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Designing Resilient Coastal Cities: A Case Study of Climate-Compatible Urban Development in Keta, Ghana

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Abstract

Purpose: Coastal cities worldwide are increasingly vulnerable to the impacts of climate change, particularly sea-level rise and extreme weather events. Keta, a historic city in southeastern Ghana, is facing severe challenges from coastal erosion, flooding, and rising tides. This article explores resilient urban planning and architectural solutions designed to mitigate these risks.

Methodology: By utilizing Keta as a case study, it investigates innovative policies, architectural designs, and sustainable infrastructure that can enhance climate resilience.

Findings: The study stresses the necessity for a shift from reactive measures to proactive, long-term solutions that integrate resilience into urban development.

Unique Contribution to Theory, Policy and Practice: Recommendations are provided for strengthening policy frameworks, adopting sustainable land-use practices, and promoting renewable energy integration to ensure the long-term sustainability of vulnerable coastal cities like Keta. Ultimately, this research makes available understandings into policy reform that supports national economic stability, promotes climate-compatible urbanization, and offers a model for resilience that may be adopted internationally to address similar climate challenges in coastal regions.

Keywords: *Coastal Resilience, Climate Change, Sea-Level Rise, Keta, Urban Planning, Sustainable Architecture*

Introduction

The increasing threat of climate change poses significant risks to global communities, particularly coastal cities that are vulnerable to rising sea levels, extreme weather events, and other environmental hazards. As one of the most pressing environmental challenges of the 21st century, climate change has altered weather patterns, increased the frequency and severity of storms, and led to rising sea levels that disproportionately impact coastal settlements worldwide. This phenomenon has far-reaching consequences not only for environmental stability but also for economic security, infrastructure resilience, and human safety.

In Ghana, the coastal regions, particularly the historic city of Keta, are experiencing the harsh impacts of these climate-related changes (Salifu, 2021). Once a bustling fishing harbor, Keta now grapples with severe coastal erosion and flooding that threaten its physical landscape and socioeconomic stability. This vulnerability extends beyond Keta, as similar patterns of erosion and flooding jeopardize various coastal communities along Ghana's southeastern shores (Tumawu et al., 2024). Such risks endanger livelihoods, exacerbate poverty, and increase the potential for displacement, putting additional stress on urban centers and fueling security concerns regarding displaced populations and land loss. Addressing these risks requires immediate attention to safeguard not only local but also national stability.

Globally, about 40% of the population lives within 100 kilometers of the coast, with 13% in low-lying coastal zones (Nhantumbo et al., 2023; Reimann et al., 2023). In Africa, particularly in West Africa, millions reside in these vulnerable areas, amplifying the risks of displacement, economic loss, and ecosystem degradation as sea levels rise (Neumann et al., 2015). Ghana's southeastern coast, including Keta, has been particularly affected, with recurrent flooding and rising tides leading to significant economic and social losses (Avornyo et al., 2023). Rising sea levels, driven by global warming and the melting of polar ice, have progressively encroached on land, devastating homes, livelihoods, and crucial infrastructure (Griggs & Reguero, 2021). The need for resilient urban planning and architectural solutions to secure these communities is not only urgent for Keta but crucial for the sustainable development and security of Ghana's entire coastal zone.

Despite the undeniable impact of climate change, there has been a slow adoption of policies and design frameworks aimed at building resilient cities that can withstand the risks associated with rising sea levels and severe weather conditions (Chakraborty et al., 2019). Much of the response has been reactive, with temporary measures focusing on damage mitigation rather than proactive, long-term solutions that integrate resilience into urban development. This lack of comprehensive planning has left cities like Keta increasingly vulnerable to coastal flooding, challenging the resilience of both local economies and critical national assets.

In response, the concept of climate-compatible development has gained traction globally, seeking to align climate change adaptation strategies with broader development goals (Taylor & Camaren, 2014). This approach emphasizes the integration of resilience and adaptability in urban

infrastructure and architectural designs, ensuring communities are better prepared for the uncertainties of climate variability. By incorporating adaptive and resilient design principles, it is possible to foster sustainable, healthy, and secure communities that can withstand environmental shocks while promoting economic and social well-being (Wholey, 2015).

This article focuses on Keta as a case study to explore how resilient architectural designs can be integrated into vulnerable coastal communities to reduce exposure to the risks of climate change. By examining policies, urban planning strategies, and architectural innovations, this study aims to present practical solutions that enhance resilience and adaptation in Keta and other similar coastal cities across Ghana and Africa. With the threat of coastal erosion and flooding intensifying, resilient design strategies must become central to urban development to secure the future of these regions and mitigate the associated socioeconomic impacts. Therefore, this research seeks to develop and propose innovative architectural solutions that incorporate resilience and adaptability into urban planning, aiming to protect flood-prone coastal areas from rising sea levels. It identifies policy frameworks, design principles, and architectural practices essential to safeguarding Keta's community and infrastructure, promoting sustainable development, economic stability, and national security for Ghana's coastal regions.

Literature Review

Coastal cities worldwide have long grappled with balancing human habitation and proximity to water. While coastlines offer abundant resources such as food, water, and transportation opportunities, they are also susceptible to natural hazards like flooding, coastal erosion, and the rising threat of climate change. These climate-induced risks are particularly severe for cities in low-lying areas, making resilience a critical focus for urban planning and architectural design. The city of Keta, in southeastern Ghana, exemplifies these challenges, as coastal erosion and sea-level rise threaten its survival. The need for resilient urban and architectural design solutions in such flood-prone areas is essential for sustainable development discussions and for understanding how similar strategies can inform resilience-building efforts worldwide, including in the United States.

Climate Change and Its Impacts on Coastal Areas

The onset of climate change introduces significant challenges for coastal regions globally, driven largely by greenhouse gas emissions that increase global temperatures and intensify extreme weather events such as floods, storms, and rising sea levels (Bolan, 2024). Coastal areas in West Africa, including Ghana, have been particularly vulnerable to these impacts. The United Nations Environment Programme (UNEP) reported that global sea levels rose by an average of 1.7 mm annually in the 20th century, a rate that increased to 3.1 mm per year between 1993 and 2003 (Gakpey, 2022). As sea levels rise, coastal communities face heightened risks of erosion, flooding, and storm surges, posing direct threats to inhabitants and necessitating a shift in urban design strategies.

Similar climate-related challenges exist for U.S. coastal cities, particularly in low-lying areas like Miami, New Orleans, and New York. According to the National Oceanic and Atmospheric Administration (NOAA), by 2050, U.S. coastal flood levels could rise as much as 12 inches or more due to sea-level rise and extreme weather events. This parallel highlights the importance of examining strategies employed internationally, as learning from places like Keta can help U.S. policymakers develop comprehensive resilience frameworks adapted to local conditions (NOAA, 2023).

Vulnerability of Coastal Communities

Coastal communities in developing countries, like Ghana, are especially vulnerable to climate change's impacts. Neumann et al. (2015) note that coastal populations have historically settled in these areas due to access to resources and transportation, although this strategic location also exposes them to water-level fluctuations, storms, and erosion. In Ghana, around 25% of the population lives in coastal regions, which constitute only 6.5% of the nation's land area (Appeaning, 2015). Along Ghana's coastline, human activities such as poor land use, deforestation, and infrastructure development have worsened erosion, with southeastern Ghana's Keta region experiencing erosion rates as high as 8 meters per year (Mann, 2023).

In U.S. many coastal cities, such as Miami, have dense populations in erosion-prone areas, increasing their vulnerability to similar hazards. In New Orleans, the combined impacts of storm surges and subsiding land have made the city particularly susceptible to flooding, underscoring the importance of learning from resilience strategies deployed globally to address U.S.-specific coastal challenges.

Resilience and Climate-Compatible Development

Resilient design is crucial for addressing climate change-related risks in coastal cities. Resilience in architecture refers to a structure's or community's ability to recover quickly, adapt to changing conditions, and maintain functionality (Castaño-Rosa et al., 2022). In coastal settings, resilient design includes structural and non-structural measures like buffer zones, elevated structures, and flood-resistant construction materials (Henrique, 2015).

Climate-compatible development aligns resilience with broader developmental goals, integrating climate adaptation into mainstream urban planning to promote sustainable growth (Taylor & Camaren, 2014). For instance, resilience-focused initiatives like the "Room for the River" program in the Netherlands and the "Making Space for Water" project in the UK illustrate how natural landscapes and flexible urban designs can help cities coexist with rising water levels rather than resisting them (Henrique, 2015). Similar approaches have informed U.S. projects, such as the New York "Rebuild by Design" initiative, which seeks to integrate natural buffers and sustainable architecture to protect against flooding while promoting urban livability.

International Case Studies on Resilient Design

Several cities worldwide have implemented resilient design principles to address climate-induced risks. Following Super-storm Sandy in 2012, New York City invested nearly $1 billion in shoreline protection projects incorporating landscape buffers and public green spaces to make these areas functional and flood-resistant (Wainwright, 2015). Similarly, Denmark's Copenhagen has implemented a "green and blue" infrastructure, which includes parks, retention zones, and storm-water management systems to address recurrent flooding (Christensen, 2017).

The Netherlands' "Amphibious Unit" project in Barendrecht showcases adaptable design by allowing buildings to float during floods and rest on the ground during dry periods (Castaño-Rosa et al., 2022). This innovation exemplifies how architectural designs that adapt to climate change uncertainties maintain livability, a model relevant to both Keta and U.S. regions vulnerable to flooding. U.S. cities could benefit from similar adaptive designs, especially in areas with fluctuating water levels, like the coastal neighborhoods of Florida and Louisiana.

Strategies for Resilience in Coastal Ghana

In Ghana, several strategies have been proposed to address climate challenges in coastal regions. The Keta Sea Defense Project, launched in the early 2000s, constructed breakwaters, groynes, and flood control gates to curb coastal erosion and flooding (Griggs & Reguero, 2021). However, these measures are primarily reactive, necessitating longer-term climate-compatible planning that encompasses adaptive infrastructure, flood-resistant materials, and natural barriers such as mangroves and wetlands.

Implementing a similar resilience approach can support U.S. coastal areas in balancing short-term mitigation with long-term adaptability. For example, the Louisiana Coastal Master Plan emphasizes restoration projects and elevating flood-prone structures, paralleling strategies seen in Keta's defense initiatives and underscoring the international applicability of resilience-focused urban planning. Moreover, policies that align climate adaptation with local development planning, as suggested for Keta, are likewise essential in the U.S. for integrating resilience across federal, state, and local levels, ensuring resources are directed toward vulnerable communities and promoting sustainable resilience-building (Chakraborty et al., 2019).

Methodology

- *Research Design*

This study used a mixed-methods approach, integrating quantitative and qualitative methodologies to analyze resilience strategies for coastal flooding in Keta. This design allows cross-referencing of data sources, enhancing the strength of the understandings on how sea-level rise impacts Keta's community, infrastructure, and economic sectors, such as tourism.

- *Sampling*

The sample included 95 residents from Keta's Ewe ethnic group, 22 urban planning professionals, and 100 tourists. This diversity allowed for a broad understanding of stakeholder views on resilience, making findings more transferable to similar socio-economic and geographic contexts, including the United States.

- *Data Collection*

Structured and semi-structured questionnaires and interviews captured both quantitative and qualitative data on community experiences with flooding, and expert understandings into resilience planning. This data collection design is versatile and applicable to other coastal regions, particularly where engaging multiple stakeholder groups is essential for developing a holistic understanding of urban resilience.

- *Data Analysis*

Data were analyzed using both qualitative and quantitative techniques. Quantitative data from surveys were statistically examined with tools such as SPSS and Microsoft Excel, employing descriptive statistics to summarize trends and key findings. Qualitative data from interviews and observational records underwent content analysis, with responses categorized into themes like flood risk, adaptation strategies, and community participation. This analytical approach is suitable for cross-regional comparisons, providing a basis for thematic analyses that can uncover common resilience challenges and successful strategies applicable across coastal areas.

- *Validity and Reliability*

To enhance the study's validity and reliability, data triangulation was used by collecting information from various sources, which allowed for cross-verification of findings. The questionnaires were pre-tested on a small group of respondents to ensure clarity, consistency, and relevance, reducing the potential for measurement error. Additionally, a peer review of the methodology and findings was conducted by climate resilience and urban planning experts to ensure accuracy and academic rigor. This approach to validity and reliability provides a methodological standard that can be adopted in coastal resilience research internationally, including in the United States.

Findings

- *Demographics*

The gender distribution revealed that 56% of the respondents are male, while 44% are female, indicating a relatively balanced representation of both sexes in the community. The age distribution of the respondents shows that a large portion of the population in Keta is young, with Keta's population is mainly young, with 54% of respondents aged 15 to 29. Furthermore, individuals between the ages of 30 and 59, who account for 41% of the respondents, are likely to be in their prime working years and play key roles in sustaining the local economy. The data on

the length of time respondents have lived in Keta offers important insights into the composition of the community. A significant portion (41%) of respondents have lived in Keta for only 1 to 4 years, while 21% have resided in the town for over 20 years. Keta's economic landscape is diverse, as reflected in the occupational data of the respondents. Students make up 21% of the population, followed by traders (16%), fishermen (10%), fishmongers (8%), and various other occupations. This diversity suggests that resilience planning in Keta must take into account the specific vulnerabilities of different sectors. This demographic composition indicates the potential for rapid urban growth, a challenge also seen in cities like Miami and New York, where young populations drive economic demand but increase vulnerability in flood-prone areas.

Table 1: Demographic Distribution of Respondents

Demographics	Categories	Percentages (%)
Gender	Male	56
	Female	44
Age	15 – 29 years	54
	30 – 44 years	23
	45 – 59 years	18
	60 – 75 years	4
	Above 75 years	1
Years Spent in Keta	1 – 4 years	41
	Over 20 years	21
Occupation of Residents	Student	21
	Traders	16
	Fishermen	10
	Drivers	6
	Fishmongers	8
	Carpenters	5
	Other Occupations	34

- *Policies Guiding Development in Flood-Prone Urban Areas*

Keta is a coastal community located between the Keta Lagoon and the Atlantic Ocean, making it highly vulnerable to rising sea levels. The study identified that although national policies exist for coastal management and disaster risk reduction, their application in Keta remains limited due to inadequate funding, weak institutional coordination, and limited local capacity to implement long-term resilient infrastructure. Local authorities, including the Assistant Municipal Chief,

acknowledged efforts to educate the community on climate change but pointed out that economic constraints hinder the residents' ability to adapt effectively.

Table 2: Respondents Profile Illustrating Stakeholder Involvement

Respondent	Numbers Sent	Number Obtained
Local inhabitant	95	95
Asst. Municipal Chief	1	1
Architect	4	4
Planner	4	4
Mechanical Engineer	4	4
Civil Engineer	4	3
Urban sociologist	4	4
Oceanographer	1	1
Tourist	100	100

Moreover, professionals such as architects, planners, and engineers recognized the threats posed by sea level rise but highlighted the lack of integrated planning. The Keta Sea Defence Project, while a significant intervention, is not seen as a comprehensive solution, as long-term planning should encompass sustainable land use management and stricter enforcement of coastal zoning regulations. The need for integrated coastal defense in Keta reflects similar requirements in U.S. cities, such as Miami and New York, where sea-level rise demands both physical barriers and community-based resilience planning. Again, Keta's coastal management needs mirror those of cities like New Orleans, where flood risk management requires both physical infrastructure and strong community adaptation measures.

Figure 1: Keta before the sea defense project (Baird, 2006)

Figure 2: Keta after the construction of the sea defense project (Baird, 2006)

- *Adopting Lessons for Improved Resilience in Architectural Design*

Architectural and planning professionals agree that incorporating adaptive design into Keta's urban planning is essential to mitigate the risks posed by climate change, particularly in flood-prone areas. Lessons from international case studies suggest that elevated buildings, constructed on pile foundations or stilts, offer a practical and resilient solution. These structures allow

floodwaters to flow underneath without damaging the building, reducing the overall impact on the environment and preventing soil erosion.

In addition, the materials used in such construction must be resistant to water and corrosion, with professionals recommending the use of treated wood, bamboo, and lightweight concrete. These materials are locally available, making them economically feasible, while also providing durability in Keta's unique environmental conditions.

Renewable energy solutions, particularly solar and wind energy, are also critical to enhancing resilience. Given Keta's exposure to unpredictable weather patterns, integrating renewable energy into the architectural design would reduce reliance on external power sources, which can be disrupted by flooding. Off-grid solar systems and wind turbines should be considered as essential components of new development projects in Keta, as they provide reliable energy even in the event of natural disasters.

Elevated building designs, effective in Keta, are increasingly relevant in cities like Charleston and Galveston, where similar approaches are essential to adapt to frequent flooding and storm surge impacts. Building elevated structures on stilts, a strategy suitable for Keta, could be adapted in cities like Miami, where similar designs mitigate flood damage. Moreover, the use of water-resistant materials and renewable energy sources provides a model for other coastal cities facing rising sea levels.

Figure 3: Wooden Platform (Pier)

Figure 4: Towards the bar and seating area

Professionals also emphasized the importance of storm water management systems and evacuation routes in the architectural design process. Dense development should be encouraged to limit urban sprawl, ensuring that available land is used efficiently while reducing the community's exposure to flood hazards. Moreover, robust drainage systems must be integrated into urban plans to control and manage rainwater effectively, reducing the risk of floods.

The cultural background plays a pivotal role in shaping resilience strategies. Many Keta residents, particularly the older generation, have strong ties to traditional building methods and designs. Therefore, while professionals advocate for modern, resilient architectural solutions, these should be sensitively merged into local practices. For example, using local materials such as bamboo and

thatch in conjunction with modern techniques can ensure that new buildings remain culturally relevant while still being resilient to climate change.

- *Current Conditions in Keta*

Keta's physical and socio-economic conditions present significant challenges to resilience planning. Despite the construction of the Keta Sea Defence Project, the town continues to face threats from rising sea levels, with scientific models forecasting that even a 1-meter rise could lead to substantial land loss by 2100. More severe rises, such as 3 meters or 5 meters, would severely impact the town, and a 9-meter rise would result in the complete submersion of Keta. The figure below shows the Sea Level Rise Simulations (1m, 3m, 5m, and 9m) projections, based on geographic and oceanographic data.)

Keta's vulnerability to rising seas and coastal erosion reflects broader issues faced by other coastal areas, like Charleston, where rapid sea-level rise threatens local economies and the stability of shoreline communities. Also, Keta's resilience challenges echo those of other coastal areas worldwide. Like New York's waterfront communities, Keta's economic vulnerability to rising seas impacts industries critical to local and regional economies, highlighting a global need for resilient urban planning.

Figure 5: 1m Sea Level Rise

Figure 6: 3m Sea Level Rise

Figure 7 5m Sea Level Rise

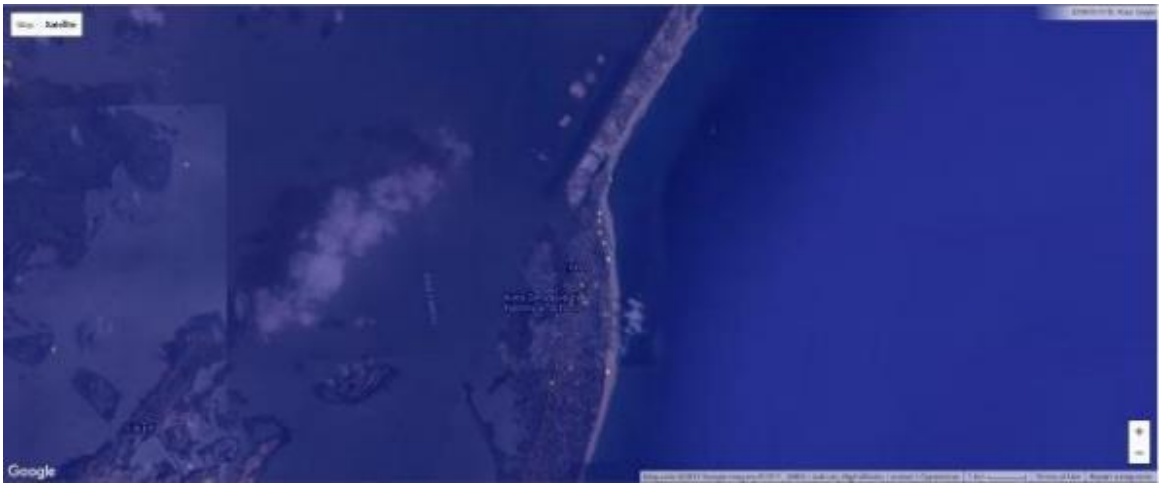

Figure 8: 9m Sea Level Rise

The population of Keta has experienced remarkable demographic shifts in recent decades, with a growing number of younger residents less concerned with cultural attachment to the land and more focused on economic opportunities. This complicates relocation discussions, as while younger residents may be more open to moving, the older generation remains steadfastly attached to their ancestral homes. This demographic shift necessitates the inclusion of younger voices in planning and policy discussions, as their priorities may differ significantly from those of the older population.

Table 3: Migration and Land Loss Data

Category	Percentage/Data
Population Increase since 2010	14% increase (from 8,726 in 2010 to 20,119 by recent estimates)
Primary reasons for migration	Coastal erosion and land loss
Major migration destinations	South along the coast to Dzelukofe and surrounding areas
Land loss due to erosion	Over two-thirds of Keta's land mass has been eroded during the 20th century
Years spent in Keta	41% of residents have lived in Keta for over 20 years
New migrants (1-4 years)	21% of residents have moved to Keta in the last 1-4 years

The town's economy remains largely agrarian, with fishing, salt production, and petty trading being the predominant activities. However, these industries are highly vulnerable to environmental changes, particularly rising sea levels and flooding. As coastal land continues to erode, fishing grounds and salt pans are increasingly threatened, reducing the economic viability of these activities. In turn, this reduces the community's ability to invest in resilience measures, creating a vicious cycle of vulnerability.

Moreover, Keta's housing stock is poorly suited to withstand future environmental challenges. Many homes are constructed from non-durable materials and are not elevated, making them highly susceptible to flooding. Data collected from the field show that housing density is relatively high, with 36.6% of households having between 5-9 occupants, and a significant portion of residents live in single-room dwellings. Additionally, with over two-thirds of Keta's land lost to coastal erosion, the housing conditions are increasingly vulnerable to flooding, as many homes are poorly constructed and not elevated

Table 4: Housing Density Data

Number of People per Household	Percentage of Households (%)
1 – 4 persons	9
5 – 9 persons	36.6
10 – 15 persons	12
16 – 20 persons	17
Above 20 persons	21

Efforts to improve Keta's resilience must therefore address not only physical infrastructure but also the socio-economic challenges that limit the community's adaptive capacity. Policies that support economic diversification, particularly in sectors less vulnerable to climate change, such as tourism or renewable energy, could provide the financial stability needed to implement long-term resilience measures.

- *Architectural Solutions to Enhance Resilience in the Keta Settlement*

Elevated Building Designs: Building structures on stilts or pile foundations is the most critical solution for mitigating flood risks. This design allows floodwaters to flow underneath buildings, preventing structural damage while minimizing soil erosion.

Water-Resistant Materials: Using durable, water-resistant materials such as treated wood, bamboo, and lightweight concrete ensures that buildings can withstand flood conditions. These materials are locally available, making them cost-effective and practical for Keta.

Storm-water Management Systems: Developing robust drainage systems to control rainwater and prevent flash floods is essential. Integrating green infrastructure like permeable pavements will also help in managing excess water and reducing the risk of urban flooding.

Renewable Energy Integration: Incorporating off-grid solar and wind energy systems provides a reliable energy source during natural disasters. These systems ensure that critical infrastructure remains functional, even in the event of floods.

Sustainable Land Use and Zoning: Implementing coastal zoning regulations and encouraging high-density development in safer areas is crucial. This strategy limits urban sprawl and minimizes exposure to flood-prone regions, ensuring a more resilient urban environment.

While tailored to Keta, these architectural solutions, such as renewable energy integration and water-resistant materials, can offer valuable lessons for U.S. cities like New Orleans, Galveston, and Charleston, where resilience to flooding and storm events remains a critical concern. These architectural solutions, while tailored to Keta, offer applicable lessons for cities such as New York and Miami, where renewable energy and flood-resistant construction can strengthen urban resilience to climate impacts.

Discussion

The findings from Keta, Ghana, offer a stark reminder of the multifaceted challenges facing coastal communities, particularly in the face of rising sea levels. As shown by the demographic data, Keta's population is composed largely of younger individuals in their productive years, but their livelihoods are directly tied to environmental conditions that are under significant threat due to climate change. This stresses the necessity of integrating both local realities and broader resilience strategies to safeguard the town's future.

- *Connecting the Findings to Resilience Theories*

Urban resilience theories, such as the concept of "*transformational adaptation*" discussed by Adger et al. (2020), emphasize the importance of structural shifts in urban planning to accommodate long-term climate challenges. In Keta's case, while the Keta Sea Defense Project represents an essential step toward protecting the city, it is insufficient on its own without further integration of adaptive architecture and planning strategies. This reflects literature that underscores the need for dynamic, long-term planning in coastal regions (O'Brien et al., 2022), which emphasizes not only physical infrastructure but also socio-economic measures that enhance community resilience. For example, many professionals cited in the study recommend the adoption of elevated buildings and storm water management systems, which aligns with the notion of "*blue-green infrastructure*" proposed by Johnson and Mehring (2021). These are systems that not only mitigate flooding but also preserve the natural environment, thereby promoting sustainability.

- *Policy Implications and Development*

The findings of this study shows the critical need for reinforced policy support in building resilient coastal communities, as evidenced in the case of Keta, Ghana. Although Ghana has coastal management policies in place, effective implementation in regions like Keta is often stymied by insufficient financial resources and limited institutional coordination. This aligns with Satterthwaite's (2018) observation that developing nations frequently face a disconnect between policy formulation and actual implementation, hampering urban resilience efforts.

From a U.S. policy perspective, similar challenges have been noted in regions vulnerable to climate impacts, such as the Gulf Coast and southeastern seaboard, where coordination across local, state, and federal levels is vital. U.S. frameworks, particularly those developed by the Federal Emergency Management Agency (FEMA) and the National Oceanic and Atmospheric Administration (NOAA), advocate for shared governance structures that facilitate coordination across all government levels, supporting Pelling's (2019) emphasis on decentralized governance. Applying these concepts to Ghana, particularly in Keta, could facilitate targeted disaster preparedness funding and technical resources, enabling local authorities to take ownership of resilience-building activities, such as raising housing infrastructure and expanding drainage systems.

This study also points the necessity of revising zoning regulations to prevent expansion into high-risk flood zones, as noted by Campbell et al. (2021). U.S. cities have addressed similar concerns through strict zoning policies and building codes, mandating construction standards that mitigate flood risk. For example, cities like New York have adopted flood-resistant construction regulations under the FEMA Building Resilient Infrastructure and Communities (BRIC) program, which prioritizes infrastructure fortification in high-risk areas. Similar zoning laws in Keta could reduce risk exposure while promoting climate-compatible development.

The resilience measures from Keta's Sea Defense Project, including breakwaters, flood gates, and zoning regulations, align with U.S. federal programs like FEMA's BRIC initiative. This alignment emphasizes the feasibility of integrating similar strategies into U.S. frameworks to protect coastal regions. With regard, U.S. policy can benefit from parallel efforts in sustainable infrastructure and flood management under BRIC, especially in coastal areas like New Orleans and Miami, which face increasing risks of flooding and storm surges.

- *Regional and National Policy Influence*

On a broader scale, the findings from Keta can inform policy development not only in Ghana but across West Africa. ECOWAS, for instance, could adopt regional policies focused on coastal resilience, as advocated by Okereke and Charles (2020). A regional approach would facilitate shared resources, data, and best practices between member states that face similar climate threats. Ghana, in particular, should look to international case studies where coastal cities have successfully integrated resilience strategies into their urban planning, such as in the Netherlands' Delta Works project (Hauer et al., 2022), which balances flood defense with sustainable urban growth.

- *Economic Benefits of Resilience Strategies for the U.S.*

Incorporating resilience strategies akin to those in Keta can yield substantial economic benefits for the United States, particularly in reducing disaster recovery costs, generating employment in renewable energy sectors, and securing long-term infrastructure investment returns. For instance, studies indicate that for every dollar spent on resilience, communities can save six dollars in future recovery costs (Mukherjee, 2023). This investment aligns with BRIC's objectives to support projects that create job opportunities and enhance local economic stability."

Specific Benefits:

Cost Savings: "Proactive resilience measures can reduce financial strain on disaster recovery budgets, as Keta's project demonstrated with its breakwaters and groynes."

Job Creation: "Renewable energy installations and adaptive infrastructure create opportunities within coastal communities."

Investment Returns: "Long-term resilience minimizes infrastructure losses, which translates into economic savings that support public safety and economic security."

- *Policy Recommendations*

Given the findings and the established literature on climate resilience and governance, several key policy recommendations can be proposed:

Strengthened Coastal Management Policies: In line with the recommendations of Brown and Riebeek (2021), Keta's resilience plan should be enhanced by stronger enforcement of existing coastal management laws, supplemented by increased funding specifically earmarked for climate adaptation projects.

Adoption of Sustainable Land Use Practices: Local authorities must implement stricter zoning laws, as noted by Carter and Turner (2022), to prevent urban sprawl in vulnerable coastal areas. High-density development in safer inland zones, combined with incentives for relocating vulnerable communities, would significantly reduce future risk.

Investments in Renewable Energy: The study identified renewable energy, particularly solar and wind, as vital to Keta's resilience. This is supported by Hughes and Koehler (2020), who argue that integrating renewable energy into urban planning not only mitigates reliance on fossil fuels but ensures the continuity of essential services during natural disasters.

Diversification of Economic Activities: Supporting the diversification of Keta's economy beyond fishing and salt production, particularly through tourism and renewable energy, aligns with the recommendations by Adger et al. (2020), who stress the importance of economic diversification in enhancing community resilience.

Conclusion

This study on climate-compatible urban development in Keta, Ghana, underscores the critical importance of resilient coastal planning. With climate change posing heightened threats to coastal communities through rising sea levels, flooding, and erosion, the case of Keta illustrates the urgent need for integrated, forward-thinking approaches to urban resilience. The relevance of this research extends beyond Keta, offering insights into national economic, social, and environmental stability. Economically, implementing resilient infrastructure in Keta promotes sustainable livelihoods and strengthens key sectors such as fishing, tourism, and renewable energy. This resilience directly benefits national economic security by protecting vital industries against climate-related disruptions. Socially, the adoption of adaptive building designs and robust storm-water management systems safeguards the well-being and safety of residents, reducing displacement and social instability. Environmentally, integrating renewable energy sources and preserving natural flood barriers aligns local development with broader sustainability goals, contributing to Ghana's commitments to climate action and environmental stewardship. Proactive adoption of resilience measures, as seen in Keta, will align with the United States' goals for

environmental sustainability, economic resilience, and public safety, ensuring that vulnerable communities are better protected against climate change impacts.

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