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Urban Climate Change Resilience Framework as a guide to achieve resilience of the heritage sector, Rashid-New Rashid

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Abstract

Heritage zones in coastal urban areas are increasingly facing various impacts from climate change, such as rising sea levels, coastal erosion, saltwater intrusion, elevated temperatures, and increased flooding risks. Even with growing global initiatives to tackle the threats posed by climate change to heritage, Egypt still lacks a holistic framework that connects climate adaptation with the urban and cultural aspects of heritage sites. This study seeks to fill this gap by utilizing the Urban Climate Change Resilience (UCCR) framework within the heritage sector in Rashid - New Rashid. The objective of the research is to formulate a practical and integrated mechanisms for resilience planning in heritage cities, incorporating spatial analysis, vulnerability assessments, and adaptive planning. The approach follows the process through four well-defined stages, leveraging Geographic Information Systems (GIS) for simulation, resilience metrics, and scenario assessment. The results indicate that the historic core of Rashid is under considerable threat from various climate-related factors and reveal significant shortcomings in institutional coordination, early warning systems, and adaptive capacity. The study recommends a series of localized, scalable mechanisms tailored to the unique features of heritage environments, such as zoning to protect spaces, policies for adaptive reuse, and urban design informed by climate considerations. These approaches aim to bolster the resilience of heritage areas and help them manage the impacts of changing climate conditions. The Rashid case demonstrates how the UCCR framework has successfully linked climate science with heritage-based urban planning, providing a model that can be replicated by other coastal heritage cities.

Keywords: Climate Change, Coastal Heritage Cities, Geographic Information Systems, Heritage Sector, Resilience of Heritage Areas, Urban Climate Change Resilience Framework

Introduction

Climate change presents escalating threats to cities worldwide, particularly coastal and heritage areas (Khalifa, 2009). Heritage cities are increasingly exposed to rising

temperatures, sea level rise, coastal erosion, and saltwater intrusion, all of which endanger cultural assets, socio-economic stability, and long-term urban sustainability (United Nations, 1972). In Egypt, Rashid exemplifies such vulnerability due to its low elevation, rich cultural heritage, and limited adaptive capacity. While international agendas highlight the need to integrate cultural heritage into climate adaptation, national planning strategies remain fragmented and lack specific frameworks (Schnass, 2024) .
The literature identifies four core climate risks facing heritage-rich coastal cities: (surface temperature increases that accelerate material degradation and heat stress - sea level rise threatening permanent inundation - coastal erosion reshaping urban-marine edges and exposing heritage assets - flooding with saltwater intrusion that damage both built and natural environments (IPCC, 2023). Despite these dangers, there is still no clear methodology linking them to planning tools, particularly in the cultural sector.

To address this gap, the Urban Climate Change Resilience (UCCR) Framework is adopted. It offers a systemic approach that integrates environmental, social, institutional, and infrastructural dimensions of resilience. This research is structured into two parts: a theoretical review of climate impacts on coastal heritage and key vulnerabilities, and an applied analysis of the UCCR framework in Rashid's heritage context. Ultimately, the paper proposes actionable mechanisms to enhance resilience in similar settings. The core objective is to support planners and decision-makers in implementing adaptive strategies that strengthen climate resilience in heritage cities.

Rashid, located along Egypt's northern shore near the Nile Delta, is both a cultural landmark and a high-risk coastal zone (Ouda, 2011). With notable exposure to sea level rise, erosion, and socio-economic fragility, it ranks second only to Historic Cairo in terms of documented heritage sites (Shaheen, Madkour, Sharaf El-deen, & Rezk, 2021).

As illustrated in (Fig. 1), heritage urban planning today confronts interconnected challenges: climate adaptation, identity preservation, tourism pressure, social change, and economic sustainability (Pereira, Tavares, & Soares, 2021). A comprehensive, multidisciplinary approach—blending cultural, environmental, and economic considerations—is essential. Heritage resilience must encompass community engagement, sustainable development, integrated planning, and targeted conservation.

Fig. 1. Challenges facing heritage in the 21st century (**Source**: Pereira, Tavares and Soares, 2021).

Aim and Methodology

Coastal urban areas with heritage significance - especially low-lying communities - are under mounting pressure from climate-related hazards including sea level rise, extreme temperatures, erosion, and saltwater intrusion (da Silva, Kernaghan, & Luque, 2012). These areas often lack resilience due to institutional, socioeconomic, and infrastructural vulnerabilities. In Egypt, the city of Rashid exemplifies this crisis, facing overlapping risks while lacking an operational planning mechanism for heritage adaptation. Although global agendas now recognize the importance of heritage in climate strategies, local frameworks remain underdeveloped and poorly integrated with scientific assessments (Fatorić & Seekamp , 2017).

This research adopts a combined applied and inductive methodology. The applied component involves implementing the UCCR framework in Rashid to test its practical utility, while the inductive component draws on environmental, historical, and spatial data to extract planning tools and mechanisms suitable for heritage adaptation. Rashid was selected based on its geographical exposure to four key climate threats—heat, sea level rise, erosion, and salinization—and its cultural significance as Egypt’s second-most heritage-rich city after Historic Cairo.

The UCCR framework offers a multi-phase methodology beginning with stakeholder engagement, followed by environmental assessment, vulnerability analysis of heritage zones, strategy formulation, and finally monitoring and implementation. This structure allows for a comprehensive resilience model that addresses climate risks while supporting heritage conservation.

By applying this framework, the study aims to identify actionable, scalable mechanisms for protecting heritage cities under climate stress. These outcomes align with Egypt’s National Climate Change Strategy 2050 and Vision 2030 goals, particularly in building urban resilience and safeguarding cultural assets. Ultimately, the Rashid case offers a model for replication across other climate-threatened coastal heritage cities in Egypt.

Urban Climate Change Resilience in heritage zones

Heritage zones are urban areas of recognized historical, architectural, and cultural value, representing collective memory and identity through traditional construction, integrated urban form, and symbolic landmarks. They encompass both tangible and intangible assets - such as historic buildings, public spaces, and landscapes - whose continuity is vital to cultural identity and sustainable development. However, heritage areas have become increasingly vulnerable to climate impacts. Their infrastructure and social functions are challenged by phenomena like variable rainfall, storms, floods, saltwater intrusion, salinization, and rising temperatures leading to material degradation and thermal stress.

In this study, four key climate hazards are prioritized based on their relevance to Rashid: rising surface temperatures, sea level rise, coastal erosion, and salinity-related impacts. These collectively endanger both the functionality and cultural role of heritage areas.

Several global frameworks have emerged to enhance heritage resilience:

- Climate-Smart Cultural Heritage (CSCH): is to include climate-smart practices into heritage preservation, with a specific focus on carbon reduction and mitigation (Fatori & Daly, 2023).

- Cultural Heritage Climate Risk Assessment (CHCRA): It relies on climate data analysis and geographic information systems to assess the level of risk facing heritage buildings (O'Neill, Tett, & Donovan, 2022).

- Climate-Change Refugia Conservation Cycle (CCRCC): Focuses on creating climate refuges to protect heritage areas with relative environmental stability from increasing climate impacts (Barrows, Ramirez, Sweet, & Morelli, 2020).

- Climate Risk Management with ABC Concept: Provides a systematic framework for assessing climate risks to heritage sites and developing proactive strategies to mitigate potential damage (Michalski & Pedersoli, 2016).

- Urban Climate Change Resilience (UCCR): A comprehensive framework that integrates institutional, environmental, infrastructural, and social dimensions to build systematic urban resilience (ADB, Urban Climate Change Resilince: A Synopsis, 2014) , (SHARMA, 2013).

As shown in (Table 1), the UCCR framework is the most adaptable to heritage urban areas like Rashid. It combines integrated urban planning with vulnerability assessments, participatory governance, and institutional adaptability. This framework actively supports the sustainability and resilience of traditional urban environments by addressing climate threats such as flooding, heatwaves, desertification, and erosion, while maintaining the historical and socio-cultural essence of heritage spaces (Fig. 2) (Beauchamp, 2018).

Unlike static preservation approaches, UCCR promotes dynamic and flexible management, integrating adaptation and mitigation within environmental and planning systems. It considers climate change a continuous force reshaping both the material and symbolic value of heritage, making it ideal for proactive and context-sensitive heritage planning.

The current study was divided into four main stages that include six interconnected steps as shown in (Fig. 3), as these steps represent the practical methodology for applying a comprehensive and integrated framework for urban cities and their heritage areas to confront climate change and the effects and repercussions resulting from this phenomenon (table 2). These phases are shown in (Fig. 4).

A) Shared Learning and Stakeholder Engagement

The UCCR framework begins with Shared Learning Dialogues (SLDs), enabling collaboration among local governments, experts, civil society, and communities. These dialogues identify urban priorities, knowledge gaps, and vulnerabilities, laying the foundation for tailored climate resilience actions (NYC, 2018; Urban Waterfront Adaptive Strategies, 2013).

B) Vulnerability Assessments

Each city then performs a climate vulnerability assessment to understand the exposure of people and systems to current and future risks. These assessments evaluate hazards, vulnerable populations, and adaptive capacities using flexible tools that reflect local conditions (Murray , 2018).

Table 1. A comparative analysis of different approaches to climate risk management and heritage area protection.

Framework	Core Climate Focus	Approach to Heritage	Planning Strategy	Tools and Outputs	Remarks
CSCH (Climate-Smart Cultural Heritage)	Emphasizes mitigation strategies and carbon-reduction in heritage conservation.	Treats heritage as a passive asset to be protected within broader climate agendas.	Applies top-down policy recommendations with limited local adaptation.	Relies on guidelines and climate metrics, with few spatial diagnostics.	Useful for integrating heritage into climate policies, but lacks local spatial action.
CHCRA (Cultural Heritage Climate Risk Assessment)	Focuses on assessing specific climate threats to heritage and building adaptive responses.	Directly targets cultural values and vulnerabilities in heritage sites.	Encourages place-based adaptation plans linked to heritage typologies.	Uses risk maps, vulnerability indices, and planning templates.	Strong in linking risk to heritage type but less effective in integrating urban systems.
CCRCC (Climate-Change Refugia Conservation Cycle)	Considers climate change as a cyclical challenge requiring repeated planning loops.	Aims to provide temporal and spatial flexibility for at-risk heritage.	Advocates for dynamic cycles of relocation, reuse, and protection.	Applies scenario planning and contingency mapping.	Valuable in unstable contexts, but less grounded in urban governance mechanisms.
ABC Concept (Climate Risk Management with ABC Concept)	Emphasizes context-sensitive, culturally-rooted adaptation strategies.	Leverages traditional knowledge and community heritage practices.	Promotes bottom-up, inclusive planning with strong community voice.	Focused more on socio-cultural processes than spatial modeling.	Culturally rich and inclusive, yet lacks technical planning depth.
UCCR (Urban Climate Change Resilience)	Integrates both adaptation and mitigation in a systemic urban climate framework.	Treats heritage as part of broader urban systems requiring resilience planning.	Merges institutional reform, infrastructure, community, and spatial planning.	Utilizes GIS, climate scenarios, vulnerability mapping, and monitoring frameworks.	Most comprehensive; adaptable, scalable, and aligned with national urban resilience goals.

Source: Author

C) Sectoral Studies

After assessing vulnerability, cities conduct targeted studies in critical sectors like water, transport, and housing. These studies often involve community participation and help identify pilot projects for immediate resilience-building (Hawley, 2017; ADB, Urban Climate Change Resilince: A Synopsis, 2014)

D) City Resilience Planning and Strategies

All findings are synthesized into a City Resilience Strategy - a comprehensive plan that outlines specific actions based on shared learning, diagnostics, and sectoral needs. This strategy guides cities in integrating resilience into urban development and governance (SHARMA, 2013).

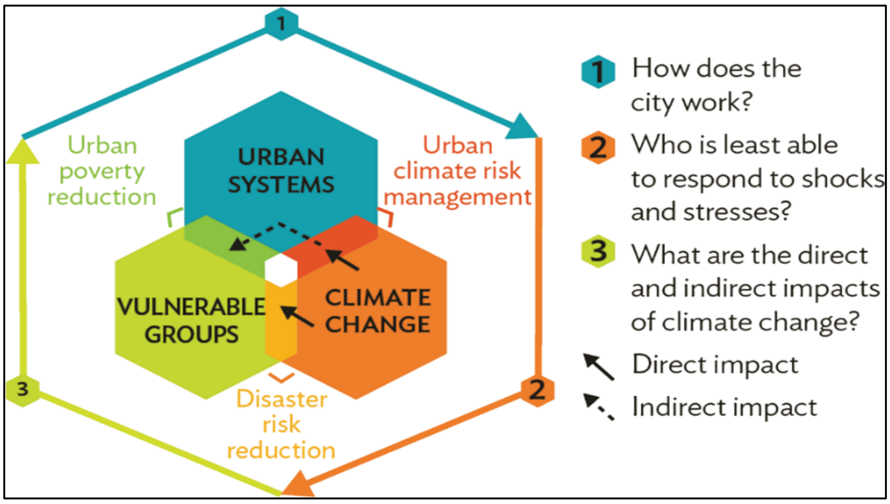

Fig. 2. The main framework for the approach to resilience in cultural and heritage areas to confront climate change (**Source**: (da Silva, Kernaghan, & Luque, 2012)).

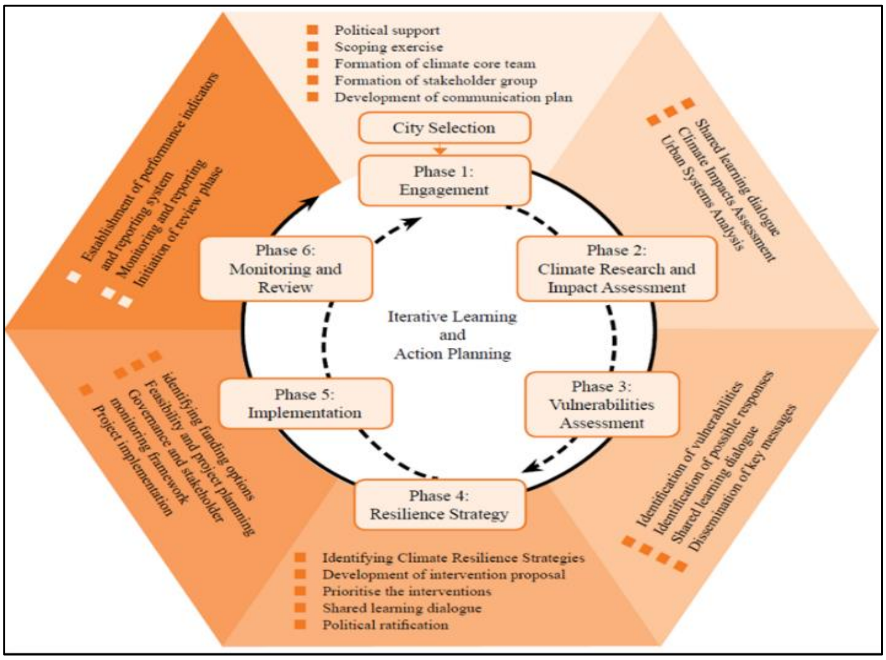

Fig.3. The methodological framework for the environmental approach UCCR (**Source**: (SHARMA, 2013)).

Material and Methods

This study adopts an applied-inductive approach to assess the climate risks facing historic urban sites and to propose a comprehensive adaptation framework. The central research question focuses on how climate change affects culturally significant coastal areas, with Rashid selected as a representative case due to its vulnerability and historical richness.

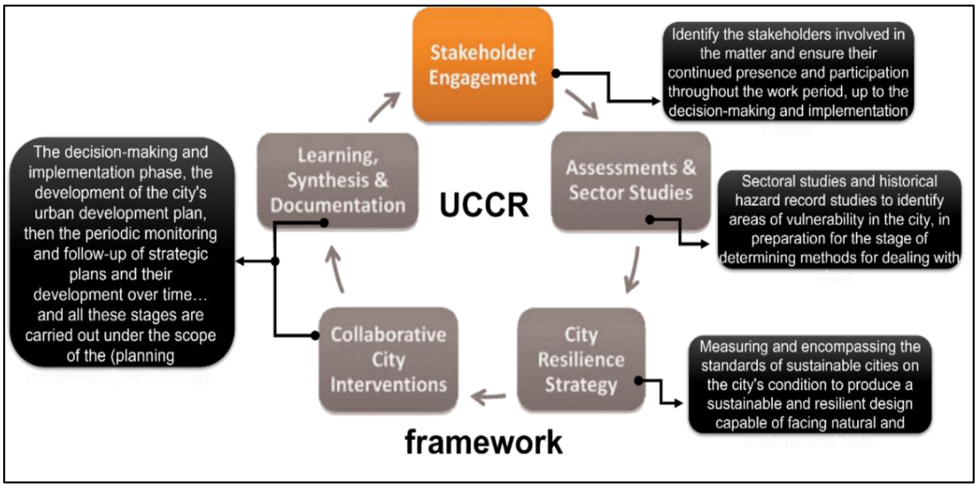

Fig. 4. Key steps of the UCCR environmental approach (**Source**: Prepared by the author based on: (SHARMA, 2013)).

Table 2. Detailed step distribution plan within the main stages of the approach.

Main Stages	Phases
1. Stakeholder Engagement	Phase 1: Engagement
2. Assessments & Sector Studies	Phase 2: Climate Research & Impact Assessment
	Phase 3: Vulnerabilities Assessment
3. City Resilience Strategy	Phase 4: Resilience Strategy
4. Collaborative Implementation & Learning	Phase 5: Implementation
	Phase 6: Monitoring & Review

Source: Prepared by the author based on: (SHARMA, 2013).

The methodology relies on the Urban Climate Change Resilience (UCCR) framework, implemented through sequential phases. First, current environmental and climate conditions are assessed using tools such as Digital Elevation Models (DEM), Coastal Erosion Analysis (DSAS), Geographic Information Systems (GIS), and sea level rise scenarios developed by the IPCC.

Next, a vulnerability assessment is conducted using social and spatial resilience indicators to evaluate exposure, sensitivity, and adaptive capacity of both the city and its heritage zones. Based on these findings, adaptive resilience plans are developed to integrate community priorities, urban development goals, and heritage preservation.

The process concludes with an implementation and monitoring phase to ensure continuous climate integration in heritage area management. This stepwise methodology not only supports local planning in Rashid but also provides a scalable model for other coastal heritage cities in Egypt and beyond (Fig. 5).

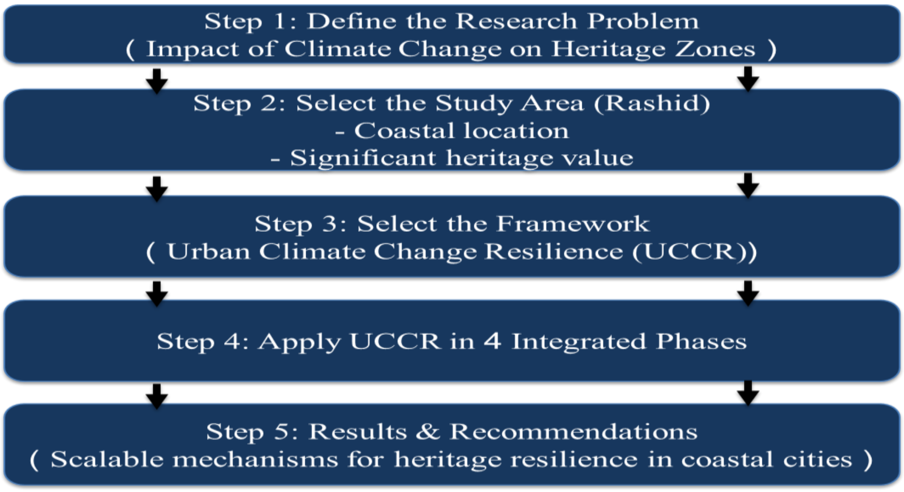

Fig. 5. Research Methodology Based on UCCR Framework (**Source**: Prepared by the author).

Study area

The study area of Rashid spans approximately 2,500 square kilometers (617,765 acres), encompassing agricultural, urban, and open spaces (Fig. 6). Urban and archaeological zones represent around 63.9% of total land use, reflecting the city's historic and built-up significance (Beheira Governorate Antiquities Unit, 2022). Known historically as “The Country of a Million Palm Trees,” Rashid has long been famous for its palm cultivation, with over 30,000 acres of agricultural land lined with towering palms. Visitors approaching the city from the Alexandria Road encounter a 35 km stretch of dense palm farms that frame the landscape (General Authority for Urban Planning, Strategic plan for the new city of Rashid, 2020).

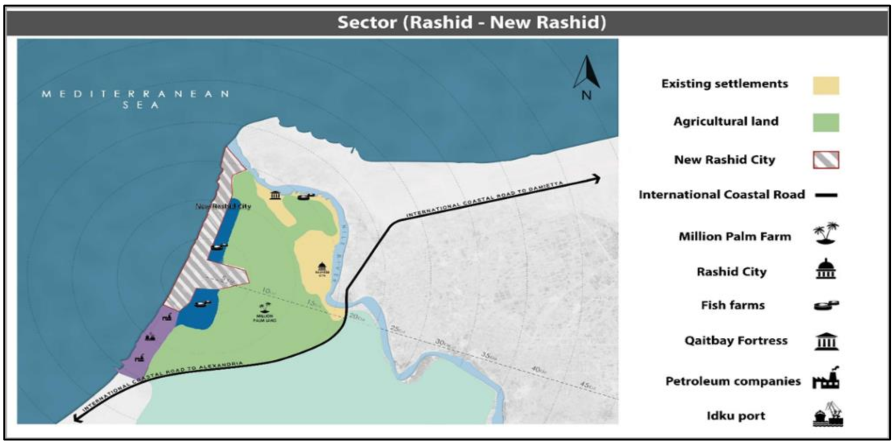

Fig. 6. Maps showing study area of Rashid-New Rashid sector (**Source**: (Zamli, 2020)).

Swot analysis of Rashid sector

Sector Potential

Rashid sector, encompassing both the historic city and New Rashid, holds exceptional strategic and cultural value. The historic city boasts a rich heritage landscape with monuments like the Rashid Stone, the Citadel, and traditional houses that reflect Egypt's urban memory and architectural legacy. In parallel, New Rashid is being developed as a smart coastal city by the Ministry of Housing, integrating heritage identity into modern planning. The design concept builds on Rashid's legacy while optimizing spatial orientation toward the Nile and the Mediterranean, ensuring visual continuity, cultural symbolism, and sustainable coastal development.

Sector Issues

Despite its value, the urban heritage of Rashid suffers from multiple climate and environmental threats, alongside planning and renewal gaps:

- The archaeological core of Rashid spans 218 acres (24.3% of the city), hosting over 45 registered heritage sites, many of which face climate-related deterioration (Fig. 7).

- Coastal erosion has severely impacted the area (Fig. 7), with over 24,934 m² lost over the past century, placing Rashid among Egypt's most erosion-prone zones (General Authority for Urban Planning, Strategic plan for the new city of Rashid, 2020).

- Salinization of coastal lands and groundwater has degraded agricultural productivity due to reduced soil moisture and sediment scarcity (Fig. 7).

- The Aswan High Dam has disrupted sediment flow, accelerating shoreline erosion in the Rashid Boghaz. Protective headlands have altered sediment deposition patterns, narrowing the Boghaz by 40 meters and raising its seabed (Fig. 7).

- The 10.5 km coastline of New Rashid has experienced noticeable retreat, with beach area shrinkage recorded over 17 years (Fig. 7).

- Since 1988, **ponds have emerged west of the estuary**, forming a depression 130 meters long and 60 cm deep, with salinity levels reaching up to 128,000 ppm due to seawater intrusion (Fig. 7).

Applying the UCCR approach to the heritage area of Rashid

Stage 1: Engagement and assessment of the local environment

The first stage of applying the UCCR framework in Rashid focuses on inclusive stakeholder engagement to build shared understanding of climate risks facing the heritage area. Rashid was selected based on its cultural value, coastal location, and high exposure to marine flooding, erosion, and institutional fragility (Beheira Governorate Antiquities Unit, 2022; General Authority for Urban Planning, Strategic plan for the new city of Rashid, 2020; Hani, 2017). A core team will form from the Rashid Local Unit, urban planning departments, the Antiquities Authority, coastal protection agencies, and civil society groups. This was accompanied by stakeholder mapping and an internal communication plan to enhance participation and dialogue.

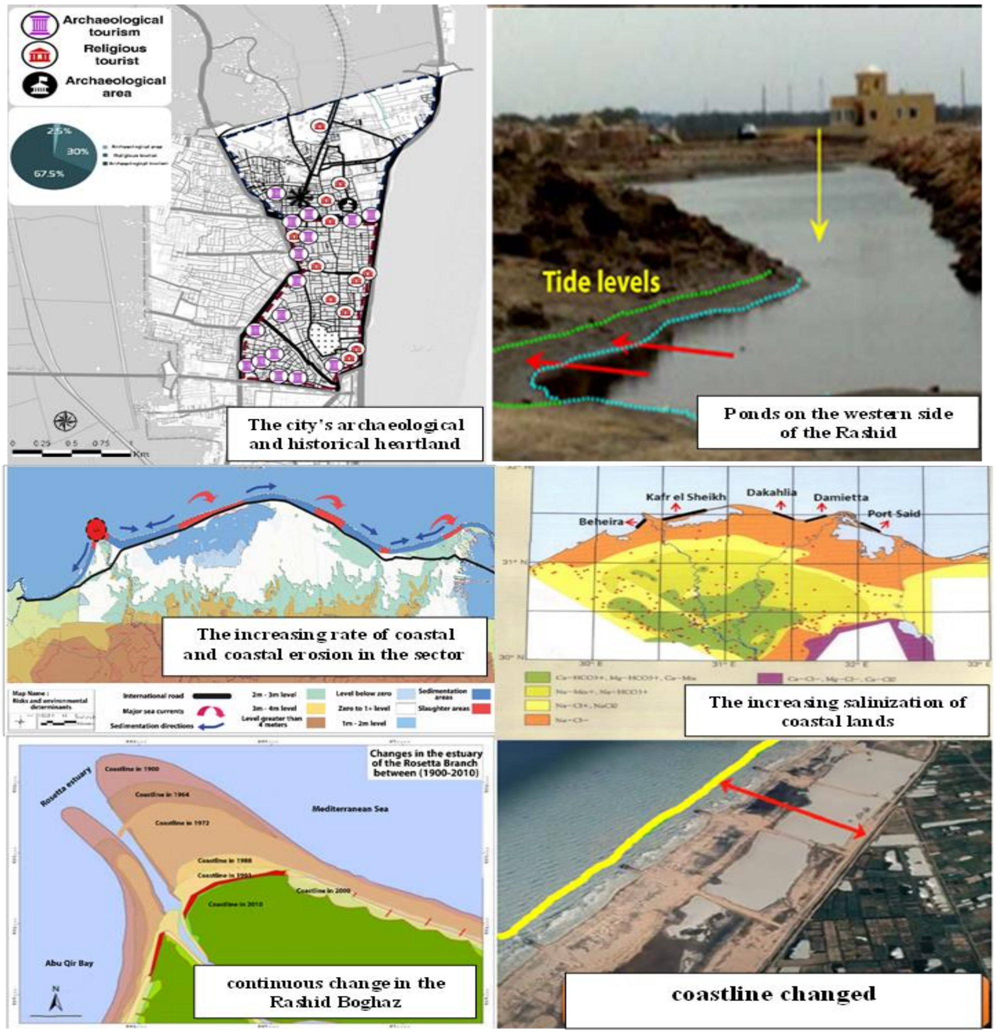

Fig. 7. Maps showing the main issues in the sector (**Source**: (Egyptian General Authority for Coastal Protection, 2010), (Zamli, 2020), (Green Climate Fund (GCF), 2017), (Google Earth, 2020)).

- Shared Learning Dialogue (SLD)

A key tool used was Shared Learning Dialogues (SLDs) - structured sessions facilitating mutual learning between officials, experts, and communities. In Rashid, three virtual SLDs were proposed to:

a) Present climate data and future sea-level scenarios (Fig. 8)
b) Document experiences with flooding events (e.g., 2010, 2015)
c) Explore community perceptions of climate risks. SLDs help bridge technical planning with local knowledge, enhancing relevance and coordination in heritage adaptation processes (ACCCRN , ACCCRN City Projects, 2012; ACCCRN, Urban Climate Change Resilience in Action:, 2014).

- Environmental, Social, and Institutional Context Analysis

This stage aims to define the climate adaptation context in Rashid by analyzing key environmental, social, and institutional factors. Environmentally, the city's location along the Mediterranean and its low elevation—less than 2.1 meters in several areas—make it highly vulnerable to sea-level rise and flooding (EL-RAEY, FOUDA, & NASR, 1997; General Authority for Urban Planning, Future vision and projects supporting the development of Beheira Governorate, 2017) (Fig. 9).

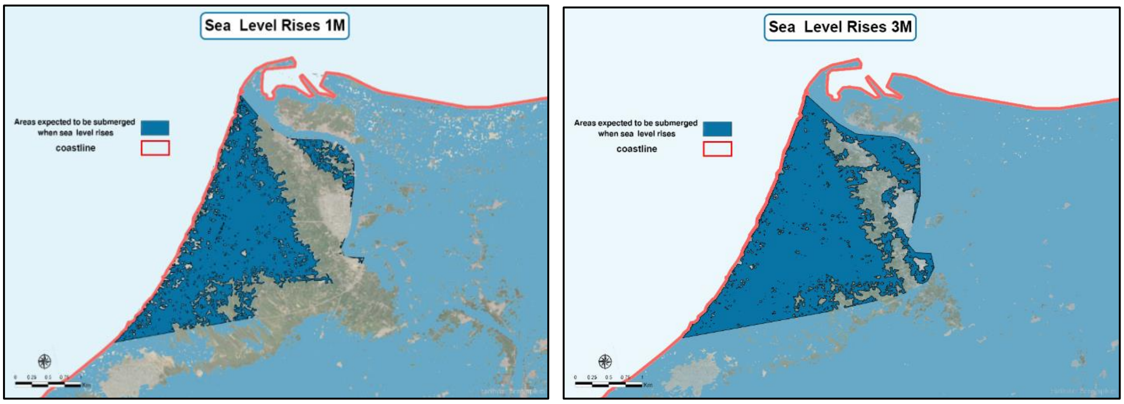

Fig. 8. Sea level rise scenarios according to IPCC data (**Source**: Prepared by the author using GIS software based on IPCC data).

Socially, Rashid faces high poverty rates in certain areas, especially among fishing communities. Its economy relies heavily on climate-sensitive sectors such as agriculture and fisheries, increasing exposure to climate shocks.

Institutionally, weak coordination between local authorities, the absence of emergency climate plans, and conflicting mandates between the Antiquities Authority and the governorate create major governance challenges (Beheira Governorate Antiquities Unit, 2022). These structural vulnerabilities limit the city's adaptive capacity and reinforce the need for a holistic resilience framework.

- Preliminary Evaluation of Strengths and Weaknesses

An initial assessment was conducted to identify Rashid's key strengths and weaknesses, drawing on stakeholder feedback and Shared Learning Dialogue (SLD) sessions. This phase serves as a transition toward deeper climate risk and vulnerability assessments. **Strengths**: include growing governmental and media attention to Rashid's heritage significance, community familiarity with flood events, and access to hazard maps from the General Authority for Coastal Protection.

Weaknesses: involve the poor condition of the drainage infrastructure, limited financial resources for climate adaptation, and the lack of a comprehensive digital inventory of heritage assets.

This evaluation supports the formation of a shared knowledge base, strengthening collaboration among stakeholders and preparing the groundwork for the next steps in the UCCR framework—particularly climate impact analysis and vulnerability mapping. It also helps establish trust and institutional cohesion, essential for successful resilience planning.

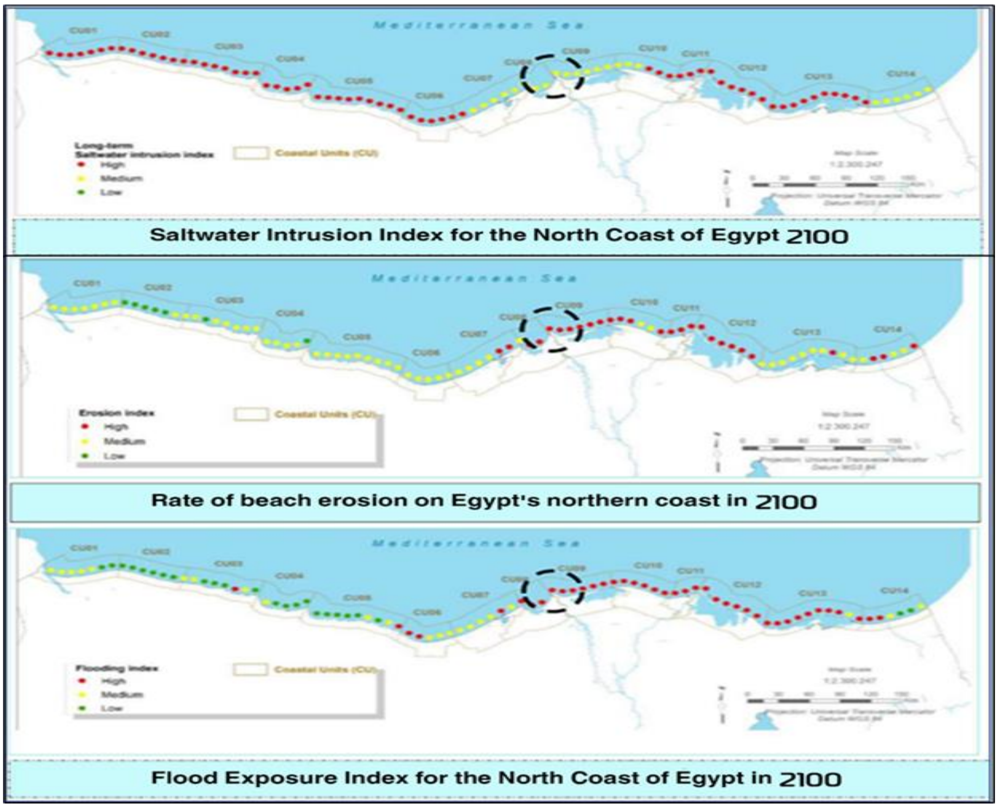

Fig. 9. Future risks in Rashid Center, Beheira Governorate (**Source**: (General Authority for Urban Planning, Strategic Plan for Urban Development of the Delta Region 2030, 2017)).

Stage 2&3: Climate Research & Vulnerabilities Assessment

This phase marks the first technical application of the UCCR framework, transitioning from general contextual understanding to detailed environmental and spatial risk analysis.

A- Historical Analysis of Climate and Temperature Change

Using GIS tools, a historical climate analysis was conducted based on Copernicus Climate Change Service data (1981–2020), which revealed that Rashid consistently lies within high surface air temperature zones (30–34 °C) (Fig. 10). This indicates a significant level of urban heat stress, posing direct threats to built heritage and social practices.

The historical warming trends in the region serve as an initial climate diagnostic, highlighting long-term exposure to heat-related risks. This analysis forms the foundation for more detailed vulnerability assessments in subsequent phases, and guides the development of tailored adaptation strategies for heritage areas.

B- Sea Level Rise Analysis Across IPCC Scenarios

Sea level rise represents one of the most critical threats to Egypt's coastal heritage zones, particularly in the Nile Delta. According to DEM-based analysis by (Hasan, Khan, & Hong, 2015) (table 3), even modest sea level rise scenarios could have severe impacts. Under a 0.5-meter rise, nearly 3 million people would be affected, alongside the loss of approximately 600 km² of vegetation, 98 km² of wetlands, 1,800 km² of agricultural land, and 70 km² of urban areas (Fig. 11).

In the case of a 1-meter rise, these impacts become even more dramatic—putting 6 million people at risk and resulting in the inundation of over 4,000 km² of cultivated land, 204 km² of wetlands, and 145 km² of urban zones. These projections highlight the vulnerability of Rashid and its surroundings and justify the need for urgent and proactive adaptation planning in heritage-rich coastal cities (Fig. 11).

Fig. 10. Geographical distribution of average temperatures in Rashid Center from 1981 to 2020 AD (**Source**: Prepared by the author using GIS and according to data issued by (Copernicus, 2020)).

Table 3. Total areas (km2) of projected land cover types exposed to sea level rise in 0.5 m and 1 m sea level rise scenarios using original DEM datasets.

Affected cover	**SRTM**	
	0.5 m	**1 m**
Vegetation	610	1272
Wetland	98	205
Cropland	1885	3928
Urban	70	146
2100 Population	3,058,227	6,116,454

Source: (Hasan, Khan, & Hong, 2015).

Fig. 11 illustrates two sea-level rise scenarios (0.5m and 1.0m) based on IPCC projections. Under the 0.5-meter scenario, water begins to encroach upon low-lying northern parts of Rashid, particularly around Ras Rashid and Lake Burullus. The 1.0-meter scenario presents more severe implications, submerging eastern urban areas, agricultural lands, and impacting heritage sites. These findings are consistent with earlier assessments by (EL-RAEY, FOUDA, & NASR, 1997) and (Shaheen, Madkour, Sharaf El-deen, & Rezk, 2021), which estimated that a 1-meter rise could submerge 30–40% of the Nile Delta's lowlands, including areas of cultural significance.

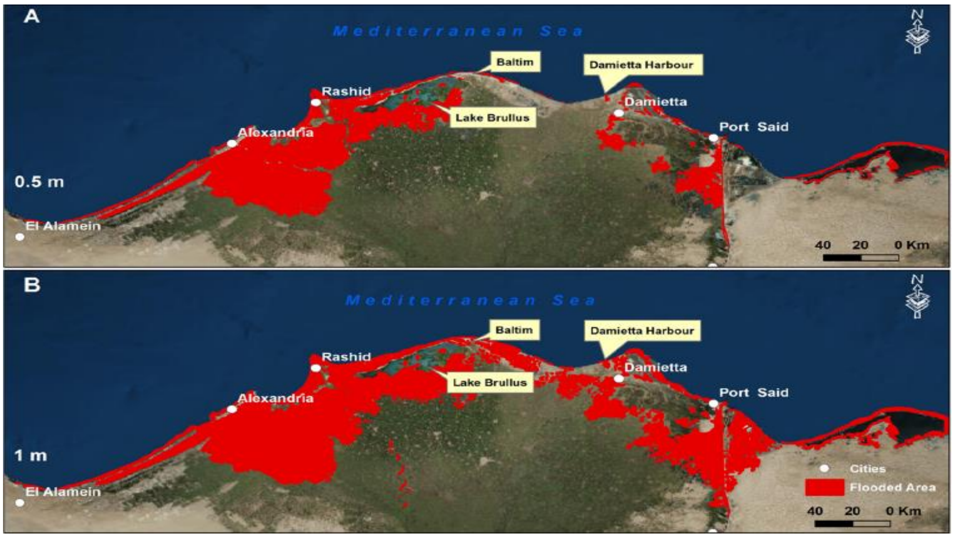

Fig. 11. Scenarios of sea level rise of 0.5 m and 1 m respectively using the SRTM-DEM dataset (Source: (IPCC, 2023) (Hasan, Khan, & Hong, 2015)).

Fig. 12 adds a spatial layer using GIS to assess water-related risks in Rashid via a composite index. Results show that most of Rashid lies within a relatively low water risk zone (<2.5%), suggesting stability in water availability and quality. However, this does not imply immunity. Localized issues persist, including:

- Elevated groundwater salinity.
- Surface water contamination from untreated sewage.
- Dependence on the Nile's limited water resources, which increases vulnerability to upstream hydrological tensions.

Fig. 12. Map with data showing 13 different types of water-related hazards in Rashid Center (Source: Prepared by the author using GIS and according to data issued by (Copernicus, 2020)).

C- Coastal retreat monitoring (DSAS + Landsat)

In this context, digital tools such as the Digital Shoreline Analysis System (DSAS), supported by Landsat satellite imagery, were applied to monitor and assess coastal changes in Rashid over several decades. DSAS operates within a GIS framework, enabling measurement of erosion and accretion rates based on multi-temporal satellite data (Abd-Elhamid, Zeleňáková, Barańczuk, Gergelova, & Mahdy, 2023).The methodology involved:(Utilizing Landsat images from the years 1974, 1980, 1990, 2000, 2015, and 2022 to observe shoreline dynamics - Integrating topographic data, remote sensing tools, and forecasting models to understand spatial and temporal coastal hazards threatening heritage sites - Using DSAS to extract shoreline change rates and predict future coastal states for 2033 and 2043).

DSAS coastal analysis relies on four key steps:
- Acquiring coastal imagery from satellites (Landsat).
- Defining a stable baseline to measure changes.
- Generating consistent transects for local shoreline assessment.
- Automating the change rate analysis.

The full process is illustrated in the flowchart (Fig. 13), showing the step-by-step application of the methodology in Rashid and its relevance to understanding coastal risks impacting heritage assets.

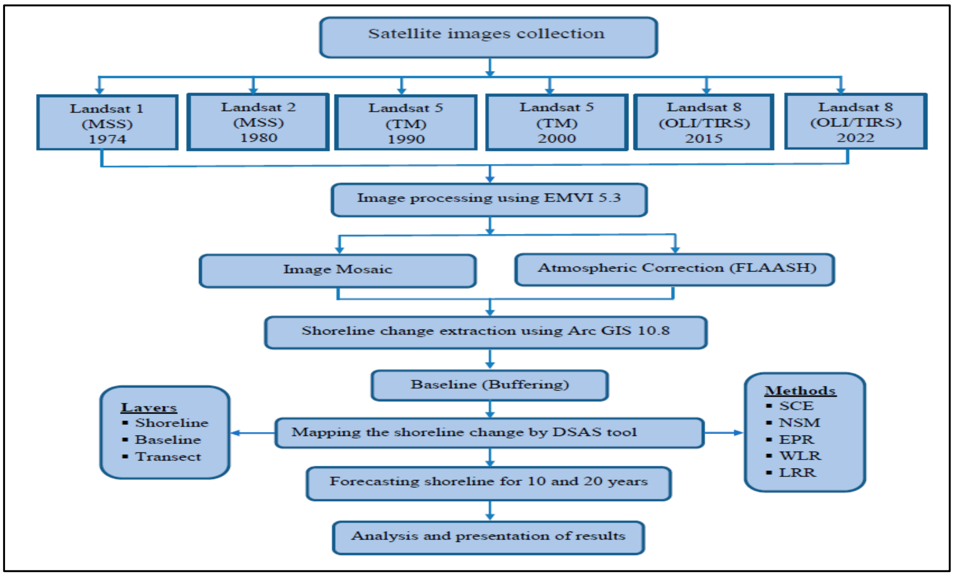

Fig. 13. A systematic flowchart for collecting and processing satellite images (Source: (Abd-Elhamid, Zeleňáková, Barańczuk, Gergelova, & Mahdy, 2023)).

Using the methodological framework (Fig. 13), the historical evolution of the Nile Delta coastline—especially in Rashid—was assessed across six time periods: 1974, 1980, 1990, 2000, 2015, and 2022. The analysis utilized six historical maps (Fig. 14) to trace shoreline changes, emphasizing the importance of archival datasets in historical shoreline studies (HTA). These maps were sourced from historical datasets provided by the Ordnance Survey.

The analysis confirmed significant coastal erosion in Rashid, with retreat rates of 2–4 m/year near the Rashid branch mouth, aligning with previous studies (EL-RAEY, FOUDA, & NASR, 1997; Shaheen, Madkour, Sharaf El-deen, & Rezk, 2021). Total retreat in some Nile Delta areas reached ~4.9 km since 1974 (NSM ≈ 4942). Severe erosion was linked to the absence or weakness of coastal defenses, while minor accumulation occurred east of Rashid due to artificial structures. To forecast future changes, DSAS with GIS and Kalman filtering was used to model the coastline for 2033 and 2043 (Fig. 15).

D- Flood Modeling Using DEM + Urban GIS Layout

Flood modeling using DEM and GIS provides a clear visual assessment of inundation risks to Rashid and its heritage assets. The process integrates elevation data, topography, and IPCC sea-level rise scenarios. Based on GIS analysis, three maps were generated (Fig. 16) simulating 0.5 m, 1 m, and 1.5 m sea-level rise scenarios in Rashid Center, helping illustrate the expected spatial extent of flooding under each condition.

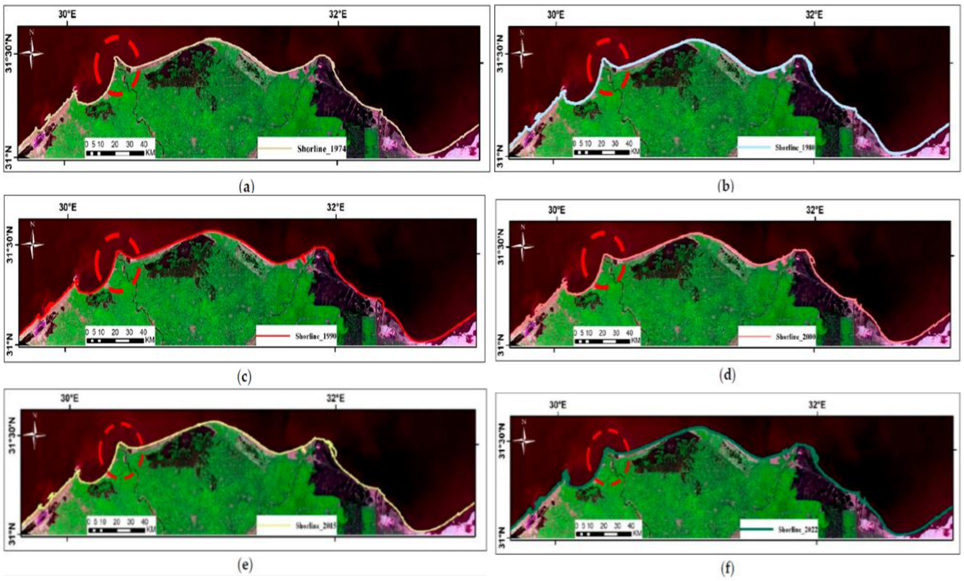

Fig. 14. Historical trend of the Nile Delta coastline for the period 1974-2022: (a) 1974, (b) 1980, (c) 1990, (d) 2000, (e) 2015, (f) 2022. (**Source**: (Abd-Elhamid, Zeleňáková, Barańczuk, Gergelova, & Mahdy, 2023)).

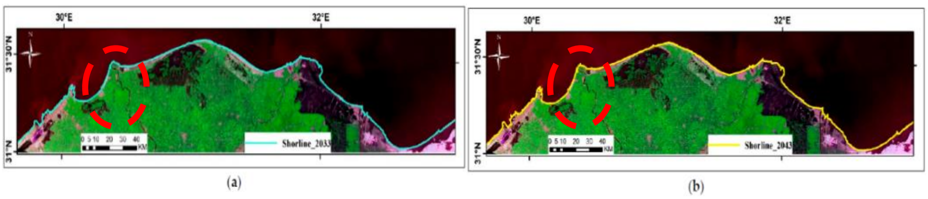

Fig. 15. Projected coastline shape of the Nile Delta during the period from 2033 to 2043. (**Source**: (Abd-Elhamid, Zeleňáková, Barańczuk, Gergelova, & Mahdy, 2023)).

To evaluate the impact of climate change on land use in Rashid, a comparative analysis was conducted on vegetation cover percentages between 2017 and 2023, using satellite data from Copernicus Sentinel 1 and 2 (European Space Agency, 2022). The 2022 vegetation distribution is illustrated in (Fig. 17).

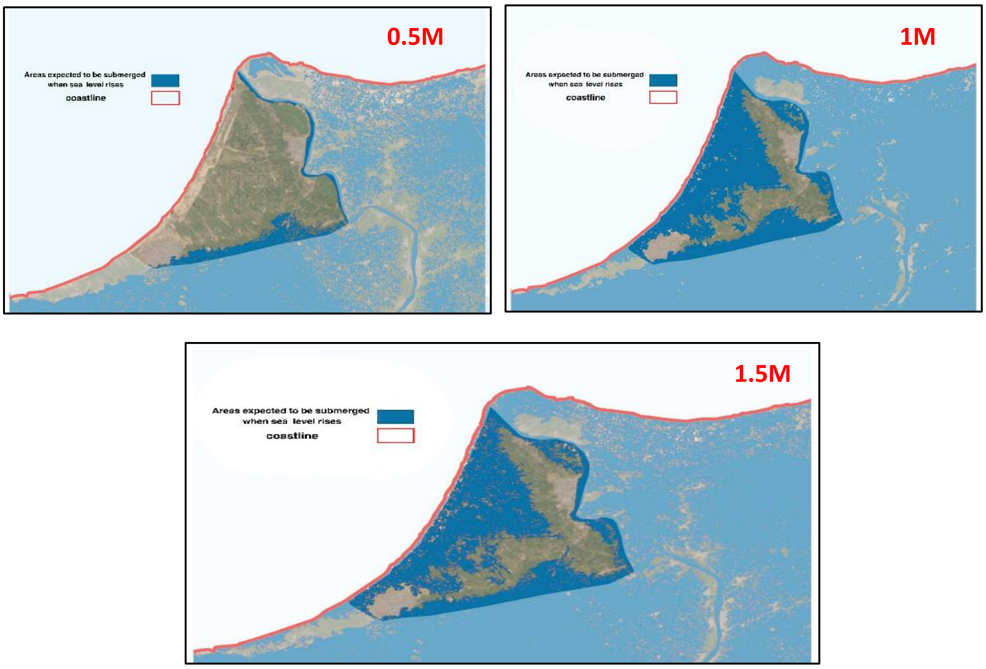

Fig. 16. Sea level rise scenarios for Rashid Center according to IPCC data. (**Source**: Prepared by the author using GIS based on IPCC data).

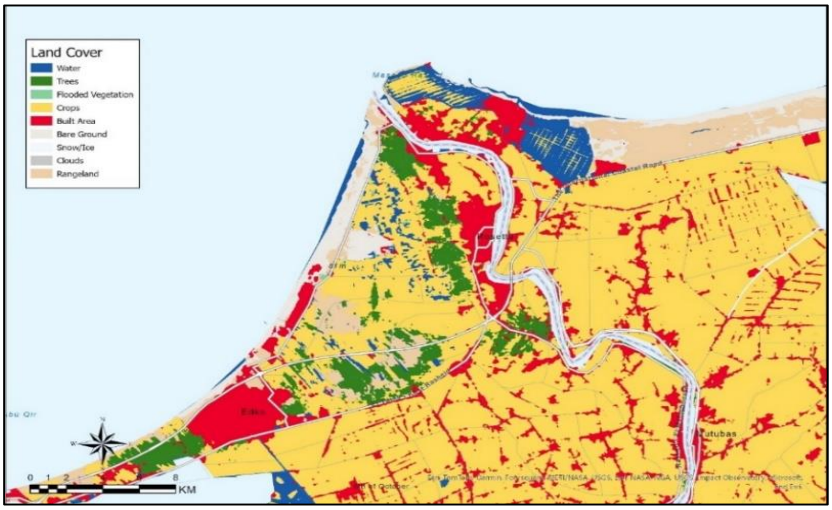

Fig. 17. Land cover study for visual uses of the Rashid Center according to European Space Agency data 2017-2022. (**Source**: Prepared by the author GIS based on data from (European Space Agency, 2022)).

Combining sea level rise scenarios with the land cover map of Rashid Center (Fig.18) highlights the progressive scale of impact:

- **0.5 m rise:** Around 1,800 km² affected, mainly submerged vegetation and coastal agricultural lands; built-up areas experience minor impact (~5%).

- **1.0 m rise:** Total losses reach 4,500 km². Vegetation is almost fully lost, agricultural lands are severely damaged, and heritage areas face a 15–25% impact due to flooding and structural threats.

- **1.5 m rise:** The most critical scenario with 5,700 km² impacted, nearly total loss of agricultural land, and over 50–75% of the heritage city submerged, making some areas uninhabitable.

Overall, sea level rise causes steadily increasing threats to low-lying areas, vegetation, and cultural heritage with each 0.5-meter increment.

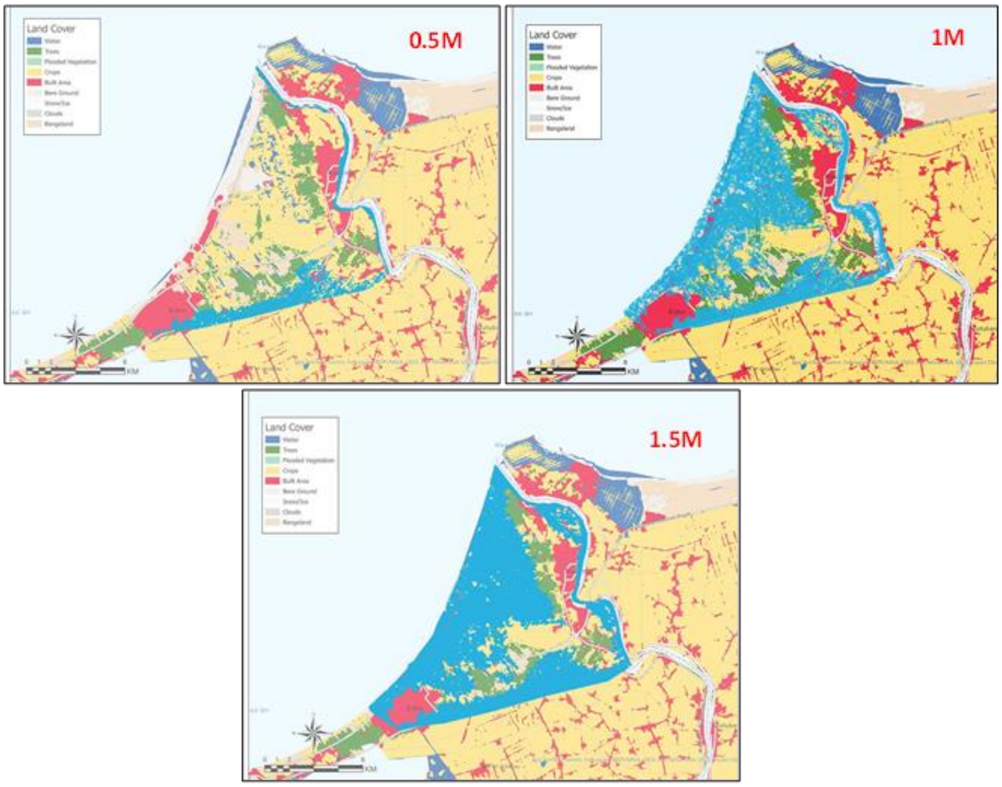

Fig. 18. Land cover areas at risk according to sea level rise scenarios. (**Source**: Prepared by the author GIS based on data from the European Space Agency and (esri, 2022)).

<u>Stage 4: Strategic Planning for Resilience</u>

This phase marks a transition in the UCCR framework from problem identification to strategy formulation for enhancing resilience in heritage areas. Based on prior assessments highlighting Rashid's coastal vulnerability, this phase proposes integrated mechanisms across six key axes:

- **Planning and urban**: Integrate climate issues into plans, redesign flood-prone areas, and update heritage building codes.

- Engineering and technical: Build natural/engineered barriers, use moisture-resistant materials, and deploy early warning systems.

- Institutional and legislative: Create a climate resilience unit, amend local laws, and form a coordination committee.

- Social and community: Launch awareness efforts, support local initiatives, and train artisans in sustainable restoration.

- Economic and financial: Conduct feasibility studies, offer tax incentives, and establish a local adaptation fund.

These mechanisms, aligned with the four UCCR resilience dimensions, establish a scalable model for heritage cities across Egypt.

Stage 5&6: Collaborative Implementation & Learning

These final phases of the UCCR framework focus on turning strategies into action and establishing mechanisms for monitoring and learning. In Rashid, challenges like institutional fragmentation and weak monitoring highlight the need for sustainable implementation tools. Four main gaps were identified (Table 4):

- Environmental/spatial: lack of coastal risk data and predictive models.
- Institutional: poor coordination and absence of emergency climate plans.
- Social: limited public awareness of climate risks.
- Knowledge: inadequate data on existing and future hazards.

To address these, the strategy includes a local resilience unit, a GIS-based monitoring system, and KPIs reviewed every 3 years. A three-tier governance model is also proposed:

- Local: a coordination unit in Rashid.
- Regional: a Beheira Governorate resilience committee.
- National: coordination with the National Council for Climate Change.

This phase ensures adaptive learning and long-term effectiveness of resilience policies for heritage zones under climate threat.

Table 4. The most important proposals for implementing follow-up and implementation in the Egyptian framework.

structural	Indicator	Measurement Mechanism
Environmental	Annual coastal retreat rate	Annual DSAS Analysis
Institutional	Number of approved climate plans	Government Document Review
Social	Rate of risk awareness	Periodic Surveys
Urban/ Knowledge	Number of protected buildings	Protection and Restoration Reports

Source: Author.

Therefore, Phases 5 and 6 constitute the implementation structure supporting the construction of comprehensive climate resilience in Rashid City, and are a pivotal part of the continued application of the UCCR approach in the Egyptian context.

Results and Discussion

The research shows that Rashid, like other heritage-rich coastal cities, suffers from compounded vulnerabilities stemming from climate-related threats (e.g., sea level rise, erosion, and temperature-humidity shifts) and institutional deficiencies (e.g., weak planning, coordination, and limited financial/social capacities). Applying the Urban Climate Change Resilience (UCCR) framework enabled a structured diagnosis across four key dimensions: environmental, urban, institutional, and societal.Key findings include:

- Coastal retreat in Rashid reaches up to 3.5 meters per year in some zones, threatening vast heritage and coastal assets over the coming decades.
- Scenario-based analysis (0.5m, 1m, and 1.5m sea level rise) revealed increasing risks of submergence, with the historic core nearing total inundation under the most severe projection.

- Institutional resilience remains weak, notably in coordination between climate and heritage stakeholders, hindering effective adaptation planning.

- The absence of updated risk maps forces communities to rely on informal, traditional knowledge, increasing societal exposure and vulnerability.

However, existing strengths were noted, including a cohesive local community and traditional construction practices adaptable to climatic stressors. These insights underscore the urgency of adopting a comprehensive resilience strategy integrating climate, cultural, and social planning. The Rashid experience offers a scalable model for similar Egyptian cities (e.g., Damietta, Port Said, Alexandria), sharing coastal and heritage vulnerabilities. Recommendations drawn from the findings—aligned with UCCR's pillars—will follow, tailored to Egypt’s institutional landscape yet informed by global resilience practices (table 5).

The UCCR approach offers a transformative model in urban planning by considering climate change not only as an environmental threat but as a structural factor reshaping urban systems and resilience strategies. In the Egyptian context - particularly in coastal cities with vulnerable heritage zones—this approach is increasingly vital for integrating climate adaptation into spatial and heritage planning.
Rashid case study demonstrated that UCCR is both flexible and locally adaptable, even amid complex institutional and urban challenges. Its application revealed the necessity of embedding climate resilience into national urban agendas through tools that combine environmental, urban, and cultural heritage dimensions.

Moving forward, the success of UCCR in Egypt depends on institutionalizing it as a planning framework capable of addressing multifaceted climate threats such as sea level rise, coastal erosion, and heat stress, while enabling adaptive, data-informed strategies across governance levels (table 6).

Table 5. Practical recommendations and linking them to the message objective.

No.	Practical Recommendation	Detailed objective of the recommendation	Relevance to Mission Objectives
1	Integrating Climate Considerations into Urban Conservation Policies	Develop urban planning policies that take into account climate change scenarios.	Enables the development of an integrated institutional framework that ensures sustainable climate resilience in heritage areas
2	Strengthening Continuous Monitoring and Evaluation Mechanisms	Periodic updating of environmental and climate data to guide conservation and intervention decisions.	Contributes to a dynamic understanding of climate challenges and fosters resilient adaptation processes
3	Empowering Local Communities and Raising Environmental Awareness	Engage residents in solutions and motivate them to adopt environmentally friendly practices.	Supports the community dimension of resilience and achieves participatory empowerment
4	Building Multi-Level Institutional Partnerships	Enhance coordination between governmental, international, and local agencies.	Activates the institutional dimension and helps develop integrated strategic plans
5	Catalyzing Climate Finance for Resilient Restoration Projects	Ensure the continuity of financial support needed to implement adaptation plans.	Supports the financial dimension within resilience planning and makes recommendations actionable
6	Integrating the UCCR Framework into National Urban Planning Tools	Transform the UCCR framework into a national standard tool for planning and conservation policies.	Consolidates the widespread application of the approach and supports the dissemination of the experience to other similar cities

Source: Author.

Table 6. Contribution of applied recommendations to achieving research objectives.

No.	Main Recommendation	Its relationship to the main research objective	Possibility of implementation in Rashid and similar areas
1	Integrate UCCR principles into national planning guidelines	Enhance the integration of the approach into urban policies, supporting the systematic application of adaptation frameworks in heritage cities	Implementation is possible by updating Rashid plans and amending building requirements.
2	Establish local climate resilience units within governorates	Facilitates the implementation of the approach at the local level and ensures the sustainability of resilience and adaptation measures	A unit could be established in Beheira Governorate as a model to be replicated in other governorates.
3	Integrate climate considerations into the evaluation of restoration and development projects	Links the urban conservation dimension to climate, in line with the goal of developing integrated mechanisms to protect heritage from climate change	Amendment of the evaluation methodology for current development projects in Rashid as an example.
4	Strengthen partnerships between universities and planning agencies	Supports the production of local knowledge, the application of the thesis findings in real-world contexts, and the training of local cadres to apply the approach	Agreements could be signed between Damanhour University and the General Authority for Planning.
5	Establish a national knowledge platform for climate resilience	Provides an institutional framework for disseminating and sharing adaptation practices in heritage cities and facilitating accurate data-driven decision-making	Digital linkage between the Rashid database and an integrated national platform.

Source: Author

Future proposals for climate change studies in heritage areas

This research provides a scientific and methodological framework for applying the concept of urban climate resilience to heritage sites. However, due to the ongoing variability in climate phenomena and the multiple challenges facing heritage contexts in Egypt, it becomes necessary to expand the horizons of research and development in the future. Based on the achievements of this study, several relevant future research areas can be proposed (Table 7).

Table 7. Linking future research proposals to the research objective.

No.	Future Research Proposal	Relationship to the main objective	Opportunities for Dissemination and Implementation
1	Developing Quantitative Indicators to Measure Climate Resilience in Heritage Contexts	Supports the development of accurate assessment tools for more objective application of the UCCR approach in heritage cities	Can be disseminated in national databases and applied in cities such as Damietta and Quseir
2	Integrating Artificial Intelligence into Climate Change Analysis	Contributes to accelerating and updating risk and vulnerability analysis processes within the UCCR implementation process	Applicable in university/local projects in collaboration with digital ministries
3	Comparative Studies of Egyptian Coastal Heritage Cities	Enhances testing of the flexibility of the methodology and reveals the limits and effectiveness of its application in diverse contexts	Achieves a balance between disseminating the framework and respecting the specificities of each city
4	Aligning Planning Codes and Legislation with Climate Adaptation Requirements	Translates the outcomes of the thesis into regulatory policies that support the activation of flexible adaptation tools	Can be presented as legislative drafts to the Urban Planning Authority and Parliament
5	Modeling Future Scenarios until 2100 in Heritage Areas	Expands the scope of UCCR application to a long-term, forward-looking perspective that enhances heritage cities' readiness for climate change	Can be integrated into national forward-looking maps for risk planning
6	Studying the Impact of Climate on Cultural Identity and the Uses of Heritage Buildings	Enhances understanding of climate-related social and cultural changes in heritage cities, supporting the sustainability of the proposed frameworks	Used to support awareness campaigns and cultural projects

Source: Author

The presented matrix illustrates how the research proposals align with the central objective of developing a scalable, applied framework for flexible adaptation using the UCCR approach.

Based on the identified vulnerabilities, it is clear that Rashid’s exposure to climate risks is not just a local concern, but rather a reflection of broader patterns in heritage-rich coastal areas around the world. For example, the Intergovernmental Panel on Climate Change (IPCC, 2023) "highlighted that low-lying heritage cities in the Mediterranean are among the most vulnerable, particularly where adaptation planning remains fragmented or delayed". In this sense, "Rashid’s case parallels the urban resilience gaps documented in similar cities such as Venice (Italy) and Georgetown (Malaysia), both of which struggle to preserve heritage under complex climatic and urban pressures" (UNESCO, 2023). One of the key analytical insights derived from the application of Rashid is the gap between risk awareness and institutional capacity. Despite the clear environmental threats, " there is a lack of up-to-date geospatial risk data and proactive governance " - a trend reflected in the findings of (Fatori & Daly, 2023), who emphasized that heritage adaptation is often delayed due to institutional inertia. In the case of Rashid, the absence of integrated climate and heritage planning units significantly hinders the activation of resilience mechanisms, a gap that the UCCR approach has clearly been able to address through its multidimensional perspective. Furthermore, the study highlights a strategic starting point in the presence of community cohesion and traditional knowledge systems.

This supports the recommendations of the International Council on Monuments and Sites (ICOMOS, 2020) " that resilience strategies should actively engage local residents, not only as recipients of protection, but also as co-creators of adaptive solutions ". The research demonstrates this by identifying the adaptive potential inherent in Rashid's vernacular architecture and community structure - resources that are typically untapped in traditional urban planning models. From a methodological perspective, the application of the UCCR model in Rashid demonstrates its operational adaptability in Global South contexts, a point emphasized by (Tyler & Moench, 2012) and further explored in the urban experiences of Surat (India) and Semarang (Indonesia), where resilience frameworks were adapted locally without compromising their underlying structures.

The Egyptian experience, as illustrated here, confirms the potential for localizing these approaches without losing strategic coherence - particularly when supported by spatial data tools, stakeholder mapping, and participatory diagnostics. Regarding the thesis objective, the findings provide concrete evidence that the UCCR model serves as more than just a conceptual model - it serves as a planning tool capable of structuring city-level strategies around climate resilience. Each of the six practical recommendations aligns directly with the research objective of activating adaptation mechanisms in heritage areas. In particular, the call to integrate UCCR principles into national planning guidelines provides a realistic policy path that reflects Egypt's current climate goals, such as those outlined in the National Climate Change Strategy 2050. Finally, the research opens new avenues for deeper integration of quantitative resilience indicators, as outlined in future research proposals. This is crucial for integrating the UCCR model into measurable outcomes, as outlined in frameworks such as the Urban Resilience Index or the ARUP City Resilience Framework, both of which emphasize the need for data-driven tools to support adaptive urban transformation.

Conclusions

This study provides a comprehensive framework for applying flexible adaptation mechanisms in heritage areas threatened by climate change, using the (UCCR) approach. Through its full application in the heritage city of Rashid, theoretical principles were translated into actionable tools supported by digital analysis and field data. The findings revealed that Rashid faces compounded climate risks—sea level rise, erosion, urban pressure, and limited risk awareness—but also possesses structural and social capacities that support resilience planning. The proposed resilience mechanisms—spanning planning, engineering, institutional, community, and financial domains—offer a flexible model for decision-makers not only in Rashid but also in similar Egyptian heritage cities such as Damietta, Alexandria, Quseir, and Siwa. This research reinforces the notion that climate resilience is a strategic, cross-sectoral necessity for safeguarding heritage, populations, and urban sustainability.

Ultimately, the study lays a foundation for future work in developing resilience indicators, incorporating AI tools, updating legal frameworks, and reconciling heritage preservation with climate adaptation. Addressing climate threats in heritage contexts is no longer optional - it is an urgent priority for researchers, planners, and policymakers alike.

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