Flooding and Climate Change Resilience

Sea Level Rise and Flooding in the Caribbean

7  **Sea levels continue to rise at increasing and alarming rates.**	Global mean sea level increased by 0.20 m between 1901 and 2018 and increasing rates have been noted since 1971. Sea levels will continue to rise in Small Island regions including the Caribbean and will result in increased coastal flooding.	With nowhere to retreat to and primarily coastal cities, towns and major infrastructure, sea level rise is already a concern for the Caribbean and will continue to be so beyond the current century, even with efforts to limit global warming. Sea level rise together with storm surges and waves, especially from more intense hurricanes, will worsen coastal inundation and the potential for aquifers to be impacted by increased saltwater intrusion. Sea level rise will also cause shorelines to retreat for most Small Islands. Protecting coastal assets using hard and soft measures must be a priority in development planning.

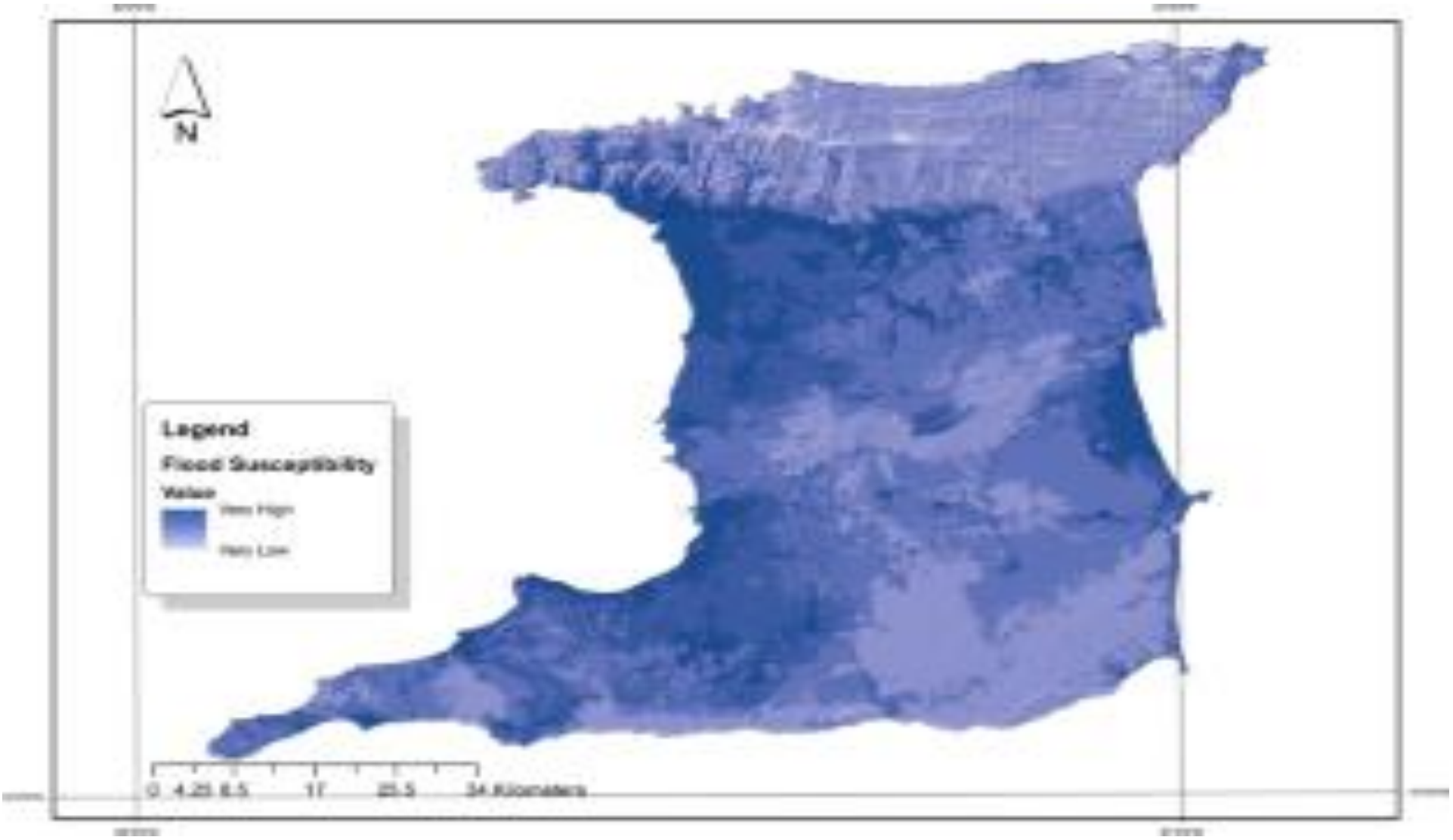
Flooding in Port of Spain, Trinidad

Building Resilience to Climate Change

- Land use zoning plans
- Site development guidelines
- Building codes and retrofitting
- Engineering and infrastructure provision
- Ecosystem management
- Governance reform

Drones

Flood Hazard Map of Trinidad



Your Excellency, The Honourable Harriet Cross, British High Commissioner,
Dean of the Faculty of Engineering of The UWI STA Campus, Professor Edwin Ekwue, Conference Chairs
Participants.

This year millions of people the world over experienced severe flooding which impacted on their lives and livelihoods and caused billions of dollars of damage to buildings and infrastructure. The floods affecting over 33 million people in Pakistan, or the devastating floods in Germany and parts of Belgium in 2021 sent shock waves across the globe. But we need not look any further…the continuous rainfall experienced a week and a half ago brought floods to many parts of Trinidad, some of which were used to flooding, and other places that were not affected by floods in the past. The economic costs associated with flooding is enormous for small island developing states (SIDS). These flood events have led many citizens to ask whether climate change is responsible for such physical destruction and disruption in their lives. Natural and social scientists from multiple disciplines recognize that floods are a complex interplay of hydrology, climate and human management.

Globally, urban centers are at a high risk of flooding, not only from more frequent and severe hydrometeorological events and sea-level rise, but also from rapid, sprawling, and often unplanned urban development that is outpacing the construction or improvement of drainage infrastructure. For Caribbean SIDS, many of our capital cities built in the colonial era, are located in the Low Elevation Coastal Zone (LECZ) which are coastal areas below 10 m of elevation above sea level that are hydrologically connected to the sea. Approximately 22 million in the Caribbean live below 6-m elevation (Cashman and Nagdee, 2017). High concentrations of population, assets and infrastructure in the LECZ are exposed to flood risks.

Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Scientists working on The IPCC'S Sixth Assessment Report confirmed that there was evidence of observed changes in extremes such as heavy rainfall, droughts, and tropical cyclones, and their attribution to human influence. We used to say that we cannot take one extreme event and attribute it to climate change. The balance of attribution science has however shifted such that we can now say with greater certainty that climate change is making our weather worse. It is affecting the intensity of floods and hurricanes that are impacting the Caribbean. We must be prepared for even more extreme weather in the near future.

A closer examination of the scientific assessment revealed that global mean sea level increased by 0.20 m between 1901 and 2018 and increasing rates have been noted since 1971. Sea levels will continue to rise in Small Island regions including the Caribbean and will result in increased coastal flooding. With nowhere to retreat to and primarily coastal cities, towns and major infrastructure, sea level rise is already a concern for the Caribbean and will continue to be so beyond the current century, even with efforts to limit global warming. Sea level rise

together with storm surges and waves, especially from more intense hurricanes, will worsen coastal inundation and the potential for aquifers to be impacted by increased saltwater intrusion.

Anthropogenic Drivers

Although climate change is occurring according to climate scientists, the impacts are being exacerbated by **anthropogenic drivers.** "Pluvial" floods, which include surface water and flash flooding, and "fluvial" floods, which occur when a river or stream overflows its banks are occurring more frequently in Caribbean SIDs because of human activity. Land use and land cover changes resulting from urbanization, built development on hillsides or flood plains whether approved or not, agricultural activity on steep slopes, deforestation either due to squatting or bush fires, wetland removal in coastal areas or poor drainage and weak solid waste management are examples of human activity which contribute to the devastating floods we experience. Caribbean SIDS are replete with examples of an inadequate governance system which is proving incapable of achieving effective flood risk reduction.

Let's examine the case of Trinidad more closely

Spatial Development Planning

Empirical evidence confirms that weak land use plan implementation has significantly increased the country's vulnerability to climate change impacts such as flooding. A review of the National Physical Development Plan of 1984 undertaken in 2012 by consultants revealed that the proposed spatial strategy was unsuccessfully implemented. Three main findings pointed to failed plan implementation which has intensified the vulnerability of the population to flooding:

- One was the proliferation of squatter settlements throughout the country characterised by the landless poor settling in sensitive watersheds and coastal lands or on vulnerable sites already prone to flooding.

- Another finding was that nearly half (46%) of the lands deemed suitable for agricultural purposes were converted to housing settlements thereby increasing the level of concretized surface area in the country which contributes to rapid surface run-off.

- A third issue was the high vulnerability of approved private sector housing as well as state subsidised housing settlements located within coastal plains composed of impermeable clay which has a natural propensity to flood. Rajack and Frojmovic (2016) noted that while state-built housing between 2000 and 2011 had some positive impact on reducing the housing shortage, the location of these projects was driven by the availability of state-owned land rather than through coordinated land use and transportation planning. This resulted in urban sprawl and flooding.

Development Control

The level of non-compliance with development standards is very high according to available data and this translates into built development occurring outside the planning framework which was designed to guide development to safe locations and to ensure public health and safety. "Between 1980 and 1990, 22% of new housing units were in full compliance with regulations and 65% was built "outside the formally sanctioned housing delivery system" (Pamuk and Dowall, 1998, 292–295). Additionally, if there are an estimated 85,000 squatter households, using a conservative average household size of six persons in these settlements, then it can be extrapolated that roughly 40% (510,000) of the country's total population of 1.3 million persons is squatting. Over 396 squatter sites are located on state lands in Trinidad and Tobago. State tolerance toward squatting continues to send a perverse incentive toward land grabbing in watersheds, flood plains and coastal zones. Illegal land occupation in ecologically fragile zones is incentivised by the existing law of adverse possession and squatter regularisation policies (Toppin-Allahar, 2001). The Certificate of Comfort is another instrument used by the state to give squatters a sense of security on state lands despite their location in environmentally sensitive areas such as hillside and floodprone areas.

Non-compliance of these informal settlements with conventional planning standards means that land use planners miss the opportunity to ensure that built structures are safe for their occupants and that they access to basic water, sanitation and drainage infrastructure that is key to public health. Without planning guidance, squatters occupy sites which are vulnerable to sea level rise, flooding, storm surges and landslides.

Weak monitoring activity and enforcement capacity of the Town and Country Planning Division have also resulted in the violation of site development standards by developers. Site and building coverage and setback distances, which help minimise run-off and flooding, are often disregarded. Additionally, engineering standards designed to regulate land clearance, cutting of slopes or quarrying are violated, a consequence of which is flooding. On-site and off-site drainage standards are not adhered to if construction occurs outside the formal regulatory framework. Informal land use activities do not have the benefit of environmental impact assessments which suggest ways of mitigating the impacts of climate change, including flooding.

A hillside development policy which restricted built development above the 91 metre contour line and on slopes in excess of 10 degrees was inconsistently implemented since the 1980s resulting in housing encroaching on steep areas which should have been left under natural vegetation. Although 60% of Trinidad's dense forest cover has survived urbanisation (United Nations Environmental Programme (UNEP), 2015), built development in steep sloping areas once under forest cover has triggered rapid surface water run-off. The need for housing has resulted in unprecedented land use changes, with the conversion of prime agricultural lands into housing areas. Furthermore, this urban sprawl has forced farmers to advance into unsuitable lands, even very steep hillsides, destroying vegetation cover and drastically changing hydrological systems. For example, a flooding episode in 2012 which occurred in Diego Martin a densely populated part

of the metropolitan region was blamed by disaster officials on the denudation of hillsides by builders and "slash and burn" farming (Chadee and Sutherland, 2014). In that year, the Minister of Planning declared a moratorium on any further approval of hillside development applications in this part of the country. That moratorium has since expired and building continues beyond the 91 metre contour line.

Recent studies confirmed small scale deforestation in watersheds lead to a significant increase in flood risks in Trinidad and progressive increase of flood damages starts below 85% forest cover (Brookhuis and Hein, 2016). The value of hydrological service per hectare is determined in part by the remaining forest cover of the catchment. This varies strongly between watersheds and ranges from US$16 to US$268 per hectare per year (Brookhuis and Hein, 2016).

Building Resilience

We need to look at ways of building resilience which is the capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function and structure.

In light of flooding that impacts many communities, governance capacity is paramount in building resilience. It refers to the ability of *governance institutions*, leaders and non-state and civil society to plan, coordinate, fund, implement, evaluate and adjust *policies* and measures over the short, medium and long term, adjusting for rapid change and wide-ranging *impacts*.

It involves pivoting to an integrated approach to land use and infrastructure planning and ecosystem management as opposed to the siloed institutional culture that still exists. It calls for *polycentric governance which involves* multiple centres of decision-making with overlapping jurisdictions. While the centres have some degree of autonomy, they also take each other into account, coordinating their actions and seeking to resolve conflicts (Carlisle and Gruby, 2017; Jordan et al., 2018; McGinnis and Ostrom, 2012).

Implementing development standards for climate proofing

Spatial planning agencies hold the key to ensuring that climate proofing is mainstreamed into policy-making and implementation. Town planning authorities need to acknowledge that incorporation of risk reduction into the location and design of buildings is of critical importance. The resilience of poor quality housing, often at risk from extreme weather, should be enhanced using structural retrofitting and interventions that reduce risks, such as flood-proofing houses or expanding drainage capacity to limit or remove flood risks. Housing and planning ministries should adopt new designs to increase the resilience of housing by ensuring that the floor levels of housing are above recorded flood levels. Moreover, the future siting and design of housing should be informed by coastal hazard risk assessments, a revised building code, and coastal setback requirements for new developments and (Simpson et al., 2012) which form part of the retreat

strategy for climate change adaptation and resilience. Shelters and critical life infrastructure also need to be built in locations that are safe from flooding.

Engineering and coastal settlements

The LECZ settlements are being protected from flooding by building coastal defences such as seawalls. Havana and Georgetown have long had seawalls to protect coastal lands and infrastructure from floods. Such measures are costly to build and maintain but so is retreating from the coasts to inland areas that are equally vulnerable to flooding.

Blue and Green infrastructure

A blend of blue, green and grey infrastructure should be mainstreamed into land use and infrastructure planning.

Blue infrastructure includes bodies of water, watercourses, ponds, lakes and storm *drainage*, that provide ecological and hydrological functions including *evaporation*, transpiration, *drainage*, infiltration and temporarily storage of *runoff* and discharge.

Green infrastructure

The strategically planned interconnected set of natural and constructed ecological systems, green spaces and other landscape features that can provide functions and services including floodwater management and coastal defence often with *co-benefits* for human and ecological *well-being*. *Green infrastructure* includes planted and remnant native vegetation, soils, wetlands, parks and green open spaces, as well as building and street-level design interventions that incorporate vegetation (after Culwick and Bobbins, 2016).

Early warning systems (EWS)

EWS is essential to resiliency building in flood prone communities. It is the set of technical and institutional capacities to forecast, predict and communicate timely and meaningful warning information to enable individuals, communities, managed *ecosystems* and organisations threatened by a *hazard* to prepare to act promptly and appropriately to reduce the possibility of harm or loss.

Education, Empowerment and Behavioural change

Education on the anthropogenic drivers of climate change and the adoption of a new outlook on finite land supply and fragile island ecosystems may help bring about a conversion among these

actors to comply with the proposals contained in spatial plans and site development standards. Education and communications experts should be deployed to utilise tools and techniques for knowledge transformation and behavioural change.

A framework for disseminating new knowledge should be developed and it should enhance interactions among (Ashley et al., 2012):

1. *Knowledge producers:* academic science, community, business, and NGO produced research;
2. *Knowledge actors or users:* most importantly, local government often in collaboration with partners; and
3. *Knowledge filters:* the media and lobby groups who can mediate between knowledge production and action.

New technologies

Caribbean SIDS have been hamstrung in their efforts to monitor and enforce spatial planning policies and development standards. However, the advent of new technologies that make planning more of an innovative, evidence-based activity which can monitor and evaluate development, holds much promise where human resource constraints exist.

Digital photography showing infringements such as squatting and building operations can enhance the surveillance and monitoring capacity of spatial planners.

The availability of earth observation data provides planners with an opportunity to track land use changes over time and empowers them to conduct vulnerability assessments and prescribe 'no-development' zones in response to climate change and disaster risks challenges.

Landsat data, which is now freely available on the Internet, and cloud mapping also hold much potential to improve spatial planning Caribbean SIDS that have struggled with a paucity of data.

The potential for mining data from new sources, for instance mobile phones and drones, is high. A drone is a low-cost and easy to use technology which can be effectively applied for data capture, spatial analysis, synthesis and visualisation of climate change impacts and vulnerabilities. Such data can be shared with planning agencies.

Geographic information systems produce flood susceptibility maps throughout the Caribbean which assist planners in land use zoning and applying building standards. The insurance industry is increasingly using such maps to calculate premiums for households and businesses.

Institutional capacity building

Building and strengthening individual organisations and providing technical and management training to support integrated planning and decision-making processes between organisations and people, as well as empowerment, social capital and an enabling environment, including culture, values and power relations (Willems and Baumert, 2003).

Conclusion

Multi-disciplinary teams comprised of land use planners, engineers, architects, geoinformatics specialists, ecologists have an instrumental role to pay in flood risk management and resiliency building which can save people's lives, economic assets and improve human health and well-being. Alleviating the economic losses and psychological trauma of flood victims calls for rigorous research, knowledge transfer on the links between climate change and anthropogenic drivers of flooding, and an improved governance system geared toward coordination and implementation. Urgent science-informed action is needed.