Impacts of climate change on cultural heritage; The case of the Greek theatre of Dionysus

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Abstract. Climate change is an ongoing fact with evident impacts on earth, humanity and our heritage. The management and protection of heritage from the effects of climate change should be taken into consideration, so as to act dynamically and immediately, since the effects of climate change are rapidly evident in all aspects of life. The objective of this research is to study the vulnerability of the ancient Greek Theatre of Dionysus, as it forms a monument with embedded heritage values exposed to the climate change. This case study is the tangible result of a particular cultural and historic research, bearing historic knowledge, cultural meanings via a recognizable architectural structure and it reflects the conjunction of culture with society and nature. Materiality and its pathology combined with the condition of the natural landscape and the altering pattern of cultural tourism can lead to the study of climate change imprint on this kind of heritage, which should be examined as a wholeness of culture and nature. The uniqueness in the Theatre’s identity and historic path deserves interpretation of the effects of climate change, so as to manage adaptation, proactive planning, mitigation and dissemination of the discovered results.

1. Introduction

According to the World Meteorological Organization the term ‘climate’ can be defined as “the statistical description in terms of the mean and variability of relevant weather quantities over a long period of time”. The alarming observation of climate change has affected the various aspects of life and thus cultural heritage, especially during the Anthropocene geological era, where the anthropogenic activities and the related changes in the climate energy balance, accelerate climate change [1].

Cultural heritage and climate change have an intense relationship, which deserves special research for the resilience and protection of heritage from the adverse effects of global warming. Studying the physical evolution of archaeological monuments exposed to natural phenomena, we could acquire information on climate variability and vice versa. For instance, archaeological sites and some buildings have survived for at least two periods of global warming (around 1500–1200 BC and 800–1200 AD) and intervening cold periods and the assessment of this heritage offers valuable information for better understanding the interaction between climate, climate change and cultural heritage. In the meantime, local weather is heavily influenced by local topography and land use, implying an intense interaction between weather, the particularities of the place and the role of community in the uses and functions of land [2]. This means that there is uniqueness of each case study, as special characteristics...
of every specific region deserve a tailor-made management plan for their past and current condition in combination with the heritage values.

Actually, the case of an ancient Greek Theatre forms a living monument with embedded values exposed to the ongoing climate change. This research frames the identification of climate change impacts on the heritage of the ancient Greek Theatre of Dionysus, located in the historical center of Athens, assessing the heritage management and adaptation to the effects of climate change.

The historical observations of the registered weather phenomena of a place (e.g. meteoblue [3]) with respect to the climate change are fundamental characteristics of the genius loci [4], which refers to the spirit of the place of heritage, expressing its distinctive identity.

2. Methodology

Data collection, in-situ documentation and interpretation of the ancient Greek Theatre of Dionysus structure its conception as a particular culture, bearing historic knowledge and values via a recognizable architectural type, connecting culture with society and nature. Materiality, pathology, study of landscape and cultural tourism can lead to the study of climate change imprint on this kind of heritage, which should be examined as a wholeness of culture and nature, in the core of the city of Athens.

2.1. Characteristics of the selected heritage

The ancient Greek Theatre of Dionysus is situated on the southern part of Acropolis hill, in Athens, Attica, Greece. It is constructed on the rock and it is a valuable source of archaeological and architectural information, as well as an important piece of cultural heritage, as it is vital part of the great route of Acropolis and it is connected to the historic core with spatial and conceptual meanings. It is made of stone and its construction started during the second half of 4th century B.C. It was in continuous use even during the Roman period, with multiple phases. The structure reveals great precision of calculations and harmony (e.g. the curve of the upper Theatre follows the curve of the cavea, which reveals cautious design based on balanced form) [5]. Excavations started at 1862 and there is an ongoing study and restoration, with the sequent phases: conservation 1977-1984, restoration program 2002-2005, structural reinforcement 2002-2009, restoration planning 2010-2015 [5].

![Figure 1. Simplified geological map of Attica Region, based on the official Greek projection system (EGSA 87) [6].](image)

With respect to the geological structure of the wider area of Athens, which belongs to Attica region (Figure 1), Alpine basement rocks, both metamorphic and non-metamorphic, and post-Alpine Sediments dominate. Slope gradient influences on a high grade the slope proneness to failure due to a
combination of reasons such as the weathering processes, the internal geometry of geological formations as well as the intensity of meteorological conditions [6].

Regarding the climate of Athens, according to the Koppen climate classification (2018) [7], it is defined as Hot Summer Mediterranean (Csa), which means mild and rainy winter and dry summer periods (see appendix 1). Nevertheless, the urbanization of Athens city resulted in enhanced urban heat island [8] and increasing rain intensity, as well as the appearance of extreme weather phenomena ([9], [10], [11]). Mechanical turbulence from increased surface roughness, sensible heat from the urban warm air and the anthropogenic condensation nuclei floating in the urban air are the synergistic factors, which cause urban induced changes in precipitation [12]. Due to these factors, heavy storms of convective nature are common in the developed mega-cities ([13], [14], [15], [16]).

The ancient Greek Theatre of Dionysus is in immediate relation to the capital urban fabric with the social services and the wealth of cultural features, permitting interpretation of the current repercussions of climate change on the capital. Its heritage value communicates with the virtuous core of Athens, which is composed of Acropolis, Agora, city centre, important circulation axles (see appendix 2).

![Figure 2. Location of the Theatre of Dionysus in the historical center of Athens.](image)

2.2. Risk assessment and vulnerability approach

As Athens is a mega-city, the urban heat island, intensified by climate change [17] and the related adverse ambient air quality with respect mainly to acid rain, cause more stress to cultural heritage. The risk assessment is a valuable tool of threat detection on the specific place of the heritage case study. The strategy for climate change management should be based on risk assessment, adaptation measures, and monitoring the effects on the historic heritage with evidence of decay [18]. For better understanding of the current conditions of climate change, the creation of climate maps, heritage climate maps, damage maps and risk maps could be helpful [11].

In order to assess the tangible results of the impacts of climate change on the cultural heritage, research should collect particular indices so as to form a vulnerability approach. Vulnerability is a function of the sensitivity, expressing the degree to which a system will respond to changes in climate, including beneficial and harmful effects. The vulnerability approach explores the key concepts and variables of this function, including hazard, exposure, sensitivity and adaptive capacity [19]. Following the ‘bottom-up’ vulnerability-driven approach usually involves both past and current
climate vulnerability of a heritage case with specific identity, applications and methods and it configures how these might be adapted to climate change conditions. Vulnerability in this context is defined as the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes [20].

For the specific case study of the ancient Greek Theatre of Dionysus, the most important measurements, which can indicate the grade of climate change impacts, are the following:

- Materiality and pathology (physical alteration on the materials and conjunctions due to humidity, corrosion and vegetation)
- Threats of natural environment (structure damage due to soil composition, landslide and aridity)
- Structure course (study of the change of materials, conjunctions and the total monument form along the passage of time)
- Detection of the periods of tourism (influence of visitation attraction due to climate change)
- Knowledge/practice/craftsmanship of conservation policy (intangible characteristics of heritage depend on climate change and on sudden change of weather condition patterns)
- Overall impression and validity of integrity-authenticity and heritage values [21] (interpretation of the influence of the wholeness of the cultural structure, its extent and percentage of truth and alteration, as well as the sequence of heritage values)

Due to the interference of values, integrity and authenticity of the heritage aspects of the case study, it should be mentioned that these terms are used in cultural management and as central concepts to values-based management [22]. The term "value" is mostly used for the positive characteristics attributed to pieces of heritage and places by legislation, governing authorities, and other stakeholders. These characteristics structure the significance of any heritage site and are the reason why stakeholders and authorities are interested in it. The benefits of heritage are inextricably linked to these values [23].

2.3. Adaptive Capacity

The vulnerability approach and the risk analysis of the heritage of the ancient Greek Theatre of Dionysus are followed by the model of mitigation-adaptation. The pursuit of heritage adaptation has been accentuated by Sabbioni et al [11] stating also the need to accept the loss of some of our heritage. An instance of mitigation is the improvement of energy efficiency of cultural sources (built heritage or combined with the nature), while adaptation to climate change risks is the pursuit of strategies for both physical adaptation to the current conditions of a place as well as for adjusting management practices (e.g. the construction of a sea wall to protect coastal heritage sites from storm surges and Sea Level Rise). Examples of the latter include improving the monitoring, maintenance, and preparedness to floods and landslides at cultural heritage sites [24].

In the case study of this research, mitigation may include practices of solar energy exploitation for the needs of the heritage, amelioration of the humidity levels of the micro-climate, according to technical measurements and cautious guidelines for tourist behaviour and environmental sustainability with adaptation techniques of preparedness to natural risks (e.g. soil erosion, landslides) with the necessary infrastructure, as the Theatre is a part of a landscape synthesis in the city fabric.

The aforementioned mitigation-adaptation model forms the adaptive capacity of the heritage, which is based on assessing the hazards of the exposure at the climate change impacts with simultaneous understanding of the sensitivity and resilience of the cultural heritage (monument and landscape).
3. Results and Discussion
Climate change is an ongoing fact with evident impacts on humanity and its creation, as in the specific case study of the ancient Greek Theatre of Dionysus. The risk analysis can lead and be combined with a vulnerability approach of the Theatre, which is a valuable inception tool for the management plan and the necessary adaptation and mitigation of the climate change for an efficient environmental design.

Ancient Greek Theatres as case studies of the impact of climate change on cultural heritage should be combined with the development of indicators of the adaptive capacity of the Theatres to the processing climatic evolution. The interpretation of this feature along with the dangers and the pathology would follow the heritage management aiming to resilience and cultural sustainability. Society, science and stakeholders have to accept and embrace the ‘loss’ which formed the current image, the impression and the values of Theatres’ heritage. All the aforementioned should result, not only in determining a strategy-methodology of documentation-assessment-action planning (for restoration, protection, preservation), but also in monitoring, having as scope the durability and the passage of heritage to the future generations.

At this point, there is an optimistic aspect of creating a model of cultural regeneration through sustainability, which may be accomplished after the documentation and interpretation of the effects of climate change. Via the necessary vulnerability approach and risk assessment, a regenerative contemplation of management of the heritage Dionysus Theatre can have as its main core the pursuit of sustainability.

4. Conclusions
The location, configuration and interpretation of the cultural character of ancient Greek Theatre of Dionysus include the timeline of impacts of climate change, which can be understood via vulnerability assessment and relevant indices, so as to conclude to a management policy for the enlightenment of heritage.

There is lack of disaster preparedness and recovery of cultural heritage. Cultural disaster policy should not only be devoted to reactive management, but also pre-disaster mitigation and planning are
necessary to protect cultural heritage to apply proactive planning [25]. This requires the cooperative composition of legislation, technical sectors and heritage management so as to accomplish social awareness and mostly precautionary work. The vital cooperation of heritage stakeholders may structure adaptation projects and a preparedness system fundamental on risk assessment for the detection of extremities and their potential threat. The cultural degradation of the case of Dionysus Theatre due to climate change merely starts from analysis of statistics, data and in-situ documentation, but it demands disaster management for mitigation of the impacts of climate change, preparedness for the adaptation to the current weather conditions, resilience and devotion to sustainability of the heritage, both specifically of the Theatre as well as spherically, as a part of the wholeness of culture for the transmission to the next generations.

5. Appendices

1.

Köppen–Geiger climate classification map (1980–2016)

![Köppen-Geiger Climate Map](source)

5. Appendices

1.

Köppen-Geiger Climate
Map of Greece

![Köppen-Geiger Climate Map](source)
2.

![Map](image1.png)

1. Acropolis and its slopes
2. Ancient Agora and the museum of the Stoa of Attalos
3. Roman Agora
4. Hadrian's Library
5. Olympia
6. Kerameikos (Archaeological site and museum)
Aristotle's Lyceum

![Photo](image2.png)

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