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SHORT OVERVIEW ON INTERNATIONAL HISTORIC CLIMATE ADAPTATION OF BUILT HERITAGE TO NATURAL HAZARDS: LESSONS FOR NORWAY

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Abstract

This paper aims to highlight the relevance of ancient international adaptation measures of built heritage and how can they be relevant and applied to Norway. Specifically, it will focus on historic measures applied to mitigate extreme hazards (fire and floods) and slow degradation (decay) of built heritage. For this, we used the scientific database Google Scholar (GS) and 20 papers and reports were deemed relevant for our analysis. There is a limited body of literature (in English) addressing decay and fire, but a richer one referring to floods. The analysis highlights the fact that there is a gap between theory and practice within contemporary adaptation measures (which is also highlighted by previous studies). It was also shown that historic climate adaptation measures are passed on through generations and traditions, rather than scientific research, a finding also supported by UNESCO.

***Keywords**: Climate change; Climate adaptation; Natural hazards; Built heritage; Mitigation; UNESCO; Norway*

Introduction

Built heritage and natural hazards

Cultural heritage represents an expression of the way communities developed and lived, passed on to future generations, including objects, places, customs, practices, artistic expressions, and values. Also, it is a significant part of contemporary community and societal well-being; the foundation upon which historical and global values are based and a strong inter-connector of the link people, society, history and landscape [1, 2]. Specifically, built heritage has been acknowledged as a key-contributing factor to quality of life and sustainable development [3]. Built heritage comprises a large spectrum of man-made environments, such as places of worship, commercial buildings, houses, monuments and built infrastructure such as bridges, railways, roads and archaeological sites of historical importance [4, 5]. Old buildings and other types of built cultural heritage are strong evidence of preservation of memories, and they can be a valuable tool in the hands of local governments and stakeholders [6]. Our cultural heritage, and especially built heritage is under great pressure both from climate change and anthropogenic factors [7].

Natural hazards have, as a result of climatic changes, become an increasingly integrated part of our present society, and we can no longer deny their impacts on cultural heritage [8-11].

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In order to strengthen the resilience of built cultural heritage, there is a growing need for climate adaptation measures. In the northern parts of the World, the temperatures are expected to rise higher and faster than in southern parts and occurrences of extreme precipitation will increase, contributing to more frequent flooding events and decay.

Since the dawn of time, humans have had the capability to adapt to the surrounding environment and to climatic changes [12]. Drawing from this notion, that idea that what was built should be protected was embedded deep in human conscience, along with adaptation measures towards natural hazards [13], such as fires [14] and floods [15]. Throughout history, there is thorough documented evidence of built heritage destroyed by various natural disasters; of the Seven Wonders of the World, only one of them – the Great Pyramid of Giza (Egypt) – has survived until today. Of the remaining six, three have been damaged by earthquakes. The Colossus of Rhodes tumbled down around 227 BC, the Pharos Lighthouse in Alexandria in the fourteenth century AD. Mausoleum in Halikarnassos, destroyed by floods and earthquakes and rebuilt several times, disappeared in the fifteenth century [16].

Fire has played an important role for mankind for thousands of years [17]. However, due to climate change, it is predicted that the magnitude and frequency of extreme climate events, such as fire, will increase at a global level. Many cultural heritage sites, especially archaeological sites, are covered with vegetation or located near forests exposed to an increased risk of forest fire. The increase in seasonal temperatures has led to an increasing number of wildfires in many forested areas. Boosted by dry winds and vegetation, many of these fires have put in danger many cultural heritage sites [18]. At the same time, fire represents one of the most destructive hazards that can affect built cultural heritage; fire causes material loss and deformation and may also increase the probability of cracking or splitting in built structures [19]. A few examples of built cultural heritage destroyed by fire at a global level are the Palace of Whitehall at Westminster – the main residence of the English, and later British, monarchs – was destroyed by fire in 1698, the Garden Palace in Sydney (Australia) was destroyed by fire on 22 September 1882 [20], the National Museum of Natural History (New Delhi, India) and its valuable collection of animal fossil and stuffed animals – was destroyed by fire on 26 April 2016 [21], Rio de Janeiro's Museu Nacional was severely damaged by a fire in September 2018 [22], etc. Also, fire was used in the past to exploit natural resources, and it was especially used in mines [23]. As for fire, also flooding have had a decisive effect through history. Due to climate change these phenomenas will appear more frequent in the future. Flooding has been acknowledged as one of the most significant consequences of climate change for cultural heritage both in Europe [24] and globally. Floods can lead to the loss of historic monuments, devastation of historic structures, changes in cultural landscape, and to the disappearance or significant distortion of intangible heritage [25]; which contribute to keeping alive our collective memory [26]. There is a lot to be learned from past adaptation flood experience; this should be considered, used in a positive way and the experience should be recorded [27]. As with fire, throughout history, flooding has affected built cultural heritage on numerous occasions, such as: during the Florence Flood of 1966 – several historic buildings, paintings, books and sculptures were destroyed [28, 29], the Old Blenheim Bridge (built in 1855) – the longest-surviving covered bridge in the U.S. [30], was destroyed by Hurricane Irene-related floods in 2011.

MICHON project

Mitigation measures for cultural heritage from natural and anthropic extreme hazards – MICHON is an internal project within the Norwegian Institute for Cultural Heritage Research (NIKU), Norway, for the period 2021 – 2023. The project's main objective is to investigate how to improve knowledge and implementation of preventive and acute measures at municipality level in Norway for increasing the resilience of built cultural heritage and mitigation of extreme hazards. The overall methodology for the project is to use translational research as a background for reviewing international research, projects, guides and plans on the topic. By reviewing already existing international work, we aim to further improve ways of working with issues related to mitigation and adaptation in Norway.

This paper aims at exploring how adaptations to fire, flood and decay were historically carried out on built heritage. It will look at how traditional solutions and practices such as the placement of buildings in the landscape, draining systems and constructions has been put into use as mitigation measures for climatic stress and risk to protect built cultural heritage. More specifically, this article consists of a survey of historic measures applied to mitigate fire and floods and decay of built heritage. This paper is part of the Work Package (WP) 4, Historic Climate Adaptation, in the MICHON project, which aims to call attention to what can be learned from historical buildings and building environments; the WP will increase the understanding of historical buildings ability to withstand both slow degradation and extreme hydrological events and fire [31]. One part of WP 4 undertakes interviews with craftsmen and architects mapping the unwritten knowledge on historic adaption. Another part of WP 4 is reviewing international articles on the topic, which will be presented here. The paper is not to be considered as a review paper, but an overview of what we can learn from the past and apply this knowledge to contemporary building and conservation practice.

Initiatives by global organisations within the cultural heritage field

World Monuments Fund is a private non-profit organization funded in 1965 by people concerned about the destruction of heritage around the world. The organization places heritage sites that are threatened on the World Monuments Watch. The World Monuments Watch is a global program launched by the Fund in 1995 and aims to identify endangered cultural heritage sites and help with funding and conservation [32]. In 2018, the organization listed for the first time two heritage sites affected by climate change: Blackpool Pier in England [33] and Potager du Roi in France [34]. Notre Dame in Paris was placed on the World Monuments Watch after the fire in 2019. After the fire, the World Monuments Fund began developing a fire risk management workshop to raise awareness of fire-related threats and prevention strategies and to build capacity among stakeholders to advance the protection of cultural heritage from fire [35]. The workshops will be held in 2022. The organization has also written a compendium of resources on fire protection for heritage places. The compendium offers key principles surrounding practical fire protection for historic buildings.

In 2006, UNESCO began working on the organizations first report on the impact of climate change on cultural heritage, Climate Change and World Heritage, published in 2007 [36]. Since then, UNESCO has concluded that climate change, which includes the hazards fire and flood, is a threat against cultural heritage, and that it will continue to be a threat in the future. UNESCO and several other organizations are looking at future climate scenarios, and based on them, new conservation and adaptation strategies are formulated. In 2007, UNESCO identified shifts in temperature, precipitation and atmospheric moisture as threats to cultural heritage [7]. Decay rates are exacerbated by climate change [37], and water is the most critical decay factor for built heritage [7]. Decay can bring significant deterioration to physical, chemical, and biological properties, leading to degradation that affects the composition and structure of the materials. Increases in relative humidity in a warmer climate could worsen biological degradation, and changes in humidity affect the growth of microorganisms on both stone and wooden heritage materials [7].

Adaptation as a measure to save built heritage

IPCC defines adaptation as "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" [38]. Adaptation of buildings refers to any work carried out in order to change the building's function, capacity, or performance. Adaptation means making minor changes or flexible changes (regarding reversal potential); and adapting for another use or environmental stress [37]. Several informants from the interview sessions undertaken in the

MICHON project understand adaptation as: the act of adapting to the specific (climatic, meteorological, geographical, and topographical) environment that the building was established in. This concerns both location and technology/construction principles [39]. Historic climate adaptation of built heritage is key to understanding the sustainability and durability of past measures that made the existence of cultural heritage for present generations possible. It is in our duty to learn from this to be able to pass on our built heritage to future generations.

Methodology

To tackle the above-mentioned aims, we made an overview of the literature on historic adaptation measures for built heritage. For this, we used the scientific database Google Scholar (GS), using the following keywords *fire/flood/decay* and *heritage* and *adapt*; GS was chosen over ISI Web of Science (WoS) and Scopus, because it samples a wider variety of publications [40] and that most papers indexed in WoS are also available in GS [41]. For practical reasons, the analysis only included articles written in English, being aware of the limitation to one search language might have led to loss of papers of interest for the study. Within the data collection phase, all authors paid attention to screening and verifying the relevance of the papers with respect to the objectives of this study. After the paper's selection, out of 45 papers, 10 were chosen to be analysed. Taking into consideration the low number of papers found, we decided to look for additional papers inside the references of the selected papers. We also decided to search for reports on the subject, based on expert knowledge. After this search, 20 papers, reports, and online documents (see Supplementary Material) were deemed relevant for our analysis, based on the MICHON project objectives and points of interest.

Results

In the following sections, the analysis of the three chosen hazards, fires, floods and decay, will be highlighted and described.

Ancient fire protection measures

Since the evidence on fire on Earth goes back over 400 Myr and the fact that fire played a significant role of the Earth system for 350 Myr [23], we will refer to this hazard first. Most of built heritage is facing serious fire threats as they could be damaged or destroyed (especially wooden built heritage) by flame, heat, smoke, dirt, falling debris, along with inappropriate fire measures [42].

Taking a leap back to the Roman Empire, Desmond, 2019 offers a detailed overview on how fire shaped the capital Rome and how Romans adapted their city to living with fires [43]. From 460 BC to AD410, there were 88 recorded fires. The study highlights the vast knowledge of Romans towards the use of different kinds of wood for buildings, since they were able to predict how different timbers would behave in a fire, and how they deliberately set fires in periods of turmoil, regime changes and protests. One thing that made Rome survive and thrive was the fact that the city was aware of the constant danger of fire and understood the measures needed to prevent and contain outbreaks. Rome can serve as an example of universality of fire within urban history [42]. Another case from Medieval Italy comes from the city of Lucca, where 1346 carpenters, stonemasons and bricklayers were required to demolish houses to prevent urban fires spreading [14]. There is an entire chain of events that a disaster creates, and humans have the capability to adapt and to be very resilient. This is managed today through the looking glass of modern technologies and scientific development [44].

When wanting to adapt and learn from the past and present, and apply the knowledge in the case of Norway, a few points can be made i) to learn to live with fire and to be aware of the constant danger (like the Romans) and ii) to act and use modern technology (like the Chinese

[45, 46], Indian [47] and Portuguese [48] cases). By following these examples, better results would be obtained both from an economical and historical value perspective; these advancements also tackle the climate change issue in the built cultural heritage sector, which is of great significance for society [48, 49].

It is also known through paintings and etchings, like the one by Jan van der Leyden in the 1680s that the inhabitants of Netherlands used large coverings on roofs and house facades to prevent the fire from spreading. This is also the case for the Nordic countries; the building that was on fire was demolished while the surrounding buildings were covered by wet blankets. This method was still in use in some Finnish towns in the 1920s. One can see firefighting in art and illustrations such as in Olaus Magnus from the 16th century, which shows the use of fire hooks (Fig. 1) to pull down burning elements from the building. Ladders and water buckets of leather (Fig. 2) were used in the Nordic countries until late 18th century [50]. The use of materials of high quality (core wood), dense and large, make the timber itself withstand fire for a surprisingly long time. This has been experienced in fires in wooden buildings in the southern part of Norway in 2021. The Romans' predictions of timber behaviour in a fire are still relevant in 2021.

Fig. 1. The fire hooks described by Suikkari used in the Nordic countries, are still to be seen in Norway, although not in use. Example of a fire hook mounted on the outer wall of a small, wooden town house in Lillesand, Agder. Photo: Nina K. Jernæs, 2021, NIKU

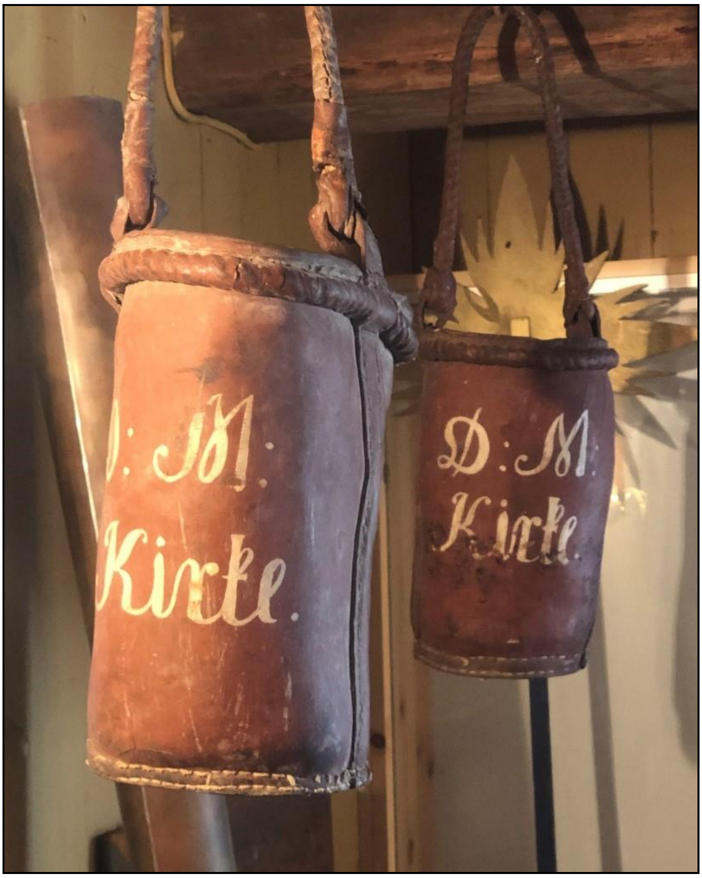

Fig. 2. Water buckets used for firefighting described by Suikkari, can be seen in Norway today, although not in use. Pictured are 19th century water buckets made of canvas, belonging to Austre Moland church, Agder. Photo: Nina K. Jernæs, 2021, NIKU

Ancient flood adaptation measures

When it comes to floods, one of the most destructive hazards worldwide [51, 52], there is evidence of living with floods and mitigation measures at a global level for thousands of years, and this continue to be the case. One of the first papers to approach this issue was published in 1989 [53], and it offers a good picture of flood adaptation measures, which have been used in China for thousands of years. This shows a comprehensive knowledge and a particular interest in measures regarding the prevention and the activities undertaken after a flood event (burying the dead, feeding the survivors, etc.). The paper identifies four main periods regarding flood control measures in ancient cities. The periods and measures are described below.

First period – Late Neolithic to the Shang Dynasty (ca. 11th century B.C.) was characterised by building city walls against flooding; it is mentioned the case of Ping Liang Tai castle in Henan Province, that was built in a trapezoidal shape and being 3-5m higher than its surroundings. The New Babylon castle's walls had a dual role (military and flood protection), and were rebuilt in 7^{th}-6^{th} century B.C. These measures were followed by incorporating earthenware drainage pipelines found in Ping Liang Tai castle (13th century B.C.).

Second period – West Zhou Dynasty to the Period of the Warring States (11th century B.C. to 221 B.C.) – was characterised by considerable urban development. Old documents show the preoccupation towards mitigating the effects of flooding by suggesting building a capital at the foot of a mountain or near a large river; this should be neither too high to make full use of water, nor too low to be susceptible to the risk of flooding or to require mitigation works, such as drainage canals and dikes. Another measure suggested was to build a drainage system in a city to divert flood waters into rivers; this idea was taken further, in diverting the water from floods against enemy cities. Various capitals had complete drainage systems. They held multiple functions, such as military defence, water supply, transportation and communication, drainage, storage, fire prevention, and environmental benefits. During the Third period – Qin Dynasty to the Five Dynasties (221 B.C. – A.D. 960) – there were many wars and flood attack was used very often. Also, walls were strengthened against floods by using stone and bricks; then, spur dikes were built for urban flood protection.

Fourth period – Song to the Qing Dynasties (A.D. 960 – 1911) – was characterised by a great development in the science and technology of flood control. It started with hydraulic surveys, water wheels to draw water out of the cities. The Forbidden City has the best drainage system. The understanding of floods and the need for keeping the cities "clean" from floods, led to a natural rhythm in learning to live with the floods. Following the technological advancement, in order to prevent floods, other measures were taken, such as terrain renovation and river basin regularisation, proper city planning (building of cities on convex banks to minimise flood erosion), the technology of city wall construction, the foundation protection, protection against rain corrosion and water permeation, changes in building materials (from lime mortar to glutinous ricelime), constant maintenance of city walls, etc. These above-mentioned structural measures were combined with non-structural measures, such as flood forecasting and evacuation. Flood prediction was possible based on the study of the periodicity and regularity of historical floods. In modern hydrological studies, this is called recurrence period [53].

A more recent paper [54] analyses historical floods in China by using mathematical model analysis, chart analysis, qualitative and quantitative analysis. By studying the past, we will be able to predict the future. Nowadays, this is "translated" into various predictive models able to predict future extent and intensity of floods [55, 56]. These models are integrated into adaptation measures that consider the future climate models [57].

A paper by Gerrard and Petley, published in 2013 [14], offers an overview of various environmental hazards (earthquakes, volcanic eruptions, severe weather – flooding) and how they were mitigated during the Middle Ages (A.D. 1000 – 1550). The woodcut from Sweden in the 1550s (Fig. 3) illustrates the flood hazard and the need for mitigation measures. Following floods, maximum water heights were sometimes notched on public buildings as evidence of people's resilience, this becoming a tradition to extend public memory of devastating events. Evidence of the largest recorded flood in central Europe has shown the devastating effects on built heritage. Unlike the Chinese, who were more disposed towards active physical work and planning, the Europeans were looked on these disasters (floods) as "Acts of God", and often used the power of prayer and belief (even though this was rarely a primary mechanism to prevent a disaster), and very often people "called" upon protective saints. However, various non-structural actions were taken; for example, after the 1333 flood in Florence, city authorities lowered taxes for those in need, weirs and mills were banned from being built close to the city. Many city inhabitants escaped from flooding by climbing to the roofs of their houses and city buildings. Acts of charity were also very popular, and people helped each other.

In terms of physical structural actions, floor levels inside buildings would be raised (in the case of the abbey church at Bordesley Abbey in Redditch, England and at the monastery of Claraa-Velha in Coimbra, Portugal). Other examples include embankments and wind-powered engines (Netherlands).

Another paper analysed [59] shows the historical assessment of Chinese and Japanese flood management policies and implications for managing future floods. In contrast to China, flood management in Japan started between 300 B.C. – 300 A.D. There is a lot to be learned from the ancient adaptation measures from China and Japan, as a large spectrum of the measures used then are still in use today. The same lessons can be learned from combining Ancient “Blue-Green” principles and modern “Sponge city” approaches. This presents the case of the coastal city of Ningbo (one of the oldest cities in China, going back to B.C. 6300), with a long history of floods since ancient times. Reviving traditional approaches to urban water management offers the possibility to control and maintain flood risk at an acceptable level without any constraints on urban growth in China; same approach can be transferred and applied to other coastal cities in the world that experience a rapid urban development [60].

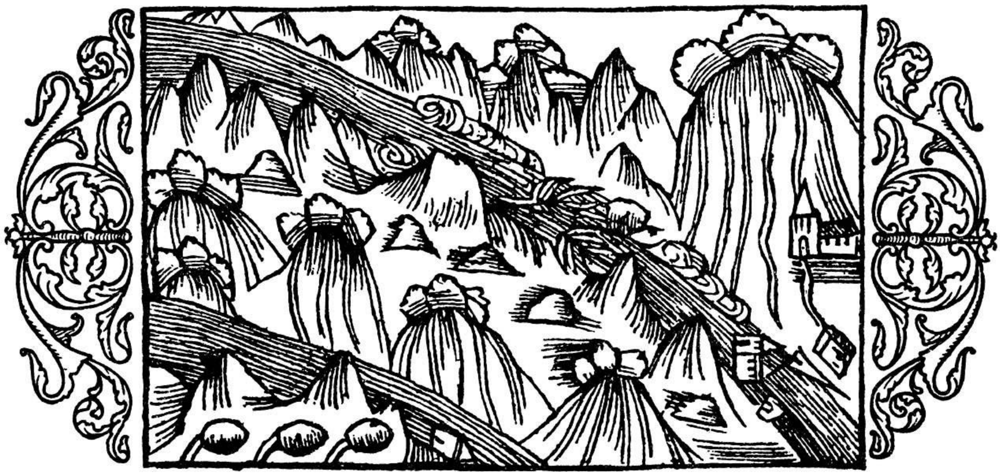

Fig. 3. Illustrations by Olaus Magnus from the 16th century depict daily life in the Nordic countries. The woodcut” On the flooding of streams” from 1555 shows the two Swedish rivers Indalsälven (top) and Ljungan (below). It is spring and the annual flood from the melting snow in the mountains destroy houses, a church and trees [58]

Mihu-Pintilie and Nicu, 2019 show the fact that the Neolithic settlements from the north-eastern part of Romania were located on hilltops. The rationale is double – for defensive purpose and being aware of the danger floods were posing to them [12]. This is similar with the situation in Ancient China.

Another great civilisation, the Greeks, have adapted to floods since ancient times [61]. The simplest way to protect against floods was not to place the settlements near lakes or rivers; being more adapted to living in a dry climate, when compared to Ancient Chinese and Neolithic populations from China and Romania, respectively. Among various ways of protection against floods were hydraulic anti-flooding systems including walls, dams, and channels. The analysis is divided into three main periods, as follows: prehistoric to medieval period (ca. B.C. 3200 – 1400 A.D), early and mid-modern times (1400 – 1900 A.D.) and contemporary times (1900 – present).

Prehistoric to medieval period (ca. B.C. 3200 – 1400 A.D), which coincides with the Minoan and Mycenaean civilisations. Evidence of protection of urban areas from floods include cisterns and dams. Minoans developed sustainable urban drainage and sewage systems which are in use nowadays; one of the most famous is the “Minoan viaduct”. Another measure was the construction of dams to control the water streams; an iconic example is the Tiryns dam, built around 1200 B.C. by the inhabitants of the Tiryns city. The dam’s purpose was to divert the periodic floods directly to the lower part of the Tiryns by transferring water into an excavated channel and for irrigation. And the list of examples can go on. The ancient Greeks were very good at developing complex urban planning and infrastructure to protect their cities from floods. Small-scale water cisterns developed by prehistoric civilisations (Minoans and Indus Valley civilisations) were enlarged by later civilisations (Romans). It is the example of the Roman Aptera in western Crete, where two cisterns in L-shape and rectangular triaisle were used to harvest, storage and water supply of urban areas. They did not last very long, as they were affected by sediments carried along with water.

In early and mid-modern times (1400 – 1900 A.D.), a lot of the rainwater collecting systems were also considered as flood protection systems. In contemporary times (1900 – present), it has been concluded that the main reason of flooding is urbanisation. Most of the measures have consisted of building dams to mitigate floods; therefore, downstream river flow was disrupted, aquifers and nutrient transfer was affected. This, along with poor maintenance of the sewage systems, enhanced flood impacts on urban areas, where many heritage buildings are present. A way to mitigate the effects of floods is to improve hydrological forecasting, along with increasing measuring points from hydrometric stations [58]. Once again, it is stressed that the lessons learned from the past should be a prerequisite to improve our understanding while planning preparedness and mitigation measures; that should take into consideration all the geoenvironmental factors both at a local and regional level. Also, interdisciplinary collaboration with heritage planners and local authorities in charge of cultural heritage should be improved.

Another iconic example is the one of the Historic City of Ayutthaya, Thailand [62], which was founded in 1350, and was the second capital of the Siamese Kingdom. The city was included in the UNESCO World Heritage List in 1991 [63]. Within this paper, a significant factor is taken into consideration in flood adaptation – local knowledge/wisdom. Since it was built, the city has been under constant threat from flooding, being surrounded by three rivers: Chao Phraya, Lopburi and Pa Sak. The early city was planned with canals, which functioned as transportation routes and as a defence system. The houses were built on pillars. This effective planning was disrupted during the floods from 2011, 2012, and 2013. This had a devastating effect both on the buildings' state of preservation and the tourism industry in the area. A vulnerability reduction guideline was established for the city, which is based on the community input to increase the adaptive capacity of the community, in order to enhance the community's resilience in preventing and mitigating the negative impacts of flooding, while maintaining a sustainable lifestyle. This approach is based on the community being self-reliant. An integrated approach that takes into consideration several key factors, like demographics, exposure to flood impacts, sensitivity to flood impacts, vulnerability to flood risk, and community adaptation methods to flood risks, represents a model to be followed by other communities in the world. This can be adapted to any climatic area in the World, especially to Norway; where it needs to be adapted according to the institutional responses to floods, which has been found to be weak. These are being governed by strong political and economic interests that coincide with the national level willingness to pay and provide support. It has also been found that new perspectives on flood management are more apparent at the national than the municipal level, as new perspectives are filtered by local power structures [64].

Decay

In *Changing minds, not the climate. Culture-based solutions to local climate adaptation*, UNESCO discusses the importance of looking at the past when trying to adapt to climate changes [65]. The organisation emphasizes that adapting to the climate is not new. Continuous adaptation to natural and climatic changes has been part of human existence, many cultures and communities have gone through a process of climate adaptation spanning over as much as thousands of years. UNESCO also point out that the resilience to adapt is built on historical experience and knowledge practices that are passed on in the form of cultural heritage, traditions, and customs. The report goes on to convey that this knowledge has not made its way into the scientific discourse, which can be a reason for the scarce number of articles that exists about historical adaptation measures to prevent decay.

Vernacular architecture is a result of a complex balance between material, shape, and nature, it is an architectural form linked with the environment [66]. Vernacular buildings have been developed over many years, and their different constructions are the results of accumulated knowledge about local climate and practical (action-based) building experience.

Palanti *et al*. [67] discusses the evaluation of biological decay of structural timber elements of an ancient hayloft. In the article, frequent maintenance is enhanced as an important historical measure to use when it comes to prevent decay in ancient buildings. The authors describe larch as a durable material, especially in an alpine climate. But even so, the authors continue, larch needs frequent maintenance, or it will start to decay. The building discussed in the article by Palanti et al. is ancient and has historically been regularly utilized for practical and productive reasons. The authors argue that therefore it surely underwent frequent repairs by substitution of elements when they were considered no longer usable. The authors mean that the condition of the wood depended more on its maintenance than on its natural durability, and decay occurred in the observed building when its functionality and its maintenance were interrupted.

Using the keywords mentioned in Section 2, we had very few relevant matches within our search theme. Most of the articles found, focused on precautionary measures necessary to meet future climate change and not undertaking historic measures to adapt to decay.

Discussion

Lessons learned from the past should be a prerequisite to improve our understanding while planning preparedness and mitigation measures; that should take into consideration all the geoenvironmental factors both at a local and regional level. Also, interdisciplinary collaboration with heritage planners and local authorities in charge of cultural heritage should be improved. Passing on know-how from craftsmanship and epistemological skills to county and technical authorities is a decisive factor in accomplishing sustainable management and conservation. We highlighted the fact that the Romans had a comprehensive knowledge about the behaviour of different types of timbers in fires. Looking at the fires of three timber houses in the Southern part of Norway in 2021, the timber structure made of core wood surprisingly withstood the fire. This gives us reason to have a look at the quality of materials to be used, both for restoration of older building structures, but also when building new houses.

When reviewing this topic through literature search using GS, it is apparent that a lot of the knowledge in historical adaptation still might be evident in traditions, as stated by UNESCO, and in the actual buildings and structures used for flooding. Further written sources are welcome, in order to get a more comprehensive international literature basis for further understanding the historic forms of adaptation through a climate in constant change. When looking beyond the written sources available through GS, we know there is physical evidence of adaptation to prevent decay of built structures. Many historic structures are constructed to withstand climatic pressure and are adapted to the prevailing stresses to which they have been exposed. Therefore, there is a lot of historical knowledge to be found by performing field studies and analysing local technical building solutions, for example by studying façade cladding or roof structures. The obvious and most effective way of regarding decay is to perform a continuous and appropriate degree of maintenance. Both in repair and maintenance, the use of materials with equal, or even higher, quality than the original is of importance. Measures taken through history to minimize destructive effects from flooding have also been, and still will be, appropriate when it comes to avoiding enhanced decay. Precautionary efforts made to protect buildings and cities from fire and floods are applicable still today and will contribute to averted decay. Preventive measures, like manipulating waterways and terrain, (re)location of buildings and infrastructure as to keep them protected from climatic stress are traditional ways of avoiding damage that can be continued or applied.

As heritage researchers, there is a strong belief in a potential knowledge transfer by looking at the past to learn about future ways of adapting to more extreme events and faster decay of built cultural heritage. When we have investigated the topic by examining research papers, it strikes us as interesting to see this in the light of translational research and “Boundary work”. Translational research defines a gap between research and needed knowledge for the management of, in this case, cultural heritage. The term boundary refers, in this context, to the boundary between science and non-science [68]. When looking at historic ways of adapting buildings and society to extreme hazards like fire and flooding, it can be done by exploring culture-based solutions. When it comes to decay, there is a need for exploring earlier ways of living and maintenance of buildings. In many ways, there is a need to look at these topics with a multidisciplinary approach including cultural science and ethnology.

Systems for translations of knowledge between users and experts are vital for ensuring the need for the new research and the knowledge produced. There should be a mutual understanding of the issues, and this requires that the users’ and management’s knowledge and that needs are translated and provided to the researchers [68].

When orienting ourselves in the research papers through GS, there was an expectation to find a larger number of papers looking at historic adaptation to extreme events and decay. Less research papers than first thought is, however, also an interesting find. It pinpoints the need for researchers to utterly explore the “silent” knowledge or the “grey literature” in order to find practical solutions that can help us understand former adaptation measures.

Conclusions

When looking at the body of literature analysed in this paper, literature referring to flooding was the most consistent, followed by fires and very few studies focusing on decay in a historical context. In the analysed literature, we obtained some interesting results. For example, the Romans did have a comprehensive knowledge concerning the behaviour of different types of timber in fires and this can be relevant in Norway today. Examples from China on how to handle excessive water contain knowledge and practises that can be continued and applied in present-day planning. We have also seen that frequent maintenance is enhanced as an important historical measure to use when it comes to prevent decay in ancient buildings.

To have more knowledge about historic climate adaptation measures, we propose that methods other than analysing scientific literature should be applied. We have discovered that historic climate adaptation measures are passed on through generations and traditions, rather than scientific research. This is also supported by UNESCO. We see possibilities for framing these issues within the methodology of translational research, “boundary work” and knowledge transfer; within a timeline, through multidisciplinary approaches and by implementing “silent” literature as art and the actual buildings. In addition, we suggest searching for physical evidence of climate adaptation measures by conducting field studies and analysing local technical building solutions, as well as by performing archive studies.

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