Flooding in Mombasa

Saffron Livaccari

November 14, 2020

Kenya experiences two seemingly antithetical water issues: droughts and flooding. Floods are typically short-term natural disasters, which has given the long-term droughts a higher priority. However, the mitigation of flooding disasters does not have to be costly. For the coastal city of Mombasa, flooding is common due to the proximity to the sea, unplanned urban development, and destruction of the natural environment. This issue can be mitigated through the restoration of natural resources: coral reefs, wetlands, mangroves, and vegetative rainwater capture. Development of green infrastructure such as these will prevent future economic loss, destruction of infrastructure, spread of water-borne diseases, and death. In order for Mombasa to flourish, cultivation of its natural resources is imperative.

Kenya has two rainy seasons that are linked to the Inter Tropical Convergence Zone along the equator. Floods and droughts in eastern Africa are connected to the cycles of El Niño, La Niña, and Indian Ocean Dipole cycles (BBC News, 2019). Clouds build over the Indian Ocean from warm water currents, and the wind blows these clouds over the east African coastline, causing rainstorms. Although the impact of climate change on these weather patterns is speculative, it is highly probable that climate change will bring more unpredictable and higher volume rainfall. Therefore, the issue of flooding is common and will become increasingly more common for eastern Africa.

Floods are the most frequent disaster in the world and affect 2.4 billion people, or 55% of the global population between 1994 and 2013. The frequency of floods is also increasing, from an average of 123 events per year between 1994 and 2003, to 171 per year between 2004 and

2013 (CRED, 2015, pp. 18–19). Droughts are the second most frequent disaster, affecting 1.1 billion people between 1994 and 2013. Africa suffered 131 droughts, more than any other continent, 75 of which occurred in East Africa (CRED, 2015, p. 23). The amount of people affected by droughts is higher in Kenya, yet the number of people killed by floods is much greater (Opere, 2013, p. 316). This difference is due to better drought management strategies, and the underdevelopment of flood management strategies. When flooding does occur, it causes massive issues: spread of waterborne diseases, loss of infrastructure and farmland, displacement, and death. Cholera, typhoid, and bilharzia outbreaks are common after flooding due to heavy pollution of local water sources, and malaria outbreaks are common from the increase in mosquitos (Opere, 2013, p. 316). The effects of floods are undeniably deleterious, proving the need for a focused development of better flood disaster mitigation strategies.

Mombasa is an important trading city on the coastline of Kenya. It is the country's second largest city, after Nairobi, with a population of 1.2 million (Mombasa, Kenya Metro Area Population 1950-2020, n.d.). Mombasa is a port city surrounded by water. Two major harbors, Kilindi and Old Port, serve Kenya and its land-locked neighbors, thereby contributing a large part to the economy of eastern Africa. There is a large section of the city that is already below mean sea level, about 55%. It has been predicted that only a 30cm rise in sea-level could result in 17% of the city being submerged, assuming no adaptation (Kebede et al., 2010, p. 18). Furthermore, Mombasa has a growing population, and there is an increase in underprivileged moving to unprotected housing in areas prone to flooding. Flooding from severe rain, storm-surge, and sea-level rise, is a reoccurring issue for Mombasa, and proper flood management needs to be a key priority for this city.

The issues surrounding flooding in Mombasa can be compiled into two main categories: coastal flood management and erosion, and urban storm water management. The first category, coastal flood management and erosion, is related to coastline preservation to reduce wave energy and storm surges, thereby reducing flood risk. Three natural barriers Mombasa can focus on are coral reefs, wetlands, and mangroves (WRI et al., 2019, pp. 1–140). The second main category, urban storm water management, is related to effective rainwater infiltration to prevent excessive water runoff, thereby reducing flood risk. Considering Kenya is a developing country with a constraint of capital, green infrastructure is a complimentary solution for both issues.

The effects of coral reef restoration will not only reduce flooding, but improve the tourism economy, help sustain the fishing industry, and reduce coastline erosion. Firstly, coral reefs help break waves and dissipate their energy before reaching the coastline, reducing wave heights by an estimated average of 70 percent (WRI et al., 2019, pp. 1–140). Unfortunately, about 50% of the world's coral reefs have died, and 90% are predicted to die before the end of the century (SECORE, n.d.). The primary issues for Mombasa's coral reefs are over-fishing and trophy collecting. Overfishing has resulted in sea urchin populations to increase without the regulation of their natural predators. An increase in sea urchins suppresses the fish population and slows the recovery rate of damaged corals after bleaching events (*Tropical Marine Protected Areas: Mombasa Marine National Park and Reserve*, 2016). A solution is to regulate or eliminate fishing and allow the ecosystem to rebalance itself. Create tourist-specific zones to reduce trophy collecting, while educating the importance of environmentally friendly snorkeling or diving. Lastly, support restoration efforts such as the Mombasa Marine National Park and Reserve.

Wetland restoration should be heavily focused on seagrass. Seagrass is an incredibly important ecosystem along shorelines. Seagrass has the capacity to trap and bind sediment, reducing shoreline erosion (Bjork et al., 2008, p. 47). The growth of sea urchin populations caused by overfishing not only destroys coral reefs, but also destroys seagrass. Sea urchins are the most common seagrass macro-grazers (Eklöf et al., 2008, p. 574). Regulating and reducing fishing with protected zones will naturally reduce the population of sea urchins and revegetate seagrass. Additional research and monitoring should be promoted, as well as educational outreach programs on the importance of this ecosystem.

For coastal flood management and erosion, restoration of the mangrove ecosystem is the third key. Mangroves are trees that grow at tropical latitudes near the equator, known for their dense roots in salt-water (*What Are Mangroves?*, 2011). The roots slow the movement of tidal water and stabilize sediment. Mangroves can reduce the height of non-storm waves by 31 percent (WRI et al., 2019, pp. 1–140). An example of a successful mangrove restoration is from the Mangrove Plantation and Disaster Risk Reduction Project in Vietnam. By 2010, $9 million was invested in the restoration of 9,000 hectares of mangroves. The success of this program has saved the coastal communities $15 million in avoided damages (WRI et al., 2019, pp. 1–140). For Kenya specifically, a cost-benefit analysis in the Tana Delta found the annual net benefit of mangroves range from USD $238/hectare/year to USD $311/hectare/year (Karanja & Saito, 2017, p. 508). Unfortunately, the current rate of mangrove loss in Kenya is around 0.7% annually (Karanja & Saito, 2017, p. 508). Successful restoration is dependent on community-based education, replanting, and legislation preventing the over-destruction of these trees.

The complementary category to coastal flood management and erosion is urban storm water management. Currently, the issue with storm water in urban areas is that rainwater is not

able to infiltrate into the ground from the grey infrastructure blocking soil (sidewalks, roads, buildings, etc.). Water will flow into the drainage system or accumulate as floods. For Mombasa, the drainage system is also the sewer system. Sewage mixed with rainwater will drain directly into the ocean when there is heavy rainfall, causing severe pollution and damage to the biosystems discussed above (Zamconsult Consulting Engineering, 2017).

The green infrastructure solution to storm water management is to decrease the surface area of grey infrastructure and increase the surface area of soil and plants. An analogous plan is Philadelphia's Green City, Clean Water program. Similar to Mombasa, Philadelphia has a combined sewer overflow that pollutes the Delaware River, and the city does not have the capital to completely revise their sewer system. The benefit of their green infrastructure development is not only a reduction of flooding and pollution, but also a natural beautification of the city.

The following examples are from Philadelphia's Green City, Clean Water program. A green roof has a layer of drought tolerant plants, succulents or grasses, designed to reduce the volume of rainwater runoff. Additionally, a downspout planter, or a box of soil and plants at the bottom of a downspout, can catch more water runoff from a roof. A secondary option to a downspout planter is a barrel to catch rain. Rain barrels can be used by the household for watering lawns or plants. For sidewalks, a stormwater tree trench is filled with a permeable layer of stone or gravel underneath the sidewalk where rainwater is collected and slowly infiltrates to the bottom. If the capacity of the trench is reached, then the water will bypass into an already existing drainage inlet. A person walking by would only notice a series of trees along the sidewalk. Alternative sidewalk options are stormwater planters or gardens, similar to a tree-trench except with shrubs and flowers. The main idea is to reduce the amount of impermeable surface area to prevent water build up (PWD, 2011, pp. 22–23).

Additional low monetary options for Mombasa is to regulate housing and settlement zones, preventing informal residency of underprivileged people in flood prone zones and focusing population and asset growth in areas that are less vulnerable (Okaka & Odhiambo, 2019, p. 1009). Furthermore, plan and communicate evacuation routes for when severe flooding does occur.

These options are given in awareness of the lack of high capital. Flooding is a serious issue, but there are preventative measures that can significantly reduce the impact. Working alongside natural vegetation rather than against will reduce the destruction of natural disasters and make the city more sustainable and beautiful. The restoration of Mombasa's natural environment may also increase the tourism of the area, boosting the economy. Without taking measures now, it is clear that flooding and sea level rise will continue to occur and will damage Mombasa's future. Kenya can take appropriate low cost measures to save the impressive city of Mombasa from future catastrophe, all while fighting climate change.

References

BBC News. (2019, December 2). *Why the floods in East Africa are so bad*. https://www.bbc.com/news/world-africa-50628420

Bjork, M., Short, F., Mcleod, E., & Beer, S. (2008). Managing Seagrasses for Resilience to Climate Change. *IUCN*, 1–56. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.575.4451&rep=rep1&type=pdf

CRED. (2015). *The Human Cost of Natural Disaster*. Centre for Research on the Epidemiology of Disasters.

Eklöf, J. S., de la Torre-Castro, M., Gullström, M., Uku, J., Muthiga, N., Lyimo, T., & Bandeira, S. O. (2008). Sea urchin overgrazing of seagrasses: A review of current knowledge on causes, consequences, and management. *Estuarine, Coastal and Shelf Science*, *79*(4), 569–580. https://doi.org/10.1016/j.ecss.2008.05.005

Karanja, J. M., & Saito, O. (2017). Cost–benefit analysis of mangrove ecosystems in flood risk reduction: a case study of the Tana Delta, Kenya. *Sustainability Science*, *13*(2), 503–516. https://doi.org/10.1007/s11625-017-0427-3

Kebede, A. S., Nicholls, R. J., Hanson, S., & Mokrech, M. (2010). Impacts of Climate Change and Sea-Level Rise: A Preliminary Case Study of Mombasa, Kenya. *Journal of Coastal Research, 28*(1), 8-19. http://dx.doi.org.proxy.library.upenn.edu/10.2112/JCOASTRES-D-10-00069.1

Mombasa, Kenya Metro Area Population 1950-2020. (n.d.). MacroTrends. Retrieved November 2, 2020, from https://www.macrotrends.net/cities/21708/mombasa/population

Okaka, F. O., & Odhiambo, B. D. O. (2019). Health vulnerability to flood-induced risks of households in flood-prone informal settlements in the Coastal City of Mombasa, Kenya. *Natural Hazards*, *99*(2), 1007–1029. https://doi.org/10.1007/s11069-019-03792-0

Opere, A. (2013). Chapter 21. Floods in Kenya. In *Developments in Earth Surface Processes* (Vol. 16, pp. 315–330). Elsevier Science. https://doi.org/10.1016/B978-0-444-59559-1.00021-9

PWD. (2011, June). *Green City Clean Waters*. Philadelphia Water Department.

SECORE. (n.d.). *Why coral reefs need our help*. SECORE International. Retrieved October 30, 2020, from http://www.secore.org/site/corals/detail/coral-reefs-are-dying.23.html

Tropical Marine Protected Areas: Mombasa Marine National Park and Reserve. (2016, April 4). Mombasa Marine National Park and Reserve. https://scalar.usc.edu/works/tropical-marine-protected-areas/mombasa-marine-park-and-reserve

What are mangroves? (2011, April 4). NOAA. https://floridakeys.noaa.gov/plants/mangroves.html

WRI, Browder, G., Ozment, S., Bescos, I. R., Gatner, T., & Lange, G. M. (2019, March). *Integrating Green and Gray: Creating Next Generation Infrastructure*. World Bank. https://doi.org/10.46830/wrirpt.18.00028

Zamconsult Consulting Engineering. (2017, January). *Environmental and Social Impact Assessment Project Report for Improving the Existing Storm Water Outlets in Mombasa Island*. Republic of Kenya Ministry of Water and Sanitation. http://documents1.worldbank.org/curated/en/514341487836900335/pdf/Environmental-and-Social-Impact-Assessment-for-Improving-the-Existing-Storm-Water-Outlets-Outfall-and-Combined-Sewer-Overflows-in-Mombasa-Island.pdf