"Climate change impacts on coastal transport infrastructure in the Caribbean: Enhancing the adaptive capacity of Small Island Developing States (SIDS)"

OVERVIEW OF PROJECT AND KEY RESULTS

Background

Small island developing States (SIDS) share a number of socioeconomic and environmental vulnerabilities that challenge their growth and development aspirations. Their climate, geographical, and topographical features as well as their critical reliance on coastal transport infrastructure, in particular seaports and airports, exacerbate these vulnerabilities, including their susceptibility to climate change factors, such as sea-level rise and extreme weather events. Furthermore, in many SIDS, international tourism, which is highly dependent on secure and reliable international transport connections, is a major economic activity and a key purveyor of revenues, jobs and foreign exchange earnings. While recent studies by UNCTAD and others indicate that the Caribbean coastal transport infrastructure is vulnerable to mean sea level rise, storm surges and waves, heat waves and flash floods, climate change is projected to increase the region's vulnerability to hydro-meteorological hazards. At the same time, however, SIDS capacity to adapt and build the resilience of their coastal transport infrastructure is constrained. SIDS have limited capacity to conduct targeted risk - and vulnerability assessments and identify, prioritize and implement requisite adaptation options.

Against the above background, and drawing on earlier related work, since 2008, a technical assistance project on "*Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of SIDS*" has been implemented over the period 2015–2017.[1] Main aims of the project were to strengthen the capacity of policy makers, transport planners and transport infrastructure managers in SIDS to (a) understand climate change impacts on coastal transport infrastructure, in particular seaports and airports, and (b) take appropriate adaptation response measures. Case studies focusing on two vulnerable SIDS in the Caribbean (Jamaica and Saint Lucia) have been carried out to enhance the knowledge and understanding at the national level and to develop a transferable methodology for assessing climate-related impacts and adaptation options in SIDS. The case studies and methodology were reviewed and refined at a technical expert meeting and were presented and discussed at national and regional capacity-building workshops; full documentation is available on the project web-platform SIDSport-ClimateAdapt.unctad.org.

Project scope

As part of the project, case studies focusing on two Caribbean SIDS (Jamaica and Saint Lucia) were carried out to (a) enhance the knowledge and understanding of the vulnerability of critical coastal transportation assets at the national level, and (b) to develop a transferable methodology for assessing climate-related impacts and potential adaptation options for all Caribbean SIDS.

The case-study approach involved the following main components: (a) an assessment of the potential climate change impacts on ports and airports in Jamaica and Saint Lucia; (b) an assessment of options for adaptation in response to the potential impacts; (c) the development of a

[1] UNDA project 1415O. Relevant technical assistance with a focus on climate change adaptation for critical transport infrastructure contributes to implementation of a number of Sustainable Development Goals and targets, (e.g. 1.5, 9.1, 9.a, 11.b, 13.1, 13.2, 13.3, 14), as well as to implementation of the AAAA, SAMOA Pathway, and Paris Climate Agreement.

methodology/tool to assist transport infrastructure managers and other relevant entities in SIDS in assessing climate-related impacts and adaptation options regarding coastal transport infrastructure.

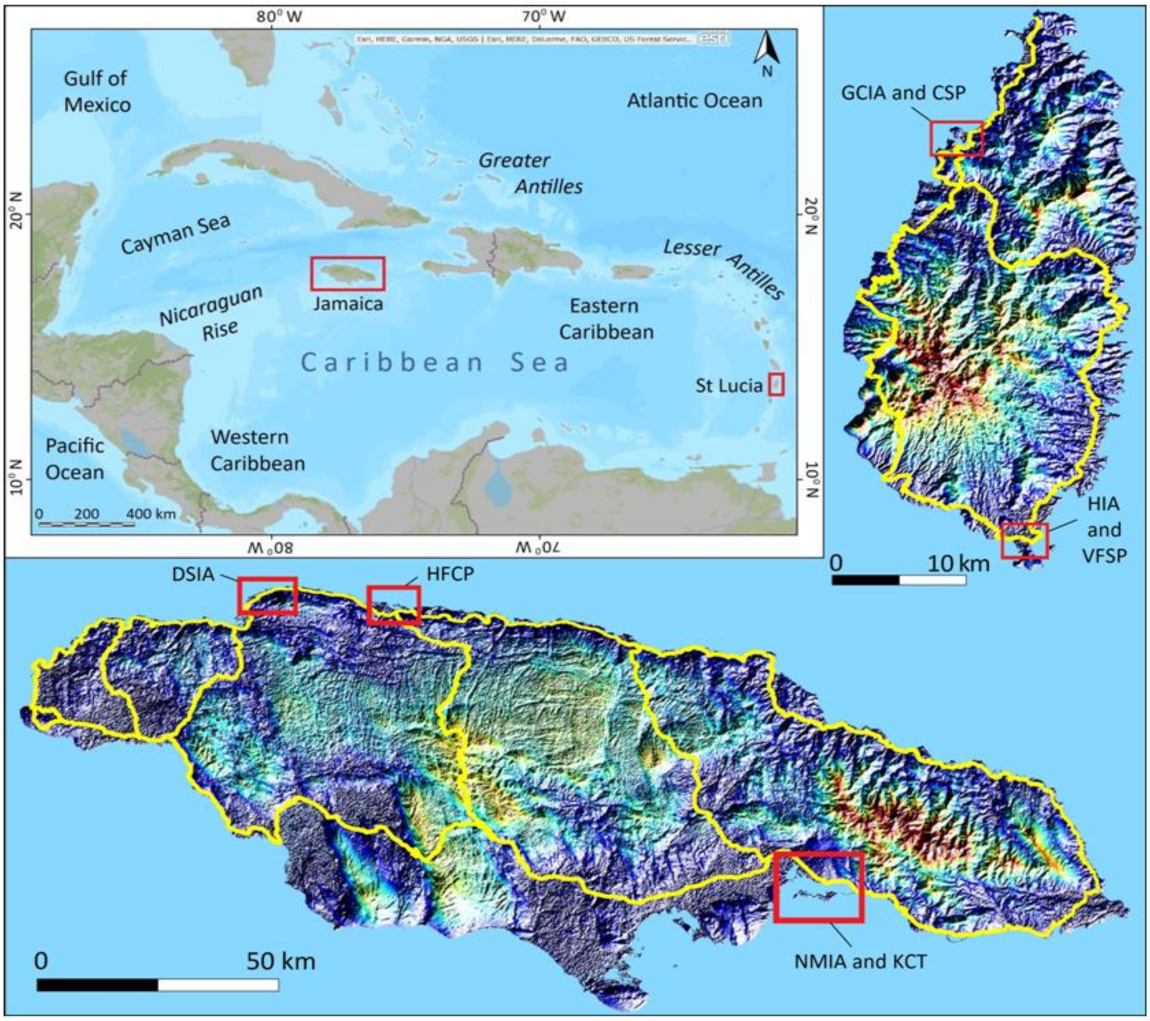

Figure 1: Location of the transportation assets of Jamaica and St Lucia considered as part of the case studies. Key: DSIA, Sangster International Airport; HFCP, Historic Falmouth Cruise Port; NMIA, Norman Manley International Airport; KCT, Kingston Freeport and Container Terminal; HIA, Hewanorra International Airport; VFSP, Vieux Fort Seaport; GCIA, George Charles International Airport; and CSP, Port Castries. Digital Elevation Model data from SRTM DTM.

The draft case studies and methodology were reviewed and refined at a technical Expert Group meeting in June 2016 and were presented and discussed at two national capacity-building workshops held in *Saint Lucia* (24-26 May 2017, Rodney Bay) and in *Jamaica* (30 May - 01 June 2017, Kingston). The workshops also provided an important opportunity for training and demonstration, as well as for feedback by a wide range of national stakeholders, with a view to finalizing the case studies. A follow up technical meeting with key stakeholders from St. Lucia and Jamaica was convened, back-to-back with the regional workshop in Barbados, in December 2017, to take stock of progress, identify obstacles and lessons learned as well as consider further technical assistance needs.

To ensure significant multiplier effects, a regional capacity-building workshop on '*Climate Change Impacts and Adaptation for Caribbean Coastal Transport Infrastructure*' was held in Barbados (5-7 December 2017, Bridgetown), bringing together seaports and airports authorities as well as a range of other stakeholders, experts, development partners, and organizations from the wider Caribbean region (21 countries and territories). The regional workshop provided an opportunity to present and discuss the findings of the national case studies for Jamaica and Saint Lucia, and to provide demonstrations and training on the methodology developed under the project. In the light of the impacts of the devastating hurricane season of 2017, the regional workshop also served as an important topical forum for exchange and discussion of collaborative action amongst stakeholders in the region. Regional workshop participants, as well as participating international organizations, experts and academics expressed the need for continued work in the area and identified several specific areas for follow-up.

UNCTAD's implementation of project activities benefited from collaboration with UNECLAC, UNDP, UNEP, the Caribbean Community Climate Change Centre (CCCCC), OECS Commission, as well as the Joint Research Centre of the European Commission (ECJRC) and academic experts, among others.

Project rationale

UNCTAD has been working, 'ahead of the curve', on the implications of climate change for maritime transportation, since 2008, with a particular focus on impacts and adaptation needs of seaports and other coastal transport infrastructure.

With an estimated 80 per cent of the volume of world trade carried by sea, international shipping and ports provide crucial linkages in closely interconnected global supply-chains and are essential for the ability of all countries, including those that are landlocked, to access global markets. While ports are at the heart of international trade and globalization, they are also exposed to the risk of climate change impacts, particularly in view of their location in coastal zones, low-lying areas and deltas. They can be particularly affected by rising sea levels, floods, storm surges and strong winds. Given the concentration of populations, assets and services associated with ports - as well as the size and value of built infrastructure - and the crucial role of ports as part of international supply-chains, climate change impacts on ports and their land-based access points, linking the maritime interface with the hinterland, may have serious broader implications.

Direct threats include accelerated coastal erosion, port and coastal road inundation/submersion, increased runoff and siltation requiring increased dredging, water supply problems, access restrictions to docks and marinas, deterioration of the condition and problems with the structural integrity of road pavements, bridges and railway tracks. In addition, port and other transport operations (e.g. shipping volumes and costs, cargo loading/capacity, sailing and/or loading schedules, storage and warehousing) may also be severely impacted. Indirect impacts on ports and, more generally, international transportation, which are even harder to assess, arise through, for example, changes in the population concentration/distribution, as well as through changes in production, trade and consumption patterns, which are likely to lead to considerable changes in demand for transportation.

Port vulnerability varies across regions, and depends on many factors, including the type of risks faced, the degree of exposure and the level of adaptive capacity. SIDS are among the most vulnerable, as they are both prone to being affected by climate change-related (and other) natural disasters and have low adaptive capacity. The significance of weather and climate-related threats has been underscored by the recent impacts of Hurricanes Irma and Maria and other storms that wreaked havoc on several Caribbean airports and seaports during the 2017 hurricane season.

While the potential risk exposure for ports is significant, there are still important knowledge gaps about vulnerabilities, as well as the specific nature and extent of exposure that individual ports may be facing. Worth noting in this context are the results of an UNCTAD port-industry survey, which revealed important gaps in terms of information available to seaports of all sizes and across regions suggesting that urgent action should be taken to increase the knowledge base in ports.[2]

Climate change data used

Impact assessments of changing climatic factors on coastal transport infrastructure and operations in Saint Lucia and Jamaica were carried out for climatic changes forced by a 1.5 °C temperature increase above pre-industrial levels, as well as for different emission scenarios and time periods in the present century.

State-of the art inundation modelling by the ECJRC was used to produce flood maps focusing on the ports and airports in Saint Lucia and Jamaica. Marine inundation was projected for different periods under different emission scenarios according to the follows: extreme sea levels (ESLs) were simulated for the baseline historical period (1995) and under the 1.5 °C warming scenario, for 9 return periods (1, 1/5, 1/10, 1/20, 1/50, 1/100,1/200, 1/500, 1/1000 years). In addition, simulations were also carried out for 2020, 2030, 2040, 2050, 2060, 2080 and 2100 under two emission scenarios (RCP4.5 and RCP8.5).

In addition to climatic factors forcing coastal marine flood inundation (i.e. sea level rise, storm surges and waves), other climatic stressors (e.g. extreme heat, precipitation and wind speed) that can cause operational disruptions/damages to the ports and airports considered in detail as part of the case studies were also covered. For the assessment of operational disruptions caused by the exceedance of operational thresholds, climatic data were extracted from the Caribbean Community Climate Change Centre's (CCCCC) database that contains downscaled daily climate projections for the period 1970 -2100 from the Regional Climate Model RCM PRECIS.

Results of the risk and vulnerability assessment of critical coastal transport infrastructure

Important outcomes of the two case studies include an assessment of the potential vulnerabilities to climatic change of two Caribbean SIDS, focusing on potential operational disruptions and the marine inundation risk of critical coastal international airports and seaports in Jamaica and Saint Lucia (Fig. 1). In that context, historical hydro-meteorological impacts and disruptions were summarized and direct and indirect impacts on the critical coastal transport assets of St. Lucia and Jamaica were assessed. For further details, see the case studies and methodology available at SIDSport-ClimateAdapt.unctad.org, as well as Monioudi et.al (2018)[3].

1. Approach to vulnerability assessment of critical coastal transportation assets in Saint Lucia and Jamaica

Direct impacts

The following approaches were adopted to assess direct impacts of climate variability and change (CV & C) on critical coastal transport infrastructure/assets in Saint Lucia and Jamaica: (a) assessment of direct impacts of changing climatic factors on coastal transport operations using the 'operational thresholds' method; and (b) assessment of direct impacts on coastal transport infrastructure

[2] Port Industry Survey on Climate Change Impacts and Adaptation (UNCTAD/SER.RP/2017/18). Although no responses were received from Caribbean seaports, the results of the port industry survey may be considered as representative as respondent ports collectively handle over 16 % of global seaborne trade.

[3] Monioudi, I.N., Asariotis, R., Becker, A. et al. Reg Environ Change (2018). *Climate change impacts on critical international transportation assets of Caribbean Small Island Developing States (SIDS): The case of Jamaica and Saint Lucia*. https://doi.org/10.1007/s10113-018-1360-4 ; https://rdcu.be/Q1OY

through modelling of the flood/inundation due to extreme sea levels (ESLs) under the present and future climate.

The operational thresholds approach included the following steps: 1) Identification of the operational thresholds (e.g. extreme temperatures and rainfall under which facility operations are impaired); as specific facility thresholds were not available, generic thresholds were used. 2) Collation of climatic data: Climatic projections from the RCM PRECIS were abstracted from the CCCCC database; available projections are for the SRES A1B scenario (which in terms of emissions and potential impacts, approximates the RCP6.0). 3) Operational thresholds and the RCM PRECIS climatic projections were then compared to assess threshold exceedance frequencies.

Assessment of the direct impacts on coastal infrastructure was carried out through modelling of the marine flood/inundation due to extreme sea levels (ESLs) under the present and future climate. ECJRC contributed to the study in that context. Extreme sea levels for different emission scenarios and periods in the 21st century have been estimated by combining projections of Mean Sea Level Rise (MSLR) with projections of astronomical tide changes, and the episodic coastal water level rise due to storm surges and wave set ups. Storm surges were simulated using a flexible mesh setup of the DFLOW FM model, whereas wave projections were provided by the spectral wave model WW3; in both cases, atmospheric forcing was provided by ERA-INTERIM projections. Effects of cyclones on coastal sea levels were also taken into consideration in the projections. The projected total ESLs were then used to simulate marine coastal flood/inundation on the basis of dynamic simulations using the open-access model LISFLOOD-ACC (LFP) and the available digital elevation models (DEMs).

Indirect impacts

In terms of indirect impacts, potential CV & C impacts on tourism in Saint Lucia were also assessed. Since most of the tourist infrastructure are concentrated along the island beaches, potential CV & C impacts on St. Lucia's tourism (with potential implications for the demand for air transport) were projected through the 'proxy' of the decrease in the carrying capacity of St. Lucia beaches due to beach erosion under different climatic forcings. The geo-spatial characteristics (e.g. beach width maxima) and other attributes (e.g. backshore development) of all ('dry') beaches of Saint Lucia have been recorded on the basis of the images and other related optical information available in the Google Earth Pro application. Seven cross-shore analytical and numerical morphodynamic models were used in appropriate ensembles to project the response of the Saint Lucia's 'pocket' beaches to long and short-term SLR.

2. Key findings

Key outcomes of the project include the assessment of the potential vulnerabilities to climatic change of two Caribbean SIDS, focusing on potential operational disruptions and the marine inundation risk to coastal international airports and seaports of Jamaica and Saint Lucia under different climate scenarios.

The 1.5 °C temperature increase cap above pre-industrial levels - included as an aspirational goal in the Paris Agreement (Art. 2.2) and of particular importance for SIDS - was translated into a date year under the project. According to the analysis, the 1.5 °C temperature increase cap will be reached by 2033 under the IPCC RCP4.5 and by 2028 under the RCP8.5 scenario. Both operational disruptions and marine inundation are projected to increase significantly in Saint Lucia and Jamaica when the temperature rise cap of 1.5 °C is exceeded.

Climatic operational thresholds:

Operational disruptions are projected when the temperature cap of 1.5 °C is exceeded. It appears that most operational problems for the Jamaican and Saint Lucian critical transportation assets will be due to rising temperatures (apart from marine inundation).

- **Outside working conditions**: By the early 2030s, staff working outdoors at the Jamaican and Saint Lucian international transportation assets could be at "high" risk for 5 and 2 days/year, respectively; by 2081-2100, such days could increase to 30 and 55 days/year, respectively
- **Aircraft take-off**: By 2030, Boeing 737-800 aircrafts will have to decrease their take-off load for 65 days/ year at DSIA and 24 days /year at NMIA, whereas by the 2070s such days could increase at least twofold for DSIA and fourfold for NMIA, assuming no targeted aircraft design changes
- **Energy needs**: It was found that for e.g. the Jamaican seaports, a 1.5 °C temperature rise will increase energy requirements by 4% for 214 days/year, whereas a 3.7 °C rise (2081-2100) will increase energy requirements by 15 % for 215 days/year. Saint Lucia seaports are projected to experience similar trends
- **Extreme rainfall**: Future disruptions due to intense (> 20 mm/day) and very heavy rainfall (> 50 mm/day) are projected not to differ significantly from those of the baseline period
- **Strong winds**: The projections show that future winds will not affect significantly airport and seaport operations on the basis of these thresholds

Limitations: As the climate projections from the CCCCC database do not include the effects of tropical storms/hurricanes, these results may be considered as underestimates. Also, facility-specific operational sensitivities that cannot be captured by generic thresholds (e.g., the disruptive effects of wind and wave directional changes on ship berthing) may also increase operational disruptions.

Coastal (marine) inundation:

Projections showed that the critical transportation assets of both SIDS would face rapidly increasing marine inundation risks compared with the current situation, with those of Saint Lucia being at higher risk than those of Jamaica (Tables 1 and 2). The results also suggest that, even under the 1.5 °C temperature increase cap, some of the critical assets of the islands will face increased direct marine inundation under extreme events, which will deteriorate very significantly and involve other assets later in the century. The flood maps (Figs 2 and 3) illustrate the vulnerability to marine flooding of key international transport assets in both countries.

Table 1: Summary of coastal (marine) inundation of critical coastal transport assets of Jamaica

JAMAICA	
Sangster International Airport (DSIA)	The low elevation of the DSIA runway will make it increasingly vulnerable to marine inundation during extreme events. Modelling results show that, even under 1.5°C warming compared to the pre-industrial times, the ESL100 will cause significant flooding. By 2050 (RCP4.5) similar flooding is projected for the 50- year event (ESL50).
Norman Manley International Airport (NMIA)	NMIA is less prone to marine inundation, as its runway has an elevation in excess of 2 m and is also adjacent to mangroves/saltmarshes that can reduce storm impacts.
Kingston Freeport and Container Terminal (KCT)	By 2030, some areas of the KCT seaport are projected to be flooded under the ESL100, whereas by 2100 much larger areas will be affected. Its access roads are also projected to be vulnerable to flooding.
Historic Falmouth Cruise Port (HFCP)	HFCP cruise port will be very moderately affected until the 2080s, even by events with return periods in excess of 200 years. However, it appears that the low-lying access roads will be increasingly vulnerable to flooding.

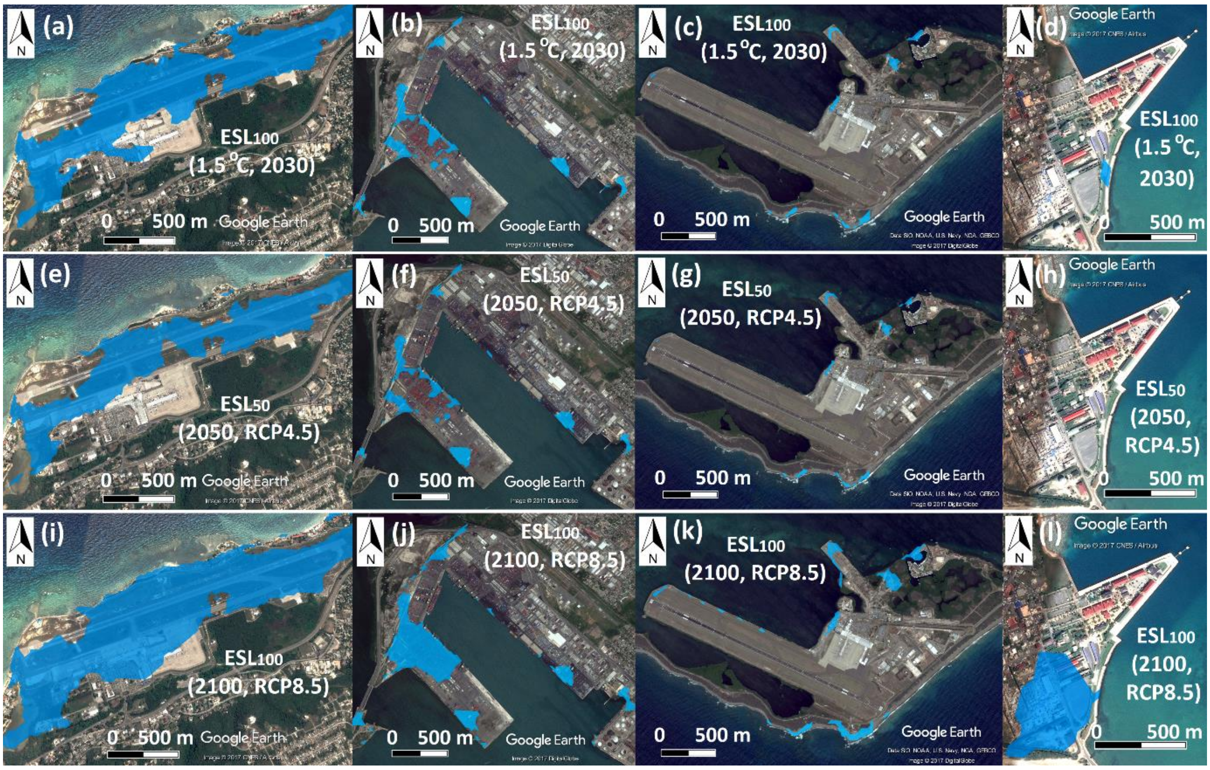

Figure 2: Coastal flooding – Jamaica Inundation maps of (a, e, i) DSIA, (b, f, j) KCT, (c, g, k) NMIA, and (d, h, l) HFCP under a 100-year ESLESL100 (1.5 °C), 50-year ESL-ESL50 (2050, RCP4.5) and ESL100 (2100, RCP8.5)

Table 2: Summary of coastal (marine) inundation of critical coastal transport assets of Saint Lucia

SAINT LUCIA	
George Charles International Airport (GCIA)	Under a 1.5 °C warming, GCIA appears vulnerable to the ESL100 mostly at its northern side (Vigie beach), as the western end of the runway is located at an elevated and armoured coastline. As the century progresses, its vulnerability will increase. Vigie beach, located only 30 m away from the airport fence, has been projected to face also significant beach erosion. This will increase further the marine inundation risk.
Hewanorra International Airport (HIA)	HIA appears vulnerable at its eastern (seaward) edge. There, the runway is projected to be inundated at lengths of about 150, 130, and 380 m under the ESL100 (1.5 °C warming), the ESL50 (2050, RCP4.5) and the ESL100 (2100, RCP8.5) scenarios, respectively.
Port Castries (CSP)	The ESL100 is projected to impact docks severely, inundate berths, cargo sheds and cruise ship facilities and cause flooding of the city, even under 1.5 °C warming scenario; later in the century and under both RCP scenarios tested, CSP flooding is projected to deteriorate in the absence of effective adaptation measures.
Vieux Fort Seaport (VFSP)	VFSP appears vulnerable to marine flooding under all tested scenarios, which is markedly different from its previous experience.

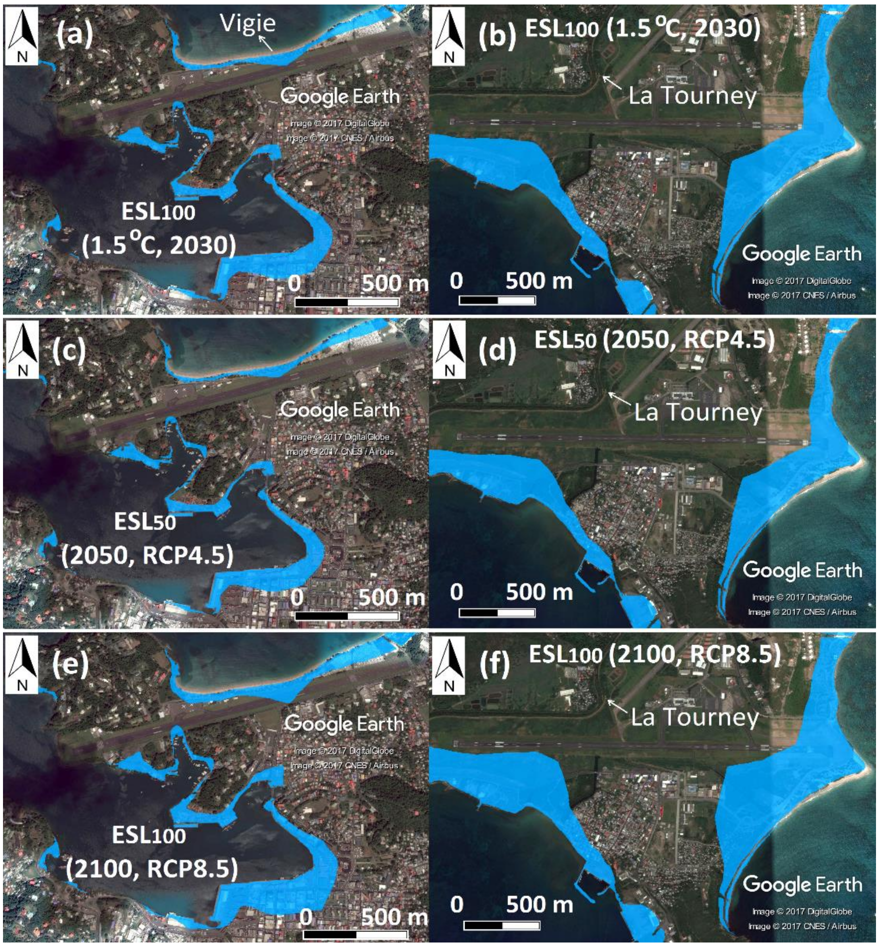

Figure 3: Coastal flooding – Saint Lucia Inundation maps of (a, c, e) GCIA and CSP and (b, d, f) HIA and VFSP under ESL100 (1.5 °C, 2030), ESL50 (2050, RCP4.5) and ESL100 (2100, RCP8.5)

Beach erosion – Saint Lucia:

Significant impacts on the beaches of Saint Lucia have been projected: The analysis has shown that in 2040, storm-induced ESLs of about 1 m combined with a moderate MSLR of about 0.2 m will result in the complete erosion and marine inundation of at least 11 % and 24 % of all island beaches, respectively. In 2100, superimposition of storm levels on the projected MSLRs could have devastating effects. A combined ESL of 1.56 m (e.g. a storm-induced extreme level of +1 m superimposed on a MSLR of 0.56 m -RCP4.5) could result in the complete erosion of at least 20 % and the complete flooding of at least 31 % of all beaches. It must be stressed that the above projections represent minimum beach erosion and flooding. These results indicate that there may be significant impacts on Saint Lucia's tourism which, in turn, may affect negatively the demand for transportation services.

3. Methodology: A climate risk and vulnerability assessment framework for Caribbean coastal transport infrastructure

A methodology was developed under the project to assist transport infrastructure managers and other relevant entities in SIDS in assessing climate-related impacts and adaptation options in relation to coastal transport infrastructure ('*Climate Risk and Vulnerability Assessment Framework for Caribbean Costal Transport Infrastructure*').

The methodology provides a structured framework for the assessment of climate-related impacts with a view to identifying priorities for adaptation and effective adaptation planning for critical coastal transport infrastructure (Figure 4); it takes a practical approach that uses available data to inform decision-making at a facility, local, and national level. Technical elements include an 'operational thresholds' method, to determine the climatic conditions under which facility operations might be impeded, as well as marine inundation modelling (see Section 1, above). The methodology is transferable, subject to location specific modification, for use in other SIDS within the Caribbean and beyond.

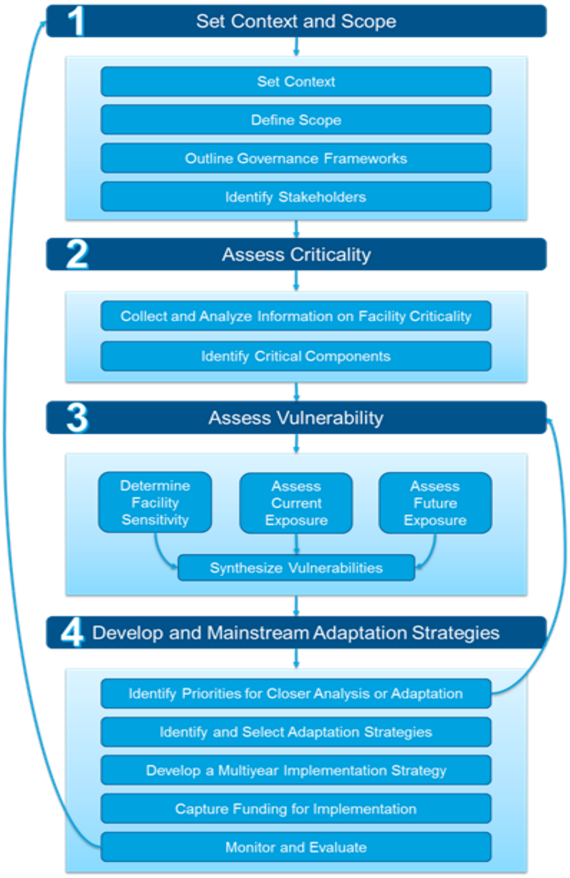

Figure 4: Schematic overview of 'Climate Risk and Vulnerability Assessment Framework for Caribbean Costal Transport Infrastructure'

Main lessons learnt

As noted above, important project outcomes include state of the art methodological approaches to assess the potential climate-related vulnerabilities of critical international transportation assets in Caribbean SIDS. In addition, the case studies and the workshops generated a wealth of information about the vulnerability assessment and adaptation process in Caribbean SIDS. Some of the major lessons learnt fall into the following three categories:

<u>Data:</u>

- Data collection efforts take time.
- Many SIDS lack baseline data.
- Site visits to facilities and interviews with local stakeholders are essential ('*the map is not the terrain*').

- Steps to validate stakeholder input from facility managers can ensure high-quality inputs.
- Identifying facility specific sensitivity thresholds can help streamline and improve the vulnerability assessment process
- Further research, including detailed technical studies, as well as collaborative concerted action at all levels is urgently required.

Awareness and coordination:

- Communication and collaboration among public and private sector stakeholders is key.
- Ports/airports already taking action to increase their resilience should share their success stories.
- There is a need for regional cooperation, and to build a knowledge base and community of practice around vulnerabilities.

Implementation:

- Organizational "best practices" can increase resilience, and vice-versa.
- "Mainstream" adaptation activities into existing planning and decision-making processes.
- Climate change adaptation often comes down to a policy decision related to risk tolerance.
- Financing for capital projects remains a major hurdle.
- Ecosystem enhancements can play a significant role in reducing natural hazard risks, including coastal hazards and inland flooding.