Systematic Approaches to Climate Change in Architectural Sciences

Editors
Asena SOYLUK
Atila GÜL

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PREFACE

Climate change refers to long-term changes resulting from the disruption of the natural balance in climate systems worldwide. The primary cause of these changes is the increase in greenhouse gases in the atmosphere due to human activities, which trap heat emitted from the Earth's surface, leading to a rise in global temperatures. Today, climate change has become one of the major global and environmental problems affecting not only specific regions but the entire world.

The effects of climate change have negative consequences on cities at the macro level, while at the micro level, they cause significant problems in the built environment and daily life. In this respect, climate change has become a disaster affecting all societies on a global scale. If necessary measures are not taken in the coming years, it is predicted that the ecological, sociological, cultural, and economic damage that may arise due to climate change could lead to serious disasters.

Therefore, there is a growing need for comprehensive and sustainable measures and actions that combine scientific knowledge with practice, local experience with academic expertise in spatial planning, design, and management processes within the scope of reducing the effects of climate change and the adaptation process.

This book has been prepared to contribute to the fight against climate change and the adaptation process by strengthening this common ground. The scientific book titled Systematic Approaches to Climate Change in Architectural Sciences contains 16 book chapters.

In this context, the book chapters prepared in collaboration with graduate students aim to serve as a scientific, original, comprehensive, and informative resource.

We would like to express our sincere gratitude to all the valuable chapter authors and reviewers who contributed to the preparation of this book. Their work not only contributes to the academic literature but also serves as an important guide for the formation of new perspectives in the fight against climate change. We would like to thank Livre de Lyon Publication and the entire team for their support in publishing this book.

We hope this book will be useful to all stakeholders. Best regards.

April 24, 2026
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CONTENTS

CHAPTER VII

INVESTIGATION OF CLIMATE CHANGE-RELATED DETERIORATION IN HISTORICAL BUILDINGS USING BIBLIOMETRIC ANALYSIS

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1. Introduction

Climate change is the disruption of the climate system through the release of carbon dioxide (CO_2) and other greenhouse gases over a period of ten or more years as a result of human activities such as the burning of natural or fossil fuels, deforestation, and industrial processes (Broecker, 1975; Keeling et al., 1995). Climate change results in increased temperatures, more frequent natural disasters such as severe storms, irregular rainfall, floods, and droughts, and changes in ocean currents. As a result of these changes, areas such as agriculture, public health, water consumption, the energy sector, and biodiversity are negatively affected (Rawat et al., 2023). Between 2011 and 2020, global surface temperature rose by approximately 1.1°C compared to the average of the 1850–1900 period. The temperature increase on land is 1.59°C, and in the oceans it is 0.88°C. The observed warming is human-induced; Warming caused by greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4) is partially masked by the cooling effect of aerosols (IPCC, 2023).

No national or international studies on the effects of climate change on cultural heritage were found before 2000. Studies on this subject began after 2004, spearheaded by Europe (Gökmen Erdoğan, 2022). The Noah's Ark project, funded under the European Commission's Sixth Framework Programme, ran from 2004-2007 and aimed to identify the risks posed by climate change on architectural cultural heritage using existing data. Although it is impossible to understand a concept with such a multifaceted impact as climate through superficial parameters, progress has been made in this area in recent years (Deniz Demirel & Umar, 2023).

Climate change is accelerating the deterioration of cultural heritage worldwide through temperature fluctuations, changes in humidity, extreme weather events, and disasters. Traditional conservation methods rely on expert supervision and intervention only when deterioration is observed; however, this approach is insufficient to combat climate change. While automated monitoring systems are used as an alternative, limited site access, high costs, and the long duration of the deterioration process also limit this method (Roqui et al., 2025).

Because cultural heritage sites are located in different regions of the world, the effects of climate change also vary. According to data from a 2008 study, 46 World Heritage sites affected by climate change include archaeological remains, churches, mosques, temples, castles, and cultural landscapes (UNESCO World Heritage Centre, 2007).

Historical buildings are structures dating back to prehistoric and historical periods, constructed using the original materials and building techniques of their time. These structures reflect the architectural, social, cultural, religious, and economic characteristics of the era to which they belong. (Law No. 2863, 1983; Çelik, 2021).

2. Causes of Deterioration In Historical Buildings

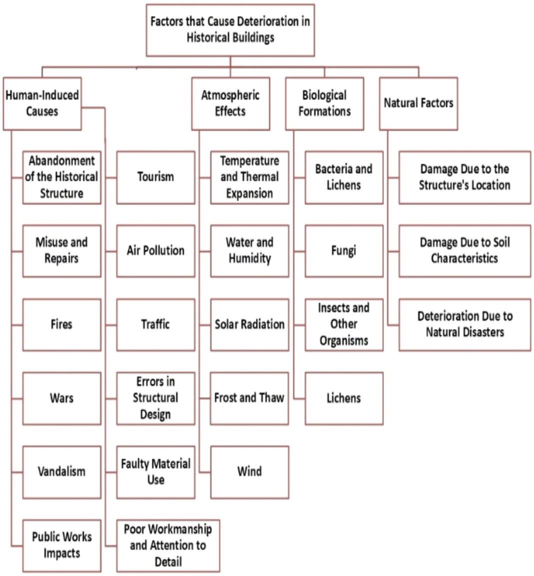
Deterioration in historical buildings is defined as the loss or alteration of the originality, material integrity, or aesthetic value of a building or material due to physical, chemical, biological, or mechanical factors, whether natural or human-induced (Ağan, 2017).

Ağan (2017), address the factors causing deterioration in historical buildings under four main headings:

- Atmospheric effects
- Biological formations
- Human-induced causes
- Natural factors (Ağan, 2017)

Table 1 shows the factors that cause deterioration in historical buildings.

Table 1. Factors Causing Deterioration in Historical Buildings (Prepared by the author.)



2.1.Deterioration by Natural Causes

It is examined under three headings.

2.1.1.Damage Due to the Structure's Location

According to Feilden (2003), the location of the structure affects the deterioration of historical structures in terms of climatic, topographical, geological and environmental conditions.

- Climatic conditions; wind direction, duration of exposure to sunlight, amount of precipitation, humidity and temperature differences
- Topography; land slope and drainage characteristics
- Geological and local soil conditions; soil type, settlement of the structure, groundwater, fault lines
- Environmental conditions; determine the effects of construction, traffic, air pollution (Feilden, 2003)

2.1.2. Damage Due to the Soil Characteristics

The low strength or non-homogeneity of the soil on which the structure sits can cause deterioration in the structure and its elements over time due to movements such as bending, rotation, and buckling. In addition, if the structure is located on a fault line or on rock with cracks, this situation can also cause soil-related damage (Ahunbay, 2009, p.38; Asımgil & Erdoğdu, 2013).

2.1.3.Deterioration Due to Natural Disasters

Disasters such as earthquakes, floods, landslides, and typhoons, which are defined as sudden and violent catastrophes whose timing cannot be determined in advance, cause damage to cultural heritage and historical environments (Ahunbay, 2009, p.45-46).

According to Shrestha et al. (2024), deterioration caused by natural disasters is divided into two main categories:

-Those that occur suddenly; floods, earthquakes, large landslides, and storms

-Those that occur at frequent intervals; events such as rainfall, temperature changes, and wind (Shrestha et al., 2024).

2.2.Deterioration by Human-Induced Causes

2.2.1.Abandonment of Historical Structures

The abandonment of a building or settlement leads to the neglect of the spaces and their exposure to external influences. Places are abandoned as a result of the death of the building's first owner, legal disputes, or migrations due to economic and social problems. (Ahunbay, 2009, p.50; Perker & Akıncıtürk, 2006).

2.2.2.Misuse and Repairs

Human-induced deterioration is evaluated in two groups: intentional and unintentional damage. Intentional damage is deterioration resulting from direct and conscious human activities. Unintentional damage, on the other hand, is the effects that occur unintentionally. Faulty use and incorrect repair practices are included in this group (El-Gohary & Abdel Moneim, 2021).

Misuse and substandard repairs of historical buildings occur when property owners migrate or move, and old residences are transferred to new users. This happens through effects such as adding new partitions, constructing mezzanine floors, and altering window and door openings. Building repair is a field requiring expertise. Substandard and incorrect repairs carried out by unqualified individuals accelerate the deterioration process (Ahunbay, 2009, p.50-53).

2.2.3.Wars

Wars, which cause widespread negative consequences as a result of their damaging effects, continue to this day. The use of air power in wars has facilitated destruction and increased its area of impact. Damaged cultural heritage sites have been rebuilt and returned to society. However, in some examples, such as the Reichstag Building, the German Federal Parliament, the building has lost its originality (Durmaz, 2019). Aleppo is among the cities affected by the war. The city, which has hosted many civilizations throughout history and has a rich cultural heritage, has faced many destructive effects on its historical fabric and daily life with the Syrian civil war. Important structures such as the Aleppo Citadel, the Umayyad Mosque, the Covered Markets, and the Carlton Hotel have been largely destroyed. One of the war-related damages is the Mostar Bridge. Built in 1566 by the architect Hayreddin, the bridge was destroyed in 1993 under artillery fire that lasted for 3 days (Elvan, 2024).

2.2.4. Fires

Fires, which are natural disasters and cause damage to many structures in our country, especially damage wooden structures. Fires resulting from negligence, carelessness, and arson are among the human-caused damages (Ahunbay, 2009, p.53). There are rules and regulations aimed at protecting historical structures, but since these regulations prioritize saving human lives, cultural and artistic values are relegated to the background. The aim of conservation experts is to prevent fires and minimize the damage caused. According to Feilden (2003), the problems in historical buildings are listed as follows:

- Inadequate communication with the fire department
- Insufficient maintenance and inspection
- Fires caused by cigarettes (11% of all fires)
- Kitchen-related practices (21% of all fires)
- Electrical installation problems (21% of all fires)
- Use of flammable materials
- Insufficient durability
- Inadequate escape routes
- Arson (especially in historical buildings, 10%) (Feilden, 2003).

2.2.5. Public Works Impacts

The construction of new roads, dams, and public spaces are urban development activities that threaten historical environments (for example, road widening projects in Istanbul in 1950, the construction of the Keban and Atatürk dams). Archaeological sites and rural settlements are submerged under dams, historical silhouettes surrounded by high structures are destroyed, narrow streets are widened, and activities such as deep excavations and tunnel construction near old buildings cause destruction and deterioration in historical areas. (Ahunbay, 2009, p.56; Amman, 2012). In particular, to ensure that underground work does not damage historical structures, thorough soil surveys and analysis of the vibrations caused by excavation are essential.

2.2.6. Tourism

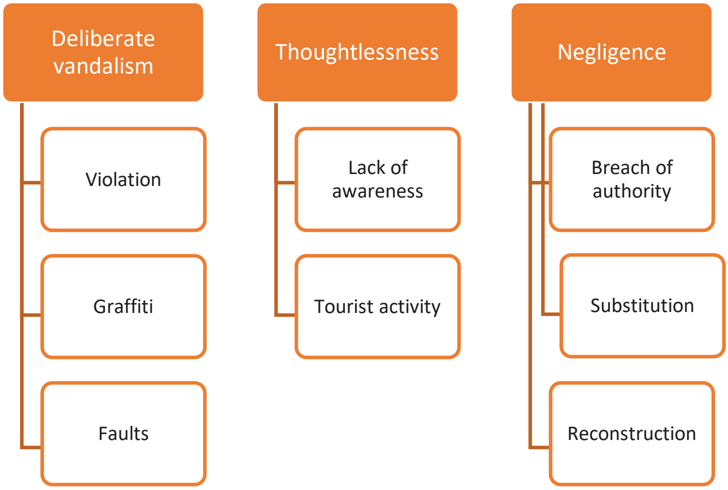
Although historical areas have a positive impact in terms of the interest and economic gain from tourists, the large crowds of visitors to historical buildings are corrosive and stressful for the structure. Although some measures are taken for visitors (covering the visitor route, reducing the speed of circulation), misuse by visitors, entry into protected areas, and damage to structures occur. (Meydan Uygur & Baykan, 2007). Authorities need to seriously consider and implement measures to prevent visitors from damaging historical structures.

2.2.7. Vandalism

The concept of vandalism was first used in 1794 by Abbé Henri Grégoire in his work "Report on the destruction carried out by vandalism and the means of suppressing it" to describe the destruction and damage caused by uprisings in the early days of the French Revolution (Merrills, 2009). Over time, the word has become more comprehensive, encompassing not only the damage caused by uprisings but also disrespect and destruction of cultural and public heritage (Şengel, 2023).

It is possible to encounter examples of vandalism worldwide in public spaces, parks, and historical sites. Structures that bear the traces of history and are part of the city's identity are under threat from vandalism. According to research, the most common type of vandalism is that caused by war and terrorism (Şengel, 2023). The lack of protection, supervision, and maintenance of historical artifacts exacerbates this effect. Table 2 shows the types of vandalism.

Table 2. Types of Vandalism (Edited by the author, referencing the article, Dominic, 2024)



Regardless of the type of vandalism that could damage historical buildings, international conservation boards need to work together with authorities to implement the necessary sanctions.

2.2.8. Air Pollution

Air pollution is defined as the disruption of the natural composition of the atmosphere by pollutants such as dust, smoke, odor, and water vapor, and the negative impact of this change on living systems in other ecosystems. Atmospheric pollution is a byproduct of industrial and commercial activities, fossil fuel use, and traffic. Industrial pollution has international consequences. In regions exposed to industrial pollution (North America, Europe, Japan), rain is acidic (Feilden, 2003).

Acid rain occurs as a result of the conversion of compounds such as carbon dioxide, sulfur, and nitrogen into sulfuric acid, carbonic acid, or nitric acid in humid environments or with precipitation due to air pollution. Acid rain causes erosion in historical buildings, and details such as ornamentation, decoration, and paintings become illegible (Ahunbay, 2009, p.57).

A dark, impermeable layer of soot forms on wet surfaces. Due to the soot layer accumulating on the facades, architectural details become imperceptible, and the surfaces beneath the layer lose their properties. The interaction of acids with the material causes the formation of salts within the material, and this sulfation on the surface fills the pores of the stones with sulfates. Depending on the degree of deterioration, the stones flake off in layers from the surface to the wetting area boundary (Ahunbay, 2009, p.57).

The study by Alessandro De Rosa and colleagues examines the deterioration of a cultural heritage site made of stone in an urban area, caused by air pollution such as traffic and heating, in the context of the facade elements of the Gesù Nuovo Church in Naples, Italy (De Rosa et al., 2025).

2.2.9. Traffic

Historic cities have narrow street layouts designed for light vehicle traffic, and opening these roads to heavy vehicle traffic causes damage to historical structures due to vibrations and pressure on the foundations (Ahunbay, 2009). Vehicle-induced ground-based vibrations occur when vehicle wheels encounter irregularities in the road surface (Department for Transport, 1996). Vibrations contribute to crack formation in materials exposed to temperature and humidity changes, or to fatigue processes in building materials. In extreme cases, they cause glass breakage, cracks in plaster, and instantaneous damage to poorly secured panels. In some cases, they affect the subsoil, reducing the foundation strength. According to Feilden (2003), the problem is twofold:

- Loss of foundation strength
- Loss of structural strength of the building body (Feilden, 2003).

The intensity of vibrations is affected by many independent components. Factors such as the disproportionate amount of force applied, vehicle speed, suspension system, and road surface determine the intensity of vibration (Hunaidi, 2000).

2.2.10. Errors in Structural Design

If the vertical load bearing elements in the structural system are not designed or constructed in sufficient size, cross-section, and number resist the vertical and horizontal loads that will be placed on them. They can cause serious damage such as collapse in the upper coverings like the dome, and cracking in the walls and supporting piers. One of the structures with an incorrectly designed structural system is Hagia Sophia. In its initial design, the structure, covered with a low sail vault, did not have a buttress system to support a dome with a span of 31 m, so the side walls opened up due to the static forces exerted by the dome, and it collapsed after the first seismic event (558) (Ahunbay, 2009, p.39-40; Amman, 2012).

2.2.11. Faulty Material Use

Monumental structures such as temples and theaters found in archaeological sites in Anatolia (for example, the Temple of Apollo in Didyma, the Temple of Artemis in Ephesus, the Theater of Aspendos) were built from durable stones. In traditional architecture, however, some of the structures have survived to this day because they were built with organic materials such as stone, adobe, brick, and wood. The poor quality of materials used today and the deterioration of their natural composition accelerate wear and deterioration. Using materials that conform to the natural stratification of stone in buildings, properly firing bricks, the quality of mortar binding the main materials in masonry structures, and using hardwood in wooden structures ensure the longevity of the building (Amman, 2012).

2.2.12. Poor Workmanship and Attention to Detail

Poor workmanship results from the use of inappropriate materials and details, and skills not matching the design (Feilden, 2003). According to Josephson &Hammarlund (1999), most defects stem from human factors such as forgetfulness, carelessness, lack of information, and insufficient motivation. According to a study conducted in Singapore, the most frequently encountered defects during construction were identified as joint defects, rough surface finishes, piece breakage, irregularities, cracks, staining, voids, and alignment errors (Wai & Sui, 2006). These defects are fundamentally based on poor workmanship.

According to Abdul Rahman et al. (1996), the factors causing poor workmanship are listed as:

- Lack of management and supervision
- Lack of experience and competence
- Communication problems
- Use of incorrect equipment
- Time and budget constraints
- Unfavorable weather conditions (Abdul Rahman et al., 1996).

2.3. Deterioration Caused by Biological Formations

2.3.1. Bacteria and Lichens

Bacteria chemically interact with building materials, causing acid formation. The acids formed create small holes on surfaces at first glance, leading to surface loss in the future. The changes not only progress chemically but also form a black sediment layer on the surface (Dolar & Yılmaz, 2014).

Lichens are a combination formed by the merging of algae and bacteria. Although they may appear aesthetically attractive on some surfaces, they accelerate stone decay due to acid production. In addition, they slow down drying after rainfall, creating a predisposition to frost damage (Uz, 2021).

2.3.2. Deterioration Caused by Insects and Other Organisms

Due to its physical and chemical composition, wood has an organic structure and therefore retains moisture. Because of this moisture, wood provides a favorable environment for the formation of fungi and insects. Especially wood used as a structural material is significantly damaged and weakened (Uz, 2021).

2.3.3. Fungi

Fungi, which particularly affect wood, thrive best in environments where the humidity is above 20% and the air temperature is between 20-22 °C (Seçkin, 2010). When sufficient conditions are met, fungi spreading on the material cause the wood to rot. Rotting wood is subject to negative consequences such as cracking, slipperiness, discoloration, visual deterioration, odor changes, and loss of durability. Fungal deterioration is more common in areas with high humidity such as basements, floors, behind baseboards, roof elements, and window frames (Uz, 2021).

2.4. Deterioration Caused by Atmospheric Effects

2.4.1. Temperature and Thermal Expansion

Increasing the temperature of a building by 1 °C requires a significant amount of heat. Since heat travels slowly through the walls and mortar, the exterior facade heats up faster than the interior. This time delay causes expansion and contraction in the exterior while keeping the conditions inside constant. These expansion and contraction-related deteriorations are called thermal expansion. Factors such as the color, reflectivity, flexibility, load-bearing capacity, bonding method with other structural elements, and moisture content of the material directly affect this situation (Seçkin et al., 2017). The stresses resulting from thermal expansion are approximately 330 kN/m² (48 lbf/in²) per 1 °C in a typical limestone with a compressive strength of 21,000 kN/m² (approximately 200 tonf/ft²). While rapid daily temperature changes penetrate only a few centimeters, the effects of seasonal temperature changes are more pronounced; this is because the wall core heats up and the entire structure tends to expand (Feilden, 2003).

According to Feilden (2003), stresses caused by thermal change in building materials depend on the following factors:

- Material elasticity
- Material size, coefficient of expansion
- Material's resistance capacity under load
- Material's capacity for movement in connection with other elements
- Change in evaporation and moisture content (Feilden, 2003).

The thermal conductivity coefficient in building materials affects their degradation performance. In regions with large daily temperature differences, different stresses occur within the material during the heating-cooling cycle. For example, there is a temperature difference between the surface and the interior of a material exposed to sunlight. This temperature difference causes different expansions in the material (Bayık & Bedirhanoğlu, 2022).

2.4.2. Water and Moisture

The main factors causing moisture-related deterioration in historical structures are rain, condensation, rising humidity, moisture accumulation within the structure, and water seepage. Material properties and environmental conditions determine the dynamics of the deterioration process.

Water exists in material voids as solid ice and gaseous water vapor. Excess water vapor in structures is considered moisture. Moisture causes physical deterioration such as chipping, chemical deterioration such as salt formation, and biological deterioration such as fungal growth in building materials. In addition, water in crack voids freezes, expands, and swells, causing material deterioration (Uz, 2021).

Wetting and drying cycles play a role in determining the direction of water penetration within the material. Rising humidity determines the physical process on the interior and exterior surfaces of masonry walls. Water causes wetting in the structure through pores in the material, capillary attraction of groundwater, and condensation of rainwater and atmospheric moisture. Soluble salts are transported to structural elements in direct contact with the ground via a capillary rise mechanism. Soluble ions carried by rainwater and from adjacent materials also contribute to salt crystallization, which causes deterioration over time. The Lecce Cathedral in the historic city of Lecce in southern Italy has been subjected to salt crystallization due to moisture (D'Agostino, 2013).

2.4.3. Freezing and Thawing

Cold climates damage buildings, but it's not the extreme cold itself that causes damage, but rather the freezing cycles. The expansion and contraction of ice during freezing and thawing is what causes the main damage.

Freezing causes damage, especially in water-saturated, porous materials like brick and stone. The durability of materials depends on pore size and hydrophilic structure. In materials without a suitable pore structure, when water freezes within the pores, it expands, damaging the material (Feilden, 2003).

In masonry structures, water seeping into the structure and undergoing freezing and thawing causes structural damage such as peeling, cracking, and material deterioration, as well as long-term effects on aesthetic integrity. In porous structures, the occurrence of this damage depends not only on freezing conditions but also on the moisture saturation exceeding a critical level (Sahyoun et al., 2025).

Studies show two different views on the effect of climate change on freezing and thawing. It is thought that the risk of damage will decrease with increasing temperatures and increase due to increasing humidity (Sahyoun et al., 2025).

According to Sahyoun et al. (2025), certain factors are evaluated to determine the risk of freeze-thaw damage during the construction or renovation phase of masonry structures. These factors are listed as follows:

- Properties of the masonry material
- Presence of moisture
- Water absorption rate
- Type of insulation used
- Environmental conditions to which it is exposed (Sahyoun et al., 2025).

According to the research by Sahyoun et al. (2025), interior insulation increases the risk of freeze-thaw damage in wall materials. Breathable and moisture-managing materials such as mineral wool and calcium silicate reduce this risk. Since moisture accumulation is high on the north, east and northeast facades, this feature should be taken into consideration when applying insulation (Sahyoun et al., 2025).

2.4.4. Solar Radiation

Materials exposed to radiation of different wavelengths react differently because their rates of light reflection and absorption vary. The ultraviolet (UV) spectrum of light has a more destructive effect, particularly damaging organic materials such as wood, textiles, and color pigments. It causes fading, embrittlement, and loss of surface matter in color pigments. Unprotected wood surfaces can undergo erosion of 5-6 mm in approximately one century due to the effects of ultraviolet light and sudden humidity changes (Feilden, 2003).

2.4.5. Wind

Wind is formed as a result of atmospheric pressure differences. The direction, speed, sudden gusts (wind gusts), and frequency of periods of calm (the rate at which wind does not blow) are among the basic characteristics of wind. Historical structures are affected not only by wind pressure but also by the suction force created in the opposite direction of the wind (Feilden, 2003).

In historical structures, wind affects durability and stability. Therefore, a structure that has withstood all wind intensities throughout its lifespan does not necessarily mean it can withstand future wind forces, as it has deteriorated over time (Feilden, 2003).

Continuous wind loads over time cause material fatigue. Wind accelerates general external erosion in materials, especially when combined with sand or dust, where the erosive effect is greater. Salt crystallization is observed within the walls due to rapid evaporation caused by wind. The most serious effects of wind occur when combined with rain. Rain, under the influence of wind, penetrates cracks, cavities, and porous materials, causing internal deterioration (Feilden,2003).

2.5. Deterioration Types in Wood and Stone Materials

Deterioration in historical buildings is evaluated not only on a general scale but also on a material-specific basis. Stone, frequently used in historical buildings, is subject to various types of deterioration due to exposure to environmental factors. Table 3 shows the types of decomposition occurring in stone material. Table 4 shows the types of deterioration in wood material.

Table 3. Types of Decomposition Occurring in Stone Material (Prepared by the author, referencing Öcal & Dal, 2012)

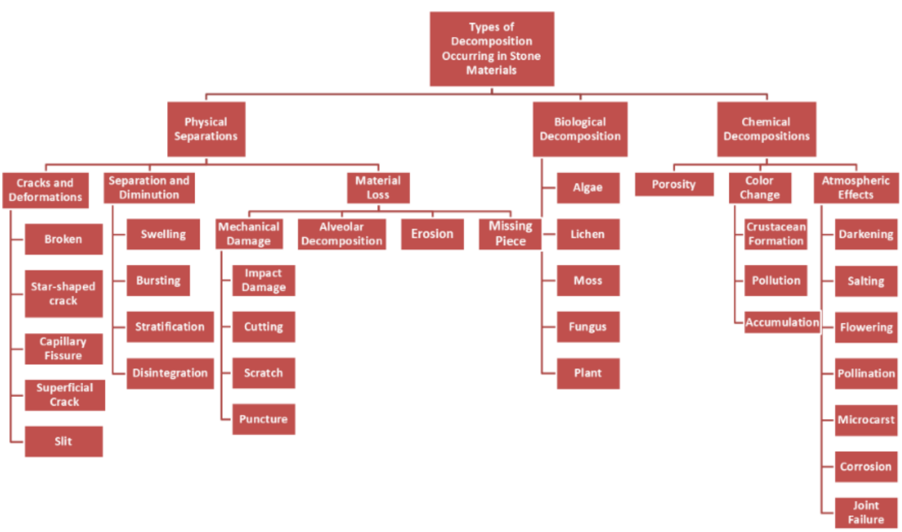
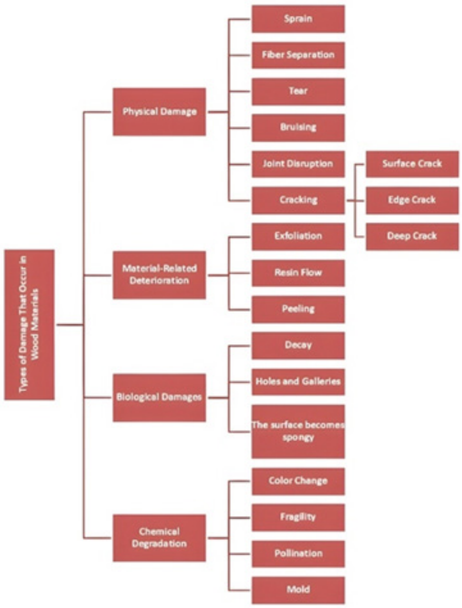


Table 4. Types of Damage Occurring in Wood Materials (Prepared by the author.)



3. Material and Method

In order to examine the relationship between climate change and deterioration in historical buildings within the context of architecture in an academic framework and to establish a strong scientific foundation through literature review, a bibliometric analysis method was applied.

Data were obtained from the Web of Science (Clarivate, 2025) database, a comprehensive and citation indexing platform that provides access to interdisciplinary academic literature. Web of Science (WoS) is a database produced by the Institute for Scientific Information (ISI) that is used worldwide due to its interdisciplinary nature and capacity for international research. WoS contains more than 10,000 journals. It consists of three citation databases:

- Arts & Humanities Citation Index (coverage extends to 1975)
- Social Sciences Citation Index (coverage extends to 1956)
- Science Citation Index Expanded (coverage extends to 1900).

WoS has more than 38 million records. More than 1.5 million new entries and 23 million new citations are added annually from over 250 disciplines, including natural sciences, social sciences, arts, and humanities (Vieira & Gomes, 2009).

Database searches were conducted using the commands:

architecture AND climate change AND (“historic building*” OR “heritage building*” OR “cultural heritage” OR monument*) AND (deterioration OR degradation OR “material decay” OR “structural damage” OR weathering OR “moisture damage”).

English was set as the search language, and publications were limited to articles only. The time frame was created to cover the years 2000-2025. After applying the specified filters, 15 articles were identified.

These articles were analyzed in terms of elements such as research aims, methods and findings, the region studied, and keywords, and evaluated under the main heading of climate change. In this study, bibliometric networks were established between citations and keywords using the Vosviewer scientific software tool developed by Van Eck and Waltman (2010).

4. Bibliometric Analysis

Figure 1 shows the distribution of publications by country. The graph shows that the UK and Italy have the highest number of publications. Italy is among the countries that conduct the most research on the deterioration of historical structures in the context of their historical context and humidity-temperature relationships, and on climate change. India and Portugal also have a high number of publications. Since Portugal is a coastal country, humidity-related deterioration is among its research topics.

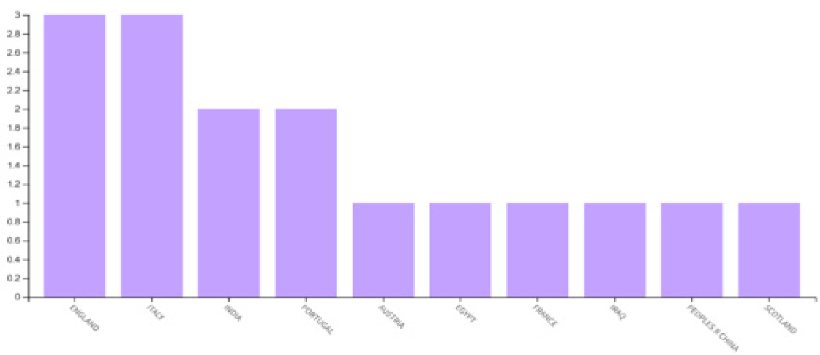


Figure 1. Article Search Publication Distribution Graph by Country

From Web of Science database (2025)

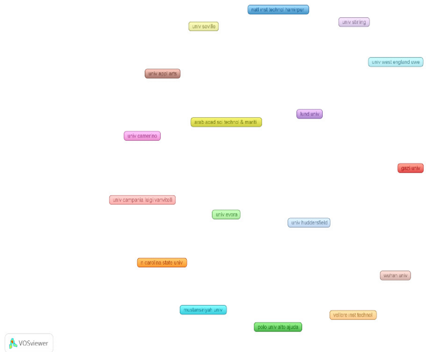


Figure 2. University Map

(Created by the author using the VOSviewer (Van Eck & Waltman, 2024).)

The university map in Figure 2 shows a lack of citation-based interaction between universities and limited shared references and publications. Lund University, the Arab Academy of Sciences, the University of Huddersfield, and Evora University, which are centrally located, are influential universities in the field, particularly regarding the deterioration of historical buildings in the context of climate change.

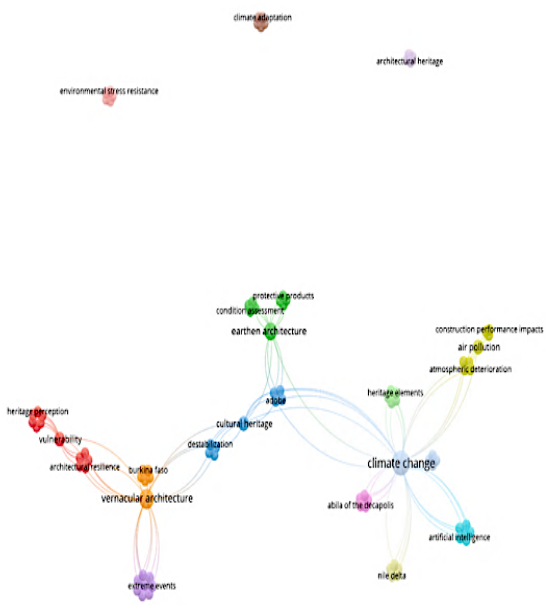


Figure 3. Keyword Map

(Created by the author using the VOSviewer (Van Eck & Waltman, 2024).)

The map shown in Figure 3 is structured around the axes of climate change, local architecture, and cultural heritage. The central concept is climate change, and it has established strong relationships with cultural heritage, air pollution, artificial intelligence, and cultural heritage elements. It offers an interdisciplinary framework by addressing environmental, technological, and cultural fields. The concept of local architecture, on the other hand, is related to concepts such as architectural resilience and fragility, and the perception of cultural heritage.

4.1.Keywords Definitions

4.1.1. Vernacular Architecture

Vernacular architecture represents the architectural language of the people along with their ethnic, regional, and local dialects. Vernacular architecture is defined as a concept that goes beyond the simplicity of local architecture and the use of local building materials and details, produced by master craftsmen and artisans in the region. It also represents the local climate, daily life, craftsmanship, and culture. Vernacular heritage brings together buildings, land use, vegetation, biodiversity, water resources, and craftsmanship not only as an architectural value but also as the sum of the surrounding landscape and its associated intangible (spiritual) values (Aktürk & Fluck, 2022).

4.1.2. Architectural Resilience

Architectural resilience aims to develop solutions to the problems brought about by industrialization, urbanization, climate change, and socioeconomic disruptions. It refers to the ability of a system or order to maintain its functionality, protect against a threat, respond to risks, adapt to similar risks, and learn and reorganize. Its purpose is to return to the situation before the risk and threat.

4.1.3. Climate Adaptation

In historical buildings, the climate adaptation process should be addressed with a layered approach, considering the preservation of cultural value as the main element and aiming to increase user comfort and energy performance. Studies aimed at improving the building envelope, which creates a physical and functional interface between the external and internal environments, and integrating HVAC systems are implemented as limited interventions without harming cultural value (Öztürk et al., 2025).

4.1.4. Extreme Events

A disaster is a sudden, natural, human-caused, or technological event that negatively affects a society, environment, or order (Varol & Gültekin, 2016).

According to research by EM-DAT, 7,348 disaster events were recorded worldwide between 2000 and 2019. These resulted in 1.23 million deaths and $2.97 trillion in economic damage. Data from 1980-1999 shows that 4,212 disasters were recorded worldwide, resulting in 1.19 million deaths and $1.63 trillion in economic damage. These figures indicate an increase in the number of recorded disasters over the last twenty years (CRED, 2020).

Extreme events are extreme situations that occur suddenly and spontaneously in the system's state, without early warning signs, and have negative social, environmental, and economic consequences. Examples include giant ocean waves, extreme weather events, and earthquakes (Farazmand & Sapsis, 2018).

There is no precise definition of disaster magnitude, duration, and frequency when defining extreme events. The attribution of extreme events to climate change is a subject of research and debate (McPhillips et al., 2018). However, there is evidence linking extreme events in climatological hazards to climate change (Sura, 2011).

5. Articles

Table 5 presents a table containing the titles, publication year, author names, regions studied, keywords, abstract, methods, and conclusions of the 15 articles examined as a result of bibliometric analysis.

Table 5. Article Analysis Table (Prepared by the Author)

ArticlTitle/ Journal Name/ Year/ Author	**Keywords**	**Abstract/Region**	**Method**	**Conclusion**
Vernacular Heritage as a Response to Climate: Lessons for Future Climate Resilience from Rize, Turkey Land / 2022 Gül Aktürk, Hannah Fluck	Climate resilience, vernacular heritage, climate adaptation	Examining the degradation of vernacular heritage due to climate change from a user perspective. Türkiye	Interviews with local people Field analysis	Increased rainfall due to climate change is causing disasters such as floods and landslides. Sustainable adaptation strategies must be developed to protect vernacular heritage.
Modeling Earthen Treatments for Climate Change Effects Heritage / 2023 Sharlot Hart, Kara Raymond, C. Jason Williams, William A. Rutherford, Jacob DeGayner	Climate change, cultural heritage, deterioration, adobe	Given the limited literature on climate change-induced degradation of adobe, a material with strong cultural significance, this study aims to identify effective cladding methods to address this degradation. Southwestern United States	Determining the surface coating material Performing analysis and tests	It was concluded that lime and clay-based mixtures significantly reduced deterioration and that organic additives increased surface stability.
Historic Building Materials from Alhambra: Nanoparticles and Global Climate Change Effects Journal of Cleaner Production / 2019 Marcos L.S. Oliveira , Carolina Dario , Bernardo F. Tutikian , Hinoel Z. Ehrenbring , Caliane C.O. Almeida , Luis F.O. Silva	Air pollution, Geochemistry, Construction performance impacts, Cultural heritage building degradations	Research is being conducted on the fact that adobe architecture is not only a heritage to be preserved, but also a potential solution in terms of sustainable housing production and energy efficiency. Latin America, the Mediterranean and the Middle East	Comparative case analysis Comprehensive literature review	Although adobe offers positive potential from a sustainable perspective, its use in modern building applications requires addressing its technical and institutional challenges.

Weathering of Soapstone ın a Historical Perspective Materials Characterization / 2004 Per Storemyr	Soapstone, weathering, history climate change	This study examines the decomposition (deterioration) of soapstone as a result of its use in outdoor environments in Norway, and how this decomposition changes over time. Norway	Retrospective monitoring	The causes of deterioration in structures include natural disasters such as fires and storms, water leaks due to roof damage, biological growth, and frost.
Impact of Climate Change on the “Trabocchi Coast” (Italy): The Trabocco Turchino Case Study Sustainability / 2023 Alessandra Mascitelli , Fernanda Prestileo, Eleonora Maria Stella, Eleonora Aruffo,Luisa Irazú López Campos, Stefano Federico , Rosa Claudia Torcasio , Anna Corsi, Piero Di Carloand Stefano Dietrich	Severe weather conditions, fragility, uses of heritage.	This study examines the physical, social, and cultural dimensions of the effects of climate change on traditional fishing structures, known as “Trabocchi,” which are considered cultural heritage. Italy / Trabocchi Coast	Meteorological data analysis Wind trajectory simulation Numerical weather prediction model Social and cultural analysis	The region has experienced an increase in both rainfall and wind speeds over the past 40 years. In response to this change, the proposal is that ‘Structures should adapt to environmental change in a flexible and resilient manner, rather than fighting against nature.’
An AI-Supported Framework for Enhancing Energy Resilience of Historical Buildings Under Future Climate Change Architecture / 2025 Büşra Öztürk , Semra Arslan Selçuk, Yusuf Arayıcı	Artificial intelligence, computational architecture, energy resilience.	By examining the effects of climate change on the energy resilience of historical buildings, they aim to develop an AI-powered conceptual perspective that will make these structures resilient to future climate conditions. Italy, Canada, Greece, Brazil, New Zealand, China	Literature review Content analysis AI integration and potential analysis Conceptual framework definition method	AI-powered findings have determined that AI is an effective tool in predicting heat load, energy consumption, and degradation risks.

Influence of Special Report on Emissions Scenarios and the Representative Concentration Pathways Scenarios on the Preservation of Churches with a Deficient Microclimate Journal of Building Engineering / 2022 David Bienvenido-Huertas, Marta Torres-Gonz´alez, Miguel Le´on-Mu˜noz, J.J. Martín-del-Río	Climate change, indoor microclimate, forecasting, conservation.	This research investigates the internal microclimate changes and conservation conditions caused by climate change in historical buildings. Spain	Fieldwork and data collection Microclimate analysis Multilayer Perceptron (MLP) Climate scenarios for the future	It has been concluded that climate change is disrupting the physical integrity of cultural heritage sites. Increased temperature and relative humidity, along with more frequent storms, are causing microclimate deterioration in historical structures.
Reversible Multifunctional Mural Protective Material With High Durability, Anti-aging, Breathability, and Harsh-Environment Resistance Journal of Building Engineering / 2025 Xiao-Hai Wu , Xiao-Jian Bai , Dong-Mei Chen , Xian-Ming Zhang	Mural conservation, Fluorosilane composites, Reversible materials, Hydrophilic-hydrophobic architecture, Environmental stress resistance	The goal is to develop a durable, recyclable, breathable, and environmentally friendly protective material for murals that are part of cultural heritage, preventing their deterioration.	Material design Experimental stages Numerical analysis (DFT)	P(HMT-Si-F) has adapted to climate change, showing positive results in parameters such as moisture control, adhesion strength, optical transparency, and environmental resistance.
Thermal Performance Assessment of Burkina Faso's Housing Typologies Buildings / 2023 Maria Aguilar-Sanchez, Jose-Manuel Almodovar-Melendo ,Joseph Cabeza-Lainez	Vernacular architecture, thermal performance, sustainable architecture.	The aim of this study is to evaluate the adaptation of traditional and contemporary housing types in Burkina Faso to environmental conditions and their thermal performance in the context of climate change. Burkina Faso	Collecting data according to housing types and analyzing them in terms of thermal insulation, heat transfer, ventilation, and humidity.	People have been forced to abandon traditional structures due to harsh climatic conditions, but while traditional structures have the potential to protect the natural microclimate balance, they are not model housing.

Conservation of Earthen Bricks in Architecture: An Experimental Campaign to Test Different Treatments on Vernacular Built Heritage Heritage / 2023 Silvia Rescic , Manuela Mattone, Fabio Fratini , Loredana Luvidi	Adobe architecture, adobe bricks, conservation issues, preservation products.	The aim is to identify suitable materials and methods for protecting adobe bricks against environmental impacts related to climate change and to develop strategies to increase their durability. Italy	Material selection Sample preparation Sample testing Evaluation	Silicate-based protectors have increased durability by forming a crystalline network in the pore walls. Nanolime applications have provided a balanced solution while maintaining breathability. Although hydrophobic materials prevent water ingress, they have limited natural breathability in the long term.
Low-Cost Photogrammetry for Detailed Documentation and Condition Assessment of Earthen Architectural Heritage: The Ex-Hotel Oasis Rouge in Timimoun as a Case Study Buildings / 2024 Haroune Ben Charif , Ornella Zerlenga, Rosina Iaderosa	Mudbrick architecture, photogrammetry, low-budget, historical heritage documentation	It aims to develop a model for the digital documentation and preservation of adobe architectural heritage at a reasonable cost. Algeria	Documentation and analysis using photogrammetry	Adobe structures deteriorating due to climate change should be documented and scientifically recorded using photogrammetry. This allows for data-driven approaches in restoration and conservation decisions.
A Review of Atmospheric Deterioration and Sustainable Conservation of Calcareous Stone in Historical Buildings and Monuments Sustainability / 2024 Yu Yan and Yansong Wang	Atmospheric degradation, sustainable conservation, limestone, built heritage	The aim is to study the deterioration processes of limestone rocks under atmospheric influences and to propose sustainable conservation approaches based on these studies.	Systematic literature review	Climate change and its effects are accelerating dissolution, expansion, and crystallization cycles in calcareous stone surfaces. Conservation strategies include nanolime, silicate consolidants, bioconsolidation, and hybrid materials.

Contributions to Architectural and Urban Resilience Through Vulnerability Assessment: The Case of Mozambique Island's World Heritage Heritage / 2025 Susana Milão , Telma Ribeiro , Mariana Correia , Isabel Clara Neves , Joaquim Flores, Olga Alvarez	UNESCO World Heritage site, fragility, architectural resilience, indigenous architecture	This study aims to assess the vulnerabilities caused by the increase in weather events due to climate change on the island of Mozambique from morphological, urban, and architectural perspectives. Mozambique Island	Cartographic and morphological analysis Construction techniques analysis Conservation and legal environmental assessment Weather event and impact analysis	In Mozambique, GIS-based risk management systems, the strengthening of traditional construction techniques with contemporary methods, and sustainable restoration and disaster management measures are offered to address the degradation caused by climate change and extreme weather events.
Floods and Their Impact on Cultural Heritage -A Case Study of Southern and Eastern Serbia Sustainability / 2022 Ana Momčilović Petronijević Predrag Petronijević	Cultural heritage, floods, risk management, structural damage, local architecture.	The aim of this study is to examine the impact of flooding on cultural heritage in the southern and eastern regions of Serbia and to assess the vulnerability of cultural assets in the context of climate change. Southern and Eastern Serbia	Archive and document research Fieldwork Interviews with local people Damage assessment and classification	Global warming, increased rainfall patterns, river floods, and erosion have led to an increase in the frequency and intensity of floods. This situation poses a particular threat to local architecture, especially that which is largely composed of organic materials.
Influence on Energy Performance in Historical Buildings Caused by The Urban Environment and Project Modifications: The Case of The Duclós House Revista Hábitat Sustentable / 2020 David Bienvenido-Huertas, Isıdro Cortés	Architectural heritage, energy conservation, modern architecture	This study examines how energy performance in modern cultural heritage buildings is affected by environmental changes and design modifications. The research analyzes these effects using the Duclos House as an example. Spain	Structural analysis Energy simulation Climate change relationship	Historic buildings may experience changes in energy efficiency due to both project modifications and urban development. While urban shading initially reduces energy efficiency, it has become an adaptable conservation strategy in light of climate change.

6. Findings

In the context of this research, a literature review was conducted in the WoS database on the deterioration caused by climate change in historical structures, and 15 articles on the subject were examined. The review revealed that the articles generally focus on deterioration caused by increased rainfall, temperature and humidity, extreme natural events, changes in wind speed, and natural disasters, all stemming from climate change. In addition to the causes of deterioration, suggestions for protection against deterioration and material-specific analyses are key topics. Six of the articles concluded that increased humidity, rainfall, and disasters due to climate change damage the physical integrity of structures and threaten cultural heritage. The methods used to reach this conclusion included interviews with local people, meteorological data analysis, literature review, field work, and damage analysis. Four studies focused on materials. Three of these studies examined climate change-induced deterioration in adobe and one in stone. Since local architecture is common in the case studies, adobe material is frequently seen. Five articles offer suggestions for protection against deterioration. As a conservation proposal, suggestions have been made to prevent deterioration with P(HMT-Si-F) material, lime and clay-based mixtures, urban shading, and adaptation to the environment.

The research areas selected generally include coastal cities and local architectural regions with high humidity and rainfall, such as Rize, the Italian coast, Spain, and Mozambique.

The articles emphasize the importance of preserving and documenting historical structures because they bear witness to the past. Methods such as artificial intelligence, photogrammetry, and 3D laser scanning have also been proposed for document-based restoration, and their application has been confirmed to yield positive results in various examples.

7. Evaluation

As a result of the bibliometric analysis conducted within the scope of addressing the impact of climate change on the deterioration of historical buildings from an architectural perspective.15 articles were examined. The study examined the subject through examples from different geographies (Mozambique Island, Southern and Eastern Serbia, Spain, Algeria, Italy, Burkina Faso, Norway, USA, Turkey). This shows that the issue is addressed on a global scale and that climate change poses a threat to historical buildings worldwide.

Turkey has seven different climate zones. It hosts many structures in the context of historical and rural architectural works. The review revealed that there are limited studies examining the impact of climate change on the deterioration of historical buildings in Turkey. The study conducted abroad by Aktürk and Fluck (2022), using the Rize example, is the only example encountered in the literature review. This situation shows that there is a need in the literature for interdisciplinary studies addressing the impact of climate change on historical buildings and deterioration processes in Turkey.

The articles reviewed address the topics in depth using a variety of methods, including field analyses, comparative case studies, comprehensive meteorological investigations, protective material recommendations and experimental studies, extensive literature reviews, energy simulations, and interviews with local people. In some studies, the inclusion of users in the process provided a deep and multi-dimensional research approach, addressing not only the physical aspects of deterioration but also the problems experienced by those living in the structure.

The articles particularly focused on the deterioration of adobe, a material of great importance to local architecture, and its conservation strategies in the context of climate change. In this context, the relationship between materials and climate change was illuminated within the context of adobe. However, it is observed that wood and stone, fundamental elements of local architecture, have not been sufficiently addressed in the context of climate change-related deterioration. In particular, the humidity factor increases and decreases due to climate change, causing structural and surface deterioration in wood materials. The literature remains limited in terms of material scope.

The articles do not limit themselves to problems related to deterioration but also offer conservation and intervention recommendations, demonstrating a solution-oriented approach. Although the proposed solutions have successful experimental results in terms of materials, they fall short due to negative factors such as economic constraints, transportation difficulties, and lack of oversight.

8. Conclusion and Discussion

Globally, world temperatures are steadily rising, and this is having a devastating impact on cultural heritage that reflects the past of society and sheds light on the future. Climate change is described by researchers as the fastest-growing threat to world heritage sites. Areas facing this threat include archaeological sites, cultural and rural sites, monuments, and cultural landscapes.

These elements combine to contribute to understanding the past and creating a sustainable understanding of history.

In the face of this serious threat, research is focused on two main areas: mitigation and adaptation. These two approaches complement each other in the fight against climate change. Minimizing the threats posed by climate change, adapting to existing threats, and proposing protection measures are among the actions currently being taken.

Historical structures are undergoing multi-layered deterioration due to the effects of climate change and environmental factors. In addition to the deterioration of the structural system or aesthetic integrity of the building, the degree to which it is affected by environmental factors varies depending on the material used. The materials used in the structure undergo physical, chemical, biological, and mechanical deterioration.

Temperature variations increase thermal expansion and contraction differences in materials such as stone, brick, and mortar, leading to cracks; high humidity, salt crystallization, biological growth, and freeze-thaw cycles cause damage in porous materials. Furthermore, air pollution and acid rain lead to the formation of gypsum, soot, and salt, particularly in limestone, as a result of chemical reactions. This damage not only disrupts the physical integrity and aesthetic perception of historical structures but also causes the loss of original data, traces, and detailed information that bear witness to past civilizations and cultural heritage. Therefore, documentation plays a crucial role in the preservation of historical structures. Today, 3D laser scanning, photogrammetry, digital modeling, and AI-supported data analysis enable accurate documentation of the current state of structures and the scientific monitoring of deterioration processes. Integrating documentation data into the restoration process contributes to interventions being carried out in a data-driven and sustainable manner, avoiding randomness. AI-based analysis methods, in particular, allow for the prediction of potential deterioration by modeling material behavior and the optimization of conservation strategies.

The bibliometric analysis of the research revealed that studies have intensified after 2020. This finding suggests that the impact of climate change on historical structures is being addressed not as a potential problem, but as a confrontable and measurable issue.

Among the regions where the literature is concentrated are England and Italy. Given its historical texture and humidity-temperature relationships, Italy is likely one of the countries that has conducted the most research on the deterioration of historical structures and climate change. Turkey, with its diverse climatic characteristics and rich historical infrastructure, falls short in addressing the deterioration of historical structures due to climate change.

In conclusion, the impact of climate change on historical structures continues in a multifaceted and accelerating manner. Therefore, for the sustainability of cultural heritage and its transmission to future generations, it should be addressed through holistic methods encompassing interdisciplinary collaboration, documentation methods, conservation strategies, AI-supported analysis methods, and adaptation to the new climate regime.

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