Management of Meteorological and Hydrological Hazards in the East Coast of Africa

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ABSTRACT

Meteorological and hydrological hazards such as tsunamis and cyclones remain development challenges, especially in the East Coast of Africa, due to the high level of vulnerability and limited adaptive capacity (UNDRR, 2023; IPCC, 2022). Communities already experiencing these disasters often lack the institutional capacity and socio-economic resilience required to implement effective mitigation strategies or engage in comprehensive disaster risk reduction. This study critically examines the complexity of managing tsunamis and cyclones on the East Coast of Africa. It focuses on the vulnerability and risk exposure of areas along the East African coast to weather- and water-related hazards. It evaluates the current systems and institutions responsible for managing these threats and identifies key gaps, including weak infrastructure, limited funding, and poor coordination. Employing a qualitative meta-synthesis grounded in the PRISMA framework, the research delineates seven core vectors in the management of meteorological and hydrological hazards, namely: vulnerability assessment, risk assessment, preparedness, mitigation, response, rehabilitation and reconstruction. Finally, it puts forward recommendations to help strengthen disaster preparedness and response. The overarching aim is to foster a more proactive and unified approach to addressing climate risks in one of the region's most at-risk zones.

Key words: Meteorological, Hydrological and Hazards

INTRODUCTION

The East Coast of Africa, which stretches from Somalia to Mozambique and Madagascar, is increasingly vulnerable to complex high-impact meteorological and hydrological hazards due to climate variability, rising sea levels, and inadequate infrastructure. This region is particularly susceptible to tsunamis, and tropical cyclones, which have become more intense and frequent due to the rising ocean temperatures and shifting weather patterns (Miklyaev & Olubamiro, 2025). These hazards have severe implications for coastal populations, infrastructure, marine ecosystems, and national economies. Low-lying coastal settlements, often densely populated and lacking resilient infrastructure, are at high risk of storm surges, flooding, and wind damage.

Madagascar alone experiences an average of 1.5 to 2 cyclones annually, with more than 250 cyclone-related fatalities reported in the last decade and over 500,000 individuals displaced due to storm-induced devastation. According to the WMO (2023) and World Bank (2020), the 2019 tropical cyclone season was particularly catastrophic, as Cyclone Idai and Cyclone Kenneth collectively accounted for over 1,300 deaths, displaced approximately 2.2 million people, and inflicted an estimated USD 2.2 billion in economic losses across Mozambique, Zimbabwe, and Malawi. In 2022, Cyclone Batsirai caused over 120 fatalities and severely affected more than 250,000 residents in Madagascar. Although tsunamis are less frequent, their impact is profound when they occur. The 2004 Indian Ocean tsunami resulted in 298 deaths in Somalia, destroyed approximately 1,200 homes, and affected over 50,000 individuals along the East African coastline. Additionally, according to the UNDRR (2022) projections indicate that sea surface temperatures in the southwest Indian Ocean may rise by 1.5°C to 2°C by 2100, exacerbating the intensity of cyclones and the magnitude of storm surges. Despite the escalating threat landscape, adaptive capacity and early warning systems remain critically underdeveloped in

Somalia, coastal Kenya, and northern Mozambique, heightening the vulnerability of millions to hydro-meteorological disasters.

Small island nations such as Comoros and Madagascar, along with coastal areas in Kenya, Tanzania, and Mozambique, are very vulnerable. In many instances, inadequate early warning systems, limited institutional capacity, and poor urban planning exacerbate the human and economic toll of these disasters (Mawren, Hermes & Reason, 2022). Kong et al. (2006) observed that the 2004 Indian Ocean tsunami marked a pivotal moment, highlighting the catastrophic potential of undersea seismic activity in a region with underdeveloped early warning capabilities and limited regional coordination.

In recent years, major cyclonic events, especially Idai and Kenneth (2019) further highlighted the fragility of national and transnational disaster response systems. These events deepened humanitarian crises, disrupted food systems and livelihoods, and caused severe damage to vital infrastructure (WMO, 2020). To effectively manage these risks, it is critical to understand the region's vulnerabilities and assess the associated risks. In this context, the imperative for robust hazard management frameworks becomes increasingly more pressing. It necessitates the integration of multi-hazard early warning systems, transboundary governance mechanisms, climate-adaptive planning, and resilience-building strategies rooted in communities themselves. This isn't just a matter of logistics or technical expertise, it's a strategic necessity for the long-term stability and development of the region, particularly as climate-related threats continue to grow in frequency and intensity.

LITERATURE REVIEW

Vulnerability Assessment

Vulnerability assessment identifies the populations, systems, and infrastructure most at risk from meteorological and hydrological hazards such as tsunamis and cyclones along the East African coast. Vulnerability varies based on geographic exposure, socio-economic factors, infrastructure strength, and institutional capacity. Molua et al. (2020) argue that Coastal communities, fishing economies, and informal settlements are especially at risk, with children, the elderly, and persons with disabilities facing heightened vulnerability

Table 2.1: Vulnerability Assessment

Element at Risk	Vulnerability Factors	Level of Vulnerability	Remarks
Coastal populations	High population density, poor housing, and low evacuation awareness	High	High exposure to storm surges and wave impact
Informal settlements	Poor construction, lack of infrastructure, and proximity to coastlines	High	Prone to destruction and displacement during extreme weather events
Tourism infrastructure	Hotels on beachfronts, limited disaster-proofing	Moderate to High	Economic losses and visitor safety are major concerns
Fishing communities	Livelihoods depend on the sea, lack of early warning systems	High	At sea during hazard onset, low recovery capacity
Children and the elderly	Physical vulnerability, limited mobility, health risks	High	Disproportionate mortality and injury rates in past disasters
Transport and port facilities	Located on coastlines, vulnerable to high winds and water damage	Moderate to High	Critical for trade and response logistics

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Hospitals and schools	May not be built to withstand cyclonic winds or flooding	Moderate	Disruption in essential services during and after hazard events
Critical infrastructure (power, water)	Above-ground power lines, coastal pipelines are susceptible to flooding and wind	High	Power and water service interruptions have cascading effects
Agricultural lands (coastal plains)	Susceptible to saltwater intrusion and flooding	Moderate	Impacts food security and income in coastal zones
Persons with disabilities	Inaccessible shelters, exclusion from warning systems	High	Need for inclusive preparedness and evacuation planning

Source: Adapted and modified based on Thirumurthy et al. (2022).

Vulnerability in the East African coastal context is shaped by a combination of physical exposure, socio-economic status, and infrastructure resilience (Onyango & Karanja, 2023). It underscores the importance of inclusive and multi-sectoral risk reduction efforts tailored to the unique needs of each vulnerable group and system. The vulnerability matrix identifies the most at-risk populations, infrastructure, and systems along the East African coast when exposed to tsunamis and cyclones. These events, though varying in frequency, have devastating consequences when they occur, especially in regions where preparedness and structural resilience are limited. Kithiia and Dowling (2010) profound that Coastal populations are among the most exposed due to their proximity to the ocean, which places them directly in the path of storm surges and tsunami waves. Many of these communities live in low-lying areas that offer little protection from flooding or high winds. In addition, a general lack of public awareness about evacuation protocols contributes to delayed responses, increasing casualties during such events.

Informal settlements, often located on marginal and hazardous land, are highly vulnerable due to poor construction standards, inadequate drainage, and the absence of early warning systems (Daraja, 2021). These communities typically lack access to secure shelters or reliable communication networks, making evacuation and survival during storms particularly difficult. The destruction of homes in such areas often leads to displacement and long-term socioeconomic hardship (Mugeni, 2023). According to the IFRC (2024), the tourism industry, vital to economies in coastal nations like Kenya, Tanzania, and Mauritius, is also at risk. Many hotels and resorts are built close to the shore to attract tourists, but are rarely fortified against major storms. Structural damage and disruption to services during cyclones not only endanger lives but also result in massive economic losses and long recovery periods.

Similarly, MTI (2023) established that fishing communities, whose livelihoods depend on daily access to the sea, face dual vulnerabilities: physical exposure while at sea and economic insecurity in the aftermath of storms. Most small-scale fishers lack the communication tools or radar systems to receive timely warnings, making them highly susceptible during sudden hazard events. The UN Women & UNESCO (2021) observe that, children, the elderly, and persons with disabilities form particularly vulnerable groups. These populations often have limited mobility and may be dependent on caregivers for evacuation. In past disasters globally, such groups have shown disproportionately high fatality rates. Inclusive planning such as ensuring accessibility of shelters, transport, and information is often lacking in the region, further heightening their risk. Transport and port facilities, critical for regional commerce and emergency logistics, are often situated along the coastline (IFRC, 2024). These facilities are vulnerable to flooding and high winds, which can severely disrupt relief supply chains and economic activities in the aftermath of a disaster. Hospitals and schools, while essential for response and community stability, are often not designed to withstand high wind loads or flooding. Damage to these institutions not only compromises public safety but also delays the recovery process (Cell Press, 2024).

Cell Press (2024) highlights that Critical infrastructure such as power lines, communication towers, and water supply systems are usually above ground or near the coast. These assets are frequently damaged during extreme weather events, leading to power outages, water contamination, and communication blackouts, conditions that exacerbate human suffering during and after the hazard. Lastly, coastal agricultural lands are increasingly at risk

of saltwater intrusion and flooding from storm surges (Wei et al., 2025). This not only reduces crop yields but can render land infertile for future planting, posing long-term threats to food security and rural livelihoods.

Risk Assessment

Risk assessment evaluates the likelihood of a hazard occurring and the severity of its potential impact on people, infrastructure, and the environment (van Niekerk & Nemakonde, 2017). In the East Coast of Africa, the risk of tsunamis, and tropical cyclones is influenced by regional climate patterns, tectonic activity, sea surface temperatures, and socio-economic vulnerabilities. While tsunamis are rare, they pose a catastrophic risk when they do occur, particularly in countries like Somalia, Kenya, and Tanzania, which lie near tectonic plate boundaries. Tropical cyclones, which frequently affect Madagascar, Mozambique, and the Comoros Islands, have shown increasing intensity due to climate change, leading to repeated damage to infrastructure, loss of lives, and displacement of populations. The following risk matrix combines hazard likelihood and severity to determine overall risk levels for each hazard type across different regions of the East African coast.

Table 2.2: Risk Assessment Matrix

Hazard	**Probability of Occurrence**	**Severity of Impact**	**Overall Risk Level**	**Remarks**
Tsunami (urban coastlines)	Low	Very High	Moderate to High	Rare but extremely destructive to coastal cities with dense populations
Tsunami (rural coastlines)	Low	High	Moderate	Less infrastructure but high exposure and lower warning capacity
Cyclone (Madagascar, Mozambique)	High	Very High	Very High	Frequent landfalls causing widespread damage and displacement
Cyclone (Kenya,Tanzania coastlines)	Moderate	High	High	Increasingly frequent; infrastructure not adapted for cyclonic events
Storm surge (low-lying settlements)	High	High	Very High	Common during cyclones; causes flash floods and saltwater intrusion
Flooding (post-storm rainfall)	High	Moderate	High	Inadequate drainage and deforestation worsen flood risk
Wind damage (informal settlements)	High	High	Very High	Poor housing construction increases vulnerability to strong winds
Damage to critical infrastructure	Moderate	High	High	Power, water, and transport systems often fail during storms
Displacement of population	High	Moderate to High	High	Recurring in cyclone-prone areas like Beira (Mozambique) and Toamasina
Economic disruption (tourism, fishing)	Moderate	High	High	Coastal economies suffer prolonged losses after hazard events

Source: Adapted and Modified from Hoque et al. (2019).

The risk assessment matrix evaluates the combined effect of two dimensions: the probability of hazard occurrence and the severity of its impact on communities, infrastructure, and ecosystems. For the East Coast of Africa, spanning countries like Somalia, Kenya, Tanzania, Mozambique, Madagascar, and island nations such as Comoros and the Seychelles, this matrix highlights the pressing threats posed by tsunamis and tropical

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cyclones, and their cascading effects. Tsunamis, though rare along the East African coast, pose a significant threat especially in densely populated urban coastal areas. Cities like Mombasa (Kenya) and Dar es Salaam (Tanzania) have critical infrastructure located near the shoreline and limited preparedness for tsunami-specific events. This combination of high exposure and low readiness places these cities at a moderate to high risk. In rural coastal regions, while infrastructure is less dense, the risk remains notable due to limited capacity for early warning, evacuation, and emergency response (Taye & Dyer, 2024).

According to UNDRR (2022), tropical cyclones are a much more frequent and dangerous hazard, particularly in Madagascar and Mozambique. These countries regularly experience intense storms, bringing heavy rainfall, strong winds, and widespread flooding. As a result, the overall risk level is very high. Each cyclone can lead to severe destruction, including loss of life, injuries, collapsed infrastructure, and prolonged economic disruption. Although the coastal regions of Kenya and Tanzania have historically been less prone to cyclones, recent trends suggest an increase in both frequency and intensity, likely linked to changing climate patterns (Nicholls et al., 2021). These areas are not well adapted to withstand cyclonic events. Building materials are often substandard, drainage infrastructure is underdeveloped, and early warning systems cover only limited areas. The UN-Habitat (2020) observes that this often leads to heightened vulnerability, especially to wind damage and flash floods.

Storm surges are a common and particularly destructive consequence of cyclones. Coastal settlements in low-lying areas—such as Beira (Mozambique) and Toamasina (Madagascar)—are often inundated by rising seas during storms (GFDRR, 2019). These surges introduce saltwater into freshwater systems and agricultural lands, affecting both water quality and food production (FAO, 2022). Storm surges are therefore classified as very high-risk hazards due to their frequency and devastating effects.

Flooding caused by heavy rainfall after storms is also a major concern, particularly where deforestation has left hillsides unstable and where urban planning is weak. Poor drainage systems in many coastal towns exacerbate the risk, often leading to flash floods, building collapses, and outbreaks of disease (IPCC, 2022). Informal settlements on the outskirts of cities are especially vulnerable. High population density, poor-quality housing, and lack of protective infrastructure mean these areas suffer extensive damage during storms, placing them in the very high-risk category (UNEP, 2021).

Critical infrastructures, such as power lines, hospitals, bridges, and water systems, are often located along coastal corridors for accessibility, but are not always built to withstand extreme weather events. Damage to these systems not only disrupts service delivery but hampers emergency response, placing them at high risk (World Bank, 2021). Finally, the matrix includes the economic and social impacts, such as population displacement and disruption of coastal livelihoods, like tourism and fishing. These consequences are frequently observed following major storms, with thousands displaced, businesses shut down, and food insecurity rising, justifying their high risk rating (IOM, 2021). This matrix demonstrates that the East Coast of Africa is increasingly exposed to complex, overlapping hazards, with cyclonic events posing the most consistent and destructive threat. Tsunamis remain a concern due to their devastating potential, while storm surges, flooding, and infrastructure vulnerabilities multiply the severity of impact. This understanding is essential for guiding the preparedness, mitigation, and response strategies that follow.

Preparedness

Preparedness is the cornerstone of effective disaster risk management, particularly in regions like the East Coast of Africa, where communities face recurrent threats from meteorological and hydrological hazards such as tsunamis and cyclones. Mashao et al. (2023) argue that preparedness encompasses proactive planning, capacity building, public education, and institutional coordination aimed at minimizing disaster impacts and facilitating rapid, organized responses when hazards occur.

At the heart of preparedness is the establishment of an early warning systems. For cyclones, meteorological agencies in the region must invest in real-time satellite monitoring, oceanic buoy data, and radar systems to detect tropical cyclones and predict their paths. Boluwade (2020) contends that regional cooperation through institutions such as the Intergovernmental Authority on Development (IGAD) and the Indian Ocean Commission can enhance data sharing and improve forecasting accuracy. For tsunamis, seismic sensors and tide gauges must

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be linked to regional tsunami warning centers to issue timely alerts. However, detection alone is not enough; these systems must be connected to robust and reliable communication networks, including mobile alerts, community sirens, local radio, and social media to ensure that warnings reach even the most remote or marginalized populations. Community engagement and public awareness are equally critical in the preparedness process. Coastal communities must be educated on the nature of these hazards, warning signs, evacuation procedures, and safe zones. Schools, religious institutions, and local leaders can play a vital role in disseminating this information. Regular evacuation drills and simulations should be conducted, especially in high-risk areas, to familiarize residents with emergency procedures and build trust in response systems (Ayugi et al., 2020).

Preparedness also involves institutional and infrastructure readiness. Local and national disaster management agencies should develop and maintain comprehensive contingency plans that outline roles, responsibilities, evacuation routes, and emergency shelter locations. These plans must be reviewed and updated periodically to reflect emerging risks and lessons learned from past disasters. Health facilities in vulnerable areas should be equipped to handle mass casualties, with standby stocks of essential medical supplies, backup power systems, and safe water sources (Thoithi et al., 2022). Prepositioning of emergency supplies is another vital aspect of preparedness. Governments and humanitarian agencies must ensure that stockpiles of food, water, medicine, temporary shelters, and other essentials are strategically stored near high-risk zones for quick deployment. Relief workers and first responders should receive continuous training in logistics, search and rescue, first aid, and emergency communications to ensure rapid and efficient mobilization when disasters strike (Comte at al., 2016).

In addition to physical and institutional measures, financial preparedness is increasingly recognized as essential. Governments should allocate contingency funds specifically for disaster response, while promoting risk transfer mechanisms such as insurance schemes for farmers, businesses, and homeowners. This ensures faster recovery and reduces long-term dependency on external aid (Obura, 2006). Preparedness for meteorological and hydrological hazards in the East Coast of Africa must be holistic, inclusive, and coordinated. By combining scientific forecasting, local knowledge, public education, and institutional readiness, countries in the region can significantly reduce the human, economic, and environmental toll of tsunamis and cyclones. Proactive preparedness not only saves lives but also enhances the resilience of communities, economies, and ecosystems against future hazards.

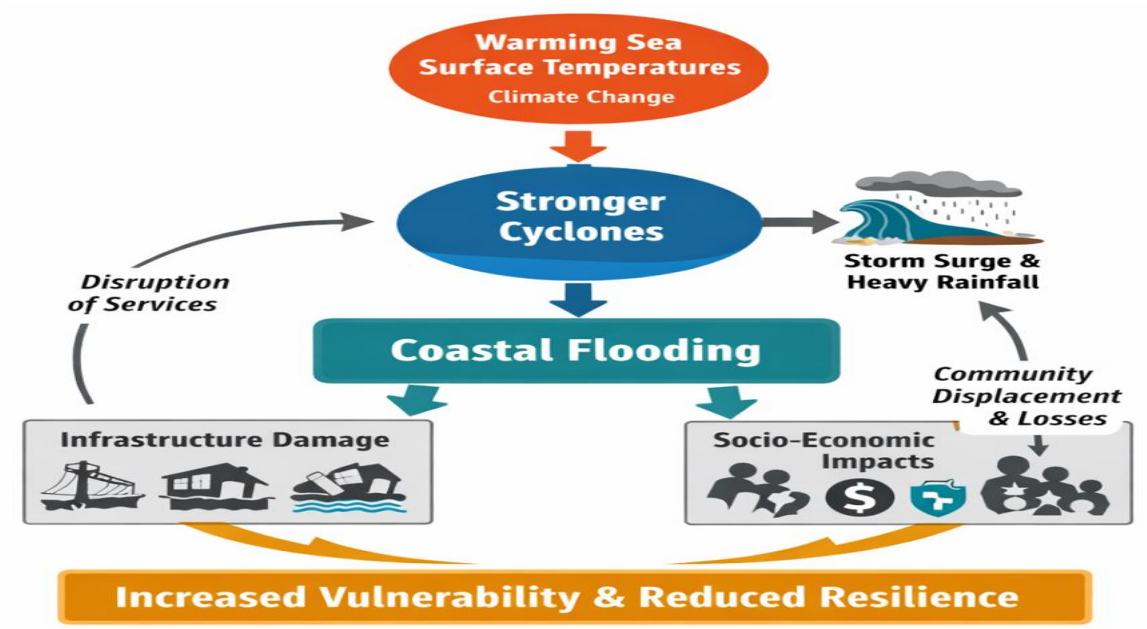

Figure 1: Multi-Hazard Interaction Framework for the East Coast of Africa

Figure 1 shows the effect of climate change on the warming of sea surface temperatures and the resulting intensification of cyclonic systems. The intensification of cyclonic systems leads to the formation of storm surges and rainfall, which causes flooding. The flooding causes damage to infrastructure such as transport, residential houses, power supplies, and water supplies. At the same time, the flooding causes socio-economic effects such

as displacement and economic decline. The framework shows the compounding effects of the hazards on the communities exposed to the risks. It also shows the cyclical effects of the hazards on the communities exposed to the risks. It is also worth noting that the coastal risks experienced in East Africa are not isolated; rather, they are interrelated.

Mitigation

Mitigation refers to the long-term strategies and measures put in place to reduce or eliminate the adverse impacts of hazards before they occur. In the context of the East Coast of Africa, where tsunamis and tropical cyclones pose growing threats due to climate change and coastal development, mitigation is essential to safeguard lives, protect infrastructure, and ensure the sustainability of coastal ecosystems and economies (May et al., 2013).

A primary mitigation strategy for meteorological and hydrological hazards is risk-sensitive land-use planning. Molua et al. (2020) assert that governments must enforce zoning regulations that restrict construction in high-risk areas such as low-lying coastal plains, eroded cliff edges, and tsunami-prone shorelines. Unregulated development, especially in informal settlements and tourist hubs along the coast, greatly increases exposure. Resettling communities from the most vulnerable zones, where feasible, and promoting vertical evacuation strategies such as multi-level shelters can reduce casualties during disasters. Strengthening infrastructure resilience is another critical mitigation approach (Molua et al., 2020). Public buildings, schools, hospitals, and critical infrastructure like power stations and water treatment plants should be constructed or retrofitted to withstand high winds, flooding, and saltwater corrosion. This includes using storm-resistant materials, elevating key structures above flood levels, and reinforcing roofs and walls in cyclone-prone areas. In areas at risk of tsunamis, seawalls, natural dune systems, and mangrove forests can act as effective buffer zones, reducing wave energy and preventing shoreline erosion (Lalljee, 2016).

Ecosystem-based mitigation also plays a pivotal role in protecting coastal communities. Healthy mangrove forests, coral reefs, and coastal wetlands serve as natural barriers that absorb storm surges, stabilize shorelines, and reduce flooding. Reforestation of mangroves, protection of sand dunes, and regulation of destructive practices like coral mining are low-cost yet highly effective strategies that yield both environmental and disaster resilience benefits (Mawren et al., 2022). Investing in weather and hazard monitoring systems further supports mitigation by improving risk modeling and early response capabilities. Installing tide gauges, wind and wave sensors, and integrating meteorological data with community-based early warning systems ensures that mitigation efforts are based on accurate, up-to-date information. These systems also help in designing engineering solutions and community risk maps that guide local action (Miklyaev & Olubamiro, 2025).

Community-level structural mitigation includes elevating homes, constructing flood-resistant buildings, and promoting cyclone-proof roofing designs using locally available materials. Incentivizing homeowners through subsidies or insurance benefits to invest in disaster-resilient modifications enhances participation and reduces long-term damage costs. Policy and legislative frameworks are essential for institutionalizing mitigation. Governments must update building codes to reflect international best practices for disaster resilience and ensure compliance through inspections and penalties for non-adherence. Local authorities must also be empowered with technical skills, financial resources, and autonomy to implement localized mitigation interventions (Mawren, et al., 2022). Lastly, financial mitigation mechanisms, such as climate adaptation funds, risk pooling, and public-private partnerships, are crucial for financing infrastructure upgrades, ecosystem restoration, and technological investments. These approaches shift the cost burden from post-disaster recovery to proactive prevention, which is both economically and socially advantageous (Lalljee, 2016). Mitigation efforts in the East African coastal context must blend engineering, ecological, policy, and community-based strategies. By reducing exposure, strengthening structures, protecting ecosystems, and enforcing regulations, the region can significantly minimize the devastating impacts of tsunamis and cyclones while promoting long-term coastal resilience.

Response

The response phase entails immediate actions undertaken before, during, and shortly after a disaster to minimize loss of life, alleviate suffering, and protect critical infrastructure. In the context of tsunamis and tropical cyclones on the East Coast of Africa, timely action is vital. Once early warning systems detect an impending hazard,

meteorological agencies must disseminate alerts via SMS, radio, and local sirens (Molua, et al., 2020). These warnings should trigger emergency protocols, including activating disaster response teams and initiating community evacuations. Clear, accessible communication ensures that even the most remote or vulnerable communities receive timely and life-saving information. Evacuation is a top priority once warnings are issued. Coastal populations, especially those in informal settlements or low-lying areas must be guided to safe zones or elevated shelters. Special provisions must be made for children, elderly individuals, and persons with disabilities to ensure inclusive and safe evacuations. Evacuation routes must be clearly marked, and community responders should be positioned to offer assistance. These actions reduce exposure and prevent casualties from storm surges, flooding, or tsunami waves. Well-practiced drills and community awareness enhance the speed and orderliness of evacuations (Van & Nemakonde, 2017).

After the hazard strikes, search and rescue operations are launched immediately. National disaster response units, police, military, and trained volunteers work collaboratively to locate survivors, recover bodies, and transport the injured to health facilities. In remote or isolated regions, air support may be necessary to reach those cut off by floodwaters or debris (Van & Nemakonde, 2017). Efficient coordination and rapid deployment of these rescue operations often determine survival rates and reduce prolonged exposure to dangerous conditions.

Simultaneously, emergency shelters are established to house displaced populations. These shelters should provide essential services such as clean drinking water, food, sanitation, and medical care (Taye & Dyer, 2024). Health teams are deployed to manage injuries, prevent the spread of disease, and offer trauma support. Temporary clinics or mobile health units are essential in areas where hospitals have been damaged or are overwhelmed. The speed of setting up these relief hubs greatly influences recovery, particularly among vulnerable groups with no access to resources. Central to disaster response is the coordination between different agencies and stakeholders. Emergency Operations Centers (EOCs) must be activated at the national and county levels to direct operations, manage resource deployment, and provide real-time updates. Effective communication among government departments, NGOs, and humanitarian actors prevents duplication and ensures swift aid delivery. A unified command system improves efficiency and allows for better situational awareness across all responders. It also strengthens accountability and ensures priority needs are addressed quickly and fairly (Mashao et al., 2023).

Security personnel also play a vital role in maintaining law and order during emergencies. Boluwade (2020) indicated that in the aftermath of disasters, the risk of looting, civil unrest, and insecurity can increase, especially in densely populated or poorly policed areas. Deployment of law enforcement and military units helps secure shelters, safeguard supply chains, and reassure affected populations. Their involvement also supports the logistics of transporting supplies, clearing blocked roads, and enforcing evacuations where resistance or misinformation is a concern. Psychosocial support is another essential aspect of disaster response. Survivors of natural hazards often suffer from trauma, grief, and anxiety, particularly those who have lost loved ones, homes, or livelihoods (Ayugi et al., 2020). Trained counselors and mental health practitioners should be deployed to provide immediate emotional support and psychological first aid. Establishing child-friendly spaces in shelters can help minimize trauma among children. Addressing emotional well-being at an early stage supports faster recovery and strengthens the resilience of communities facing future hazards.

Finally, rapid damage and needs assessments must be conducted. These assessments inform the allocation of aid, prioritization of interventions, and transition to recovery. Teams should map affected zones, estimate displaced populations, and identify shortages in shelter, water, healthcare, and food. Data collected during this stage enables evidence-based decision-making and ensures that the most affected groups receive timely support. Effective assessments also aid in mobilizing international assistance and resources for the rehabilitation and reconstruction phases (Thoithi et al., 2022).

Rehabilitation and Reconstruction

Rehabilitation and reconstruction mark the long-term recovery phase following the response to meteorological and hydrological disasters. This stage focuses on restoring normalcy, rebuilding infrastructure, reviving livelihoods, and improving resilience. Along the East Coast of Africa, where communities frequently face the aftermath of cyclones and tsunamis, this phase is crucial for sustainable recovery. Rehabilitation involves

immediate efforts to restore essential services such as clean water, electricity, healthcare, and schooling. Temporary facilities may be used while permanent ones are rebuilt. The goal is to ensure that affected populations regain access to critical services while reducing future vulnerabilities (Comte et al., 2016). According to Obura (2006), reconstruction involves rebuilding infrastructure and housing destroyed or damaged during the disaster. This must follow the principle of "building back better," using storm-resistant materials and improved designs that can withstand future hazards. Roads, bridges, hospitals, schools, and homes should be redesigned to incorporate climate adaptation features and resilient engineering standards. Additionally, land-use planning must be re-evaluated to prevent reconstruction in high-risk zones. Governments should enforce stricter building codes and zoning laws, while offering incentives and subsidies for compliant construction. This approach reduces long-term risk and ensures safer communities post-disaster

Equally important is the restoration of livelihoods, particularly in coastal regions where fishing, tourism, and agriculture form the economic backbone. Support mechanisms such as cash-for-work programs, grants, and microfinance can help individuals restart businesses, repair fishing gear, or replant damaged crops. Governments and development partners must also provide technical training and recovery packages tailored to the affected sectors. Rehabilitating livelihoods not only restores income but also contributes to community stability and psychosocial recovery after trauma and displacement (Ballesteros & Esteves, 2021). Social rehabilitation includes supporting mental health recovery, reuniting families, and re-establishing community structures. Post-disaster trauma can lead to long-term psychological issues if not addressed. Mental health professionals should continue offering counseling and group therapy well into the recovery phase. Child-friendly spaces, gender-sensitive support services, and safe spaces for vulnerable populations must also be integrated into recovery efforts. Cultural and spiritual rebuilding—such as restoring places of worship and community centers—also aids in restoring social cohesion and a sense of normalcy (May et al., 2013).

Institutional learning and policy reform are key components of effective rehabilitation and reconstruction. Governments should evaluate the disaster response and recovery process to identify gaps and opportunities for improvement. These lessons should inform the revision of disaster risk reduction policies, urban planning frameworks, and emergency response protocols. Building local capacity and decentralizing decision-making empowers communities to take ownership of resilience-building measures. Integrating disaster preparedness and resilience into national development plans ensures a more forward-looking and coordinated recovery approach (Maselli et al., 2020). Rehabilitation and reconstruction after tsunamis and cyclones require a holistic and inclusive approach that addresses physical, social, and economic recovery. The process must not merely restore what was lost, but rebuild stronger, safer, and more resilient communities. This phase provides a crucial window for transformation, turning disaster into an opportunity to correct structural weaknesses, reduce inequality, and invest in sustainable development that prepares the East Coast of Africa for future climatic and geological hazards.

RESEARCH METHODOLOGY

This study employed a qualitative, interpretative methodology, grounded on an extensive review of literature, official reports, and scholarly analysis utilizing qualitative document analysis to examine meteorological and hydrological hazards management in the East Coast of Africa (tsunamis, and cyclones). The researcher also utilized analytical synthesis grounded on the PRISMA model (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to enable systematic inclusion and analysis of sources. This method is appropriate for exploring complex, multidisciplinary topics such as meteorological and hydrological hazards management, where extensive literature already exists.

The data for this study were obtained from peer-reviewed publications in scientific journals, institutional reports, policy briefs, and books from renowned agencies such as the World Meteorological Organization (WMO), World Health Organization (WHO), World Bank and United Nations Office for Disaster Risk Reduction (UNDRR) among others. Source choice was guided by relevance, Africa regional focus, publication credibility, and thematic priority of climate-influenced issues such as meteorological and hydrological hazards management. Thematic content analysis was employed to record patterns and recurring themes in disaster management. These were framed into six central thematic domains: vulnerability assessment, risk assessment, preparedness,

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mitigation, response, rehabilitation, and reconstruction. This was achieved in a manner that highlighted knowledge gaps, best practices, and policy implications. The study, therefore, provides additional information on meteorological and hydrological hazards management for sustainable development policies. The table below is the PRISMA model details

Table 3.1: PRISMA table for the study

Stage	**Description / Number of Records**
Identification	Records identified from databases (n = 78)
	Records identified from other sources (n = 20)
	Total records identified (n = 98)
Screening	Duplicates removed (n = 10)
	Records screened (n = 88)
	Records excluded after title/abstract screening (n = 40)
Eligibility	Full-text articles assessed (n = 48)
	Full-text articles excluded with reasons (n = 12)
Included	**Studies included in qualitative synthesis (n = 36)**

Articles were excluded during title and abstract screening if they (i) lacked geographic relevance to East Africa, (ii) focused solely on inland hydrological hazards without coastal relevance, (iii) were non-peer reviewed opinion pieces, or (iv) lacked empirical or policy-oriented content. During full-text review, articles were excluded due to methodological weakness, duplication of datasets, or insufficient focus on tsunami or cyclone risk governance

FINDINGS

i. The East Coast of Africa faces significant and multifaceted vulnerability to meteorological and hydrological hazards, including tsunamis and cyclones. This vulnerability is driven by a combination of environmental exposure, socio-economic fragility, and inadequate infrastructure. Coastal populations, especially those in informal settlements and fishing communities, are particularly at risk due to poor construction practices, limited evacuation awareness, and inadequate access to early warning systems. Children, the elderly, and persons with disabilities often bear the brunt of these disasters, with higher mortality and injury rates due to barriers in mobility, communication, and access to shelters. The region's vulnerability is further intensified by weak governance structures and historical underinvestment in resilient public systems, resulting in widespread human and economic losses when disasters strike.

ii. Risk assessments confirm that while tsunamis occur infrequently, their potential for destruction remains extremely high, particularly in urban coastal centres with dense populations and limited preparedness. In contrast, cyclones, especially in Madagascar, Mozambique, and more recently, parts of Kenya and Tanzania pose a recurring threat, with increasing frequency and intensity attributed to climate change. These storms routinely cause widespread damage to infrastructure, disrupt livelihoods, and displace thousands. Storm surges, flash floods, and high-velocity winds compound the risks, often overwhelming public services and cutting off access to critical facilities such as hospitals, ports, and communication networks. The repeated damage to essential infrastructure and economic systems reveals a pattern of cascading risks that deepen vulnerability across sectors.

iii. Preparedness efforts in the region remain inconsistent and underdeveloped. Although progress has been made in meteorological monitoring and early warning capabilities, significant gaps persist in community outreach, public education, and institutional readiness. Many coastal communities lack practical knowledge of evacuation procedures, and emergency drills are infrequently conducted. Disaster

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management agencies face chronic challenges in maintaining updated contingency plans, ensuring inter-agency coordination, and mobilizing timely resources. Financial preparedness mechanisms, including insurance coverage and dedicated disaster funds, are also largely absent, limiting governments' ability to respond swiftly and effectively. As a result, preparedness in the region often fails to translate into tangible resilience on the ground, leaving populations exposed and response systems strained.

iv. Mitigation and emergency response strategies remain largely reactive and fragmented. Structural mitigation measures such as cyclone-resistant housing, elevated infrastructure, and storm barriers is still limited in scope and scale, especially in poorer or rural areas. Ecosystem-based measures like mangrove restoration and dune preservation show promise but are often undermined by competing land use demands and lack of sustained investment. During disaster events, response teams work under intense pressure to deliver life-saving services, yet often encounter logistical bottlenecks, coordination challenges, and resource shortages. In many cases, psychosocial support, livelihood rehabilitation, and long-term recovery planning are treated as afterthoughts. These findings highlight the urgent need for a coordinated and forward-looking approach that addresses both immediate risks and the structural causes of vulnerability in coastal communities across the East African region.

v. The Southern African Development Community (SADC) has also contributed to enhancing climate services in the region through its Climate Services Centre that enables the implementation of seasonal forecasting and climate outlook forums in the region. These have helped in enhancing anticipatory planning and harmonization in climate information dissemination in Southern and Eastern Africa. However, these approaches in the SADC region are largely based on forecast-oriented rather than impact-based approaches. Seasonal forecasts are useful tools but cannot replace fully integrated real-time early warning systems that require the integration of meteorological, hydrological, and marine data. Besides, interoperability between national meteorological centers also faces difficulties in data exchange between these centers. These are not binding in nature (Van Niekerk & Nemakonde, 2017; World Bank, 2021).

vi. In a similar vein, the Indian Ocean Commission (IOC) has enhanced cooperation in marine observation and the deployment of early warning systems for tsunamis. In so doing, it has strengthened upstream detection systems, especially in island and coastal countries such as Madagascar and Comoros, through support for oceanographic monitoring and the integration of global tsunami early warning systems. However, a wide divergence in technical capacities to use shared data exists among the countries. The effectiveness of early warning systems in communicating to affected individuals, especially in informal settlements, is a major challenge in the region. The absence of strong institutional linkages between regional monitoring centers and national disaster management agencies is a major hindrance to effective response to early warnings (UNDRR, 2022; WMO, 2023).

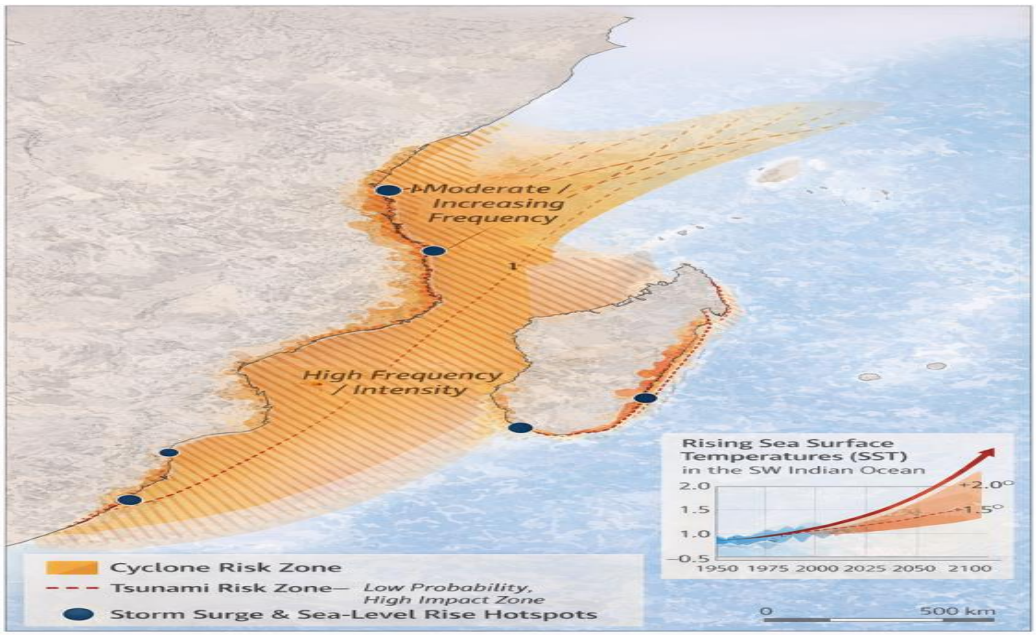

Figure 2: Simplified Spatial Map of Overlapping Coastal Hazards along the East Coast of Africa

The map visually demonstrates the geographic convergence of multiple hazard drivers across the region. The shaded cyclone risk zone highlights the Mozambique Channel and eastern Madagascar as areas of high frequency and intensity, with risk gradually decreasing northward toward Kenya and Tanzania. A continuous coastal band represents low-probability but high-impact tsunami exposure along the shoreline. Dark blue markers identify particularly vulnerable low-lying coastal hotspots susceptible to storm surge and sea-level rise. An inset graph illustrates long-term warming trends in sea surface temperatures, reinforcing the climatic driver that intensifies cyclone activity.

Together, the spatial overlays show that hazard exposure in the region is layered and interconnected rather than isolated, supporting the manuscript's argument on overlapping and compounding risks.

CONCLUSION AND RECOMMENDATIONS

Meteorological and hydrological hazards remain a persistent threat along the East Coast of Africa, often resulting in loss of life, displacement, and widespread economic and environmental damage. The analysis presented highlights the diverse nature of these hazards and underscores the urgent need for comprehensive management strategies tailored to the region's unique vulnerabilities. While countries such as Kenya, Tanzania, and Mozambique have made efforts to improve forecasting, early warning systems, and disaster preparedness, these initiatives are frequently hindered by institutional, financial, and technological constraints.

The study emphasizes the importance of enhancing regional cooperation and investing in modern infrastructure and capacity building to improve the effectiveness of hazard monitoring and response systems. Strengthening community-based risk reduction programs, improving public awareness, and integrating hazard management into broader development planning are critical steps toward resilience. Furthermore, international support, both technical and financial, remains vital in enabling East African nations to implement robust and sustainable disaster risk reduction strategies.

Meanwhile, managing meteorological and hydrological hazards on the East Coast of Africa requires a shift from reactive to proactive approaches, rooted in science-based planning, inclusive governance, and cross-border collaboration. With climate change intensifying the frequency and severity of extreme weather events, the urgency to act cannot be overstated. A coordinated, well-funded, and inclusive regional strategy will not only protect lives and livelihoods but also support long-term sustainable development in this ecologically and economically significant region.

In order to operationalize "building back better," there is a need to establish standards, risk-based approaches, and measurable targets for building resilience. In rebuilding areas that are prone to cyclones, there is a need to specify wind-resistant designs, elevated construction above expected flood levels, and the use of resistant materials in key infrastructure such as hospitals, schools, ports, and power plants. Building codes for coastal areas need to be legally binding, with strict inspection and compliance.

Equally important is risk-sensitive land use planning. Coastal setback zones should be made obligatory and protect against rebuilding in storm surge areas and low-lying floodplains. Hazard mapping should inform rebuilding efforts. Coastal buffers such as mangroves and dunes should also be restored to minimize wave energy and flooding impacts.

Governments should establish clear indicators of resilience, including the percentage of public facilities retrofitted to hazard standards and the percentage of coastal districts that have developed plans. Dedicated funds for disaster contingencies and risk pooling are essential to support resilient rebuilding and to break the cycle of repetitive losses.

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