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Adaptive Conservation Strategies for Butrint's In-Situ Mosaics: Addressing Climate Change Impacts on World Heritage Sites

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Abstract

In a still unspoilt corner of Albania's coast, the WHS of Butrint is a unique combination of nature and art surrounded by a lake connected by a canal to the sea. The abundance of spring waters with healing properties decreed the success of its foundation, while the later difficulties in defending it from flooding increasingly depopulated it until it was abandoned. Today, the site, one of the most significant in the Mediterranean basin for high values of nature and culture in an environmental context of rare integrity, is also among the sites most threatened by climate change. The scenario predicted by the 2021 IPCC report reveals that the future sea levels in the Ionian Sea will affect the ancient city of Butrint, which will be submerged within decades. Sea level rise in coastal regions of the Mediterranean could reach peaks of 2.2 metres by 2100 in the extreme scenario projection. For the coasts of the Ionian Sea in the region of Corfu and Butrint, the worst-case scenario forecasts a rise in sea level of between 1.6 and 1.8 metres by 2100. Some of its monuments are already permanently or periodically waterlogged. The present study constitutes one piece of a broader doctoral research programme and focuses on defining conservation strategies for the valuable mosaics in situ, in adherence to the approach of preserving mosaic floors in situ. The different environmental conditions of the various mosaics are analysed according to their current conditions and predicted level of submersion risk. Beyond a historical and typological framework of execution, the construction characteristics and the types of tesserae used are described. The study connects the chemical-mineralogical characterization of the marbles and materials used with the most significant chemical-physical environmental parameters to assess the vulnerability level according to the environmental variations. The variation of the saline solution content in the water that permanently or periodically floods some mosaics is analysed as a key factor affecting the on-site conservation of the mosaics. The information gathered from the archaeological study and documentation on previous work allows us to assess the characteristics of the constituent materials, given that the mosaics are currently covered by a protective layer that prevents them from being inspected. Furthermore, the archaeologists' information about their value and significance is essential to support a future conservation plan that links the assessment of the risk of loss with the relevance of the artefacts. A method for sustainable adaptations based on an innovative strategy of environmental and water parameter monitoring is outlined in order to intervene promptly to mitigate climate change decay factors.

Keywords

Climate change; Butrint; WHS; Mosaic conservation; Cultural heritage monitoring; Sustainable adaptation

1. Introduction

1.1. Motivations and background

The interest in the subject was born from the strong ethical and professional motivation, considering the scenario predicted by the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2021). It reveals that the future sea levels in the Ionian Sea will affect the ancient city of Butrint, which will be submerged within decades. Some of Butrint's monuments are already permanently or periodically waterlogged. This motivation drives my professional actions and is combined with a strong emotional appeal for a WHS by exceptional beauty, as a unique mix of Archaeological remains & Nature (woods, channel/lake with brackish water). The peculiarity that the immense mosaic heritage of Butrint is still on the site but not visible to visitors because it is covered is considered a penalty of the site that limits the full understanding of its high cultural heritage value. The protective layer is justified for conservation reasons, pending the definition of a better and more effective conservation strategy. Among the many possible options for a more effective conservation of mosaics, the author clearly prefers the option of in situ conservation, in line with the theoretical approach -now generally followed-, and considering the excellent results achieved over decades of activity in support of this practice undertaken by the Getty Conservation Institute at major UNESCO sites in the Mediterranean Basin. The study is a challenging professional opportunity considering the exceptional complexity of the site from the concomitant factors of degradation and treatments. The subject project is the experimental component of a larger Doctoral Research conducted within the University of Alcalà de Henares (UAH) and directed by Professor Mrs. Ángeles Layuno Rosas. The investigation is focused on five WHS in the Mediterranean Basin affected by Climate Change. Finally, the project benefits from a Grant from the European Union implemented under Contract with the Goethe-Institut. The activities were carried out in cooperation with the Butrint Management Foundation (BMF) in the framework of the EU Grant.

1.2. Hypotheses and the state of the art

The present study is based on the assumption that the most advanced technologies in real-time multidimensional data collection and management enable the definition of effective tools for the implementation of preventive and adaptive conservation strategies. Numerous projects developed in recent years have refined the ability to connect multidimensional data. They are generally aimed at creating risk assessment models for cultural heritage and constitute a knowledge base to support conservation and management plans. The study hypothesis is that it is possible to take a further step beyond the two fundamental technological, scientific, and theoretical advances, which are the following:

a) The GIS (Geographic Information System) platform is an interface for integrating, visualizing, and analysing spatial and attribute data. It acts as an interface between environmental monitoring data and cultural heritage vulnerability indicators. GIS allows data collection and interaction to support management strategies. A project exemplification is "Increasing Resilience of Cultural Heritage (ResCult)" aimed to support civil protection to prevent, lessen, and mitigate disaster impacts on cultural heritage using a unique standardised 3D geographical information system (GIS), including both heritage and risk and hazard information. (Colucci et al., 2022). Another reference is the study for "Identifying Coastal Cultural Heritage Assets Exposed to Future Sea Level Rise Scenarios" (Chalkidou et al, 2024). Its methodology connects datasets used, including: Copernicus GLO-30 DSM, the European Ground Motion Service's dataset on Vertical Ground Motion, the Sea Level Change Projections' Regional Dataset by NASA, and a hybrid coastline dataset created with the purpose of assisting in delineating the study area (Chalkidou et al, 2024).

b) Design of risk assessment models based on the identification of exposure and vulnerability of cultural heritage through a qualitative and quantitative estimation of risk factors.

The further step that the study intends to explore is the possibility of dynamically combining knowledge data and vulnerability indices through an alert system that allows immediate corrective measures to be taken to bring values above the threshold back to acceptable levels. An exemplification is the research aimed at risk assessment of coastal fortifications in the Canary Islands. The methodology implemented in this project identifies the exposure and vulnerability of these fortifications, based on a scorecard assigning values of risk to rising sea levels (García Sánchez et al, 2020). This study analyses the multidimensional value of coastal areas consisting of cultural heritage, economic, and social dimensions. The article highlights the importance of integrating these values into risk management and climate change adaptation strategies in order to ensure effective and sustainable protection of coastal cultural heritage. ResCult promotes integrated planning for emergency prevention and management, combining scientific knowledge and GIS technologies. The aim is to protect Europe's cultural heritage by integrating it into risk management systems, facilitating a rapid and effective response in the event of a crisis (García Sánchez et al, 2020).

1.3. Goals

The objective of this research is to develop an innovative strategy for the adaptive and sustainable conservation of in situ mosaics, based on the multidimensional interconnection between the following elements: A) Monitoring data on environmental risk factors and their effects; B) Predictive data; C) Multidimensional values of cultural and landscape heritage (i.e., integrity, heritage value and significance; landscape relevance, ecosystem importance, economic and social value, symbolic values of identity and collective memory); D) Vulnerability levels assigned to both the cultural heritage and the associated ecosystem.

The present paper aims to expose the first sound results and proposals of the ongoing doctoral research. The quality of the desk research, the bibliography consulted, the reports examined, the data collected, and the numerous on-site surveys conducted, complemented by the results of the laboratory analysis carried out, allowed us to define the vulnerability levels of the on-site mosaics.

The final design of experimental equipment that will result at the end of the ongoing research for the mosaics of Butrint will offer an exceptional opportunity to develop a system that can be replicated in other similar contexts where progressive flooding is affecting the archaeological areas.

2. Materials and Methods

This section outlines the methodological framework for mosaic conservation.

2.1. Theoretical framework for an adaptive conservation strategy of in situ mosaics

The following theoretical framework aims to outline the methodological and regulatory foundations that support the ongoing research focused on the adaptive conservation of in situ mosaics at the UNESCO site of Butrint, which is under threat from climate change. The theoretical reflection developed herein follows a multidisciplinary approach that merges the recommendations of international bodies (UNESCO, 2021; ICOMOS, 2013; ICOMOS, 2019), innovative methodologies for assessing cultural and environmental risk, and the principles of sustainability and climate adaptation set forth in international agreements such as the Paris Agreement.

2.1.1. UNESCO Recommendations and ICOMOS Guidelines for Cultural Heritage Conservation

The recommendations and declarations of UNESCO, along with the doctrines and practices promoted by ICOMOS, constitute the core regulatory reference for the conservation of cultural heritage. In particular, the 1972 UNESCO Convention on the Protection of the World Cultural and Natural Heritage establishes the obligation of State Parties to identify, protect, conserve, and transmit to future generations the properties recognized as World Heritage.

ICOMOS, as an advisory body to UNESCO, has produced a series of fundamental documents, including the Venice Charter (1964), which represents a milestone in defining the principles of conservation and restoration. More recently, the "Guidelines for Risk Management for Cultural Heritage" (ICOMOS, 2019) offers a crucial resource for understanding how to integrate risk assessments into decision-making processes for conservation.

These guidelines emphasise the importance of proactive and integrated planning that accounts for the environmental, cultural, and social specificities of the context. They recommend adopting methodologies capable of assessing the exposure and vulnerability of cultural properties to natural and anthropogenic risks, including climate change. They encourage the implementation of permanent monitoring systems to promptly identify critical issues.

2.1.2. The UNESCO Climate Action Working Group and World Heritage Action Goal 3

In 2023, UNESCO established the Climate Action Working Group (CAWG), an initiative aimed at integrating climate action into the management of cultural and natural heritage. This working group focused on formulating concrete strategies to strengthen the resilience of UNESCO sites to climate change, with particular emphasis on developing monitoring systems and timely responses to climate threats (UNESCO, 2023).

World Heritage Action Goal 3, included in the "Policy Document on Climate Action for World Heritage" (UNESCO, 2021), promotes the adoption of mitigation and adaptation measures based on scientific evidence. Among the most relevant articles, Article 3.2 encourages the development of decision-making tools that integrate climate data into conservation plans. This goal specifically suggests the implementation of integrated systems capable of correlating climate data with the cultural and landscape values of the site, to formulate more appropriate adaptation responses. This objective is a cornerstone of this research for the conservation of mosaics in situ.

2.1.3. Value-Led Risk Assessment in the IPCC 2023 Context

The 2023 IPCC Report introduces the concept of "Value-Led Risk Assessment" (VLRA), a methodology that proposes integrating the cultural and social value of a property into risk assessment models. This approach is particularly relevant in contexts such as Butrint, where the cultural significance of the mosaic goes far beyond its material value, encompassing aspects of collective identity, historical landscape, and ecosystem interrelations.

According to the Report, this approach allows for a fairer and more sustainable evaluation of conservation priorities. Using participatory techniques, communities are involved in defining the values of the site and clarifying their relationship with cultural heritage (IPCC, 2023, p. 142). The Value-Led methodology also involves integrating quantitative and qualitative data and applying predictive models based on climate scenarios to estimate the probability and impact of risks.

2.1.4. The Burra Charter and the Centrality of Values in Decision-Making

The Burra Charter, adopted by ICOMOS Australia in 1979 and revised in 2013, is one of the main theoretical references for the values-based approach to heritage conservation. It states that every conservation decision must begin with an understanding of the cultural values of the asset, including not only material aspects but also social, spiritual, and symbolic ones (Australia ICOMOS, 2013).

In the context of Butrint, the approach advocated by the Burra Charter suggests that adaptive conservation strategies should be developed in dialogue with local stakeholders and based on a shared analysis of the site's values. This approach aligns perfectly with the principle of "informed participation" also promoted by UNESCO and ICOMOS, which ensures community involvement in defining intervention priorities, as well as with the VLRA methodology.

2.1.5. The Paris Agreement and Article 7 on Climate Resilience

The 2015 Paris Agreement, a global treaty on climate change, establishes in Article 7 the need to “enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change” (UNFCCC, 2015, art. 7.1). When applied to cultural heritage, this principle translates into the need to develop adaptation strategies that are both environmentally sustainable and capable of safeguarding the identity and cultural values of heritage properties.

Adaptation, in this sense, must be regarded not as an extraordinary action but as a systemic component of heritage management. Conservation plans must, therefore, include measures for climate risk mitigation and resilience enhancement, adopting an integrated and flexible approach capable of responding to ongoing environmental transformations.

2.2. Towards an Integrated and Multidimensional Adaptive Conservation Methodology

In light of the references outlined above, the adaptive conservation methodology proposed in this study is based on an integration of:

- continuous monitoring of environmental parameters (humidity, salinity, groundwater variation);

- predictive models based on IPCC data and local climate scenarios.
- analysis of the cultural and social value of the asset, including the landscape and ecological context, through participatory tools.
- assignment of vulnerability levels based on quantitative and qualitative data.

This methodology is primarily based on the study of the historical context, the analysis of the mosaics' construction and material characteristics, their value and significance, and their authenticity. The perceived value component was studied in stakeholder engagement reports and through additional interviews conducted by the author with economic operators working within the Butrint National Park. In the second step, data collected and the specific analyses carried out have made it possible to define a baseline of knowledge of the factors contributing to the deterioration of the mosaic areas and their correlation with the conditions of deterioration. In the third phase, a simplified model for assessing the level of multidimensional vulnerability is proposed, which takes into account not only physical and environmental data but also the historical, symbolic, and landscape significance of the mosaics. The construction of this grid is inspired by the principles of "Value-Led Risk Assessment" and the Burra Charter and will be further refined in the subsequent phases of this research, involving experts, administrators, and local communities in defining the criteria of value and vulnerability.

The outcome of these first three phases of the research is the main contribution of this paper. The research will be further developed by applying the theoretical-practical reference framework. In fact, an adaptive monitoring and conservation strategy will be developed based on the use of advanced technologies for data collection and management, such as environmental sensors, drones for photogrammetric surveys, and GIS interfaces capable of integrating multidimensional data in real time. These tools enable the creation of an early warning system to detect significant changes in environmental parameters and activate immediate corrective measures.

In conclusion, the theoretical framework described provides a solid foundation for developing effective adaptive conservation tools. It integrates the recommendations of major international organizations, the latest developments in risk assessment, and the fundamental principles of environmental sustainability and community participation. Applied to the site of Butrint, this approach enables the transformation of climate change threats into opportunities to innovate conservation processes.

2.3. First step of the research: historical-morphological-environmental characters of the site.

"Inhabited since prehistoric times, Butrint has been the site of a Greek colony, a Roman city, and a bishopric. Following a period of prosperity under Byzantine administration, then a brief occupation by the Venetians, the city was abandoned in the late Middle Ages after marshes formed in the area" (UNESCO, 1992). The statement is from the declaration of universal interest of the Butrint site for its inscription in the UNESCO World Heritage List since 1992; it clarifies the main historical phases that characterized the site. The remains of *Buthrotos* occupy the area of a low promontory of approximately 16 hectares as part of the more extensive archaeological world heritage site, over 200 hectares. Located on the western shore of the coastal Salt Lake of Vivari, the promontory of Butrint is separated from the Vrina floodplain by the Vivari Canal, which connects the lake with the Ionian Sea. All these areas are part of the Butrint National Park, inscribed on the National Heritage List of Protected Monuments in 1948. The first traces of occupation date back to the 10th-8th centuries BC, and offer evidence ranging from the Illyrian period (4th century B.C., represented by walls and gates), the Hellenistic period (3rd century B.C. with the theatre and the sanctuary of Aesculapius) and the Roman period (with the numerous baths, the Forum, Apollo's sacellum, the Nymphaeum). The famous Baptistery was built in the Late Antiquity (4th-5th century A.D.), as well as the grandiose Early Byzantine Basilica (6th century A.D.). The Castle on the Acropolis dates back to the Venetian period (14th-16th century) and is home to the museum, and houses the artefacts found at the archaeological site, most of them unearthed by the Italian archaeologist Luigi Maria Ugolini. In fact, the 'rediscovery' of Butrint is due to the commendable work of Luigi Maria Ugolini, who, similar to Schliemann's search for Troy in the Homeric poems, set out in 1927 to find the city of *Buthrotum* decanted by Virgil in his Aeneid. Ugolini directed the Italian archaeological mission from 1927 to 1940

(Ugolini, 1937); the archaeological excavations concerned the highest part of the city, including the acropolis. In fact, even back then, the slopes of the promontory were flooded with water, making exploration difficult, if not impossible.

2.3.1. Main topographical variations and environmental modifications

The site has been characterized by continuous topographical variations with relevant expansion or retraction of its use. The morphology of the territory is a consequence of the deposition of alluvial sediments carried to the large estuary. The site became a relevant site because of its position along the coast, favourable for access to a hinterland rich in natural resources, the connections with the cities located further north, and considering the control of routes and commerce towards Greece and the Adriatic and Ionian seas. For all these reasons, the area of the city was first occupied during the late Bronze Age and continuously used until the fall of the Ottoman Empire. The alternate phases of use and reuse have given rise to a highly stratified settlement.

The first traces of occupation date back to the 10th-8th century BC, while the walls and gates date back to the Illyrian period (4th century BC). Among the reasons for choosing the site for the first settlements was the presence of hot springs believed to be beneficial. The Temple of Asclepius, dating back to the Hellenistic period, was built near a thermal spring at the end of the 4th century and expanded after the Roman conquest in the early 3rd century BC (Hodges, 2010). After Augustus's victory at Actium, the city of Butrint prospered as a Roman colony, taking advantage of its location near the Via Egnatia. At that time, Butrint played a fundamental role in the epic founding of Rome, celebrated in Virgil's epic poem, the Aeneid. In the Aeneid (III, 291-293), Virgil attributes the founding of ancient Buthrotum to fleeing Trojans; this information is confirmed by the Greek historian Dionysius of Halicarnassus, his contemporary, in Roman Antiquities (I, 42). During the Roman phase, the urban fabric expanded over the area of alluvial deposits with richly decorated buildings. A monumental aqueduct reached Butrint via a bridge and supplied the city and its numerous baths. After the Roman phase, Butrint became an episcopal centre until the 7th century. During the early Byzantine period, several Christian monuments were erected. Partially renewed in the Medieval era, much later, Butrint was controlled by the Venetians and Ottomans (Raynaud, Islami, 2018).

The catastrophic earthquake dating back to the 3rd-4th century AD caused profound damage to architectural structures, with subsidence due to tectonic movement and consequent flooding and rising water level (Pavlides et al, 2001). Some structural damage caused by this event is still visible in the Hellenistic-Roman Theatre, where the deformed composition of the stone structures and the pattern of diagonal cracks on the western side of the auditorium can be seen. The cracks crossing the foundation of the Triconch Palace Portico, documented in the past archaeological excavations, and the impressive subsidence shown in Figure 1 are further evidence of this event. The diagrams published in The Past (Hodges and Prince, 2022) show the ground level before and after the catastrophe, when part of the forum dropped by almost a meter, with subsequent serious flooding. Inundation by water in the lower city from AD 400 became a regular nuisance. Afterwards, sediment deposition saw ground level rise again. Another seismic event affecting Byzantine monuments is also probable (1153).

However, the disastrous seismic events did not discourage the inhabitants, who repaired their houses and returned to occupy them, making the struggle against periodic flooding a leitmotif of life in Butrint. Currently, the Roman Theatre orchestra is permanently waterlogged by a water depth of 0.5 m. The Triconch Palace, built at the beginning of the 5th century and then abandoned, presumably due to flooding, is also mostly completely submerged, as shown in Figure 2. The archaeological study and on-field research "demonstrated beyond doubt that the environmental circumstances at Butrint have never been static, and in different ways over nearly three millennia the people here have adapted accordingly" (Hodges, 2010).

Figure 1: House of the Venetian *Merchant* (*Source: by author, 2024*)

Figure 2: The Triconch Palace's Portico (*Source: by author, 2024*)

The latest study on continuous subsidence of part of the ancient city, and the documentation of the presence of evaporate diapirs, confirms that the seismic activity in Butrint is still active, and this condition is an aggravation of the condition of rising waters due to climate change.

2.3.2. Historical and typological features of the mosaics

A document of fundamental importance for the present study is the publication by Marie-Patricia Raynaud and Agron Islami (Raynaud & Islami, 2018), who are the authors of a vast research project on the entire body of mosaics in Albania. The first outcome is Volume 1, dedicated to the Butrint *intramuros* mosaics. In volume 25, mosaics are analyzed according to the following areas of investigation:

- Technical description including mosaic's architectural setting, the execution techniques, the type and composition of the mosaic supports, the density and dimension of tesserae, the materials and colours employed; physical properties of the glass mosaic tesserae by laboratory analysis are included.
- Identification of the chronological phases of the mosaics based on the overall identification of the construction phases of the relevant building and room.
- Study of the design and composition of decorative motifs; interpretation of iconographic value with arguments based on parallels derived from comparative studies on other regional and local mosaics. Marie-Patricia Raynaud has identified several artisan workshops that worked on the production of the Butrint mosaics, presumably also involved in the creation of other mosaics for other cities in the surrounding region.
- Description of the state of conservation at that time (2015) and information on the conservation methods applied to the mosaic. References to previous assessment reports are included.

2.3.3. Main chronological periods of Butrint's mosaics

The construction of mosaics in Butrint covers three main chronological periods: the Hellenistic Period (Figure 3), the Roman Period, including first and second phases (Figure 4), and the Protobyzantine Period (Figure 5).

The surviving part of the Hellenistic mosaic is on display in the museum. Dating back to the end of the 3rd or beginning of the 2nd century BC, is a fragmentary mosaic panel that decorated the interior space of the Asklepios temple and depicts a coiled snake, an animal considered sacred to Asklepios's cult. The mosaic shows a mixed technique of *opus signinum* dotted with white cubes for the background and *opus tessellatum* for the serpent, with thin lead strips to outline its contours. Red, blue, and yellow tesserae model the snake by neatly laid rows, with shades of pink, white, and yellowish-green tesserae appearing on its underside. The execution is refined, and the panel, once removed from its original setting, is now exhibited in the Butrint Museum. The original Hellenistic mosaic has been subsequently overlapped by another mosaic during the Roman period.

Figure 3 – Snake mosaic detail, Hellenistic period, from Asclepius Temple (Source: by author)

Figure 4: Floor mosaic detail, Roman period, from Butrint Museum *(Source: by author)*

Figure 5: Floor mosaic detail, Protobyzantine period, Great Basilica *(Source: by author)*

Most of the mosaics in situ belong to the Roman period and date from the early 3rd to early 5th centuries. An exemplification is the numerous mosaics in the Triconch Palace Complex. It was built in several stages over several centuries and, in its final phase, extended over two insulae. The mosaics in the building date back to various periods and display great originality of geometric design. Some include figural elements, such as the Mosaic of the Masks, finely crafted in *opus vermiculatum*. The decorative motifs of the Roman mosaics mainly use black, white, grey, and pink tesserae.

The most important mosaic from the Protobyzantine period in Butrint is the complex of the Baptistery. The well-preserved and iconic mosaic that adorns the Baptistery was completed at the end of the 6th century. The remarkable size of the Baptistery, which exceeds that of many other Eastern baptisteries, as well as the fact that this religious architecture is the last early Christian example in the western Mediterranean region, make this archaeological monument and its almost completely preserved mosaic *unique* in terms of value and significance. The Baptistery's mosaic pavement displays at least seven circular friezes, with intertwined pink circles filled with a multitude of animals symbolizing God's creation in the air, land, and sea, and includes floral motifs. Similar to the other Protobyzantine mosaics in the city, the tesserae materials include assorted hues of glass in addition to stone, marble, and terracotta tesserae.

2.4. Second step of the research: data collected on Butrint's on-site mosaics

2.4.1. Mosaics materials components

The study by Marie-Patricia Raynaud and Agron Islami (Raynaud and Islami, 2018) has made it possible to define the basic knowledge framework for the in-situ conservation project for the mosaics. For each mosaic, information is available on the materials components of the substrate, generally deduced from visual observation of the layers that emerged from the gaps and cracks before restoration work began. It should be noted that there is a lack of data on petrographic characterization of both the bedding mortars and individual mosaic tesserae. The only laboratory analyses carried out concern a few vitreous tesserae, the results of which, relating to the chemical components identified, have been published.

Observation of the composition of the substrate confirms that it was constructed in accordance with Vitruvius' treatise (De Architectura), namely with three layers: *Nucleus, Rudus, Statumen*. Mortars rich in dust or brick fragments are often present, a detail that informs us of the presence of mortars with more or less hydraulic characteristics depending on the size or smallness of the brick fragments.

Regarding the characteristics of the mosaic's tesserae, unfortunately, nothing else is known except that they are made of local limestone in various colours ranging from white to grey and black or from light pink to dark pink. Red tesserae are usually made from squared fragments of brick. Based on a study of the geological map of Albania and the area around Butrint, the soils outcropping in this area generally date from the Lower Jurassic to the Burdigalian (Lower Miocene) periods, so it can be said that they are indeed limestones. Their characteristics are believed to be similar to those of the coeval limestones found in the Adriatic region on Italian territory; based on these assumed similarities, the low porosity of this type of limestone is a positive factor for its in-situ conservation.

Table 1: Exemplification of the collected data on mosaic materials components and value, and significance (Source: by author)

Ref. Name	Period	Typology	Materials	Support Composition	Value and Significance
Triconch Palace Complex	Roman period 2nd/3rd century as Ph 2 in the South	a) Gallery- *Opus Tassellatum in situ* b) Room of Masks *Opus Tassellatum, Opus vermiculatum (for the mask) in situ* c) Apsided room *Opus Tassellatum, in situ,* and *Opus vermiculatum*	a) Stone: black, white, red, pink, yellow ochre, and beige. Marble: grey-blue and light-blue. Few glass tesserae: opaque sky-bleu, and translucent in several tones of blue and green. b) black, white, grey-blue (marble), light grey, light blue (marble), ochre yellow, beige, pink, red.: few glass tesserae c) presence of a cube in glass or translucent	a) Support - three habitual layers: *nucleus (*with a grey surface but with a thin, fragile structure and very fine broken tile powder - slightly pink, and fine gravel 1-3 cm maximum); *rudus* (usual, relatively flat and smooth, and in some place hard as stone: this means the mortar has been well dried before overlapping the nucleus laid)*,* and *statumen.* Pinkish support is particularly rich in broken tile. b) Room of Masks: nucleus very white, bedding layer fragile.	b) Room of Masks: exceptional quality; theatre masks of great refinement of colours and nuances c) Apsided room: Significant decorative arrangement of nesting a small central panel in myriad borders of diverse widths gives the expression of the work.

The above table 1 shows a synthesis of the main information on the most important mosaics in the Triconch Palace Complex, including information on value: data supports a general strategy for mosaics conservation.

2.4.2. State of conservation of the on-site mosaics

The accurate descriptions provided by Raynaud and Islami inform us about the extent of the mosaics based on the investigations carried out, the state of conservation observed at the time of their protective layer removal for the purpose of the study, and the safety measures performed. In addition, the publication provides information on the level of exposure of the mosaics to flooding, defined as periodic/seasonal or permanent. Based on the information provided, the state of conservation of the mosaics has been defined as limited to the following parameters:

- Level of integrity based on the percentage of remaining mosaic.
- Level of exposure to flooding.

Table 2 shows a synthesis of other key information collected on a selection of the most important mosaics, including data on altitude.

Table 2: Exemplification of the collected data on the state of conservation of the on-site mosaics (Source: by author)

Reference Name	Altitude	Flooding	Percentage of on-site mosaic
Triconch Palace Complex	2,58 m	Permanently underwater Since Antiquity, it has been seasonally inundated	a) Gallery: 35% b) Room of Masks: 40% c) Reception room: 65%
Gymnasium	8,28 m	Pools are permanently underwater Other areas are seasonally underwater	40%
Baptistery complex	4,60 m	Seasonally underwater, the perimeter sections	100% perception *95% as a result of restoration*

Overall, although the information gathered indicates that the mosaics have a good level of integrity, it is equally clear that their conservation is seriously at risk because of fluctuations/variations in the sea level. The continuous water level variation is affecting the conservation of the archaeological structures and the on-site mosaics. In fact, rising damp on the supporting structures, with consequent evaporation and efflorescence salt formation, has a destructive effect on the archaeological remains. This phenomenon is emphasized in the areas affected by seawater and brackish water flooding.

It should be noted that the mosaics are currently neither inspectable nor visible as they are covered by a protective layer composed of Bidim® (non-woven fabric), sand, and gravel. Given that it is impossible to inspect mosaics, their state of conservation has been assessed based on the following data collected from various sources, as indicated below:

- From the consulted bibliography: construction technique, construction period, materials used, main events affecting the sites, state of conservation reported, implemented interventions, flooding risk, integrity, value, and significance (Raynaud and Islami, 2018);
- Previous reports informing, for instance, about a soft /mud substrate of the mosaics, and about the seasonal flooding of some mosaics according to the rainfall phenomena (Prince, 2020);
- Analysis of the data on 10-year channel water level monitoring (2012 - 2022) documenting a water rising level trend of 1 cm each year (monitoring data kindly provided by Archaeologist Mrs. Erjona Qilla);
- Analysis of the data of water level on relevant mosaic sites for a limited monitored period (Massari, unpublished);
- Ion Chromatography Analysis data of 5 collected water samples documenting the high level of chloride salts (Laboratory Report by Chemist Mr. Pietro Rosanò);
- On-site visits with final assessment on the topographical and environmental context of the mosaic location.
- Predicted data for the next decades according to the IPCC report (IPCC, 2021);
- On-site interviews with stakeholders, local experts, and knowledgeable individuals.

2.4.3. Data on 10-year Channel water level monitoring (from 2012 to 2022)

The monitoring data analysed are related to the period from September 2012 to November 2022. Measurements of the water level of the Vivari Channel were taken twice a day, at 8:30 am and 15:30 pm, corresponding to the low tide and high tide periods, respectively (see figure 6).

The following observations can be drawn from the analysis of the 10 years of monitoring of the canal water level measured near the site entrance:

- Water level trend shows an increase of 10 cm from 2012 to 2022;
- Rising water level of the channel until 74 cm (December 2022);
- Extreme fluctuation, reducing the water level to 0 cm, also in December;
- A very low level of water in March, April, and May.

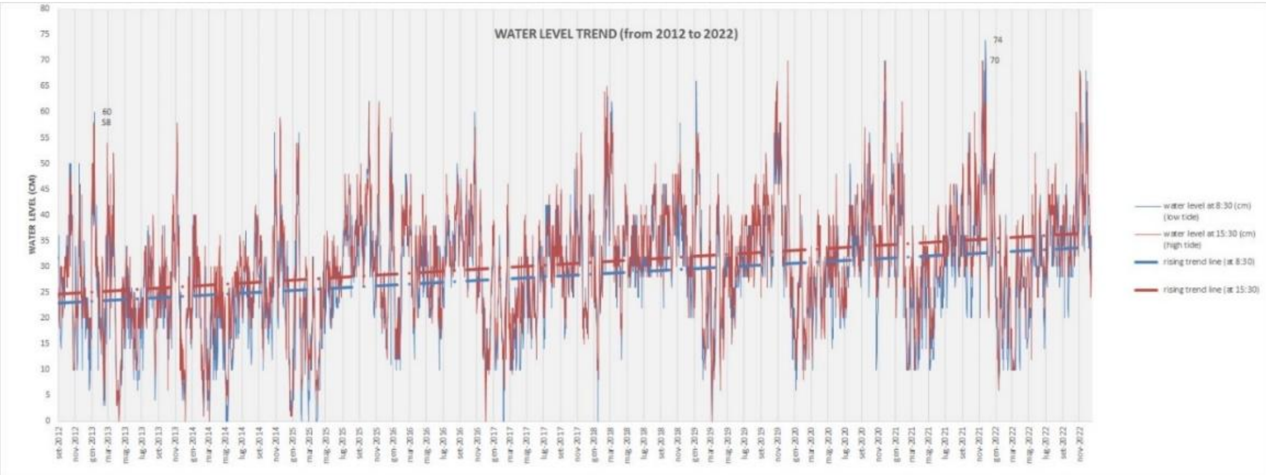

Figure 6: Water level fluctuation diagram and growth trend over 10 years *(Source: by author)*

2.4.4. High chloride content in the flooding water

During the long on-site mission in Butrint held in August 2024 for survey and investigation, 5 samples of the water flooding the mosaics were collected. Table 3 shows the laboratory analysis results.

Table 3: Ion Chromatography Analysis data of five collected water samples (Source: P. Rosanò analysis report commissioned by the author)

N.	Localization	Chlorides, Cl, (g/l)	Nitrites, NO2, (g/l)	Nitrates, NO3, (g/l)	Sulphates, SO2−4 (g/l)	, Classification
S1	Heron/Shrine	12,00	absent	0,70	1,10	brackish water
S2	Nymphaeum’s pool	10,5	absent	0,60	1,20	brackish water
S3	Triconch Portico	18,70	absent	0,70	1,80	seawater
S4	Baptistery	8,30	absent	0,40	traces	brackish water
S5	Columbarium	7,90	absent	0,40	0,20	brackish water

The results of ion chromatography analysis reveal that the water flooding the Triconch Complex’s mosaic is actually seawater, while all other sites have chloride salt content that makes them brackish water. It is surprising that this result also applies to sampling site S1, which is the highest point on the slope (see figure 7).

The high chloride content in the water flooding the mosaics, combined with fluctuations in the water level, is a key factor affecting the conservation of the mosaics. The diagrams below (Figure 8) show the fluctuations in the water level at six relevant sites in the Butrint area, based on monitoring data collected over a period of approximately three months.

Figure 7: Mosaics localization corresponding to the five water samples collected (*Source: by author*)

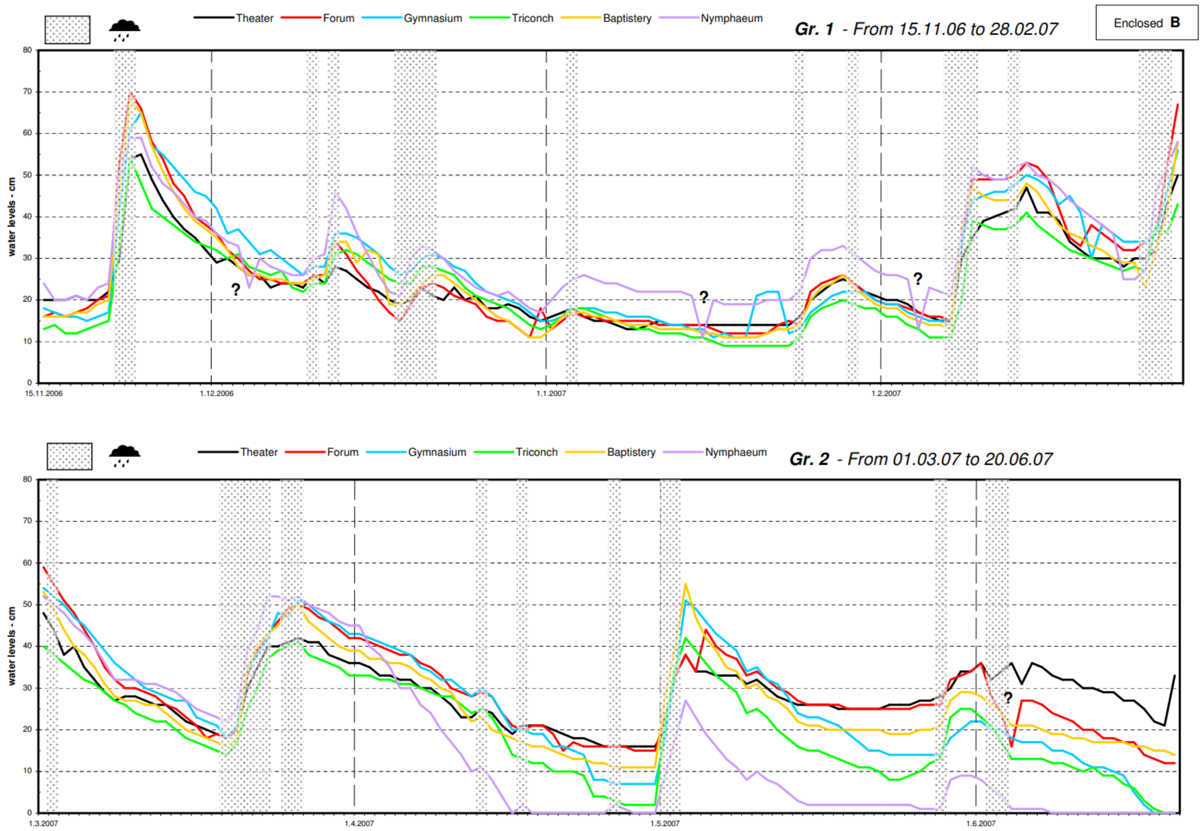

Figure 8: Water level fluctuation diagrams on 6 relevant sites of Butrint (Massari, 2007)

The monitoring period at the six sites was very limited in time, covering only seven months, corresponding to the rainiest months. Nevertheless, the data collected clearly show a direct correlation between rainfall events and the rise in water level, which peaks after the end of the weather event. The same observation was made by the author during the repeated on-site visits after the reining events. Furthermore, it is interesting to note that the highest sites near the mountain slope maintain a water level of about 10 cm, while the Nymphaeum area tends to dry out again, and finally, the Gymnasium and Triconch sites tend to dry out with the arrival of summer. Considering the data collected and the impossibility of carrying out a visual assessment of the conditions on site due to the protective layer, two questions arise: 1) Does the protective layer really perform a protective function, or is it rather a factor amplifying the degradation? 2) How far has the degradation progressed since the last inspection?

3. Results

3.1. Step four of the research: vulnerability assessment of the mosaics

The following results derive from field surveys and analyses.

Based on the data collected and analysed, on-site observations before and after rainwater, and the results of the laboratory analysis on five water samples, four vulnerability levels have been defined for the mosaics (see Figure 9). The key factors taken into consideration were the chemical composition of the water in the flooded areas and the water level fluctuations/variations:

- Low Level of Vulnerability (LLV) - Exposure to atmospheric agents;
- Low/Medium Level of Vulnerability (L/MLV) – Flooding due to rainwater run-off from hill;
- Medium/High Level of Vulnerability (M/HLV) – Flooding due to rainwater and rising groundwater;
- High Level of Vulnerability (HLV) - Flooding due to rising groundwater and channel water levels

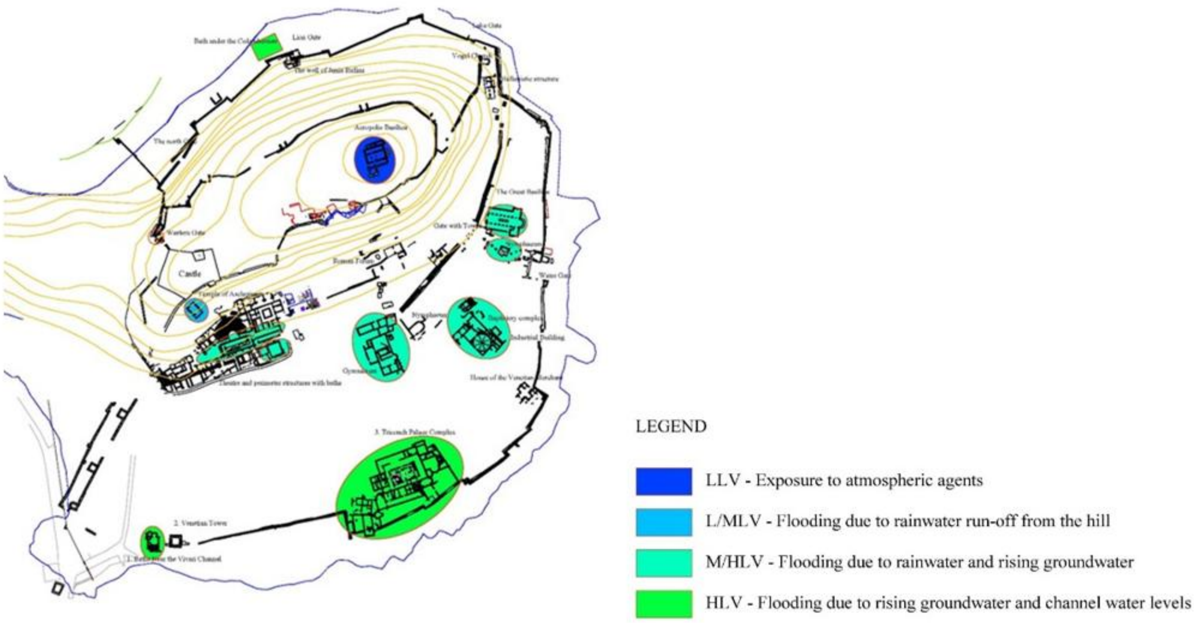

Figure 9: Vulnerability assessment of the mosaic's sites (*Source: by author*)

3.2. Step five of the research: a preliminary conservation strategy of the mosaics

The conservation strategy is based on the data collected, the predictions of future scenarios, the surveys carried out, and the assessment of vulnerability levels. The strategy is divided into six areas linked to topographical elevation, taking into account the importance of the water channel level: 1) The Acropolis site with the Basilica; 2) The area between the Acropolis and the middle slope; 3) The site of the Temple of Asclepius; 4) The area between the middle slope and the lower slope of the hill; 5) The flat area far from the channel, 6) The flat area closest to the channel.

The conservation strategy involves the adoption of diversified measures mainly related to drainage works as follows:

- measures to control rainwater runoff to limit the accumulation of water into the archaeological excavations located on the slopes of the mountain: the interventions consist of the construction of rainwater collection and drainage channels at intermediate levels of the mountain slope.
- measures to drain water flooding sites downstream by removing or partially opening recent infrastructure works that promote water stagnation in sites such as the Gymnasium.

- measures to create protective edges at specific points along the perimeter of the canal's coastline to limit the entry of water into the Triconch Palace Complex.
- measures to remove sedimentary debris from the Vivari canal, which currently has a depth of only 6 metres; this would both lower its water level and facilitate the exchange of brackish water from the lake affected by the warming phenomenon that is altering the ecological system.

As regards the conservation of the mosaics affected by flooding in the strict sense, two different approaches have been identified, which are still being studied through the analysis of specific cases and consultation with experts in the field.

The first approach, which we can call "countering the effects of climate change", consists of defining strategies aimed at keeping the groundwater level sufficiently below the level of the mosaics, thus preventing flooding. To achieve these conditions, it is necessary to drill deep boreholes and install powerful pumping systems.

A second approach, which we can call "adaptation to the effects of climate change", consists of keeping water in places where the fight to control it (in line with the model of the first approach) could be lost or require costly, overly invasive measures that are not sustainable given the country's level of technological and professional expertise. In this case, the focus would be on maintaining acceptable water parameters by controlling the content of salt and other harmful components. In this context, the design of a system for monitoring key parameters, such as the measurement of electrical conductivity, which is an indicator of the salinity, is the main issue. The monitoring system should then be linked to alert thresholds capable of activating corrective measures of the monitored parameters, such as desalination systems. Figure 10 below summarises the set of measures consistent with the "adaptation to the effects of climate change" approach.

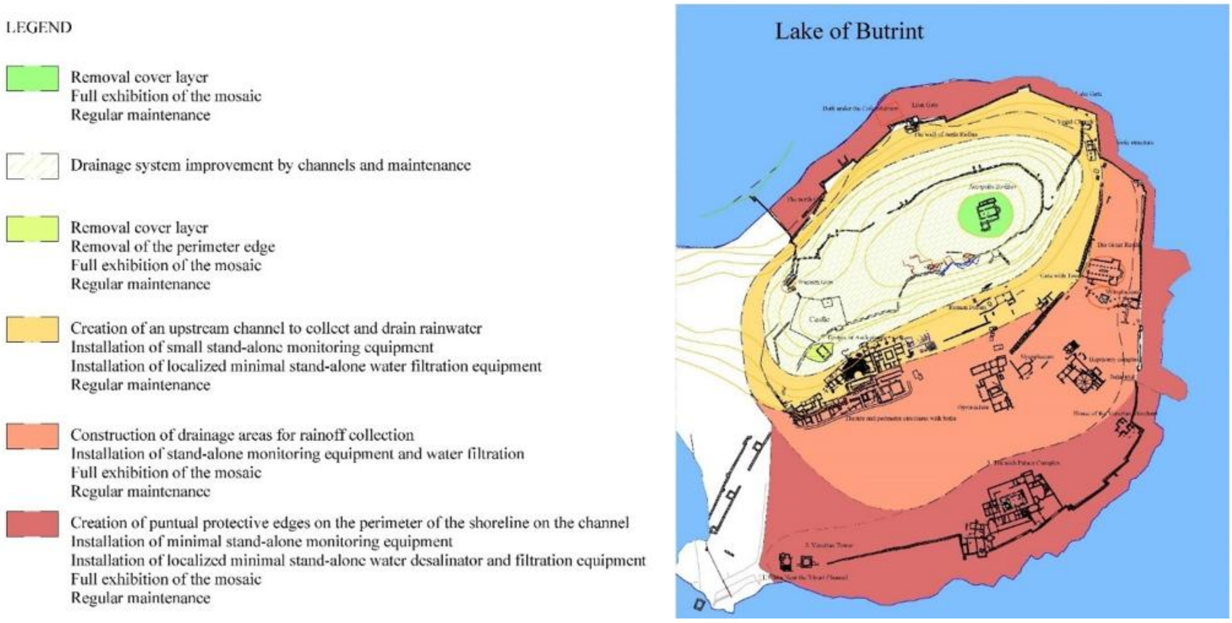

Figure 10 – Strategy for on-site mosaics conservation by climate change effects adaptation (Source: by author)

4. Discussion

In this section, findings are interpreted in relation to current conservation theories.

4.1. Theoretical-practical debate on the possible approaches for conservation of the on-site mosaics.

The search for a sustainable, innovative, and adaptive strategy for the conservation of mosaics in situ is motivated by three strands of theoretical and practical reflection. The first stems from the awareness that decades of "detachment" and musealization of mosaics have certainly contributed to their conservation but have distorted the places where they were located, drastically reducing the understanding of the context in which the mosaics were inserted and, consequently, compromising the appreciation of the mosaics themselves. Numerous theoretical elaborations (Brandi, 1957) and theoretical-practical studies (Nardi, 2002) document the parable of the approach to detachment of decorative elements and mosaics in particular (Nardi, 2002). Also significant is the statement by Giorgio Torraca, who in 1973 said: "The parable of the detached fresco may perhaps one day symbolically represent the conservation policy of cultural heritage based on restoration as a use of the heritage itself. No matter how noble the aims of this use may be, it is likely that the damage it produces will outweigh the combined effects that environmental factors and crises of civilization have caused in the past" (Metelli, 2007).

A second motivation is supported by the excellent results of the Getty Conservation Institute's extensive “Mosaikon Project”: a multi-project initiative ranging from resources, training, and funding to improve the care and conservation of ancient mosaics in the Mediterranean region. The Mosaikon Project has invested significant resources in training on aspects of the conservation and management of archaeological sites containing mosaics in situ, including documentation and recording, site management planning, material deterioration, basic conservation interventions, and site presentation and interpretation (Alberti et al., 2013).

The third reason is based on the belief that in this era of irreversible climate change, managing the effects in terms of adaptation, rather than eliminating the problem, is an excellent communication strategy for educating people to understand the real extent of the phenomenon.

Supported by the theoretical framework described above, we act in the belief that the conservation of the mosaics in situ constitutes an intrinsic value for the site, as a vehicle for widely transmitting the cultural values of the whole site and their perception. Furthermore, mosaics in situ, including those submerged under water, add value to the visitor experience, allowing them to fully appreciate the significance of the site and develop critical awareness; indeed, submerged mosaics have a powerful evocative power of the inexorable future that awaits us.

5. Conclusions

The level of knowledge acquired about the problems afflicting the mosaics of Butrint paints an alarming picture for their conservation. The measures implemented over time, justified by conservation aims, seem to be more of a problem than a solution. This is the case with the protective concrete border surrounding the remains of the mosaic in the Temple of Asclepius, the raising of the walkway along the Gymnasium, and the access from the canal built near the Triconch Palace to allow the unloading of restoration materials. Above all, however, the covering layer of the mosaics appears questionable, as without regular maintenance and inspection, it is likely to deteriorate beyond repair.

The investigations and analyses carried out require further in-depth studies, for example, to investigate the biological components present in the water submerging the mosaics, as well as comparative studies in the past conditions and future time to understand the progression of visible degradation.

The proposal for a Conservation Strategy of the mosaics in situ considers the exposure of the mosaics to be the main challenge for the site, given the complexity of the issues involved. The reasons for in situ conservation, supported by theoretical and practical experiences, are as follows:

- the wider transmission and dissemination of cultural values of the entire site and their perception;
- the superb educational content that the submerged mosaics, which are highly evocative of the inexorable future that awaits us.

In conclusion, the significance of the project’s research is based on the following perspectives:

- The study of the solutions adopted for the two different approaches to the system (the first approach, which we can call " countering the effects of climate change", and the second approach, which we can call "adaptation to the effects of climate change") will help to assess the theoretical and scientific feasibility and the technological and practical sustainability of the respective characteristics. The relevance of this final assessment is to provide a solid scientific and practical basis for guiding the choice of the conservation approach in sites with similar characteristics.

- The research defines an integrated approach to mitigate current and future challenges for sustainable development, taking into account the conservation of cultural and natural heritage in relation to the well-being of the local community.
- The experimental part of the research aims to define the integration of the most advanced technologies for data collection and management. The combined use of remote monitoring tools and technologies will enable the creation of an early warning system to detect significant changes in environmental parameters and activate immediate corrective measures.

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Ethics Approval

Not applicable.

Conflict of Interest

The authors declare there is no conflict.

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