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Vulnerability of Coastal Heritage in the Context of Climate Adaptation : A Review

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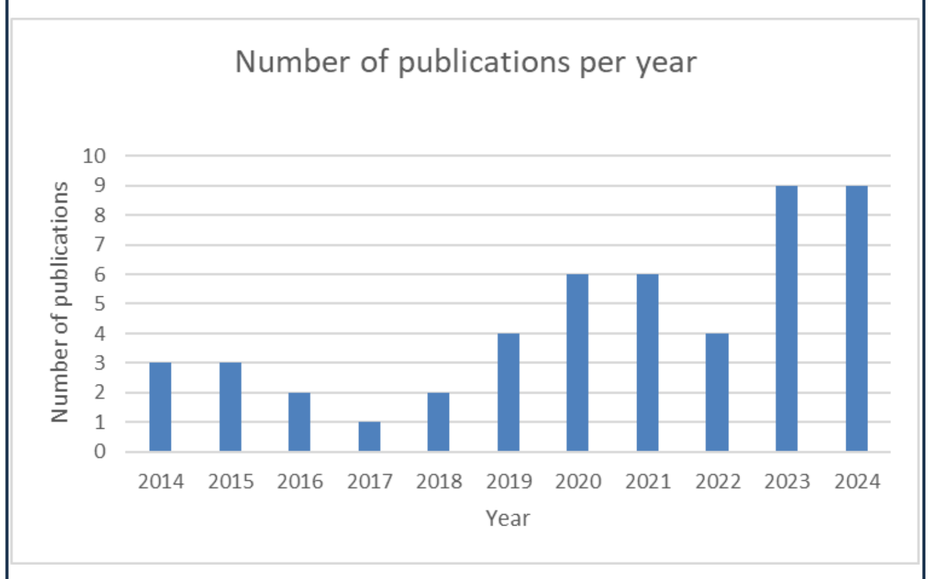
INTRODUCTION & AIM

- Coastal heritage sites are increasingly vulnerable to the impacts of climate change, particularly from sea-level rise and coastal erosion. These effects threaten both the preservation of cultural monuments and local economies dependent on tourism (Reimann et al., 2018)
- In the Mediterranean coastal area, approximately 49 cultural UNESCO world heritage sites, including well-known tourist destinations such as Alexandria in Egypt, Carthage in Tunisia, Venice in Italy, Tarraco in Spain, and the Greek island of Delos, are located on vulnerable coastal areas being at risk from flooding and erosion (Reimann et al., 2018)
- To address these threats, Integrated Coastal Zone Management (ICZM) strategies and technological solutions like GIS and remote sensing and predictive modeling are critical in monitoring and mitigating these threats (Kefi et al., 2024)
- This review aims to present a comprehensive framework of ICZM and how sustainable tourism practices can play a crucial role in mitigating these threats, supporting long-term conservation under climate change

METHODOLOGY

The PRISMA 2020 methodology was used to conduct a systematic review, selecting 50 studies from databases such as Scopus, Web of Science, and Google Scholar.

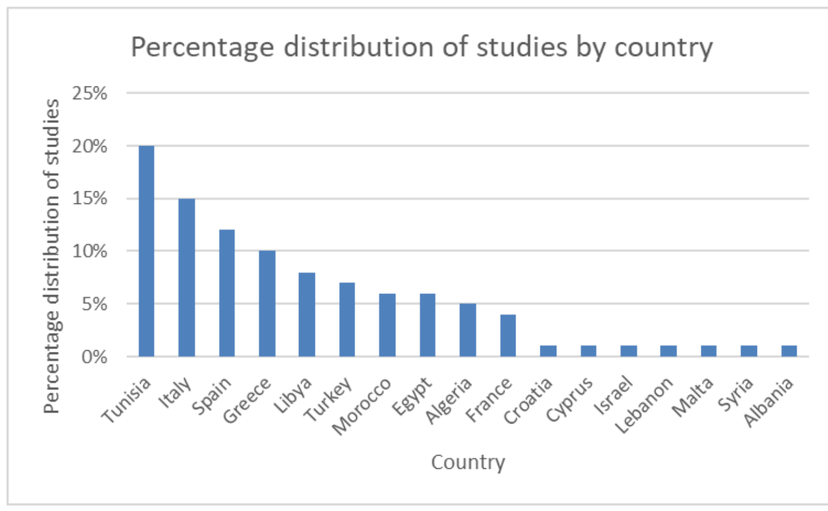


According to the diagram, the number of publications per year has been on the rise since 2019, with a noticeable peak in 2023–2024. This suggests a growing academic interest in the vulnerability of coastal archaeological sites to climate change. The increase in publications may also reflect a response to technological advancements such as GIS and remote sensing, which have become essential tools in monitoring and mitigating the effects of coastal erosion and sea-level rise.

SUMMARY & DISCUSSION

This diagram shows the breakdown of where the reviewed studies focus geographically

- Tunisia represents the highest percentage (20%) of the studies, primarily focusing on sites like Carthage and Kelibia
- Italy (15%) follows, with significant attention on Venice and coastal archaeological sites like Pyrgi
- Spain and Greece represent smaller percentages, but their vulnerability to sea-level rise is well-documented
- Other Mediterranean countries, such as Libya, Turkey Morocco, and Egypt account for more than 5%



Technological Tools and Strategies

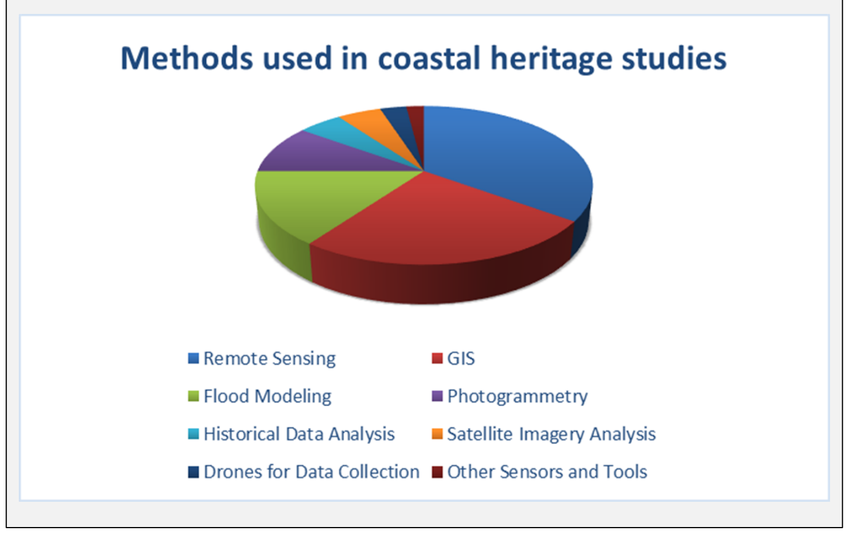
Coastal heritage sites are increasingly monitored and protected using a combination of **software** and **hardware** solutions.

•**Software Measures:**

- **Remote Sensing (35%)**: Utilizing satellite data and aerial imagery for shoreline detection and erosion monitoring.
- **GIS (25%)**: Mapping coastal vulnerabilities, creating risk models, and supporting decision-making processes.
- **Flood Modeling (15%)**: Predicting sea-level rise impacts and flooding scenarios to design preventive measures.
- **Photogrammetry (10%)**: Generating 3D models of vulnerable structures to assess deterioration and structural integrity.
- **Historical Data Analysis (5%)**: Leveraging past records to understand long-term erosion patterns and changes in sea levels.
- **Satellite Imagery Analysis (5%)**: Monitoring coastline shifts over time to assess risk levels.

•**Hardware Measures:**

- **Drones for Data Collection (3%)**: High-resolution imagery for real-time monitoring and surveying.
- **Other Sensors and Tools (2%)**: Use of tide gauges, environmental sensors, and ground-penetrating radar to assess site stability and environmental changes.



Key Risks to Coastal Archaeological Sites:

1.Sea-Level Rise: Increasing water levels threaten to submerge and erode coastal heritage sites, causing irreversible damage.

2.Coastal Erosion: Natural erosion, worsened by storms and rising seas, gradually destroys important archaeological structures.

3.Extreme Weather: Frequent and intense storms accelerate the damage to coastal sites, causing destabilization and loss.

4.Flooding: Floods from rising seas and storms introduce damaging sediment and salt, weakening historical materials.

5.Human Activities: Urbanization and improper coastal management disrupt natural processes and contribute to site damage.

6.Climate Change: Temperature rises and changing weather patterns intensify these risks, further endangering coastal heritage.

To protect these heritage sites, ongoing use of technology is vital for risk monitoring and mitigation (Kefi et al., 2024). ICZM frameworks offer effective solutions by incorporating sustainable tourism practices with technological monitoring. Additionally, proactive measures such as building coastal defenses, restoring natural barriers like wetlands, and engaging local communities in conservation efforts are essential to ensure the resilience of these sites. International cooperation and funding are crucial to support these initiatives and address the long-term challenges posed by climate change.

CONCLUSION / FUTURE WORK

There is a clear need for more comprehensive and collaborative efforts between governments, researchers, and communities to safeguard coastal heritage (Vousdoukas et al., 2022). Future research should focus on integrating new technologies, improving predictive models, and implementing adaptive management strategies (Kefi et al., 2024). Increased attention to sustainable tourism and its potential to generate revenue for conservation efforts will also play a pivotal role in the future of coastal heritage preservation.

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