workshops confirmed, that planning time-scales in the heritage sector are often much longer than conventional planning cycles (Figure 3).

Out of 57 questionnaire respondents, only 13 indicated a planning timeframe of five years, whereas 21 respondents indicated a timeframe of over 100 years. This 'long view' is vindicated by the emphasis on preparation and adaptation in the Third Assessment Report of the United Nations Intergovernmental Panel on

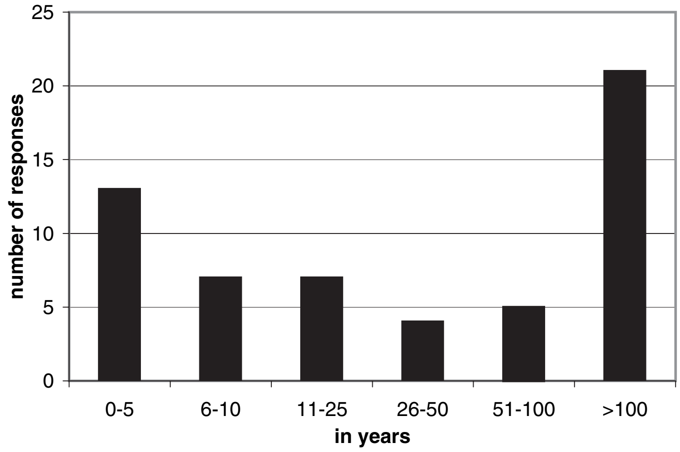

Figure 3. Heritage managers' questionnaire responses on planning time-scales

Climate Change (McCarthy et al. 2001) which advises policy makers that adaptation is a necessary strategy at all scales to complement climate change mitigation efforts and that '*Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages*'. Heritage professionals can make a positive contribution to longer-term planning for climate change by other authorities, can ensure that cultural heritage is integrated into these plans and more specifically in conservation plans directly affecting cultural heritage. However, caution must be exercised as confidence in longer-term predictions is lower overall than short-term predictions.

Monitoring, management and maintenance

The research did not reveal new problems for cultural heritage but it drew attention to long standing conservation issues. Maintenance and condition monitoring will become more critical as climate change takes effect. Where there is concern that drainage and rainwater disposal systems in historic buildings may not have the capacity to deal with torrential rain, it will be important to keep all gutters, hoppers and down pipes, even the most difficult and inaccessible, meticulously clean so that an increase in rainfall can flow away safely. Crucially, there was consensus among heritage experts and managers that non-invasive or concealed improvements might not be possible, requiring difficult choices on what to sacrifice and a preference for funding to be directed towards maintenance instead of new building work.

Loss and obsolescence

The issue of acceptance of loss of some heritage elements to save the rest was raised in the context of coastal archaeological sites. One heritage manager stated: '*We'll never save everything, so hard decisions are needed as to which to let go*' with an emphasis on assessments of value, significance and life expectancy. There was a different view from some stewards of the natural environment with measures being taken to reverse the loss of natural habitats by reinstating salt marshes in south east England. The question of environmental obsolescence was raised for ageing buildings that will need adapting to survive climate change and to remain relevant to modern use. As the historic building fabric interacts with rather than excludes moisture, the issue that needs addressing is whether there might ever be sound environmental reasons for demolition.

Policy actions

In conclusion, several key policy recommendations emerged from the research to indicate the way forward for understanding the impact of climate change on cultural heritage.

Cooperation

The different strands of cultural heritage need to cooperate, share information and speak with unity on the issue of climate change and that there are benefits from integration with the natural environment. Cultural heritage cannot stand alone and that common concerns are an opportunity for cross-disciplinary cooperation.

Funding

Maintenance emerged as a key concern, necessitating a more equitable balance between funding for repair and maintenance, tax incentives for sustainable maintenance, the formation of partnerships with other interested parties such as the insurance industry and support for skills training for upgrading, repairing and maintaining cultural heritage.

Research

The lack of good data on the effects of environmental change and the lack of understanding of the behaviour of the materials worsening with the shift of climate goal posts was a significant issue. Research is needed on monitoring change and developing appropriate sustainability indicators, with outputs being used to drive policy, develop strategies and disseminate knowledge and awareness.

Education

The public needs educating on the impact of climate change on cultural heritage and on the importance of cultural heritage as a climate change indicator. At a local level, site logbooks are needed to record impacts of climate change as part of the implementation of conservation plans. At an international level, a mechanism for sharing knowledge and experience would enable information, resources and good examples of adaptation to be shared.

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Notes

1 The researchers were: Professor May Cassar and Dr Robyn Pender (conservators); Professor Bill Bordass, Professor Tadj Oreszczyn and Professor Philip Steadman (building physicists); Jane Corcoran and Taryn Nixon (archaeologists); and Professor Lord Julian Hunt (climate modeller).

2 Southeast England sites: Audley End House and gardens, Dunwich medieval town, Flag Fen Bronze Age wetlands site, Languard Fort 19th century fortification and Sutton Hoo barrow site. Northwest England sites: Beeston Castle ruins and grounds, Birdoss Wald (Hadrian's Wall), Birkenhead Park, Brough Castle ruin, Broughton Castle ruin, Chester Castle medieval tower, Chester Roman Amphitheatre, Furness Abbey ruins, Lanercost Priory ruin, Poltross Burn (Hadrian's Wall), Stott Park Bobbin Mill industrial complex and Walton Old Rectory 13th century complex.

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