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Mombasa: Stepping Stones to a Climate-Resilient Future?

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African perspectives
Global insights

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Executive summary

This policy insight illustrates the challenges faced by many coastal cities in tackling the interwoven issues of demographic growth, climate change and waste management. With a focus on Mombasa, Kenya, it looks at how the priority climate hazards of flooding and sea-level rise interact with water and solid waste, and focuses on the potential for nature-based solutions. Treating grey water through constructed wetlands, revegetating urban zones to optimise the benefits residents receive from natural spaces, and investing in mangrove fringes for coastal protection, water treatment and blue carbon finance provide opportunities for multiple co-benefits to urban residents. The latest recommendations for restoring nature down to the smallest scale (to 1km^2 areas), opportunities for generating income for informal groups, and the recognised value of building social capital at neighbourhood levels may provide a golden opportunity to reinforce ecological, economic and social resilience in responding to the multiple hazards facing East African coastal cities.

Introduction

This policy insight explores the potential for climate-resilient infrastructure in the port city of Mombasa, Kenya. Urban expansion in Africa is expected grow considerably in coming decades, at a time of particular vulnerability owing to the scale of population growth and increasing limitations in natural resource health and availability (eg, food, water, affordable energy and construction materials such as sand). At the same time climate change is reshaping the basic living environment in many ways. Changes in rainfall and warming temperatures will affect people's living conditions and impact the ecosystems on which coastal populations rely (such as for fisheries), and sea-level rise may render prime urban zones uninhabitable, requiring costly relocation and/or coastal defences.

Mombasa is an ancient coastal port, first mentioned in the 12th century. Like other such centres of commerce, it has characteristics both of change and of stability. Change comes through people and cultures, shipping and trading technologies, tides, rivers and climates. Stability refers to the natural assets that have made it so attractive for so long – the deep channel and harbour, intricate sheltered coastlines and flat hinterland for settlement. The settlement and its culture have been shaped successively by the Arab-Swahili trading culture over more than five centuries, then by European colonisation for more than a century, and then a post-independence era for half a century. Now entering the third decade of the 21st century, the city faces a new and unknown horizon defined by global trade, the rise of Asian powers, burgeoning African populations and economies, and a changing global climate that will shifts its natural asset base, its coastline, faster than at any other time in history.

BOX 1 MOMBASA CITY PROFILE

Mombasa is Kenya's second largest city, with Mombasa County covering an area of over 260km² on Mombasa island and the mainland surrounding it to the north, west and south. The 2019 census counted 1.2 million people in Mombasa County, and almost three times that in the surrounding metropolitan region (see Table 1), where satellite/commuter settlements can be found. From the 2019 census, both national and Mombasa city population growth rates have been close to 2.5 % per year, but that of the Mombasa metropolitan area as a whole may be far greater, with coastal zones typically growing at double the national average, so some 5%.[a] The city is the main port for East and parts of Central Africa, with the Northern Economic Corridor passing through Nairobi to the west, and fanning out to include the western Democratic Republic of Congo, Rwanda, Uganda and South Sudan.

a Barbara Neumann et al., "Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding – A Global Assessment", *PLoS ONE* 10, no. 6 (2015).

TABLE 1 TOTAL POPULATION (NUMBER OF PEOPLE)

National population	47,564,296
Nairobi	4,394,073
Mombasa (county)	1,208,333
Mombasa (metropolitan region)	3,528,940
% annual growth (2009–2019)	
National (linear)	≈2.5%
Coastal cities (estimate)	≈5%

Source: Kenya Data Portal, "2019 Kenya Population and Housing Census", November 15, 2019, https://kenya.opendataforafrica.org/msdpnbc/2019-kenya-population-and-housing-census-population-by-county-and-sub-county?county=1000020-mombasa

What will Mombasa's future be, and what type of resilience might the city show?

This policy insight focuses on two aspects that will interact to determine the future of Mombasa – its natural infrastructure, and climate change. Mombasa's primary natural asset is its coastline, and the access and benefits it affords city residents and commerce. Climate change is a multi-faceted challenge, but the policy insight will focus on two aspects identified by Mombasa residents as their greatest concern and where natural infrastructure can be both a victim and a solution – rising sea levels and flooding.

In the past decade port and transport infrastructure expansion in Mombasa has been frenetic, after decades of stasis. The port, railway and highway are all growing rapidly with

investment from abroad, principally Asia. Mombasa's 'Gate City Master Plan'[1] envisages new arteries, ring roads and other infrastructure, growing at a slower pace than the trade infrastructure. As in other Kenyan counties, the County integrated Development Plan[2] is the operational instrument for city officials, and the potential for integrated city planning is considerable.[3] Nevertheless, storm water management infrastructure in the city is rudimentary, and municipal sewage treatment has been absent for decades.

Climate change is a new and emerging threat, but is not systematically addressed in the major planning documents. This leaves the city's infrastructure and near-term future highly vulnerable to chronic and acute stressors. There have been multiple studies of Mombasa's vulnerability to natural hazards, particularly climate change.[4] Close to 10% of Mombasa's population was impacted by flooding in 2006, while 17% of the city has been cited as being at risk of submergence by a sea-level rise of 0.3m – its high vulnerability a result of low elevation and high temperatures and humidity in the coastal zone.[5] Future projections of impacts using business-as-usual climate estimates find that while population exposure in Mombasa doubles, the cost of impacts balloons 30 times: from $470 million in 2005 to $15 billion in 2080.[6] Importantly, the increase in vulnerability and cost owes more to increased exposure driven by socio-economic factors than the magnitude of the climate hazard itself.

Close to 10% of Mombasa's population was impacted by flooding in 2006, while 17% of the city has been cited as being at risk of submergence by a sea-level rise of 0.3m

Climate impacts to Mombasa city are varied, and summarised here from the studies cited above. Direct impacts include coral mortality in coral reefs, which is well reported in the literature. But mangroves and coastal vegetation are also vulnerable to warming and storms from the sea, and to flooding and sedimentation from rivers during severe weather events. Mombasa is built on a porous limestone bedrock from ancient reef growth, so

1 County Government of Mombasa and Japan International Cooperation Agency, "Mombasa Gate City Master Plan: A Premier Gateway Port City that Upholds Diversity and Heritage", http://www.gatecitymp.mombasa.go.ke/sites/default/files/Mombasa%20Gate%20City%20Master%20Plan%20Pamphlet_light_2.pdf.

2 Republic of Kenya, County Government of Mombasa, "Mombasa County Integrated Development Plan (2018–2022)", February 2018, http://www.mombasaassembly.go.ke/wp-content/uploads/2018/06/Mombasa-County-Draft-CIDP-2018-22.pdf.

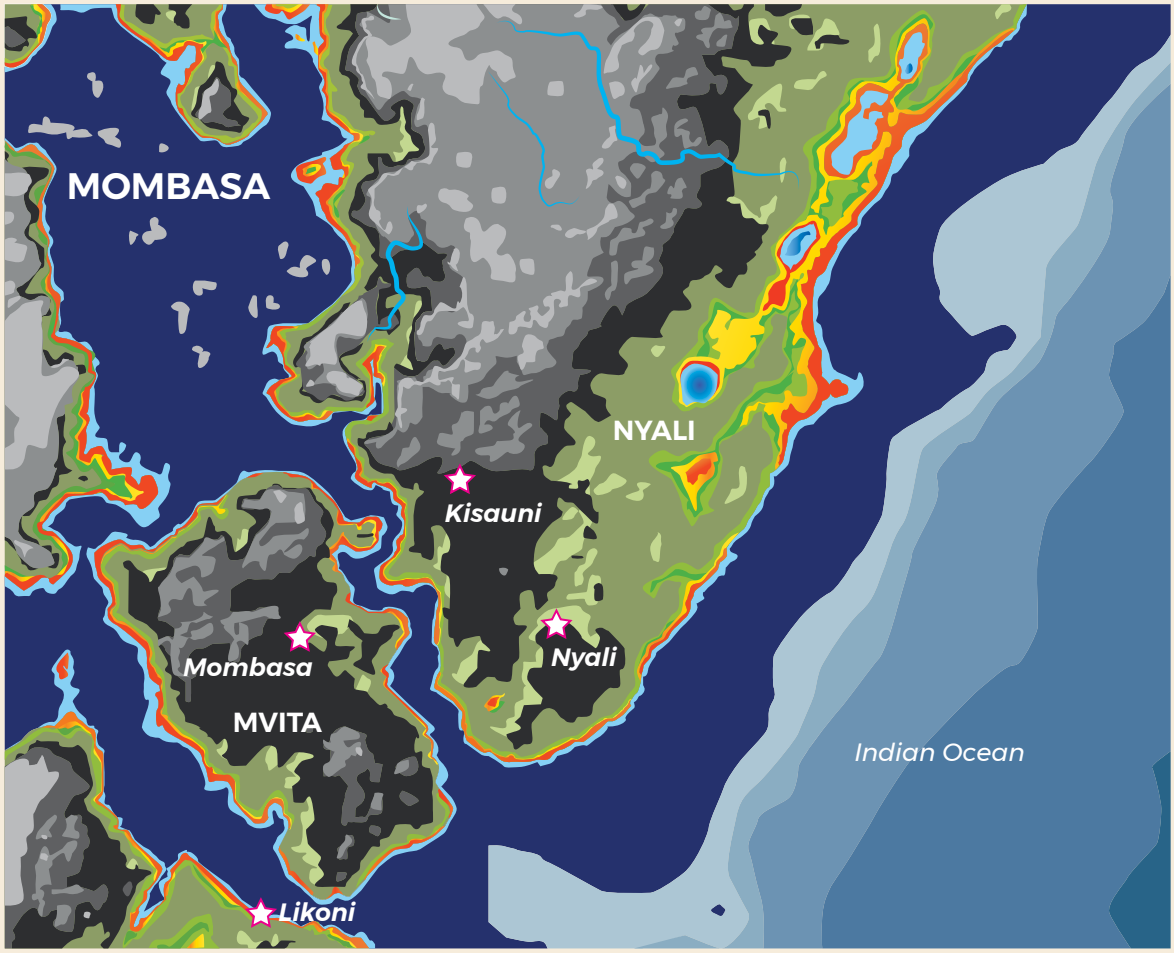
3 Justus Kithiia and Robyn Dowling, "An Integrated City-Level Planning Process to Address the Impacts of Climate Change in Kenya: The Case of Mombasa", *Cities 27*, no. 6 (2010): 1–11.

4 Justus Kithiia, "Climate Change Risk Responses in East African Cities: Need, Barriers and Opportunities", *Current Opinion in Environmental Sustainability* 3, no. 3 (2011): 176–180.

5 Cynthia Brenda Awuor, Victor Ayo Orindi and Andrew Ochieng Adwera, "Climate Change and Coastal Cities: The Case of Mombasa, Kenya", *Environment and Urbanization* 20, no. 1 (2008): 231–242.

6 Abiy Kebede et al., "Impacts of Climate Change and Sea-Level Rise: A Preliminary Case Study of Mombasa, Kenya", *Journal of Coastal Research* 28, no. 1 (2012): 8–19.

Figure 1 Elevation and sea-level rise vulnerability map of Mombasa city



Note: The intertidal zone to the maximum spring high tide is shown in dark to light blue shades, up to 4m above Mean Low Water (MLW). Above this, high (4–6m above MLW in red), moderate (6–7m above MLW in yellow) and low (8–9m above MLW in green) risk elevations are highlighted. The greatest part of Mombasa Island is at 20m elevation and above, while the heavily populated areas of Nyali and Bamburi on the north coast are 10–20m (olive green) and 20m and above MLW (black to graduated grey shades).

Legend

- Urban centers
- Rivers

Depth (meters)

- 10–20
- 21–30
- 31–90
- 91–100
- >240
- Sub-counties

Elevation (meters)

- =>40
- 30–35
- 25–30
- 20–25
- 11–20
- 10
- 9
- 8
- 7
- 6
- 5
- 4
- 3
- 2
- 1
- 0

Low risk
Vulnerable
High risk
Intertidal

Source: Prepared by James Mbugua, CORDIO, http://maspawio.net/maps/409/view

is vulnerable to saltwater intrusion driven by storm surges and sea-level rise. Freshwater availability is worsened by pollution and contamination of groundwater owing to the growing population and the lack of water sanitation and sewerage. As a result, severe water shortages may be experienced even during flooding, and may in turn cause higher food prices and food insecurity. Impacts are exacerbated by intensified resource use and damaging practices (such as mangrove cutting) during times of economic and social stress, as well as poor solid waste management, which results in blocked drains and natural watercourses, and the flushing of pollution and litter into the sea.

Sea-level rise is a particular vulnerability of coastal cities. Scientific literature and the press commonly warn of parts of Mombasa 'falling into the sea', with large percentages of the city 'submerging' under relatively small sea-level rise scenarios. However, much of the city is on carbonate rock 6m or more above current high-tide levels, calling into question past estimates of how much area may be prone to inundation as a result of sea-level rise. This analysis (Figure 1) indicates that for the most part, only a narrow fringe of Mombasa's steep shoreline will be vulnerable to direct inundation by rising seas. However, it is significant that some of these shorelines along the sheltered creeks are becoming heavily populated with informal settlements as the city's population grows. The greatest inundation risk is clearly the low-lying areas along Bamburi Beach where tourism development is concentrated, and in the Bamburi Cement Company quarries where some areas (old quarries) are currently below high-tide level (light blue in Figure 1).

Flooding is a compound phenomenon, however, that includes aspects of rising water tables, excessive rainfall, changes in the absorptive capacity of the land owing to urbanisation, and coastal inundation by rising seas. Some of the more elevated parts of Mombasa may be highly vulnerable to these other aspects of flooding, as well as salinisation of groundwater and underground seepage.

Challenges

A recent consultation on key challenges facing Mombasa as a city[7] used an 'ocean risks' framework developed by the International Union for Conservation of Nature.[8] The approach focused on a set of challenges related to climate change and ocean interactions, asking Mombasa county residents, non-governmental organisation representatives and officials to identify three top concerns. They selected flooding, pollution (waste management) and urbanisation (Table 1), which interact in complex ways. For example, the flooding of low-lying areas and unmanaged urban waste compound one another's effects, as a failure to manage the latter exacerbates flooding (blocking drainage, and resulting in the wide

7 International Union for Conservation of Nature and Coastal Oceans Research and Development – Indian Ocean, "Unlocking a Resilient Blue Economy at the County Level, Kenya" (Unpublished Report, CORDIO East Africa, Mombasa).

8 IUCN, "Acting on Ocean Risk: Documenting Economic, Social, and Environmental Impacts Being Felt by Coastal Communities" (Gland: IUCN Global and Marine and Polar Programme, forthcoming).

dispersal of waste into the environment). Both are compounded by urbanisation patterns, particularly where planning and infrastructure development are minimal and population density becomes very high.

These priorities are grouped in Table 2 to highlight:

- the potential for climate-resilient actions based on natural ecosystems, nature-based solutions and innovative 'green' technologies; and
- the critical role of 'social capital'[9] across the key challenges.

TABLE 2 CLASSIFICATION OF ACTIONS IDENTIFIED IN RELATION TO FLOODING, POLLUTION AND URBANISATION

	Class*	Priority ocean-risk hazards		
		Flooding	**Pollution**	**Urbanisation**
Actions	**Green or blue, and potential mix with grey**	Promote rainwater harvesting and storage through legislation for new developments, green technologies, water collection from roofs, wetlands, etc.	Ensure infrastructural development, including upgrading/developing sewage treatment; may be integrated with nature-based solutions such as wetlands	Enforce existing laws on wetland regulation and shoreline management (integrated agency approach; rehabilitation of degraded areas)
		Invest in nature-based flood control solutions, eg, vegetation and mangrove rehabilitation	Promote waste management that minimises environmental impacts (waste treatment, sorting and processing) and maximises co-benefits (composting of food waste, support for urban agriculture, etc.)	Encourage urban and peri-urban agriculture, which provides food/nutrition, and has co-benefits of increasing green spaces and nature-based infrastructure
		Upgrade drainage systems; physical works required, but may be integrated with nature-based solutions (green-grey)	Promote waste segregation at source and recycling of waste streams to minimise entry to the environment in environmentally friendly ways	Expand low-cost housing, with integration of green/blue solutions
	Technology, green potential	Invest in technologies with sensors to manage drainage to determine and manage blockage risks	Establish a water quality monitoring system that accounts for multiple waste types, sources and pathways	Promote climate-smart technologies for alternative livelihoods that support climate mitigation and/or adaptation, eg, urban agriculture

9 Justus Kithiia, "Old Notion – New Relevance: Setting the Stage for the Use of Social Capital Resource in Adapting East African Coastal Cities to Climate Change", *International Journal of Urban Sustainable Development* 1, no. 1-2 (2010): 17–32; David O Obura, "Getting to 2030: Scaling Effort to Ambition Through a Narrative Model of the SDGs", *Marine Policy* 117 (July 2020).

	Class*	Priority ocean-risk hazards		
		Flooding	Pollution	Urbanisation
Action	**Social, business and stakeholder engagement**	Educate and raise awareness of all stakeholder groups, specific to localised experiences of flooding and waste management, with the potential for solutions with relevant stakeholder engagement		
		Ensure the participation and involvement of all key stakeholders in problem identification, solution identification and management		
		Establish incentives (financial and non-financial) for household, business, local area and neighbourhood investment in solutions and encourage participation in broader schemes that alleviate problems and costs		
	Management, planning and finance	Develop disaster management strategies that are fully integrated across relevant sectors, and with social/business stakeholders	Develop and implement waste management plans (sewage, solid, etc.)	Update urban/city master plans with relevant information to support climate/ocean risk management
		Map/zone vulnerable areas, with restrictions/ provisions for their alteration and impacts from adjacent/distant construction	Map waste hotspots, infrastructure and solutions to support coordination and integration at local (ward), county and (if relevant) national levels	Develop county marine spatial plans, to be integrated with urban master plans
		Control/enforce physical plans	Establish county incentives to youth for solid waste management (eg, interest-free grants)	Decentralise key government functions, including healthcare and administration, to facilitate local adaptation
		Ensure the frequent maintenance of drainage systems and other infrastructure		

***** Note: The colours green, blue and grey are used to denote sustainable eco-friendly practices in terrestrial (green) and marine (blue) contexts. Grey indicates a mixing of these practices with traditional hard engineering solutions.

Source: This table is reorganised from findings in International Union for Conservation of Nature and Coastal Oceans Research and Development – Indian Ocean, "Unlocking a Resilient Blue Economy at the County Level, Kenya" (Unpublished Report, CORDIO East Africa, Mombasa)

The local geography of solutions may be strongly dependent on elevation, slope and natural water-flow patterns, to which the analysis in Figure 1 can be adapted. There is a pressing need for detailed mapping of the smaller administrative wards and neighbourhoods, focusing on the matrix of built vs. natural environment and water courses, to identify options for green/grey infrastructure that addresses flooding and waste issues.

Nature-based solutions

Urban green zones are increasingly recognised as being critical for providing multiple benefits to urban residents.[10] This has been demonstrated in Mombasa, where abandoned limestone quarries have been restored to forests and nature trails[11] and are in daily use by both residents and tourists. A key characteristic of natural zones such as these is that they have the potential to adapt to a changing climate, given appropriate management. New findings on ecosystem services provided by pockets of natural ecosystems in urban and agricultural zones suggest 10–20% of every 1km² of land should be restored to natural ecosystems.[12] The specification 'of every 1km²' is important, as this is the scale at which some benefits provided by natural zones may function most effectively and benefit people. In densely populated cities getting this proportion down to neighbourhood scales of 1x1km may be very beneficial, particularly in low-income areas and informal settlements.

Urban green zones are increasingly recognised as being critical for providing multiple benefits to urban residents

Within Mombasa several projects are building constructed wetlands to treat wastewater, including in a high-density neighbourhood (Kiembeni) and at the Shimo la Tewa prison on the northern edge of Mombasa County. These may provide replicable solutions at the scale of urban villages and neighbourhoods for locally treating and recycling grey water. This approach would depend on the 'local geography of solutions' as described above, helping break up urban infrastructure into manageable and independent units, appropriately designed around local topography and natural water flow to minimise engineering infrastructure and cost.

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10 Viniece Jennings, Lincoln Larson and Jessica Yun, "Advancing Sustainability through Urban Green Space: Cultural Ecosystem Services, Equity, and Social Determinants of Health", *International Journal of Environmental Research and Public Health* 13, no. 2 (2016).

11 Justus Kithiia and Anna Lyth, "Urban Wildscapes and Green Spaces in Mombasa and Their Potential Contribution to Climate Change Adaptation and Mitigation", *Environment and Urbanization* 23, no. 1 (2011): 251–265.

12 S Diaz et al., *Synthesizing the Scientific Evidence to Inform the Development of the Post-2020 Global Framework on Biodiversity: Earth Commission Meeting Report to the Convention on Biological Diversity* (Subsidiary Body on Scientific, Technical and Technological Advice, Convention on Biological Diversity, CBD/SBSTTA/24/inf/9, 2020).

Mangroves fringe the coastline, and may provide among the greatest suite of services a city like Mombasa can use. Like terrestrial vegetation, they can control and absorb nutrients from waste,[13] reducing eutrophication in the creeks and coastal ocean waters. In addition, mangroves play a primary role in coastal protection and sediment capture,[14] mitigating flooding from the sea and resulting coastal erosion, and trapping sediment from terrestrial flooding. This reduces inundation and sedimentation of sensitive seagrass beds and coral reefs. Further, they provide myriad benefits in relation to fishing and food security, sustainable aquaculture and wood harvesting. Mangrove restoration is a core part of the county's mangrove management plan,[15] which promotes community action in replanting mangroves at multiple locations in the county. Many of these efforts are led by local community or youth groups, and significant upscaling through local government and broader public support is needed to strengthen their impact.

An additional benefit of mangroves, as well as seagrass beds, is their efficiency in trapping carbon dioxide and the potential to monetise this service.[16] The Mikoko Pamoja project south of Mombasa already demonstrates the potential for income from carbon sequestration through restored mangroves to finance social and economic benefits in the area. It is bringing in just over $10,000 annually to the community. This is a significant sum that supports local healthcare centres, education and other welfare projects, and provides meaningful reinforcement of social capital at this scale. The project is upscaling to additional sites in Kenya and the region, and has influenced national policy on mangrove restoration and climate action. This potential for 'blue carbon' finance is one of the most promising nature-based mechanisms, not just to increase resilience through the ecological functions and services provided but also to directly monetise one benefit supporting other co-benefits. This has great potential for low-income neighbourhoods around Mombasa, and indeed for income generation for the county government itself.

Getting to action

Mombasa has a number of projects in the planning and research phases of encouraging climate change resilience. The MijiBora Project (Box 2) is financed through the Western Indian Ocean Marine Science Association's (WIOMSA) Cities and Coasts Project (Box 3).

13 Mohamed Omar S Mohamed et al., "Mangrove Forests in a Peri-Urban Setting: The Case of Mombasa (Kenya)", *Wetlands Ecology and Management* 17, no. 3 (2009): 243–255.

14 Edward B Barbier et al., "The Value of Estuarine and Coastal Ecosystem Services", *Ecological Monographs* 81, no. 2 (2011): 169–193.

15 Kenya Forest Service, "Mombasa Mangrove Forest Participatory Management Plan (2015–2019)", https://sgp.undp.org/all-documents/country-documents/927-kenya---mombasa-mangrove-forest-participatory-plan/file.html.

16 Lindsay Wylie, Ariana E Sutton-Grier and Amber Moore, "Keys to Successful Blue Carbon Projects: Lessons Learned from Global Case Studies", *Marine Policy* 65 (March 2016): 76–84.

BOX 2 MIJIBORA PROJECT

The MijiBora ('better' or 'smart' cities in Kiswahili) Project is a research and action project funded by WIOMSA, linking two East African cities – Mombasa in Kenya and eThekwini municipality in South Africa. It combines research and learning activities to fast-track new information into managing priority urban challenges, particularly in Mombasa. The priorities of the project confirm the nexus between solid waste management, flooding and climate change. The project addresses this through multiple approaches.

RESEARCH

Waste management: A situation analysis identified key obstacles in solid waste management, setting out tangible actions supported by the project to help resolve key obstacles:

- the project contributed to the Mombasa County Solid Waste Bill, which was subsequently passed by the County Assembly; and
- the project is mapping all dumping sites and collection points, both legal and illegal, and compiling their characteristics to facilitate further action.

Flooding: The project is investigating aspects related to the inadequate storm water system and poor solid waste management, and inadequate urban planning and management. It has undertaken an assessment of informal settlements in relation to their vulnerability to the identified challenges.

SOLUTIONS

Mapping and scenarios: The project is using geospatial technology to create updated land use/land cover data for the county and developing scenarios to explore how these and the challenges of waste management and flooding may change in the future. Results from this will be shared with the county to aid in planning.

Learning: The project has established learning exchange activities involving policymakers, urban researchers and other stakeholders through peer-to-peer exchange. The purpose is to facilitate cross-learning about approaches implemented in Durban and their applicability and adoption in Mombasa. For example, a framework for community ecosystem-based adaptation in eThekwini focuses on the link between communities and the ecosystems that underwrite their welfare and livelihoods. However, as a result of the Covid-19 pandemic physical visits by officials between the two cities have been suspended.

Other general information on the project can be found at MijiBora, https://mijibora.org/.

Other projects addressing climate change and vulnerabilities in Mombasa include:

UN-Habitat waste flow mapping: Technical experts helped to quantify solid waste amounts, types and flows in Mombasa County, coming to an estimate of 474 tonnes per day of domestic and commercial waste. Improvements are intended to address collection processes, particularly separating wet and dry waste, to improve waste recovery for remanufacturing, reuse, recycling, etc., and final disposal.

ICLEI 100% Renewables Cities and Regions: This project will raise awareness of renewable energy sources and show how local, regional and national governments can create coordinated enabling frameworks and policies towards achieving 100% renewable energy. At the same time, they will reap the benefits of increased uptake of renewable energy in their communities. The project has a target to achieve net zero emissions in participating cities in the second half of this century.

Mombasa is not alone in its challenges. Now, as throughout history, it is one of several coastal cities with common strengths and challenges along the East African coast. Reflecting this, the WIOMSA Marine Science for Management research funding programme has initiated a project focused on the coastal cities of the region (Box 3). In partnership with the Nairobi Convention regional programme supporting pilot projects to limit and manage land-based impacts to the coastal zone, training to upscale solutions such as constructed wetlands is being undertaken.[17]

BOX 3 WIOMSA'S CITIES AND COASTS PROJECT

WIOMSA, based in Zanzibar, has established the Cities and Coasts Project with funding from the government of Sweden. The project, running initially from 2018–2021, is aimed at building a regional expert community on coastal urban issues, with several objectives:

- to improve scientific knowledge and stimulate research;
- to support and facilitate capacity building in coastal city planning;
- to mobilise planners to collaborate with stakeholders to co-produce knowledge; and
- to encourage partnerships among stakeholders.

17 Western Indian Ocean Marine Science Association and UN Environment Nairobi Convention, "Regional Training Workshop on Use of Constructed Wetlands Technology for Wastewater Treatment, Mombasa, Kenya, November 18–22, 2019: Training Workshop Report", November 29, 2019, https://www.wiomsa.org/wp-content/uploads/2020/02/CW-Workshop-report_submitted-to-WIOMSA.pdf.

The project will link many of these practical problems to policy, through linkages to the Sustainable Development Goals (SDGs) and specific targets that may be addressed by funded projects. Three projects have been funded in the first funding cycle, including the MijiBora Project, and an additional activity in collaboration with UN-Habitat has contracted a status report on 'Coastal Cities of the WIO region and the Blue Economy' and a 'Roadmap for the Development of the Blue Economy in Coastal Cities'. These will provide strategic guidance and recommendations to assist cities in their current and future planning activities in relation to the Blue Economy. Further, the project will develop a climate change portal, which will also include a registry for regional experts working on climate change to submit their brief bios. A new type of funding – 'Innovations for Sustainability' – was launched in mid-2020 to target demonstration and pilot projects that will develop sustainable solutions to maintain the functioning of marine and coastal ecosystems.

For further information see WIOMSA, "Cities and Coasts Project", https://www.wiomsa.org/cities-coasts-project/.

Seeds of transformation

Borrowing the concept 'seeds of transformation', which refers to nurturing the early life stages of ideas that may be critical in the future, the various efforts highlighted in this policy insight point to potential solutions. These are examined in no particular order, and do not exclude other solutions. They illustrate the need for nexus and 'joined-up' thinking, as exemplified by the SDGs (Box 4), and to identify the priorities of stakeholders on the ground and joint interests, to build social capital from the ground up.[18]

Flooding

- redesign water management systems around natural ecosystem assets and processes to manage surface and groundwater flows, to store water in wetlands and to treat grey water via wetlands and natural processes;
- restore and strengthen mangrove forest fringes around sheltered coastlines to buffer flooding from the sea to the land, and from the land to the sea; and
- improve the performance of water management systems by transforming inflows:
  - » separate domestic and commercial grey water and sewage waste to minimise the volume of water that needs treatment and increase circular flows/reuse of grey water;

18 Kithiia, "Old Notion – New Relevance".4,20]]},"issued":{"date-parts":[["2010",5,24]]}}],"schema":"https://github.com/citation-style-language/schema/raw/master/csl-citation.json"}

- » improve water harvesting to reduce loss and surface flow, and increase access to water, sanitation and resilience;
- » reduce impervious surfaces that increase surface water flows; and
- » design waste management systems to minimise blockages of and interference by waste and flood water flows.

Natural infrastructure in the city

- restore natural vegetation and zones within urban areas to cover 10–20% of every 1km^2 (this may be forested or 'bush', wetlands or riparian zones); and
- promote restoration of natural vegetation as a key asset for urban resilience, in particular:
  - » mangroves for shoreline protection, food security, blue carbon revenue and to absorb and sequester nutrients; and
  - » wetlands and other terrestrial vegetation to improve water management and treatment, and provide other services to people.

Urbanisation and social capital

- design climate resilience and waste management infrastructure in ways that provide opportunities for building social and economic resilience, thus reducing not only exposure to climate hazards but also the vulnerability of stakeholders; and
- promote youth involvement to diversify opportunities for informal and formal engagement and reduce unemployment.

BOX 4 SCIENCE-BASED TARGETS, THE SDGS AND WAYS FORWARD?

This policy insight has covered the territory of multiple SDGs[a] from the perspective of SDG 11 on sustainable cities and communities. Direct interactions with climate change (SDG 13), water and sanitation (SDG 6), economic activity and job insecurity (SDG 8), food insecurity (SDG 2), the roles of natural habitats on land (SDG 15) and sea (SDG 14) and the impacts of unsustainable resource use practices (SDG 12) have been front and centre, while knowledge (SDG 4), city and county governance (SDG 16) and the roles and participation of stakeholders and residents in villages and neighbourhoods are key (SDG 17). The text has not directly addressed poverty (SDG 1), gender (SDG 5) and marginalised communities (SDG 10), or energy (SDG 7) and innovation (SDG 9) aspects, but they could easily be brought into the narrative for generating solutions.

Each of the elements relating to different SDGs could be parametrised with a relevant variable to measure and assess progress locally. For example, for a given neighbourhood the number of people (SDG 11) in various income brackets (SDG 1), the

amount, proportion and quality of water they use resulting from wetland processing (SDG 6), and their impacts on mangrove (SDG 14) and riparian (SDG 15) vegetation from unsustainable extractive practices (SDG 12) all provide relevant metrics to assess success in meeting science-based targets for sustainability that may be developed. And these may all be aggregated upwards for reporting at city/county and national levels, to quantify national performance under formal indicators for SDG target achievement.

a Obura, "Getting to 2030".

Imagining a sustainable future

As yet, the major policy documents guiding Mombasa's future development do not acknowledge the potential of the solutions presented here. The County Integrated Development Plan (2018–2022) lists mangroves and wetlands but no other ecosystems, and not enough for them to play the role they could as primary infrastructure for building climate resilience. The Gate City Master Plan, while focused on transport and port infrastructure, does not mention natural infrastructure either as an asset or a vulnerability, or the terms 'climate' or 'resilience'.

As a forerunner to the development of supportive policy instruments that can be implemented by city officials and stakeholders, 'soft tools' may provide opportunities to guide and align stakeholders and city processes towards the small and big decisions needed to build resilience in the future:

- Box 4 illustrates the potential of applying a narrative model for the SDGs to identify the multiple interactions between sectors necessary for sustainable solutions, and the necessary representatives and stakeholders that should be involved in each of those.
- This structure may also help identify critical axes or decision points in considering scenarios for investment in potential solutions. Vision scenarios developed for Western Indian Ocean countries may provide a framework for considering multiple SDGs, potential targets, and the decisions and support necessary to promote the desired outcome.

Creative exploration of citizen approaches aligned with emerging county policies is needed to address the immediate risks and hazards that climate change and urban intensification hold for Mombasa residents. One hazard or another, at some geographic scale in Mombasa, is now very likely to be experienced on an annual basis. Of critical importance will be building social capital among resident and community groups[19] to promote collective

19 Kithiia, "Old Notion–New Relevance".

action. For example, designing natural vegetation and waste management solutions at the local scale (to achieve the percentage/1km² recommendation) while empowering informal groups at the first tier of waste collection, separation, sorting and remanufacturing may provide essential social and economic capital for local resilience.

Creative exploration of citizen approaches aligned with emerging county policies is needed to address the immediate risks and hazards that climate change and urban intensification hold for Mombasa residents

Meanwhile, developing long-term policies and making investments in the right natural infrastructure, as mature and functioning ecosystems require decades to grow, are crucial to maximise social and ecological resilience in decades to come. These should be aligned with demographic and urban planning to ensure the carrying capacities of these ecosystems are not exceeded.

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Cover image

Mombasa Island (Hamids Lens/Getty Images)

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