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"Climate Change Impacts and Adaptation for Coastal Transport Infrastructure in the Caribbean"

Case Study Saint Lucia: approach, methods and key findings

By

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UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT
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Climate Change Impacts on Coastal Transportation Infrastructure in the Caribbean:

The case study of SAINT LUCIA

Approach, methods and key findings

Isavela Monioudi

Synopsis

Introduction: SIDS vulnerability to CV & C

- ✓ SIDS face significant challenges from CV & C, prompting the Alliance of Small Island States (AOSIS) to strongly advocate for a cap of 1.5 °C on global warming above pre-industrial levels (2015 Paris Agreement)
- ✓ SIDS are particularly vulnerable due to their small size and economies, the high concentration of population, infrastructure, and services at the coast
- ✓ It has been suggested that the Caribbean States could face climate-related losses in excess of $22 billion annually by 2050 (IDB 2014)

Introduction: CV & C impacts on transport/tourism

Impacts on transport infrastructure

Transport infrastructure and operations mostly located at the coast are likely to be seriously affected:

- ✓ Marine flooding of the low-lying coastal airports; high temperatures can affect runways (heat buckling) and aircraft lift, resulting in payload restrictions and disruptions: runway length extensions will be required (which may not be always easy)
- ✓ Seaports will be incrementally affected by MSLR and storm events; their quays, jetties and breakwaters will be affected, requiring redesigning and/or strengthening; alteration of nearshore flows inducing port scouring and/or silting
- ✓ Heavy precipitation can affect services and induce flash floods and landslides that can have an impact on coastal transportation assets and their connecting road network

Introduction: CV & C impacts on transport/tourism

Impacts on tourism

Caribbean is based on the “3S” tourism model (Sea, Sand and Sun). Critical component is the availability of beaches that are environmentally and aesthetically sound and retain adequate carrying capacity

Carrying capacity is defined as the “maximum number of people that may visit a tourism destination at the same time, without causing destruction of the physical, economic and socio-cultural environment and an unacceptable decrease in the quality of the visitor’ satisfaction”

Beach erosion due to e.g. sea level rise might reduce the carrying capacity of the beaches and consequently the touristic attractiveness, resulting to significant international travel expenditure loss.

Saint Lucia: Country Profile

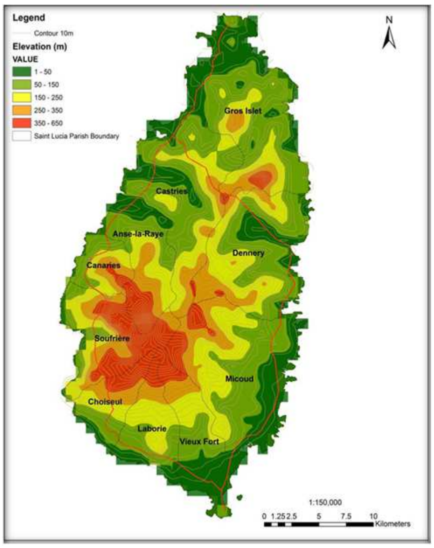
Saint Lucia

- area 616 km^2, population 185,000
- GDP of 1.43 billion USD
- Tourism sector contributes up to 41 % (direct and indirect contributions, 2015)

Saint Lucia: Country profile

- Windward Island
- Volcanic origin: mountainous/rugged topography
- Has a relatively high biological and ecosystem diversity
- High concentration of population and tourism development at the coastal zone

All of the above lead to increased risks with regard to CV & C



(Source: ESL, 2015)

Saint Lucia: Country profile

Current climate and climatic hazards

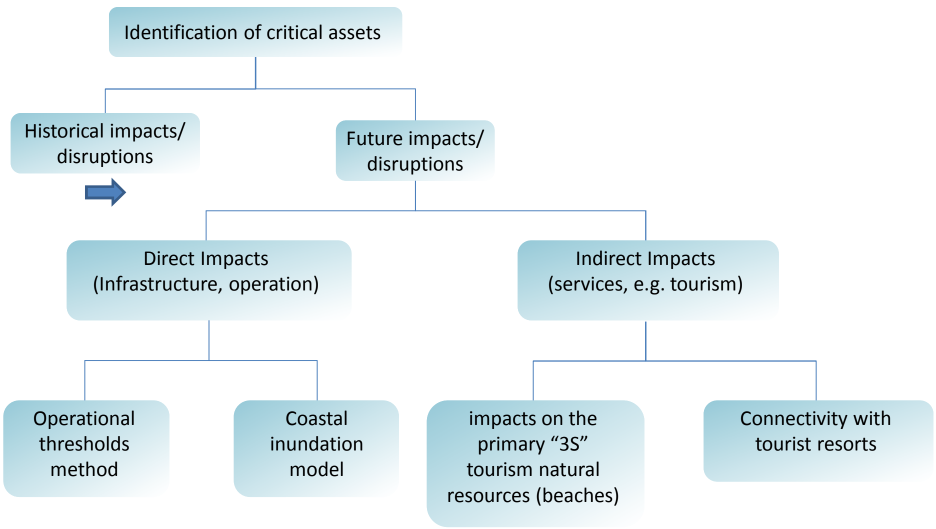
- Mean daily temperatures: 23.3°C -30.9°C. Increasing trend of mean annual temperature by about 0.16 °C/decade, together with the frequency of warm days and nights
- Rainfall is about 12.6 cm at the coast and up to 34.2 cm in the interior. Flash floods and landslides are historical hazards;
- MSLR, based on tidal records from Fort-de-France, Martinique, shows a rising trend since 1976; this has accelerated over 2005-2016 to 7 mm/year
- The island has also been hit by tropical storms/hurricanes that caused human losses and significant damages. Hurricane Allen (1980) and hurricane Tomas caused damages equivalent to 60 % and 43.4 % of GDP respectively

Saint Lucia: Country profile

Climate projections

- The island is projected to be warmer compared to the 1970-1999 average temperature by up to about 1.8 °C by the 2050s and 3 °C by the 2080s.
- Both GCMs and RCM project decreases in annual rainfall of up to 22 % and 32 %, respectively. Also, projections suggest likely decreases in total heavy rainfall
- Sea levels are also expected to rise, with MSLRs of 13 - 14 cm, 31-35 cm and 56-76 cm projected for the year 2030, 2060 and 2100, respectively, depending on the scenario (RCP 4.5 and RCP 8.5)
- The frequency of ESLs will increase considerably. ESL_{100} of the baseline year (1995) will occur about every 10 years in 2030, becoming the 1-year event before 2040

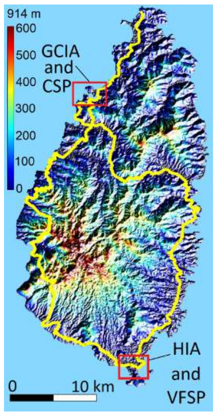
Assessment of CV&C impacts on transport - Methodology



Application of the methodology (SAINT LUCIA)

Critical assets – Saint Lucia

	Runway length (m)	Runway width (m)	Elevation (m)	Passengers (2016)	Cargo handled (tonnes, 2016)
Hewanorra International Airport (HIA)	2743.2	45.72	3.3	644837	2138
George Charles International Airport (GCIA)	1889.76	45.72	6.1	195859	1079
Castries Seaport (CSP)	940.6 (cargo +cruise)	5.5-10	1.5	677,394	480770 tonnes (2016)
Vieux Fort Seaport (VFSP)	373	11	1.5-2.5	N/A	~46000 TEU per year



Application of the methodology (SAINT LUCIA)

Future disruptions - Direct impacts

- ✓ Impacts under the AOSIS advocated 1.5 °C temperature cap were also assessed; the 1.5 °C temperature increase cap was also translated into a date year.
- ✓ The date year that the temperature will increase by 1.5 °C above pre-industrial levels has been projected using the complete ensemble of CMIP5 General Circulation Models (Taylor et al. 2012) and following an approach similar to Alfieri et al. (2017).
- ✓ The analysis projected that the 1.5 °C temperature increase cap would be reached by 2033 under the IPCC RCP4.5 and by 2028 under the RCP8.5 scenario.
- ✓ Therefore, the results for the 1.5 °C temperature increase cap are based on climatic factor projections for 2030.

Application of the methodology (SAINT LUCIA)

Future disruptions - Direct impacts

Operational thresholds method

Identifying the operational thresholds

i. Employee ability to work safely outdoors - heat index (a function of temperature and relative humidity) (airports and seaports)
ii. Take off runway length requirement is a function of air temperature (airports)
iii. Energy cost and Temperature (seaports)
iv. Crane operation and precipitation (seaports)

Collection of Climate data

i. Raw daily climate model data from the database of the Caribbean Community Climate Change Centre (CCCCC)

Estimation of days of disruption

Trough the comparison of the operational thresholds with the climate data, the days that these thresholds would be exceeded were estimated

Application of the methodology (SAINT LUCIA)

Days of disruptions for airports and seaports in Saint Lucia

Climate Stressor	Sensitivity	Threshold	Disruptions (average days/year)					
			1986-2005	2006-2030	*2030*	2031-2055	2056-2080	2081-2100
Extreme Heat	Employee ability to work safely outdoors in airports and seaports	Heat Index (NOAA) over 30.8 °C (87.5 °F) with relative humidity 80% is "high" risk	1.25	1.96	***2.00***	11.86	29.13	55.33
		Heat Index (NOAA) over 32.9 °C (90.7 °F) with relative humidity 80 is "very high" risk	0.00	0.00	***0.00***	0.59	2.42	9.06
	Aircraft take-off length requirements	Boeing 737-500 aircraft would not be able to take off from HIA if the temperature exceeds 31.2°C	0.55	0.96	***0.00***	10.64	31.38	69.72
	Energy costs in seaports	0.8°C = 4% increase if temperature exceeds 27.6°C (1986-2005 average: 26.8 °C)	80.55	114.32	***168.00***	225.50	322.13	355.72
		1.3°C warming = 6.5% increase if temperature exceeds 28.1°C	49.05	71.76	***113.00***	161.59	279.58	343.61
		3°C warming = 15% increase if temperature exceeds 29.8°C	5.90	9.72	***18.00***	40.32	98.54	182.78
Precipitation	Inhibits crane operation in seaports	Intense rainfall (e.g., > 20 mm/day)	48.20	44.60	***51.00***	45.55	46.88	48.00
		Very heavy rainfall (e.g. >50 mm/day)	0.45	0.72	***1.00***	1.05	0.54	0.83

Application of the methodology (SAINT LUCIA)

Future disruptions – Direct impacts

Coastal inundation model (JRC-EC)

Estimation of future exposure to coastal flooding/inundation

- ✓ Estimation of extreme sea levels (ESLs) (for different periods in 21st century, and 10 return periods and for 2 RCP scenarios 4.5 and 8.5).
  ESLs are driven by the combined effect of MSL (regional projections), tides (Topex/Poseidon) and water level fluctuations due to waves and storm surges (dynamic simulations forced by atmospheric conditions). Cyclone effects have been included.

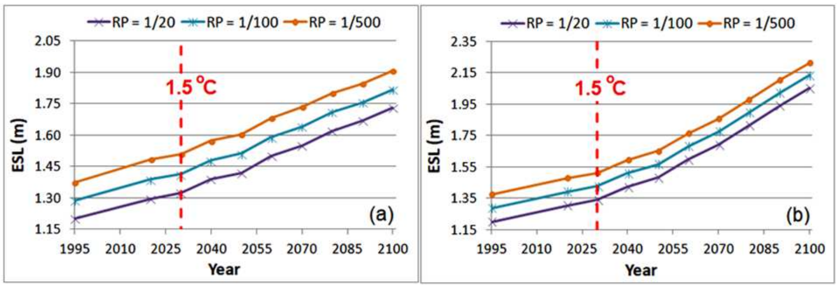
- ✓ Flood/inundation assessment is being carried out, using dynamic simulations using the open-access model LISFLOOD-ACC.

Application of the methodology (SAINT LUCIA)

Future disruptions - Direct impacts

Coastal inundation model (JRC-EC)

Extreme Sea Level projections

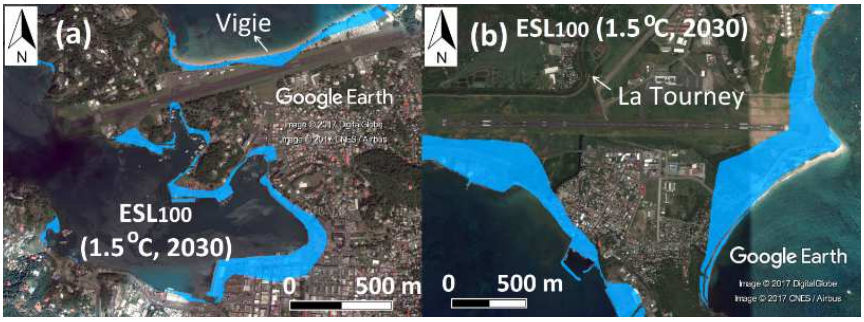


Time evolution of ESLs for 3 return periods (RP) and according with the RCP scenarios (a) 4.5 and (b) 8.5. The red stippled line represents the projected date year of the 1.5 °C temperature increase since the pre-industrial period

Application of the methodology (SAINT LUCIA)

Future disruptions – Direct impacts

Coastal flooding – Saint Lucia

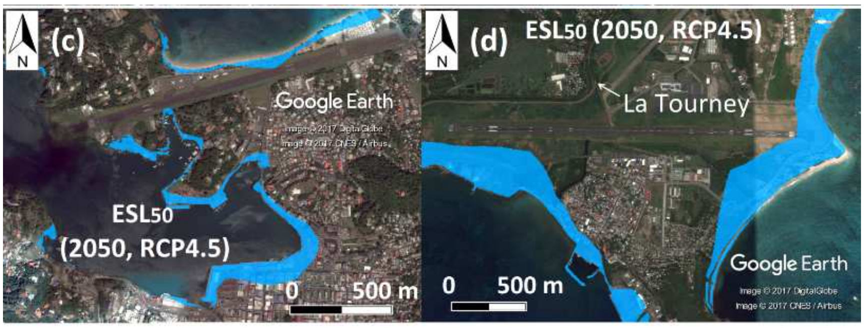


Inundation maps of GCIA, CSP, HIA and VFSP under ESL_{100} (1.5 °C, 2030)

Application of the methodology (SAINT LUCIA)

Future disruptions – Direct impacts

Coastal flooding – Saint Lucia

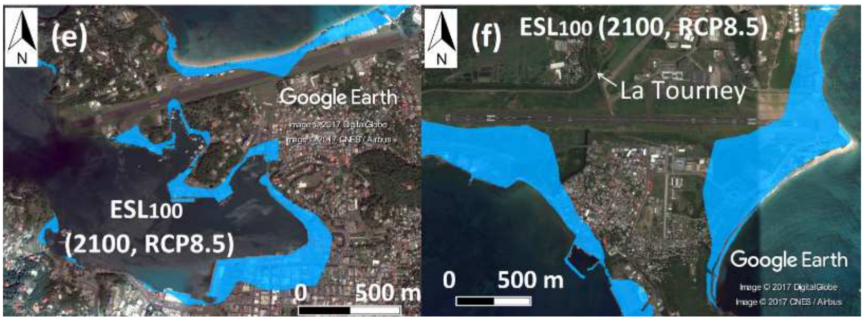


Inundation of GCIA, CSP, HIA and VFSP under ESL_{50} (2050, RCP4.5)

Application of the methodology (SAINT LUCIA)

Future disruptions – Direct impacts

Coastal flooding – Saint Lucia



Inundation of GCIA, CSP, HIA and VFSP under ESL_{100} *(2100, RCP8.5)*

Application of the methodology (SAINT LUCIA)

Future disruptions – Direct impacts

Coastal flooding

Hewanorra airport
will be affected only at its eastern side of the runway, which is projected to be inundated by:

- 130 m under the 50-year ESL of RCP 4.5 by 2050
- 380 m under the 100-year ESL of RCP 8.5 by 2100

George Charles airport
appears vulnerable at its northern side. The inundation of the Vigie beach will make the airport very vulnerable to the incident waves.

Port Castries
All studied scenarios show severe impacts. (impacts on the docks, inundation of berths, flooding in areas of the city adjacent to the docks, in the Cargo Sheds and equipment, and cruise ship facilities)

Port Vieux Fort
All studied scenarios show severe impacts on Port Vieux Fort (flooding of the docks and berths and surrounding areas)
Breakwaters will be also impacted

Application of the methodology (SAINT LUCIA)

Future disruptions – Direct impacts

Coastal flooding

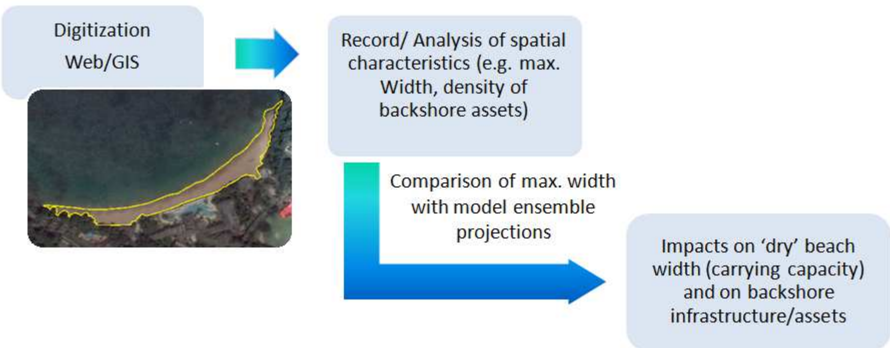
Table summarizing the impacts on major transportation assets due to coastal flooding. 0: no impacts, 1: Low impact, 2: medium impact, 3: high impact.

Scenarios	ESL plus Hurricane (m)	Graded impacts to the Major Assets			
		HIA	GCIA	VFSP	CSP
RCP 4.5 – 2050 (RP=1/10)	1.38	1	0	3	3
RCP 4.5 – 2050 (RP=1/50)	1.47	1	1	3	3
RCP 4.5 – 2050 (RP=1/100)	1.51	1	1	3	3
RCP 8.5 – 2050 (RP=1/10)	1.44	1	0	3	3
RCP 8.5 – 2050 (RP=1/50)	1.53	1	1	3	3
RCP 8.5 – 2050 (RP=1/100)	1.57	1	1	3	3
RCP 4.5 – 2100 (RP=1/10)	1.69	1	1	3	3
RCP 4.5 – 2100 (RP=1/50)	1.78	2	2	3	3
RCP 4.5 – 2100 (RP=1/100)	1.82	2	2	3	3
RCP 8.5 – 2100 (RP=1/10)	2.01	2	2	3	3
RCP 8.5 – 2100 (RP=1/50)	2.10	3	2	3	3
RCP 8.5 – 2100 (RP=1/100)	2.13	3	2	3	3

Application of the methodology (SAINT LUCIA)

Indirect impacts

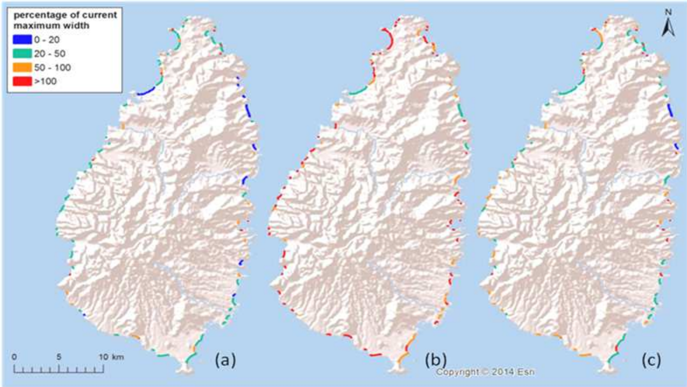
Impacts on the primary "3S" tourism natural resources (beaches)



Application of the methodology (SAINT LUCIA)

Indirect impacts

Impacts on the primary "3S" tourism natural resource (beaches)



Max. width reduction (expressed in percentage of their initial max. width) according (a) minimum and (b) maximum beach retreat under an ESL of 1.2 m (for the year 2040) and (c) minimum beach retreat under an ESL of 1.8 m (for the year 2100).

Application of the methodology (SAINT LUCIA)

Indirect impacts

Connectivity of international gateways with the tourist resorts

An estimation has been carried out on the basis of the number of landslides along the connecting road network between the 2 international airports of Saint Lucia and 30 coastal tourist resorts through

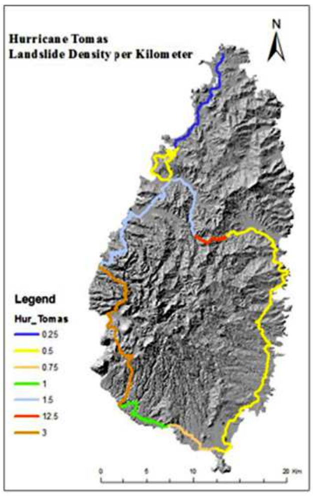
(i) digitization of the major road network using the Google Earth Application and

(ii) the landslide density per km recorded during the Hurricane Tomas

Application of the methodology (SAINT LUCIA)

Indirect impacts

Connectivity issues : airports - tourist resorts



Landslides along the road network		
Major touristic destinations	**From HIA**	**From GCIA**
Cas en Bas	45.9	2.8
Anse Petience	9.5	33.5
Coconut Bay	0.4	42.6
Anse de Sable_1	0.4	43.0
Anse de Sable_2	0.9	44.3
Sugar Beach	46.6	83.9
Malgretoute	53.2	77.4
Soufriere	60.2	70.4
Anse Chastanet	65.9	64.7
Canaries	98.0	38.3
Anse Cochon	111.3	25.0
Anse Galet	114.6	21.6
Anse La Raye	116.7	19.6
Roseau	124.4	11.9
Marigot	126.5	9.8
Grande Cul DeSac	40.6	3.3
La Toc	42.2	1.4
Vigie	43.0	0.0
Choc	43.5	0.5
Almond Morgan	43.8	0.8
St. James	43.9	0.8
Labrelotte_1	44.2	1.1
Labrelotte_2	44.2	1.2
Trouya	44.3	1.3
Reduit	44.9	1.8
Rodney_1	45.4	2.4
Rodney_2	45.6	2.5
Pigeon Island	45.7	2.6
Smugglers Cove	45.9	2.8
Le Sport	46.2	3.1

Conclusions

- ✓ There is significant and increasing marine inundation risk to the critical assets, with the seaports being the most vulnerable
- ✓ Severe impacts are projected even under the AOSIS advocated temperature increase cap of 1.5 ^{o}C
- ✓ It appears that most operational problems will be due to rising temperatures, with rainfall and wind effects projected to have minor impacts. However, as the climate projections from the CCCCC database do not include the effects of tropical storms/hurricanes, these results may be considered conservative
- ✓ Under increasing beach erosion and flooding, the long-term recreational value of the Saint Lucia beaches may fall considerably
- ✓ In Saint Lucia, connectivity of the major transportation assets to the major tourist destinations of the island is under increased risk by the large density of landslides

Further work

This work represents a first evaluation of the vulnerabilities of critical transportation assets of Saint Lucia to climatic change, which could be fine-tuned if the following are available.

- facility-specific operational sensitivities that cannot be captured by generic thresholds
- a DEM of good quality and of high resolution, required for more accurate inundation projections

Coastal transportation assets could be directly and indirectly impacted by additional hazards and their combinations, making multi-hazard assessments necessary for effective adaptation planning.

Potential technical adaptations responses

The methodological framework for the implementation of adaptation options may include the following steps:

- Collation/collection of detailed information (e.g. historical disruptions, climate data, facility specific operational thresholds, good quality DEM etc.). Installation of water level recorders at the facilities (or their vicinity).
- Detailed 2-D modeling for integrated combined hazards from marine and flash flooding (multi-hazard risk assessments)
- Design/testing (using simulations) of appropriate technical adaptation responses under climate change, including cost benefit analyses
- Study of socio-economic parameters (including a review of pertinent national policies and regulation)
- Planning/implementation of technical responses; monitoring of the technical projects after their completion

Potential technical adaptations responses

Action Area	Adaptation Action
Engineering	Enhance the structural integrity and efficiency of critical facility components
	Future procurement of mechanical components for the assets against future operating environment requirements
	Assess and develop new design standards for hydraulic structures
	Ongoing hydrographical monitoring
	Construction of storm retention basins for flash flooding
Technology	Investment in more climate-resilient technologies and equipment in planned expansion and upgrade programmes
	Refrigerated storage specifications should be upgraded and seek less energy intensive alternatives
	Automation of logistics procedures
Planning, design and development	Internal capacity-building and retraining building of redundancy into critical operations
	proactive infrastructure and management plan
	Re-examine land use planning in flood prone areas
Management	operational systems need to mainstream climate-change considerations
Insurance	Some risks cannot be avoided; therefore, they must be insured by third parties

Thank you for your attention!

Date	Name	Wind (mph)	Cat.	Recorded damage
07/1960	ABBY [1]	63	TS	Damage to roads and bridges; 6 deaths; US$ 435,000 damage
09/1980	ALLEN [2]	130*	H4	Landslides (70) damaging road network and tourism industry; 6 deaths; US$ 87 million total damages
09/1994	DEBBY [3]	63	TS	Floods and landslides blocked roads and destroyed/damaged 10 bridges; HIA covered by 5 cm of silt; 4 deaths, 750 people affected; US$ 103 million total damage
1999	LENNY [4]	155*	H4	Storm surge/waves had major coastal impacts, including beach erosion at the NW coast; roads, coastal defences and walkways washed away; $6.6 million infrastructure damages
08/2007	DEAN [5]	104	H2	Damages (US$ 370,400) to CSP and the rock armouring at the end of the GCIA runway; 1 death; US$ 18.8 total damages
10/2010	TOMAS [6]	98	H2	Storm surge and waves (1 in 15-year event) had relatively small direct damages; roads/bridges severely impacted, mostly from landslides and floods; HIA and GCIA were closed; HIA runway flooded and silted; total impact on transport infrastructure US$ 52.8 million; 7 deaths, 5,952 people severely affected; US$ 336 million total damage
12/2013	CHRISTMAS EVE TROUGH [7]		TT	Severe flash floods and landslides across the island; HIA closed for 2 days due to river flooding of terminal and runway; Operations at GCIA suspended for few hours; severe damages to main connecting highway; transport infrastructure sustained most damages (72 % out of US$ 99.9 million total damage); 6 deaths; 19,984 people directly impacted
09/2016	MATTHEW [8]	60	TS	Landslides and floods; several roads blocked; both GCIA and HIA airports closed during the storm