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An economic analysis of flooding in the Caribbean

The case of Jamaica and
Trinidad and Tobago

Luciana Fontes de Meira
Willard Phillips



UNITED NATIONS



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This document has been prepared by Luciana Fontes de Meira, Associate Environmental Affairs Officer, and Willard Phillips, Economic Affairs Officer, of the Sustainable Development and Disaster Unit of the ECLAC subregional headquarters for the Caribbean, with the assistance of Mauricio Gonzales, external expert on geographic information systems (GIS), for the map design and analysis. The authors also acknowledge the assistance of Shawn Campbell of the ECLAC subregional headquarters for the Caribbean, for his assistance in the conduct of field work in Trinidad, and Michael Wilson of the Water Resources Authority of Jamaica, for his support in the completion of the assessment in Jamaica.

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Contents

Abstract	5
Introduction	7
I. Flooding in the Caribbean	9
A. Trinidad and Tobago	11
B. Jamaica	14
II. Methodological approach	19
III. Selected areas of study	25
A. Socioeconomic profile of Chaguanas/Charlieville, Trinidad and Tobago	26
B. Socioeconomic profile of Tunapuna/Piarco - Kelly Village/ St. Helena, Trinidad and Tobago	27
C. Socioeconomic profile of Saint Mary, Jamaica.....	29
IV. Potential effects and mitigation measures	31
A. Trinidad and Tobago - Flooding in Tunapuna/Piarco and Chaguanas, a case study of St. Helena, Kelly Village and Charlieville.....	31
1. Effects	31
2. Flood mitigation measures	37
B. Jamaica - Flooding in the Parish of St. Mary: A Case Study of Port Maria	38
1. Effects	38
2. Flood mitigation measures	44
C. Summary of analysis – two case countries.....	44
V. Conclusions	47
Bibliography	49
Studies and Perspectives series-The Caribbean: issues published.....	51

Tables

Table 1	Summary of affected population and damage in the Caribbean region (1990 – 2018)	8
Table 2	History of disasters in Trinidad and Tobago	12
Table 3	Catastrophic Hydrometeorological Events that have affected Jamaica: 1933 – 2017	15
Table 4	Summary of elements considered in the analysis	21
Table 5	DaLa methodology sectoral data map	23
Table 6	Municipal Indicators – Chaguanas.....	27
Table 7	Municipal Indicators – Tunapuna/Piarco	28
Table 8	Municipal Indicators – St. Mary.....	30
Table 9	Government budget transfer to individual producers	36
Table 10	Summary of Flooding Costs - Trinidad and Tobago	37
Table 11	Areas Suitable for Development in St. Mary and Specific Mitigations.....	44
Table 12	Summary of Flooding Costs - Trinidad and Tobago and Jamaica	45

Figures

Figure 1	Damage and affected people by disasters in the Caribbean.....	10
Figure 2	2018 October flood - major impacts	14
Figure 3	Damaged premises of St. Helena Hindu Primary School in 2018 October Flood	33
Figure 4	Houses in Charleville area.....	33
Figure 5	Flooding at Port Maria Primary (top) and Secondary (bottom) Schools, 2012	41
Figure 6	Debris deposits due to flooding – Port Maria Beach, May 2017	43

Box

Box 1	Financial protection in Trinidad and Tobago.....	38
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Maps

Map 1	Map of flood prone areas of Trinidad highlighting study areas.....	12
Map 2	Distribution of Flooding Events in Jamaica – as at 2010	16
Map 3	Flood Hazard Map – Jamaica	17
Map 4	Flood risk in selected areas/ Rivers in selected areas, Trinidad	25
Map 5	Flood risk in selected areas/ Rivers in selected areas, Jamaica	26
Map 6	Land cover type in study areas.....	36
Map 7	Population Density – Jamaica (2011).....	39
Map 8	Location of the Parish of Saint Mary, Jamaica	39
Map 9	Flood Boundaries for Port Maria	40

Abstract

Flooding as an extreme event has become progressively evident in the Caribbean sub-region, as a result of an increased number of intense rainfall events, and storm surges from hurricanes. Such events in turn, have been linked to the impacts of global climate change, which has been shown to be the cause for several specific events including sea-level rise; global temperature rise, ocean warming and acidification, and the melting of glaciers. In the specific instance of the Caribbean subregion, flooding events often result in significant disruptions of economic and social life. The study will use a case-study approach of selected areas in Trinidad and Tobago and Jamaica to investigate the potential economic impacts of recurrent flood events and compare with a potential cost saving benefit of specific flood control interventions. Previously developed maps and analysis of the spatial impacts of past flooding is used to define the specific geographical scope of the research in terms of exposure and vulnerability. The Damage and Losses Assessment methodology (DaLA) is used to estimate potential effects related to flood events. Planned government interventions in the selected areas will be used as a parameter of cost of flood adaptation measures.

Introduction

The occurrence of flooding has been increasing globally in recent decades. This phenomenon has resulted in growing impacts, assessed in terms of damages, loss of life, and loss of economic output. According to Douben (2006), since the mid 1980's, flooding has been the most frequently occurring, has claimed the highest number of human lives, and has generated the largest economic losses among all natural hazards worldwide. Of some 7,000 recorded natural disasters, 75 percent were identified as water-related events, of which floods were the most frequent, accounting for roughly one-third of these. Furthermore, when assessed in economic terms, floods were the cause of roughly 20 percent of all losses for the 30 year period up to 2003. Such losses were estimated to be in the order of 208 billion, during the same period, with human casualties exceeding 184,000 between 1986 and 1995 alone (Douben, 2006). While the increase in flooding has been widespread on a global scale, specific regions have suffered more events than others. Asia for instance experienced roughly 45 percent of all major floods between 1985 and 2003, with the Americas experiencing some 25 percent.

Several factors have been identified as principal drivers for the enhanced pervasiveness and effects of flooding around the world. Among these are the more widespread occurrence of heavy and/or long-lasting rain, the increased intensity of precipitation in the form of brief but torrential rainfall, and a greater frequency of tropical cyclones and monsoon rains. With respect to impacts, flooding produces greater human casualties and economic losses due to the rising share of global populations that have settled on flood-prone areas.

In the specific instance of the Caribbean subregion, flooding events often result in significant disruptions of economic and social life. By way of examples, the island of Hispaniola has suffered several flooding events over the past two decades, with one of the most significant causing loss of life of more than 900 persons in Haiti and the Dominican Republic in 2004, and several repeated occurrences up to 2017. Jamaica (2017, and 2018) has also experienced repeated flooding events, with the most recent occurring in 2012, 2017, and 2018. Similar events have also been noted for several islands of the Eastern Caribbean including Antigua and Barbuda (2010); Barbados (2010); the British Virgin Islands (2010, 2017); Dominica (2013, 2017); Saint Lucia (2013, 2016); Saint Vincent and the Grenadines (2013); and

Trinidad and Tobago (2016, 2017, and 2018). Mainland Caribbean territories have also had their challenges with flooding, as was the experience of Guyana in 2005; Suriname in 2008; and Belize in 2015.

Caribbean countries such as Jamaica and Trinidad and Tobago, face a potentially great reversal in economic and social improvements, at local level, due to weather related disasters such as flooding. For instance, their portfolio of investments and existing debt could be affected by spending shifts that force the diversion of resources destined for productive sectors and social spending into reconstruction efforts. Quantitative information on the effects and impacts of flooding is also useful when formulating long-term development plans with proper budgetary allocations to prevent future impacts and build resilience. Although systematic disaster loss accounting and comprehensive risk assessment do not guarantee more government investments, they do encourage governments to identify possible trade-offs of investing in mitigation measures and help in informed decision-making (UNISDR, 2011). Unfortunately, this type of analysis is not systematically done for what are considered to be low-impact localized events such as riverine flooding. Between 1990 and 2018 for instance, only around 20 per cent of flooding that took place in the region have had overall damage reported to EM-DAT¹, in comparison to 44 per cent when it comes to storms (table 1). However, with high probability of occurrence of yearly flooding in certain areas, small but recurrent impacts such as lost hours of schooling by children and young people, and disruptions of small businesses may cause long term consequences for the quality of life in the area. In spite of their persistent effects and long-term economic impacts, they often go unassessed.

Table 1
Summary of affected population and damage in the Caribbean region (1990 – 2018)

Type of event	Occurrence	Percentage Assessed	Total affected population	Total damage ('000 US\$)
Flood	119	20	6 077 603	1 460 082
Storm	237	44	29 770 071	112 803 519

Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

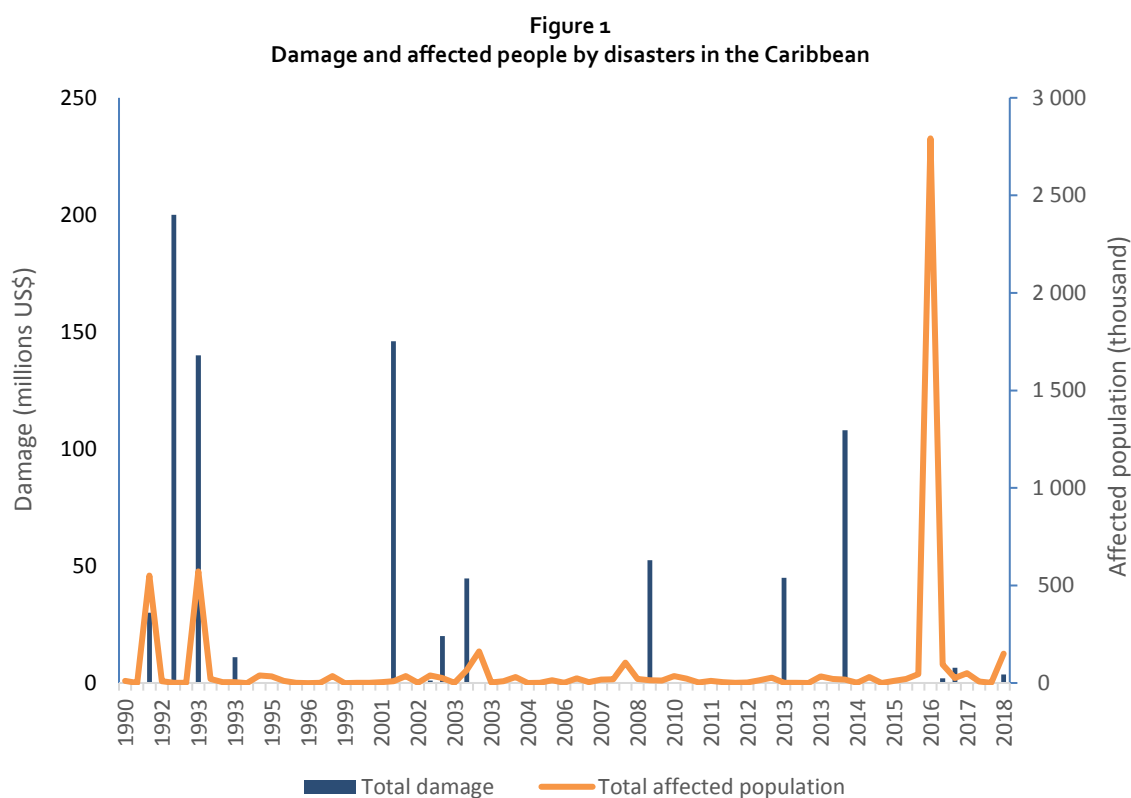
On the basis of the above, the aim of this study is to undertake an economic analysis of costs associated with flooding in selected areas and to create a model of analysis which could be reproduced in similar events. The study will focus on land-based flooding particularly in respect of potential riverine, and flash flooding events. The study uses the DaLA methodology as a basis for the cost assessments. Although a comprehensive Damage and Loss assessment as done by ECLAC in post-disaster situations was not carried out, the aim of the paper is to demonstrate how the methodology can be used to assess low-impact recurrent events such as flooding. This is intended to be a pilot study which combines desk research complemented with data collected in interviews and field visits.

It seeks to partition out potential costs specific to flooding events in selected locations, and to develop a methodological approach for measuring such costs in a manner that can be replicated in similar cases in other locations. The paper also aspires to demonstrate the importance of a systematic collection of data related to such events in order to facilitate not only the recovery and reconstruction processes, but also to provide an evidence-based approach to planning and selecting flood mitigation measures.

¹ EM-DAT contains basic data on the occurrence and effects of more than 22.000 disasters worldwide from 1900 to the present. The database is compiled from several sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. This database defines a disaster as a situation in which at least one of these four conditions occurred: a) ten or more deaths; b) one hundred or more people affected; c) a state of emergency declared; d) a call for international assistance made.

I. Flooding in the Caribbean

Although all nations are exposed to some type of natural event to a greater or lesser extent, their effects do not necessarily result in a disaster with the destruction of physical assets and deterioration of means of subsistence for the population. Disasters result from a combination of two factors: (i) natural phenomena capable of triggering processes that lead to physical damage and loss of human lives and capital; and (ii) vulnerability of individuals and human settlements to such events. This vulnerability could be related to infrastructure (no application of a building code), lack of land-use planning, social factors (poverty), or institutional framework (lack of proper disaster risk management policies). Vulnerability is a prerequisite (manifested during the disaster), as well as an indicator of the exposure of the physical and human capital, and of the capacity of individuals, households, communities and countries to endure and recover from disasters (ECLAC, 2014). According to data collected from the EM-DAT platform, the average number of disasters per decade, as well as the affected population and the magnitude of the damage suffered has increased significantly since the 1970s in the Caribbean. Analyzing the period between 1990 and 2017 in the region, 90.4 per cent of disasters were associated with hydro-climatic hazards, stressing the high occurrence of storms (58.1 per cent), and floods (27.2 per cent) (ECLAC, 2019). Although the number of deaths related to floods in the period has not been high, total affected population has been significant. Despite the recurrent disruptions cause by flooding, its effects and macroeconomic impacts have not been consistently measured, as normally these are localized events when compared to hurricanes and storms which tend to have national implications and receive more international attention. Of 119 flooding events recorded in the region in the period from 1990-2018, only 23 have been assessed in terms of damage. While data on damage related to flooding have not been systematically measured, flood events have been reported every year, with economic figures only available for certain years (see figure 1).



Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium, 2019.

This historical profile of Caribbean flood emergencies emphasizes the case that flooding has become a widespread and routine occurrence which threatens lives, livelihoods and the economy of the subregion. The impacts of flooding are further exacerbated by the general weakness of drainage infrastructure in many Caribbean countries; the degradation of hillsides of drainage basins in order to facilitate both planned and unplanned built development; poor maintenance of drainage systems particularly in urban areas; and the indiscriminate disposal of municipal wastes into drainage systems.

In the broader context of climate change impacts on the Caribbean subregion, two important considerations are relevant in approaching a study of the flooding phenomenon in the subregion. Firstly, the increased occurrence of flooding appears to be contradictory, given that projections suggest a reduction in annual precipitation ranging from 3.7 percent to 14.1 percent between 2030 and 2090 (ECLAC, 2011)². Significantly however, further projections also indicate that while the actual quantity of rainfall is likely to decline over time, the intensity of precipitation is also likely to increase, thus resulting in a temporal distribution of rainfall with extremely intense spells separated by occasions of relative drought. Secondly, it is important to make a clear distinction between seaborne flooding events, typically associated with the flooding of coastal areas due to tropical cyclone generated storm surge, and land-borne flooding events resulting from the overwhelming of natural and built drainage systems due to excessive rainfall. Given the prevailing evidence of climate change, these considerations taken together suggest that the issue of flooding will continue to become a major development challenge for the Caribbean over time.

² ECLAC, 2011, "The Economics of Climate Change in the Caribbean – Summary Report, 2011.

Different types of floods are classified on the basis of the source of the floodwater, factors triggering it and the potential area flooded. This study focusses on riverine flooding, which occurs when a body of water exceeds its containment capacity and overflows its banks and have been particularly recurring in the analyzed countries. The impacts caused by this type of hazard can be classified into tangible and intangible ones. Tangible damage refers to impacts on physical assets such as buildings, economic goods, standing crops and livestock that can be measured in economic terms. This is often combined with intangible impacts such as the contamination of ecosystems and disruption of social activities that may affect localities beyond the inundated areas. This study will focus on approaches for measuring the potential economic costs of the tangible impacts while highlighting often observed non-measurable impacts of such events. The next section presents a brief historical analysis of flooding events in the study countries and a description of the specific areas selected for the analysis.

A. Trinidad and Tobago

The Republic of Trinidad and Tobago consists of two main neighboring islands, Trinidad and Tobago, as well as numerous smaller islets. Trinidad is the larger of the two main islands representing about 93 per cent of the country's territory. The two islands are quite distinct in their historical, populational and geographic characteristics. Trinidad's landscape is characterized by three mountain ranges, the steepest of which – the Northern Range – occupies the northern area of the island, with the other two as undulating hills in the central and southern regions. These upland areas are separated by plains, which occupy most of the central portions of the island. Tobago's landscape is characterized by a highland area, which runs through the northeastern three quarters of the island, eventually giving way to a small coastal plain towards the southwest. Trinidad and Tobago has a population of 1,359,193 (Central Statistical Office, Trinidad and Tobago, 2018). Although a period of very high population growth followed the Second World War, growth has slowed markedly since 1990. The rate of urbanization, however, has continued to increase. The result is that almost three-quarters (72% percent) of Trinidad and Tobago's people now live in urban areas (National Development Strategy for Trinidad and Tobago, TT Government). Trinidad's population is concentrated in urban areas along the west coastal areas and at the foothills of its northerly located mountain range. On the other hand, Tobago's population is concentrated in the southwest part of the island. The country's economy is fueled by its oil and gas sector, which provides roughly 32 per cent of GDP³ and 80 per cent of exports, but less than 5 per cent of employment. Services is the main component of GDP (57 per cent), followed by industry (7.8 per cent) and agriculture (0.4 per cent) (2016 est. Central Bank of Trinidad and Tobago, 2019).

Trinidad and Tobago is exposed to a number of natural hazard risks such as earthquakes, flooding and landslides, storm surge and wave impacts (CCRIF, 2014), (see table 1). The official hurricane season in the Greater Caribbean region coincides with Trinidad and Tobago's rainy season and officially begins the first of June and lasts through November, with 84 per cent of all hurricanes occurring during August and September. The heavy rains in this season are concentrated in a short time period, and usually result in major flooding in key areas of the country (map 1). Although comparably being perceived as events of lower magnitude, flooding has had a significant economic and social impact in the country throughout the years. The 2018 October flood in Central Trinidad, for example, affected an estimated 150,000 people (11 per cent of the country total population) and 4,100 households, further impacts will be discussed in the upcoming sections of the paper.

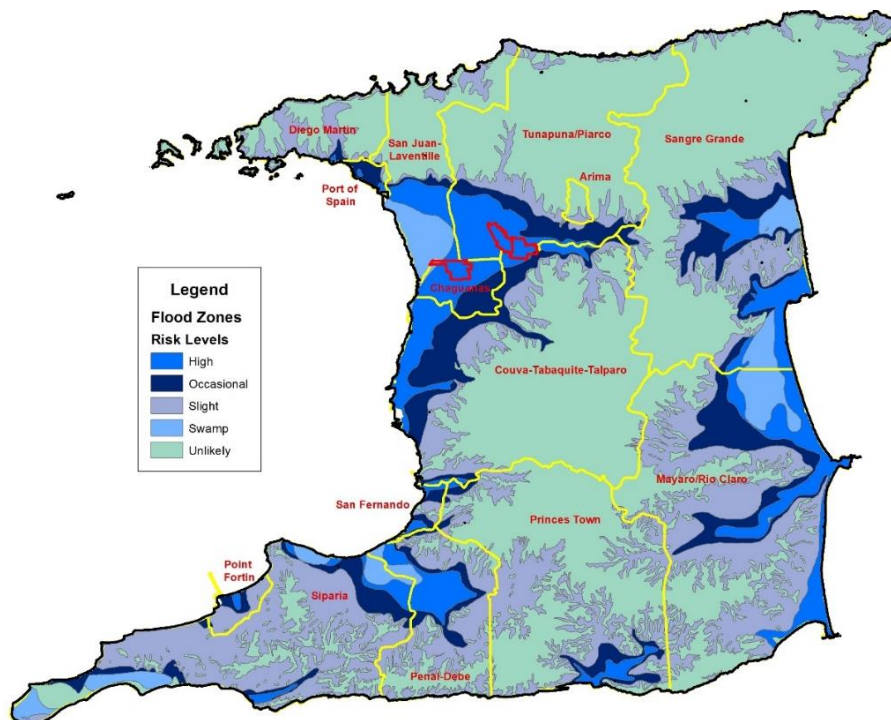
³ Based on constant 2000 prices.

Table 2
History of disasters in Trinidad and Tobago

Year	Disaster type	Total deaths	Injured	Affected	Homeless	Total affected	Total damage ('000 US\$)
1933	Storm	13					3 000
1963	Storm	24					30 000
1974	Storm	2		50 000		50 000	50 00
1990	Storm			1 000		1000	
1993	Flood	5			10	10	70
1993	Storm						57
1996	Flood			200		200	
1997	Earthquake		2		15	17	25 000
2004	Landslide	2		1 200		1 200	
2004	Storm	1		560		560	1 000
2005	Storm						
2008	Flood	No data					
2009	Flood	No data					
2010	Drought						
2011	Flood	No data					
2012	Flood	No data					
2018	Flood			150 000		150 000	3 700

Source: EM-DAT and MNS/ODPM Archives.

Map 1
Map of flood prone areas of Trinidad highlighting study areas



Source: ECLAC, 2019 – Prepared by the authors on the basis of GIS data provided by the country.

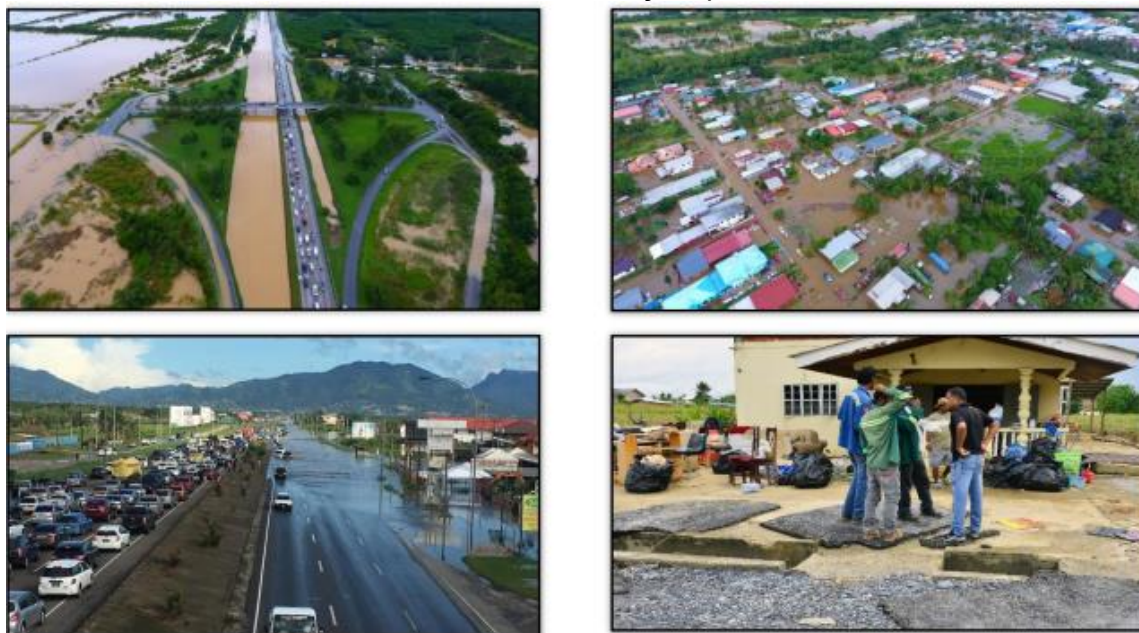
Flooding as other types of hydro-meteorological events have been exacerbated by developmental change and urbanization patterns. Loss of protective vegetation caused by bush fires, indiscriminate clearing and degradation of forests for housing and urban development are key drivers. Combined with bad agricultural practices such cultivation on steep slopes, "slash and burn" and poor watershed management, these all contribute to soil erosion and increased sediment yields in rivers and canals that cause changes in the distribution of the total basin runoff over peak flows and baseflows. The "oil boom" experienced during the 1970s spurred a period of growth and urban development in the country that still characterizes the country's patterns of territorial development today. The prohibitively expensive costs of land within the Port of Spain urban area led to the development of low-density housing along the major transportation route of the east-west corridor. The type of loose, non-compact and non-continuous settlements observed at that time continued and expanded into flood prone areas. Nevertheless, the development of new urban and agricultural areas has not always been accompanied by an expansion of the appropriate infrastructure, specially drainage systems. Moreover, the urban development has progressively sprawled northwards and upslope into several valleys in the southern flank of the Northern Range, areas considered critical for soil and water conservation (Rudo Udika, 2010).

In order to understand and mitigate the impacts of this phenomenon, Trinidad and Tobago started collecting data to facilitate flood mapping in 1981 using crest gauges distributed over seventeen (17) areas. Fifty-nine (59) crest gauges have since been installed in flood prone areas (WRA-TT, 2001). Over the years, several studies have identified and mapped risk areas in the country. However, there is still no systematic collection of data in relation to the potentially exposed assets and economic impacts of flood events.

The most recent major event reported in the country took place in October 2018 (figure 2), affecting several areas of the country. Severe flooding was reported in the following areas: Saint Helena, Kelly Village, Santa Monica, Madras, Vega Oropuche, and North Oropuche (CCRIF SPC, Event Briefing, Excess Rainfall 2018). An estimate of 150,000 people was affected in 4,100 households (CCRIF, Event Briefing, 2018). According to the president of the Agricultural Society of Trinidad and Tobago, approximately 75 per cent of local farmers in the country have been severely affected through the loss of crops and livestock.⁴

⁴ International Red Cross. Emergency Plan of Action, Trinidad and Tobago, 2018. Available at: <https://reliefweb.int/disaster/fl-2018-000194-tto>

Figure 2
2018 October flood - major impacts



Source: CCRIF SPC, Event Briefing, Excess Rainfall 2018 with images from Trinidad Express Newspapers, Loop and Jamaica Observer.

B. Jamaica

Jamaica is located in the west-central Caribbean at approximately 145 kilometres south of Cuba, and 191 kilometres west of Hispaniola, and lies between 17 – 19 degrees north latitude, and 76 – 79 degrees west longitude. It is an island of approximately 10,990 squares kilometres, with a generally rugged topography, especially towards the eastern portion of the island where its highest elevations are attained in the well-renowned Jamaica Blue Mountains. Less steep elevations occur towards the west and central regions. This generally mountainous topography is partitioned by several valleys which form the major watersheds, while narrow undulating coastal plains constitute the principal topography on most of the island's coasts. The country has a population of 2.7 million persons (Statistical Institute of Jamaica, 2018), which is distributed throughout two main cities of Kingston to the south east, and Montego Bay to the North West, with other major settlements in towns such as Mandeville, Spanish Town, Ocho Rios, and Portmore. Administratively, the island is divided into 13 Parishes, with each parish having its own municipal capital and administration. Jamaica's economy is dominated by services (mainly tourism), manufacturing, agriculture and mining, with the shares of GDP for each sector⁵ estimated at 68.7 percent, 7.5 percent, 6.1 percent, and 1.8 percent respectively for 2016 (Statistical Institute of Jamaica, 2019).

Flooding has been identified as the most frequently recurring natural hazard in Jamaica (Nandi et al., 2016). It is related to extreme rainfall typically associated with tropical storms, hurricanes and depressions, which, combined with hydrological, soil, and land use variables lead to flooding. Based on a catalogue of flooding events assembled by Burgess et al. (2015), Jamaica suffered some 198 flooding events between 1978 and 2010. These events have also had significant social and economic impacts, as further analysis revealed an annual flood risk for potential loss of life of 4 persons, and annual damage of USD 96.3 million, or roughly 0.84 percent of GDP measured in 2010 values. Since 2010, Jamaica has

⁵ Measured in constant 2007 prices.

experienced several more flooding events, with at least three major occurrences in 2012, 2017, and 2018 (Planning institute of Jamaica – PIOJ, 2012, 2017, 2018). Given the increasing frequency of climate change induced extreme rainfall events over Jamaica, there's evidence that the potential for losses due to flooding has been increasing. As summarized by the PIOJ (2017) for instance, six storm events between 2002 and 2007 resulted in 60 fatalities and USD 1.02 billion in damages. This amounts to roughly 10 fatalities per year, and an average cumulative loss of 1.75 percent of GDP for the period. A profile of hydrometeorological events for Jamaica over the past eighty-four years is summarized in table 3.

Table 3
Catastrophic Hydrometeorological Events that have affected Jamaica: 1933 – 2017

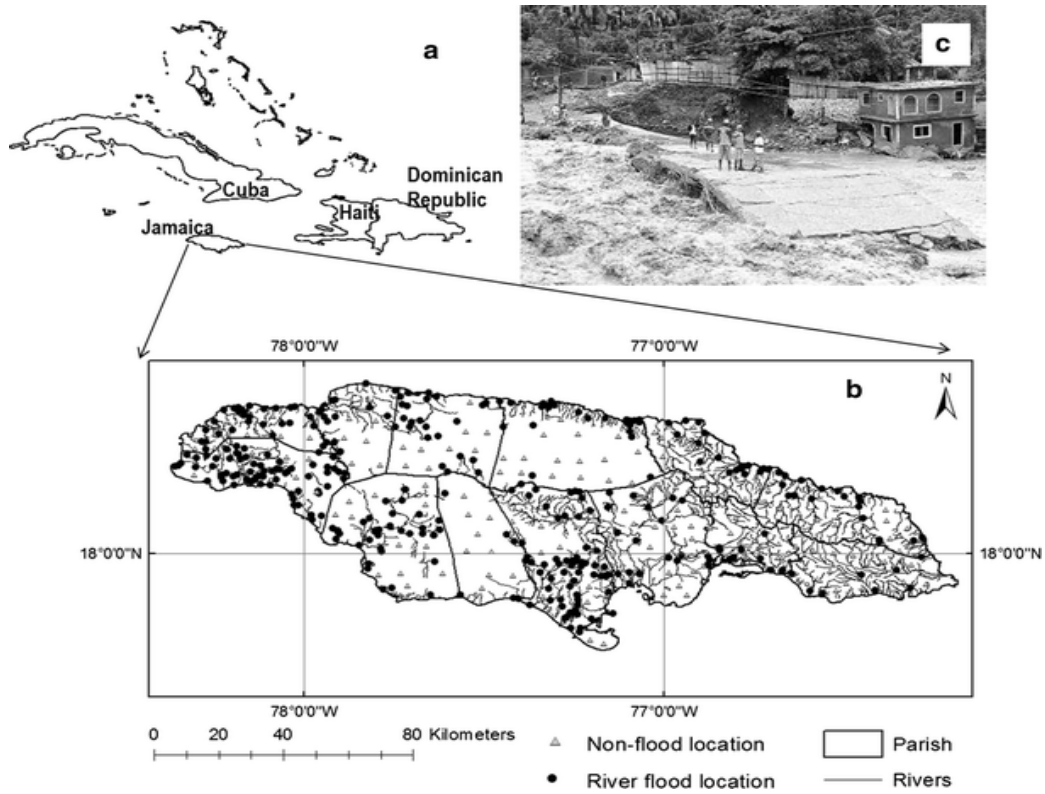
Year	Disaster type	Occurrence	Total deaths	Injured	Affected	Homeless	Total affected	Total damage ('000 US\$)
1933	Flood	1	53					
1933	Storm	1	10					
1935	Storm	1						2 000
1937	Flood	1	111					
1940	Flood	1	125			2 000	2 000	
1944	Storm	1	32			2 000	2 000	
1951	Storm	1	154	200	20 000		20 200	56 000
1963	Storm	1	11					11 525
1973	Storm	1	6	10	2 500		2 510	1 700
1979	Flood	2	44		200 000	50 000	250 000	
1980	Storm	1	6	9	30 000		30 009	64 000
1985	Storm	1	7			300	300	5 200
1986	Flood	1	54		400 00		40 000	76 000
1987	Flood	1	9		26 000		26 000	31 000
1988	Flood	1						440
1988	Storm	1	49		810 000		810 000	1000 000
1991	Flood	1	15		550 000	1 340	551 340	30 000
1993	Flood	1	9		4 290	82	4 372	11 000
1994	Storm	1	4					1 000
1996	Storm	1				800	800	3 000
2001	Storm	1	1			200	200	55 487
2002	Flood	1	9		25 000		25 000	20 000
2002	Storm	2	4		1 500		1 500	1 030
2004	Storm	2	16	6	350 120		350 126	895 000
2005	Storm	3	6		10 396		10 396	34 500
2006	Flood	1	1		5 000		5 000	
2007	Storm	2	5		32 000	1 188	33 188	300 000
2008	Storm	2	13		4 000		4 000	66 198
2010	Storm	1	15	26	2 480		2 506	150 000
2012	Storm	1	1		215 850		215 850	16 542

Year	Disaster type	Occurrence	Total deaths	Injured	Affected	Homeless	Total affected	Total damage ('000 US\$)
2016	Storm	1			125 000		125 000	
2017	Storm	1			5 000		5 000	

Source: EM-DAT and MNS/ODPM Archives.

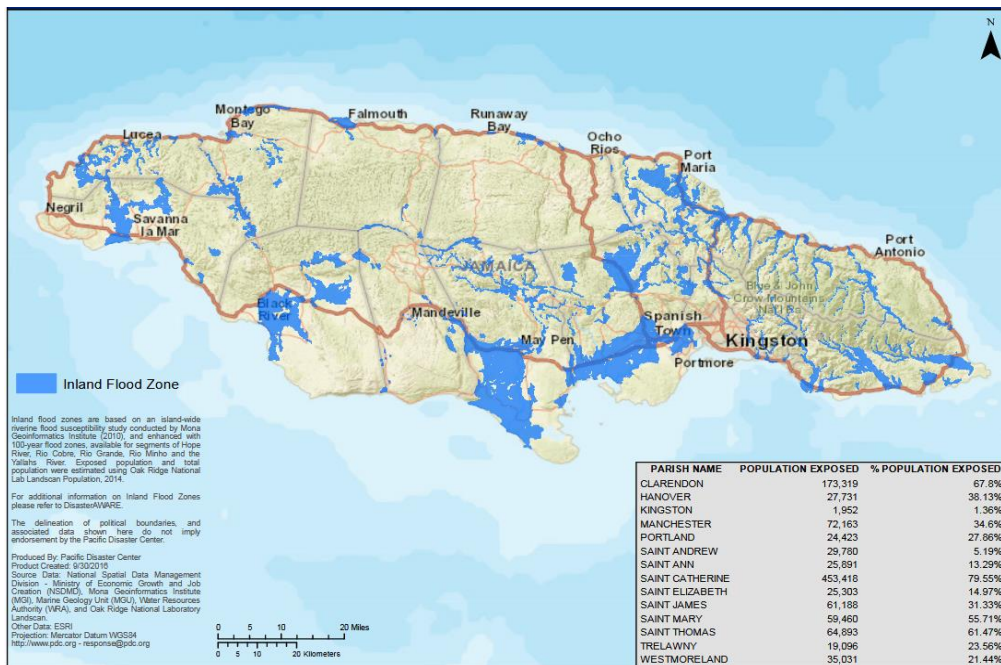
Apart from its frequency, flooding is also quite pervasive in Jamaica, as it occurs to varying degrees in all parishes of the island (map 2). Many flooding events are associated with storm surges from hurricanes and tropical storms, and therefore manifest themselves on low-lying coastal areas. But riverine flooding also occurs in valleys and inland plains of watersheds as a result of extreme rainfall which may overwhelm the drainage capacity of rivers.

Map 2
Distribution of Flooding Events in Jamaica – as at 2010



Source: Nandi et al, 2016.

Map 3
Flood Hazard Map – Jamaica



Source: ODPEM, 2019.

According to Nandi et al. (2016), at least five broad factors are responsible for the occurrence of riverine flooding in Jamaica. These are 1) the hydrostratigraphy or soil structure and related soil drainage variables; 2) land elevation; 3) land cover and use; 4) local annual rainfall and topographical wetness; and 5) distance from a river. Jamaica’s soil types comprise broadly limestone, which facilitates greater soil water drainage, clay loams, and clays which do not drain so readily. Hence locations of higher concentrations of clay are more disposed to flooding, compared to other areas. Higher elevations and slope angles also facilitate higher rates of surface water runoff, thus reducing the possibility of flooding in upland locations relative to flatter areas. By the same token, areas of built development typically reduce soil water percolation, while increasing the speed of surface run-off, and can therefore be more prone to flooding compared to others. Locations of higher rainfall are also likely to be more ground water saturated over time, and with torrential rainfall, have higher potential flood risks. The same logic also applies for areas that are closer to rivers, since such locations are under immediate threat of rivers overtopping their banks compared to places further away. It is the dynamics of these combination of variables that are reflected in the areas of high flood risk hazards as shown in map 3.

II. Methodological approach

As mentioned in the initial section of this chapter, there is not necessarily a direct association between a natural phenomenon and the occurrence of a disaster. While rainfall is essential for the survival and economic prosperity of countries, it only becomes a problem when the society is susceptible to its potential damage. The inability to resist to a hazard or to respond to a hazard when it occurs is defined as vulnerability. There are different methods to measure vulnerability as well as different aspects to consider in a vulnerability analysis such as physical, social, economic and environmental vulnerability. In this research the latest Census and survey data are combined with a previously developed Flood Susceptibility map to identify areas of socio-economic vulnerabilities with high propensity to flooding⁶, using the following criteria: highly populated areas, high housing density, schools, and business operating in the areas reporting previous damage from past flood events.

For measuring the costs associated with the flooding events in the selected areas, the DaLA methodology⁷, detailed in the upcoming section, was used. Although the methodology is normally applied in post-disaster situations, the underlying reasoning and approach for treatment of data are adapted to this study. The following procedure for data collection and analysis was applied:

- Review of key documents and maps on flood hazard, flood risk and related policies was undertaken.

⁶ The focus of this research is on the economic impacts of recurrent flood events. Therefore, we do not aim to develop vulnerability or risk maps. We use already developed hazard maps to identify areas, which have frequently flooded. A deductive approach complemented with interviews with Regional Corporations and local disaster management agencies was then used to identify the areas susceptible to flooding.

⁷ The Economic Commission for Latin America and the Caribbean (ECLAC) is the pioneer institution in quantifying the disaster risk financially to support informed reconstruction and risk reduction efforts. The DaLA methodology, as it is called, had its first edition published in 1991 and has been used frequently in the Caribbean and Latin America region to estimate the economic impact of disasters. The methodology is framed within the priorities of the Sendai Framework, mainly in relation to the strengthening in the preparation to give an effective response to the occurrence of disasters, guaranteeing the necessary capacities that lay the foundations for an effective recovery.

- Review of the most recent available Census and economic surveys undertaken to collect data on relevant socio-economic parameters.
- Semi-structured interviews and meetings were undertaken with government ministries, regional corporation representatives, disaster management entities and local communities to collect information to past event and previous reported damages.
- All selected locations (for Trinidad only) were visited to gather insights into the relevant public and private infrastructure in place. Observation and informal conversation were used to gather data on damage and losses not captured in official documents and on intangible impacts of flooding in the areas.

All identified assets within the boundaries of the selected areas were considered as hypothetically affected. According to the DaLA methodology, the potential costs associated with the event are categorized into damage, losses and additional costs. Two approaches were used for selecting and organizing the data. In the case of Trinidad and Tobago where no previous assessments were available, the analysis relied mainly on data reported by different government institutions and assumptions were made based on information available from the latest census and other administrative data. In the case of Jamaica, where previous assessments were available, the information was organized according to the DaLA methodological approach.

In both cases, a significant limitation of the study was the unavailability of data. While the census and existing surveys, provided an important source of information, there were significant gaps in data on past flood occurrences and updated maps of relevant infrastructure, business and agricultural activities in the areas. Moreover, and in the specific case of Trinidad and Tobago, there was no systematic collection of data on damage and losses for different sectors in previous events. Sectoral estimation of damage is important to identify the precise costs of each sector and better understand the non-monetary long-term effects of such recurrent events. In cases where estimations were not possible to be completed due to missing data, a methodological approach to be used in the future to complement this study is recommended.

Damage comprises the effects a disaster has on the assets of a certain sector in monetary terms. Damage includes impacts on physical assets such as buildings, installations, machinery and equipment, furnishings, road systems and ports for example. It also comprises impacts on stocks of final or semi-finished goods and raw materials (ECLAC, 2014). Losses and additional costs are disruptions to flows resulting from a disaster. Losses are defined as goods that go unproduced and services that go unprovided from the moment the disaster occurs until full recovery and reconstruction is achieved (ECLAC, 2014). Good examples are the reduction in the size of future harvests due to the flooding of farmland, or the decline in production because of damage to an industrial plant. Losses are calculated as the difference between the expected normal evolution of the sectors before the disaster and the assumed behavior that will take place after the disasters. Additional costs are the outlays required to produce goods and provide services after a disaster. They might be, for example, related to additional spending or budgetary shifts from public and private institutions to cover unanticipated expenses. The present study will consider the sectors included in table 4 below.

Table 4
Summary of elements considered in the analysis

Damage	Physical damage to housing, relevant infrastructure, public buildings and commercial and industrial facilities in the area.
Losses	Losses related to housing, educational sector and business interruption in the area. Losses related to traffic interruption will also be considered in the case of Jamaica.
Additional costs	Government expenditure in emergency response in past events in the area to remove debris, set temporary shelters and assist displaced population.
Risk mitigation costs	Set – up of infrastructure costs of flood mitigation structures in selected areas.

Source: Prepared by the authors.

The term housing refers, strictly speaking, to any building intended to serve as a dwelling for individuals or families. Damage in this sector covers: (a) the total or partial destruction of dwellings and their equipment (furniture, electric appliances, sanitary facilities, and equipment in general) as well as the indoor components of water, sanitation, electricity and communications facilities; (b) the total or partial destruction of public buildings; and (c) the total or partial destruction of public spaces. Estimating damage requires knowledge of the degree of destruction of dwellings and their furnishings, as well as their replacement prices. Losses in housing corresponds to the value of rents paid or imputed for dwellings rendered uninhabitable through destruction or damage resulting in a decline in the rental income. The calculation is done in the following way: (i) percentage of rented houses in the area; (ii) the cost of imputed rents forgone (average in the region) in the dwellings affected (partially or totally destroyed); (ii) multiplication of the foregoing by the estimated number of days (or weeks) that it will take to rebuild/ recuperate the dwelling.

Damage in houses and business in the area also have a negative impact on connected sectors such as electricity and telecommunications, services of which may be interrupted, or revenues reduced due to the evacuation of the affected zone. In the power sector, revenue lost by companies are due to a reduced supply, or because of lower demand due to the destruction/ evacuation of homes and productive facilities. Gross revenues forgone can be determined by an estimation of the decline in the consumption resulting from the destruction or damage of houses and commercial establishments.

Damage to road infrastructure refers to the effects of the disaster on any of the elements of roads and highways that lead to total or partial suspension of service. The value of damage will represent the cost of the works needed to restore the infrastructure to pre-disaster conditions. This estimate includes the rehabilitation works required to restore service (i.e. to make a road accessible and passable), as well as the replacement works needed to return the infrastructure to its original state. Assumptions about the characteristics, conditions and magnitude of the disaster's impact on roads and highways are based on information about previous events.

Other damage considered is related to any relevant public infrastructure identified in each area of study that has or might be affected by future flooding, for example, schools and public buildings. Disaster damage in the education sector involves the destruction or partial impairment of its various assets: buildings, furnishings and equipment, books and other education material.

Losses in the education sector encompass educational services provided by either the public or the private sector, at all levels and for any profession within the identified areas. In this sector, the affected flows include a reduction in output, measured in terms of the number of hours or days of classes taught valued as the wage received by teachers for the hour/class. For this study, the following variables were taken into consideration in each region:

- Number of schools in the area
- Average number of students in each school
- Average number of teachers in each school
- Approximate number of days schools stay closed during extreme events.

Public education, or education provided by non-profit institutions, does not have market prices. As such, gross "output" value must be calculated from the sum of its costs, pursuant to international recommendations on national accounting. For the purpose of this study, the output of this sector was defined as the quantity of teaching received by the students. Losses were calculated considering a reduction in the number of hours of classes students have received because of the flooding event multiplied by the monthly wage of teachers by the number of teachers in the schools affected. Private education losses, where reported in the area, were estimated based on the value of the tuition fee.

Damage sustained by industrial and commercial establishments located in a disaster area will obviously have a negative impact on production flows because of both the temporary suspension of activities and relative shortages of inputs caused by the temporary interruption of communications and sales channels. The disruption in flows will result in losses. The impact will be felt by the establishment and the local economy, and not the sector as a whole or the economy at the national level, because increased production flows in similar establishments in other parts of the country can compensate for the interruption of the production of a good in one area. In the case of an industrial complex where the firms are the only producers of a particular good in the country, the impact will be fully passed on to the manufacturing sector and therefore to the economy at large.

When the affected areas have agriculture activities, an estimated decrease in the gross output value (GrOV) can be calculated for each crop. Such a reduction may result from a smaller harvested area or from lower yields on lands that were not directly affected (not flooded) by the disaster but have been compromised by a greater incidence of phytosanitary problems caused by excessive ambient or soil humidity.

The additional costs considered in this paper were calculated based on the official information of the government expenditure in emergency response in past events in the area to remove debris, set temporary shelters and assist displaced population. Recovery activities can include for example distribution of food grants, bottled water, cleaning materials and rehabilitation activities to restore proper treatment of human waste such as installations to divert outflows from sewage or storm water pumping stations.

The paper goes beyond an attempt to put costs into often not assessed events, but also identifies data gaps and areas for future improvement in each studied country. Therefore, the table below highlights the main sources of information used, the data that has been collected and can also serve as a parameter for future areas of improvement in terms of data collection per sector in each country:

Table 5
DaLa methodology sectoral data map

Jamaica	Trinidad
Social sectors	
Affected population	Data usually collected and provided by ODPM
Education	Data on affected schools available, but no systematic collection of information on number of school days lost and number of affected students per event. Information complemented by interviews of local school managers.
Health	No impact measured and reported in the health sector due to the small and localized nature of the events. However, potential health impacts related to this type of disaster and increasing in expenditure in the health sector could be measured long term.
Housing	Estimations based on information about areas affected and census data. Collection of data on damage per household done by regional corporations, but no estimation of costs.
Infrastructure	
Transportation	Information on roads affected available, but no systematic collection of costs of repairing and additional costs due to the closure of main roads.
Water and sanitation	Qualitative information on damage reported on sewage system. No data on costs.
Power	Usually no damage reported on the sector. Costs to power companies estimated based estimated based on census data and average of electricity consumption.
Economic sectors	
Agriculture	Estimation on overall damage to country's agricultural sector available, but no information per region or event.
Manufacturing	No systematic collection of data on business losses and damages.
Commerce	Local commerce has been recurrent affected by flooding, but no systematic collection of data on commerce losses and damage has been done or reported.
Tourisms	No systematic collection of data on impacts on touristic activities in the area.

Source: Prepared by the authors.

III. Selected areas of study

The areas selected for a more detailed study in the two case countries were identified based on official hazard maps as flood prone zones with high risk and identified social economic vulnerabilities. In the case of Trinidad and Tobago, the areas of Charlieville in the Borough of Chaguanas and Kelly Villa/St. Helena in the Borough of Arima were selected (map 4). These areas have reported frequent flood events are densely populated and present a high density of housing, services and commercial activities that provide a rich model of analysis to be replicated in other areas of the country.

Map 4
Flood risk in selected areas/ Rivers in selected areas, Trinidad



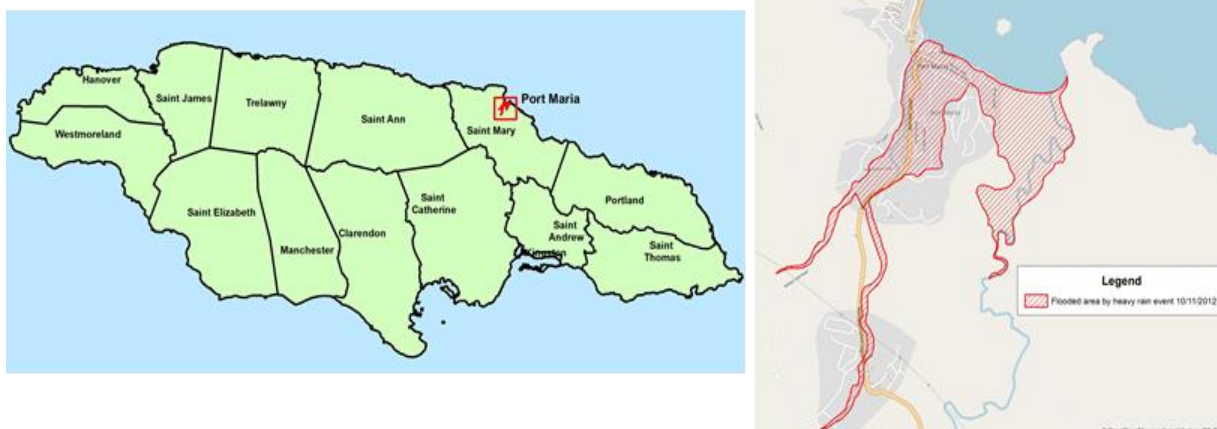
Source: ECLAC, 2019 – Prepared by the authors on the basis of GIS data provided by the country.

For Jamaica, the parish of Saint Mary was selected (Map 5), with greater focus on the municipal capital of Port Maria. This northeastern parish is highly subjected to flooding, given its generally rugged

topography, and widespread distribution of rivers. Moreover, this parish has a reasonable mix of agricultural, tourism and general services economy, with a fairly even distribution of population.

Its main town of Port Maria also provides a good context for the assessment of flooding dynamics in a rural municipality, and subsequent application to other rural municipalities in Jamaica.

Map 5
Flood risk in selected areas/ Rivers in selected areas, Jamaica



Source: Water Resources Authority, Jamaica – WRA – Jamaica, 2019.

A. Socioeconomic profile of Chaguanas/Charlieville, Trinidad and Tobago

The first study area selected is Charlieville located in the Borough of Chaguanas. Chaguanas is a low-lying area upstream from the Caroni Swamp. The borough is comprised of the main town, Chaguanas and a number of rural villages and suburban areas. It is approximately 59 km² in area, with a population of 80,000 persons, or roughly 6 per cent of the total country population (Trinidad and Tobago census 2011). The large expanse of agricultural lands that fall within the boundaries of the Borough defines its rural character. Much of the Borough's land was previously used mainly for sugar cane cultivation. However, this is gradually changing with the closure of the sugar industry, and the increase of housing projects and the development of urban centers. Chaguanas does not have its own power generation facilities and gets its power from utilities outside the Borough. Its potable water supply is also from the Caroni/Arena Water Treatment Plant, which is located outside the Borough at Piarco. Most of the population has access to water, sanitation, electricity services and educational facilities (see table 6).

The region has always played an important role as a commercial center due to its central geographical location between the cities of San Fernando and Port of Spain. Today, its economy is primarily based on retail activity and some light industrial manufacturing. Monthly revenue from micro and small and medium sized enterprises (MSME) in the area varies between TTD 1,500 per month to TTD 55,000 per month. The average annual income generated among micro enterprises was TTD 13,933 and for small enterprises 120,846 TTD (Local Area Economic Profile. Chaguanas Corporation). Clay and plastering and sand-mining activities also take place in the area, particularly in Longdenville. There are eleven primary schools and eleven secondary schools located in Chaguanas.

Table 6
Municipal Indicators – Chaguanas

	Chaguanas	Trinidad and Tobago
Life expectancy at birth	73.6	73.22
Percentage of the population with chronic illnesses	21.1	22.3
Primary and secondary educational attainment	98.9	91.4
Secondary and higher educational attainment	62.9	64.8
Household Income per capita (US\$ according to 2005 PPP\$ conversion rate)	5 452.9	61 92.8
Population without electricity (percentage)	0.8	2.5
Population without drinking water (percentage)	0.3	3.9
Population without improved sanitation(percentage)	7.3	7.9
Labor force participation	78.3 (male) 49.6 (female)	73.5 (male) 50.9 (female)

Source: Trinidad and Tobago Human Development Atlas 2012.

The headquarters of the Youth Training and Employment Partnership Programme (YTEPP) is headquartered in Chaguanas and YTEPP operates two training centres in the Borough delivering nine different programmes. There are two health facilities in the Borough – the Chaguanas District Health Facility and the Chaguanas Health Centre and several other private clinics (Local Area Economic Profile. Chaguanas Corporation).

Chaguanas also hosts some important environmental areas such as the Longdenville Forest Reserve and the Caroni Swamp. The wetlands provide a source of employment and income from natural resource exploitation as well as tourism and it the nesting site of the national bird – the Scarlet Ibis. The Chaguanas Borough has many waterways, which contributes to its propensity to experience flood events during the raining season. The problem is aggravated during high tides and could be further intensified by climate-related sea level rise, land subsidence, and the loss of natural barriers.

As per media reports and interviews with local inhabitants and business owners, flooding in the area cause damage to private property with temporary displacement of people, interruption to business activities, schools and commerce.

B. Socioeconomic profile of Tunapuna/Piarco - Kelly Village/ St. Helena, Trinidad and Tobago

The Tunapuna/Piarco Regional Corporation is a combination of two regions namely the Tunapuna region and the Piarco Region both comprising a total area of 527.21 km². The region is located in the Northern and part of central Trinidad. According to the Central Statistical Office (CSO), there are 70 communities in this municipality. As per the 2011 Population and Housing Census, the population of Tunapuna/Piarco was 215,119 persons (16.2 percent of the national population), with a growth of 5.5 percent between 2000 and 2011. The census also revealed that an average of 3.3 persons lived in the 64,176 recorded private households in the region. Some of the settlements are dormitory communities, with many of the residents engaged in employment or other activities outside of the area of residence. Key socio-economic indicators of the Tunapuna/Piarco region are shown in table 7.

Table 7
Municipal Indicators – Tunapuna/Piarco

	Tunapuna Piarco	Trinidad and Tobago
Life expectancy at birth	75.47	73.22
Percentage of the population with chronic illnesses	22.8	22.3
Primary and secondary educational attainment	79.1	91.4
Secondary and higher educational attainment	67.4	64.8
Household Income per capita (US\$ according to 2005 PPP\$ conversion rate)	6 214.8	6 192.8
Population without electricity (percentage)	2.5	2.5
Population without drinking water (percentage)	1.4	3.9
Population without improved sanitation(percentage)	8.7	7.9
Labor force participation	70.3 (male) 52.8 (female)	73.5(male) 50.9 (female)

Source: Trinidad and Tobago Human Development Atlas 2012.

The geography of Tunapuna/Piarco is dominated by the Northern Range. The natural drainage channels on the southern side of the Range are steep, narrow, gorge-like valleys through which the Yarra, Madamas and Marianne Rivers among others flow. Southern Tunapuna/Piarco falls within the Northern Basin which extends from the foothills of the Northern Range to the foothills of the Central Range and comprises the floodplains and alluvial flats of Caroni River and the Northern Terraces. Tunapuna/Piarco consists of 16 watersheds named for the rivers which drain the surrounding areas. The landward slopes are less steep with the Maracas Valley being wider and deeper than the others. Many of the large rivers in North Trinidad have their sources on these slopes including the Maracas/St Joseph, Caura/Tacarigua, Lopinot/Arouca, Mausica, Arima, Oropuna, Guanapo, El Mamo, and Aripo Rivers which all flow into the Caroni River (Municipality of Tunapuna/Piarco Local Area Economic Profile).

The main activities in the region are provision of public services, agriculture, fisheries, distribution, commerce, industry, medical services, tertiary education and tourism. The country's international airport that handles passenger and cargo traffic is located in the Municipality. The area also has three industrial estates at Macoya, Trincity, and Frederick Settlement and other private industrial complexes such as Nestle and Unilever, Carib Brewery, and Coca Cola Caribbean Bottlers. The Main Campus of The University of the West Indies (UWI) is also located in the area, along with other institutions of higher learning and an important country hospital, the Mount Hope Hospital. The Municipality is also the base for a number of important national institutions: the Water and Sewerage Authority (WASA), Trinidad and Tobago Postal Corporation Limited (TTPost), the Trinidad and Tobago Bureau of Standards (TTBS), and the Airports Authority of Trinidad and Tobago (Municipality of Tunapuna/Piarco Local Area Economic Profile).

Significant acreages of land are devoted to agriculture in the area to the south of the Churchill Roosevelt Highway and on both sides of the Caroni River. Much of it is utilized for intensive cultivation of rice, food crops, and vegetables. Further east is the Orange Grove Estate of which part has been allocated for the development of a 41-hectare mega farm for the production of vegetables. Other areas of this estate have been subdivided into small agricultural plots (0.8 hectare) to be distributed to former Caroni agricultural employees⁸. Another major agricultural area is Wallerfield where livestock farming,

⁸ These were employees of the former state-owned sugar company, Caroni 1975 Limited, which ceased operations in 2003.

and poultry rearing are undertaken. Tree crops (mainly citrus), vegetables, and other mixed food crops are also cultivated along with the rearing of livestock. This is the eastern extremity of the agricultural area on the plains which also incorporate almost all of the land to the east of Piarco, including Oropune, Centeno, and Carapo. Quarrying operations also take place in the Wallerfield area where extensive deposits of sand and gravel are mined for use in the construction industry and for road building. Limestone and other minerals found in the upper Maracas and Lopinot Valleys, as well as at Guanapo and in the Arima/Blanchisseuse area, are also exploited for use in the construction industry (Municipality of Tunapuna/Piarco Local Area Economic Profile).

The type of business enterprises in the area consist mainly of retail and distribution (54.9%) and the provision of personal services (14.0%). Firms involved in food processing, chemical production and construction although not significant numerically, tend to be larger and thus employ a greater number of persons. Large commercial centres such as Trincity Mall, Valpark and Grand Bazaar cater not only to the needs of those in the Municipality but also to the needs of consumers across the country, given their strategic positions (Municipality of Tunapuna/Piarco Local Area Economic Profile).

Flash flooding, largely due to increased urban runoff, and landslides are common throughout the Municipality during the rainy season. According to the Municipal Development Plan 2010, the problem is compounded by inadequate and clogged drainage systems and water courses, poor maintenance of drains and culverts and river channels, indiscriminate dumping of garbage into waterways, and changes in land use.

C. Socioeconomic profile of Saint Mary, Jamaica

The parish of Saint Mary is approximately 611 square kilometres in size (Jamaica Information Service, 2019), and is bordered by Portland to the east, and St Ann to the west, with parts of St. Catherine and St. Andrew forming its southern boundary. Apart from its narrow coastal plain, St. Mary is largely a mountainous parish, attaining an elevation of 1,220 meters at its highest point, with less than 13% of the area having slopes below 10 degrees. The overall terrain approximates two main watersheds separated by a large valley into which drain several rivers. The largest of these are the Rio Nuevo, Wag Water and White Rivers, with the smaller Otram (formerly Port Maria River) and Pagee rivers emptying into the northern coast in the area of Port Maria.

St. Mary parish had a resident population of approximately 114,867 at the end of 2018 (Statistical Institute of Jamaica, 2012), with the population of Port Maria, its municipal capital, approximating 7,500 persons in 2012. (ODPEM, 2012). The main economic activities of the Parish have been agriculture, through the production bananas, root crops, vegetables and condiments, as well as a diverse range of livestock (poultry, pigs, sheep, goats, cattle, rabbits and bees). Fishing is also an economically important activity for coastal communities of the Parish. While it is not among the largest agricultural producers, St. Mary's share in national agriculture remains significant as it was reported to have just under 21,000 hectares or roughly 6.4% of total land under agriculture in 2007 (Statistical Institute of Jamaica, 2011).

Within recent years, there has been some decline in this sector, but this has been offset by growth in tourism services, which was further stimulated by the recent establishment of the Ian Fleming International Airport, which now facilitates direct international access to Jamaica's north east coast. Municipal services, as well as retail trades and services (finance, bakeries and restaurants, fuel distribution, block-making and funeral services) also contribute to the economic activities in the main parish town of Port Maria.

With respect to social dimensions, the Parish of Saint Mary reflects consistency with the national average for many social indicators, with some exceptions. As a mostly rural parish, the share of households regarded as urban is 26 percent, compared to an average of 54 percent for Jamaica as a

whole. Access to public health care measured as the number of public hospital beds per capita is also somewhat lower at 1 bed per 650 persons, compared to the national average of 1 bed per 560 persons. In terms of quality of housing, Saint Mary lags behind the national average of households with improved sanitation facilities, with only 59 percent, for the parish relative to 71 percent for all of Jamaica. The parish is however better off with respect to public education services, boasting an average of 1,767 parishioners per public education institution, compared to 2,729 for the nation. The measures are even better for primary education, as the Parish averages one primary school for 2,553 residents, compared to one primary school per 4,669 Jamaicans nationally. For other social indicators such as use of Liquefied Propane Gas (LPG) for cooking; household access to piped water; and use of electricity for lighting, Saint Mary closely approaches the national average as summarized in table 8 below.

Table 8
Municipal Indicators – St. Mary

	St. Mary	Jamaica
End of Year Population (2018)	114 867	2 726 667
Bed Compliment of Public Hospitals (2015)	177	4 865
Total Number of Public Education Institutions (2016)	65	999
Total Number of Primary Schools (2016)	45	584
Total Number of Teachers in Public Schools (2016)	1 078	23 811
Percentage of Households Using LPG for Cooking (2011)	78	80
Number of Dwelling Units (2011)	35 601	853 660
Percentage of Households Using Piped Water Supply (2011)	70	73
Percentage of Households Using Electric Lighting (2011)	87	92
Percentage of Households with Improved Sanitation Facilities - water closet (2011)	59	71

Source: Statistical Institute of Jamaica, 2019.

IV. Potential effects and mitigation measures

A. Trinidad and Tobago - Flooding in Tunapuna/Piarco and Chaguanas, a case study of St. Helena, Kelly Village and Charlieville

1. Effects

Approximately 295,000 persons live in these two boroughs and are susceptible to primary or secondary impacts from yearly flooding events. In the Tunapuna /Piarco region, most of the population was significantly affected by the 2018 flooding event. According to the Tunapuna/Piarco Regional Corporation (TPRC), the number of families displaced by the flood was around 2,600, not including those that did not report to the RC office. Based on information collected from the Disaster Management Unit of the TPRC, events of this type are recurrent, as the area experiences on average 3 to 4 major flood events every rainy season. The recession of the floodwaters is typically slow in the lower areas and the problem can be aggravated by tidal factors with water being retained for up to 6 days. The borough of Chaguanas was relatively less impacted by the most recent flood event, but a similar pattern of flooding has been reported in the area.

(a) Social sectors

Families in the households affected by the 2018 October flooding received a “minor repairs and reconstruction grant” from the National Commission for Self Help. The assistance was provided in the form of a purchase order for up to a maximum amount of TTD 10,000.00 allowing people to buy building materials to replace damaged components of the house. An additional grant was provided by the Ministry of Social Development and Family Services to replace damaged appliances and furniture and repair the home’s electrical wiring and sanitation plumbing up to a maximum amount of TTD 10,000. Additionally, families were also able to receive a clothing grant of TTD 1,000 per person, a school supply grant of TTD 700 (for primary school) and TTD 1,000 (for secondary school). A food support programme was also put in place to provide financial assistance in the amount of TTD 410 (families of 1-3 persons), TTD 550 (5-6 persons) and TTD 700 (more than 7 persons in the family). The National Social

Development Programme also provided additional funding for materials for sanitary plumbing, house wiring and improved water supply up to an amount of TTD 20,000.⁹ Considering that each of the officially reported affected families received one package of assistance for clothing, school supply and food, a estimated cost of TTD 5,486,000 would have been incurred.

As indicated in interviews with local schools and the Regional Corporations in both areas, the 2018 flooding event resulted in schools in the areas most affected being closed for an average of two days. Additionally, some schools were used as shelters for displaced families with larger closure periods¹⁰. A visit to the St. Helena Hindu School affected by the 2018 floods, reported that the compound was under 3 feet of water for around 2 days, the most impacted the school has been in over 20 years. School documentation, materials and furniture were severely damaged. The building structure was also affected causing minor damage to walls, doors and floors (figure 2). This particular school remained closed for one week and no extended teaching time was expected to recover the number of hour/classes lost. In an unofficial inquiry with school management, the damage resulting from the event was estimated at 15,000 TTD.

Based on this information, the potential hours of class lost by students over a one-year period were calculated considering the following assumptions: (i) 3 major flood events occurring every rainy season; (ii) school activities in the area are paralyzed for an average of 2 days for each event; (iii) a school normal day has an average of 6 hours. Based on the population residing in the area and the percentage of population attending an educational institution in the borough as per the 2011 census, the following losses were calculated: 36 hours of school per year for each student and an overall loss of 72,256.67 hours of class in Kelly Village/St Helena and 67,292 hours in Charlieville. On this basis, a total of nearly 140 thousand hours of school hours were lost yearly.

Using the average day salary of a teacher and the pupil teacher ratio average for the country, considering 8 schools potentially affected in St Helena, Kelly Village and Charlieville, a total loss of TTD 112,576.00 was calculated for the educational sector in the area for every major flooding event in which the schools remain closed for 2 days. Note that this number might be even higher considering that some schools might experience longer closure periods for cleaning (as reported in 2018) or be used as shelter for displaced families.

It is important to highlight that these are average numbers as not all schools are necessarily flooded or directly affected by this type of event every year. However, students, teachers and school staff that normally reside in the area are often impacted by the annual floods resulting in a frequent and expected partial or total interruption of education services in the areas. This could in turn have long term impacts on school performance and educational achievement of children and young people residing in these areas.

⁹ Source: Ministry of Social Development and Family Services, Trinidad and Tobago, 2019.

¹⁰ Source: <http://www.looptt.com/content/22-schools-closed-following-heavy-rains-flooding>

Figure 3
Damaged premises of St. Helena Hindu Primary School in 2018 October Flood



Source: Photos provided by school management.

In terms of damage, houses in the area are mostly single level constructed using concrete or wood materials, which can suffer severe impact with flood waters over time. However, construction practices in the area have slowly been adapting to the recurrent situation, so that newer houses have been elevated and the floors have been constructed with easy to clean materials to facilitate removal of debris after flooding (see figure 4).

Figure 4
Houses in Charleville area



Source: ECLAC team.

However, yearly damage and loss of housing appliances and furniture have been reported in different areas in both boroughs. In Damage and Needs assessments carried out by the Regional Corporation in Chaguanas after the 2018 event, interviewees reported damages to beds, mattresses, washing machines and refrigerators as often cited items. As it is not possible to conduct a detailed inventory of all units in the area, damage or destruction of furniture and equipment was calculated as an estimation based on the official assistance given by government for similar events, and information from the needs assessment carried out by disaster units in the areas after major events. Considering the percentage of houses that reported drainage problems in the 2011 census as potentially impacted houses, and using the grants provided in the 2018 flood events as a proxy for costs associated with replacement and repair of household goods¹¹, the following values per household were estimated for a major flood event: Kelly Village – TTD 20,402,080; St. Helena – TTD 24,769,292; Charlieville – TTD 33,857,328.

In terms of losses, the census information on the number of rented dwellings, the percentage of households that reported drainage issues in each area, and the average rent for each region were used to arrive at estimates. In St. Helena, 43 percent of households reported drainage issues, therefore, considering the average rent for the region and the percentage of households rented (as per 2011 census), an average loss of TTD 92,635 in terms of rents paid is imputed, if rented dwellings in the area are rendered uninhabitable for a period of two weeks. For Kelly Village, considering the average rent, and that 60 per cent of households reported drainage issues, an average loss of TTD 132,304 is expected. By applying the same methodological premises in Charlieville, an average loss of TTD 174,335 is estimated.

(b) Infrastructure

Note that in this event there were no damage reported for infrastructure assets such as telecommunication, power, transportation, and water and sewerage. Losses were however identified in the power and water sector associated with damage in housing sector. With this percentage of affected housing, considering the average national electricity consumption (for 1-400kWh, 401-1000kWh, over 1000kWh) at current prices and assuming that the same percentage of houses are affected for a period of two weeks, the loss in terms of revenues forgone by electric power utilities during the period of disruption were observed for each area as: Kelly Village – TTD 54,199; St. Helena – TTD 66,630; Charlieville – TTD 90,306.

In the most recent events, no specific damage has been reported in relevant public buildings and public spaces, or in critical services in the specific study areas. However, due to its location in a flood prone area, the Caroni police station was heavily affected in the 2018 flooding. Nevertheless, no official repair costs were available.

(c) Economic sectors

Although the major commercial roads in both boroughs and the industrial areas are not normally flooded, small and medium sized businesses and enterprises that operate in both regions have been affected by flood water, by the interruption of traffic on local roads, or the displacement of the population in the area. The study areas are characterized by small businesses such as supermarkets, general merchandise and hardware stores, restaurants, printing services, religious temples and health clinics. With the occurrence of flooding events, businesses in severely affected areas typically request support from the Regional Corporation for cleaning and disinfection services and are reported to remain closed for an average of two to three days. In the flooding event of 2018, two major business establishments in the area - the Kentucky Fried Chicken restaurant, and the American Stores - were

¹¹ 10,000 TTD for minor repairs and reconstruction; 10,000 TTD for household items; and 20,000 TTD as additional funding for materials for sanitary plumbing, house wiring and improved water supply.

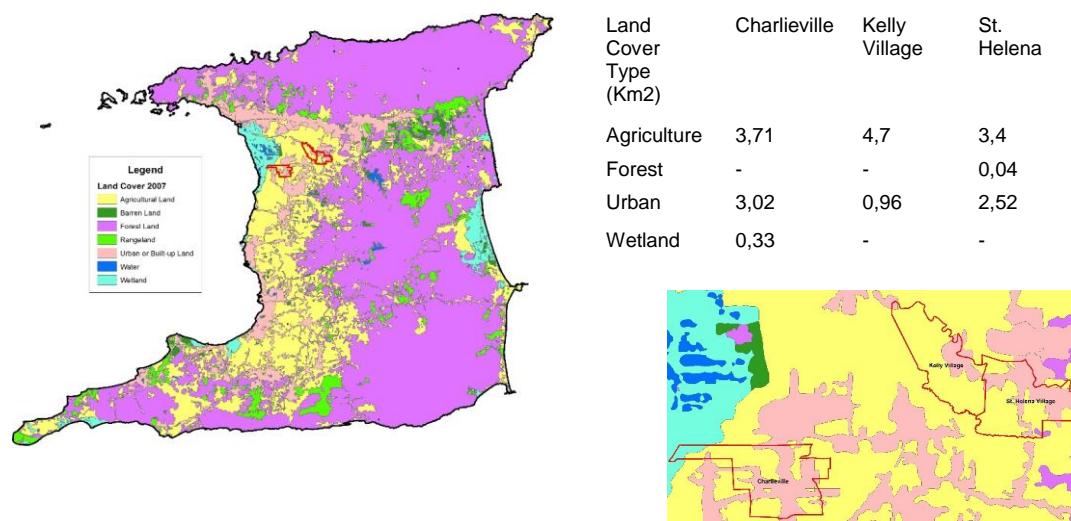
closed for a period of two days. Moreover, both lanes of the Uriah Butler Highway, the main connection with larger urban centers in the country, became underwater with the traffic blocked for light vehicles, for a period of two days. Considering the average income for small and medium sized businesses in the areas, as reported in the economic profile of the regional corporation, a decrease in business activities, even if for a short period, could have significant impacts on households. Moreover, given that a few settlements in Tunapuna/Piarco are dormitory communities, many of the residents engaged in employment outside of the area of residence were affected by road disruptions.

There are no official data on estimated losses by the business sector in the area. A systematic collection of such information is recommended for assessing three essential parameters: (i) the number of days (weeks) that production/commercial activity is suspended; (ii) an estimation of the flow that would have been produced monthly had the disaster not occurred; and (iii) the decrease in production/revenue as a result of the event. Lost income should be recorded for the period of time that is required to rebuild facilities, repair or replace furnishings and equipment that may have been destroyed, and reinstate a full supply and flow of merchandise. Damage in the small manufacturing and business sector can also be established by considering the potential effects on its assets such as buildings and machinery. The estimation of damage can be done with an approximated count of the number of establishments in the area, their type of activity and their size (large, medium-sized and small firms, depending on the number of staff employed) and by systematically collecting information on the equipment, machinery and vehicles damaged in the flooding event. The damage is converted into monetary units by valuing the relevant assets in terms of replacement costs (considering assets of similar characteristics to the original design). Information on the pre-disaster status of these types of enterprises is useful to form a baseline and inventory of existing businesses. Household surveys or income and employment surveys in the area can be combined with the geographical data on the municipalities that were the hardest-hit by the disaster (ECLAC, 2014). This type of data collection is relevant for the two boroughs as many shops and small enterprises operating in the area are family business that employ members of the local population and rely upon the income derived from this activity for their livelihoods. Usually, this is also an economic sector that has the greatest difficulty in making a recovery, since businesses are often underinsured. Further, business owners have little access to financing and therefore rely on recovering community members as their main source of clientele after the flooding event.

Although agricultural activities occupy a small percentage of the specific study areas under analysis (see map 6), analyzing agricultural losses is relevant on a national scale as according to the 2004 Agricultural Census, 33.6 per cent of agricultural land in the country is subject to flooding and local producers have received yearly flood damage transfer from government (IDB, 2018) (table 9). In 2018, the president of the Agricultural Society of Trinidad and Tobago stated that approximately 75 per cent of local farmers in the country were severely affected through the loss of crops and livestock, harvesters, tractors, and equipment¹².

¹² <http://www.guardian.co.tt/news/floods-cripple-agriculture-6.2.706397.3fob5bfdc7>

Map 6
Land cover type in study areas



Source: ECLAC estimation based on geospatial analysis.

Table 9
Government budget transfer to individual producers
(\$TT Millions)

	2010	2011	2012	2013	2014	2015
Current receipts/income: flood damage	18.61	14.69	9.67	3.83	9.44	17.0

Source: IDB, Analysis of agricultural policies in T&T, 2018.

Damage in agriculture could be related to: (i) erosion, sedimentation, salinization, or other negative effects that reduce or destroy the actual or potential production capacity of the soil; (ii) destruction of infrastructure used in farming, livestock, poultry, aquaculture and forestry activities such as roads or bridges within the farm property; buildings and installations for the storage of equipment, harvested products; irrigation or drainage systems; silos, stalls, corrals, troughs and pens among other items; (iii) machinery, equipment and tools used in farming, livestock, poultry, aquaculture and forestry activities; (iv) permanent crops that may be destroyed and must therefore be replanted, meaning that production levels may take several years to recover.

The losses are associated with: (i) decline in the production of transitory or permanent crops because they could not be harvested, or production could not take place within normal or customary time limits; (ii) reduction in physical productivity or lower yields than normal for the different types of transitory and permanent crops; (iii) lower quality of the harvest or of by-products obtained from the various components of the agriculture sector.

For a precise estimation of agricultural losses in each area, baseline data on the types of crops and previous assessments on yearly yield are essential to evaluate the volume of production lost because of the flood. The volume of production lost multiplied by the average producer price could be

used to obtain the gross output value lost on the unharvested area due to the flooding. An analytical comparison between normal production indicators and those relating to the damage suffered will provide information that can be used to determine whether the damage or loss has been permanent, or temporary and recoverable. With annual crops, the period that elapses between sowing and harvesting must be considered, while with permanent crops what is important is the period from flowering until harvest. As a consequence of flooding, there might also be additional costs due to the need to use greater quantities of inputs to neutralize the effects on crops, livestock and agricultural infrastructure (ECLAC, 2014).

(d) Additional costs

Additional costs can represent relevant expenditures when it comes to flooding. According to the Chaguana Borough Corporation, the additional costs related to the 2018 October flood was approximately TTD 56,000.00 which included among other expenditures overtime for workers, sandbags, and immediate relief items such as mattress, pillows, bed sheets, blankets and sanitizing agents. Another relevant cost is related to the removal of debris normally done by the Health Department due to the danger posed by items contaminated by flood waters. However, these costs have not been reported. Support provided to families in terms of clothing, education and food reported in the first section can also be considered additional costs (TTD 5,486,000).

The table below provides a summary of costs associated with the flooding events in Trinidad and Tobago.

Table 10
Summary of Flooding Costs - Trinidad and Tobago
(TTD)

	Tunapuna/Piarco (St Helena, Kelly Village)		Chaguana (Charlottesville)	
	Damage	Losses	Damage	Losses
Social sectors (Education/Housing)	45 186 272	281 218	33 857 328	230624
Infrastructure sectors	-	120 830	-	90 306
Economic sectors	-	-	-	-
Additional Costs*		56 000 + 5 486 000 (grants/ family)		

Source: Prepared by the authors.

2. Flood mitigation measures

Information on flood mitigation plans and current flood mitigation measures have been obtained from the Regional Corporations and the Drainage Division of the Ministry of Works and Transport. Among flood mitigation measures cited as relevant in the area, the Chaguana Borough Corporation identified the plan to implement a TTD 1 million flood hazard alarm system with water-level sensors in the most relevant streams in the area. Maintenance and retention ponds are also cited flood mitigation measures in both areas. The Chaguana Borough Corporation has also acquired two mini excavators to clear water courses at an initial approximate cost of TTD 500,000.

At a national scale, for 2018, the Ministry of Planning and Development reported a planned allocation of TTD35 million for the implementation of projects under the National Programme for the Upgrade of Drainage Channels. An investment of TTD 9 million will also be made for the commencement of projects under the Major River Clearing Programme (Ministry of Planning and Development, 2017).

Box 1**Financial protection in Trinidad and Tobago**

Although, not being a mitigation measure it is relevant to cite that the Government of Trinidad and Tobago purchased two separate Excess Rainfall policies with CCRIF, one for Trinidad and one for Tobago¹³. The Rainfall Index Loss calculated for this Covered Area Rainfall Event (CARE) that started on 18 October and ended on 20 October 2018, indicated government losses above the attachment point of Trinidad's Excess Rainfall policy. Trinidad's policy was triggered by this event indicating a payout of US\$ 2,534,550.65.¹⁴

Source: Excess Rainfall Event Briefing Trinidad and Tobago – Trinidad 26 October 2018. CCRIF.

B. Jamaica - Flooding in the Parish of St. Mary: A Case Study of Port Maria

1. Effects

Over the past decade, Jamaica has experienced two major flooding events, which have impacted the national population to varying degrees (WRA- Jamaica, 2012; PIOJ, 2017). The first, in 2012, occurred as two chronologically related weather events affected the country over a three-week period between October to November 2012. These were the passage of Hurricane Sandy on October 24th, 2012, and an intense rainfall event on November 12th, 2012. These two combined events resulted in significant flooding, with the second occurrence being more severe as a consequence of several antecedent conditions¹⁵ from the hurricane.

Five years later, in 2017, the country was again subjected to extensive flooding arising from an extended period of intensive rainfall from March to June, 2017 (PIOJ, 2017). During this time, a particularly severe rainfall event occurred in mid-May, and was responsible for most of the flooding impacts during the period.

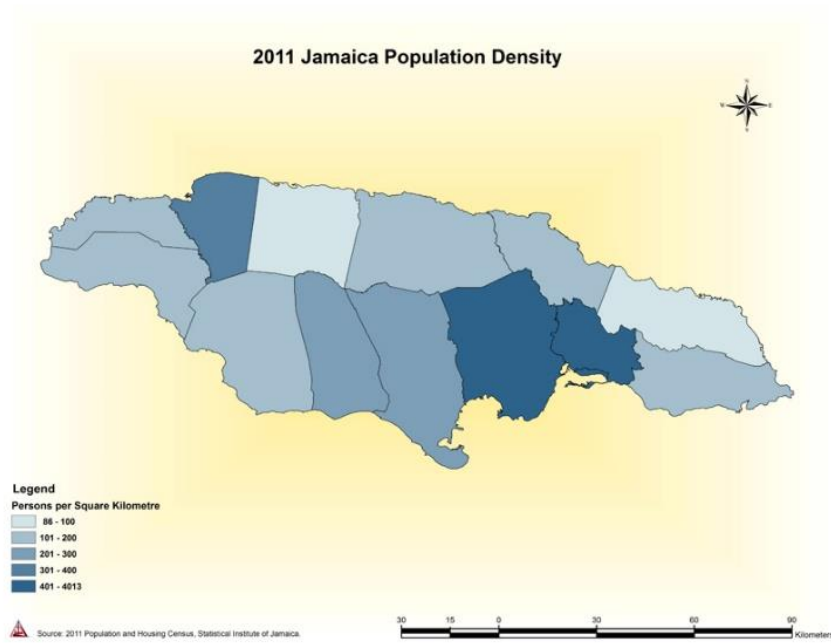
In both events, between 25.2 percent (2012), and 90.6 percent (2017) of the population was affected by floods, with the eastern and northern parishes bearing the brunt of the impacts. The population density distribution (Map 7) for Jamaica provides some perspective of the geographic scope of impacts of these flooding events.

¹³ The payment generated by this insurance is estimated as follows: first, CCRIF SPC immediately considers the threats for each type of product. This is the speed of the wind and the tidal wave (tropical cyclones) or the movement of the soil (earthquakes) or the volume of rainfall (excess of rain). In each case the information is incorporated into the damage simulation models of the CCRIF SPC which are based on a baseline information where there is a measurement of the physical assets exposed. The simulated damage in the previous point is compared to the minimum level insured. If you overcome, it generates a payment up to the limit of coverage. CCRIF SPC makes payments 14 days after the event. Since its founding, 38 payments have been generated for a total amount of 138.8 million dollars.

¹⁴ Excess Rainfall Event Briefing Trinidad and Tobago – Trinidad 26 October 2018. CCRIF.

¹⁵ Blockage at bridges and points of significant meanders by debris; saturated soil conditions leading to high runoff.

Map 7
Population Density – Jamaica (2011)



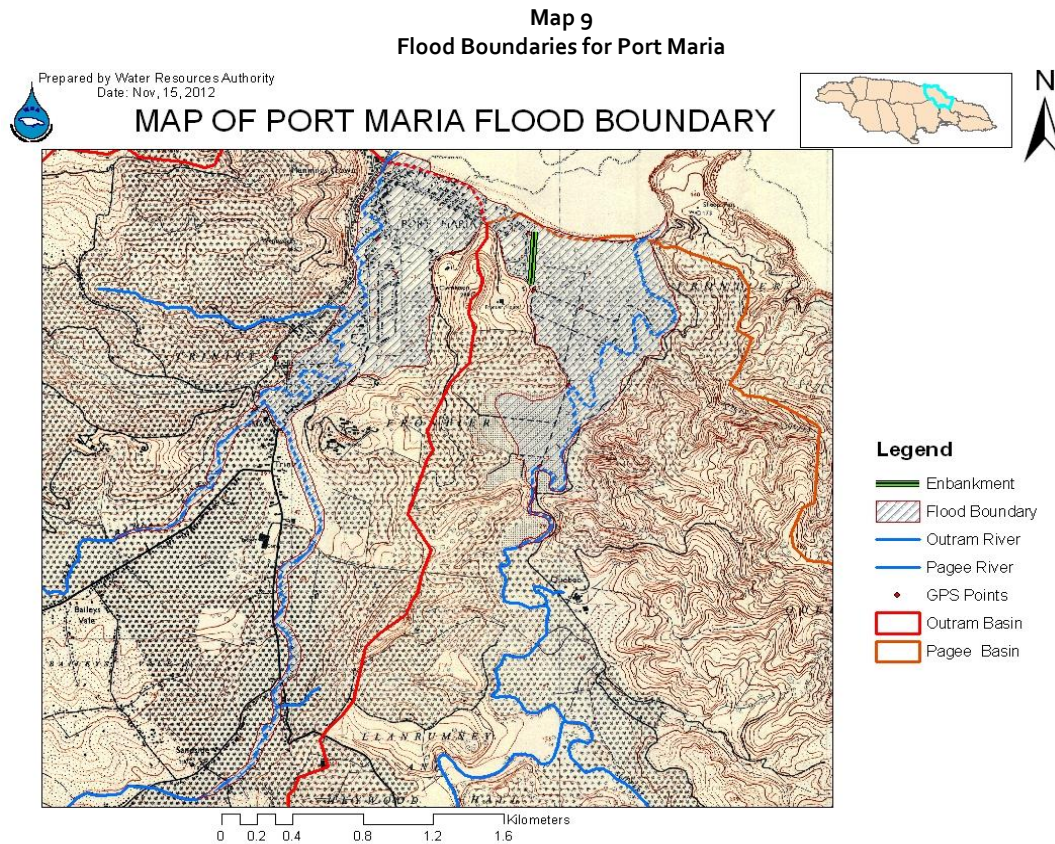
Source: Statistical Institute of Jamaica, 2012.

The parish of St. Mary and the town of Port Maria were unfortunate to have been significantly affected by these two flooding events. Flooding impacted dwellings, businesses and public infrastructure in the wider parish, and in the specific municipal region of Port Maria. Maps 8 and 9 show the geographic location of the parish, and the flood boundaries for the town of Port Maria.

Map 8
Location of the Parish of Saint Mary, Jamaica



Source: Statistical Institute of Jamaica, 2012.



Source: Water Resources Authority, Jamaica, 2019.

Unlike the Trinidad and Tobago case study, the researchers did not have the opportunity for extended field visits to the targeted study areas in Jamaica. Hence the assessment of potential long-term economic impacts on Saint Mary is based on a calibration of estimates by the PIOJ to the specific study area for the two flooding events.

According to the PIOJ (2012, 2017), approximately 38,576 persons or 34 percent of the population of Saint Mary was affected by the passage of Hurricane Sandy and the subsequent rain event in 2012. Although the 2017 rain event was more widespread affecting up to 90.6 percent of the national population (PIOJ, 2017), the impact on the population of Saint Mary was considerably smaller with only 480 persons or 0.04 percent of the parish population being directly affected.

On both occasions, affected families received welfare and relief support from the state in the form of shelters, food packages, hygiene kits and replacement mattresses. In extreme and life threatening circumstances, persons were also evacuated through interventions from the national Office for Disaster Preparedness and Emergency Management (ODPEM), the Jamaica Defence Force (JDF), and individuals in the affected communities. In the specific instance of the 2017 floods, an estimated 100 families from the town of Port Maria received emergency support from the state.

Although costs of emergency relief at parish level were unavailable, the ODPEM reported an expenditure of \$J 35 million and \$J 50.8 million for the 2012 and 2017 events respectively. Financial disbursements to individual parishes for the 2012 floods were also reported to range between \$J 350,000 – 500,000.

(a) Social sectors

With respect to the economic impact of flooding on the education sector, significant damage and losses were recorded for the two events in the parish of Saint Mary. For 2012, country wide damage to schools amounted to \$J170 million. Moreover, the share of the total number of schools damaged across Jamaica was largest for Saint Mary at 21.1 percent. Assuming a similar level of damage for each school, the apportioned value of damage for the parish was estimated at \$J 35.9 millions. Among some 32 schools structurally affected by floods, both the Port Maria High and Primary Schools were especially severely impacted (figure 5). For the 2017 event, structural damage to schools in the parish was limited to mainly roof leaks, and mild ingress of water to ground floors. The extended period of rainfall however resulted in school closures for one day.

Losses to the education sector are assessed in terms of lost teaching time due to flooding events. For the two events over the period, all schools in the Saint Mary parish were closed for a total of four days – 3 in 2012, and 1 in 2017. Based on the research of Gordon (2012), an average *hourly* cost of teaching time was estimated at \$J850.50. Since the parish of Saint Mary has 1,078 teachers, serving 32 public teaching institutions, then the cost of lost teaching services due to flooding was estimated at \$J22,004,136 for the 2012 event, and \$J7,334,712 for the 2017 event (figure 5).

Figure 5
Flooding at Port Maria Primary (top) and Secondary (bottom) Schools, 2012



Source: Water Resources Authority, Jamaica, 2019.

A total of 5,519 houses sustained damage and/or loss of household items due to flooding in Saint Mary in 2012. This represents 32 percent of the total number of houses affected in the country. According to assessments by the Ministry of Labour and Social Security, more than half (57 percent) of the affected homes were wooden structures, while approximately 26 percent were constructed with concrete blocks and steel. Based on a country-wide total housing damage estimate of \$J 1.15 billion, the proportionate value of damage attributable to Saint Mary was \$J 369 million. By similar assessment, the parish bore 20 percent of the total housing damage for the 2017 flooding event. However, no cost estimate of the damage to housing was available for the 2017 event.

(b) Infrastructure

With respect to electricity, most of Jamaica suffered minimal structural damage due to Hurricane Sandy in 2012. The transmission and distribution systems were nevertheless severely impacted, particularly in the parish of Saint Mary. Given the nature of the events in 2012 however, it is difficult to ascribe direct damage costs to the occurrence of flooding, since most of the effects would be most likely due to wind damage. Nevertheless, assessments of the overall impact of the disaster by the PIOJ (2012) indicated an overall electricity sector damage (including third party costs, material/equipment and overtime) of \$J 644 million, of which the share attributable to Saint Mary would have been among the most significant. No electricity infrastructure damage was reported for Jamaica in 2017.

Damage to sanitation is reflected in disruptions to the water supply due to the occurrence of an event. The share of damage to the water for Saint Mary in 2012 was \$J 2.35 millions. This was due to disruption of water distribution infrastructure including power outages, pipeline dislocation especially around bridges, high turbidity in water treatment plants and blocked intakes. For the 2017 flooding event, the damage to the national water systems was more severe, as the impact of flooding was more widespread nationally. Total damage in this case, assessed as the costs for system restoration, was \$J 27.3 million. While the largest share of these costs was for the Kingston/St. Andrew area, damage for Saint Mary was also notable (PIOJ, 2017). However, one measure of damage that was specific to Saint Mary was the destruction of the water utility's commercial office at Port Maria, for which replacement costs were estimated at \$J 86 million (PIOJ, 2012).

Considering economic losses, these measures for housing are reflected in deferred rental incomes for homes which might have been rendered uninhabitable for a period after the disaster. This measure is imputed from the costs of holding persons in shelters during the events. As reported by ODPEM, emergency relief costs for shelters, and related supplies at parish level were between \$J 300,000 – \$J 500,000 in 2012. No shelters were activated for Saint Mary in 2017.

Losses for electricity and sanitation are measured in terms of revenues forgone over the period of service disruption. As reported by the PIOJ (2012), as many as 460,893 electricity customers nationally were left without power for up to 13 days after the storm in 2012. The numbers specific to Saint Mary are not known, but this parish was reported to have suffered most severely from the disruption. In 2017 however, 1,179 Saint Mary parishioners were left in the dark for at least 2 days after the intensive rain event.

In the case of water, the passage of Hurricane Sandy interrupted water supply to 248,612 customers in 2012. Of this number, 3,848 customers (1.5 percent) were from the Parish of Saint Mary. Based on averaged daily revenues to the utility, and reported service disruption of 2 days, the potential economic losses apportioned to the parish was estimated¹⁶ at \$J 513,180. For 2017, the total national losses from water supply disruptions were assessed at \$J 105.8 millions. In this instance, the share of losses to Saint Mary was deemed to be relatively minor (PIOJ, 2017).

¹⁶ Based on area estimates of customer base and annual revenue collections by the National Water Commission.

(c) Economic sectors

As indicated above, agriculture and services are the predominant economic activities in the parish of Saint Mary. A specific challenge relating to the assessment of hurricane impacts on agriculture, is the partitioning out of water and wind damage. Nevertheless, the PIOJ assessed overall damage to agriculture for Saint Mary in 2012 to be \$J 225 millions. This impact occurred on 415 hectares of farmland and affected 5,500 farmers. For the 2017 rain event, the impacts on agriculture were clearly related to flooding and landslipping due to excessive rainfall, as reported by 86 percent of affected farmers. The situation was exacerbated, by slow run-off as the rainfall persisted for several days.

With respect to services, flooding damage centered on the commercial district of Port Maria, which suffered severe losses due to flooding of the town both in 2012, and 2017. While no specific figures were available for these impacts, the evidence of the impacts suggest that water damage would have affected specific commercial establishments such as the Courts Furniture Store, and the Shell Gas Station, as well as several restaurants. Considering the parish's limited establishment of manufacturing activities, no specific estimates of damage to manufacturing were reported for the parish of Saint Mary.

(d) Additional Costs

As noted for Trinidad and Tobago, additional costs for flooding typically include expenses for clean-up, as well as the provision of shelter facilities for persons displaced due to flooding. Clean-up costs often involve the removal of debris such as might accumulate on coasts, riverbanks and commercial and residential areas. Figure 6 shows the deposit of such debris on the beaches of Port Maria after the 2017 rain event.

Figure 6
Debris deposits due to flooding – Port Maria Beach, May 2017



Source: PIOJ, 2017.

Given that such activities may be undertaken by public agencies such as municipal bodies, as well as private and volunteer organizations, it is often not possible to fully assess all costs. Costs for the set-up and operations of shelters are usually more readily calibrated as these facilities are normally established and regulated by national emergency management organizations.

In the case of Hurricane Sandy, just under 100 persons were housed in shelters over a period of four days in the parish of Saint Mary. Shelter expenses included the provision of relief supplies such as blankets, tarpaulins, mattresses, drinking water, raincoats, waterboots, and food packages. The ODPEM estimated the cost of this service to the parish at between \$J 300,000 – \$J 350,000.

In 2017, the wider scope of the rainfall event meant that a larger number of Jamaicans were forced to seek shelter from floods. Nationally, some 750 households or 2,408 persons were provided with emergency relief. Specific figures for Saint Mary, as well as overall costs were however not available.

2. Flood mitigation measures

Specific flood risk assessments undertaken by the ODPEM (2012) and the WRA-Jamaica, have identified specific mitigation measures for the wider Saint Mary parish, as well as the town of Port Maria. For parish wide mitigation, the ODPEM recommends zoning for development and no-development areas based on the assessed flood hazards of selected locations. In this regard, coastal areas which are susceptible to storm surges during hurricanes, and the Albion Mountain region which is at high risk for landslides were designated as 'no-development' areas. For those areas approved for development, specific mitigation requirements were identified as shown in table 11.

Table 11
Areas Suitable for Development in St. Mary and Specific Mitigations

Area	Recommended Mitigation Measure
Pagee	Gabion basket; dredging; river training
Heywood Hall	Bridge (Fording)
Sandside	Bridge (Fording)
Tryall	Bridge (Fording)
Cox Street	Gabion basket; dredging; river training; retaining wall
Brimmer (Bernside Road)	Bridge repair; gabion basket
Port Maria	River dredging; extension of existing sea-wall to prevent sand washing ashore and blocking river outlets

Source: ODPEM, 2012.

Additional proposals identified for mitigating the impacts of flooding specifically in the Port Maria area include the mapping of flood boundaries, which has already been completed by the WRA-Jamaica, the upgrade of existing drainage systems, the construction of new drains, and the implementation of early warning systems for flooding.

C. Summary of analysis – two case countries

A summary of the analysis (tables 9 and 10) shows that for the specific locations assessed for the period 2015 to 2018, the impact of flooding on the economies of Jamaica and Trinidad and Tobago amounted to approximately 0.06% and 0.05% of (2012) GDP respectively. Although this is apparently small, it does not consider the pervasiveness both in terms of geographical dispersion, and frequency of flooding events in the countries. Moreover, the non-monetary effects of recurrent disasters are significant, for example, considering the impact of yearly interruptions of educational activities and the mental burden on the local population. Further, the unavailability of specific data relating only to flooding suggests that these estimates are at best under-estimations of the true cost of flooding on these economies.

Table 12
Summary of Flooding Costs - Trinidad and Tobago and Jamaica
(United States dollars)

Damage and Losses	Trinidad and Tobago	Jamaica
Social sectors (Education/Housing)	11 749 060	6 541 391
Infrastructure sectors	31 187	738 111
Economic sectors	-	3 413 218
Additional Costs	818 617	4 930
Total Costs	12 598 864	10 697 650
Percentage of GDP	0.05	0.06

Source: Prepared by the authors.

V. Conclusions

This study examined the specific economic dynamics of flooding by looking at two case countries in the Caribbean. The focus on flooding is intended to highlight the potential impact of flooding as a stand-alone natural event on the economies of Caribbean SIDS. Given the frequency of flooding in the sub-region, as well as the specificity of variables which affect its likelihood, site specific analyses were undertaken for three locations, by applying the DaLA methodology as a potential economic costing given a certain expectation of flooding at selected locations over time. Although the approach was constrained by site specific data, the calibration of the approach through the examination of past events suggests that the economic impacts of flooding could be significant, at both the national and municipal level over time.

The results of the damage and losses analysis provide estimations of effects of flooding in an average raining season. For a better evaluation of the benefits of investing in certain flood mitigation measures in comparison to the costs in damage, losses and additional costs derived from these events, a long-term detailed analysis of the impacts of flooding in each area should be carried out. The apparent low impact of these events on the GDP may disguise the cumulative effects and non-monetary implications to local populations in such areas.

These results strengthen the case for increased public sector investments that are spatially allocated in order to mitigate both the economic and social effects of flooding in the Caribbean. Moreover, they demonstrate the necessity to encourage the systemic and sectoral collection of data related to low-impact recurrent events to allow for a better understanding of the pervasive effects of flooding.

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