UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT
PROSPERITY FOR ALL

Climate Change Impacts on Coastal Transportation Infrastructure in the Caribbean

Case studies: Key Findings and Approaches

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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 particular vulnerable due to their limited physical size, small economies, the high concentration of populations, 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

- ✓ SIDS are sea-locked so they depend on international transportation for accessibility and connectivity and interactions with the global community and markets

- ✓ Transport facilities and infrastructure enable tourism a key component of SIDS economies and the largest employer and earner of foreign exchange for most Caribbean SIDS, with tourism accounting for between 11 and 79 % of their GDP.

Therefore, seaports and airports in SIDS—and their intermodal connections—are vital lifelines for movement of goods and tourism; any damage to these infrastructures can disrupt transport services and affect significantly small island economies

Introduction: CV & C impacts on transport/tourism

Impacts on transport infrastructure

Transport infrastructure and operations that are situated 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 always be easy)
- ✓ Seaports will be incrementally affected by MSLR and storm events; their quays, jetties and breakwaters will be less efficient, requiring redesigning and/or strengthening
- ✓ 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

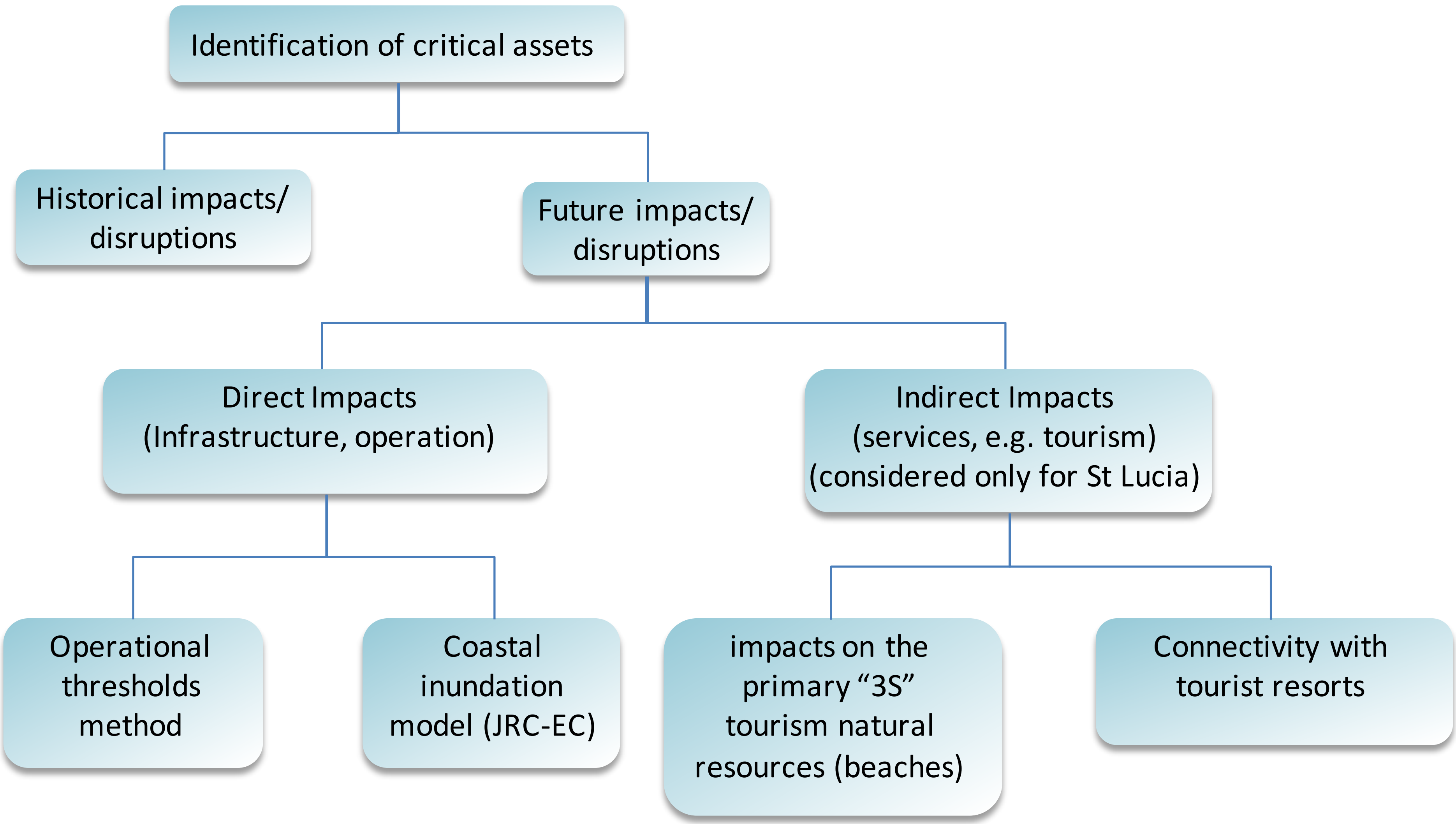
Impacts on touristic beaches

The tourist industry in the Caribbean is based on the “3S” model (Sea, Sand and Sun). A most critical component of 3S tourism 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”

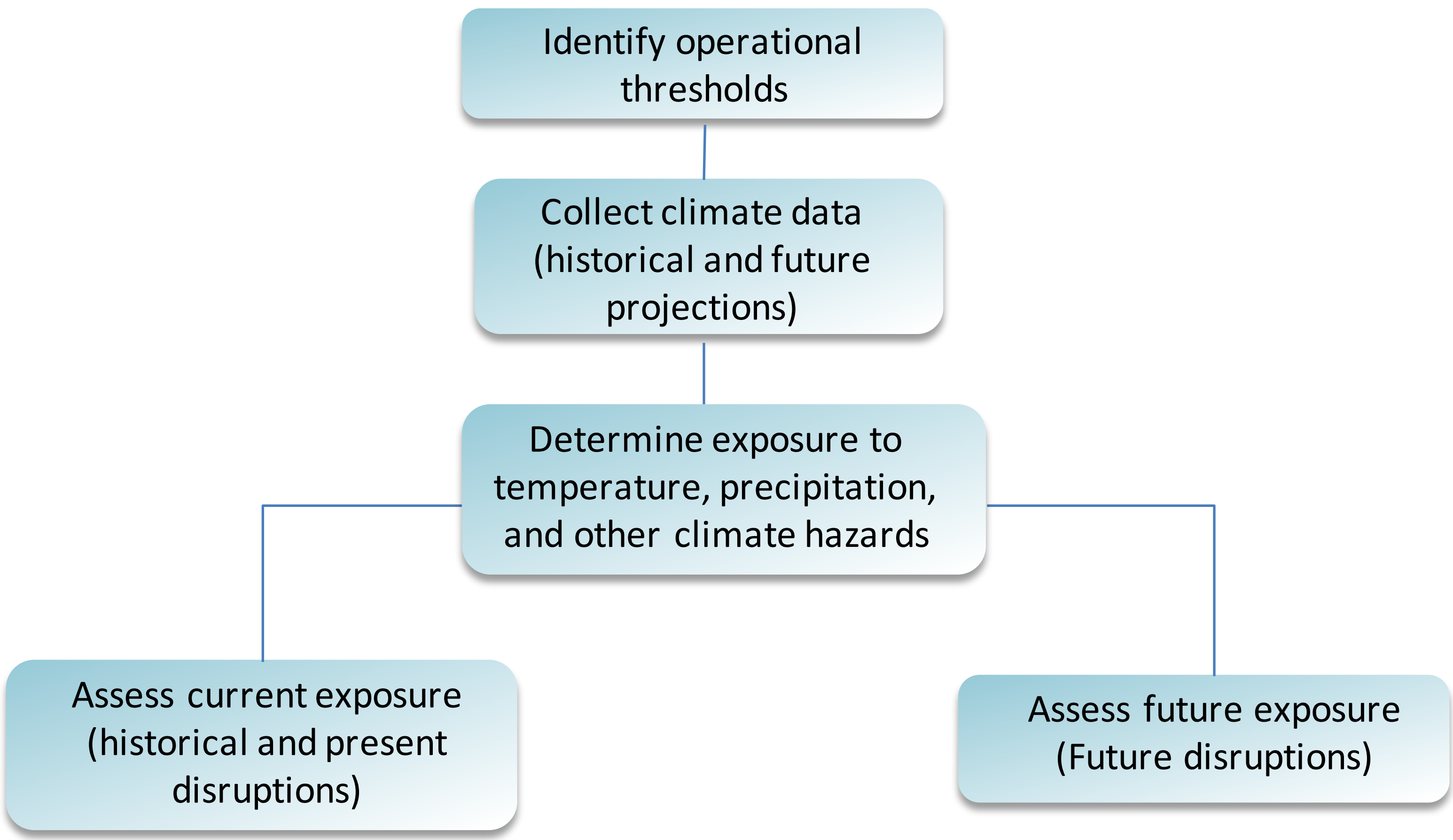
Beach erosion due to e.g. sea level rise might reduce significantly the carrying capacity and the quality of the beaches as environments of leisure and consequently the attractiveness of the country for tourism and travel, <u>resulting in potentially significant international travel expenditure loss.</u>

Assessment of CV&C impacts on transport - Methodology

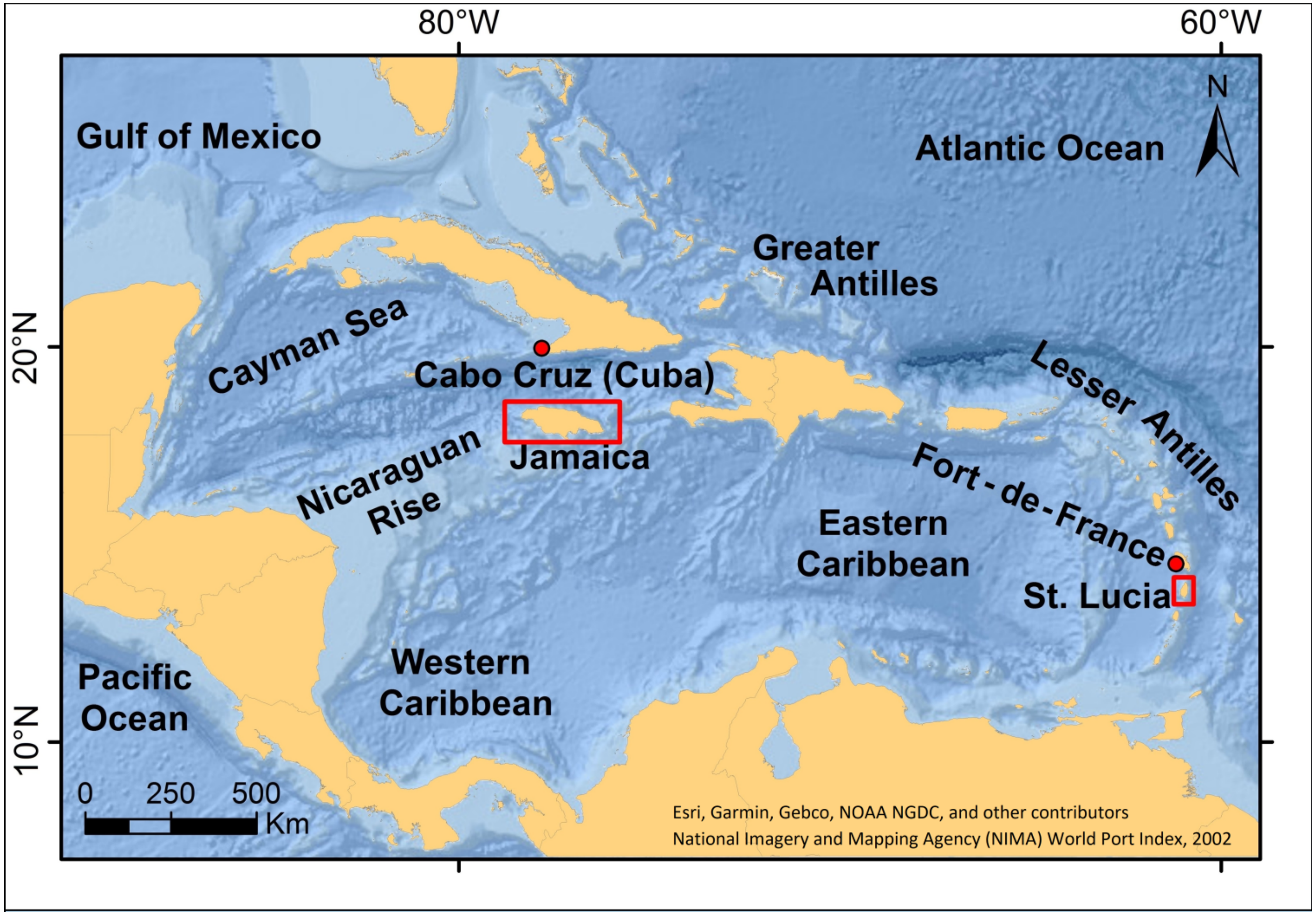


Assessment of CV&C impacts on transport - Methodology

The operational thresholds method



Application of the methodology (Jamaica & Saint Lucia)



Jamaica

- land area of 10,990 km^2, population 2.7 million
- GDP ~14.75 billion USD
- Direct contributions from tourism 9%.

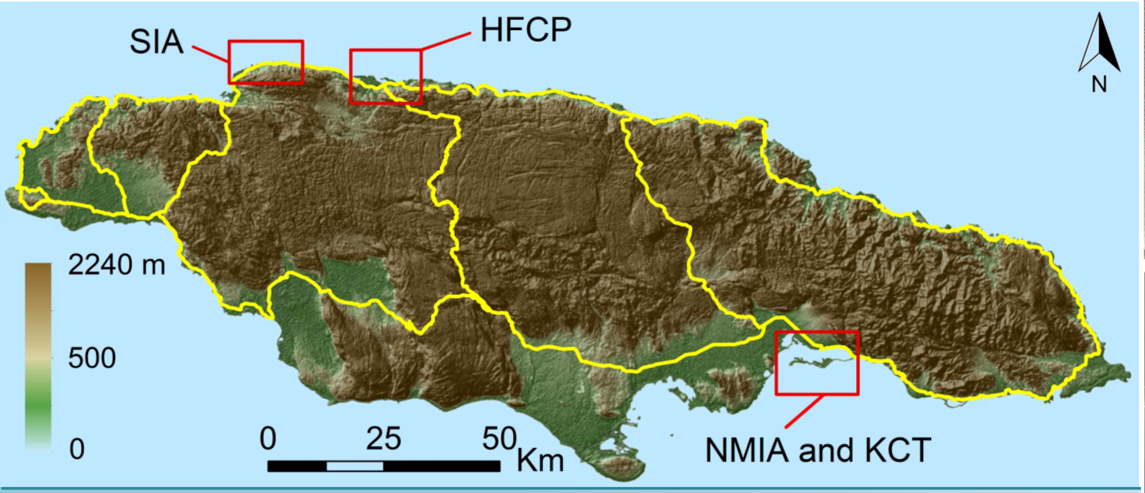
Saint Lucia

- area 616 km^2, population 185,000
- GDP of 1.43 billion USD
- Tourism sector contributes up to 41 %

Application of the methodology (Jamaica & Saint Lucia)

Critical assets - Jamaica

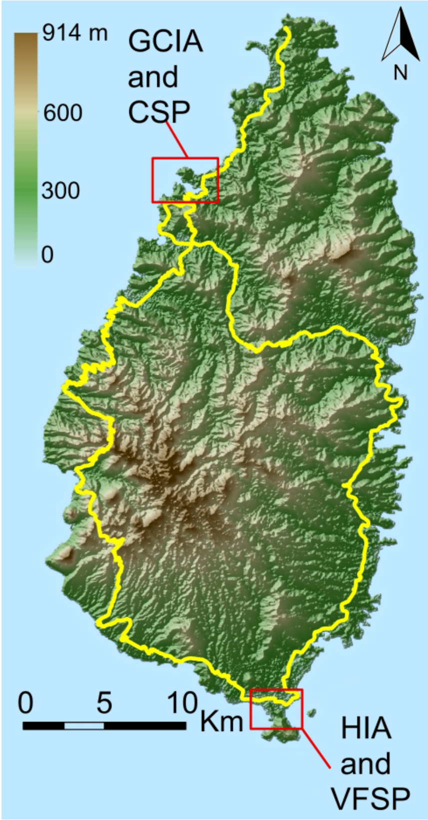
AIRPORTS	Runway length (m)	Runway width (m)	Elevation (m)	Passengers (2016)	Cargo handled (tonnes, 2016)
Sangster International Airport (SIA)	2,662.4	46	1.18-1.37	3,952,273	6,497 (2015)
Norman Manley International Airport (NMIA)	2,716	46	1.95-2.5	1,594,096	12,528
SEAPORTS	**Berth length (m)**	**Depth (m)**	**Elevation (m)**	**Passengers**	**Cargo**
Historic Falmouth Cruise Port (HFCP)	675	11.3	2.9	752,205	-
Kingston Freeport Terminal (KCT)	2310	13	4	N/A	Domestic: 1,051,633 Transshipment: 7279722 (2015)



Application of the methodology (Jamaica & Saint Lucia)

Critical assets – Saint Lucia

AIRPORTS	Runway length (m)	Runway width (m)	Elevation (m)	Passengers (2016)	Cargo handled (tonnes, 2016)
Hewanorra International Airport (HIA)	2,743.2	45.72	3.3	644,837	2,138
George Charles International Airport (GCIA)	1,889.76	45.72	6.1	195,859	1,079
SEAPORTS	**Berth length (m)**	**Depth (m)**	**Elevation (m)**	**Passengers**	**Cargo**
Port Castries (CSP)	940.6 (cargo +cruise)	5.5-10	1.5	677,394	480,770 tonnes (2016)
Vieux Fort Seaport (VFSP)	373	11	1.5 -2.5	N/A	~46,000 TEU per year



Application of the methodology (Jamaica & 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 (Jamaica & Saint Lucia)

Future disruptions - Direct impacts

Operational thresholds method

Identifying the operational thresholds

i. Employee ability to work safely outdoors and heat index (a function of temperature and relative humidity)
ii. Take off length requirement of aircrafts and temperature
iii. Energy cost and temperature
iv. Crane operation and precipitation

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 (Jamaica & Saint Lucia)

Days of disruptions for airports and seaports in Jamaica

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 39.4 °C (103 °F), resulting from 30.6 °C (87.1 °F) and 80 % relative humidity presents 'high' risk	4.40	5.76	***5.00***	13.45	22.21	29.67
		Heat Index (NOAA) over 46 °C (115 °F) resulting from 32.5 °C (90.5 °F) and 80 % relative humidity presents 'very high risk'	0.05	0.12	***1.00***	1.95	4.88	10.89
	Aircraft take-off length requirements	Boeing 737-800 aircraft would not be able to take off from SIA if the temperature exceeds 33.2°C	23.70	44.92	***65.00***	84.91	138.75	183.78
		Boeing 737-800 aircraft would not be able to take off from NMIA if the temperature exceeds 34.1°C	5.35	14.64	***24.00***	44.41	99.25	146.00
	Energy costs in seaports	0.8°C warming = 4% increase if temperature exceeds 30.3°C (1986-2005 average: 29.5 °C)	145.20	177.36	***214.00***	216.73	271.46	303.44
		1.3°C warming = 6.5% increase if temperature exceeds 30.8°C	121.50	153.44	***182.00***	196.41	248.50	286.61
		3°C warming = 15% increase if temperature exceeds 32.5°C	47.25	74.92	***97.00***	117.95	168.96	214.83
Precipitation	Inhibits crane operation in seaports	Intense rainfall (e.g. > 20 mm/day)	3.70	3.60	***0.00***	4.59	4.00	3.11
		Very heavy rainfall (e.g. >50 mm/day)	0.90	0.64	***0.00***	1.45	0.92	0.89

Application of the methodology (Jamaica & 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 39.4 °C (103 °F), resulting from 30.6 °C (87.1 °F) and 80 % relative humidity presents 'high' risk	1.25	1.96	***2.00***	11.86	29.13	55.33
		Heat Index (NOAA) over 46 °C (115 °F) resulting from 32.5 °C (90.5 °F) and 80 % relative humidity presents '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 (Jamaica & 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). ESLs are driven by the combined effect of MSL, tides and water level fluctuations due to waves and storm surges. Cyclone effects have been included.

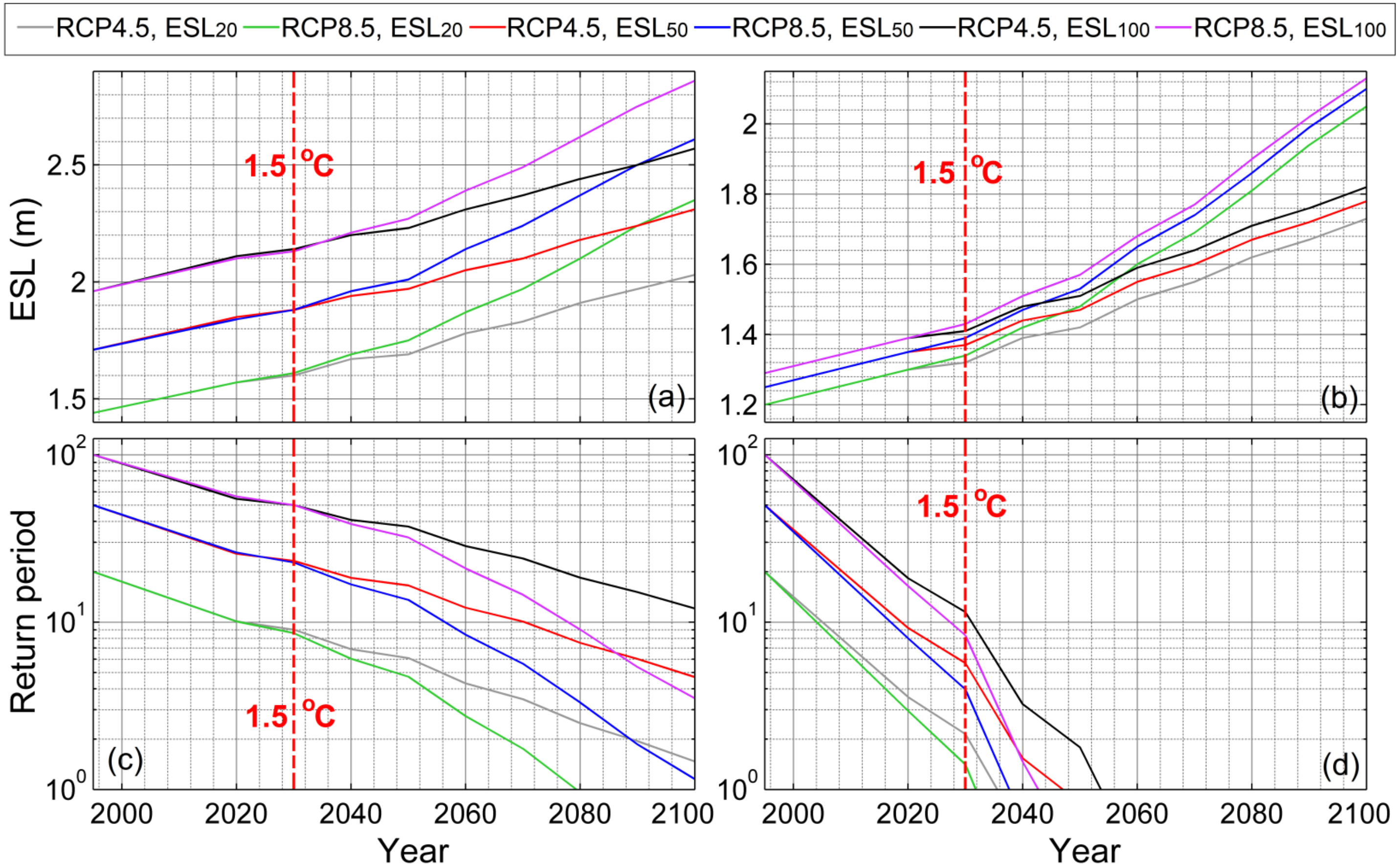
- ✓ Flood/inundation assessment has been carried out, using dynamic simulations using the open-access model LISFLOOD-ACC

Application of the methodology (Jamaica & Saint Lucia)

Future disruptions - Direct impacts

Coastal inundation model (JRC-EC)

Extreme Sea Level projections

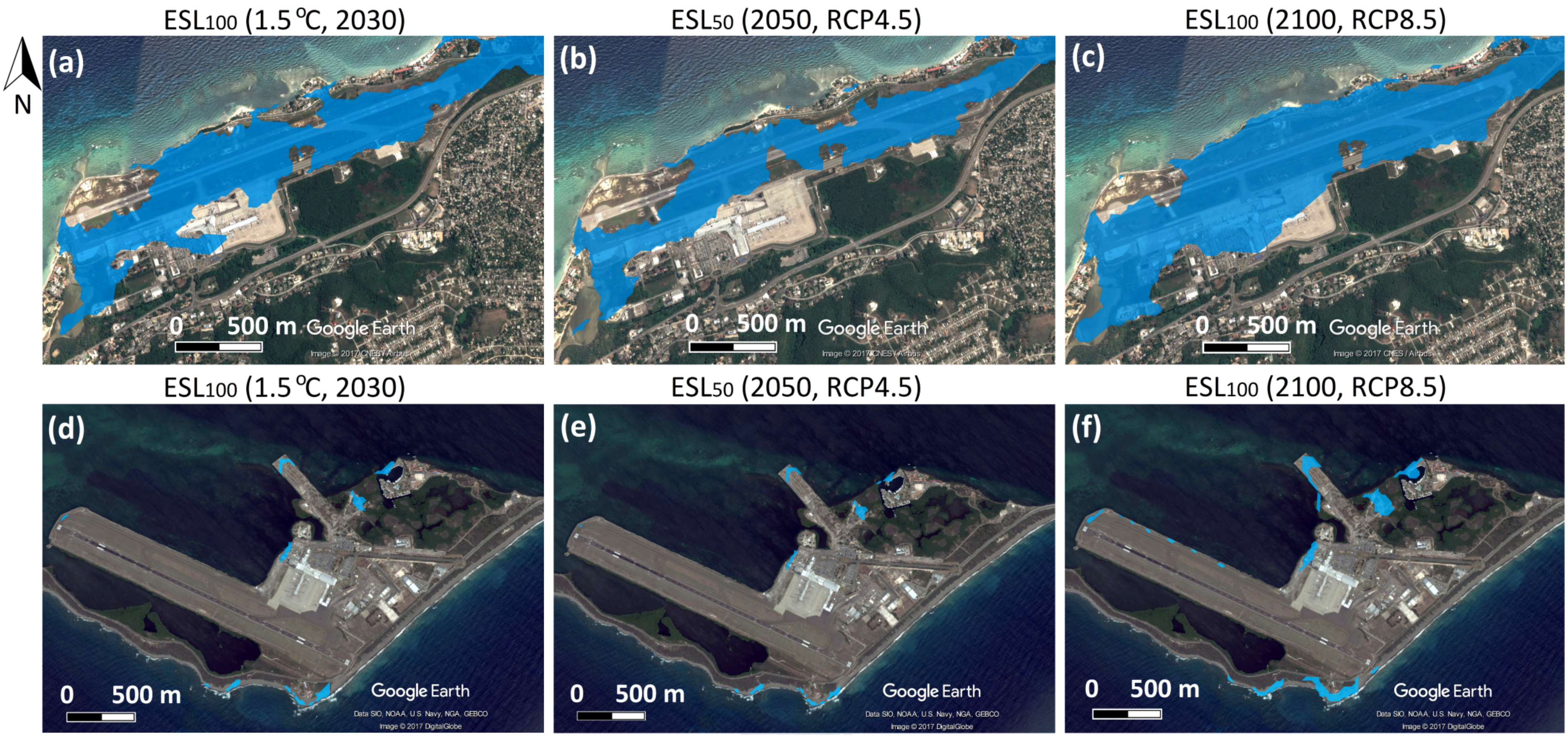


Time evolution of ESLs and their baseline (1995) return periods: (a, c) Jamaica; (b, d) Saint Lucia. The red stippled line represents the projected date year of the 1.5 °C temperature increase since the pre-industrial period

Application of the methodology (Jamaica & Saint Lucia)

Future disruptions – Direct impacts

Coastal flooding - Jamaica

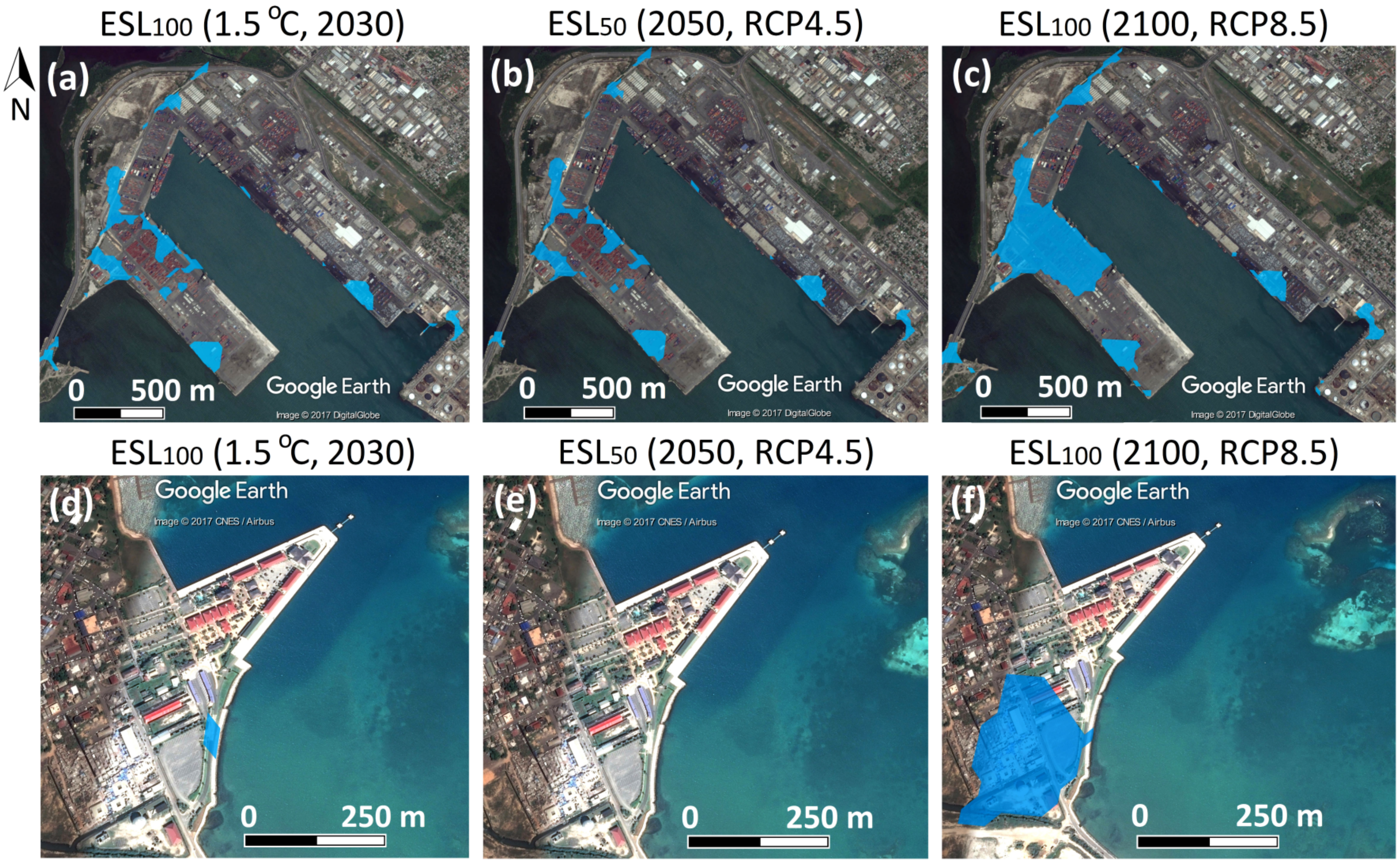


Inundation of SIA (a, b, c) and NMIA (d, e, f)

Application of the methodology (Jamaica & Saint Lucia)

Future disruptions – Direct impacts

Coastal flooding - Jamaica

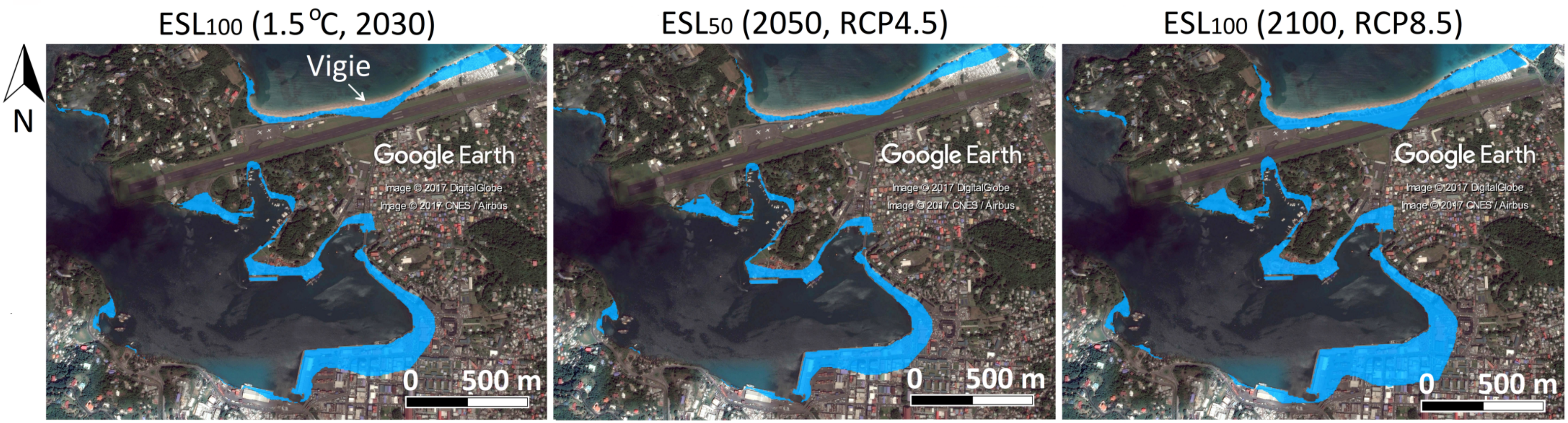


Inundation of KCT (a, b, c) and HFCP (d, e, f)

Application of the methodology (Jamaica & Saint Lucia)

Future disruptions – Direct impacts

Coastal flooding – Saint Lucia

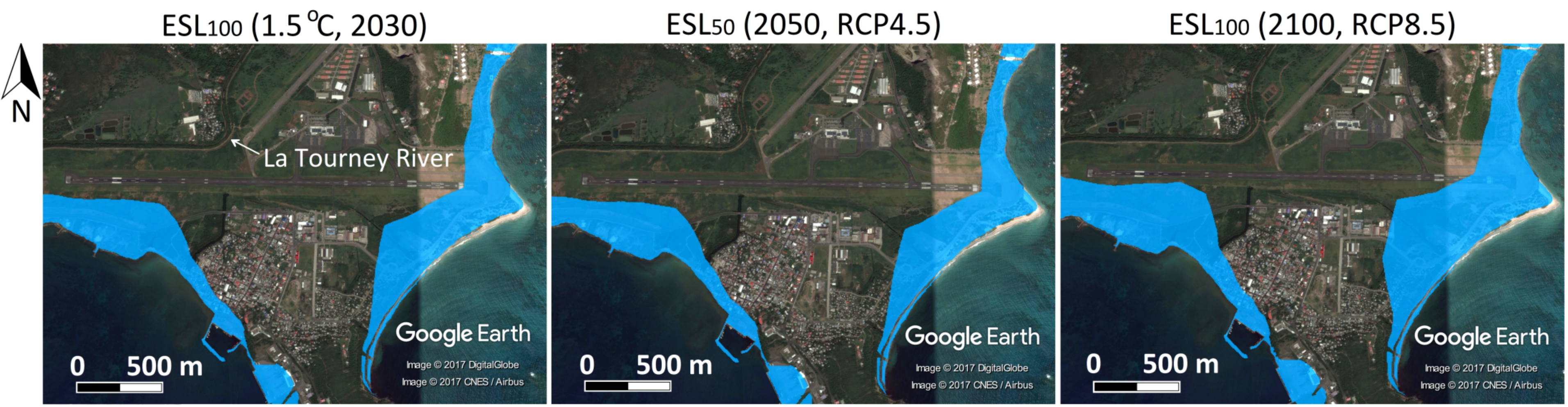


Inundation of GCIA and CSP

Application of the methodology (Jamaica & Saint Lucia)

Future disruptions – Direct impacts

Coastal flooding – Saint Lucia



Inundation of HIA and VFSP

Application of the methodology (Saint Lucia)

Indirect impacts

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

Digitization

Web/GIS

Record/ Analysis of spatial characteristics (e.g. max. Width, density of backshore assets)

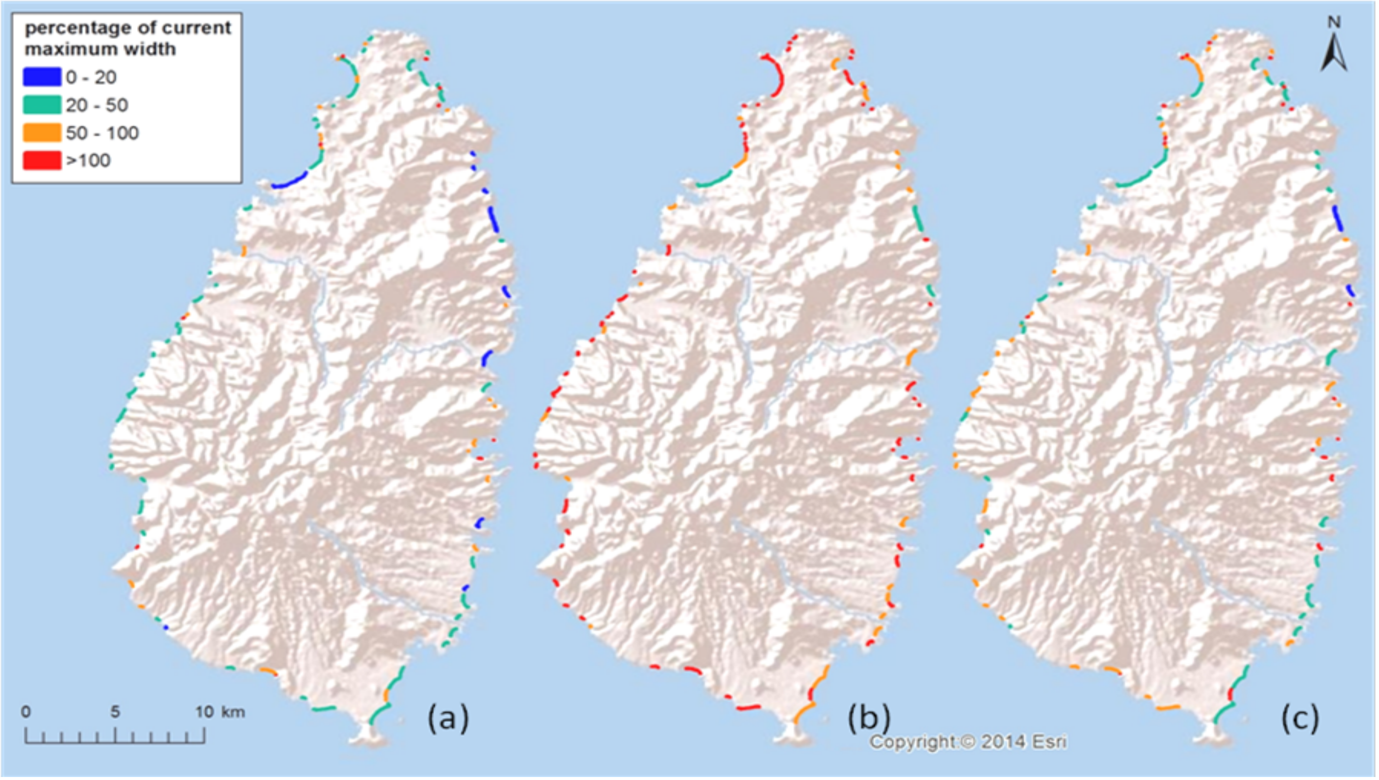
Comparison of max. width with model ensemble projections

Impacts on 'dry' beach width (carrying capacity) and on backshore infrastructure/assets

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) and (b) minimum and 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 with tourist resorts

An estimation of connectivity impacts on the basis of the number of potential landslides has been carried along the connecting road network between the 2 international airports of Saint Lucia and 30 tourist resorts identified along the island coastline through

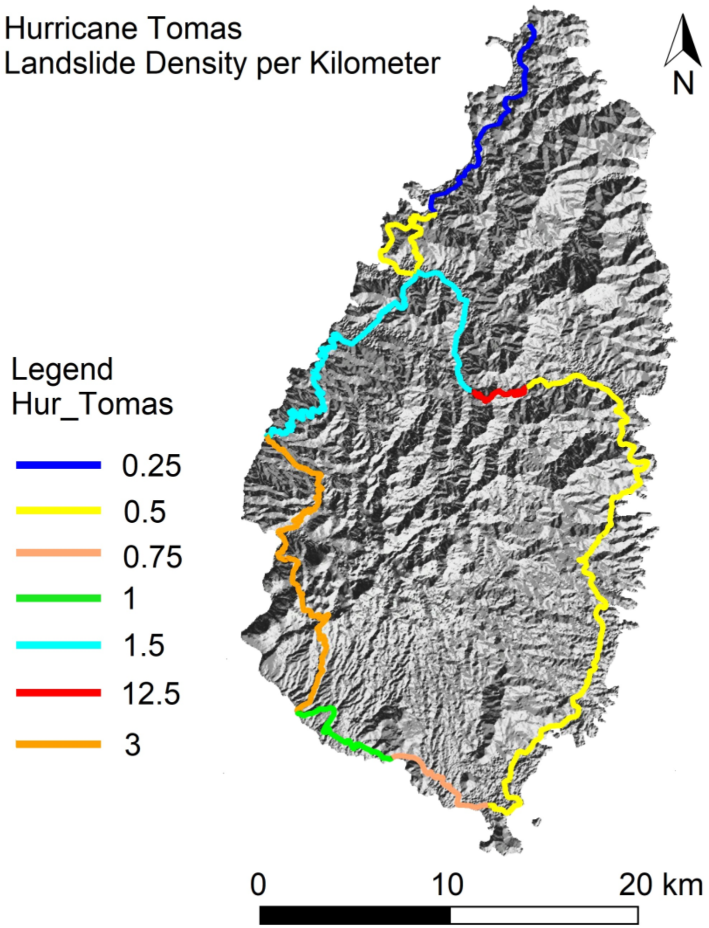
(i) digitization of the major road network using the Google Earth Application and

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

Application of the methodology (Saint Lucia)

Indirect impacts

Connectivity issues : airports with 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 critical assets, with the SIA in Jamaica and the Saint Lucian airports and seaports being the most vulnerable

- ✓ Severe impacts are projected even under the AOSIS advocated temperature increase cap of 1.5 ^{o}C.

- ✓ Under increasing beach erosion and flooding, the long-term recreational value of the Saint Lucia beaches may fall considerably

- ✓ In Saint Lucia the connectivity of the major transportation assets to the major tourist destinations of the island is under increased risk by the large density of landslides

- ✓ The projected CV & C impacts on critical transport infrastructure, if not addressed by appropriate adaptation options may have very serious implications for the connectivity of SIDS to the international community and markets, as well as economic and trade-related repercussions.