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Climate Change and Environmental Pollution: A Comparative Study of Deinze (Belgium) and Pemba, Cabo Delgado (Mozambique)

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ABSTRACT

Climate change and environmental pollution are among the most significant global challenges of the twenty-first century, affecting ecosystems, public health, economic development, and social well-being. While developed countries have implemented extensive environmental policies to mitigate these impacts, developing countries continue to face substantial challenges due to limited infrastructure, rapid urbanization, and increasing environmental degradation. This study presents a comparative analysis of environmental conditions and climate change impacts in Deinze, Belgium, and Pemba, Cabo Delgado Province, Mozambique. A comparative case-study approach was adopted, combining a review of scientific literature, policy documents, environmental reports, and secondary datasets. The analysis focuses on air quality, waste management, water resources, urban development, biodiversity conservation, and climate adaptation strategies. The findings indicate that Deinze has achieved significant progress through integrated environmental governance, sustainable urban planning, and effective waste management systems. In contrast, Pemba faces increasing environmental pressures associated with population growth, inadequate waste disposal, coastal erosion, flooding, and vulnerability to extreme climatic events. Despite these differences, both cities are affected by climate change and require continuous investment in sustainable environmental management. The study concludes that strengthening international cooperation, promoting environmental education, improving governance, and investing in climate resilience are essential to achieving sustainable development in both European and African contexts.

Keywords: Climate Change; Environmental Pollution; Sustainable Development; Belgium; Mozambique; Pemba; Deinze; Environmental Governance

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INTRODUCTION

Climate change has become one of the most pressing environmental and socio-economic challenges of the twenty-first century. Rising global temperatures, sea-level rise, changing precipitation patterns, biodiversity loss, and increasing frequencies of extreme weather events have profound consequences for both developed and developing countries. Human activities, particularly greenhouse gas emissions, industrialization, deforestation, unsustainable land use, and pollution, have accelerated environmental degradation worldwide.

Environmental pollution further exacerbates climate-related challenges by degrading air, water, and soil quality. Air pollution contributes to respiratory diseases and climate warming, while inadequate waste management and water contamination threaten ecosystems and public health. These interconnected environmental problems require integrated policy responses that combine mitigation, adaptation, and sustainable development strategies.

Belgium has developed comprehensive environmental policies that emphasize circular economy principles, renewable energy, waste recycling, and sustainable urban planning. Municipalities such as Deinze have benefited from effective governance, environmental awareness, and strong institutional capacity to reduce pollution and improve environmental quality.

In contrast, Mozambique remains highly vulnerable to climate change because of its geographical location, dependence on natural resources, and limited adaptive capacity. Pemba, located in Cabo Delgado Province along the Indian Ocean coast, experiences increasing risks from coastal erosion, flooding, solid waste accumulation, marine pollution, and the impacts of tropical cyclones. These environmental challenges are compounded by rapid urbanization, population growth, and socio-economic constraints.

Comparing Deinze and Pemba provides valuable insights into how different governance systems, levels of economic development, and environmental policies influence climate resilience and pollution management. The lessons learned may contribute to strengthening environmental governance, promoting sustainable development, and supporting evidence-based policy formulation in both developed and developing countries.

Research Objectives

General Objective

The primary objective of this study is to comparatively assess the impacts of climate change and environmental pollution in Deinze (Belgium) and Pemba, Cabo Delgado Province (Mozambique), with the aim of identifying similarities, differences, and opportunities for strengthening sustainable environmental governance and climate resilience.

Specific Objectives

- To examine the major environmental pollution challenges affecting Deinze and Pemba, including air, water, soil, and solid waste pollution;
- To assess the impacts of climate change on natural ecosystems, urban infrastructure, public health, biodiversity, and local livelihoods in both study areas;
- To compare environmental governance frameworks, climate policies, and institutional capacities for pollution control and climate change adaptation in Belgium and Mozambique;
- To identify the principal socio-economic and environmental factors contributing to climate vulnerability in Pemba and climate resilience in Deinze;
- To evaluate the effectiveness of current environmental management practices, including waste management, water resource protection, sustainable urban planning, and ecosystem conservation;
- To analyse how local governments, civil society organizations, communities, and other stakeholders contribute to climate adaptation and environmental protection;
- To identify transferable good practices from the Belgian experience that could support environmental management and climate adaptation initiatives in Pemba, while recognizing differences in local contexts and available resources;
- To formulate evidence-based recommendations that support sustainable urban development, environmental protection, and climate resilience in both developed and developing country settings.

Research Questions

- What are the main environmental pollution challenges affecting Deinze and Pemba?
- How does climate change influence environmental quality, public health, and socio-economic development in the two cities?
- What similarities and differences exist between the environmental governance systems of Belgium and Mozambique?
- Which environmental management strategies have been most effective in reducing pollution and strengthening climate resilience?
- What lessons can be shared between the two case-study cities to promote sustainable environmental governance and climate adaptation?

Significance of the Study

This study contributes to the growing body of knowledge on climate change and environmental pollution by providing a comparative analysis of two urban areas with contrasting socio-economic and environmental contexts. It highlights how governance capacity, public policies, and local environmental management influence resilience to climate-related risks.

The findings are expected to benefit policymakers, municipal authorities, environmental agencies, researchers, development partners, and civil society organizations by providing evidence-based recommendations for improving environmental governance, reducing pollution, and enhancing climate resilience. Furthermore, the study supports the implementation of the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land).

MATERIALS AND METHODS

This study adopted a comparative case study design to examine the impacts of climate change and environmental pollution in two geographically and socioeconomically distinct urban areas: Deinze, Belgium, and Pemba, Cabo Delgado Province, Mozambique. Comparative case studies are particularly appropriate for analysing similarities and differences in environmental governance, climate vulnerability, institutional responses, and sustainable urban management across contrasting development contexts [1-2].

A mixed-methods approach based exclusively on secondary data was employed, integrating qualitative and quantitative information from scientific literature, governmental reports, and international institutional databases. This methodological approach enables a comprehensive understanding of environmental challenges while considering ecological, institutional, socio-economic, and policy dimensions [3-4].

Study Areas Deinze, Belgium

Deinze is located in the Flemish Region of Belgium and is characterized by a temperate maritime climate, well-developed urban infrastructure, efficient waste collection systems, advanced wastewater treatment facilities, and robust environmental governance. Environmental management is supported by municipal, regional, national, and European Union policies that promote pollution prevention, circular economy practices, biodiversity conservation, and climate adaptation [5].

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Pemba, Cabo Delgado Province, Mozambique

Pemba is the capital of Cabo Delgado Province in northern Mozambique, situated along the Indian Ocean coastline. The city possesses important coastal and marine ecosystems but faces increasing environmental pressures associated with rapid urbanization, population growth, inadequate waste management, insufficient sanitation infrastructure, coastal erosion, flooding, and recurrent tropical cyclones. These factors substantially increase environmental degradation and climate vulnerability [4,6].

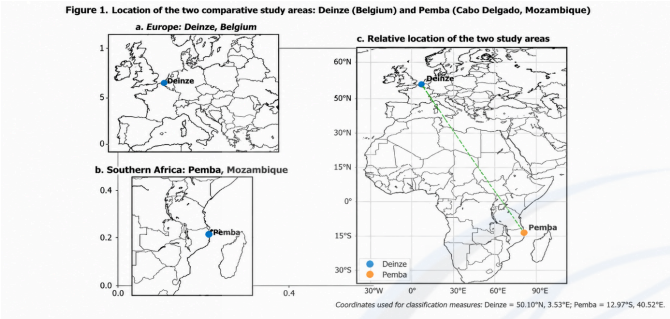


Figure 1: Location of the two comparative study areas: Deinze (Belgium) and Pemba (Cabo Delgado, Mozambique).

Source: Author's elaboration. City-location coordinates are used only to identify the study areas; the figure is a locator map and not a cadastral or administrative-boundary map.

Data Sources

The study relied exclusively on secondary data obtained from internationally recognized scientific and institutional sources to ensure reliability, credibility, and comparability. The principal sources included:

- Peer-reviewed scientific journal articles;
- Reports published by the Intergovernmental Panel on Climate Change (IPCC) [1];
- Publications from the World Bank;
- Reports from the United Nations and its specialized agencies;
- World Health Organization (WHO) publications;
- European Environment Agency (EEA) reports;
- Belgian and Mozambican governmental policy documents;
- Municipal environmental reports, where available; and
- Academic books and conference proceedings.

Only authoritative and scientifically validated publications were considered to strengthen the robustness of the comparative assessment [1,7].

Data Collection Procedures

A systematic literature review was conducted to identify publications addressing climate change, environmental pollution, urban sustainability, waste management, biodiversity conservation, water resources, environmental governance, and climate adaptation.

The review process comprised four sequential stages:

1. Identification of relevant scientific publications;
2. Screening according to the study objectives;
3. Extraction of environmental, institutional, and socio-economic information; and
4. Organization of evidence into thematic categories for comparative analysis.

Whenever available, official environmental indicators were incorporated to improve comparability between the two study areas [4,8].

Data Analysis

The collected information was analysed through comparative thematic analysis, allowing the identification of similarities, differences, strengths, and environmental challenges across both case studies.

The comparative analysis focused on the following dimensions:

- Climate change impacts;
- Air pollution;
- Water pollution;
- Solid waste management;
- Biodiversity conservation;
- Environmental governance;
- Climate adaptation measures;
- Institutional capacity;
- Public participation; and
- Sustainable urban development.

Triangulation of evidence from multiple scientific and institutional sources enhanced the consistency and credibility of the analytical findings [1,3].

Validity and Reliability

To ensure methodological rigor, only peer-reviewed publications and reports from internationally recognized organizations were used. Cross-validation of information obtained from different sources reduced potential bias and improved the reliability of the comparative analysis [1,7].

The use of multiple independent sources strengthened the scientific robustness of the study and supported evidence-based interpretation.

ETHICAL CONSIDERATIONS

The research relied exclusively on publicly available secondary data. Consequently, no human participants, interviews, questionnaires, or confidential information were involved.

All consulted sources were appropriately acknowledged through in-text citations and references, ensuring compliance with internationally accepted standards of academic integrity and research ethics.

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Limitations of the Study

Some limitations should be acknowledged. First, the study depended exclusively on secondary data, and the availability of environmental information differed between Belgium and Mozambique. Second, variations in environmental monitoring systems and reporting standards may influence direct comparisons between the two case studies. Third, localized environmental datasets for Pemba remain relatively limited owing to financial, technical, and institutional constraints, as well as the recent socio-political context of Cabo Delgado [4,6].

Despite these limitations, the comparative design provides valuable insights into environmental governance, pollution management, and climate adaptation in contrasting urban contexts. The findings also establish a solid foundation for future empirical research involving environmental monitoring, field observations, and stakeholder engagement.

Conceptual Framework

A conceptual framework linking anthropogenic drivers, environmental pressures, climate impacts, governance responses, and sustainability outcomes guides the study. Human activities—including urbanization, industrialization, land-use change, transport, and population growth—generate environmental pressures such as greenhouse gas emissions, pollution, and ecosystem degradation. These pressures contribute to climate change, which in turn affects ecosystems, infrastructure, public health, and livelihoods [1,7].

Governance responses—including environmental legislation, climate adaptation strategies, public participation, ecosystem conservation, and sustainable resource management—play a decisive role in reducing environmental risks and strengthening resilience. Comparing these interactions in Deinze and Pemba provides evidence for identifying transferable policy lessons and supporting sustainable urban environmental management [5,9].

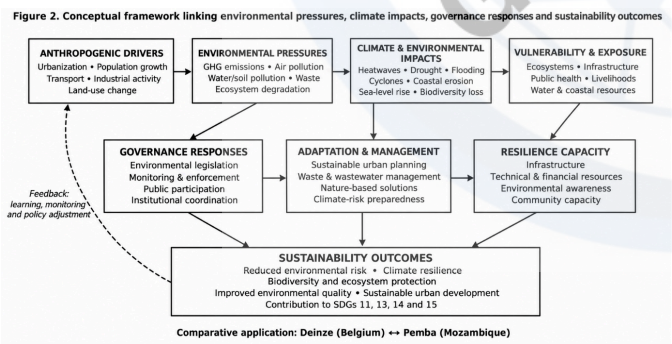


Figure 2: Conceptual framework linking environmental pressures, climate impacts, governance responses and sustainability outcomes.

Source: Author's elaboration based on the conceptual framework described in the manuscript. The framework links anthropogenic drivers, environmental pressures, climate and environmental impacts, vulnerability, governance responses, adaptation and management, resilience capacity, and sustainability outcomes.

RESULTS AND DISCUSSION

Overview of the Comparative Assessment

The comparative analysis demonstrates that although Deinze (Belgium) and Pemba (Mozambique) differ substantially in their levels of economic development, institutional capacity, and environmental infrastructure, both cities are increasingly affected by climate change and environmental pollution. The findings reveal that environmental governance, investment in public infrastructure, and community awareness play critical roles in determining local resilience to climate-related risks.

Climate Change Impacts

In Deinze, climate-related risks are primarily associated with increasing temperatures, more frequent heatwaves, periods of drought, and episodes of intense rainfall that may contribute to localized flooding. These impacts are moderated by advanced infrastructure, comprehensive land-use planning, and well-established emergency management systems.

Pemba experiences more severe climate-related challenges due to its coastal location and greater socio-economic vulnerability. The city is increasingly exposed to tropical cyclones, coastal erosion, sea-level rise, storm surges, flooding, and changes in rainfall patterns. These hazards threaten residential areas, transport infrastructure, fisheries, tourism, and freshwater resources.

The comparison suggests that climate vulnerability depends not only on physical exposure but also on governance capacity, infrastructure quality, and the availability of financial and technical resources for adaptation.

Dimension	Deinze, Belgium	Pemba, Cabo Delgado, Mozambique
Main climate-related hazards	Increasing temperatures; heatwaves; drought periods; intense rainfall and localized flooding; storms.	Tropical cyclones; flooding; coastal erosion; sea-level rise; storm surges; changing rainfall patterns.
Physical exposure	Primarily inland/riverine exposure, with risks associated with intense rainfall, heat and water stress.	High coastal exposure along the Indian Ocean, including coastal flooding, erosion and storm-related hazards.
Infrastructure impacts	Localized flood pressure and heat-related stress; risks moderated by planning and established infrastructure.	Flooding, drainage constraints and coastal hazards place pressure on residential areas, transport and urban

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		infrastructure.
Impacts on livelihoods	Climate risks affect urban well-being, water resources and local economic activities.	Risks affect fisheries, tourism, coastal livelihoods, freshwater resources and urban economic activities.
Adaptive capacity	Relatively stronger institutional, technical and financial capacity supports preparedness and adaptation.	More constrained adaptive capacity because of infrastructure, financial, technical and institutional limitations.
Overall vulnerability	Moderate and comparatively better managed through planning, infrastructure and governance.	Higher vulnerability because physical coastal exposure interacts with socio-economic and institutional constraints.

Table 1: Comparative assessment of climate change impacts and vulnerability

Note: Qualitative synthesis based on the manuscript's reviewed secondary literature and policy/environmental sources.

Environmental Pollution

In Deinze, integrated waste collection, wastewater treatment, recycling programmes, and environmental regulations have substantially reduced environmental pollution. Air and water quality are continuously monitored, and environmental standards are supported by strong institutional enforcement.

In contrast, Pemba continues to face significant challenges related to solid waste management, open waste disposal, plastic pollution, inadequate drainage systems, and limited wastewater treatment. During periods of heavy rainfall, unmanaged waste may obstruct drainage channels, increasing flood risk and degrading coastal ecosystems.

Although pollution sources differ between the two cities, effective environmental governance is a decisive factor influencing environmental quality.

Dimension	Deinze, Belgium	Pemba, Cabo Delgado, Mozambique
Air pollution	Environmental standards and monitoring support pollution control; pressures are managed through established regulation and planning.	Urban growth, transport and other human activities contribute to air-quality pressures, with more limited monitoring capacity.
Water pollution	Wastewater treatment and environmental regulation contribute to protection of water quality.	Limited wastewater treatment, inadequate drainage and waste accumulation create risks to surface, coastal and marine environments.
Solid waste	Structured collection and treatment systems, recycling and composting support integrated waste management.	Collection challenges, informal disposal, open dumping and plastic waste remain significant concerns.
Flood–waste interaction	Drainage and waste-management systems help reduce the likelihood that unmanaged waste will obstruct urban drainage.	Unmanaged waste can obstruct drainage channels during heavy rainfall, increasing flood risk and environmental degradation.
Pollution-control capacity	Stronger monitoring, enforcement and municipal environmental management capacity.	Greater implementation constraints associated with limited technical, financial and institutional resources.

Table 2: Comparative assessment of environmental pollution and waste management

Note: Comparisons are qualitative; the study does not treat the two cities as having directly equivalent monitoring systems or datasets.

Biodiversity and Ecosystem Conservation

Deinze protects river ecosystems, green spaces, and biodiversity through environmental planning, habitat restoration, and sustainable land management initiatives. Municipal policies encourage ecological connectivity and nature-based solutions that contribute to climate adaptation.

Pemba is characterized by ecologically important coastal and marine ecosystems, including mangrove forests, coral reefs, beaches, and seagrass habitats. These ecosystems support fisheries, tourism, shoreline protection, and local livelihoods. However, increasing coastal development, pollution, overexploitation of natural resources, and climate change threaten ecosystem integrity.

Strengthening ecosystem-based adaptation and biodiversity conservation is therefore essential for enhancing long-term environmental resilience in both locations.

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Dimension	Deinze, Belgium	Pemba, Cabo Delgado, Mozambique
Biodiversity and ecosystems	River ecosystems, wetlands/green areas and other urban ecological spaces benefit from environmental planning, habitat restoration and sustainable land management.	Coastal and marine ecosystems—including mangroves, coral reefs, beaches and seagrass habitats—are ecologically important but face pressures from habitat loss, overfishing, pollution and climate change.
Environmental governance	Established multi-level governance and municipal planning provide comparatively strong institutional support.	Environmental governance frameworks exist, but implementation is constrained by institutional, technical and financial capacity.
Monitoring and data	More developed environmental monitoring and reporting systems support planning and enforcement.	Localized environmental datasets and monitoring capacity are more limited, restricting fine-scale comparison.
Public participation	Environmental awareness and opportunities for citizen engagement support environmental management.	Community participation and environmental awareness can be strengthened to support pollution prevention and adaptation.
Climate adaptation	Adaptation is integrated into urban planning, infrastructure management, emergency preparedness and nature-based approaches.	Adaptation needs emphasize flood and cyclone preparedness, coastal protection, drainage improvement, resilient infrastructure and ecosystem-based approaches.
Transferable lesson	Integrated governance, monitoring, waste systems, urban planning and nature-based solutions offer useful reference points.	Approaches should be adapted to Pemba's coastal ecology, socio-economic conditions, institutional capacity and available resources.

Table 3: Biodiversity, environmental governance and climate adaptation

Note: Transferability should be understood as policy learning rather than direct replication across different socio-economic and ecological contexts.

Urban Governance and Climate Adaptation

The comparative analysis demonstrates that governance capacity significantly influences environmental outcomes.

Belgium has established comprehensive environmental legislation supported by strong institutions, technical expertise, financial resources, and active public participation. Municipal climate adaptation plans, sustainable mobility policies, flood management, and circular economy initiatives contribute to long-term environmental sustainability.

Mozambique has adopted national climate change and environmental policies; however, implementation remains constrained by financial limitations, institutional capacity, technical resources, and competing development priorities. Local governments, including those in Pemba, continue to strengthen environmental management despite these challenges.

International cooperation, technical assistance, and capacity-building programmes remain important mechanisms for improving local adaptation and environmental governance.

Public Awareness and Community Participation

In Deinze, public awareness campaigns, environmental education in schools, recycling initiatives, and community engagement support sustainable environmental practices and encourage responsible resource use.

In Pemba, environmental education initiatives have expanded through schools, community organizations, non-governmental organizations, and local authorities. However, broader public participation and sustained investment in environmental awareness remain necessary to improve waste management, pollution prevention, and ecosystem conservation.

Increasing environmental literacy can enhance community resilience and strengthen local support for climate adaptation measures.

Comparative Synthesis

- Climate change affects both cities despite their differing climatic and socio-economic conditions;
- Effective environmental governance substantially reduces vulnerability to environmental degradation;
- Sustainable urban planning and integrated waste management contribute to improved environmental quality;
- Coastal cities such as Pemba require additional investment in climate adaptation because of increasing exposure to sea-level rise, coastal erosion, flooding, and tropical cyclones;
- Ecosystem conservation, particularly the protection of mangroves and coastal habitats, represents an effective

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nature-based adaptation strategy; and

- International knowledge exchange between developed and developing countries can facilitate the transfer of good practices while adapting solutions to local contexts.

Analytical theme	Comparative finding	Implication for sustainable development
Climate resilience	Both cities face climate risks, but Pemba has greater coastal and socio-economic vulnerability.	Combine risk reduction with resilient infrastructure, ecosystem protection and preparedness.
Environmental pollution	Pollution-management capacity is comparatively stronger in Deinze, while Pemba faces more pronounced waste, drainage and wastewater challenges.	Improve integrated pollution prevention, collection, treatment, monitoring and enforcement.
Biodiversity	Both contexts require ecosystem protection, but Pemba's coastal and marine ecosystems are especially exposed to climate and human pressures.	Strengthen marine/coastal conservation and nature-based adaptation while maintaining urban green infrastructure.
Governance	Institutional capacity, financing, monitoring and enforcement strongly influence environmental outcomes.	Invest in local institutional capacity, inter-agency coordination, data systems and participatory governance.
Urban sustainability	Deinze demonstrates more established sustainable urban-management practices; Pemba faces rapid urbanization and infrastructure pressure.	Promote context-sensitive sustainable planning, drainage, waste services, green infrastructure and climate-risk screening.
International cooperation	The two cases provide opportunities for policy learning between European and African urban contexts.	Support knowledge exchange, technical cooperation, environmental education and climate-resilience financing.

Table 4: Synthesis of comparative findings and policy implications

Note: These conclusions reflect the comparative interpretation presented in the manuscript.

DISCUSSION

The findings are consistent with previous research indicating that climate risks are shaped not only by environmental exposure but also by governance quality, institutional capacity, infrastructure, and socio-economic conditions. Deinze illustrates how sustained investment in environmental management, urban planning, and public participation can reduce environmental risks and improve resilience.

Pemba, meanwhile, exemplifies the complex challenges faced by rapidly growing coastal cities in developing countries, where climate hazards interact with infrastructure deficits, demographic pressures, and financial constraints. These findings suggest that strengthening local institutions, improving waste management systems, investing in resilient infrastructure, and protecting coastal ecosystems should be prioritized.

The comparison does not imply that one city provides a universal model for the other. Rather, it highlights that effective adaptation requires context-specific solutions informed by local environmental, economic, and social conditions. Nevertheless, the experience of Deinze demonstrates the value of integrated planning, stakeholder engagement, and evidence-based environmental policy, while Pemba underscores the urgency of mobilizing national and international support to enhance resilience in highly vulnerable coastal regions.



CONCLUSION

This study comparatively examined the impacts of climate change and environmental pollution in Deinze (Belgium) and Pemba, Cabo Delgado Province (Mozambique), highlighting how differences in governance capacity, infrastructure, socio-economic conditions, and environmental policies influence urban resilience and sustainable development. Although the two cities differ considerably in their levels of economic development and institutional resources, both are increasingly affected by climate-related environmental challenges that require continuous adaptation and effective environmental management.

The findings demonstrate that climate change is a global phenomenon with localized impacts. Deinze experiences climate-related risks such as heatwaves, changing precipitation patterns, and localized flooding; however, these impacts are

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mitigated through effective environmental governance, integrated urban planning, modern waste management systems, and well-developed public infrastructure. In contrast, Pemba faces more severe environmental vulnerabilities, including coastal erosion, sea-level rise, flooding, tropical cyclones, marine pollution, and inadequate solid waste management. These challenges are intensified by rapid urbanization, limited financial resources, and infrastructure constraints.

The comparative analysis confirms that effective environmental governance is a key determinant of climate resilience. Strong institutions, environmental legislation, public participation, scientific monitoring, and long-term investment in sustainable infrastructure significantly improve the capacity of cities to respond to climate-related risks. Conversely, limited institutional capacity and financial constraints increase vulnerability and reduce the effectiveness of adaptation measures.

The study also emphasizes the critical role of ecosystem conservation in climate adaptation. Protecting mangrove forests, coastal habitats, freshwater resources, and urban green spaces contributes not only to biodiversity conservation but also to flood control, shoreline protection, carbon sequestration, and improved ecosystem services. Nature-based solutions should therefore be integrated into urban planning and environmental management strategies in both developed and developing countries.

Furthermore, the research highlights the importance of environmental education and stakeholder engagement. Active participation by governments, local communities, educational institutions, civil society organizations, and the private sector is essential for promoting sustainable environmental practices, strengthening public awareness, and encouraging behavioral changes that reduce pollution and improve resilience to climate change.

This study contributes to the scientific literature by providing a comparative perspective on environmental governance in two contrasting urban contexts. It demonstrates that while environmental challenges differ in scale and intensity, many of the underlying principles of sustainable environmental management—such as integrated planning, institutional cooperation, evidence-based policymaking, and community participation—are broadly applicable across different regions.

The findings support the achievement of the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land). They also reinforce the importance of international cooperation in addressing climate change through knowledge exchange, capacity building, technology transfer, and financial support for vulnerable regions.

Finally, this study recommends that future research incorporate primary data collection through field observations, household surveys, environmental monitoring, and stakeholder interviews to complement the secondary data used in this analysis. Longitudinal studies examining the evolution of environmental conditions and the effectiveness of adaptation policies over time would further strengthen understanding of climate resilience in both European and African urban environments. Such research would provide valuable evidence to support more effective environmental governance and sustainable development policies at local, national, and international levels.



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