Adapting to Sea Level Rise in Small Island Developing States: Employing IoT Technology, Leveraging Coastal Infrastructure and Ecosystem-based Adaptation, and Continually Engaging the Public

Samantha Saks, University of Virginia School of Engineering and Applied Science, United States of America
(samesaks@gmail.com)

Abstract

Sea level rise (SLR) is one of the most direct and destructive impacts of climate change, and its increasing severity is globally pervasive. While a multinational phenomenon, SLR disproportionately impacts Small Island Developing States (SIDS), putting them at risk of inundation and displacement. Two of the most intense effects of SLR, coastal flooding and saltwater intrusion, threaten the vitality and livability of SIDS, destroying infrastructure, rendering lands unconducive to cultivation, and contaminating critical water supplies. To combat SLR-driven coastal flooding and saltwater intrusion, SIDS require adaptive systems tailored to the needs and conditions of varying community types.

Rising global sea level, as well as its associated rate of increase, amplifies the imperative for widescale climate action. Since 1880, global mean sea level has risen between 21 and 24 centimeters, and today, sea level rises at a rate of about 0.44 centimeters per year, over double the global long-term rate. Sea level rise (SLR) poses severe risks globally, which include increasing tidal flooding frequencies, threatening local water supplies, eroding shorelines, forcing migration from coastal communities, and stressing coastal ecosystems. Coastal flooding and saltwater intrusion are two of the most direct impacts of SLR. These effects are becoming increasingly difficult to address, as they are both caused and exacerbated by SLR, and more frequent inundation intensifies saltwater influxes and contamination. While extensive resources must be funneled into reducing greenhouse gas emissions, the primary driver of the warm conditions that precipitate SLR, equally important is adapting to the current and projected near-term impacts of SLR, specifically coastal flooding and saltwater intrusion.

Small Island Developing States (SIDS) are disproportionately affected by these impacts and are least equipped to mitigate and respond to related disasters. These countries are actively enduring some of the most intense bearings of climate change, which will grow to affect almost all other regions of the world. Support of SIDS in adapting to SLR not only benefits these low-lying countries but expands the global knowledgebase for all to combat SLR into the future. This is not only an investment in SIDS, but an assurance that the global community will be better prepared to adapt to the effects of SLR. To work toward accomplishing UN Sustainable Development Goal (SDG) 13, the United Nations must take substantive steps toward connecting adaptive mechanisms with those who need them most. The United Nations should convene forums between expert coastal scientists and engineers, and SIDS leaders and community members to implement adaptive systems. Case-by-case evaluation is necessary in determining the most effective adaptive system for each type of community.

SLR in SIDS

Located across the globe and home to 65 million people, SIDS are linked by their shared social, economic, and environmental conditions. Their small population sizes, isolated geographies, dependence on global markets, fragile land and marine ecosystems, and vulnerability to environmental and economic shocks worsen the effects of SLR. SIDS' low elevations and high water-to-land ratios intensify the impacts of tropical cyclones, loss of freshwater resources, flooding, and rising tides.

Coastal flooding and saltwater intrusion are particularly chronic in SIDS. Saltwater intrusion impacts all SIDS, and the most severe contamination threatens the lowest-lying states, such as the Maldives and Caribbean Islands. SLR is invariably linked to increased risk of saltwater intrusion for SIDS by transporting increased quantities of brackish water onshore and further inland into groundwater aquifers. Additionally, increased sea level inhibits draining of low-lying lands due to a higher groundwater table.

Together, this results in decreased salt removal capabilities from lands over time, significantly impairing the viability of the agricultural sector. Furthermore, when communities withdraw groundwater, thin freshwater aquifers are depleted, leaving openings for more saline water to enter.

Irrigation that employs saline-contaminated groundwater further degrades soil quality. Due to saltwater intrusion and other forms of water pollution, over 70% of SIDS are threatened by water shortage, and this number increases to as much as 91% at the lowest altitudes. For example, the groundwater on most of the islands of the Maldives is unusable due to saltwater intrusion and sewage pollution, and the outer islands face annual water shortages necessitating emergency shipments from the capital. Increased salinization has harmed rice production in Guinea- Bissau, and the Northern Aquifer, which provides 50- 60% of domestic-based water in Mauritius, has a major fracture line allowing for saltwater intrusion. As a result of widespread saltwater intrusion issues, many SIDS employ desalination through reverse osmosis techniques and harvest rainwater for water supplies.

SLR also increases the frequency of coastal floods, which are growing more intense from elevated extreme rainfall due to warmer atmospheric conditions. The most at-risk SIDS include Guyana, the Turks and Caicos Islands, and Belize.

Typical Flood and Saltwater Intrusion Mitigation Solutions

There are varying types of SLR-driven flooding solutions, and success is dependent on individual communities' characteristics. The seemingly clearest technological solutions to coastal flooding are hard protection and coastal infrastructure (e.g., sea walls, dikes, breakwater structures, revetments). These shore-based technologies work to blunt incoming waves, serving to protect coastal communities while also stabilizing shorelines. While most of these technologies target coastal flooding, dikes and sluice gates can additionally inhibit saltwater intrusion with careful water level management. The Caribbean region and Cuba in particular have invested heavily in coastal protection infrastructure.

While hard coastal defense structures can reduce flood risks for several meters of SLR in some coastal cities and settlements, this success must be viewed in relation to their increasingly maladaptive characteristics. These can include the following:

- Beach loss and erosion acceleration
- Degraded ecosystems (e.g., mangroves, reefs)
- Reduced flexibility to a changing climate
- Pose unaffordable costs for poorer regions
- Ongoing maintenance requirements due to weathering
- Carbon-intensive
- Increased flood water speeds and worsened conditions for downstream residents

In SIDS specifically, additional effects should be considered, including:

- Induced shoreline erosion and lowland inundation elsewhere
- Localized seawall collapse and its spread
- Limited external funds prevent repairs (e.g., Pacific SIDS, Puerto Rico)

Other measures include ecosystem-based adaptation (EbA) and other nature-based solutions. EbA serves as a low-cost and low-maintenance strategy of employing natural ecosystems (e.g., marshes, seagrass, coral reefs) for protection. EbA can take the form of watershed management, mangrove replanting, and agroforestry, and can reinforce coastal foreshore regions experiencing SLR-induced coastal erosion and flooding. Mangroves serve to minimize coastal flooding damages in Fiji and the Marshall Islands, among other SIDS. EbA solutions also strengthen biodiversity, increase food supplies, and increase human health and well-being. Natural coastal vegetation (e.g., saltmarshes and mangrove swamps) can stabilize shorelines and lessen wave impact in certain locations. However, much like hard infrastructure, EbA and nature-based solutions have their own limitations, including the following:

- Less effective in coastal zones with limited area
- Low performance under higher rates of SLR
- At 1.5°C, some ecosystems (e.g., coral reefs, certain coastal wetlands) will reach adaptation limits

Other solutions include land reclamation and relocation of people and institutions. As SIDS' residents have personal and cultural ties to their coastal communities, in-situ adaptation is preferable for short- term mitigation.

Hard shoreline strategies for saltwater intrusion adaptation overlap with some of those described for coastal flooding mitigation, including dike and seawall employment. Saltwater intrusion, like coastal flooding, also sees soft solutions, including the planting of submerged aquatic vegetation, creating dunes and marshes, and using natural breakwaters of oysters.

Alternative strategies include creating permitting and zoning rules to preserve coastal land and manage development and maintaining and restoring wetlands.

Introducing IoT into SIDS' communities

The solutions described above are either fully or somewhat established as common measures in flood mitigation. However, emerging technologies can provide quantitative data that form assessment on the effectiveness of these solutions and lend certain unique advantages to further adaptation. IoT technologies involve systems of interconnected devices that exchange data over wireless networks without human intervention. As information regarding groundwater pollutant concentrations and coastal water level fluctuations are key indicators of saltwater intrusion and coastal flooding, respectively, the ability to monitor them continuously in real-time is critical in improving adaptation. While its accuracy and data storage platforms require refinement, IoT is an emerging technology that has vast potential, specifically in regard to tracking saltwater intrusion and coastal flooding. There exist a variety of IoT sensors that can detect a range of water quality parameters, including pH, temperature, dissolved oxygen, and conductivity. Conductivity is the strongest gauge for detecting saltwater intrusion, as the characteristic increases with salinity and can serve as an indicator of pollution. IoT technologies can also be employed to detect changes in groundwater levels, which can indicate discharge and recharge in aquifers. Fixed (i.e. within buoys) and floating observation platforms can be used to position sensors in coastal settings. IoT sensors can also be used to monitor coastal wave height, period, and direction, which may provide indications of potential flood and storm surge events as immediately as this data is received and transferred to the Cloud. In this way, IoT can serve as an early warning system for coastal flooding. IoT can also serve as a key mechanism in rainwater harvesting, which is critical as many SIDS depend on rainwater due to salt-contaminated groundwater aquifers.

Policy Recommendations

The feasibility and implications of leveraging each of the above systems, both in isolation and in combination, will vary in degree and scope between individual SIDS communities. As such, the development, initiation, and sustainability of the most effective system, as defined by each community, that successfully alleviates coastal flooding and saltwater intrusion sustainably and equitably is challenging. To enhance SIDS' response to coastal flooding and saltwater intrusion, the United Nations must facilitate knowledge-sharing that will serve to aid SIDS in implementing adaptation measures. The United Nations must convene forums between expert coastal scientists and engineers, and SIDS leaders and community members to implement new coastal technologies and systems effectively. SIDS' community members have the greatest insight into their islands and potential impacts of technologies and systems, making their engagement critical. Each forum should focus on developing strategies for addressing the implementation, costs, and sustainability of each system for every SIDS community type. These systems may leverage coastal infrastructure, EbA, and/or emerging IoT technologies, or potentially integrate other types of adaptive technologies and natural barriers, depending on the unique needs of SIDS' range of coastal communities. Collaboration between experts and SIDS members allows for a widening global knowledge base and refined approach to combatting sea level rise for each community type. The UN has expertise in bringing people together to solve complex issues, and developing forums for similarly categorized SIDS is both well within the UN's capabilities and falls directly within the scope of SDG 13 of combatting climate change by developing climate change-related planning and management in SIDS.

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