Climate Change Adaptation Planning in Latin American and Caribbean Cities

FINAL REPORT: CASTRIES, SAINT LUCIA

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Climate Change Adaptation Planning in Latin American and Caribbean Cities

A report submitted by ICF GHK
in association with

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Cover photo: Castries Port as shown from Vigie, May 2012

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Abbreviations

ACCC..........Adapting to Climate Change in the Caribbean
ACI..........Adaptive Capacity Index
CARICOM..........Caribbean Community
CBD..........Central Business District
CCC..........Castries City Council
CCRIF..........Caribbean Catastrophe Risk Insurance Facility
CCTA..........Climate Change Technology Needs Assessment
CDEMA..........Caribbean Disaster Emergency Management Agency
CDERA..........Caribbean Disaster Emergency Response Agency
CDM..........Comprehensive Disaster Management
CPACC..........Caribbean Planning for Adaptation to Climate Change
DRR..........Disaster Risk Reduction
ECLAC..........Economic Commission for Latin America and the Caribbean
FDI..........Foreign Direct Investment
GCAP..........Global Climate Adaptation Partnership
GDP..........Gross Domestic Product
GoSL..........Government of Saint Lucia
IPCC..........Intergovernmental Panel on Climate Change
LAC..........Latin America and the Caribbean
LRTP..........Land Registration and Titling Program
MPDE..........Ministry of Physical Development and the Environment
NCCAP..........National Climate Change Adaptation Plan
NCCC..........National Climate Change Committee
NEEP..........National Environmental Education Policy
NEES..........National Environmental Education Strategy
NEMAC..........National Emergency Management Advisory Committee
NEMO..........National Emergency Management Office
NEP..........National Energy Policy
NLP..........National Land Policy
OECS..........Organization of Eastern Caribbean States
PPCR..........Pilot Program for Climate Resilience
SDED..........Sustainable Development and Environment Division
SEP..........Sustainable Energy Plan
SGD..........Saint Georges Declaration of Principles for Environmental Management
SIDS..........Small Island Developing State
SLASPA..........Saint Lucia Air and Sea Ports Authority
SLDB..........Saint Lucia Development Bank
SLOSH..........Sea, Lake, and Overland Surges from Hurricanes
SPACC..........Special Programme on Adaptation to Climate Change

SPCR……………………………………………….*Saint Lucia Special Programme for Climate Resilience*

UNDESA..*United Nations Department of Economic and Social Affairs*

UNDP……………………………………………………………*United Nations Development Programme*

UNFCCC………………………………………*United Nations Framework Convention on Climate Change*

UNISDR……………………………………..*United Nations' International Strategy for Disaster Reduction*

WRMA…………………………………………………………..*Water Resources Management Agency*

Glossary

The following glossary is from the United Nations' International Strategy for Disaster Reduction (UNISDR) terminology on disaster risk reduction (2009 version). The terms are defined by a single sentence. The comments paragraph associated with each term is not part of the definition, but is provided to give additional context, qualification and explanation.

Adaptation

The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Comment: This definition addresses the concerns of climate change and is sourced from the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The broader concept of adaptation also applies to non-climatic factors such as soil erosion or surface subsidence. Adaptation can occur in autonomous fashion, for example through market changes, or as a result of intentional adaptation policies and plans. Many disaster risk reduction measures can directly contribute to better adaptation.

Capacity

The process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions.

Comment: Capacity development is a concept that extends the term of capacity building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems, and the wider social and cultural enabling environment.

Climate change

The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

Comment: This definition can be paraphrased for popular communications as "A change in the climate that persists for decades or longer, arising from either natural causes or human activity."

Coping capacity

The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Comment: The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during crises or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

Comment: Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation.

Disaster risk

The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

Comment: The definition of disaster risk reflects the concept of disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped, in broad terms at least.

Exposure

People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Comment: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

Forecast

Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area.

Comment: In meteorology a forecast refers to a future condition, whereas a warning refers to a potentially dangerous future condition.

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Comment: The hazards of concern to disaster risk reduction as stated in footnote 3 of the Hyogo Framework are "… hazards of natural origin and related environmental and technological hazards and risks." Such hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis.

Mitigation

The lessening or limitation of the adverse impacts of hazards and related disasters.

Comment: The adverse impacts of hazards often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures encompass engineering techniques and hazard-resistant construction as well as improved environmental policies and public awareness. It should be noted that in climate change policy, "mitigation" is defined differently, being the term used for the reduction of greenhouse gas emissions that are the source of climate change.

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.

Risk

The combination of the probability of an event and its negative consequences.

Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks.

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Comment: There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time.

Source: extracts from UNISDR terminology (2009 version), http://www.unisdr.org/we/inform/terminology

Executive summary

The *Climate Change Adaptation Planning in Latin American and Caribbean Cities* project is designed to inform policy making and climate change adaptation planning in small and medium-sized cities. The focus is on floods and landslides, which are two of the most common climate-related risks in cities across the Latin America and Caribbean region.

Five cities were selected for involvement: Castries, Saint Lucia; Cusco, Peru; El Progreso, Honduras; Esteli, Nicaragua and Santos, Brazil. For each city, five main activities were carried out:

1. A climate-related hazard assessment focused on floods and landslides
2. An urban, social and economic adaptive capacity assessment
3. An institutional adaptive capacity assessment
4. A climate-related vulnerability assessment; and
5. Based on the findings of the four assessments, a combined strategic climate adaptation institutional strengthening and investment plan, intended to complement and be integrated into existing urban, environmental and disaster risk reduction planning instruments for each city.

The figure below graphically shows the process and main activities carried out under the project.

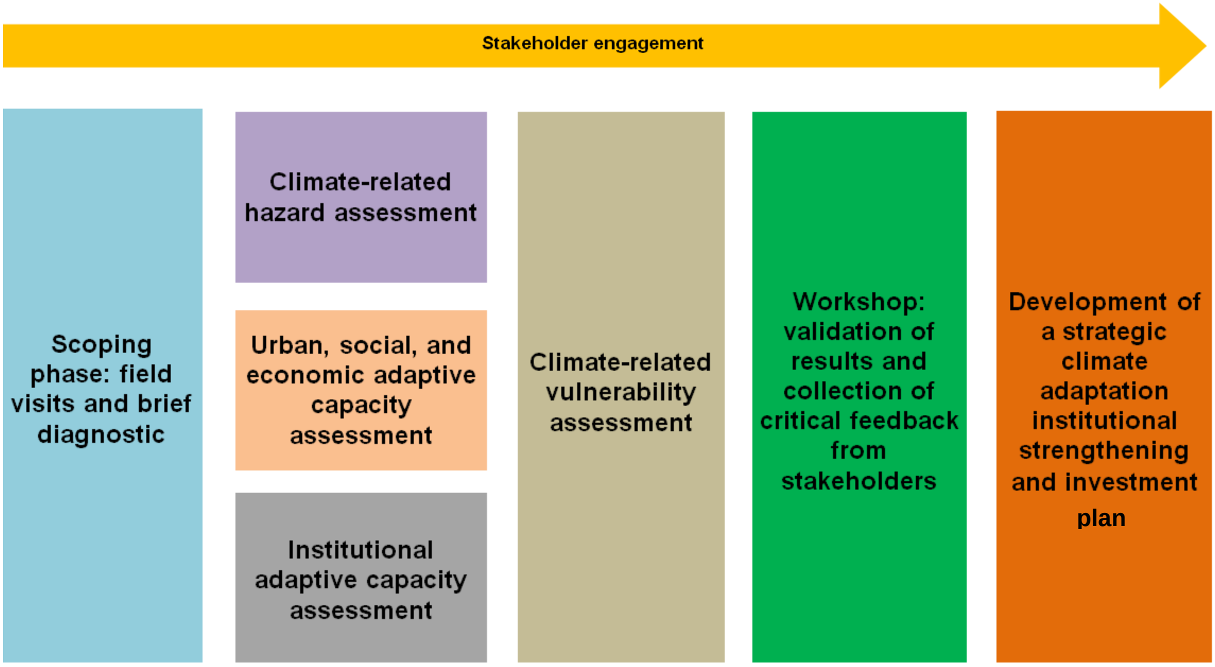


Figure 0.1: The process and main activities of the project

A summary of key findings of this report now follows.

Understanding the problem of flooding and landslides

Climate-related flood and landslide hazard risks

Present-day Castries is susceptible to flood and landslide hazards that have a substantial impact on the local population. Castries's exposure to floods, particularly coastal flooding associated with storm surge, is projected to increase with sea level rise associated with climate change. Landslides, on the other hand, are not projected to increase, although urban development patterns can have an amplifying effect on existing landslide risk.

Flooding in Castries is often the result of relatively small rains. This is largely due to three factors: an increase in impermeable surfaces as urban development has proceeded, the lack of an adequate storm water drainage system, and inappropriate waste disposal. First order analysis suggests that the projected change of precipitation may not produce a significant change in inland flooding.

For Castries, flooding caused by rain is commonplace, rather than flooding caused by tidal waves and storm surge. Climate change, however, will likely exacerbate the current impacts of coastal flooding; growth in population and tourism will likely compound this impact. Castries is coastal and largely at sea level. The coastline hosts a high concentration of hotels, ports, roads, and settlements with a majority of the island population and critical infrastructure located on low-lying reclaimed coastal land and can be prone to flooding. The settlements of greatest vulnerability to coastal flooding include: Cul de Sac, Ciceron/Monkey Town, Barre St Joseph, Marigot, La Toc, and Conway.

High-slope areas subject to rock or landslides also pose special hazards in the hilly environs of Castries. They can result in a loss of life and cause damage to roadways, bridges, buildings, other infrastructure, and agricultural crops. The most affected areas in Saint Lucia tend to be steep-sloped areas with soils or geological characteristics that are particularly susceptible to landslides. In Castries, the landslide hazard is generally lower than other areas of the island, although there have been notable events that have caused disruption of services and displacement of people. Climate projections suggest that landslide risk may be reduced as the intensity of rainfall patterns is generally expected to decrease in the area. However, urban development may have a greater influence in landslide risk. The settlements of greatest ongoing vulnerability to landslides include: Black Mallet, Bois Patat, Morne Dudon, and Pavee.

Urban development and exposure to disaster risk and climate change

Linking the potential climate projections to the way urban development is taking place is essential in understanding the possible effects that climate variability and change could have in Castries. Although climate projections show a potential decrease in precipitation and a rise in temperature which might result in a decrease in flood and landslide risk, the trends in urban development could actually lead to risk staying constant or even increasing.

Saint Lucia's shift from agriculture to a services-oriented economy, dominated by the tourist sector, has influenced the way in which urban and suburban development has taken place. Approximately 30 per cent of the total population is located in urban Castries and 55 per cent located in the Castries-Gros Islet corridor which runs along the northwest coast of the island. Urban development takes place vertically (up slopes) and/or horizontally (peripheral expansion), and is marked by unplanned components. In this context, the anticipated impacts of climate change will likely exacerbate current vulnerabilities of the housing and critical infrastructure sectors.

Critical infrastructure networks in Saint Lucia are exposed to coastal as well as inland flooding. Key economic and critical infrastructure networks in the Castries study area, including roads, the airport, the seaport, and the fuel storage, are located along the coast or on low-lying reclaimed coastal land. The water and the energy supply networks are further inland, although distribution networks are located nearby human settlements within our study area. Climate change will likely exacerbate the current impacts of flooding; growth in population and tourism will likely compound this impact.

Institutional vulnerability issues

In small-sized cities, such as Castries, the capacity of urban management and governance institutions to identify and respond to current and future climate vulnerability defines not only the resilience of the urban system, but also its potential for future growth and sustainable expansion.

Saint Lucia is a small island state and its systems for climate change adaptation and disaster risk management are primarily located at the national level. As yet, there are no independent policy tools or implementation mechanisms for climate change consideration and adaptive action for Castries. Castries City Council (CCC), the only functioning city level government department, has limited mandate and resources to undertake such tasks. Enhancing the risk management and planning capabilities of the City Council, or establishing new city level agencies to address adaptation and planning would be a means of promoting local level adaptive capacity in the context of the city.

Through the National Emergency Management Organization (NEMO), Saint Lucia has developed effective and comprehensive systems for disaster response and management. The relatively frequent incidence of floods and landslides in the region has drawn attention to weaknesses in the risk management system, allowing for rapid learning and improvement in flood and landslide risk management practices, notably after the experience of Hurricane Thomas in 2007 and Hurricane Dean in 2010. Yet, the institutional risk governance system continues to be reactive in its nature, focusing on disaster management and emergency response rather than proactively addressing climate change adaptation. Within this disaster risk management framework, efforts in risk identification, risk reduction and adaptive governance are not as strong as required, with most investment currently being directed towards response and short-term recovery.

Although there are no specific in-built mechanisms for improving foresight and planning in government organizations, participation in international agreements, and more recently, an increased incidence of floods and landslides are pushing national risk management systems to change. This momentum could be extended to the implementation phase of strategic and action planning in order to demonstrate effectiveness in reducing existing vulnerability and future risk. The future of sustainable development in the country generally, and Castries in particular, depends on the degree to which climate change vulnerability is considered in institutional planning and development activities across all sectors of government operation.

To a large degree, Saint Lucia has already demonstrated its ability to successfully plan for and manage disaster response in emergency situations. Similar efforts now could be made in the preparedness, risk reduction, and adaptation phases of risk management at the national level and in Castries.

Strategic climate adaptation institutional strengthening and investment plan

The findings of the assessments provide a basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions that can be linked or incorporated into existing priorities, sectoral plans and planning instruments in Saint Lucia and Castries. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon.

The plan draws accordingly on the conclusions and the feedback obtained during a workshop held in Castries in February 2013. The feedback served to validate assessment findings, update or readjust them and establish a set of specific actions to be proposed based on the needs and major issues identified by stakeholders. This process helps ensure that the proposed climate change adaptation measures can be linked or incorporated into existing priorities, sectoral plans and planning instruments, and form part of an overall climate change adaptation strategy, for Castries in particular, and Saint Lucia generally.

There is strong potential for utilizing the outputs of this project for inclusion in current and future urban planning and management activities in Castries, in particular, and Saint Lucia in general. A notable link is to the World Bank-funded Pilot Program for Climate Resilience (PPCR) and the ensuing proposed Disaster Vulnerability Reduction Project (DVRP) for Saint Lucia, which are designed to provide programmatic finance for climate resilient development plans.

The overreaching goal of the strategic plan is to increase resilience to floods and landslides in Castries. On the basis of planning themes, specific measures to address particular urban development challenges as well as institutional shortcomings are identified. These measures also promote a more sustainable and resilient urban development process. Finally, a set of specific actions that can be undertaken to implement climate change adaptation measures are proposed.

The planning themes that create the foundation for a climate change adaptation strategy to help Castries build its resilience against floods and landslides, both now and in the future, are:

(i) devolved risk management and planning capacity at the city level for Castries; (ii) capacity building in national and city level government institutions engaged in climate change planning and risk management; (iii) mechanisms for data collection, storage and dissemination to be created and/or improved for better climate monitoring, risk planning, and information sharing; (iv) improved insurance mechanisms and climate financing for long-term recovery and building resilience against floods and landslides; (v) cross-scale integration of risk management practices; and (vi) a shift from disaster management to long term risk reduction and climate change adaptation to ensure a proactive and forward-looking system of risk governance.

An integrated strategic plan requires the use of both structural and non-structural measures. Similarly to the Saint Lucia DVRP, our proposed measures thus follow a “no-regrets” approach. They include, *inter alia*: to incentivize green infrastructure projects; the rebuilding and protection of natural ecosystems; sustainability of existing drainage systems; Management of Slope Stability in Communities (MoSSaiC); prioritizing and enhancing civil society’s awareness to risk; capacity building in national and city level government institutions engaged in climate planning and risk; improved mechanisms for data collection, storage and dissemination; integrated land use planning and risk-sensitive zoning; improved budgetary resources and climate financing; formalized structures of cooperation with the private sector in planning and risk reduction; mortgage finance or security backed loans for climate change adaptation activities; and improved insurance mechanisms and climate financing for long-term recovery and building resilience against climate change hazards.

The timing and scale of local climate change impacts affects the types of measures to be adopted and prioritization of investments and action. The main challenge for policy- and discussion-makers is to implement a climate change adaptation process that considers the trade-offs between current development priorities and long-term risks and embraces uncertainty. The ability and willingness of key actors to address climate change impacts will be of utmost importance.

1 Introduction

1.1 About the project

An ICF GHK consortium was commissioned in May 2012 by the World Bank's regional Urban and Disaster Risk Management Unit for Latin America and the Caribbean (LAC) (LCSDU) to carry out second phase activities for the initiative *Climate Change Adaptation Planning in Latin American and Caribbean Cities*. This initiative started in April 2010 and will be completed in 2013.

The wider initiative seeks both to build and to strengthen capacities for adaptation to climate change in LAC cities. The primary focus is cities in the region less likely to have had access to climate change (CC) adaptation training, finance, or knowledge networks. In practice, this implies a focus on medium and small-sized cities, as larger cities have more human and financial resources to draw on.

Five medium-sized cities were therefore selected: Castries, Saint Lucia; Cusco, Peru; El Progreso, Honduras; Esteli, Nicaragua and Santos, Brazil.[1] The first phase involved an initial institutional mapping and rapid diagnostic for the initiative. The second phase assignment's objective is to inform policy making and adaptation planning at the city level by incorporating local and international technical knowledge, tools and expertise into existing planning structures to better respond to the adverse effects of climate change.

The emphasis is on floods and landslides, which are two of the most common climate-related risks in cities across the LAC region. Poorly planned and managed urban development and spatial expansion also contributes to flood and landslide hazard risks. **The ultimate goal is to strengthen local adaptive capacity and to increase urban resilience through mainstreaming climate change adaptation into current planning systems.**

For each involved city, there were four main activities specified for the second phase:

1. A climate-related risks assessment focused on floods and landslides
2. A socio-economic adaptive capacity assessment
3. An institutional adaptive capacity assessment
4. Based on the findings of the three assessments, a combined strategic climate adaptation institutional strengthening and investment plan, which will complement and be integrated into existing urban, environmental and disaster risk reduction planning instruments for each city.

The outputs from the above-mentioned activities in this assessments report constitute a critical input for the main output of the overall initiative in its third phase: a regional Guidebook for city officials on urban adaptation to climate change.

1.2 Outline of the report

This report is divided into the following sections:

- ***Climate-related hazard assessment.*** This section first provides an assessment of current coastal and inland flood risk and landslide risk for Castries. It then considers how climate change may impact these existing flood and landslide hazards in the future.
- ***Urban, social and economic adaptive capacity assessment.*** The section assesses how vulnerability to climate-related hazards is linked to topographical, human settlement and urban development characteristics: the location and condition of settlements and the materials used in their construction have a direct impact in the level of exposure they

[1] The selection of the pilot cities was based on the following: a) survey results from Phase 1 of the project; b) diversity of geographic region and climate; c) recommendations provided by World Bank staff leading operational activities across LAC, ensuring the cities' political willingness, interest, and commitment to working with the initiative; d) prevalence of floods and/or landslides as major climate change-related risks; and e) availability of climate risk-related data.

have for landslide and flood risk. Studying these variables allows assessment of how the urban development trajectory of Castries impacts upon climate change vulnerability in the city.

- ***Institutional adaptive capacity assessment.*** The institutional assessment focuses on the disaster risk management and urban planning structures and capacities of institutions and stakeholders in Castries and how they take into account and incorporate climate change adaptation.
- ***Climate-related vulnerability and risk assessment.*** Using the information from the three previous assessments, this section synthesizes information on landslide and flood vulnerabilities, focusing on physical risk, urban, social and economic conditions and institutional arrangements to create maps that identify the most vulnerable areas and populations within the city exposed to flood and landslide hazards. The analysis considers the exposure, sensitivity, and adaptive capacity of settlements and critical infrastructures to flood and landslide hazards, and provides an informative screening of which settlements and critical infrastructures are more likely to be affected by and be vulnerable to landslides and floods some 30 years into the future (i.e., the 2040s).
- ***Strategic climate adaptation investment and institutional strengthening plan.*** The *Climate-related vulnerability assessment* provides the basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions that can be linked or incorporated into existing priorities, sector plans and planning instruments in Castries. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon.

The above-mentioned assessment approach is broadly consistent with the Urban Risk Assessment (URA) tool developed by the World Bank, but at the same time incorporates aspects that can add a dynamic element to the analysis. [2]

Assessments in the URA tool are associated with three levels of complexity (primary, secondary, and tertiary). The primary level provides an 'entry point' to assess the challenges posed by climate-related hazards. The secondary level provides a more 'refined' analyses to identify and map the most vulnerable areas and populations exposed to climate-related hazards and to consider how hazards may change in the future. Finally, the tertiary level undertakes specific probabilistic risk assessments and makes use of advanced risk management tools.

Progression from the primary to the tertiary level in any city or town is dependent upon the availability of what can be significant amounts of data, the technical capabilities of relevant staff and actors, and the ability and willingness of politicians, officials and others to commit what can amount to not inconsiderable financial resources and time to conducting assessments – and to building policy, strategy and action plans on the basis of findings. Box 1 below elaborates on our experience for the case of Castries.

Box 1 Using the URA for Assessment in Castries

The Terms of Reference for the phase two activities described above derives from the World Bank's Urban Risk Assessment tool. As will be seen in the sections of this report which follow, we were able to apply the URA approach to guide and create our assessments for each city, in a process which saw good collaboration with local governments and other stakeholders.

Some provisos are nonetheless required. The URA is avowedly a flexible tool, as it needs to be. In Castries, and given the city's location within the broader national context of Saint Lucia, data availability and time and resource constraints meant the following adaptations to the 'pure' URA approach:

1. **Climate-related risks assessment for floods and landslides**: It was possible to assess present-day current flood and landslide hazard levels, which are well-understood and studied for

[2] World Bank (2011) *Urban Risk Assessment: An Approach for Understanding Disaster and Climate Risk in Cities*. Urban Development and Local Government Unit; Finance, Economics and Urban Department, The World Bank.

the city. The availability of precipitation data, in particular, allowed consideration of the likely impacts of climate change and, consequently, a projection of changes in hazard levels for a period of some 30 years in the future. Full assessment of the risk levels for the flooding and landslide hazards, both currently and for the future, was not possible as the financial and demographic data necessary was not readily available to us. In addition, the projection for future changes in hazard levels on account of climate change is broad-brush rather than detailed, as this level of detail requires such efforts as hydrologic/hydraulic modelling under future scenarios. This certainly does not preclude future elaboration of risk levels (i.e. detailed risk assessment) in the future on the part of government authorities and other stakeholders in Castries. The findings of our analysis based on simpler approaches can in fact provide guidance regarding the best use of funds for conducting such a vulnerability and risk analysis (e.g., which hazards are likely to worsen, are there potential hotspots where hazards may get even worse, amongst others.). The first assessment in this report is therefore titled – and more correctly seen as – a climate-related hazard assessment.

2. **Socio-economic adaptive capacity assessment**: in Castries, the availability of data meant that it was possible, within the time frame, to conduct socio-economic assessment, and ascertain the exposure and sensitivity of urban residents to current and future flood and landslide hazards. We attempted to add to and 'thicken' the URA approach with more detailed consideration of the dynamics of both urban and economic growth, change and development for Castries – and indeed for Saint Lucia more generally. Adding this dimension makes assessment more dynamic (i.e., 'adaptive') – accordingly, we have re-titled this assessment to emphasize these urban and economic aspects.

3. **Institutional adaptive capacity assessment**: the willingness of stakeholders to share their experience in planning, primarily for urban development and disaster risk, rather than climate change itself, permitted a full assessment within the time frame. Our assessment attempted to incorporate the dimension of how institutions in Castries had changed over time, notably in the past decade, again to stress the element of dynamism that has (or may have) inhered to the institutions under study.

4. **Climate-related vulnerability and risk assessment**: to compensate for the limitations on risk assessment, we developed a wider vulnerability assessment than originally intended. This is based on the findings of the three preceding assessments, and identifies and maps, to the degree possible, the most vulnerable neighborhoods, populations and infrastructures within the city that are exposed to floods and landslides hazards both currently and in the future. This should be seen as an overview of vulnerability, rather than full assessment: this vulnerability 'screening' could usefully be complemented by fuller and more detailed vulnerability analysis on the part of local stakeholders in the future. The assessment concludes with a section on risk information, which suggests studies and data collection activities to continue the development of pertinent risk information for Castries.

5. **Combined strategic climate adaptation investment and institutional strengthening plan**: In a workshop in February 2013 in Castries, there was enthusiastic participation by stakeholders in discussing initial assessment findings and suggesting future strategy and concrete measures for adapting to current and future flood and landslide hazard risks. This interaction forms the basis for the plan as outlined in this report. It should be emphasized that, by design, this plan has no particular institutional affiliation or 'official' status – it, and the assessment and analysis upon which it is founded, now stands as a contribution offered to a debate that is already occurring on climate change adaptation in Castries and Saint Lucia. Again, stakeholders in Castries will be able to adopt and elaborate the measures proposed as they see necessary.

1.3 Context and study area

Saint Lucia is a Small Island Developing State (SIDS) within the Lesser Antillean Arc of the Caribbean Archipelago. SIDSs are particularly prone to natural disasters and are likely to suffer strongly from the adverse effects of climate change. As small economies that are highly sensitive to external shocks, SIDS also share certain characteristics that further increase their overall vulnerability to climate change and variability, namely a high concentration of population and economic assets along the coastal zone, accompanied with rapid demographic growth and limited financial, technical and institutional capacities,. In this sense, climate change is a constitutive element of the Caribbean in general, as well as in the Saint Lucian developmental context (Bishop and Payne, 2012).

Castries was established as an urban centre and capital in the late 18th Century under French occupation. Following the same layout pattern of many other Caribbean capitals, Castries is located along a west-east oriented harbour. However, unlike the Spanish for whom the settlement of towns was an essential feature of colonial policy, the British initially discouraged the development of settlements in the West Indies, as they believed this would hinder the growth of sugar plantations (Hudson, 1980).

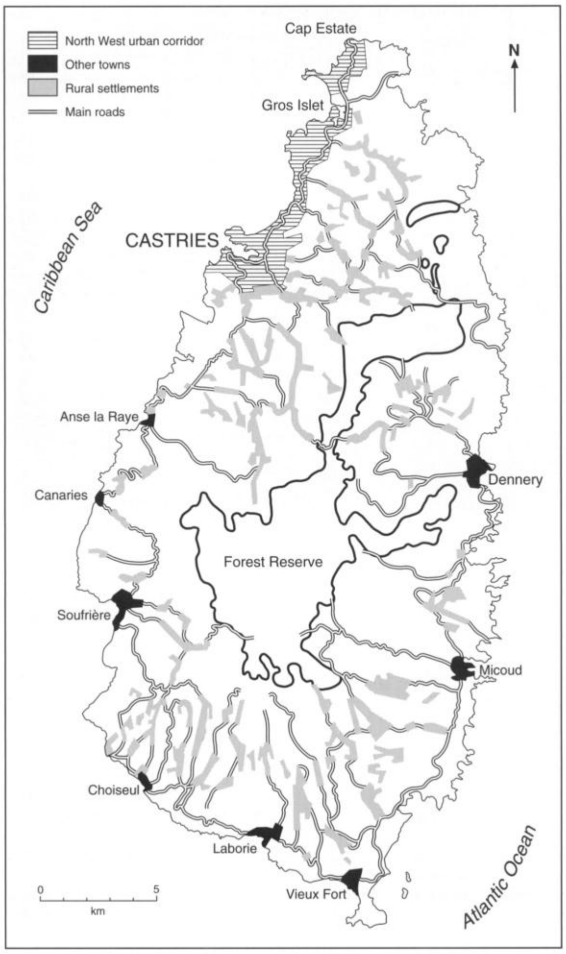


Figure 1.1 The island of Saint Lucia with Castries and the northwest urban corridor highlighted at the top left, Source: Potter, 2001.

Thus while in the Spanish Caribbean towns were planned following the grid and central square plan, in the British Caribbean less emphasis was given to creating new settlements. Nonetheless, cities grew primarily due to the needs of commerce, and Castries in particular was developed as a coal bunkering station (Potter, 2001). As with many other cities in the Caribbean, Castries became a point of administrative and commercial control (Potter, 1992).

In its colonial past, Saint Lucia constantly changed hands between the French and the English until the island finally succeeded to the English in 1814. The French occupation left a clear mark in the island: although the official language is English, French Patois is widely spoken and most of the names of Saint Lucia's villages and communities are French (Pugh, 2005).

Saint Lucia has retained a Westminster-style system from the British colonial period. Elections are held every five years, which means that policy-making is often marked by a short to medium-term cycle (Tulsie, 2006).

In addition, public sector bodies actually have narrow sectoral mandates. This has a significant impact when designing planning strategies: development planning in Saint Lucia is held to be characterized by a short-term perspective as well as fragmentation, with little cooperation and cross-border interaction between agencies and ministries. In effect, this prioritizes short-term objectives and disintegrates development policy.

Acknowledging the challenge, in 2002 the Government of Saint Lucia (GOSL), with the support of the United Nations Department of Economic and Social Affairs (UNDESA), launched a process for developing an Integrated Planning Process for Sustainable National Development. This aims at creating a culture of cross-sectoral collaboration and a model of integrated development planning. As it will be seen later on, this is of real importance for climate change adaptation strategies on the island.

Saint Lucia's constitution refers to local government, but has no particular provisions in this regard. The country is divided into 13 administrative divisions, known as 'quarters,' including Castries. The spatial and administrative definition of Castries as a city – also specified as such in the legislation – is complex. The academic literature correctly points to the emergence, since the 1980s, of Castries as a micro- or mini-metropolitan area (Potter, 2001). Driven to a large degree by the development of coastal area tourism, the Castries mini-metropolitan area is comprised of a central business district (CBD), inner city redevelopment, central and suburban informal (or less formal) residential areas, high-income residential areas, ribbon development and tourist/leisure facilities, mainly in the form of large-scale resort hotels.

There is no fixed spatial definition for this mini-metropolis, which is also characterized by analysts as Saint Lucia's northwest urban corridor (Figure 1.1). Present-day Castries as a mini-metropolitan area covers an area starting at Cul de Sac Bay, to the south of Central Castries, and extends through Gros Islet to the north and then further to Cap Estate, located at the northernmost tip of the island (ibid). This area covers parts of both Castries and Gros Islet districts, and is to a large degree captured by the GoSL census districts Castries City, Castries Suburban and Castries Rural, all of which fall within Castries District itself.

This spatial expansion reflects how Saint Lucia's population has become urbanized – and more recently suburbanized – in past decades (MPDE, n.d). Castries has been the principle exemplar: as shown in Table 1.1, the population increased from 51,994 inhabitants in 1991 to 65,656 inhabitants in 2010, which is approximately 40 percent of Saint Lucia's overall population of 165,595 inhabitants at the time. Castries Rural, marked by the presence of steep hills, is the area that is experiencing the fastest demographic growth, along with Gros Islet. Population in Castries City and Castries Suburban areas is actually reducing over time, as can be seen below. As in other cities and towns in Latin America and the Caribbean, the rate of urbanization is decreasing, and a strong trend of population growth in peripheral suburban, peri-urban and rural areas of Castries has emerged.

Table 1.1 Population growth in Castries

Districts	1991	2001	2010	Percentage change: 1991 to 2001	Percentage change: 2001 to 2010
Castries Quarter	51,994	64,344	65,656	**23.8**	**2**
Castries City		12,439	4,173		**-66.5**
Castries Suburban		25,110	17,938		**-28.6**
Castries Rural		26,795	43,545		**62.5**

Source: Saint Lucia Population & Housing Census 2010.

The definition of urban Castries has thus varied over time, and a shared understanding is limited. In defining the study area for assessment, we have of necessity been guided by the spatial and functional classification above, as well as by the local government structure. The recently passed Constituency Councils Act of 2012 is helpful here as it effectively redefined urban Castries to consist of the four electoral districts (or constituencies) of Castries Central, Castries North, Castries South and Castries East (Figures 1.2 and 1.3), which collectively have a population of above 40,000. The area is now to have its own appointed council, the Castries Constituency Council, which supersedes the current City Council (Constituency Councils Act, 2012). This area, falling as it does within Castries District, effectively constitutes the core study area for this report as seen in Table 1.2.

Table 1.2 Estimated population by political constituency

Political constituency	Total households	Total population
Castries North	4,321	11,825
Castries East	4,232	11,939
Castries Central	2,813	7,398
Castries South	3,424	9,504

Political constituency	Total households	Total population
Total	14, 790	40,666

Source: Saint Lucia Population Census 2010.

Figure 1.2 Saint Lucia's Districts. Source: Saint Lucia Population Census 2010.

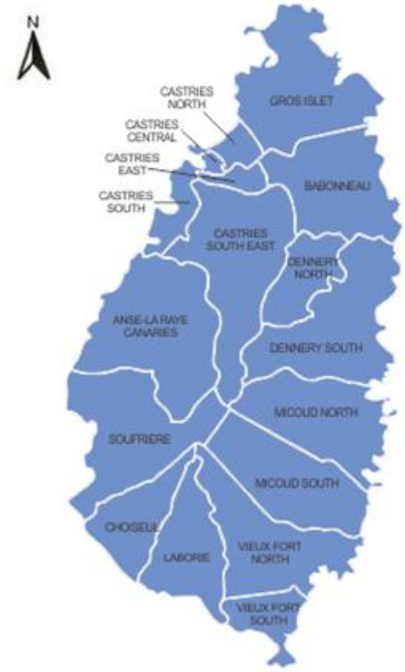


Figure 1.3 Saint Lucia electoral districts or constituencies, Source: Saint Lucia Electoral Department.

However, to capture risk in the broader mini-metropolitan area, conditions in the urbanized part of Castries South East, which has its own council and a population of very close to 15,000, are also considered.

The study covers an area which concentrates around a third of the island's population, or approximately 55,000 people. It needs to be seen within the context of the rapidly growing urban areas within the northwest corridor in Gros Islet District (which also has a council), the population of which rose 21 percent, from 20,872 in 2011 to 25,210 in 2010,(Huntley, 2011). Moreover, given the status of Saint Lucia as a SIDS, a national perspective is also taken where necessary.

Table 1.3 below shows the settlements and the corresponding constituencies and districts that are further discussed in terms of exposure to flooding and landslides in the chapters that now follow.

Table 1.3 Settlements and their corresponding constituencies and districts

Settlement	Constituency	Census District
La Pansee	Castries Central	Castries City
Faux a Chaud	Castries Central	Castries City
Castries City	Castries Central	Castries City
Conway	Castries Central	Castries City
Pavee	Castries East	Castries City/ Castries Rural
Entrepot	Castries East	Castries Rural
Black Mallet	Castries East	Castries Suburban
Maynard Hill	Castries East	Castries Suburban

Settlement	Constituency	Census District
Bocage	Castries East	Castries Suburban
Choc	Castries North	Castries Suburban
Bois Patat	Castries North	Castries Suburban
Morne Du Don	Castries North	Castries Suburban
Vigie	Castries North	Castries Suburban
Vide Bouiteille	Castries North	Castries Suburban
La Toc	Castries South	Castries City
Tapion	Castries South	Castries City
Coubaril	Castries South	Castries Rural
Monkey Town/ Ciceron	Castries South	Castries Rural
Barre St Joseph	Castries South	Castries Rural
Marigot	Castries South	Castries Rural
Banannes Bay	Castries South	Castries Rural
Cul de Sac	Castries Southeast	Castries Rural

Source: Saint Lucia Population and Housing Census 2010.

2 Climate-related hazard assessment: floods and landslides

2.1 Introduction

Castries is susceptible to a multitude of natural hazards such as storm surges, hurricanes, tropical cyclones, landslides, and other extreme weather events. Much of central Castries is built on low-lying reclaimed land, making the city centre prone to flooding. Castries is also surrounded by hilly topography which coupled with the soil types and volcanic geology, creates flood and landslide conditions.

Even minor rainfalls often lead to flooding in Castries. This is largely due to an increase in impermeable surfaces as urban development has proceeded, to the lack of an adequate storm water drainage system and to inappropriate waste disposal. For Castries, flooding caused by rain is commonplace, rather than flooding caused by tidal waves and storm surge.

High-slope areas subject to rock or landslides also pose special hazards in the hilly environs of Castries. The Bagatelle area to the east of Castries City is predominantly developed with houses and infrastructure. This area is susceptible to landslides as it comprises primarily residual soils (sands, silts and clays) frequently overlying fissured basement rock. Infiltration into fissured basement rock also leads to the development of artesian water pressures, which frequently manifest at the ground surface as springs and sinkholes. Although recent Bagatelle slides did not result in complete loss of the roadway, upslope land slippage, predominantly rotational and translational, has occurred up to the building line of many buildings, making these uninhabitable.

Three hazards are considered in this chapter: coastal flooding, inland flooding and landslides. Each hazard is discussed and draws from available information and data. This chapter divides the analysis into the following sections:

- **Methodology:** a discussion of the approach for considering how current and future climate, aka climate change, may impact floods and landslides.
- **Physical description**: an overview of physical characteristics in Castries that are relevant to floods and landslides, and the meteorological drivers of events associated with flood and landslide hazards.
- **Coastal flooding**: a general description of coastal floods relevant to Castries, a summary of prior events, and a description of the flood tools used to inform disaster management and municipal planning.
- **Inland flooding**: a general description of inland floods relevant to Castries, a summary of prior events, and a description of the flood tools used to inform disaster management and municipal planning.
- **Landslides**: a general description of landslides relevant to Castries, a summary of prior events, and landslide hazard maps, and a description of the landslide tools used to inform disaster management and municipal planning.
- **Future hazards**: an overview of future changes of climate and the potential impacts on future landslide and flood events relevant to Castries, including a section describing gaps and limitations.

2.2 Methodology

This analysis utilizes existing planning tools, data and resources (in short, tools) used by Saint Lucia's government to consider how flood and landslide hazards may change in the Castries study area by approximately mid-century (more specifically, the 2040s). To effectively inform future disaster risk and urban planning, it is important our approach be appropriately aligned with the available local data and planning procedures.

The steps taken to consider how climate changes by the 2040s may impact the timing and frequency of future landslide and flood events are:

1. Reviewing available information describing the physical system such as hydrology and geomorphology to understand the drivers that affect landslides and floods.
2. Collecting and investigating data on past landslide and flood events in Castries to assess the degree of impact per event and the conditions that precipitate events.
3. Assessing available tools used by the municipality to describe zones susceptible to landslides and floods, and inform emergency planning.
4. Assessing available future precipitation and temperature data for the 2040s.
5. Assessing the application of three distinct approaches that consider how climate change may impact the tools investigated in Step 3.

Each step, available data, and tools are discussed in greater detail in Annex 1.

2.3 Physical environment

This section provides an overview of the physical attributes that affect floods and landslides in the Castries study area: geomorphology, hydrology, and climate and weather.

2.3.1 Land characteristics

St. Lucia sits on a volcanic ridge and is distinguished by a north-south oriented mountain range as illustrated in Figure 2.1 (Second National Communication, 2011). While the mountain range is at elevations reaching over 2,800 feet, Figure 2.2 shows that much of the Castries study area is at an elevation below 600 feet (ibid).

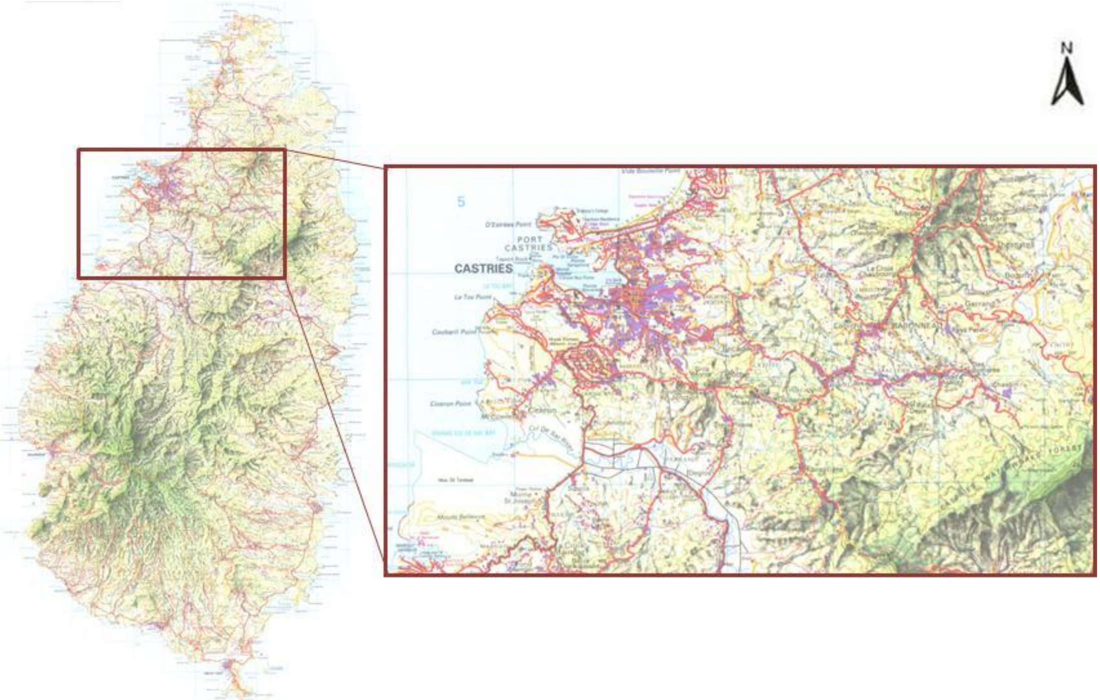


Figure 2.1 Physical map of Saint Lucia with a detailed map provided for the Castries study area, Source: Government of St. Lucia, scale 1:50,000.

Slope is considered an important factor in the occurrence of landslides. The CIPA (2006) pilot study found the greatest incidence of past landslides in areas with a slope between 20 to 30 degrees compared above or below this range.

Steep-slope areas subject to rock or landslides pose special hazards in the hilly environs of Castries. The Bagatelle area east of Castries (and outside our study area) is predominantly developed with houses and infrastructure. This area is susceptible to landslides as it comprises primarily residual soils (sands, silts and clays) frequently overlying fissured basement rock. Infiltration into fissured basement rock also leads to the development of artesian water pressures, which frequently manifest at the ground surface as springs and sinkholes. Although recent Bagatelle slides did not result in complete loss of the roadway, upslope land slippage, predominantly rotational and translational, has occurred up to the building line of many buildings, making these uninhabitable.

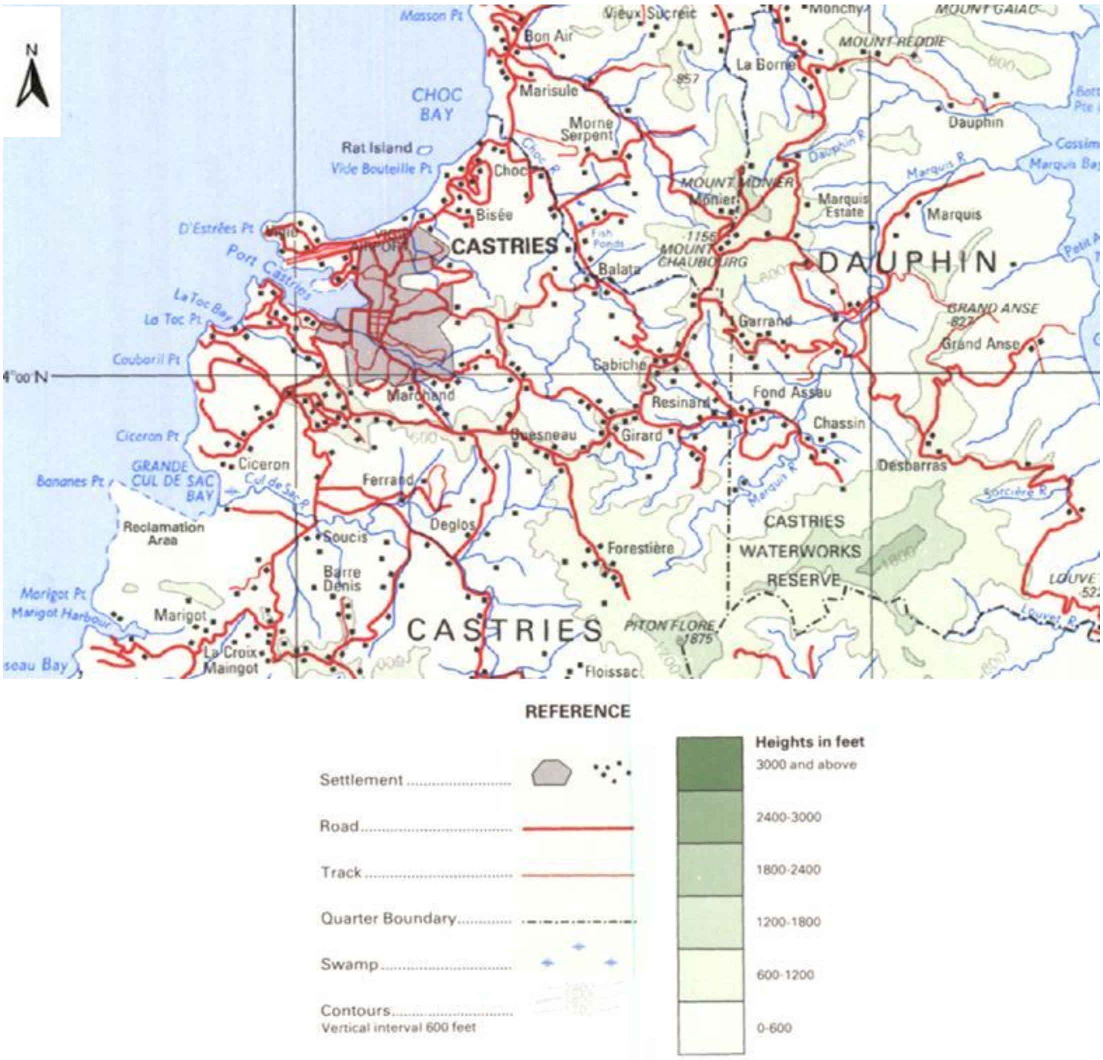


Figure 2.2 Elevation map of the Castries study area, Source: Government of St. Lucia, scale 1:125,000.

St. Lucia is composed of three distinct sets of rocks with the southern portion of the island being largerly from the late tertiary period, the central portion of the island composed of rock from the middle tertiary period, and the northern portion of the island composed of rock from the early tertiary period. The rock is of either sedimentary or volcanic origin. The Castries study area includes portions of central and northern St. Lucia.

Figure 2.3 details the rocks within the study area where rock types labeled between No. 16 and 30, inclusive, are of middle tertiary origin, and rock types labeled above No. 31 are of early teritary origin. The rock, alluvium, beach, and terrace sands, labeled with a “1” are considered of recent origin. Based on prior landslide events, the CIPA (2006) found that landslides were more apt to occur with specific rock types. Andesitic types in Saint Lucia (not shown in the figure) dominate the basaltic types (No. 26 and 27) as landslide prone areas (CIPA 2006). Of the historic landslides, 28 percent of the landslides occurred at Andesitic ash, altered andesite (No. 21), and more than 5 percent occurred at Andesite agglomerate (No. 23) and at Basalt (No. 26).

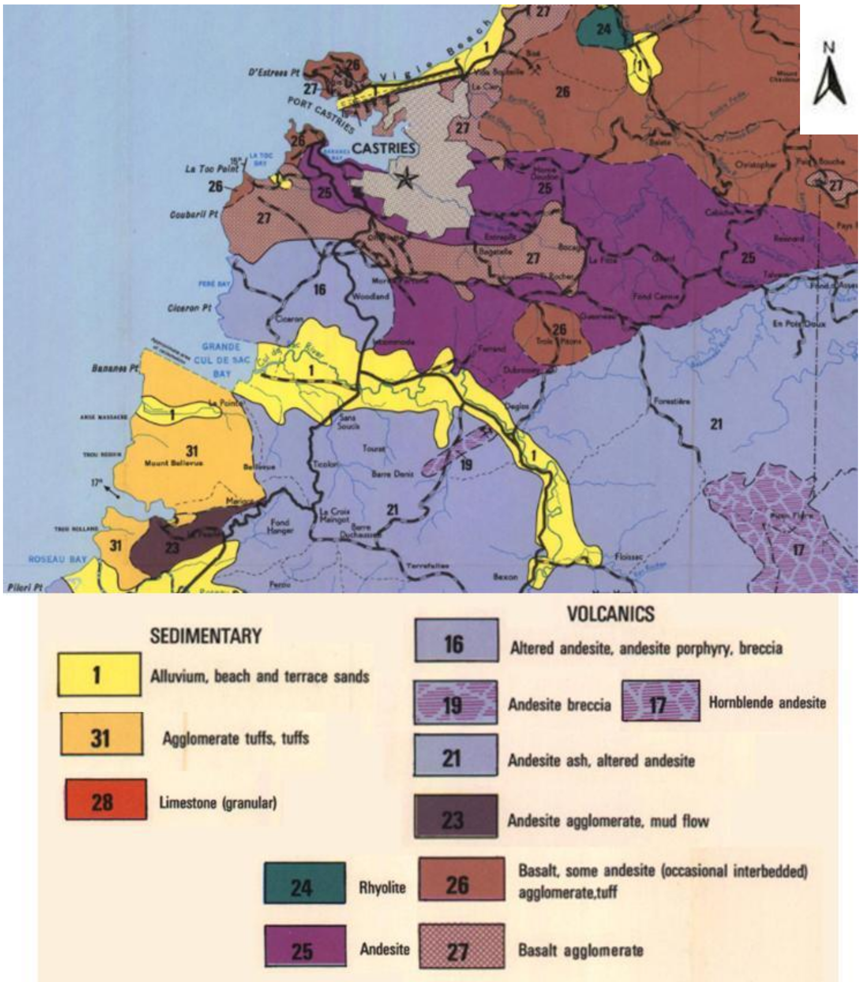


Figure 2.3 Geological map of the Castries study area, Source: Government of St. Lucia, scale 1:50,000.

Figure 2.4 shows the variability in land use types in the Castries study area. The city is shown in grey as urban settlement and is largely considered covered by impermeable surfaces. Surrounding the city are areas of scrub forest, farming, grasslands and open woodlands, and natural trpoical forest.

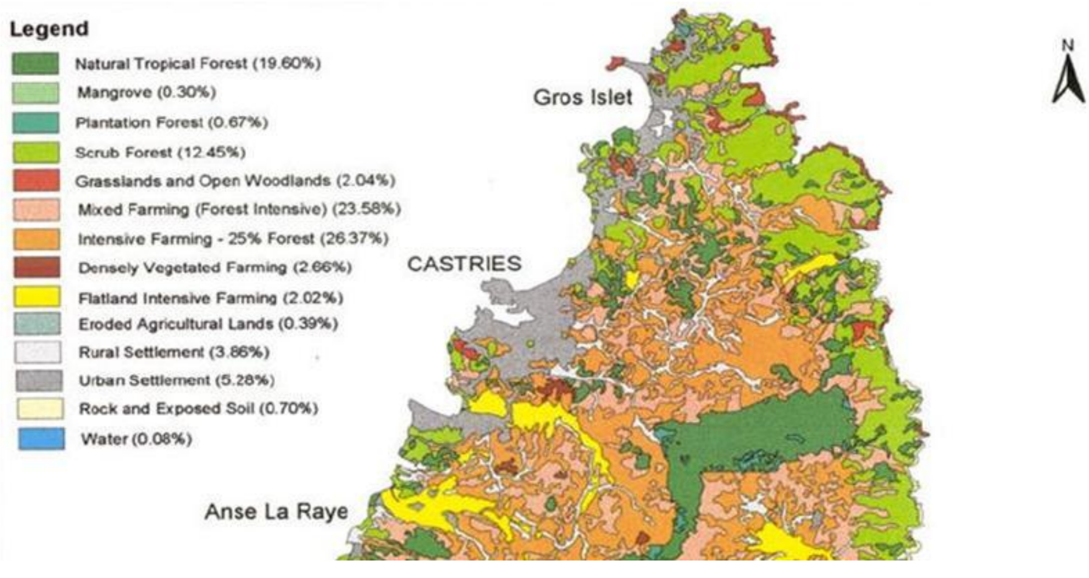


Figure 2.4 Land use map in 2000, Source: Government of St. Lucia.

2.3.2 Hydrology

Within the Castries study area there are four main rivers, including Roseau River, Cul de Sac River, Castries River, and Choc River (see Figure 2.5). Castries River travels through the city. There are a multitude of smaller tributaries which either feed into these waterways or meander towards the coastline. Castries is comprised of three drainage systems: the Castries River, the storm drains that run through the center of the city which are pumped into the Castries Harbor, and the ravines from the north east flowing into urban Castries.

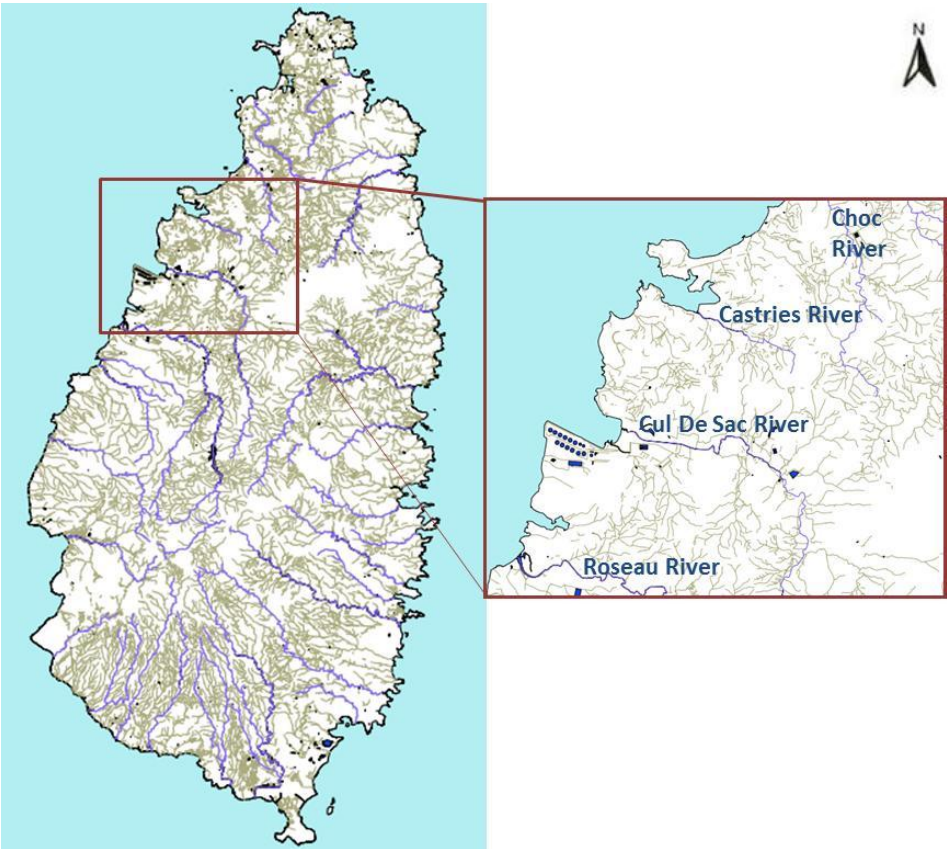


Figure 2.5 Hydrologic system of Saint Lucia with a detailed map provided for the Castries study area, Source: Government of Saint Lucia.

2.3.3 Climate and weather

Saint Lucia's climate is tropical, and is warm and humid all year round. The temperatures remain relatively consistent throughout the year with annual mean temperatures averaging 26.4^{o}C with less than a 2^{o}C difference between summer and winter seasons (McSweeney et al., 2010).

Though there is not significant fluctuation in intra-annual temperature, Saint Lucia does experience two distinct precipitation patterns. It has a wet season from June to November and a dry season from December to May (second communication). Rainfall during the dry season is largely produced by mid-latitude storm systems entering the region (second national communication). Rainfall during the wet season is largely in response to tropical disturbances such as tropical cyclones and convective activity (second national communication).

From 1970 to 1999, average annual rainfall for Saint Lucia was 2,150 mm with the wet season averaging about 1,454 mm, contributing 68 percent of the annual rainfall (based on data from McSweeney et al., 2010). There has been about a 1 percent increase in rainfall per decade from 1960 to 2006 for the wet and dry season which is not considered statistically significant (McSweeney et al., 2010). Figure 2.6 illustrates the variability of annual precipitation amounts across the island from less than 1,800 mm to over 3,000 mm in the mountainous region.

The rainfall within the Castries study area is largely consistent with island averages. The figure also illustrates mean annual precipitation thresholds linked to landslide hazards where the importance of each threshold is ranked: above 3,048 mm are considered extremely important; between 2,032 mm and 2,038 mm is considered important; and below 2,032 mm is considered unimportant (see Section 2.6 for more discussion).

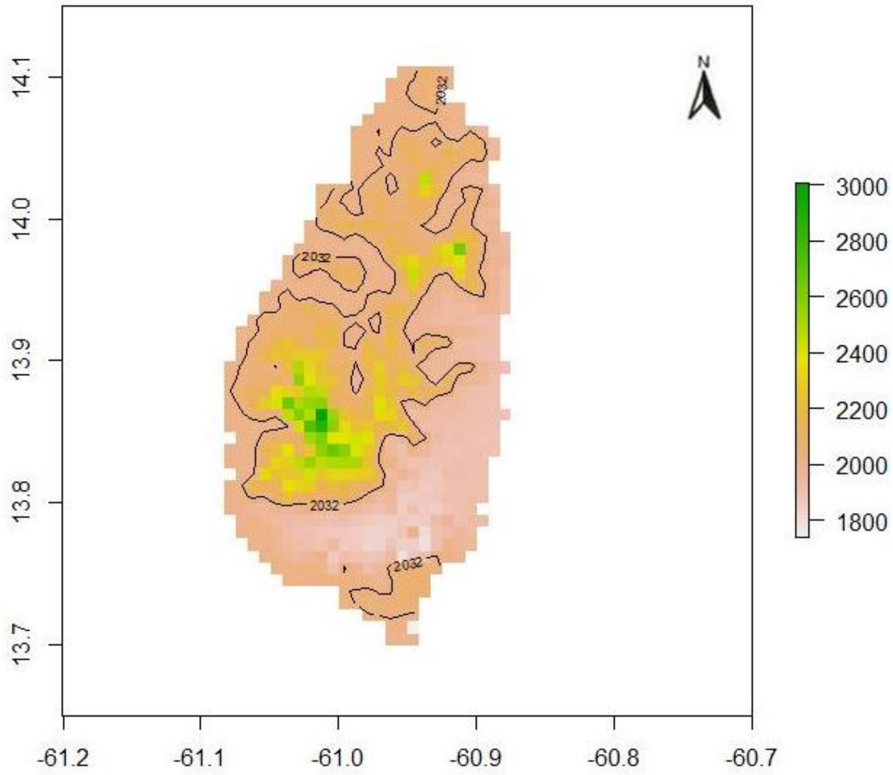


Figure 2.6 Mean annual precipitation (mm) in Saint Lucia from 1950 to 2000, Source: we developed this analysing data from Hijmans, 2005.

Local Observations Data from two weather stations provided by Saint Lucia Meteorological Services were used to inspect monthly and daily precipitation averages (see Figure 2.7). These two coastal stations are located on opposite sides of the island, with one of them located at George F. L. Charles airport, in the Castries study area, and the other one at Hewanorra International Airport, in the southeast of the Island.

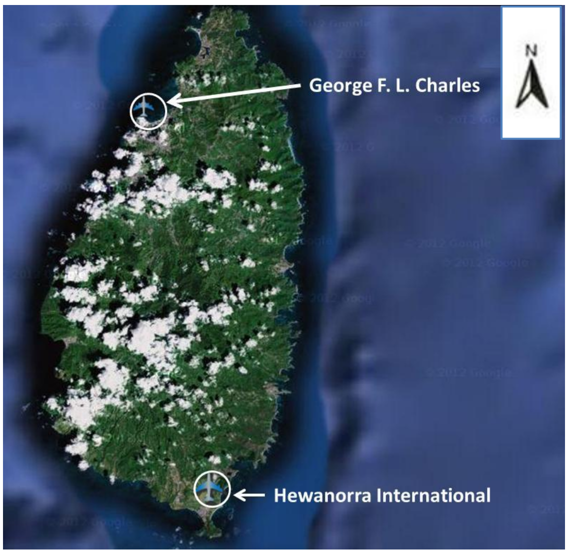


Figure 2.7 Location of two weather stations provided by Saint Lucia Meteorological Services: George F.L. Charles airport and Hewanorra International airport.

Figure 2.8 shows the average monthly precipitation (mm) for the Castries study area, where the distinct wet season from June to November can be very well appreciated. Averaging from 1989 to 2010, the George F. L. Charles airport receives about 1,900 mm of rain every year, about 20 percent more than the Hewanorra International Airport in the southeast of the island. The bars show the lowest and highest monthly values recorded. The lowest values recorded occur during the dry season and the highest occur during the wet season.

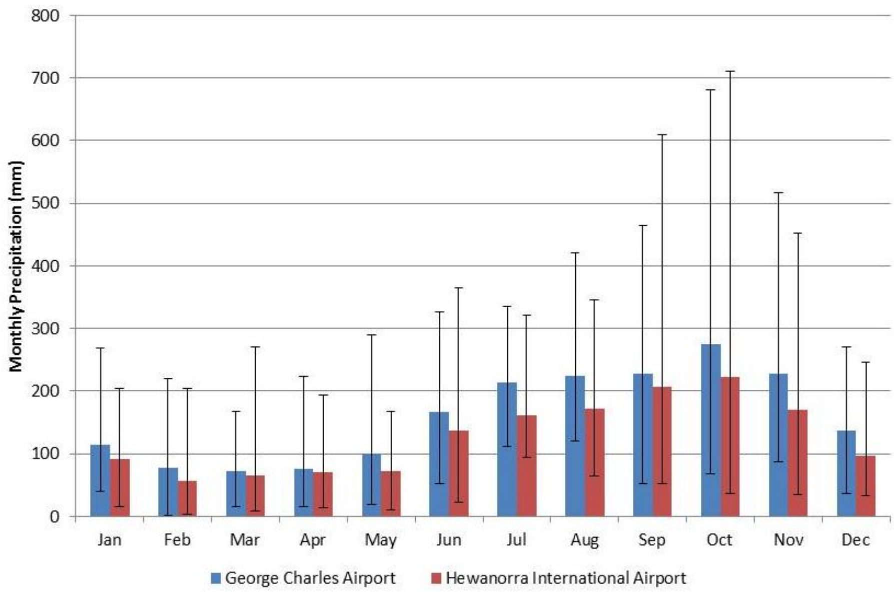


Figure 2.8 Average monthly precipitation (mm) for the Castries study area from 1989 to 2010 with bars indicating the lowest and highest monthly values recorded, Source: developed using data from Saint Lucia Meteorological Services

Figure 2.9 shows the number of days of rain per month averaged from 1989 to 2010.[3] The wet season has about a 26 to 32 percent greater number of rainy days compared to the dry season, depending on location. On average, this suggests that a storm event in the wet season produces more than twice the amount of rain per day than a storm event during the dry season.

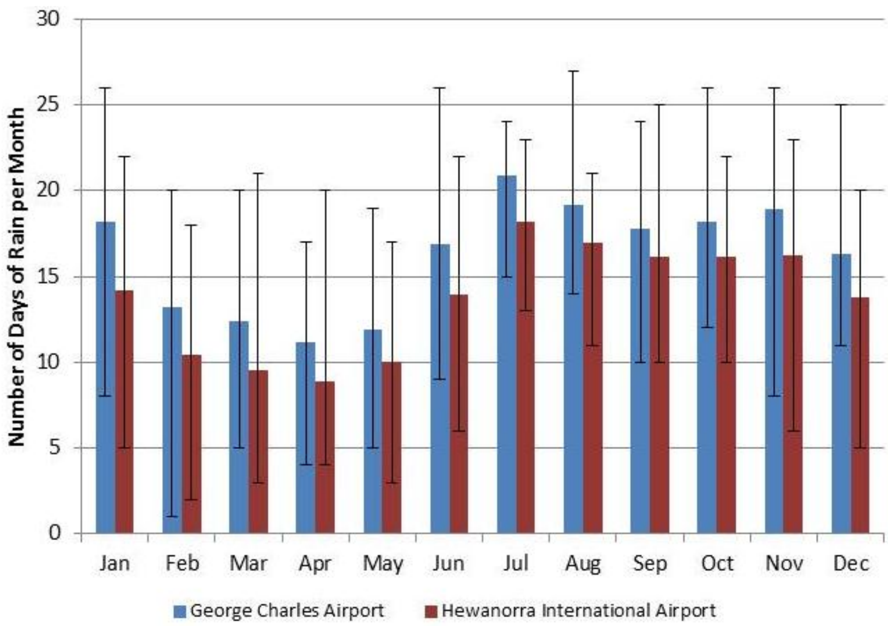


Figure 2.9 Average number of days of rain per month for the Castries study area from 1989 to 2010 with bars indicating the lowest and highest monthly values recorded, Source: developed using data from Saint Lucia Meteorological Services.

The 1-day extreme rainfall estimates (2.33 return period (RP)) was constructed for this analysis using the provided observation station data for two 10-year periods and a 20-year period (see Table 2.1). The 1-day extreme rainfall estimates represent a storm event with a

[3] A day of rain is defined as days with recorded rainfall at or above 1 mm within a day.

2.33 year RP. This was calculated by averaging the maximum 1-day precipitation event for each year in the time period.

Figure 2.10 illustrates that almost all of the 1-day extreme rainfall estimates for both locations are above 60mm (this is an important precipitation threshold that is utilized in the development of the inland flood maps presented in Section 2.5).

Table 2.1 Observed 1-day rainfall extreme values (2.33 RP) for two station locations in Saint Lucia, Source: developed using data from Saint Lucia Meteorological Services

Weather Station	1989-1998	1999-2008	1989-2008
Hewanorra Airport	116 mm (4.6 inches)	86.8 mm (3.4 inches)	100.7 mm (4.0 inches)
George F.L. Charles Airport	120 mm (4.7 inches)	88.4 mm (3.5 inches)	104.1 mm (4.1 inches)

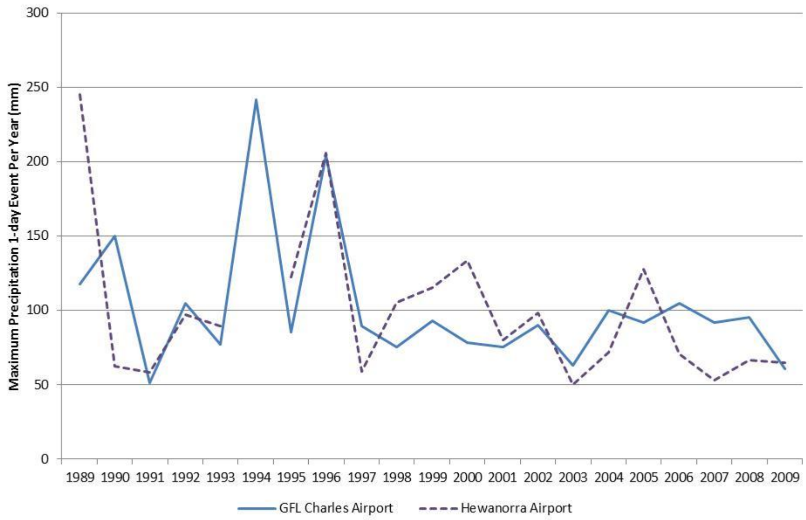


Figure 2.10 Maximum daily precipitation per year at Hewanorra International Airport and Georges F.L. Charles Airport, Source: developed using data from Saint Lucia Meteorological Services.

Box 2 Overview of ENSO which affects Saint Lucia climate

The El Niño/Southern Oscillation (ENSO) cycle is the cyclical change in sea surface temperatures, rainfall patterns, surface air pressure, and atmospheric circulation that occurs around the Equatorial Pacific Ocean. The extremes of the ENSO cycle are termed El Niño and La Niña. During an El Niño period, the sea surface temperature in the Pacific becomes warmer than normal and the strength of winds reduce. Conversely, during La Niña the sea surface temperatures become colder than normal and the strength of the wind increases. These events usually occur every 3 to 5 years and can last over 12 months. Scientists have found that climate models adequately capture the ENSO cycle; hence, the projections presented later in this section consider the ENSO cycle.

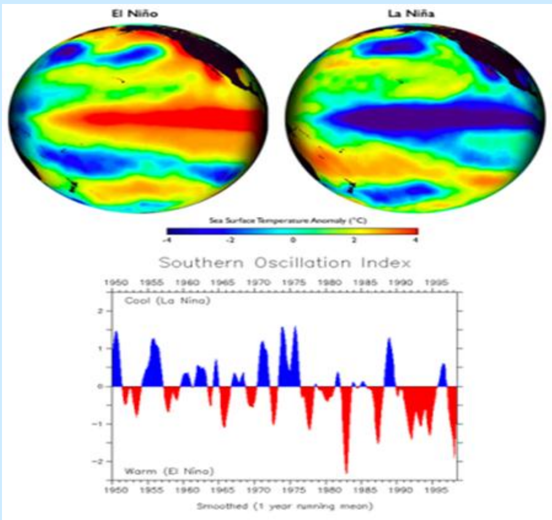


Figure 2.11 Top: Sea surface temperatures for El Nino and La Nina events; Bottom: El Nino (blue) and La Nina. Source: NOAA, 2012a

2.4 Current coastal flooding hazard

Saint Lucia has been severely impacted by extreme weather events, and the impacts of projected sea level rise are expected to be severe. The coastline hosts a high concentration of hotels, ports, roads, and settlements with a majority of the island population and critical infrastructure located on low-lying reclaimed coastal land (Lewsey et al. (n.d.)). Climate change will likely exacerbate the current impacts of coastal flooding; growth in population and tourism will likely compound this impact.

To assess the impacts of climate change on coastal flooding in Castries itself, we used available storm surge and wave flood maps to identify the areas within the study region potentially vulnerable to coastal flooding during tropical storms and hurricanes (CDC, 2006).

Storm surge and wave hazards will increase as sea level rises. We obtained sea level rise inundation maps to determine which coastal locations are vulnerable to projections of sea level rise and qualitatively considered how sea level rise would affect the mapped storm surge and wave hazard flood in those locations. There is uncertainty in how tropical storms and hurricanes may change in the future and how that may affect a storm's surge and wave heights.

By the end of the century, recent scientific consensus suggests the frequency of these storms in the Atlantic may reduce while the intensity increases (Knutson et al., 2010). In other words, fewer of these storms may occur overall, but those that develop may be intensified. However, there is significant uncertainty in the projections of tropical cyclone frequency across models for individual basins. This information does not directly indicate changes in storm tracks or how the impact of storm surge and extreme waves may be affected by drainage and changes in inland topography. Natural and artificial barriers will also play an important role on the behaviour of waves and the extent of coastal erosion and flooding.

2.4.1 Description of coastal flooding

In Saint Lucia, coastal flooding is primarily caused by tropical storms and hurricanes.[4] Storm surge, tide waves, and freshwater input are all contributors to the intensity of the coastal flooding. Storm surge is largely driven by strong winds from the storm blowing onshore (see Box 3). Within a storm, wind speeds are variable and tend to increase in sustained speeds towards the center of the storm (World Bank, 2002). The winds along the right front quadrant of the hurricane (i.e., northeast of the eye) are generally the strongest and are responsible for the worst of the storm surge and battering waves (Cambers, 2001). As the center of the storm travels over land, the winds will dramatically lessen but as the center of the storm moves away, the winds will quickly rise though blowing in the reverse direction (World Bank, 2002). Given all the factors that affect storm surge, there can be great variability in the experienced storm surge for a given tropical storm or hurricane with similar sustained wind speed (NOAA, 2012b).

In the Caribbean, hurricanes generally travel east to west. Though hurricanes may shift in direction, the east-to-west track suggests a hurricane may be more likely to hit the eastern side of Saint Lucia (CDMP, 2001). One study found that a 1-in-100 year storm surge event is predicted to have the greatest surge heights of 2 to 2.5m on the east coast of the island compared to 1.25 to 1.5m for Castries (CDMP, 2001).

[4] A tropical cyclone starts as a tropical wave with sustained winds below 36 km/hr (22 miles/hr). The storm can then develop into a tropical depression with sustained winds between 37 and 60 km/hr (23 to 37 miles/hr) to a tropical storm with sustained winds at 61 to 117 km/hr (38 to 73 miles/hr). If the tropical storm continues to strengthen, the storm becomes a hurricane. Hurricanes are classified into five categories based upon sustained winds and increasing damage as suggested by the Saffir-Sampson hurricane wind scale: category 1 has sustained winds at 118 to 152 km/hr (74 to 95 miles/hr); category 2 has sustained winds from 153 to 176 km/hr (96 to 110 miles/hr); category 3 has sustained winds from 177 to 208 km/hr (111 to 130 miles/hr); category 4 has sustained winds from 209 to 248 km/hr (131 to 155 miles/hr); and a category 5 has sustained winds above 248 km/hr (155 miles/hr) (NOAA, 2012a).

Box 3 Coastal flooding

Tropical storms and hurricanes can produce a destructive storm surge and large battering waves resulting in loss of life, buildings destroyed, beach and dune erosion, and road and bridge damage along the coast. Depending on the coastal elevation, a storm surge can travel several miles inland.

The figure below illustrates a hurricane moving onto the coastline. The winds are moving in a circular direction around the “eye” of the storm forcing water onto the shoreline (the circular direction is counter-clockwise in the northern hemisphere). This surge of water can lead to extreme flooding particularly when the storm surge occurs during normal high tide. Storm intensity, forward speed, size, angle of approach, and central pressure of the approaching storm along with coastline characteristics all affect the nature of the storm surge. For example, the impact of the storm surge is greater for coastlines with a shallow slope than a coastline with a steep shelf. Battering waves combined with a storm surge can be particularly dangerous. Successive pounding of waves, for example, on buildings can cause significant damage. As a storm surge travels inland, it carries with it the battering waves, producing greater damage inland.

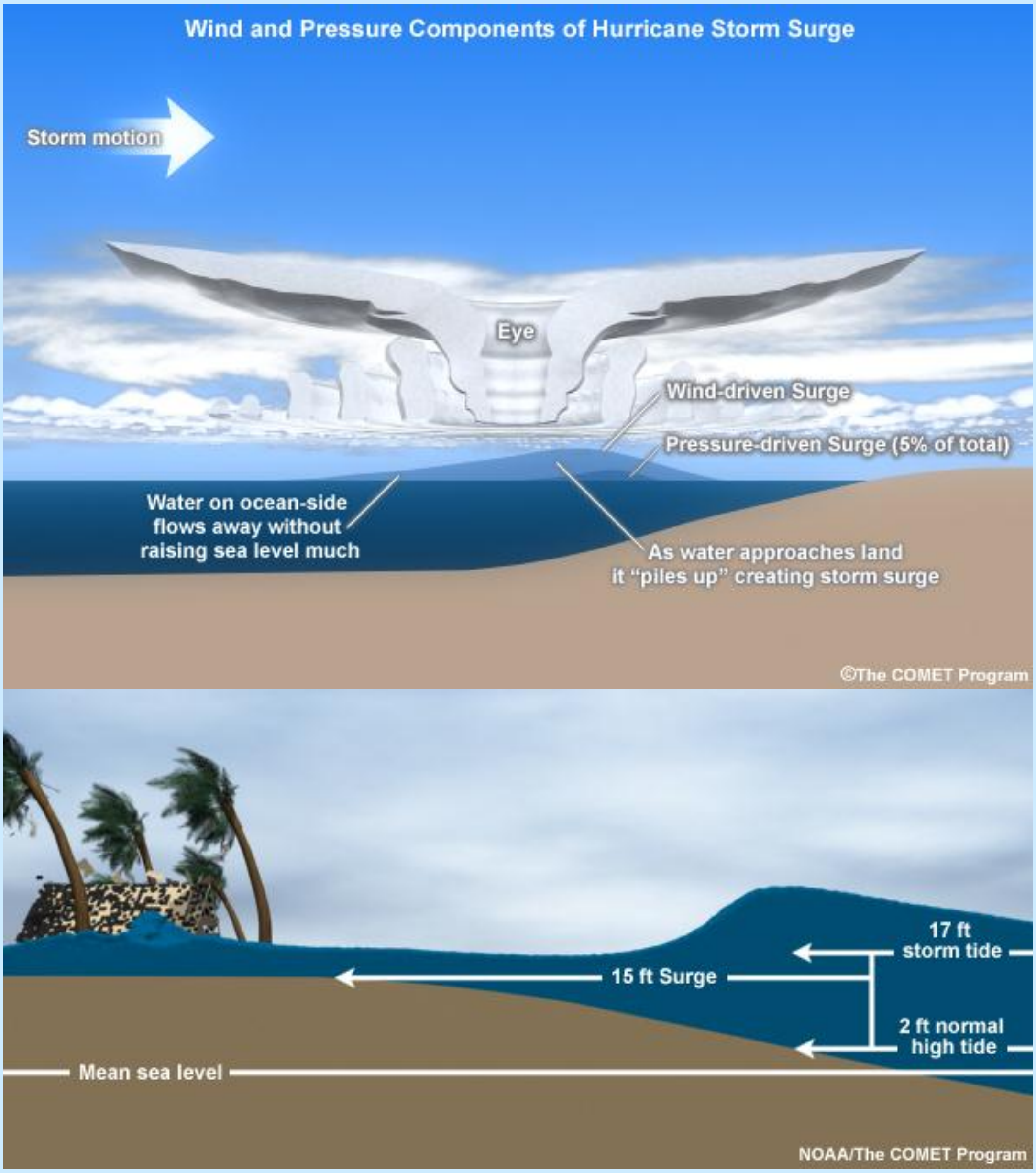


Figure 2.12 Illustration of storm surge, NOAA, 2012b.

2.4.2 Historical and observed coastal flooding

Saint Lucia is a volcanic island with coastal areas vulnerable to erosion and coastal flooding (Simpson et al. 2010). Agriculture, water supply, fisheries, tourism, and coastal resources are all located within the coastline (Second National Communication, 2011). Saint Lucia has already experienced storm surge and wave hazards that have damaged coastal infrastructure and caused detrimental coastal erosion.

Castries City is coastal and largely at sea level. Large parts of the city are built upon reclaimed land and can be susceptible to flooding. The George F.L. Charles airport, situated at approximately 3.4 m above mean sea level and separated from the sea by only a two-lane road, is prone to flooding from both precipitation and storm surge events due, in part, to poor drainage. The main drain runs underground to Ganters Bay, which tends to back up during periods of heavy precipitation. The roadside drain was blocked during a recent re-surfacing of the adjacent road, compounding the impact. In 2007, Hurricane Dean caused storm surge that washed sand onto the adjacent road and into the airport site, creating a barrier near the existing terminal. Eroding sea defences that have been weakened and ineffective during past storm events have compromised the west end of the runway (King-Joseph, 2010).

The port of Castries is approximately 1.5 meters above mean sea level. The Castries docks have withstood past storm surges without sustained damage. A breakwater structure was built to reduce the impact of waves breaking against the eastern harbor front and onto the primary road next to the government buildings. However, during Hurricane Dean, waves transported boulders from the breakwater structure onto the roadway, thereby compromising the structural integrity of the breakwater structure for future events. Large vessels return to open waters during storm events to prevent, in part, being harmed by floating debris that drains off the island into the harbor. Floating debris in the southwest end of the harbor can form deposits on to the bottom of the harbor. Dredging of the harbor can be required every four to five years to ensure there is enough depth for the safe passage/access of vessels (King-Joseph, 2010).

Changes in the landscape including beach erosion and the removal of a mangrove have increased the storm surge experienced/impact in Ganters Bay within Castries Harbor. Infrastructures along the shoreline at Ganters Bay are at sea level and are extremely vulnerable to storm events (King-Joseph, 2010).

The tropical storm and hurricane season is from June through November. During this time, Saint Lucia is particularly prone to storms strong enough to produce significant coastal flooding. A few recent events in Saint Lucia that illustrate the damage associated with storm surge and battering waves include the following:

- During the 1990s, Saint Lucia's beaches experienced net erosion due to a series of tropical cyclones. The cyclones occurred so frequently, the beaches were unable to recover between events (Simpson et al., 2012).
- Though Hurricane Lenny did not directly hit Saint Lucia in 1999, the 6-meter waves produced by the storm caused reported damage to at least 70 homes. This storm was particularly unusual in that it travelled west-to-east in the Caribbean. Main areas affected were Soufriere, Gros Islet, Choiseul, Canaries, and Anse La Raye, with damage to fisheries in Choiseul and Laborie (GFDRR, 2010; Guiney, 2000; World Bank, 2002)
- Hurricane Dean was a category two hurricane when it struck Saint Lucia in 2007, causing a strong storm surge during high tide along the northwestern coastline of the island. The hurricane damaged marine equipment and infrastructure in Castries Harbor and the northern tourism resort area. Hourly sea level data recorded the maximum height at 10.2 m (34 feet) (Augustine, 2007)
- In 2010, Hurricane Tomas produced waves that were approximately a 1 in 15 year event (ECLAC, 2011).

To understand how likely Saint Lucia is to be impacted by a tropical cyclone, the World Bank (2002) conducted an analysis to assess the probability of a tropical cyclone occurring in a 2-degree square (about 220 km by 220 km) centered over Barbados. These probabilities are estimated to be similar to those that would be estimated for Saint Lucia. Based on this, Table 2.2 demonstrates how vulnerable Saint Lucia is to being impacted by tropical cyclones. A direct hit to Saint Lucia is suggested to be simply 65% of the probability of the storm passing through the grid cell. This table demonstrates that Saint Lucia currently has a 2 percent chance of being hit by a strong hurricane in a given year (World Bank, 2002).

Table 2.2 Probability of a tropical cyclone (%) simulated for Barbados and considered a proxy for Saint Lucia.

Number of years	Tropical storm	Hurricane				
		Category 1	Category 2	Category 3	Category 4	Category 5
1	12	3	8	8	4	3
2	23	6	16	16	7	6
5	48	13	36	36	17	13
10	73	25	58	58	32	25
20	93	43	83	83	53	43
50	100	76	99	99	85	71

Source: adapted from World Bank, 2002.

2.4.3 Coastal flood resources

Several national and international organizations developed coastal flood hazard maps for Saint Lucia in 2006 (CDB, 2006). To illustrate hazard, the maps combine the threat of high waves (i.e., a crest to trough wave height of 1 m or higher) and storm surge (i.e., water depth 0.3 m above terrain height or higher). The frequency with which these conditions occur is used to estimate hazard levels for the Saint Lucia coastline drawing from the available history of hazardous events. The hazardous zones are defined from high to low corresponding to three return periods:

- 50-year maximum likelihood event (a.k.a. 50-year flood plain), i.e., the map of this event suggests which populations are living in areas *likely* to experience the hazard once during an average lifetime;
- 100-year maximum likelihood event (a.k.a. 100-year flood plain),[5] i.e., the map of this event suggests which populations are living in areas *less likely* to experience the hazard within an average lifetime; and
- 100-year 90 percent prediction limit event (a.k.a. 500-year flood plain),[6] i.e., the map of this event suggests which populations are living in areas *unlikely* to experience the hazard within an average lifetime.

The coastal flood level values calculated and shown on the coastal flood maps are measured relative to the terrain height on land and the mean sea level in open water. The water levels over open water account for both storm surge and wave setup. The maps further label those at high wave risk areas (CDB, 2006).

The maps were developed at the 1:25,000 scale for the entire island and at the 1:10,000 scale for Castries.[7] Most of the study area is captured in the maps developed for Castries. Both sets of maps are presented below to capture the full study area. The Saint Lucia government provided the coastal flood hazard maps for the entire island as a collection of 32

[5] This is estimated by considering a collection of 50-year and 100-year periods, where half of the periods would experience a higher maximum value than the maximum likelihood event. This is not the inundation value that could occur once every 100 years.

[6] This estimate corresponds to values that would only be exceeded by 10 percent of the periods. Hence, this is a very conservative description of coastal flood hazards.

[7] The scale is a ratio describing the “distance on the map”: “distance on Earth”. The smaller the number for the “distance on Earth” the finer the map and the more detail that can be provided.

map tiles (i.e., a tile corresponds to a specific region in Saint Lucia) to be combined as appropriate for this analysis.

Figure 2.13 illustrates the estimated water height associated with storm surge and wave action for the three hazardous zones for the entire study region. The figure shows that Castries is somewhat protected by the bay compared to nearby coastal locations, as are other coastal locations with steeper slopes or higher elevations. As these maps illustrate, a 50-year maximum likelihood event is estimated to generate water heights from 1 to 2m along much of the coastline. A 100-year maximum likelihood event may generate water heights from 1 to 3m along the coastline. However, these events are somewhat benign compared to the water height of 4m to above 6m along the coastline for the 100-year 90% prediction event.

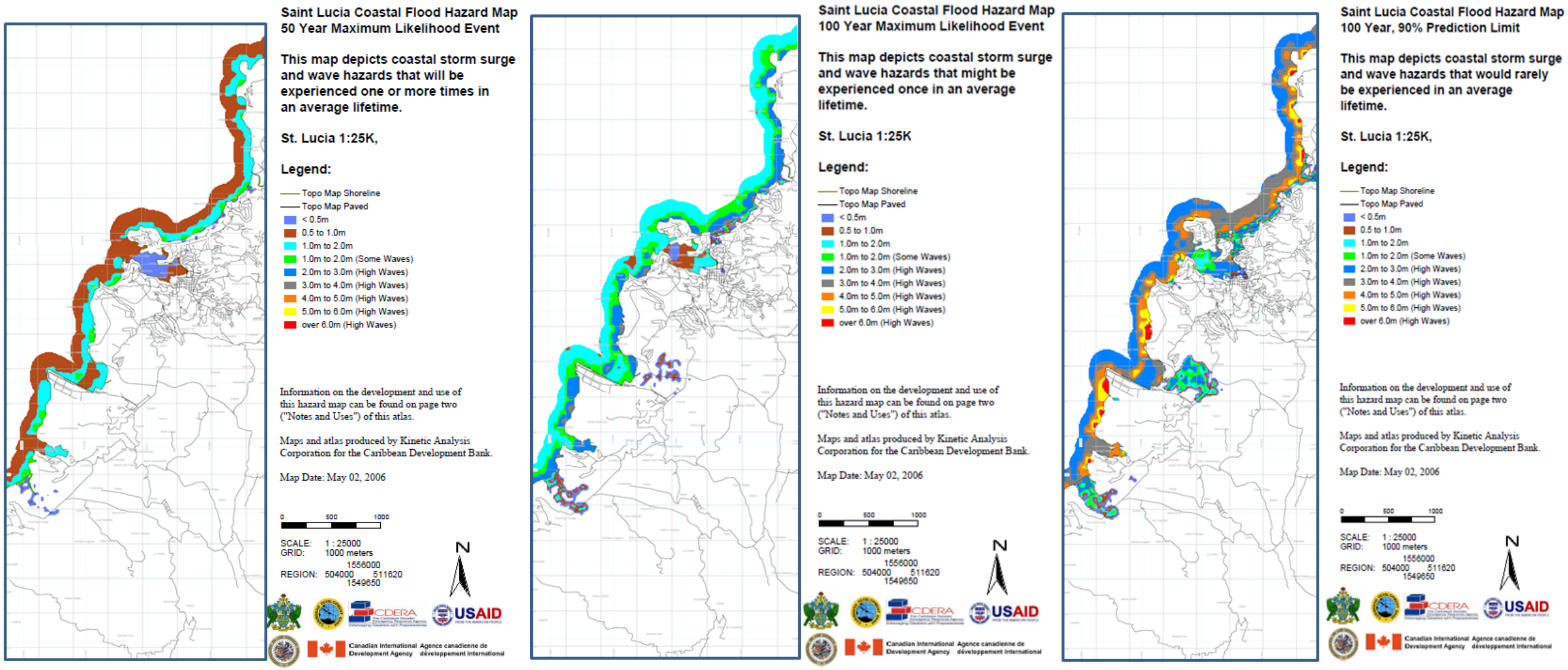


Figure 2.13 Coastal flood hazard maps depicting the 50-year maximum likelihood event, the 100-year maximum likelihood event, and the 100-year 90% prediction limit for the study area at a scale of 1:25,000, Source: developed using maps from CDC, 2006, tiles 18, 22, and 26.

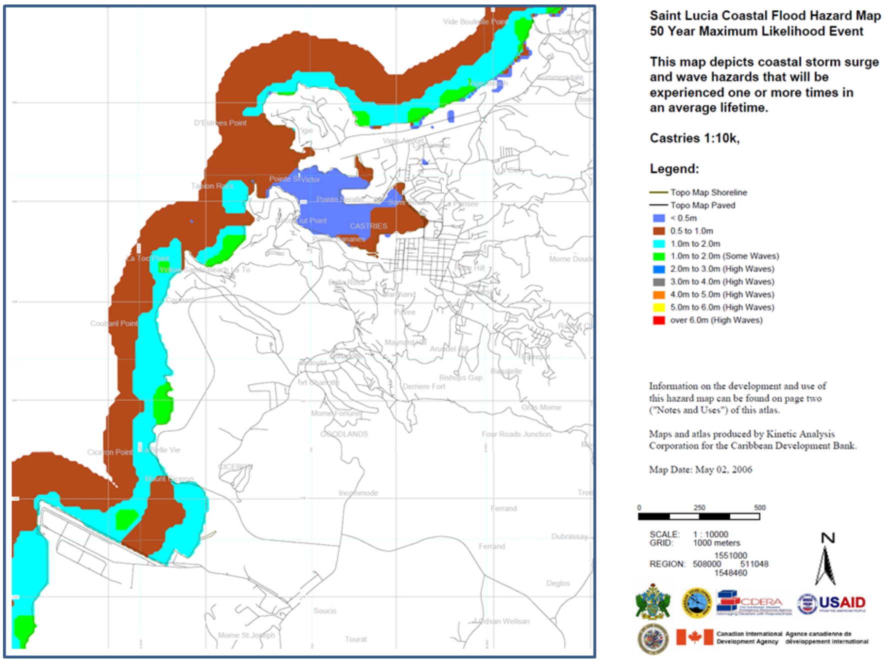


Figure 2.14 Coastal flood hazard map for the Castries area for the 50-year maximum likelihood event at a scale of 1:10,000, Source: developed using maps from CDC, 2006, tiles 1, 2, 4, 5, 7, 8.

Figure 2.14 shows a coastal flood hazard map for the 50-year maximum likelihood event for the Castries portion of the study area. The map shows locations projected to flood as a result of an event that is statistically likely to occur every 50 years. The following settlements are shown to be susceptible to minimal flooding of up to 1 meter along the coastline during this event (many instances along beaches): La Toc, Ciceron, Barret St Joseph, Tapon, Fauxand, and Coubaril. A few settlements show evidence of pockets of minimal inland flooding: Choc, Vide Boutelle, Vigie, Conway, and Castries City. These are high hazard zones and comparable to a "50-year flood plain" (CDB n.d.(a)).

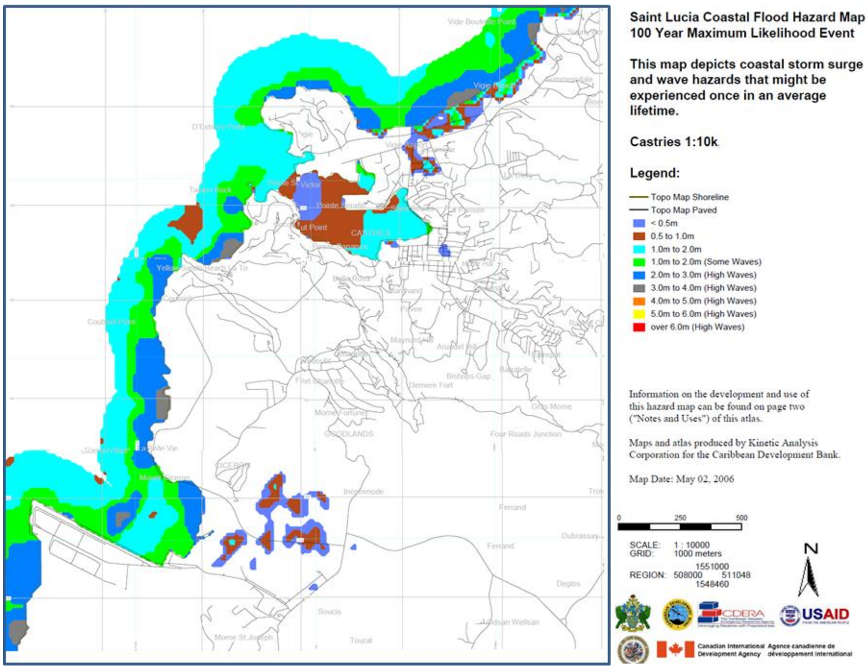


Figure 2.15 Coastal flood hazard map for the Castries area for the 100-year maximum likelihood event at a scale of 1:10,000, Source: developed using maps from CDC, 2006, tiles 1, 2, 4, 5, 7, 8.

Figure 2.15 shows a coastal flood hazard map for the 100-year maximum likelihood event for the Castries portion of the study area. This map depicts areas that will statistically be impacted once every 100 years and is comparable to the "100-year flood plain." The map shows increased water levels and more areas prone to flooding along the coastline.

If this event were to occur, inundation becomes more severe in some locations. For example, water heights up to 4 meters with waves could impact the sections of the coastline in Coubaril, La Toc, Vigie, and Vide Boutelle. During the event, Cul de Sac could experience portions of land under 1 meter of water. The duration of flooding is not provided. According to the map developers, the areas that are not likely to be susceptible to flooding under the 50-year return period but could be susceptible to the 100-year return period could be considered for housing, though precautions such as flood proofing is advised (CDB, n.d.).

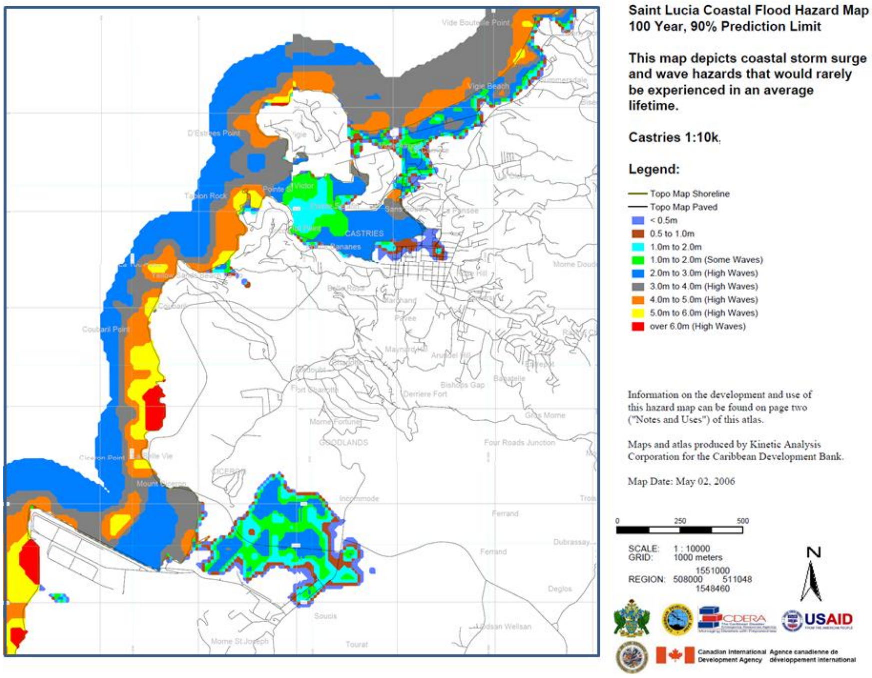


Figure 2.16 Coastal flood hazard map for the Castries area for the 100-year, 90% prediction limit at a scale of 1:10,000, Source: developed using maps from CDC, 2006, tiles 1, 2, 4, 5, 7, 8.

Figure 2.16 shows areas within Castries that are susceptible to the highly unusual 100-year event at the 90% probability level. Inland areas may be flooded by as much as 2 meters above the terrain elevation. Some locations very near the coast could experience waves reaching above 6 meters. A large inland portion of Cul de Sac could be under 1 to 2 meters of water. The map developers suggest that locations susceptible to an extreme storm such as the one depicted in these maps should not support critical infrastructure or emergency response during and after storm events (CBD, n.d.). Critical infrastructure is better suited in the areas on the map that are shown in "white" (indicating they are less susceptible to coastal flooding as a result of an extreme storm event) (CDB, n.d. (b)). Other hazards (e.g., landslides and inland flooding) as well as other factors should also be considered.

2.5 Current inland flooding hazard

Inland flooding from rainfall occurs more frequently than inundation from storm surge and tidal waves in the Castries area (Chase, 2012). Increased urban development and other challenges have reduced storm water drainage capacity to the point where even minor rain events can cause flooding in the city area. Inland flooding from rainfall is not associated with the same physically-destructive force of storm surge and tidal waves events, but can cause damage through inundation, erosion, and scour of homes and other buildings, farmers' fields, roads, bridges, airport runways, and embankments. Major events in the Castries area include flooding in the autumn of 1996 that caused severe damage and cut off access to the south part of the city. Hurricanes Dean, in 2007 and Tomas in 2010 were also associated with heavy flooding events in the city area.

To assess the impacts of climate change on inland flooding in Castries, we used inland flood hazards maps to identify susceptible locations within the study area. The island flood hazard map and the Castries flood hazard map describe the locations within our study area susceptible to flooding. The island flood hazard map was constructed using a number of factors including 1-day extreme precipitation data. We obtained historic and projected 1-day extreme precipitation data to assess how changes in precipitation may impact changes in flooding.

This first order analysis suggests that the projected change of precipitation may not produce a significant change in flooding. In addition, the uncertainty associated with precipitation as demonstrated by the wide variability in projections across the model simulations further suggests that planners may want to consider these findings qualitatively too, rather than only on the basis of projections.

2.5.1 Description of inland flooding

Flooding in Castries is often the result of minor rain fall events due to; (1) an increase in impermeable surfaces associated with urban development; (2) the lack of an adequate storm water drainage system; and (3) inappropriate waste disposal. According to local stakeholders consulted for this project, the drainage system in the city centre was considered adequate a few decades ago. More recently, flooding in the city centre started occurring under relatively small precipitation events. Stakeholders suggest that a combination of natural and man-made stressors are to blame, including the natural topography (i.e., a basin surrounded by hilly topography), increases in impermeable surfaces, an inadequate and poorly maintained storm water drainage system, and the build-up of garbage that blocks the drainage system. Over the past two decades, the man-made stressors have increasingly worsened in response to unplanned and unmanaged urban development.

Box 4 Inland flooding

An inland flood is an event in which an abnormally high level of "overland flow" is generated (Fleming, 2002), resulting in areas that are temporarily or permanently inundated. *Overland flow* is the result of a rainfall event and a saturated soil (or soil that is unable to absorb additional water) whose only option is to flow above the surface toward a river or stream. The resulting overland flow may be intercepted and channelled by vegetation, buildings, and other natural or anthropogenic obstacles. It is also dependent on soil characteristics, land cover, slope, and type of rainfall event.

As illustrated by the figure, anthropogenic influences frequently reduce the soil's *infiltration capacity,* or ability to absorb rainfall: increasing levels of urbanization induce greater overland flow since structures and roads are effectively waterproof, while increased deforestation may reduce the areal coverage needed for absorbing the needed rainfall to prevent or mitigate flooding events. In contrast, a properly designed and maintained water management system with adequate drainage coverage and conduit sizes may reduce the flood risk in urban areas.

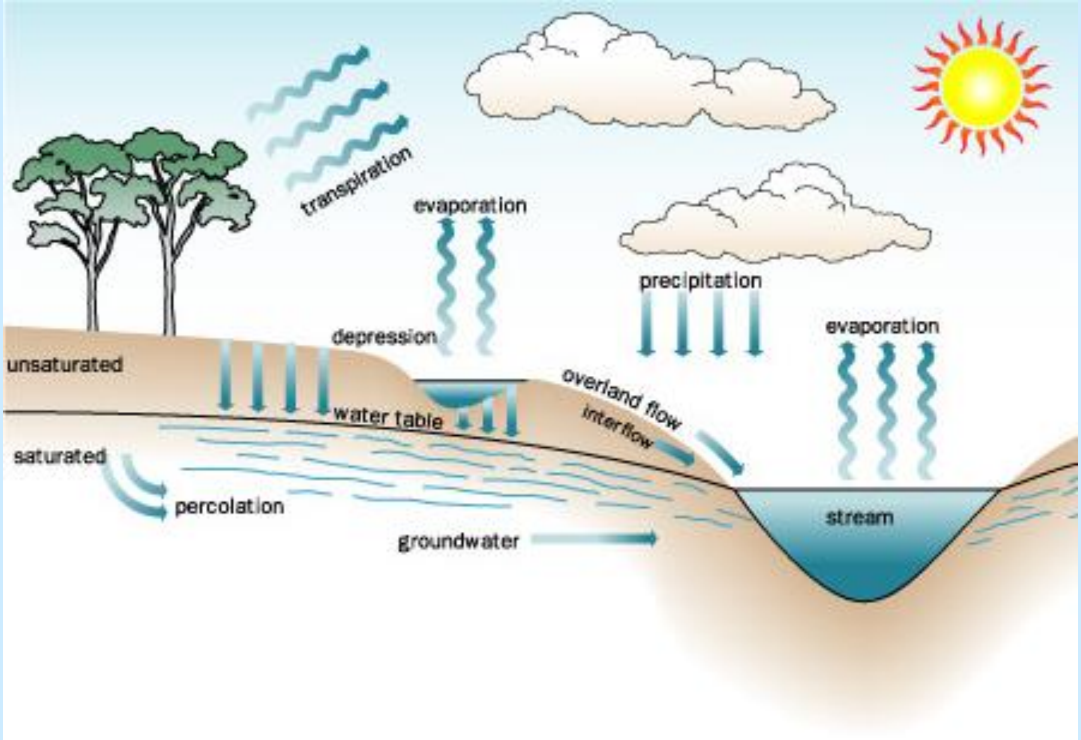


Figure 2.17 Components of Hydrologic Cycle, Source: http://www.itlrc.com/earth_science_1/introduction.html

2.5.2 Historical and observed inland flood events

The eastern boundary of the city centre is located at the intersection of three ravines that originate from the suburbs of Castries and channel the water between building developments and underneath roads to the harbor. The channels can be quite narrow and the land is flat and low-lying; as a result, there is limited natural flow to the harbor. In addition, urban development has created significant siltation from soil erosion in the catchments. In the channels where the gradient is shallow, the water may slow down enough that sedimentation will occur (exacerbating? the drainage issues). The siltation is compounded by garbage thrown into the rivers that clogs the drainage system at various points of flow. A culvert with a trash screen may capture garbage upstream but, without removal of the garbage, the trash screen becomes chronically blocked with debris and causes the banks to overflow.

The city centre underwent an engineering assessment that led to the construction of a significantly enhanced water drainage system which was completed in 2007. The system included the addition/replacement of two pumps and a widening of a critical drainage pipe. Local stakeholders consulted for this project indicated that the system has been unsuccessful due to poor maintenance. The filters have continued to clog with garbage. In addition, it was suggested that the pumps automatically shut down once the water level becomes too high (so as not to damage the pumps). Stakeholders still consider the flood maps developed for the city centre in 2006 (before the installation of the enhanced water drainage system) to provide an accurate indication of the areas in the city that are most vulnerable to flooding.

Under heavy precipitation events, flooding also occurs in the hilly environs of Castries where development has resulted in a loss of natural vegetation in channels and caused increased runoff. As the climate changes, flooding may worsen if precipitation events increase in intensity, frequency, and/or duration. In addition, if urban development continues around the city centre without improvements in the public treatment of solid waste, the impact will be greatly magnified.

Until the late 1970s, flood events in Saint Lucia were not well documented. The country's National Emergency Management Office has a list of hazards that have occurred, and while they do not specifically categorize flood events, the agency mentions hurricanes often lead to inland flooding (NEMO, 2003). For example:

- A significant flood event from heavy rainfall was caused by 'Tropical Storm Debbie' in 1994. The villages of Anse LaRaye and Dennery were flooded with depths reaching up to five feet in houses south of the playing field in Anse La Raye. Dennery also suffered damages to roads and to supports of timber houses. Consequently, damages caused by Debby are estimated at 230 million EC dollars as transportation assets were damaged, 55% of the banana acreage was destroyed, 33 of 34 water supplies were compromised, three schools suffered damage, and numerous landslides resulted (NEMAC, 2003).
- A heavy precipitation event occurred in October, 2006. During this event, flooding in Cul de Sac cut Castries off from the rest of the island (Second National Communication, 2011). Stakeholders indicated that air travel was the means of transport between Castries and the rest of the island.
- Flooding in Castries occurred in 2007 during Hurricane Dean (Second National Communication, 2011).

2.5.3 Inland flood resources

A 2006 study by Cooper and Opadeyi investigated inland flooding hazards for Saint Lucia (Cooper and Opadeyi, 2006).[8] The authors developed an island-wide flood hazard map at a scale of 1:25,000 that defines three hazard zones (high, medium, and low). These hazard zones are defined by the dangers posed to an average adult as a result of floodwater depths.[9] For example, a low hazard zone suggests any size adult is not in serious harm to floodwater while a moderate hazard zone suggests extreme caution for an adult. High hazard zone places almost any sized adult to be in danger to flood water. The methodology used to identify these hazard zones is described in more detail below. Cooper and Opadeyi developed another more detailed flood hazard map for Castries at a scale of 1:8,500 that illustrates the spatial extent of floodwaters for various return periods. The Castries map accounts for both high water levels and water velocity.

Cooper and Opadeyi developed the island-wide flood hazard map based on the following parameters as defined in their study:

- **Land Use**: Land cover from Saint Lucia was used from the Common Digital Database with some modifications to match the land covers provided in standard curve number (CN) tables based on the empirical curve number approach of the National Resources Conservation Services. CN tables suggest how much precipitation become runoff and enters the drainage basin, the curve number is a? simplified index from 1 to 100 where 100 represents highest potential runoff. The curve number is based on the land coverage and soil type (soil type is described below). A curve number between 40 and 70 is considered to contribute moderately to flood risk with values below and above representing low and high risk, respectively.
- **Soil**: Soils were classified into four hydrologic soil groups based on their infiltration rate from soil that freely drain with depths to the lower horizon in excess of 900 mm to soils with impeded drainage.
- **Rainfall**: The precipitation thresholds are based on the 1-day extreme rainfall event per year averaged over a given time period. The risk of inland flooding is considered for three ranges: high risk for values above 60 mm, a moderate risk for values between 25 and 60 mm, and a low risk for values below 25 mm.
- **Slope risk**: Slopes were categorized into three levels of "risk" with slopes less than 0.1% (0.06 degrees) considered a high risk while slopes greater than 0.5% (0.3 degrees)

[8] This report uses the term "risk" to describe the importance of physical parameter characteristics to the total hazard. In this study, we consider this use of risk to actually be a scale of intensity where higher intensities lead to higher degrees of hazard. To remain consistent with the 2006 study, we will adopt their use of "risk" in this section and when describing their methodology and results.

[9] These maps do not account for water velocity.

considered a low risk. Floodplains in Saint Lucia have been delineated in areas where the mean slope of the land mass is equal or lesser than 0.001m/m as storage of water is more likely to occur on these flat slopes opposed to steep ones. This categorization does not account for water velocity but simply flood levels.

As described in Figure 2.18, Cooper and Opadeyi consider soil "risk" (combination of land use and soil), rainfall "risk", and slope "risk" collectively to estimate flood "risk" (i.e., Total risk = Soil risk + Rainfall risk + Slope risk). The rates of "risk" for each parameter was weighted according to its importance (i.e., a high rainfall "risk" and soil "risk" was assigned a "3", while high slope "risk" was assigned a "6").

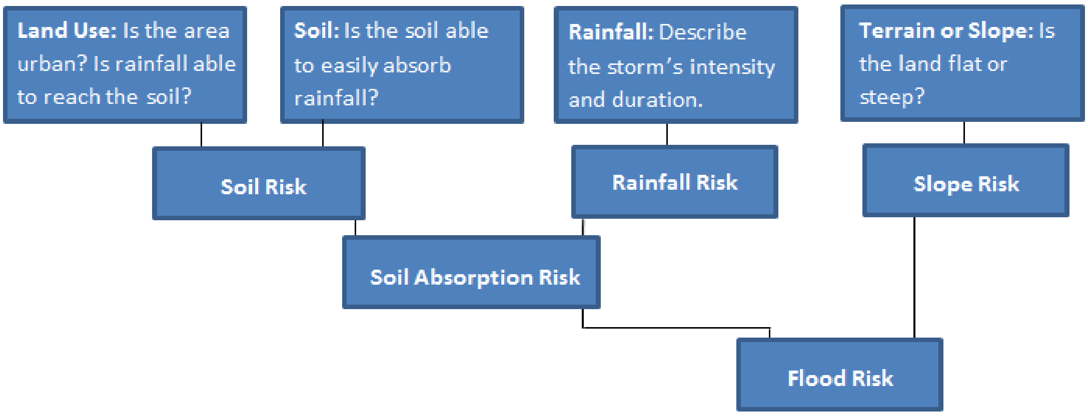


Figure 2.18 Flood hazard assessment, Source: adapted from Cooper and Opadeyi, 2006.

The Saint Lucia inland flood hazard maps used 1-day extreme rainfall estimates for ranking rain risk (i.e., the 2.33 year return period (RP) of 1-day extreme rainfall event). Locations with an associated high rain risk are areas that tend to experience strong rain events which can trigger inland flooding (see Table 2.3).

Table 2.3 Values of 1-day extreme rainfall amounts (2.33 RP) for each level of risk to flooding

Rain Risk	Rain Value (mm)	Rain Value (inches)
1	< 25	<1
2	25 – 60	1 – 2.4
3	>60	> 2.4

Due to the steep terrain located throughout the island of Saint Lucia, few areas are susceptible to flooding. However, "flat" landforms with increased hazard are found in the eastern and northern side of the island, as well as in the Gros Islet and Castries coastal plains. In addition, the slopes on the southeastern end of the north-south ridge are flatter with extensive coastal plains extending from Hewanorra International Airport in the south to Micoud Settlement on the north (Cooper and Opadeyi, 2006).

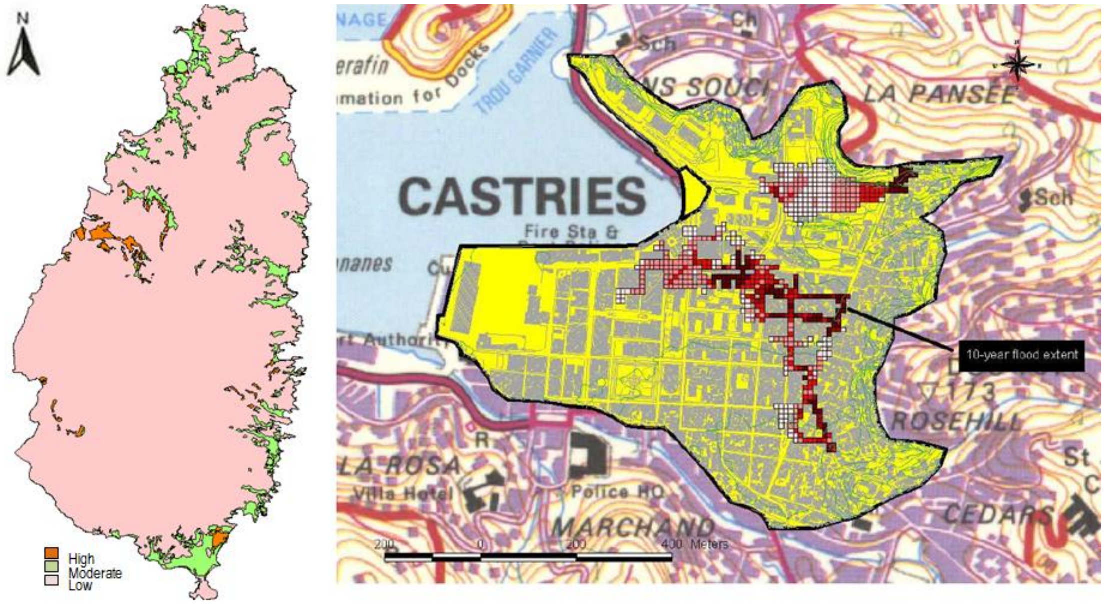


Figure 2.19 Flood hazard maps for Saint Lucia and the centre of Castries, Source: detailed map of Castries city is based on Cooper and Opadeyi, 2006 (no legend provided), scale 1:8,500; the island flood hazard map was developed from shapefiles provided by the Physical Planning Unit, Government of Saint Lucia.

Due to the steep terrain, floods in Saint Lucia are usually classified as the ‘flash flood type’. According to the Saint Lucia National Floodplain, a typical inland flood lasts less than six hours and would very seldom last more than twelve hours (Cooper and Opadeyi, 2006).

A further analysis of detailed inland flooding was provided for the city of Castries considering both high water and water velocity. The detailed inland flood hazard maps were produced using a two-dimensional hydraulic model, FLO-2D, to simulate the flood extent for extreme rainfall events. This model uses a gridded mesh of 10 m by 10 m cells for the study area aligned in a north-south orientation and can include drainage channels, street, and levees that alter flow (e.g., a cell may block water while other cells may be a street that allows water to pass through). Given the mesh size and that some cells may not perfectly align with the structures within each city block, the locations where flooding is simulated to be considered as an approximate location. The model calculates the water level and flow velocity within each grid cell for each extreme rainfall event. This analysis relied on hydrographs developed for three ravines at Chaussee Street and assumed the drains were in poor maintenance during the storm event and that sea level was at the highest astronomical tide level. This then represents a ‘bad-case’ scenario.

Figure 2.19 shows sections within the city that are susceptible to the 10-year flood return period. The colouring on the map indicates the potential of that grid cell to become flooded when a storm that has the probability to occur once every 10 years (darker red colour indicates a greater potential to flood based on water level and velocity; the analysis does not provide a description or legend to define the hazard zone associated with each colour). Additional maps of lower flood return period (e.g., 100-year flood map) have been developed but were not made available for this analysis.

2.6 Current landslide hazard

Landslides are common in Saint Lucia and have occurred in the Castries urban area. They can result in a loss of life and cause damage to roadways, bridges, buildings, other infrastructure, and agricultural crops. The most affected areas in Saint Lucia tend to be steep-sloped areas with soils or geological characteristics that are particularly susceptible to landslides. In the Castries study area, the landslide hazard is generally lower than other areas of the island, although there have been notable events that have caused disruption of services and displacement of people. The largest landslide in Castries occurred in 1999 in the southeastern neighbourhoods of Black Mallet and Maynard Hill, which required the relocation of 20 households (Chase, 2012).

One of the objectives of this analysis was to assess the impacts of climate change on landslide hazard in Castries. We evaluated current landslide hazards in Saint Lucia and Castries, identified climate-related thresholds above which landslide hazard may increase, considered the changes in relevant climate variables such as annual precipitation and intense rainfall events across various climate models, time periods, and climate change scenarios, and applied these data to assess how future climate change will affect landslide hazard. We found annual precipitation is projected to decrease across most climate models and climate change scenarios, lessening the susceptibility of Castries to landslide hazards. However, there is great variability across climate models in projections of precipitation. A few climate models that tend to project the wettest future climate suggest annual precipitation and heavy rainfall episodes could increase under certain climate change scenarios, increasing the susceptibility of certain area in the Castries region to landslide hazard.

2.6.1 Description of landslides

Landslides in Saint Lucia are predominantly triggered by rainfall (Rogers, 1997), but the hazard in Saint Lucia is correlated with a number of factors related to slope angle, slope curvature, slope aspect, bedrock type or geology, and soil type:

- **Slope steepness:** Steeper slopes have a higher incidence of landslides than gradual slopes, particularly for slope angles greater than 20° (CDERA, 2006; Prior and Ho, 1972; Quinn, 2012; Rogers, 1997).
- **Slope curvature:** Slope curvature may influence landslide hazard. Previous hazard assessments have yielded different results on the susceptibility of flat, concave, and convex slopes. Concave slopes may be most susceptible to landslides (Anderson, 1983; Anderson and Kneale, 1985), although Quinn (2012) found that both concave and convex slopes are more susceptible to landslides than flat slopes. Rogers (1997) assumed that concave and straight slopes are more susceptible than ridge or nose slopes.
- **Slope aspect:** Slope aspect is the direction in which a slope faces. Aspect may have a small effect on landslide incidence resulting from the alignment of a slope with prevailing winds (Quinn, 2012; CDERA, 2006); however, CDERA (2006, p. 19) found that slope aspect generally did not have an important role in landslides in the Castries area.
- **Bedrock type:** Different bedrock types may be more prone to landslides, depending on the presence of discontinuities or their susceptibility to weathering (CDERA, 2006).
- **Soil type:** The type of soil may also influence landslide hazard. Using agricultural or forestry classification schemes to evaluate soil type, however, may not adequately reflect mineralogical differences related to landslide incidence. This may result in a weaker relationship between soil type and landslide incidence than if a more mineralogically-representative classification system is used (Quinn, 2012).

Box 5 Landslide terminology

Landslides refer to a range of ground movements that are driven by gravity, which cause slope-forming materials (e.g., rock, soil, artificial fill) to move downward and outward. Landslides may involve falling, toppling, sliding, spreading, or flowing motion of ground material characterises types of landslides (USGS, 2004).

Table 2.4 Classification of landslides, Source: USGS, 2004 based on Varnes, 1978.

Type of movement	Type of material		
	Bedrock	Engineering soils	
		Coarse	Fine
Falls	Rock fall	Debris fall	Earth fall

Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational	Rock slide	Debris slide	Earth slide
	Translational			
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow (deep creep)	Debris flow	Earth flow
Complex		Combination of two or more types of movement		

The most common types of landslides in Saint Lucia are debris flows and debris slides (Quinn, 2012; Rogers, 1997; UWI, 2005). Debris flows involve rapid movement of slope material (e.g., soil, rock, organic matter) that is saturated by rainfall to form a slurry that flows downslope. Debris slides are triggered by separation of a weak zone of material from a stable, underlying material. Slides can be either rotational or translational, as shown in Figure 2.18; rotational slides generate a concave rupture, whereas translational slides move along a planar surface (USGS, 2004).

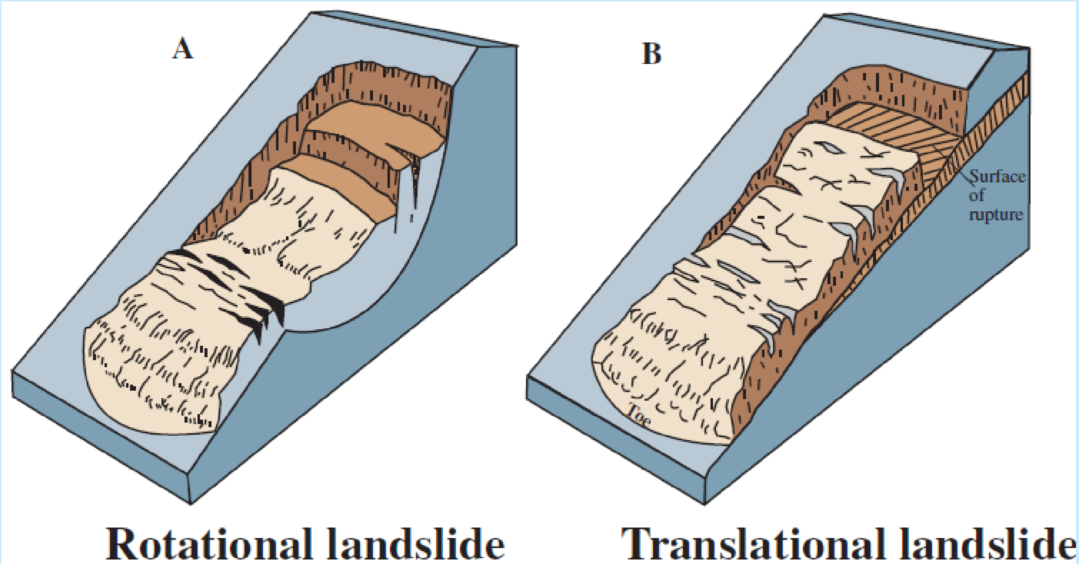


Figure 2.18 Diagrams of rotational (A) and translational (B) landslides, Source: USGS, 2004.

Earth flows, rock slides, and rock falls occur in Saint Lucia, but are less frequent than debris flows; complex landslides are the least common type. (Quinn, 2012; Rogers, 1997; UWI, 2005) Earth flows occur by a similar mechanism to debris flows, but involve fine-grained materials or clay-bearing rocks, typically saturated with water during precipitation events, although dry flows are also possible. Rock falls are sudden movements of rocks and boulders that detach from steep slopes or cliffs along fractures, joints, bedding planes, or other discontinuities (USGS, 2004).

2.6.2 Historical and observed landslide events

Saint Lucia has a history of severe landslides that have resulted in fatalities, damage to critical infrastructure, agricultural crop losses, and other economic impacts. Figure 2.20 provides an illustrative description of where landslides have been recorded. Most of the landslides occur outside of the study area. Some of the most severe landslide events on Saint Lucia and in the Castries area include the following:

- The 1938 Ravine Poisson and Ravine Ecivisse landslides, which occurred an hour apart in these neighbouring ravines, creating a “sea of mud” that killed 62 and injured 32 people (Quinn, 2012; Rogers, 1997; UWI, 2005).

- The Barre de L'Isle landslide caused by Hurricane Allen in 1980, which severely damaged the East Coast road connecting Castries and Dennery. Repairs to the road cost nearly half a million dollars, severely disrupted transportation between the two urban centres, and negatively impacted the tourism industry (UWI, 2005).
- Landslides initiated by Tropical Storm Debbie in 1994, which caused widespread debris flows that cleared vast amounts of forest and agricultural land. The loss of agricultural land, soil erosion, and infrastructure damage results in a 58% loss of the island's banana crop (Rogers, 1997).
- Island-wide landslides triggered by Hurricane Tomas in 2010 that killed 10 people in Fond Saint Jacques, blocked and destroyed roads, damaged bridges and culvert, and caused an estimated USD$336 million in damage. (ECLAC, 2011; Quinn, 2012). The Bagatelle area to the east of Castries itself experienced rotational and translational landslides that damaged a roadway and rendered many buildings uninhabitable (ECLAC, 2011; Chase, 2012).

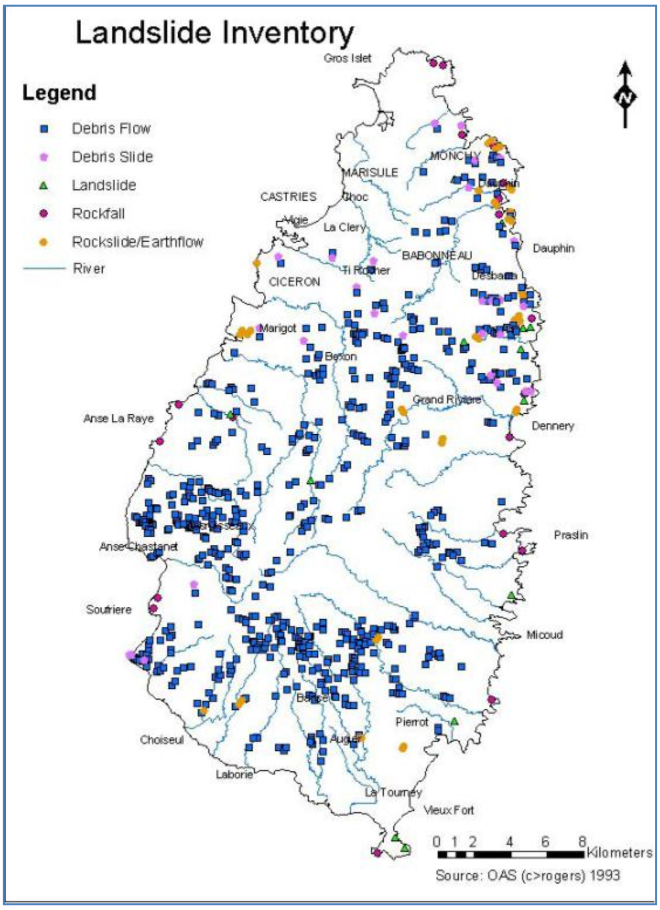


Figure 2.20 Locations of landslide occurrences, Saint Lucia, Source: Provided by the Physical Planning Unit.

In 1985, Saint Lucia spent between USD$38,000 to $146,000, some 2 to 6% of the country's annual road maintenance budget, on clearing landslide debris, depending on the severity of landslide events in a given year (UWI, 2005). Rogers (1997) acknowledged that the incidence and impacts of hazards has risen over time due to increases in the intensity and frequency of low pressure weather systems in the region, and human pressures from deforestation.

2.6.3 Landslide resources

A number of landslide hazard maps have been developed for Saint Lucia (DeGraff, 1985; Rogers, 1997; CIPA, 2006; Quinn, 2012). The CIPA (2006) landslide hazard risk maps for Saint Lucia and Castries were chosen to display current landslide hazards. They provide coverage of the relevant areas and are used by the Government of Saint Lucia to consider areas susceptible to landslides. The CIPA (2006) Saint Lucia map was available in a GIS format, which facilitated assessment and manipulation of the hazard data. However, these maps were not developed using a precipitation factor. Because of this, these maps cannot directly show how changes in future precipitation may impact the landslide hazard. In order to consider how precipitation affects landslide hazards, the Rogers (1997) study is used. This study defines precipitation thresholds that influence landslide hazards.

The CIPA (2006) landslide analysis identified five factors as causing landslides: slope, slope aspect, elevation, geology, and soils. Elevation was used as a surrogate for the influence of rainfall intensity. Maps were developed for each factor using factor susceptibility rankings (e.g., elevation was divided into 7 bins in 50m increments). These maps at the factor-level were combined by reclassifying the susceptibility factors into five categories (very low, low, moderate, high, and severe). All factors were considered equally, except soil whose influence on landslides was considered twice that of the other factors.

Saint Lucia maps. Figure 2.21 shows the locations across Saint Lucia susceptible to landslides at a 1:50,000 scale developed by CIPA (2006) based on DeGraff (1985). For comparison purposes, Annex 2 contains additional hazard maps developed for Saint Lucia by Quinn (2012) and Rogers (1997). The maps generally show a higher level of hazard in the higher elevation, steep-sloped areas of the island, concentrated in the south-western areas of Soufriere surrounding Mount Gimie and the southern portion of the Anse-la Raye Quarter.

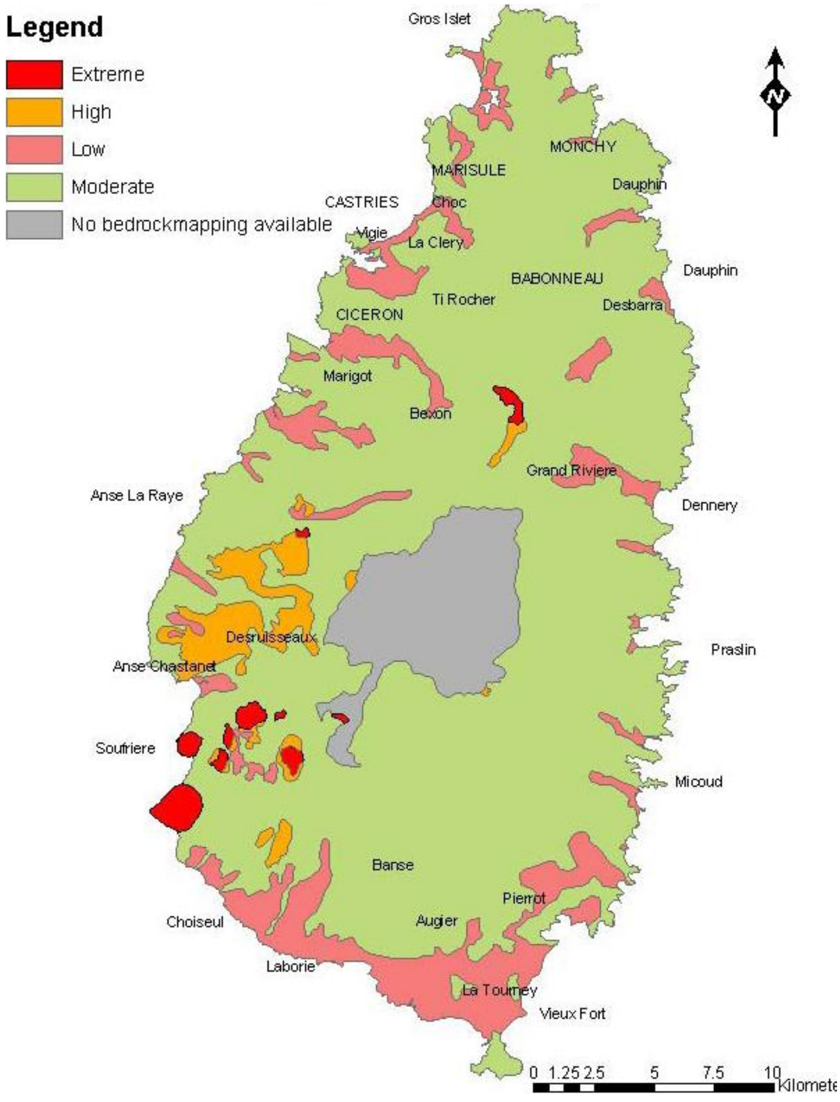


Figure 2.21 Landslide hazard map for Saint Lucia, Soucre: CIPA, 2006 citing DeGraff, 1985; scale 1:50,000.

Also at the island scale, Rogers (1997) established a system for rating the relationship between mean annual precipitation and landslide hazard risk, shown in Table 2.5. This relationship is discussed here as it is used in this study to consider how future changes in precipitation might increase or decrease the level of exposure of susceptible areas to landslides. As stated previously, we were not able to draw from the CIPA (2006) landslide hazard map as it does not directly allow for the influence of precipitation. Areas receiving less than 2032 millimetres of rain annually are rated unimportant to landslide hazard; areas receiving between 2032 and 3048 millimetres are rated very important, and areas receiving more than 3048 millimetres are rated extremely important.

Table 2.5 Mean annual precipitation exposure thresholds

Hazard Rating	Mean Annual Precipitation Class	
	millimetres / year	**inches / year**
Unimportant	< 2032	< 80
Very important	2032 – 3048	80 – 120
Extremely important	> 3048	> 120

Source: Rogers, 1997.

City of Castries maps Figure 2.22 shows the landslide hazard map for Castries showing low to moderate susceptibility in higher density areas of Entrepot, Bagatelle, Ravine Chabot, and Pave where landslides have previously occurred (CIPA, 2006). In Castries, the eastern neighbourhoods of La Pansee, Bois Patal, and Mome Du Don are susceptible to a moderate to high level landslide hazard in most areas, with a severe risk in a small number of steep areas. In the south of Castries, the Pavee and Maynard Hill/Black Mallet neighbourhoods—the site of major landslide events in 1999 and 2005—have a high landslide hazard level (CIPA, 2006). In the southeast of Castries, there is a high to severe landslide hazard in the areas south of Entrepot and Bocage.

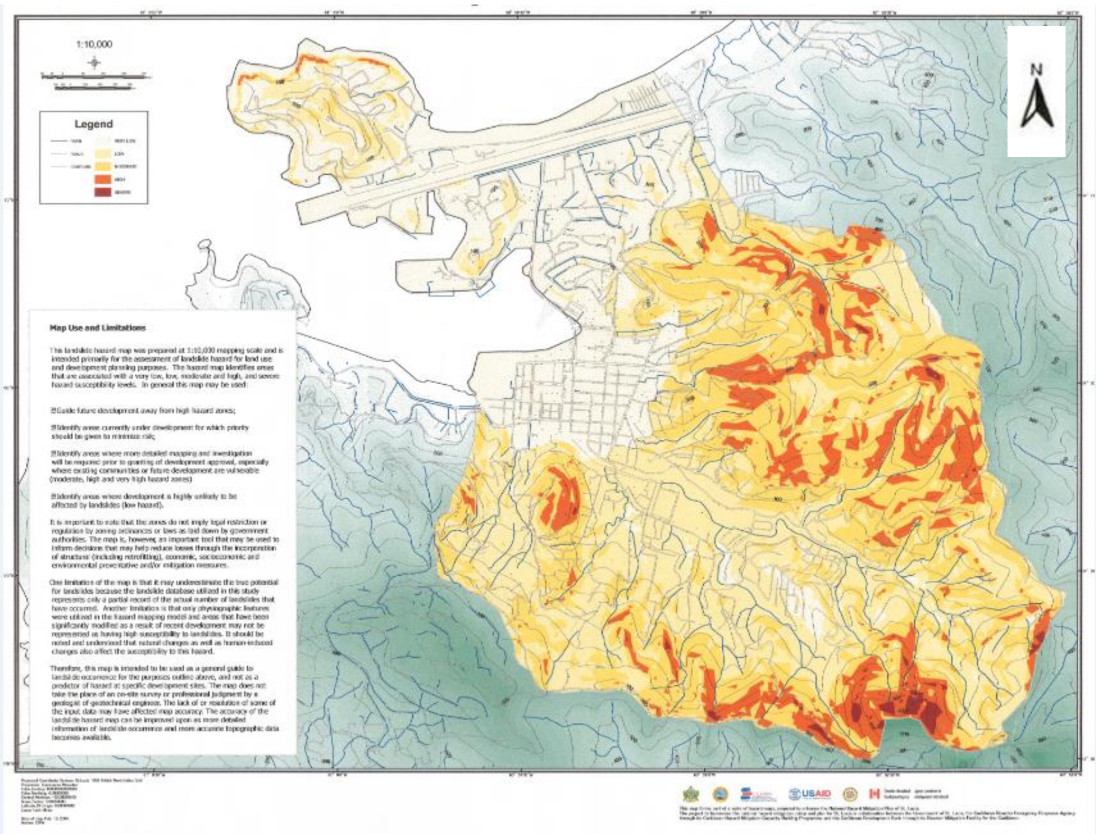


Figure 2.22 Landslide hazard map for the city of Castries, Source: CIPA, 2006.

In a recent study, the historical events were found to generally validate the the maps as to which areas are susceptible to landslides (ECLAC, 2011). However, the accuracy of these maps will depend upon how human activities, such as road construction along steep slopes, deforestation, or urban development into landslide-prone areas, change as these activities can also increase the vulnerabilities of areas to landslides or may serve as a triggering mechanism (UWI, 2005).

2.7 Future hazards

This analysis uses available information and data to identify areas within the study area region that are vulnerable to flooding and landslides. This analysis reviewed available climate change projections and considered their impact on these existing hazards. This analysis does not account for future changes in the landscape (e.g., deforestation or urbanization) that may shift and/or expand current areas threatened by landslides and floods.

As flooding and landslide events for the Castries study area have been connected to storm events and mean annual precipitation thresholds, projections of how precipitation may change under a changing climate can help assess future vulnerability to flooding and landslide events. Runoff is not treated in this analysis given the lack of stream gage sites in Castries (i.e., the existing sites cannot support an adequate record of observed runoff). Unfortunately, there is limited information on how precipitation is projected to change in the future and significant uncertainty associated with those projections. The findings presented should be carefully applied to the municipality planning within the context of the associated uncertainty.

2.7.1 A changing climate

Annual temperature Since 1960, the mean annual temperature for Saint Lucia has increased at an average rate of 0.16^{o}C per decade (McSweeney et al., 2010). This rate is projected to remain relatively constant with about a 1^{o}C increase projected by the 2040s compared to a 1970 to 1999 baseline (see Table 2.5).[10] The minimum and maximum projections for each scenario demonstrate a small range of variability across the individual climate models.

Table 2.5 Annual temperature projections in 2040 for Saint Lucia under Scenario 1 and Scenario 2 compared to a 1970 to 1999 baseline.

	Time Period	Current	Scenario 1			Scenario 2		
			Min	Median	Max	Min	Median	Max
Annual Temperature (^{o}C)	Current	26.4	-	-	-	-	-	-
	2040s	-	26.8	27.3	27.5	27.2	27.4	27.7

Source: calculated based on data from McSweeney et al., 2010.

Annual precipitation Annual precipitation for the 2040s was collected for Saint Lucia. The percent change in future annual precipitation was then applied to a range of observed values. Table 2.6 shows the future change in annual precipitation applied to the current highest and lowest levels of precipitation in Saint Lucia (based on Figure 2.6), and the observed values for the George F.L. Charles airport. By the 2040s, the two scenarios both suggest the George F.L. Charles airport will experience a decrease in annual precipitation of no more than 11 percent compared to a 1989 to 2010 baseline.

Table 2.6 Annual precipitation (in millimetres) for Saint Lucia under current conditions and future climate change scenarios. Coloured shading denotes where precipitation exceeds landslide risk exposure thresholds.

	Time Period	Current	Scenario 1			Scenario 2		
			Min	Median	Max	Min	Median	Max
Charles Airport	Current	1900	-	-	-	-	-	-
	2040s	-	1064	1798	1975	1263	1682	2104

[10] Where Scenario 1 is the climate model ensemble median under the B1 emission scenario and Scenario 2 is the climate model ensemble under the A2 emission scenario.

	Time Period	Current	Scenario 1			Scenario 2		
			Min	Median	Max	Min	Median	Max
Highest Precip.	Current	3004	-	-	-	-	-	-
	2040s	-	1683	2842	3123	1996	2660	3326
Lowest Precip.	Current	1737	-	-	-	-	-	-
	2040s	-	973	1643	1806	1154	1538	1923

Source: calculated based on data from Saint Lucia Meteorological Services; Hijmans, 2005; McSweeney et al., 2010.

Notes: Green shading = Annual precipitation is below 2032 millimetres (i.e., considered unimportant for landslide hazard). Yellow shading = Annual precipitation is between 2032 and 3048 millimetres (i.e., considered an important contribution to landslide hazard). Red shading = Annual precipitation is greater than 3048 millimetres (i.e., considered an extremely important contribution to landslide hazard).

Table 2.6 also shows, however, that for each climate change scenario there are cases where annual projected precipitation is projected to increase relative to current levels. Increases are only projected in climate models that give the highest precipitation results, or in other words, climate models that tend to project the “wettest” future climate out of all available climate models. For both scenarios, the highest projected annual precipitation will exceed the 3048 millimetre threshold, meaning that this level of precipitation would have an extremely important effect on landslide hazard. For the lowest levels of annual precipitation, the projected increases in precipitation are not sufficient to change the hazard ranking threshold, meaning that this level of precipitation would continue to have an unimportant effect on landslide hazard.

Precipitation events The projected change in the 1-day extreme event (i.e., events in the 95th percentile of daily rainfall across all rainfall events) was combined with the observed data at George F.L. Charles airport to investigate how sensitive the change in rain risk may be to future climate. Since the projections are presented for a later time period than the 2040s, the information presented should be considered qualitatively when considering future planning.

In addition to annual precipitation, the amount of precipitation that falls during extreme events is expected to decrease in most projections, ranging from a 26% decrease in rainfall falling during extreme events to a 6% increase. A recent study also suggests the largest one- and five-day periods of rainfall are similarly expected to decline in most projections, ranging from a decrease in 31 millimetres of precipitation to an increase of 13 millimetres (McSweeney, 2010).

Table 2.7 Projected change 1-day extreme precipitation (2.33 RP) for George F.L. Charles Airport (mm).

Time Period	Observed	Scenario 2			Scenario 1		
		min	Median	Max	Min	Median	max
1989-1999	116 mm	-	-	-	-	-	-
By 2060	-	107.7	116.1	118.5	93.6	114.0	121.3
% Change	-	-7.2%	0.1%	2.2%	-19.3%	-1.7%	4.6%
1999-2008	86.8 mm	-	-	-	-	-	-
By 2060	-	78.5	86.9	89.3	64.4	84.8	92.1
% Change	-	-9.6%	0.2%	2.9%	-25.8%	-2.3%	6.1%

Source: calculated based on data from Saint Lucia Meteorological Services; McSweeney et al., 2010.

These results show that the maximum daily precipitation variable may decrease by almost 26% or increase by almost 10% by 2060. The range of projections across emission scenarios suggests the uncertainty associated with plausible socioeconomic futures (each scenario is equally plausible). The projected change under Scenario 2 is close to a 0% change. The projected change under Scenario 1 suggests similar findings for the ensemble average.

Sea level rise and storm surge. Saint Lucia's coastline is likely to become more susceptible to coastal flooding as the climate changes. As sea level rises, infrastructure and other assets at or near sea level may be flooded more frequently or more severely. For example, conversations with the port authority charged with protecting the George F.L. Charles airport suggest that flooding above 6 to 8 feet would inundate the airport runway.

During the 20th Century, global average sea level has risen by 6.7 inches (0.17 meters) (IPCC 2007). A number of studies suggest mean global sea level may rise within the range of 0.5 to 2.0 meters by 2100 with a general consensus of 1 meter (IPCC, 2007; Rahmstorf, 2007; Rohling et al., 2008; Pfeffer et al., 2008; Grinsted et al., 2009; NRC, 2011). Assuming a linear trend in the increase in global mean sea level over the 21st Century, mean global sea level may rise between 0.25 to 1.0 meters by 2050. This range demonstrates the large uncertainty associated with estimating sea level rise. Maurice et al. (2010) suggest that sea level rise for the Caribbean will be close to the global mean. Sea level rise may differ locally due to locally-specific factors such as changes in salinity, ocean circulation, sediment and erosion, and geomorphology (uplift/subsidence). As Saint Lucia is a volcanic island, land movement caused by being tectonically active may also increase or decrease the local sea level rise (Simpson et al., 2010).

This analysis assumes a global mean sea level rise of 1 m by the end of the century. Similar to Rahmstorf (2007), this analysis assumes an increasing linear trend in global mean sea level to 1 m by the end of the century (i.e., a rise of 1.1 cm per year calculated from 1 meter divided by the 90 year period (2010 to 2100). These are approximations as global mean sea level is not apt to rise steadily over the course of the century. This rough approximation suggests a global sea level rise of 38.5 cm by 2045.

With increasing sea level, the water height of the storm surge associated with tropical storms will correspondingly rise, allowing the surge and waves to travel farther inland. This will cause greater shoreline erosion and local damage, in effect magnifying the impact of weaker storms. Though there is much debate regarding how tropical storms may be affected by climate change, there is general consensus that these storms in the Atlantic basin may decrease in frequency but increase in intensity by the end of the century. This section divides future coastal hazards into three distinct investigations: the impact of sea level rise along the study area's coastline, the impact of sea level rise on storm surge, and the impact of tropical storms in a changing climate.

Summary The projected precipitation and temperature changes associated with each of the two scenarios developed for this analysis are summarized in Table 2.8. While there is considerable uncertainty associated with the available climate projections, this first order approach indicates that by the 2040s, precipitation may be reduced, decreasing the possibility of floods and landslides. For Scenario 2, this may be further enhanced by a reduction in the intensity of rainfall during precipitation events, suggesting that there will be more frequent, but less severe rainfall evens in the future.

Table 2.8 Summary of the projected change in temperature, precipitation for the 2040s and 1-day extreme precipitation for the 2060s.

Scenarios	Annual Temperature Change	Annual Precipitation %Change	1-day extreme precipitation
Scenario 1	0.9°C	-5.4%	0.2%
Scenario 2	1.0°C	-11.5%	-2.3%
Sea Level Rise		38.5 cm	

Source: based on data from McSweeney et al., 2010; Rahmstorf, 2007; Grinsted et al., 2009; Rohling et al., 2008; Pfeffer et al., 2008; NRC, 2011.

2.7.2 Changes in future flood and landslide events

Our assessment uses available information and data to identify areas within the study area that may be susceptible to flooding and landslides in the 2040s. This approach largely investigates the changes in hazard areas that are currently prone to flooding and landslides. A streamlined approach is developed, tailored to the available information to consider how climate change may impact each hazard.

These first-order results suggest that coastal flooding will likely become a greater threat in the study area while the future threat of inland flooding and landslides may remain similar to that experienced today. There is a significant amount of uncertainty, however, associated with the projections of climate change that have been used.

Table 2.9 Qualitative summary of change in flood and landslide hazard in Castries by 2040 compared to current levels.

Hazard	Location	Projection	Projected change in hazard
Coastal Flooding	Castries City is coastal and largely at sea level. Much of the city is built upon reclaimed land and can be prone to flooding. The George F.L. Charles airport, situated at approximately 3.4 m above mean sea level and separated from the coastline by only a two-lane road, is prone to flooding from both precipitation and storm surge events due, in part, to poor drainage. Port Castries is approximately 1.5 meters above mean sea level. Changes in the landscape have increased the storm surge experienced in Ganters Bay within Castries Harbor.	Global mean sea level rise: La Toc Bay, Anse Fere, Roseau Bay, Marigot Habour, George F.L. Charles airport, and the southern tip at the entrance of Port Castries. The impact of storm surge and waves will intensity with rising sea level.	↑
Inland Flooding	Due to the steep terrain located throughout the island of Saint Lucia, few areas are potentially prone to flooding. However, “flat” landforms with increased risk are found in the eastern and northern side of the island, as well as in the Gros Islet and Castries coastal plains. In addition, the slopes on the south-eastern end of the north-south ridge are flatter with extensive coastal plains extending from Hewanorra International Airport in the south to Micoud Settlement on the north.	Rainfall may remain about the same as that currently assumed in the inland flood hazard map for Saint Lucia.	—
Landslides	In the Castries study area, the landslide hazard is generally lower than other parts of the island, although there have been notable events that have caused disruption of services and displacement of people in the neighbourhoods of Black Mallet and Maynard Hill.	These projections suggest that landslides may be further reduced as the intensity of rainfall patterns is generally expected to decrease in the area.	↓

The reminder of this section continues the discussion of how the intensity and/or frequency of floods and landslides may change in the 2040s. We used the rankings described in Table 2.10 to distinguish areas on the hazard maps where the projections suggest a reduction, increase, or no change in flood and landslide events. This approach could be broadened and enhanced by engaging local stakeholders to consider how the climate projections presented in this analysis may impact the findings of these maps.

Table 2.10 A ranking system to distinguish areas on the map projected to experience change or no change in landslide and flood hazards.

Ranking	Description of Projected Change in Hazard
⇩	The temperature and precipitation projections suggest that an overall reduction in the intensity and/or frequency of the hazard.
▭	The temperature and precipitation projections suggest that areas prone to the hazard will not change in the future.
⇧	The temperature and precipitation projections suggest that an overall increase in intensity and/or frequency of the hazard.

Changes in coastal flooding

This section uses the available coastal flood tools and the scientific literature to discuss the projected change in coastal flooding due to changes in sea level rise, storm surge, and tropical cyclones.

Coastal flooding due to sea level rise

Soomer et al. (2009) developed sea level rise maps for Saint Lucia based on IPCC (2007) projections (Murray and Tulsie, 2011). The methodology that was used to develop this figure was not available for our review. The maps show the projected coastal setbacks for 2020, 2030, 2050, and 2080 based on the IPCC (2007) global mean sea level rise estimate of 24 cm by the end of the 21st Century (Murray and Tulsie, 2011). The coastal setback lines on the maps illustrate the minimum building line within which construction should be allowed. Though unclear in the map documentation, the projected coastal setbacks appear to be developed by assuming a linear sea level rise over the century from 2009 to 2100 (i.e., a rise of 0.27 cm per year).

These projections are considered very conservative compared to today's state-of-the-science. Due to significant uncertainty associated with future changes in the volume of glaciers and ice sheets at the time that report was written, the IPCC excluded major contributions from those factors in its projections of sea level. These thresholds of sea level rise were, thus, adjusted to account for more recent estimates. This analysis estimates a global sea level rise of 38.5 cm by 2045 (i.e., a rise of 1.1 cm per year).

Table 2.11 includes the year and sea level rise assumed for the sea level hazard maps and links the sea level rise to our estimated year based on the state-of-the science. For example, the coastal setback for 2030 is associated with an approximate global mean sea level rise of 5.4 cm. If we assume instead that global mean sea level will rise by 1.1 cm per year, a 5.4 cm rise would be experienced much earlier, around 2014. For this analysis, we believe the 2080 coastal setback scenario is a reasonable, though conservative, first-order estimate of rise by the 2040s.

Table 2.11 Changes in Sea Level Rise

Assuming 0.24m rise by end of century		Assuming 1m rise by end of century
Year for Coastal Setback Scenario	**Global Mean Sea Level Rise**	**Proposed Adjusted Year for Corresponding Coastal Setback Scenario**
2020	2.7 cm	2011

Assuming 0.24m rise by end of century		Assuming 1m rise by end of century
2030	5.4 cm	2014
2050	10.8 cm	2019
2080	18.9 cm	2026

Figure 2.23 illustrates the coastal locations within the study area that are vulnerable to global mean sea level rise as indicated by the red lines (see Table 2.13). The red areas are coastal areas where the shoreline will recede in response to rising sea level. Not shown are the areas of Saint Lucia outside the study area that are most potentially impacted by sea level rise, including Pigeon Island, Pigeon Causeway, Rodney Bay, and Soufriere (Simpson et al., 2012).[11] Much of the immediate coastline along the northern stretch outline of the study area will be under water. The following areas also appear potentially prone to global mean sea level rise: La Toc Bay, Anse Fere, Roseau Bay, Marigot Habour, George F.L. Charles airport, and the southern tip at the entrance of Port Castries. The central part of Castries does not appear, however, to be at risk.

Figure 2.23 Receding coastline in response to projected sea level rise, Source: adapted from Murray and Tulsie, 2011.

[11] For the entire island of Saint Lucia, a 1 meter sea level rise places 7% of the major tourism resorts, 50% of airports, and 100% of ports at risk (Simpson et al., 2012).

Coastal flooding due to storm surge

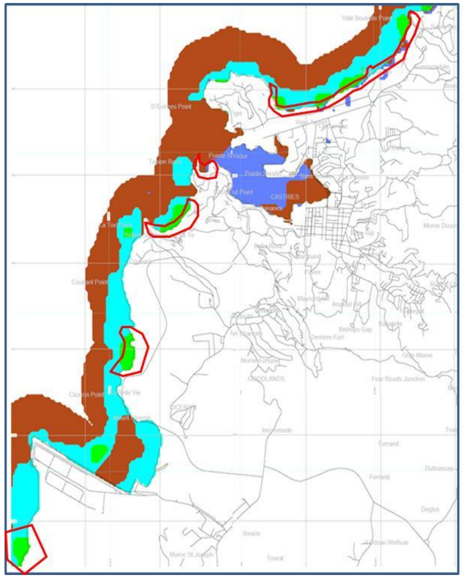
Given the effort and modelling that would be required, we cannot reproduce the coastal flood hazard maps under higher sea level conditions. Instead, we consider how the level of inundation at the coastline may be further impacted under the higher sea level rise scenario. When considering sea level rise effect on the coastal flood hazard maps, the degree of inundation can roughly be assumed to increase by the amount of sea level rise approximated by the 2040s (i.e., 0.385 m). Working with the original data supporting the development of these maps would be ideal since it's difficult to determine where this will, in fact, occur. In addition, this method does not account for heterogeneity of coastline elevation, coastal erosion, or other additional factors that may impact the penetration of storm surge.

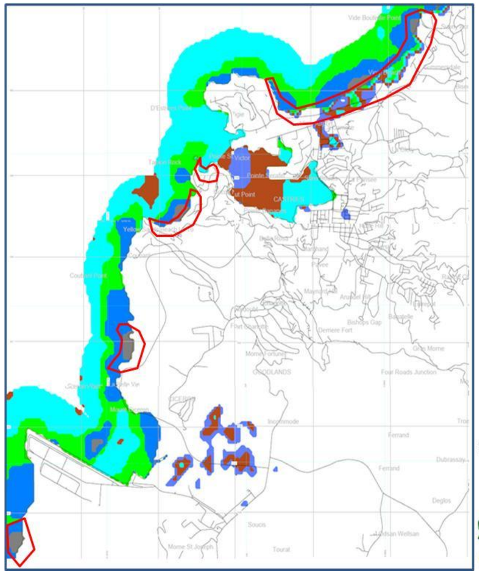
The adjusted coastal flood hazard maps illustrated in Figure 2.24 approximately reflect projected coastal levels that will lead to flooding from storm surge and waves based on future global mean sea level. In addition, the maps include in red the areas identified in Figure 2.24 to be below future sea level rise. Waves are more likely to begin propagating once the water level is sufficiently deep (i.e., approximately 1 meter) (CDB, 2006). Rising sea level will add to each representative storm's water level (e.g., 50-year maximum likelihood estimate, 100-year maximum likelihood estimate). The impact on coastal structures and residential areas in the flood zone will likewise increase.

It is suggested by a report for the Caribbean Development Bank that areas shown to be at risk to:

- Today's 50-year maximum likelihood event are considered highly vulnerable and should not have housing or structures that are not designed to withstand the potential flooding indicated on the map (CDB, n.d. (b)). These new maps suggest higher coastal line inundation will occur
- Today's 100-year maximum likelihood event are considered susceptible and that sea defences and roads be built to withstand the flooding caused along the coastline (CDB, n.d. (b)).

These maps suggest these areas will expand by the 2040s.





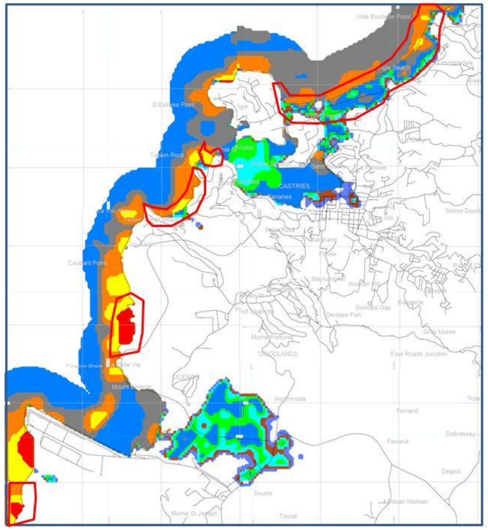


Figure 2.24 The 50-year, 100-year coastal flood maps adjusted to reflect projected sea level rise in the 2040s. The flood levels provided in the legends have been adjusted to include a global sea level rise of 0.385 m. In addition, these maps indicate in red the hot spot areas where the coastline is projected to be below sea level regardless of storm surge. Source: adapted from CDC, 2006.

Tropical storms in a changing climate

There is great uncertainty associated with how tropical storms may change in a changing climate. Over the past few decades, increases in the intensity of North Atlantic hurricanes has been observed and attributed to increased sea surface temperatures, but it is unclear whether these changes are influenced by natural variability or human activity (NRC, 2010; IPCC, 2012).

Global climate model simulations do not adequately represent tropical storms; thus, other finer-scaled modelling is used to simulate future conditions. Many of these studies run Monte Carlo experiments “seeding” their model with tropical waves and depressions off the coastline of Africa and mirroring conditions to reflect those projected by the global climate models (i.e., wind shear and sea surface temperatures).

A recent scientific consensus on tropical cyclonic activity (i.e., tropical storms and hurricanes) describes the globally averaged intensity of tropical cyclones as increasing by 2 to 11% by the end of the century while the globally averaged frequency of tropical cyclones is consistently projected by modelling studies to decrease by 6 to 34% (Knutson et al., 2010). This suggests tropical storms may become stronger but less frequent. This is supported by findings from another study which suggests tropical storms in the Atlantic will experience a 28% reduction in the overall frequency of storms, but an 80% increase in the frequency of major hurricanes (Category 4 and 5 on the Saffir-Simpson scale) over the next 80 years (IPCC, 2012). As discussed previously, an increase in storm intensity does not describe changes in the storm track or directly translate to a greater storm surge. Understanding how tropical storms may change in the future is useful, but provides only a limited contribution to quantitative-based analyses of how climate change may affect coastal flooding.

Changes in inland flooding

Due to climate projection availability, this analysis is limited to projections of maximum daily precipitation by the 2060s relative to a 1970 to 1999 baseline. The projected change for Scenario 2 is close to 0 percent. The variability across the range of climate models used to inform Scenario 2 is not large, with all models projecting less than a 10 percent change to what is experienced today. This suggests that the rainfall “risk” level may remain close to what is currently assumed in the inland flood hazard map for Saint Lucia. The projected minimal change in the maximum daily precipitation variable under Scenario 1 suggests similar findings, though one climate model suggests a noticeable reduction of approximately 20 percent in these extreme events. Overall, these findings suggest that the rainfall “risk” level may remain at the same levels as that currently assumed in the inland flood hazard maps for Saint Lucia.

This analysis was largely limited by not having the capacity to re-run the hydrologic and hydraulic modelling used to inform the flood maps for the city of Castries with future climate projections. Future work in this arena is recommended.

Changes in landslides

To evaluate the influence of future climate change on landslide hazards, we applied the projected change in future precipitation for Saint Lucia from McSweeney et al. (2010) to the regional data on current precipitation across the island to calculate the absolute level of precipitation expected in the future. We then assessed the projected change in annual precipitation against the precipitation exposure thresholds from Roger (1997) to identify areas where the hazard rating was expected to increase or decrease. Finally, we compared these changes in hazard rating against the maps of current landslide hazard (CIPA, 2006) to identify areas that may become more or less susceptible to landslides under future climate changes.

For most climate change scenarios and time periods, the hazard rating is expected to remain constant for both the highest and lowest levels of mean annual precipitation. Although annual precipitation is projected to decrease relative to current levels across most of the scenarios and time periods, the decreases are not large enough to reduce the hazard rating based on the classification system developed by Rogers (1997).

Figure 2.25 shows projections of mean annual precipitation hazard ranking for a series of climate scenarios for the 2040s (see Section 2.6.3 for further discussion of ranking). The projection rankings are based on a summation of the observed mean annual precipitation across the island (see Figure 2.6) and the projected change in mean annual precipitation for the model grid cell which overlays Saint Lucia.

In the 2040s, the contribution of precipitation to landslide hazard decreases compared to current observations across both climate scenarios for most climate models, although precipitation remains an important factor to landslide hazard primarily in high elevations that receive the most rainfall. For the “wettest” climate models —i.e., those that generally predict the wettest future climate out of all models—annual mean precipitation is projected to increase (see Figure 2.23 plots labelled with “max”). These projections suggest a slight increase in precipitation contributing to landslide risk (i.e. the mean annual precipitation crosses the threshold from one hazard rating to the next hazard rating as shown in Table 2.10). However, these increases do not appear large enough to cause precipitation to become an “extremely important” factor in the landslide hazard rating. Though precipitation remains an important factor in landslide hazard in these areas, it does not exceed the threshold at which it would become an “extremely important” contributor to landslide hazard. Consequently, even with the projected increases in annual precipitation, the contribution of precipitation to landslide hazards remains fairly constant for much of the island. The scenarios (see Figure 2.26 plots labelled with “Scenario 1” and “Scenario 2”) suggest Saint Lucia will experience a slight decrease in landslide hazards.

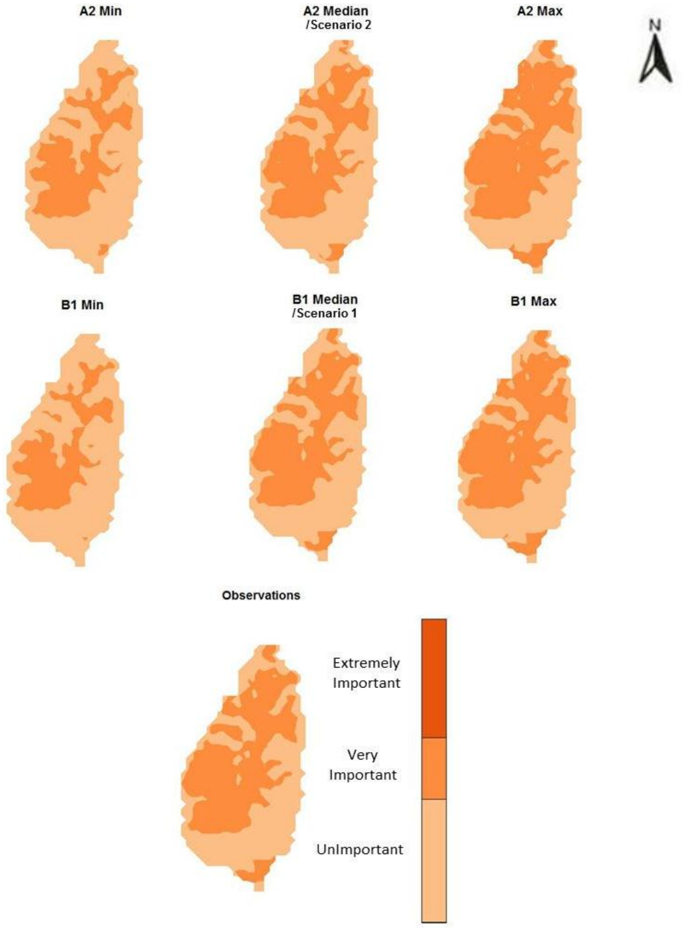


Figure 2.25 Projected 2040 rainfall risk maps based on the algorithm used in the landslide hazard map, Source: we produced these maps based on data from McSweeney et al., 2010; Hijmans, 2005.

By the 2040s, areas within the Castries study area are projected to reduce in landslide hazard in response to reductions in annual precipitation. As discussed, the Castries study area is considered to be within the "low" to "moderate" landslide hazard range. Figure 2.26 illustrates the projected rainfall risk for the climate scenarios and applies the rankings described in Table 2.13 to identify how future hazards may change compared to today. There are slight variations between the scenarios in the areas projected to reduce rainfall risk. The blue areas denote regions where the rainfall risk reduces from "very important" to "unimportant." There are no areas that are projected to increase in rainfall risk. For Castries, in the most landslide-prone areas in the south, east, and southeast of the city, most climate models project that precipitation levels will decrease, which would lessen the overall landslide hazard in these areas.

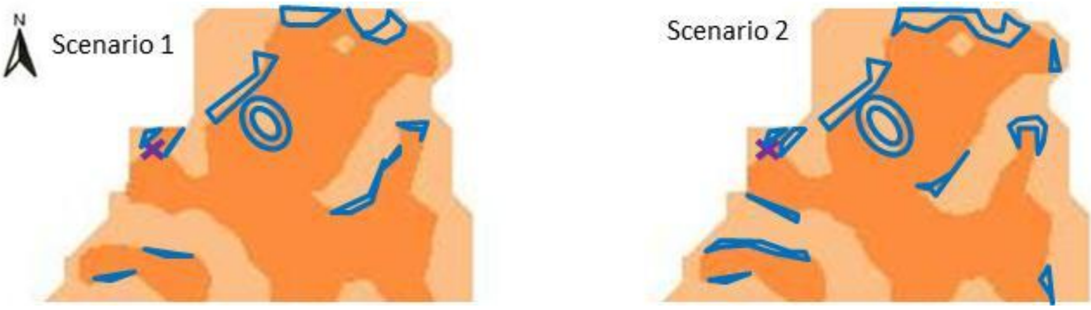


Figure 2.26 Projected 2040 rainfall "risk" maps for the Castries study area based on the algorithm used in the landslide hazard map. The areas denoted by blue are projected to experience a decrease in hazard. The purple "x" approximately marks the downtown Castries, Source: we produced these maps based on data from McSweeney et al., 2010; Hijmans, 2005.

2.7.3 Gaps and limitations

This section provides an overview of the gaps and limitations for each of the three hazard analyses.

The coastal flood hazard assessment is subject to the following data gaps and limitations:

- Sea level rise maps are based upon conservative estimates. These coastal flood level maps were developed using the terrain height relative to mean sea level in open water and, for example, do not include local coastal drainage which could affect the behaviour of waves and flooding in a rising sea level.
- The scientific understanding of how tropical storms may respond to a changing climate is unclear. Warming sea surface temperatures will contribute to strengthening these storms, but changes in wind shear may dampen these storms. In addition, the storm track across the coast of Africa towards the Caribbean may be impacted.
- Simulations estimating how the inundation from storm surge and waves may change under rising sea levels were not available to inform this assessment.

The inland flood hazard assessment is subject to the following data gaps and limitations:

- This analysis used daily precipitation data observed at a single station in the study area located in an area moderately at risk to inland flooding. Basing this analysis on the observations from the George F.L. Charles airport weather station may mask variability within the study area.
- The 10 year flood return period was available for use in this analysis. The use of the additional hazard maps for the 2 year, 5 year, 25 year, and 50 year flood return periods would have been beneficial to identifying additional areas at risk to more extreme events.

This landslide hazard assessment is subject to the following data gaps and limitations:

- As shown in Table F, the landslide hazard maps consider slope angle, curvature, aspect, bedrock and soil type, elevation, and rainfall to show areas vulnerable to landslide hazards. They do not evaluate other factors, such as infiltration, pore-pressure changes, or stability analyses that are related to landslide hazard, and do not model the impacts associated with specific precipitation events based on analyses of historic storm intensity (ECLAC, 2010).

- The landslide hazard maps available for Castries and Saint Lucia generally only represent landslide initiation, and do not consider landslide run-out. During periods of heavy rain, landslide debris flows may be carried a long distance, causing damage or fatalities in areas that are identified as having a low or moderate hazard. (Quinn, 2012)
- Rogers (1997) investigated probable locations for debris flow run-out for primary areas of landslide initiation in specific watersheds in Saint Lucia. The author was only able to assess the path of debris flow travel, since the width and distance travelled by a debris flow depend on the volume of material in the landslide and obstructions in the path of flow, in addition to the slope angle.
- The landslide hazard maps developed for the island of Saint Lucia are generally applicable at a regional level and cannot be used for site-specific hazard assessment at individual properties, except for the city of Castries where localized maps are available. These island maps are primarily intended to help inform planning priorities and identify areas for further study (Quinn, 2012).
- The soil maps used for several of the landslide hazard maps were developed for agricultural or forestry purposes. They may not capture important textural or mineralogical characteristics that affect susceptibility to landslides. (Quinn, 2012) In addition, the soil samples used in the soil maps are typically taken within 1.5 meters of the surface, and consequently do not provide details on internal soil strength, and hydro-geologic characteristics at the depth of typical failures zones in landslides that are typically 2 to 6 meters below the surface (ECLAC, 2011).
- The landslide hazard maps do not include the effects of vegetative cover, previous or current land use, or hydro-geological conditions such as artesian water potential or groundwater conditions, which may have an influence on landslide susceptibility (ECLAC, 2011).
- To evaluate future changes in precipitation, we scaled current, regional precipitation data across Saint Lucia to the mean change in precipitation for the entire island projected in McSweeney et al. (2008). This may over- or under-estimate the actual change in precipitation, to the extent that regional changes differ from the mean change in precipitation across the island.
- Future precipitation projections are associated with a high level of uncertainty; models often differ widely in both the magnitude and direction of changes in precipitation. The level of uncertainty in climate models has been represented by showing the minimum, median, and maximum projected changes in precipitation from an ensemble of 15 climate models for 2040s. This affects the application of the findings of future change in landslide and flood hazards presented in this report.

These projections have focused on change in annual precipitation and the impact that these changes could have on landslide hazard in Saint Lucia and Castries. Extreme precipitation events will also affect landslide risk, but there is a high level of uncertainty in how this relationship may be influenced by the likely decrease in storm intensity. Further examination of specific historical events and landslide hazards may help increase understanding in how individual extreme events contribute to landslide hazard. For example, see ECLAC (2011) for an investigation of landslides cause by Hurricane Tomas in 2010.

3 Urban, social and economic adaptive capacity assessment

3.1 Urban, social and economic context

Saint Lucia's small size and distinctive topography, marked by the presence of a mountainous interior and low-lying coastal land, have directed the way in which human settlements develop (MPDE, n.d.). Human settlements have tended to concentrate on the available land along the coast. This pattern is visible in Castries: the available land for development is actually very limited, and most of the settlements in present-day central Castries sit on reclaimed land (Potter 2001).

The island's shortage of land and topography has shaped Castries's urban landscape. The Human Settlement Vulnerability Assessment Report (MPDE, n.d) clearly distinguishes the three types of human settlements that can be found in Saint Lucia:

- A spatial pattern of urban settlements following the low-lying coastal regions of the island, notably within harbours and bays.
- A development pattern of rural settlements marked by either a scattered and unplanned design or continuous design. These patterns usually start from the coast and tend to go inwards, into ridges, spurs and plateaus.
- A suburban settlements type has emerged. It is marked by the presence of satellite communities or dormitories. These settlements are nowadays present in inland locations within the hinterlands of urban centres.

Castries's urban landscape and layout is composed by a mixture of the abovementioned types of settlements. The city's morphology on the other hand is characterized by the following three types of urban forms:

- Older and traditional settlements located in the existing urban core. This corresponds to Castries City.
- Recent suburban communities adjacent to the core and mainly holding economic and housing supportive functions to it and to the wider mini-metropolitan area. This corresponds to Suburban Castries.
- Urban settlements forming part of the urban area, but marked by unplanned and rural components. This corresponds to Rural Castries.

The northwest urban corridor of Saint Lucia, which includes the Castries study area, predominates in the (spatial) economy of the island. The assessment, of necessity, thus covers the area's economic and spatial dynamics within the national context.

Farrell et al. (2010) point out that many of the Small Island Developing States (SIDS)[12] in the Caribbean, including Saint Lucia, are particularly vulnerable to climate-related hazards due to their "geology, topography, significant coastal urbanization, small climate sensitive economies and lack of significant economic diversity." The *v*ulnerability of economic systems and social processes to climate variability and change could thus compromise the attainment of sustainable development goals.

Although country data shows good overall social indicators, poverty is increasing – on one account from 25 percent in 1995 to 29 percent in 2005/06 (Saint Lucia Country Poverty Assessment, 2005/06). According to data collected by the National Emergency Management Organization (NEMO), the Saint Lucia Red Cross and the Ministry of Housing, the suburban and rural Castries areas has a significantly high proportion of people classified as

[12] The Small Island Developing States (SIDS) group comprises 52 small countries and territories in the tropics and low-latitude sub-tropics. SIDS tend to share similar sustainable development challenges, including small but growing populations, limited resources, remoteness, susceptibility to natural disasters, vulnerability to external shocks, excessive dependence on international trade, and fragile environments (adapted from Wikipedia).

vulnerable[13] (17 percent). Generally, poverty combined with urban concentration leads to increased vulnerability.

3.2 Methodology

For the assessment, a mix of quantitative data and qualitative information is used that was identified during the scoping and identification field visit. Qualitative information supported by the quantifiable data which was collected during consultations and from publicly available reports and other material are both used to discuss a number of issues. These include economic and residential land uses, their interplay, and the connectivity provided by infrastructures as well as the distribution and quality of critical infrastructure networks, including those that extend beyond the urban administrative boundaries, and with special focus on transportation, water and energy. This is set within the trajectory of urban expansion and growth as it is currently taking place in Castries and in the Castries-Gros-Islet (northwest) corridor.

Limitations

There is one key limitation associated with the scale of the information available. The vast majority of secondary material and grey literature focus at the island level and only limited information is available at the local level. For this reason, the data that were collected during the field visit were very important for reflecting to the local characteristics of the study area.

Specific limitations include:

- **Patterns of urban expansion and demographic growth.** Some fast growing urban areas, for example towards the northwest of the island, fall outside the study area.
- **Distribution and quality of critical infrastructure.** We present findings for the water, transport, and energy sectors. These sectors were selected because they rely on resources that fall or are inter-connected with systems outside the study area. Further investigation could examine other critical infrastructures located within the study area, such as telecommunications, hospitals, schools, and police and fire stations.
- **Economic characteristics.** Available economic data and information are not disaggregated at the study area's level and thus a more descriptive and qualitative analysis is employed as necessary. Marine, biodiversity and fisheries were not considered since these activities are mostly concentrated outside our study area and have limited influence to the study area's function.

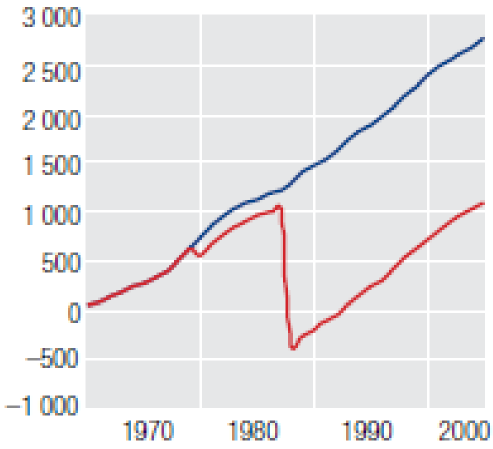
3.3 Economic characteristics

Recent studies have shown that disasters in SIDS can have significant impact on the accumulation of capital stock. Saint Lucia, along with other SIDS Samoa and Grenada, are the three countries in which the ratio of economic losses to capital stock is highest worldwide (GAR, 2009). In Saint Lucia for example, economic losses due to the impacts of Hurricane Allen in 1980 and Hurricane Gilbert in 1986, appear to have set back the country's economy by about 20 years. It was not until 2000 that the island's capital stock recovered to its late 1980s level (see Figure 3.1).

Economic systems in SIDS are thus highly potentially exposed to climate change impacts. Extreme exposure to external shocks such as fluctuations of commodity prices, reductions in access to concessional financing and inflows of foreign direct investment (FDI), along with Saint Lucia's vulnerability to climate-related hazards such as floods and landslides, could have considerable implications to its ability to successfully implement economic policy measures (Juste, n.d.; Terrelonge, 2007).

[13] The vulnerability line is 125 percent of the poverty line. Persons who live in households with per capita consumption expenditure below the vulnerability line are said to be vulnerable (Saint Lucia Country Poverty Assessment – 2005/06).

Figure 3.1 Impact of economic loss in Saint Lucia



Source: GAR 2009. Description: Cumulative net capital formation (NCF) from 1970 to 2006, in millions of constant 2000 US$, with (red lines) and without (blue lines) the effect of economic losses in disasters.

According to the latest Saint Lucia Economic and Social Review, preliminary estimates suggest that the fiscal position of the central government deteriorated in 2011/12 due to what were substantial increases in capital expenditure, including continued spending on Hurricane Tomas-related rehabilitation works. According to the Second National Communication on Climate Change for Saint Lucia, the sectors which have climate change sensitivities accounted for 74.5 percent of the GDP in 2006.

Many point out to the fact that the heightened vulnerability of Saint Lucia's economy to external shocks can be viewed in the context of the historical shift towards a services- oriented economy over the last three decades. For example, landslides initiated by Tropical Storm Debbie in 1994 caused widespread debris flows that cleared vast amounts of forest and agricultural land. The loss of agricultural land, soil erosion, and infrastructure damage resulted in a 58 per cent loss of the island's banana crop (Rogers, 1997).

During the 1980s the island's economy had in fact been driven by the agricultural sector, particularly through banana production. However, during the 1990s, changes in the European Union (EU) import preference regime and increased competition from Latin American bananas resulted in a shift in the island's main economic sector from agriculture to a services-oriented economy, dominated by the tourist industry which contributed 73 percent to the national GDP in 2002 (Walker, 2004).

The share of agriculture, manufacturing and mining and non-services sectors to total GDP has declined consistently from 21.6 percent in the 1980s to 10.9 percent in the 2000 to 2007 period. Since the 1980s the share of the agricultural sector fell from 13.7 percent to 4.6 percent of the GDP. The services sectors, on the other hand, which include tourism, transport, communications, wholesale and retail, banking and insurance and government services, have increased their share from 78.4 percent to 89.1 percent over the same period. In particular, the share of the tourism sector, which includes hotels and restaurants, rose from 9.5 percent to 12.6 percent. Further, tourism earnings account for approximately 68 percent of total exports of goods and services (Juste, n.d.). The historical dependence upon the production of primary commodities, such as bananas until the 1980s, and to tourism since then, has inhibited diversification, and hence the potential resilience of the economy (Bishop and Payne, 2010; forthcoming).

Moreover, the location of economic activity in Saint Lucia has shifted and has now become more coastally oriented. As mentioned above, Saint Lucia's coastline is likely to become more vulnerable to coastal flooding as the climate changes. The Gross Domestic Product (GDP) contribution of coastal economic activities in 2007 (at 1990 constant prices) is estimated at USD 520 million (Government of Saint Lucia, 2008, Economic and Social Review 2007, at page 2 of Statistical Appendix). Investments and employment are also almost wholly coastal (ECCB, 2007). Economic exposure and economic damages will likely increase if new development along the coast is not built to withstand the impacts of rising sea levels and increasing occurrences of floods. For the entire island of Saint Lucia, a 1 meter sea level rise (SLR) places 7 percent of the major tourism resorts at risk (Simpson et al. 2012). A 2 m SLR places 10 percent of major tourism resorts at risk (ibid).

The case study below (Box 6) examines the impacts of climate change and variability to the tourism sector.

Box 6 Tourism sector case study

As mentioned above, the tourism industry is very important to Saint Lucia's economy. The majority of tourism activity takes place along the coast, with most hotels located close to the shoreline, such as the one shown in Figure 2.17 below. Investments in the tourism sector are thus susceptible to climate change and variability.

Further, erosion of the beaches could diminish their aesthetic appeal and reduce the quality of the tourism product, while the loss of the rich diversity of flora and fauna could reduce the revenues from ecotourism. It is also important to take into consideration the value of non-marketed goods and services, such as traditional skills and knowledge provided by the coastal sector, and which would also be at risk from climate change.

Impacts of climate change to coastal tourism include:

- Loss of recreational value and carrying capacity of beaches
- Loss of property value resulting from declining amenity value
- Loss of land use
- Deterioration of landscape and visual appreciation
- Cost of beach and property protection

Figure 3.2 Aerial photo of tourism infrastructure in La Toc Bay, Source: The Physical Planning Section, tile 0648.

Therefore, climate change adaptation requires consideration of this sector. Consideration must also be given to the impacts that can occur as a consequence of adhering to even desirable adaptation strategies. Strictly applied building setbacks can have major opportunity costs for properties currently within these setbacks.

Source: Watson et al., 2000; Terrelonge, 2007.

Bueno et al. (2008) examined the potential costs to the island nations of the Caribbean if global greenhouse gas emissions continue unchecked.[14] Table 3.1 presents the cost of inaction for Saint Lucia. The projected cost of inaction reaches 49.1 percent by 2100, more than double the regional average. It is important to note that economic data in Saint Lucia are not disaggregated at the local level, and thus the assessment covers the economy within

[14] The methodology used by Bueno et al. (2008) is based on the World Bank's 2002 projection of climate impacts on selected Caribbean countries. In particular, they compared projected future climate damages to the 2004 population and gross domestic product (GDP) for each country. This allows them to isolate the impacts of climate change, separated from the impacts of population and economic growth. Damage estimates are projected as percentages of GDP. In the decades to come, GDP will likely be larger than it is today for most or the entire region, so the damages will grow as well. Projections are based on three categories of effects: (i) Hurricane damages, extrapolated from average annual hurricane damages in the recent past ; (ii) tourism losses, assumed to be proportional to the current share of tourism in each economy; and, (iii) infrastructure damages, due to sea-level rise (exclusive of hurricane damage), which are projected as a constant cost per affected household.

the national context. Given that a large percentage of the economic activity, such as services and tourism, takes place along the northwest corridor, and in particular within the Castries study area, the implications discussed here can be seen as analogous for the local economy of the Castries area.

Table 3.1 Cost of global inaction on climate change

Cost of inaction as a percentage (%) of GDP				
	2025	**2050**	**2075**	**2100**
Saint Lucia	12.1	24.3	36.6	49.1
Total Caribbean	5	10.3	15.9	21.7

Source: Bueno et al., 2008. Percentages based on 2004 GDP and represent the High-Impact minus Low-Impact Scenarios.

Table 3.2 presents the projected costs for three categories: increased hurricane damages, loss of tourism revenue, and infrastructure damages.

Saint Lucia's annual cost of inaction in a low impact scenario is projected to total $20 million annually by 2025 and $70 million by 2100. For the high impact scenario, costs are projected to total $100 million annually by 2025 and $410 million by 2100. These costs represent 14.9 percent and 59 percent, respectively, of the current Saint Lucia economy.

Table 3.2 Saint Lucia: Low- and High-Impact Scenarios

Climate change scenarios in billions US$				
LOW-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.00	0.00	0.00	0.00
Tourism	0.01	0.01	0.02	0.02
Infrastructure	0.01	0.02	0.03	0.05
Total	0.02	0.03	0.05	0.07
% Current GDP	2.8%	5.2%	7.6%	10%
HIGH-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.00	0.01	0.01	0.01
Tourism	0.03	0.05	0.08	0.11
Infrastructure	0.07	0.15	0.22	0.29
Total	0.10	0.21	0.31	0.41
% Current GDP	14.9%	29.5%	44.2%	59%

Source: Bueno et al., 2008. Amounts in 2007 US dollars; percentages based on 2004 GDP. Saint Lucia GDP: 0.7 billion US dollars. CTO 2004 Storms: 17 year average (1990–2007), data from Emergency Events Database EM-DAT, using Advanced Search. Tourist Expenditures: Visitor Exports from WTTC 2007 Infrastructure: Haites et al. 2002.

Losses in infrastructure from the effects of sea-level rise are the largest contributor to these costs. These figures provide one indication of the magnitude of potential consequences of unconstrained climate change in the region in the absence of adaptation efforts.

3.4 Urban development, spatial expansion and demographic change

3.4.1 Drivers of urbanization

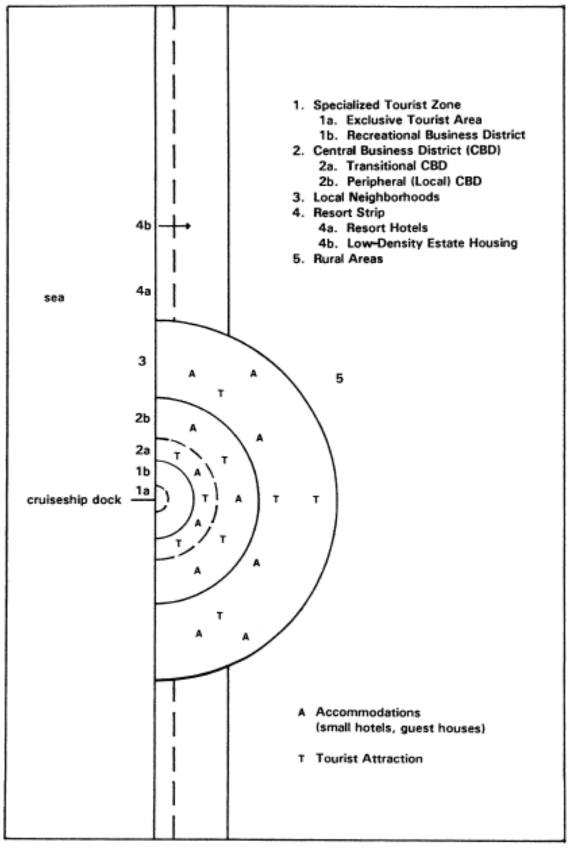


Figure 3.3 The urban tourism city structure, Source: Weaver, 1993.

Saint Lucia's economic shift from agriculture to a services-oriented economy, dominated by the tourist sector, has influenced the way in which urban and suburban development has taken place (Potter, 2001). Indeed, tourism created an appeal for impoverished populations from the rest of the island to move to Castries in the search of better economic prospects.

Studying several Caribbean cities, Weaver (1993) presented an "urban tourism model". This model corresponds in fact to a city structure, characterized by five clearly identifiable areas (see Figure 3.3). These areas include:

- A specialized tourist zone
- A central business district
- Local neighbourhoods
- A resort strip
- The rural periphery.

This structure can roughly be identified in Castries. Central Castries holds the main administrative and commercial functions. The port, where cruise ships disembark, is adjacent to it. As such, central Castries acts as the CBD and a specialized tourist zone. Local neighbourhoods are located in the immediate periphery surrounding central Castries. The suburban and peri-urban periphery extends beyond these neighbourhoods, mostly to the south, east and southeast. The northwest corridor, expanding towards Gros Islet and the northern Cap Estate, concentrates recent tourism infrastructure. It is mainly composed of upscale beach resorts and high-end real estate. This area corresponds to the resort strip, or "elite strip" (Waver, 1993). It is also the area where urban population growth and spatial expansion is occurring most rapidly.

Despite the categorization of this city structure, urban development in Castries often occurs in an unplanned manner. Land tenure patterns and policies as well as the drivers behind urbanization have shaped Castries's urban expansion. Demographic trends as well as land use and planning instruments are essential in understanding the way in which urban development increase exposure to climate-related hazards, such as floods and landslides

Unplanned urban expansion interrelates with topography to influence upon hazard risk. It is thus the way in which urban development takes place that exacerbates risk. Urban development takes place as it occurs 'vertical' (up slopes) and/or horizontally (peripheral expansion). In this context, the anticipated impacts of climate change will likely exacerbate current vulnerabilities of the housing and critical infrastructure sectors.

Figure 3.4 on the next page shows the most urbanized part of the study area, which includes Castries Central, and parts of Castries North, East and South.

Figure 3.4 Aerial photo of Castries. George F.L. Charles Airport, Port of Castries and Castries Central are shown here. Source: The Physical Planning Section. We developed this figure using tiles 0847, 0848, and 0849.

3.4.2 Land use policy and planning

According to our interviews, urban planning on the island is primarily reactive, with very few local (layout or neighbourhood) plans, and no forward (e.g., structure) plans or town planning (zoning) scheme or zoning plan. Development control, on which basis building permits are issued, functions according to practical but limited planning guidelines (Annex 4 provides details). Much construction is, however, outside the purview of the Development Control Authority – and there is apparently little connection with those physical plans that do exist. This is a real problem given that it is not necessarily the concentration of people and critical infrastructure as such that increases risks, but rather the way urban development takes place.

Unplanned urban expansion is related to the existence or inexistence of land use policies. Until 2000, Saint Lucia lacked of an appropriate land use policy (GoSL et al., 2007). The absence of a comprehensive land use policy is of significant importance for urban development patterns. The non-existence of statutory land zoning regulations that establish optimal and coherent spatial distribution allows the appearance of unplanned development. Saint Lucia's land management system lacks an integrated approach. The planning system is reactive and it tends to be sectorally driven (GoSL et al., 2007). Zoning plans and local area development maps are lacking, as is the presence of a housing strategy (MPDE, n.d; Potter 2000).

In effect, this means that Castries's urban expansion is driven to a larger extent by market-driven forces rather than by strategic urban and spatial policy guidelines. In turn, this results in the appearance of informal settlements: as urban development is not guided by coherent expansion principles, settlements can emerge in areas that are neither appropriate nor destined for development. These areas include hilly slopes, often prone to landslides or low lying and coastal areas, exposed to flooding. The lack of adequate land use policy and planning instruments which do not forbid or dissuade populations settling in risk areas thus directly influences hazard risk.

Our research here indicates that there is little overall perspective on the quantum of new development on Castries's suburban and peri-urban fringes that is either – or both – informal and located in at risk areas. Developing this understanding is an urgent task for the country's planning system.

In coastal areas, unplanned development has likely exposed areas to flooding. Institutional frameworks establishing what types of developments are allowed along the coast are virtually non-existent. One of the possible measures to cope with this is adaptation through retreat initiatives. However, these initiatives often present considerable challenges, as they are costly and legally problematic (Simpson et al., 2012). For instance, tourism infrastructure, such as resorts along the coast requires significant investments and cannot be moved easily. Retreat policies should follow an integrated approach including loss of property, land, heritage and high compensation costs for potentially affected businesses and homeowners.

In an attempt to improve its land management system, and with UNDP's assistance, GoSL launched the Land Registration and Titling Program (LRTP) in the 1980s (Williams, 2003). As with many Caribbean countries, Saint Lucia is marked by the existence of a "family-land" system, inherited from the colonial period. The purpose of the LRTP program was to formalize individual land registration (Griffith-Charles, 2004). This would contribute to economic and social development through enhancing land rights and land access. However, the importance of family ties and family transactions hindered individualized formal land registration. Land titling failed to improve the formal structure of the land market.

Acknowledging the issues generated by appropriate regulatory frameworks to guide urban expansion and urban morphology, the Government of Saint Lucia also attempted to address the issue. It started the process for the creation of a National Land Policy (NLP) in 2000 (GoSL et al., 2007). Based on a consultative process, the NLP aims at rationalizing land management and guide urban expansion (MPDE, 2007). Complementary to this, the government also started the process to develop a Coastal Zone Management Strategy and Action Plan in 2004, with the objective to guide development along the coast (Walker n.d.).

3.4.3 Urban poverty

Many authors have highlighted the links between urban poverty, vulnerability and climate change. The lower income population is the most affected population group during a disaster event. The locational dynamics of the urban poor is a key issue in this context. While the middle class is generally (re)locating to the northwest, along the Castries – Gros-Islet northwest corridor, Castries East in particular concentrates 'pockets' of low income population, implying that unplanned, informal or semi-formal residential conditions predominate.

Saint Lucia has been proactive in developing tools to identify poverty areas. The "Basic Needs" index was developed in order to categorize impoverished communities. Box 7 below outlines the methodology, while Figure 3.5, which follows in the next page, is a poverty map of the study area based on the "Basic Needs" index.

The map shows that worse off settlements are located to the south and southeast of the study area. Settlements in the north and west concentrate wealthier communities. It is important to note that the worse off areas are also often areas experiencing fast population growth.

Box 7 The "Basic Needs" Index for Saint Lucia

The "Basic Needs" Index was used for the Saint Lucia 2010 Housing and Population Census. It is a multidimensional index used to measure poverty at the household level. It includes the following variables:

- Wall type, toilet type, light sources as well as household assets derived from questions asked regarding housing conditions (basic services and building material)
- Level of education achieved by the head of the household (literacy)
- Number of persons per room (overcrowding).

These variables assess a household's basic needs. The scores of each household in are then aggregated to derive a total household score for the corresponding community. Subsequently, the total household score is divided by the total number of households within the community to derive the index score.

For more details about the methodology that has been used see: http://www.stats.gov.lc/StLuciaCommunityRanking2010.pdf

Source: Catherine, 2011.

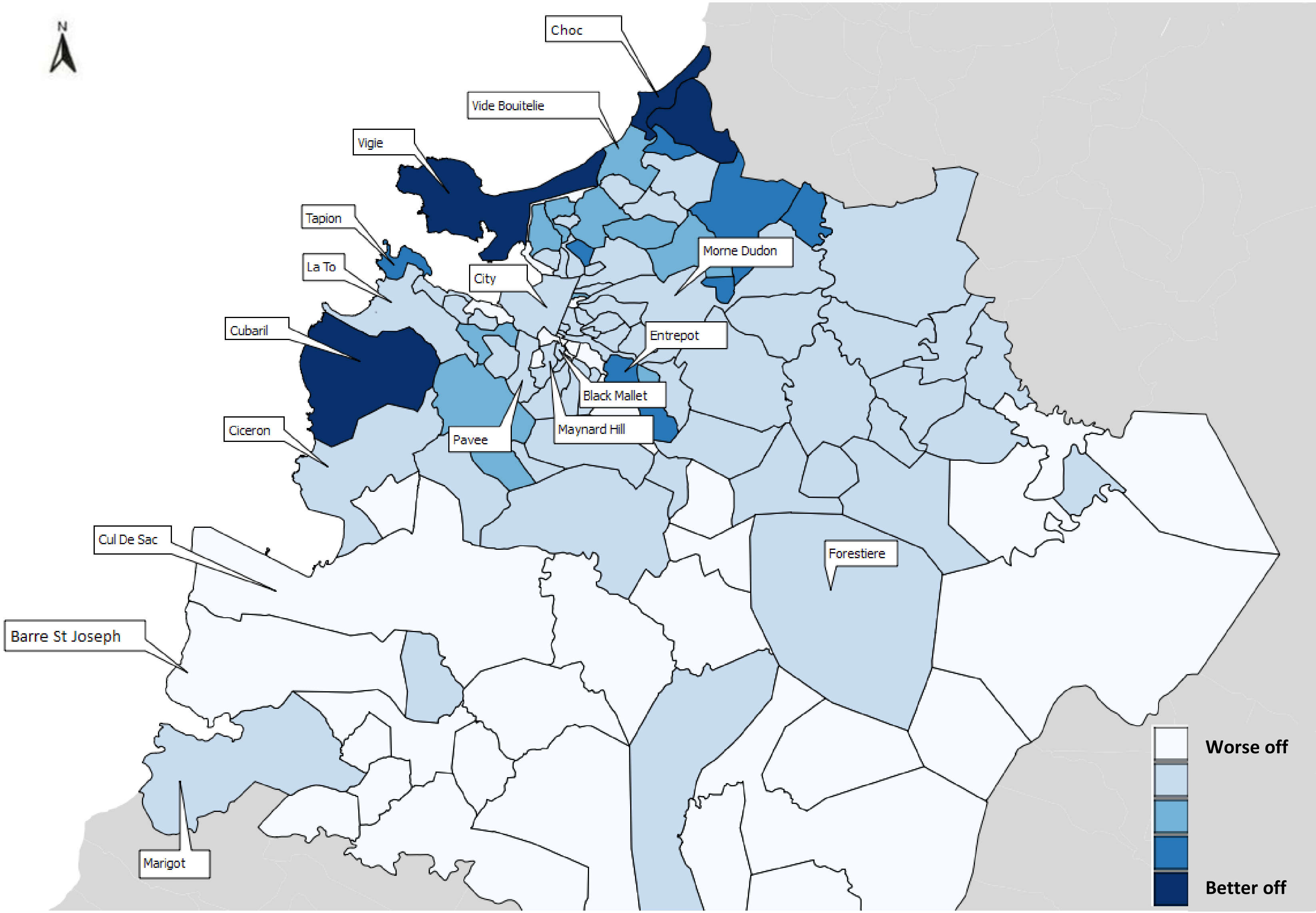


Figure 3.5 Poverty map of the study area. Source: modified from Catherine, 2011, Saint Lucia Population & Housing Census 2010.

Flood-exposed settlements

Settlements located in the centre-north of the study area such as Choc, Vigie, and Vide Bouteille in Castries North concentrate upper middle class/upper class households (Figure 3.5). In these settlements, a large percentage of the households have home insurance, telecommunications and internet access, and houses are built with concrete walls (Table 3.3). These characteristics increase their capacity to cope with disasters.

In contrast, coastal districts located in the south of the study area concentrate both better off and worse off settlements. Tapion, La Toc, and Cubaril in the Castries South constituency are considered to have higher coping capacity, while others, such as Ciceron, Cul de Sac, Barre St Joseph and Marigot, are considered to have lower coping capacity. Nevertheless, in contrast to their northern counterparts, in the southern settlements fewer households have home insurance, while access to information is limited and a smaller percentage of households are built with concrete walls (Table 3.3). As such, the socio-economic characteristics of these settlements make them more vulnerable should a climate-related disaster occur.

Inland flooding mostly affects the district corresponding to Castries City. This district is the commercial and administrative centre of Castries but concentrates some relatively poor households (Figure 3.5). Although a high proportion of building structures are old, most of them are made of resistant materials. Home insurance is also widespread (Table 3.3). As such, despite the district's exposure to flooding, its resilience capacity is relatively high.

Table 3.3 Poverty indicators in households (%) – flood-exposed settlements

Settlement	Population	No internet connection	No home insurance	Land tenure (owned)	Construction year before 1980	Households with concrete walls
Coubaril	257	8.4	9.8	84.2	26.1	84
Cul de Sac	765	72.6	83.6	88	10.1	41.5
Monkey Town/ Ciceron	1,016	78.3	79.4	54.3	5.7	31.6
Barre St Joseph	634	74.2	81.6	37.2	13.2	30.5
Marigot	792	72.4	47.1	47.1	13.8	2.7
La Toc	826	65.1	69.8	32.8	22.1	30.1
Tapion	133	28.8	62.5	74	2.3	3.8
Banannes Bay	364	52.1	60.5	28.7	36	43.8
Faux a Chaud	306	78.3	89.6	0.8	1.2	4.2
Castries City	805	54.3	20.6	28.6	67.6	69.3
Conway	78	82.6	69.4	N/A	20.8	1
Vigie	211	5.4	8.3	73.8	51.6	80.9
Vide Bouiteille	531	52.4	22.4	37.3	26.1	65.7
Choc	5	60	60	40	40	N/A
Saint Lucia	165,595	73.5	N/A	74.3	19.9	51

Source: Saint Lucia Population & Housing Census 2010.

In Castries, several factors interrelate in vulnerability to climate-related risks. The island's distinctive topography, associated with unplanned urban expansion and persistent urban poverty create a context of vulnerability.

Landslide exposed settlements

Communities to the south, east and southeast are often located on unplanned steep hills, and are thus more strongly exposed to landslide risk. This is the case for the settlements of Black Mallet, Maynard Hill, Entrepot, Bocage and Pavee, all falling within the Castries East constituency, Bois Patat and Morne Dudon within Castries North, and La Pansee in Castries Central. These communities also concentrate "pockets of poverty". Urban poverty decreases their resilience: the poor conditions of construction, lower access to basic services as well as the limited financial resources undermines the capacity to go through a crisis without major disruptions.

Timber house structures are the most common type of settlement in the hill-slopes (Anderson et al., 2011). Poor quality and substandard housing provide shelter to a significant percentage of Saint Lucia's urban population. It is estimated that 60 percent of Saint Lucia's settlements are unplanned (Anderson et al., 2011). Although Table 3.4 shows that in Saint Lucia there is an improvement trend in the materials used in settlements, a considerable proportion of the housing stock (31.5 percent in 2010) still consists of low-resilience materials. Squatter settlements characterized by poor construction materials are also a real component in the urban landscape and morphology of Castries.

Table 3.4 Distribution of households by material of outer walls (% of households)

Material	1980	1991	2001	2010
Wood	73.6	53.5	39.9	31.5
Concrete/ Concrete Blocks	12.4	29.7	41	51
Wood & Concrete	8.9	16	17.5	16.2
Other	0.4	0.8	0.6	0.4
Non Stated	4.6	0.1	0.9	0.9

Source: Saint Lucia Population & Housing Census 2010.

Additional variables, such as the access to information, the age of the housing stock and access to insurance, also need to be considered when assessing how poverty may influence vulnerability to climate-related risks. As Table 3.5 shows, the aforementioned districts usually lack access to insurance schemes, have no internet connection (an indicator for access to information), and have housing stocks older than the national average.

Table 3.5 Poverty indicators in households (%) – landslide-exposed settlements

Settlement	Population	No internet connection	No home insurance	Land tenure (owned)	Construction year before 1980	Households with concrete walls
Black Mallet	102	65.4	70.4	45.4	66.7	28.8
Maynard Hill	580	60.2	62.5	48.1	29.8	44.9
La Pansee	448	48	50.7	49.9	28.3	70.4
Bois Patat	425	60.6	63.7	43	27.6	34.3
Morne Dudon	1,284	63.1	64.4	33.5	19.6	34.8
Pavee	1,168	58.9	57.9	51.1	26	39.2
Entrepot	935	35	56.8	56.8	42.6	88.2

Settlement	Population	No internet connection	No home insurance	Land tenure (owned)	Construction year before 1980	Households with concrete walls
Bocage	1,463	56.5	50.7	55.3	9.4	47.3
Saint Lucia	165,595	73.5	N/A	74.3	19.9	51

Source: Saint Lucia Population & Housing Census 2010.

The settlements located on slopes lack of an appropriate surface water drainage provision system (Anderson et al 2011). Although an adequate drainage system existed previously, the unplanned urban expansion that has occurred in Castries in the last two decades has completely outstripped the system (French, 2010). This situation, coupled with the absence of an effective recollection instrument for garbage disposal, block drains. Further, it is important to point out that drainage is not specifically addressed in Saint Lucia's building code (Anderson et al., 2007). And even if it was, it would only incorporate a small percentage of the settlements, as most of Saint Lucia's settlements are unplanned as discussed above (ibid.). Because landslides mostly result from rainfall infiltration, the absence of an appropriate drainage system exacerbates risk, notably in unplanned poor communities. As Hurricane Tomas in 2010 revealed, disaster impacts were more significant in areas marked by the presence of poverty. Poor communities located at steep slopes strongly suffered from landslides (Simpson et al., 2012).

3.5 Distribution and quality of critical infrastructure

Critical infrastructure networks in Saint Lucia are exposed to coastal as well as inland flooding. Key economic and critical infrastructure networks in the Castries study area, including roads, the airport, the seaport, and the fuel storage, are located along the coast or on low-lying reclaimed coastal land (Chase, 2012; MPDE, 2010; Lewsey et al., n.d.). The water and the energy supply networks are further inland, although distribution networks are located nearby human settlements within our study area. Climate change will likely exacerbate the current impacts of flooding; growth in population and tourism will likely compound this impact.

According the Ministry of Physical Development and the Environment (MPDE, 2010) vulnerable areas within the Castries study area include:

- Castries waterfront (surge at east and south sections)
- Airport runways (storm surge, flood)
- Low lying and coastal service stations (storm surge, flood)
- Sewage lift stations in low-lying, coastal areas in Castries
- NEMO warehousing in Castries.

In addition, more attention to issues intersecting along an 'urban (coastal) – rural (inland) continuum' needs to be paid. Rural (inland) areas are important for Castries and the northwest urban corridor as they influence the availability of food through concentrating agriculture production, but are also important for the urban economies, as they concentrate many critical infrastructure networks, important for the day to day life of Castries, such as energy and water supply infrastructure.

The connectivity provided by infrastructures as well as the distribution and quality of critical infrastructure networks, including those that extend beyond the urban administrative boundaries and with special focus on transportation, water, energy and transport, are now discussed.

3.5.1 Water supply and availability

Water supplies in Saint Lucia are highly susceptible to climate variability and change. The capacity of the water management system to respond to water demand is the main cause of concern. Water demand is concentrated in the north of the island where most of the population growth and tourism development takes place. With only one major water storage facility on the island, Saint Lucia is highly vulnerable in situations of lower than normal precipitation (Simpson et al., 2012). For example, Saint Lucia was impacted by the 2009/2010 drought that triggered a state of emergency (UNEP, 2012).

Floods can also be a problem for water resources in Saint Lucia. Flooding can affect water quality, have implications for sanitation, and cause soil erosion. Further, hurricanes can damage water intakes, dams and reservoirs and this can result in decreased water supply and quality (MPDEH, 2001). Increased precipitation can also result in siltation of river courses. At intakes such siltation is sometimes so severe that it takes 3 to 4 days before turbidity levels fall and raw water is at the basic quality which treatment plants can handle (Simpson et al., 2012).

Finally, the Castries sewerage system has lift stations located in areas[15] that are likely to flood during extreme precipitation events, although no problems have been reported in this regard to date, according to the MPDE (2010). The reduction in water quality and flooding is also likely to impact upon health, and for example, increase vector and water borne infectious diseases (Terrelonge, 2007).

3.5.2 Energy supply and distribution networks

Saint Lucia currently depends almost entirely on fossil fuels for energy production and energy efficiency management practices are minimal (Marín et al. 2005). Between 2002 and 2010, diesel consumption increased by 68 percent and aviation fuel use increased by over 300 percent in the same period (Simpson et al., 2012). Energy demand has increased significantly due to recent economic and tourism growth. The potential physical climate change and variability impacts on energy infrastructure as well as the rising prices for fossil fuels worldwide make the energy sector in Saint Lucia increasingly vulnerable to climate change impacts.

The island's power plant is located at Cul de Sac in South-Eastern Castries. Seven substations are distributed across the island. Due to flood risk, the Castries power substation is housed and elevated. According to the Second National Communication (2011), transmission cables are installed underground in urban environments as a precaution against tropical storms and hurricanes, but also for aesthetics. Poles used for overhead cable installation are placed away from slopes to the extent possible to reduce landslide risk. There are 13 fuel stations at the northwest part of the island. These are located in close proximity to the coastline, although none are highly vulnerable to storm surge. A number of fuel stations in the low lying Castries urban area may be prone to flooding (MPDE, 2010).

Energy infrastructure in Saint Lucia in general, and Castries in particular, is thus exposed to impacts from coastal and inland flooding, as well as high winds during tropical storms and hurricanes. An increase in the intensity and possibly frequency of hurricanes has the potential to affect both energy production and distribution infrastructure, such as generating plants, transmission lines, and pipelines. For example, high winds during Hurricane Tomas in 2010 damaged transmission lines and poles, while the Union substation (adjacent to the north boundaries of our study area) was also damaged from inundation (UNECLAC, 2011). Erosion of river banks, inland flooding and landslides can also damage poles and other related infrastructure.

[15] Areas include Independence City, Entrepot School, Queens Lane, Jeremie Street and Sans Souci.

Figure 3.6 Aerial photo of Hess Oil Terminal in Cul de Sac, Source: The Physical Planning Section, tile 0645.

3.5.3 Transport infrastructure

Flood and landslide impacts to infrastructure in Saint Lucia could result in disruption of transport networks. The road infrastructure suffered badly from the effects of Hurricane Tomas in 2010, particularly to the east and south of Castries. The Barre de L'Isle landslide caused by Hurricane Allen in 1980, although not in the Castries study area, severely damaged the east coast road connecting Castries and Dennery. Repairs to the road cost nearly half a million US dollars, severely disrupted transportation between the two urban centres, and negatively impacted the tourism industry (UWI, 2005).

Figure 3.7 below shows the areas of the island that were most seriously affected during Hurricane Tomas.

Figure 3.7 Sections of roadway affected by Hurricane Tomas are highlighted in blue, Source: Critical Infra 2010.

Saint Lucia's coastline is likely to become more vulnerable to coastal flooding as the climate changes. As sea level rises, infrastructure and other assets at or near sea level may be flooded more frequently or more severely. For the entire island of Saint Lucia, a 1 meter sea level rise places 50 percent of airports and 100 percent of ports at risk (Simpson et al. 2012).

The George F.L. Charles airport, situated at approximately 3.4 m above mean sea level and separated from the coastline by only a two-lane road, is prone to flooding from both precipitation and storm surge events due, in part, to poor drainage. This airport primarily serves small, short haul aircrafts serving the Caribbean area. Despite being a smaller airport, this airport processes a larger volume of traffic than the Hewanorra International Airport in Vieux Fort at the far south of the island (Critical Infrastructure, 2010). In this sense, the airport (along with the port) is particularly important for connecting Castries and the northwest urban corridor to the rest of the Caribbean. This also means that the airport can also serve as the only operative transport network in case of Castries is disconnected to the rest of the island for example, due to road infrastructure disruptions.

Hurricane Dean in 2007 caused storm surge that washed sand onto the adjacent road and into the airport site, creating a barrier near the existing terminal. Eroding sea defences that have been weakened and ineffective during past storm events have compromised the west end of the runway (King-Joseph 2010). Nevertheless, the G. F. L. Charles Airport runway has never been closed as a result of surge or flood (MPDE, 2010).

Port Castries is approximately 1.5 meters above mean sea level. Changes in the landscape have increased the storm surge experienced in Ganters Bay within Castries Harbor. The Castries docks have withstood past storm surges without sustained damage. A breakwater structure was built to reduce the impact of waves breaking against the eastern harbour front and on to the primary road next to the government buildings. However, during Hurricane Dean, waves transported boulders in the breakwater structure onto the roadway. Large vessels return to open waters during storm events but can be at risk from floating debris that drains off the island into the harbor. As with the case with the airport, operations at Port Castries have never entirely stopped due to flooding (MPDE, 2010).

3.6 Social and economic impact upon disaster risk

Overall, the urban social and economic adaptive capacity assessment of Castries can be summarized in the following table (Table 3.6). It describes key characteristics that impact upon climate related disaster risks, such as floods and landslides. A qualitative codification is applied to each characteristic: minimal (it is unlikely that this characteristic will impact upon hazard risk), moderate (it is likely that this characteristic will impact upon hazard risk), and significant (it is highly likely that this characteristic will impact upon hazard risk). Classification follows a subjective, multi-criteria approach. The level of influence assessment is thus based on a combination of stakeholder meetings, secondary literature and the institutional mapping and rapid diagnostic developed in the first phase of the initiative.

Table 3.6 Socio-economic characteristics that impact upon climate related disaster risks

Characteristic	Description	Level of influence
Location of economic assets and human settlements	Saint Lucia in general, and Castries in particular, has experienced significant coastal urbanization. The location of economic activity in Saint Lucia has shifted and has now become more coastally oriented. At the same time however, settlements appear in the hill-slopes in the peripheral suburban areas of Castries.	Significant
Demographic change	Population in Castries City and Castries Suburban areas is actually reducing over time. Castries Rural is the area that is experiencing the fastest demographic growth, along with Gros Islet.	Minimal
Economic characteristics	Disasters in SIDS, such as Saint Lucia, can have significant impact on the accumulation of capital stock. For example, economic losses due to the impacts of Hurricane Allen in 1980 and Hurricane Gilbert in 1986, appear to have set back the country's economy by about 20 years. It was not until 2000 that the island's capital	Significant

Characteristic	Description	Level of influence
	stock recovered to its late 1980s level. Further, the historical dependence upon the production of primary commodities, such as bananas until the 1980s, and to tourism since then, has inhibited diversification, and hence the potential resilience of the economy.	
Spatial expansion	Urban development in Castries often occurs in an unplanned manner. Unplanned urban expansion interrelates with topography to influence upon hazard risk. In effect, this results in the appearance of informal and squatter settlements: as urban development is not guided by coherent expansion principles, settlements can emerge in areas that are neither appropriate nor destined for development. These areas include hilly slopes, often prone to landslides or low lying and coastal areas, exposed to flooding. The lack of adequate land use policies thus influences hazard risk. It is because land use planning instruments are absent that populations settle in risk areas.	Significant
Urban design and characteristics of low-income housing	Timber house structures are the most common type of settlement in the hill-slopes. Poor quality and substandard housing provide shelter to a significant percentage of Saint Lucia's urban population. Although in Saint Lucia there is an improvement trend in the materials used in settlements, a considerable proportion of the housing stock (31.5% in 2010) still consists of low-resilience materials.	Significant
Urban infrastructure	The settlements located on slopes lack of an appropriate surface water drainage provision system. Although an adequate drainage system existed previously, the unplanned urban expansion that has occurred in Castries in the last two decades has completely outstripped the system. This situation, coupled with the absence of an effective recollection instrument for garbage disposal, block drains.	Significant
Critical infrastructure networks	Critical infrastructure networks in Saint Lucia are exposed to coastal as well as inland flooding. Key economic and critical infrastructure networks in the Castries study area, including roads, the airport, the seaport, and the fuel storage, are located along the coast or on low-lying reclaimed coastal land. Rural (inland) areas are important for Castries and the northwest urban corridor as they influence the availability of food through concentrating agriculture production, but are also important for the urban economies, as they concentrate many critical infrastructure networks, important for the day to day life of Castries, such as energy and water supply infrastructure.	Moderate
Urban poverty	While the middle class is generally (re)locating to the northwest, along the Castries-Gros-Islet northwest corridor, Castries East in particular concentrates 'pockets' of low income population, implying that unplanned, informal or semi-formal residential conditions predominate. In contrast, coastal districts located in the south of the study area concentrate both better off and worse off settlements. Communities to the south, east and southeast are often located on unplanned steep hills, and are thus more strongly exposed to landslide risk.	Significant

4 Institutional adaptive capacity assessment

4.1 Institutional context

Although classified as a medium-sized city, Castries is the capital of St Lucia and the largest urban centre on the island. Its economic and administrative importance in the small island state gives Castries a central role in the institutional and governance structure of the country. The city's prominence as the only major urban hub on the island has resulted in synonymy between planning and administration structures at the central government and city level, with the same government institutions and policy frameworks serving both national and sub-national scales of operation. Risk management in Castries is, therefore, a direct function of national government, with little authority devolved to city level administration. An examination of climate change adaptation and institutional risk management practices in Castries is necessarily an investigation of the jurisdiction and management of risk in St Lucia as a whole.

Like most small and medium cities, development and expansion in Castries is closely linked with economic and social activity in its surrounding suburban, peri-urban and rural areas. The rapid rate of urbanization and expansion of city limits has resulted in ambiguous physical and administrative boundaries of the city, with Castries City proper functioning only as a commercial and administrative district. Although much of the critical physical and financial infrastructure of the island, including government offices, banks, and the sea port, is located in Castries city centre, the main airport as well as the island's agricultural, tourist, telecommunications and power infrastructure is found outside of the city. Residential neighbourhoods also lie outside Castries central, making the maintenance of transport and communications links between central and suburban Castries critical for business continuity and ongoing economic and social activity in the city, especially during emergency situations. The parity of national and urban risk management institutions in St Lucia, and the influence of surrounding socio-economic activity and geo-physical environment on risk and vulnerability in Castries offer interesting insights into some of the challenges encountered in adapting to climate change in small and medium-sized cities.

4.2 Methodology

Data collection for this institutional assessment was based on three phases. The first phase utilized background data provided in the local consultant report from the initial rapid diagnostic, along with other relevant secondary data and reports. The second phase was undertaken during the preparatory scoping visit, where interviews with key informants were used to characterize the background institutional architecture and culture of decision-making for risk management in Castries, verify the appropriateness of the overall framework, and identify any remaining written data sources. Additionally, the visit was used to contact a wider range of stakeholders from government agencies, civil society and the private sector that were willing to complete the questionnaire survey. In the third phase, the questionnaire survey was circulated to these respondents, and the results collated with all other collected data.

4.2.1 Background data

For Saint Lucia and Castries, a good proportion of the required data was available through documentary evidence – dates and extent of legislation, urban planning guidelines etc. The primary source for this type of information was the report prepared by local consultant Vasantha Chase. Using desk based research and interviews with key stakeholders, the report provided a detailed diagnostic of the relevant institutions and policy frameworks for climate change adaptation and risk management in St Lucia. A list of available documents, reports and policy resources was also provided. Although the report provides data for the mapping of risk institutions for St Lucia and Castries, further data was required in order to assess the efficacy and robustness of risk management structures, and their potential to adapt in the context of increasing climate change risk. Interviews using the Adaptive

Capacity Index were conducted during the preparatory scoping visit to provide this information.

4.2.2 Adaptive capacity tool

For the analysis of the institutional context and capacity for adaptation building, the consultants deployed the Adaptive Capacity Index (ACI) developed for the EC FP7 project MOVE, which assesses institutional adaptive capacity for climate change and multi-hazard disaster risk at the local and national levels. The ACI seeks to measure disaster risk management in terms of the perceived performance of public policy and adaptive capacity for four fields: risk identification, risk reduction, disaster management, and adaptive governance. Each policy field is evaluated using the benchmarking of a set of sub-indicators that reflect performance targets associated with the effectiveness of disaster management activities. The participation of external experts as well as disaster managers in validating the quality of specific activities and capacities is incorporated to minimise bias. Each of the four elements of the framework identified above is populated by four sub-indicators. A detailed list of the variables can be found at http://www.move-fp7.eu/. The table below illustrates the framework structure of the ACI.

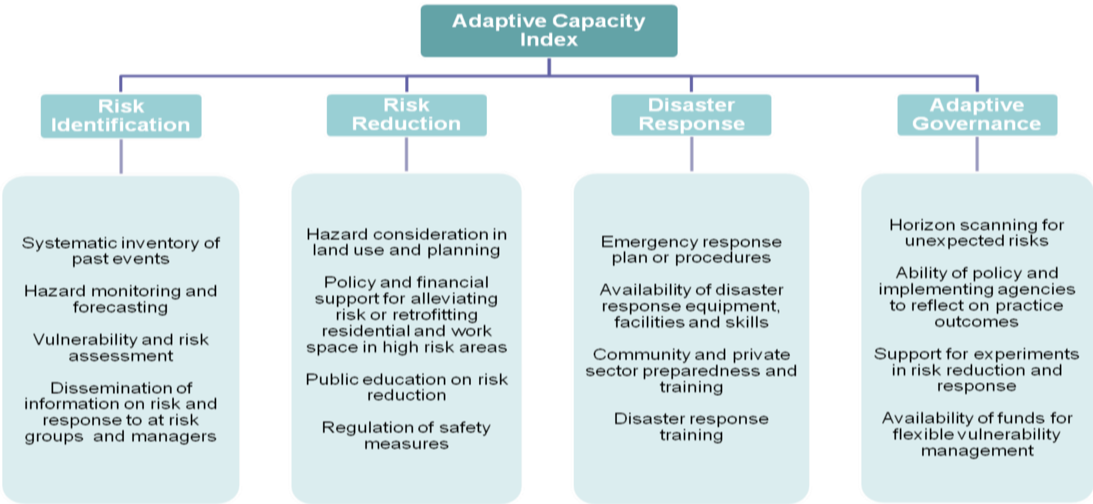


Figure 4.1 Framework structure of the ACI

The ACI was presented in questionnaire form to match the data collection needs of this project. The questionnaire survey is a single tool with different methods of data collection. In Castries, it was used by our team as a framework for discussion on the institutional risk management system with key respondents during the scoping visit. In addition to one-on-one interviews, a shortened version of the survey was emailed to some respondents identified during the initial visit. The combination of the two types of survey responses allowed for a wider sample of stakeholder groups, as well as providing a detailed discussion of risk management mechanisms in Castries.

A quantitative (though relativistic) assessment of each of the four topic areas in the ACI questionnaire was developed using the following performance levels:

- Limited (No formalized capacity; Activity is ad hoc, very infrequent and not planned or captured by strategy)
- Basic (A low level of formal capacity. Activity is planned. Action is infrequent and superficial, below the levels or intensity required to make a concrete difference to outcomes)
- Appreciable (A modest level of formal capacity. Activity is planned and strategic. Action is regular and outcomes can be identified but are limited in the depth of impact)
- Outstanding (Strong formal capacity. Activity is planned, strategic and integrated into all major sectors. Action is frequent, outcomes have made a clear difference to risk and its management), and

- Optimal (Very strong formal capacity. Activity is planned, strategic, integrated and a part of everyday practice. Action is constant, and outcomes have reshaped risk and its management and continue to do so in continuous cycles of activity).

Assessment of each topic area was also differentiated across prescribed time periods to generate a trajectory of capacity over time and assess how these trajectories are changing for different sample groups (e.g., public or private sector). The years 2000, 2005 and 2012 were selected as benchmark years, with a total time span of 12 years regarded by stakeholders as sufficient for capturing recent hazard events and for demonstrating trends in disaster risk management (while recognizing the limitations of institutional memory in each organization). The benchmark dates successfully reflected transformations in policy and capacity that occurred after important disaster events such as Hurricane Tomas in 2010.

There were an insufficient number of completed questionnaire surveys to attribute a numerical value to each performance level in order to derive a quantitative representation of management performance. However, the qualitative data generated using performance indicators was adequate in allowing for a direct comparison of performance across organizations and time. In addition, interviewed respondents were also asked for statements describing examples of capacity or of capacity changing tools or events. This discussion-review process served as a verification tool for the qualitative performance assessments, and was an important way of revealing cross-cutting and influential practices that could be transferred to other participating cities in a process of horizontal learning.

A final stage of the methodology will be local verification of findings. The findings of the assessments report will be presented to respondents to provide scope for additional input and as a verification exercise.

4.3 Policy instruments

4.3.1 National

Climate change-relevant policy in Saint Lucia is driven by international, regional and domestic imperatives. As a party to the United Nations Framework Convention on Climate Change (UNFCCC), Saint Lucia participates in negotiations on issues that have ramifications for national policy. Likewise, as a member of the Caribbean Community, (CARICOM) with a leading role in climate change issues; and as member of the Organisation of Eastern Caribbean States (OECS) and a signatory to the Saint Georges Declaration of Principles for Environmental Management in the OECS (SGD), Saint Lucia has an obligation to implement certain policy measures at the national level. For example Saint Lucia’s National Environment Policy and National Environmental Management Strategy (NEP/NEMS) have their origin in the SGD. In 2011, the country developed a Strategic Programme for Climate Resilience as part of a Pilot Programme for Climate Resilience. This initiative seeks to mainstream climate change adaptation into all aspects of development planning and practice in St Lucia.

Saint Lucia has undertaken, or is in the process of undertaking, projects that have generated policy outputs or that demonstrate clear policy stances on climate-relevant issues. These include the Caribbean Planning for Adaptation to Climate Change (CPACC), Adapting to Climate Change in the Caribbean (ACCC) and Special Programme on Adaptation to Climate Change (SPACC) projects. Under the SPACC Project in Saint Lucia for example, local actions are being implemented through two subcomponents that address the (i) sustainability of water resources and supply of the Vieux-Fort Region and (ii) the strengthening of critical coastal Infrastructure in the Castries area.

On the other hand, domestic issues, at times driven by sectoral requirements, have led to the formulation of policy instruments such as the National Water Policy. At the national level, the National Climate Change Policy and Adaptation Plan (NCCPAP) is the first policy instrument formulated to specifically address climate change, while the draft Environmental Management Bill is the first piece of proposed national legislation that makes specific legal provisions for climate change actions. National policy instruments with direct and indirect relevance are many and varied and, include, in addition to the foregoing: the Sustainable

Energy Plan (SEP), the National Energy Policy (NEP), the draft National Environmental Education Policy (NEEP) and the draft National Environmental Education Strategy (NEES).

Due to the intensity of natural disasters between 2001 and 2006, Saint Lucia and other Caribbean countries realized the need to develop sound initiatives in disaster loss reduction. This led to the creation of the Enhanced Comprehensive Disaster Management Framework (2006-2012), targeting disaster loss reduction through risk management and introducing a program-based approach with a special focus on Results Based Management. Additionally, Saint Lucia has engaged in several regional initiatives in disaster risk reduction. Notably, the country is part of the Caribbean Disaster Management Response Agency Agreement. This scheme seeks to provide institutional strengthening, capacity building and technical assistance in disaster management to its participating members.

Saint Lucia has rich and articulated legal and policy frameworks for disaster risk management which include: a Disaster Preparedness and Response Act (No.13 of 2000) which sets the legal and administrative framework for the role of the National Emergency Management Office (NEMO), a number of policy documents providing strategies and guidelines for disaster mitigation and response, and hazard and sector specific plans. In particular the Hazard Mitigation Policy is the strategic instrument for integration of risk reduction into all aspects of private and public sector activities including those of local communities and individuals. The key objectives of the policy are:

- to encourage the incorporation of hazard mitigation measures in all public and private sector development planning initiatives and programme budgets;
- to foster a collaborative approach to hazard risk reduction among all stakeholder groups;
- to empower local community groups, institutions and individuals to undertake hazard mitigation measures;
- to increase the awareness of hazard mitigation at every level of society and encourage their involvement in hazard risk reduction;
- to develop an effective and comprehensive legislative and institutional framework that supports hazard mitigation.

The policy mandates line departments for planning and enforcement of risk mitigation in the relevant sectors. Challenges for implementation include strengthening human and institutional capacities; public education and outreach, financial constraints and lack of appropriate information and communications systems for multi-sectoral decision making.

Much of the legislation addressing aspects of Disaster Management is old and therefore does not address the effects of climate change. The revised legislation is in actuality a renumbering of statutory instruments, which address a series of declarations, with no effort at substantive changes. However a series of plans, policies, procedures and programmes are increasingly addressing the effects of climate change and have begun to lay the framework for action.

An initial National Emergency Management Plan was first approved by the Cabinet of Ministers in 1996. It is regularly reviewed and its latest version in 2007 has now begun to address the effects of climate change through such documents as the National Climate Change Risk Register, the National Hazard Mitigation Plan, and draft versions of a Hazard Mitigation / Climate Change Policy, and a Hazard Mitigation National Action Plan.

Saint Lucia has also made efforts to improve its insurance system to cope with the aim of improving its response to natural disasters. As part of the Hyogo Framework for Action 2005-2015, that establishes the need to “promote the development of financial risk sharing mechanisms, particularly insurance and reinsurance against disasters,” Saint Lucia participated with 16 other CARICOM countries in 2007 in the creation of a multi-country pooling facility, the Caribbean Catastrophe Risk Insurance Facility (CCRIF). Through the adoption of a regional Strategy and Results Framework for Comprehensive Disaster Management (CDM), CCRIF seeks to bond CDM to development decision-making and planning.

A number of steps have been taken in Saint Lucia with regard to the transfer of environmentally sustainable technologies. In 2003, a Climate Change Technology Needs Assessment (CCTNA) was conducted for Saint Lucia in order to determine the country's priority environmentally sustainable climate change technology needs. With regard to adaptation, the CCTNA addresses a number of sectors, namely: coastal zone, freshwater resources, tourism, agriculture, health, human settlements and disaster response. For mitigation, the CCTNA addresses energy generation, road transport, new and renewable energy and land use, land use change and forestry (LULUCF) and wastes. The CCTNA identifies adaptation and mitigation options, development benefits, technology needs and barriers to the transfer or adoption of these technologies.

Numerous persons in Saint Lucia, largely through the support of the SDED, have benefitted from national, regional and international training exercises and programmes. This includes public and private sector individuals in various areas related to climate change. In addition, some agencies have benefitted from the acquisition of equipment or data.

Overall, although Saint Lucia has a rich policy framework creating a disaster risk management system, most of the implementation work of agencies concentrates on disaster response and recovery. Climate change adaptation is a relatively new policy topic, which has yet to be mainstreamed into risk or urban management practice.

4.3.2 City level

Reflecting the limitations of city level institutions, currently there are no planning instruments available for climate change adaptation and risk management exclusive to the scale of urban Castries. Urban planning remains weak in Castries, with no forward-looking town planning or zoning. Development control is poorly regulated and the Development Control Authority has severely limited resources and no legal mandate for implementing planning regulations. Castries City Council also has limited responsibility for post-disaster recovery, and does not play a role in disaster risk reduction or climate change adaptation planning. Recently, the Constituency Councils Act has been passed in 2012, which redefines the urban boundaries of Castries. However, awareness of the Act's existence is low even across government institutions, and it is not clear whether clarifications on the city limits of Castries will be accompanied by a reconfiguration of the responsibilities of Castries City Council or the Development Control Authority.

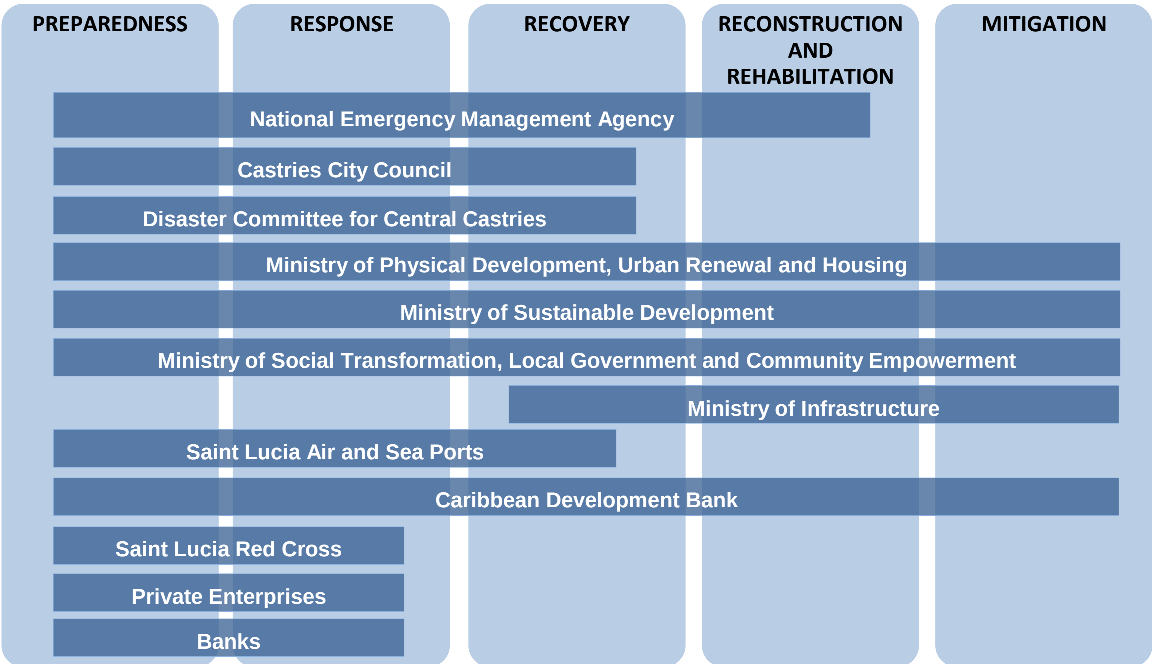


Figure 4.2 Organogram of risk management institutions in St Lucia, Source: adapted from Chase, 2012.

4.4 Institutional mapping

4.4.1 National

Following the directives of the National Climate Change Adaptation Plan, the National Climate Change Committee (NCCC) - composed of public sector agencies, the private sector and NGOs - is responsible for responding to climate change. The primary goal of the NCCC is to ensure that Saint Lucia fulfils its commitments under the United Nations Framework Convention on Climate Change (UNFCCC). In practice, much of the work related to climate change has been led by the Sustainable Development and Environment Division (SDED), part of the Ministry of Public Service, Sustainable Development, Science, Energy and Technology. The Government of Saint Lucia (GoSL) also seeks to specifically address the linkages between vulnerability to climate change impacts and vulnerability to disasters within the Saint Lucia Special Programme for Climate Resilience (SPCR). The programme associates climate change adaptation with disaster risk reduction, reflecting the overall approach to climate change risk in the country.

A relatively elaborate institutional set up for climate change adaptation and disaster risk management operates primarily at national level and is reinforced by regional (Caribbean-level) initiatives. The system is not localized, and few, if any, links appear to exist with the urban planning system for Castries. Risk management for natural hazards and climate change related disasters is primarily focused on disaster management and response.

Saint Lucia's disaster management system is structured around three tiers:

- National: National Emergency Management Advisory Committee
- Committees: National and District Disaster Committees
- Coordination unit: National Emergency Management Organization Secretariat.

NEMO is the cornerstone of Saint Lucia's disaster risk management system. Although the National Disaster Management Plan overall describes NEMO's capabilities, its legal and administrative structure is established in the Disaster Preparedness and Response Act 2006. The Act sets up NEMO's Secretariat as the government organ responsible for coordinating nationally all response activities in the event of a disaster. The National Emergency Management Advisory Committee (NEMAC), chaired by Saint Lucia's Prime Minister, is NEMO's operative direction. NEMO is composed by a wide range of stakeholders including government agencies, non-government actors, faith-based organizations as well as representatives from civil society. These also include the Royal Saint Lucia Police Force, the Fire Service and the Saint Lucia Air and Seaports Authority. NEMO's main task is to improve the country's response and preparedness in the case of a disaster. It coordinates response at the local, national and international levels.

The National Disaster Management Plan is the Official Guideline for National Coordination of all resources involved in emergency management. It describes the overall responsibilities of NEMO and the role of all concerned sectors in assisting in minimizing loss of life and suffering. The areas of prevention and mitigation are not fully developed in this Management Plan although they are referred to in later Annexes of the plan.

There are thirteen National Disaster Committees in Saint Lucia. There is a Local Disaster Committee for Castries Central which services Castries City. This Committee has a Disaster Plan that is modelled according to the Model District Plan provided by NEMO. The Committee also has Emergency Procedures for flooding in Castries and is responsible for initial damage assessments after a hazard event.

Disaster management, nationally and at the level of the community is well coordinated through the various inter-sectoral and inter-agency committees. Each sector and agency has a designated responsibility and function, which is activated according to the disaster management legislation and emergency management plans and procedures. The functions and responsibilities of the vast majority of the agencies are focussed on disaster response and recovery.

The Ministry of Infrastructure is the main agency responsible for mitigating works and for cleaning and de-silting drains. The Ministry has undertaken drainage and river stabilisation projects to reduce flooding in Castries. Some of the funding for such works comes from the national budget; most however is sourced as concessionary loans, primarily from the Caribbean Development Bank (CDB).

The nature of interaction, when there is no disaster, between the agencies involved in disaster management, in general, and in Castries City in particular, is very limited; the interaction is activated only after a change of an Alert Level and on the behest of NEMO.

NEMO provides training or facilitates training in disaster management for its member agencies. Most of these workshops are sponsored by the Caribbean Disaster Emergency Management Agency (CDEMA). There has not been any training in disaster management in urban areas. There is only one early warning information and prediction system for the country. This is located outside Castries. It is NEMO's intention to mobilise external resources to finance an early warning and prediction system for Castries.

Finally, there are established procedures and mechanisms for flooding and landslides in general; these are also applicable to Castries.

4.4.2 City level

Castries City Council is the only city level organization operating in Castries. It area of influence extends to Castries Central and some surrounding neighbourhoods at present, although, as seen above, a new Constituency Council will apparently cover a broader area. The Council is a non-elected body that is responsible for rubbish collection, maintenance of specific drainage arteries and pumps in the city centre, and plays a role in post-disaster recovery by performing a clean-up operation after flood events. The human and financial capacity of the city council and its revenue generation ability are severely limited. The Council is not involved in any planning or implementation exercises for risk reduction or disaster management. National level government departments are also responsible for urban planning and development regulation in Castries.

4.5 Gaps in existing capacity and opportunities for adaptation

Because Saint Lucia is a small island state, its systems for climate change adaptation and disaster risk management are primarily located at the national level. Most risk management and planning functions for Castries fall under the jurisdiction of national ministries and government departments. There is no evidence of climate change adaptation planning activity at the city level for Castries. Castries City Council, the only city level department, has a narrow municipal mandate, lacks adequate financial resources and equipment to effectively undertake its responsibilities, and relies on support from other government departments to fulfil its tasks. It has no authority for controlling or regulating urban development and as such, has no capacity to influence or implement risk management and climate adaptation measures at the national or local level.

The absence of a city level governance organization is reflected in the complete lack of risk management plans and adaptive strategies targeting a rapidly suburbanizing Castries and the northwest corridor into which it fits. The particular vulnerabilities associated with climate change impacts in urban contexts have yet to be outlined, with no clear definition of the demographic groups and physical areas at risk within Castries. Enhancing the risk management and planning capabilities of the City Council, or establishing new city level agencies to address adaptation and planning would be a means of promoting local level adaptive capacity in the context of the city. Until then, an institutional assessment of Castries necessarily focuses on national level agencies engaged in climate change adaptation planning and disaster risk management for the whole of island.

Policy instruments in Saint Lucia are increasingly being used to highlight the importance of climate change adaptation in planning and regulatory frameworks, but the incorporation of forward-looking adaptive practices in development activities remains a challenge. A number of government ministries and agencies are directly involved in activities that shape future climate change resilience in the country. An overarching framework is needed to address gaps and overlaps in institutional responsibilities, coordinate collaboration among public sector agencies, and resolve fragmentation of authority and roles among the wide range of environment and risk management organizations. The SDED is the leading organization working towards mainstreaming climate change adaptation in development practices, but limited capacity has resulted in an uneven application of policies and programmes across scales and sectors.

Disaster risk is one aspect of institutional management for climate risk in which Saint Lucia has demonstrated capacity. The island has developed effective and comprehensive systems for disaster response and management through NEMO, which have been successfully deployed during hazard events in recent times. The relatively frequent incidence of climate hazards in the region has drawn attention to weaknesses in the risk management system, allowing for rapid learning and improvement in risk management practices, notably after the experience of Hurricane Tomas in 2007 and Hurricane Dean in 2010.

However, the institutional risk governance system continues to be reactive in its nature, focussing on disaster management and response rather than proactively addressing climate change adaptation. Even within the disaster risk management framework, efforts in risk identification, risk reduction and adaptive governance remain weak, with most investment currently being directed towards response and short-term recovery. Many of the problems associated with developing an adaptive, futures-oriented disaster risk management system are symptomatic of the larger challenges of strengthening capacity for climate change adaptation across all institutional sectors.

For example, weak knowledge and data management systems are a key issue in risk reduction. A disaster inventory and risk register have been established for Saint Lucia but the data contained in these records is basic and not consistently updated for all regions. There is no analysis of trends or patterns of loss, and low data resolution prevents the use of these inventories as a basis for informing decision-making and practice. No existing data sets contain sufficient information to monitor climate change or assess effectiveness of adaptation strategies. It is possible to observe an improvement in risk monitoring and forecasting activities in some parts of the country, with more information becoming available on flood and drought monitoring.

The Water Resources Management Agency (WRMA) is currently involved in extending its network of rainfall stations in watersheds across the island by putting in additional instrumentation for flood monitoring. However, these initiatives need to be part of a more strategic and consistent engagement with establishing risk identification and data management systems. Both the robustness of information, as well as the systems for information management need to be improved. Platforms for information dissemination across government agencies as well as the private sector are also needed for data accessibility in informed decision-making.

There have been increased efforts at the national level for undertaking vulnerability and risk assessments after the first National Communication to the UNFCC. Combined with efforts by local level organizations such as the Red Cross, appreciable sectoral and community interventions and strong methodologies for vulnerability and capacity assessments have emerged in Saint Lucia. Data generated out of assessments by local organizations is comprehensive but not standardized across sites and there is no central inventory for sharing such assessments. Challenges in scaling these assessments to other locations, and a lack of GIS and mapping resources have led to problems with replication and consistent application. There has been little strategic response by the government towards integrating these resources and developing methodologies and application for better analysis.

Figure 4.3 in the next page reflects the contrast between risk reduction and disaster management in Saint Lucia. While there has been considerable improvement in the field of disaster management and response, sub-indicators in the field of risk reduction remain largely static. To some degree this can be seen as symptomatic of the current prioritization of response-led disaster management strategy over long term risk reduction and climate adaptation planning in the country.

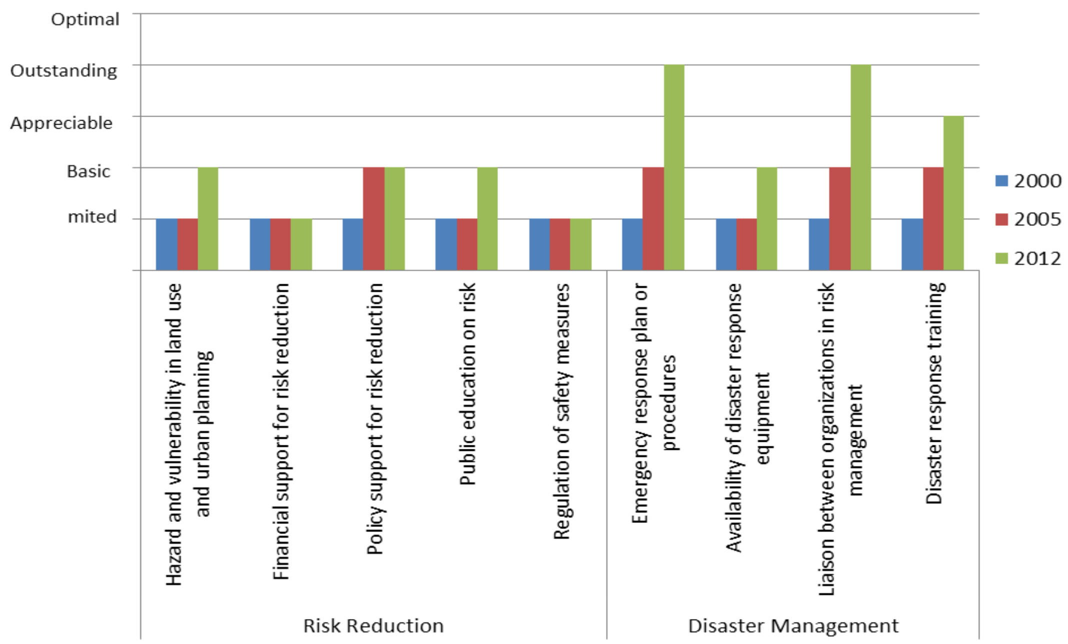


Figure 4.3 Risk identification in Castries.

Currently, there is low consideration of hazard and vulnerability in land use planning, with insufficient GIS and scientific information available for land use planning. Urban planning laws and building control are weak in Saint Lucia, with no regulatory legal framework for controlling construction and development. The Land Conservation Act 1990 has had little impact on risk reduction since there are no regulations attached to the law for implementation of policies. The Development Control Authority has no legislative mandate for enforcement and can only make advisory recommendations on new developments. Financial investment into improving physical infrastructure is largely provided through private sector or donor interventions. Legal instruments for stronger implementation of building control, as well as increased funding and capacity building within the urban planning authorities for the creation of accurate zoning maps and regulations is necessary for vulnerability and risk reduction in Castries.

Emergency response planning is of a good standard in Saint Lucia. Individual initiative within NEMO has resulted in progress in the development of disaster response procedures but there is a limited amount of formal capacity within the organization for implementing these plans. Additionally, the response plans are generic in nature, with gaps in context appropriate application for specific disasters or sectors. There are no formal points of contact identified in other agencies and organizations for emergency response or adaptation planning. The creation of staff posts for risk management and adaptation planning in pertinent government institutions would improve dissemination of information, facilitate collaborative decision-making processes, and allow for the creation of a more sustained and contextually relevant strategic vision for climate change adaptation.

According to respondents, the availability of personnel with risk management skills and qualifications has improved over time, but these individuals are not identified or deployed through a formal procedure. A formal identification of the skill set necessary for risk reduction and response has not been conducted. Disaster response relies on the assistance of volunteers that are provided some degree of training by NEMO but this skilled base is dispersed and not organized. Several committees have been instituted for response coordination but they are formed of sector relevant individuals with organizational influence rather than professionals qualified in risk management (for example, supply chain managers in the emergency supply committee). Disaster response has not been recognized as a programmed area by the government so availability of response equipment is primarily linked to donor support, which can be requested during disasters. There is no formalised government support or funding for the maintenance of existing emergency response resources.

There is also a need for strengthened coordination between government agencies for effective risk management and planning. Although NEMO effectively coordinates inter-agency response during disaster events, there is no structure for inter-agency communication and coordination outside the disaster response phase. Experience of past disaster events has demonstrated that collaboration or financial support for recovery activities is also limited. The Ministry of Social Transformation relies on public donations and government subventions for post-disaster recovery of livelihoods and housing, but these are sufficient only for short term restoration work after a disaster event. Interviews with stakeholders revealed the need for a more consistent approach towards long-term recovery and reconstruction, with funding for adaptation and community level participation needed to avoid repeat losses.

Further attention needs to be paid to the level of engagement and liaison between the government and private sector in both risk management and climate change adaptation. At present there is a well-defined and formal structure for coordination between the two sectors during the disaster response phase. But this framework does not provide a clear definition of roles and responsibilities that exist at each individual level of engagement. There is a need for pre-defined MOUs and TORs for outlining any relational engagement since the private sector is not legally obligated to cooperate with the government. Progress is being made in attracting private sector investment through the concessional loan facility. Expansion of insurance coverage and financial instruments is needed to alleviate financial pressure on the government during recovery and adaptation phases.

NEMO employs a full time trainer who works with private sector organizations and other agencies (such as the port authority) to ensure business continuity by creating plans for emergencies and running simulations. Although limited at the community level, the availability of training capacity in NEMO has had an appreciable impact in the private sector. In part, this is due to the willingness of private sector actors to learn and integrate risk assessment mechanisms in operations. Risk monitoring and planning in SLASPA is an example of the demonstrable outcome of training and collaboration by NEMO on risk management approaches in private sector organizations.

There is currently no structured mechanism for providing and updating climate change risk and adaptation information for the public. A very low level of public education on risk can be found in Castries, and Saint Lucia in general, with most community level knowledge emerging out of learning through past disaster events and experiences. There have been several public information initiatives led by the SDED, but these are not regular or consistent enough for a sustained impact. Problems with availability of adequate data, accessibility of information, and platforms for information dissemination have resulted in low levels of sensitization and preparedness amongst the public. Public practices such as waste tipping and illegal construction are a major driver of vulnerability to floods and landslides in St Lucia. Civil society organizations such as the Red Cross and Caritas play a critical role in building community level resilience and adaptive planning. The Ministry of Social Transformation has also deployed local representatives in each district and community, who play a useful role in disaster response and can be further utilized as liaisons in planning and risk reduction programmes. However, both sets of organizations have limited capacity and resources for implementing large-scale public awareness campaigns. Greater engagement of local level actors and civil society organizations in national public education campaigns needs to be initiated as a means of strengthening institutional capacity for climate change adaptation. Institutional vulnerability can also be decreased through a more formalised role for these organizations in the adaptive planning process.

As such, there are no in-built mechanisms for improving foresight and planning in government organizations but international agreements and global pressures push local systems to change. Performance assessments are occasionally undertaken through donor driven initiatives for review but there are no formal or regular instruments for assessing adaptive capacity at the national level. The private sector is compelled to engage in critical self-reflection and review due to competition and business continuity but systems for learning and change in public sector institutions largely depends on the organizational culture within each agency. For example, SDED allows for discussion and critique, and supports experimentation but does not necessarily possess the resources to implement it. Agencies such as NEMO have also built up a strong ability to influence risk management at higher scales. However, availability of good data and progressive systems of risk management and adaptation are key in supporting future influence and the justification for additional resources.

Overall, the institutional capacity of Castries can be summarized in the following table (Table 4.1). The assessment is based on a combination of completed questionnaires, stakeholder meetings, secondary literature and the local consultant report. As such, the assessment is an illustrative rather than representative measure of institutional adaptive capacity in St Lucia and Castries.

Table 4.1 Institutional capacity of Castries

Risk Identification	
Inventory of disasters and losses	Basic
Risk monitoring and forecasting	Basic
Vulnerability and risk assessment	Basic
Information on risk and response measures	Limited
Risk Reduction	
Hazard and vulnerability in land use and urban planning	Basic
Financial support for risk reduction	Limited
Policy support for risk reduction	Basic
Public education on risk	Basic
Regulation of safety measures	Limited
Disaster Management	
Emergency response plan or procedures	Outstanding
Availability of disaster response equipment	Basic
Liaison between organizations in risk management	Outstanding
Disaster response training	Appreciable
Adaptive Governance	
Foresight and planning for risk management	Appreciable
Critical self-reflection	Basic
Learning and transformation of practices	Basic
Experiments in risk reduction and response	Limited

The table serves to highlight the general trends for planning and response to climate change risk in the country, and reflects the strength of institutional mechanisms for disaster management and emergency coordination. These institutional strengths can be further developed and supported through financial and technical capacity building to engage with climate change and hazard risk in a more forward-looking and proactive manner. Improving local level institutions and promoting risk identification and reduction can rapidly improve the overall capacity for planning and adaptation in the system.

5 Climate-related vulnerability and risk assessment

5.1 City profile

Castries is located on the northwest coast of the island nation of Saint Lucia. Castries is exposed to a multitude of natural hazards such as storm surges, hurricanes, tropical cyclones, landslides, and other extreme weather events. The purpose of the climate-related vulnerability and risk assessment is to identify flood and landslide hazards that may be caused or exacerbated by climate change in Castries, and to assess the likelihood and relative consequence of these hazards in order to prioritize responses and mitigate risks.

There is no fixed spatial definition for Castries as a city, which is often also characterized as Saint Lucia's northwest urban corridor. Present-day Castries, as what analysts term a mini-metropolitan area, covers an area starting at Cul de Sac Bay, to the south of Central Castries, and extends through Gros Islet to the north and then further to Cap Estate, located at the northernmost tip of the island. This area covers parts of both Castries and Gros Islet districts, and is to a large degree captured by the Government of Saint Lucia (GoSL) census districts Castries City, Castries Suburban and Castries Rural, all of which fall within Castries District itself

Saint Lucia has undergone rapid urbanization, with approximately 30 per cent of the total population located in urban Castries and 55 per cent of the population located in the Castries-Gros Islet corridor which runs along the northwest coast of the island. Population in Castries has increased from 51,994 inhabitants in 1991 to 65,656 inhabitants in 2010, which is approximately 40 percent of Saint Lucia's overall population of 165,595 inhabitants that year.

The island's topography and a corresponding shortage of land have shaped the morphology of urban Castries. Situated in the flood plain of the Castries River, the city centre was built on reclaimed land. Steep ridges, which flank the city's east and southern areas, limit urban growth. Castries Rural, marked by the presence of steep hills, is the area that is experiencing the fastest demographic growth, along with Gros Islet. Population in Castries City and Castries Suburban areas is actually reducing over time.

Over the years, in fact, the location of economic activity in Saint Lucia in general and Castries in particular, has shifted and has now become more oriented to and located on the coastline. Key economic and critical infrastructure networks, including airports, tourism facilities (notably hotels and resorts), sea ports, fuel storage, as well as hospitals and schools, are often located along the coast, and are thus exposed to climate-related hazards. Telecommunications infrastructure and the power supply network are further inland, although the distribution networks are located nearby human settlements

This spatial expansion reflects how Saint Lucia's population has become urbanized – and more recently suburbanized – in past decades. A strong trend of population growth in more peripheral suburban, peri-urban and rural areas of Castries has emerged.

The definition of urban Castries has thus varied over time, and a shared understanding is limited. In defining the study area for assessment, we have also been guided by the local government structure. The recently passed Constituency Councils Act of 2012 effectively redefined urban Castries to consist of the four electoral districts (or constituencies) of Castries Central, Castries North, Castries South and Castries East which collectively have a population of above 40,000. The area is now to have its own appointed council, the Castries Constituency Council, which supersedes the current City Council (Constituency Councils Act, 2012).

This area, falling within Castries District, effectively constitutes the core study area However, to capture risk in the broader mini-metropolitan area, conditions in Castries South East, which has its own council and a population of very close to 15,000, and those in the rapidly growing urban areas within the northwest corridor in Gros Islet District (which also has a council), the population of which rose 21 percent, from 20,872 in 2011 to 25,210 in 2010, are also considered (Huntley, 2011). Moreover, given the status of Saint Lucia as a SIDS, a national perspective is also taken where necessary. Section 1.3 provides further statistical and mapping information.

Settlements in or near hazard prone areas susceptible to floods and landslides are a particular cause for concern, particularly in the growing peripheral suburban areas of Castries alluded to above (e.g., Cul-de-Sac and Black Mallet/Maynard Hill). Settlements closer to Castries City are relatively well ordered while those further away tend to be unregulated settlements with extremely poor drainage. The locational dynamics of the urban poor are a key issue in this context. As seen in the *Urban, social and economic adaptive capacity assessment*, the middle class is generally (re)locating to the northwest, along the Castries-Gros Islet corridor, while Castries East concentrates pockets of low income population.

Urban planning on the island is primarily reactive, with few local (layout or neighbourhood) plans, and little forward (e.g., structure) plans or town planning (zoning) scheme or zoning plan. Development control, on which basis building permits are issued, functions according to practical planning guidelines. A significant proportion of construction is, however, outside the purview of the Development Control Authority. This is a problem given that it is not necessarily the concentration of people and critical infrastructure as such that increases risks, but rather the way urban development takes place as it occurs 'vertically' (up slopes) and/or horizontally (peripheral expansion). In this context, the anticipated impacts of climate change may likely exacerbate current vulnerabilities of the housing and critical infrastructure sectors in Castries.

Predominant features of the built environment in Castries area and urban population that impact upon flood and landslide hazard risks are summarized in Figure 5.1.

In the sections that follow, available information is compiled into a profile of vulnerability for Castries. This is based on the evidence discussed in the *Climate-related hazard assessment*, the *Urban, social and economic adaptive capacity assessment*, and the I*nstitutional adaptive capacity assessment.*

Figure 5.1 Predominant features of the built environment in Castries that impact upon flood and landslide hazard risks.

5.2 Institutional vulnerability in Castries

The institutional architecture of a city plays a central role in shaping the risk and vulnerability experienced by urban populations to natural hazards. It determines the distribution, accessibility and quality of critical services and physical infrastructure available to residents, and the provision of a safe and healthy environment. The institutional architecture refers to formal structures of government management such as legislation, planning guidance, and public organizations, as well as the more informal aspects of governance such as transparency and accountability, which characterize the social contract between citizens and the state.

In small and medium sized cities, such as Castries, the capacity of urban management and governance institutions to identify and respond to current and future climate vulnerability defines not only the resilience of the urban system, but also its potential for future growth and sustainable expansion.

Climate change policy instruments

Saint Lucia is a small island state and its systems for climate change adaptation and disaster risk management are primarily located at the national level. As yet, there are no independent policy tools or implementation mechanisms for climate change consideration and adaptive action for the capital city of Castries. Castries City Council, the only functioning city level government department, has a limited mandate and resources to undertake such tasks. Enhancing the risk management and planning capabilities of the City Council, or establishing new city level agencies to address adaptation and planning would be a means of promoting local level adaptive capacity in the context of the city (although international studies have highlighted the pros and cons of this approach as 'silo-ing' adaptation concerns, this might require further discussion). Until then, an institutional assessment of Castries necessarily focuses on national level agencies engaged in climate change adaptation planning and disaster risk management for the whole of island.

Policy instruments in Saint Lucia are increasingly being used to highlight the importance of climate change adaptation in planning and regulatory frameworks, but the incorporation of forward-looking adaptive practices in development activities remains a challenge. A number of government ministries and agencies are directly involved in activities that have the potential to shape future climate change resilience in the country. An overarching framework is needed to address gaps and overlaps in institutional responsibilities, coordinate collaboration among public sector agencies, and resolve fragmentation of authority and roles among the wide range of environment and risk management organizations.

Institutional capacity for adaptation

The Sustainable Development and Environment Division (SDED) of the Ministry of Sustainable Development, Energy, Science and Technology, is the leading organization working towards mainstreaming climate change adaptation in development practices, but greater capacity is needed for a more consistent application of policies and programmes across scales and sectors. Sub-national and local capacity within public sector organizations to mainstream climate risk considerations into development planning and programming processes also needs to be promoted through training and learning exercises.

Disaster risk is one aspect of institutional management for climate risk in which Saint Lucia has demonstrated capacity. The island has developed effective and comprehensive systems for disaster response and management through the National Emergency Management Organization (NEMO), which have been successfully deployed during hazard events in recent times. The relatively frequent incidence of climate hazards in the region has drawn attention to weaknesses in the risk management system, allowing for rapid learning and improvement in risk management practices, notably after the experience of Hurricane Tomas in 2010 and Hurricane Dean in 2007. However, disaster response has not been wholly recognized as a programmed area by the government so availability of response equipment is primarily linked to donor support, which can be requested during disasters. There is also little formalized government support or funding for the maintenance of existing emergency response resources. Overall, the institutional risk governance system continues to be reactive in its nature, focussing on disaster management and emergency response rather than proactively addressing climate change adaptation. Within this disaster risk management framework, efforts in risk identification, risk reduction and adaptive governance are not as strong as required, with most investment currently being directed towards response and short-term recovery.

Technical knowledge generation and data management systems are also key challenge in formulating risk reduction policies in Castries. Critical information and data to orient decisions at the sub-national and local level, as well as for the elaboration of climate change induced socio-economic scenarios, is lacking in Saint Lucia. A disaster inventory and risk register have been established for the country but the data contained in these records is basic and not consistently updated for all regions. There is no analysis of trends or patterns of loss, and low data resolution prevents the use of these inventories as a basis for informing decision-making and practice. Existing data sets do not contain sufficient information to monitor climate change or assess effectiveness of adaptation strategies. Without better information, it is impossible to undertake local adaptation activities that rely on the downscaling of climate change models and climatic data.

However, an improvement in risk monitoring and forecasting activities in some parts of the country is observable, with more information becoming available on flood and drought monitoring. For example, the Water Resources Management Agency (WRMA) is currently involved in extending its network of rainfall stations in watersheds across the island by putting in additional instrumentation for flood monitoring. These initiatives need to be integrated into a more strategic and consistent engagement with developing risk identification and data management systems. Both the robustness of information, as well as the systems for information management needs to be improved. Platforms for information dissemination across government agencies as well as the private sector are also needed for data accessibility in informed decision-making.

There have been increased efforts at the national level for undertaking vulnerability and risk assessments after the first National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). Combined with efforts by local level organizations such as the Red Cross, appreciable sectoral and community interventions and strong methodologies for vulnerability and capacity assessments have emerged in Saint Lucia. Data generated out of assessments by local organizations is comprehensive but not standardized across sites and there is no central inventory for sharing such assessments. Challenges in scaling these assessments to other locations, and a lack of GIS and mapping resources have led to problems with replication and consistent application. There has been little strategic response by the government towards integrating these resources and developing methodologies and application for better analysis.

Urban planning laws and building control are weak in Saint Lucia, with a limited regulatory legal framework for controlling construction and development. The Land Conservation Act 1990 has had little impact on risk reduction since there are no regulations attached to the law for implementation of policies. The Development Control Authority has no legislative mandate for enforcement and can only make advisory recommendations on new developments. There is also low consideration of hazard and vulnerability in land use planning, with insufficient GIS and scientific information to support planning decisions. Legal instruments for stronger implementation and enforcement of building control, as well as increased funding and capacity building within the urban planning authorities for the creation of accurate zoning maps and regulations is necessary for vulnerability and risk reduction in Castries.

Further attention needs to be paid to the level of engagement and liaison between the government and private sector in both risk management and climate change adaptation. At present there is a well-defined and formal structure for coordination between the two sectors during the disaster response phase. But this framework does not provide a clear definition of roles and responsibilities that exist at each individual level of engagement through pre-defined MOUs and TORs, and the private sector is not legally obligated to cooperate with the government. Progress is being made in attracting private sector investment through the concessional loan facility. Expansion of insurance coverage and financial instruments is also needed to alleviate financial pressure on the government during recovery and adaptation phases.

A low level of public education on risk is present in Castries, and Saint Lucia in general, with most community level knowledge emerging out of learning through past disaster events and experiences. There have been several good public information initiatives led by the SDED, but these are not regular or consistent enough for a sustained impact. Issues around the availability of relevant data, accessible information, and platforms for information dissemination have impeded sensitization and preparedness at the community level. Public practices such as waste tipping and illegal construction are a major driver of vulnerability to floods and landslides in Castries. Civil society organizations such as the Red Cross and Caritas play a critical role in building community level resilience and adaptive planning. The Ministry of Social Transformation, Youth and Sports has also deployed local representatives in each district and community, who play a useful role in disaster response and can be further utilized as liaisons in planning and risk reduction programmes. However, both sets of organizations have limited capacity and resources for implementing large-scale public awareness campaigns. Greater engagement of local level actors and civil society organizations in national public education campaigns could be initiated to strengthen local capacity for climate change adaptation.

Overall institutional assessment

Risk management and planning in Saint Lucia is thus currently undergoing a process of rapid change and development. Institutional structures and planning instruments are evolving to a more mature stage of disaster management and policy planning. Although there are no specific in-built mechanisms for improving foresight and planning in government organizations, participation in international agreements, global pressures, and more recently, an increased incidence of climate hazards are pushing national risk management systems to change. This momentum needs to be extended to the implementation phase of strategic and action planning in order to demonstrate effectiveness in reducing existing vulnerability and future risk. The future of sustainable development in the country generally, and Castries in particular, depends on the degree to which climate change vulnerability is considered in institutional planning and development activities across all sectors of government operation.

To a large degree, Saint Lucia has already demonstrated its ability to successfully plan for and manage disaster response in emergency situations. Similar efforts now need to be made in the preparedness, risk reduction, and adaptation phases of risk management at the national level and in Castries.

Table 5.1 in the next page lists policies, programs, projects and studies related to environmental management, urban development, disaster risk management and climate change adaptation.

Table 5.1 Policies, programs, projects and studies related to DRM and/or CCA

Environment, disasters and climate	Overview
National Disaster Management Plan	Official guideline for National Coordination of all resources involved in emergency management; the Plan is referred to in any emergency situation.
Strategic Program for Climate Resilience (SPCR)	World Bank implemented program across 5 areas: i) Human welfare and livelihood protection; Ii) Integrated natural resource protection, conservation and management to promote sustainable development; iii)Building resilience through business development, innovation, and productivity development; iv) Capacity development/building and institutional /organizational strengthening; and v) Reducing risk to climate related disasters.
Disaster Management Policy Framework for Saint Lucia	Emphasizes the strengthening and enhancing of capacity for disaster risk management from the regional level to the community level, incorporating the effects of climate change.
Hazard Mitigation Policy	Strategic instrument for integration of risk reduction into all aspects of private and public sector activities including those of local communities and individuals. Does not mention climate change.
National Emergency Management Plan (NEMP)	Plan which is beginning to address the effects of Climate Change through such documents as: Impact of Climate Change on Design Wind Speeds, Engineering Guidelines for Incorporating Climate Change into the Determination of Wind Forces, National Climate Change Risk Register, National Hazard Mitigation Plan, DRAFT Hazard Mitigation / Climate Change Policy, DRAFT Hazard Mitigation National Action Plan
Saint George's Declaration of Principles for Environmental Management in the OECS (SGD)	Many national and regional policies are climate change-relevant or specifically mention climate change. These include the above-mentioned SGD, the NEP/NEMS, the National Land Policy and the National Water Policy.
National Climate Change Policy and Adaptation Plan (NCCPAP)	First policy instrument formulated to specifically address climate change.
Coastal Zone Management Strategy and Action Plan	Objective of maintaining integrity and productivity of the coastal zone and resources therein; optimizing the contribution of the coastal zone to social and economic development through the sustainable use of resources and the equitable sharing of benefits; and harmonizing uses of the coastal zone awareness.
Landslide Response Plan	Outlines preparedness, mitigation and response measures in managing landslides and associated activities such as structural counter measures to reduce the impact of landslides. Also, under non-structural counter measures, landslide forecasting and landslide early warning monitoring systems are highlighted.

Hurricane Response Plan	Outlines preparedness, mitigation and response measures in managing landslides and associated activities such as structural counter measures to reduce the impact of landslides. Also, under non-structural counter measures, landslide forecasting and landslide early warning monitoring systems are highlighted.
Comprehensive Disaster Management (CDM) Framework	Five thematic areas have been embedded in this framework which expires in 2015. These are hazard mapping and vulnerability assessment; flood management; community disaster planning; early warning systems; and climate change and knowledge management.
Sectoral studies	
Climate Change and Vulnerability Assessment for the Tourism, Agriculture, Water, Human Settlements, Biodiversity and Forestry Sectors in Saint Lucia	Vulnerability assessments under current climate variability and change, specifically pointing to areas of high vulnerability and prioritizing investment measures to address current and future climate risks.
Climate Change and Vulnerability Assessment for the Water Sector in Saint Lucia	
Climate Change and Vulnerability Assessment for the Forest and Biodiversity Sector in Saint Lucia	
Climate Change and Vulnerability Assessment for Human Settlements in Saint Lucia	
Climate Change and Vulnerability Assessment for the Agriculture Sector in Saint Lucia	
Vulnerability and Adaptation Assessment – synthesis report for Saint Lucia	
Other studies	
A pilot community-based, low-cost landslide risk reduction program was completed in the Skate Town in Suburban Castries, in 2004/05 MoSSaiC	Worked with the community to identify areas of drainage and stability concern and to produce an integrated landslide risk map. This methodology allowed zoning of the area based on differing dominant slope instability processes and the identification of differing intervention strategies in different zones. Such strategies have included surface water management (low cost methods as well as conventional drainage design), detailed slope monitoring, debris trap construction, house waste water management and detailed slope stability analysis
Caribbean Disaster Management Agency (CDEMA)	Financed a detailed flood hazard map for the City of Castries and suggested improvement of the drainage systems in Castries to reduce flooding. Design options were developed concurrently with extensive public and stakeholder meetings.
Caribbean Planning for Adaptation to Climate Change (CPACC)	This project was undertaken during the period 1997 to 2001 and was aimed at building capacity in the Caribbean region for the adaptation to climate change impacts, particularly sea level rise, through the completion of vulnerability assessments, adaptation planning, and

	capacity building activities.
Adapting to Climate Change in the Caribbean (ACCC)	The ACCC Project succeeded the CPACC from 2001 – 2004. This project was designed to sustain activities initiated under CPACC and to address issues of adaptation and capacity building not undertaken by CPACC. This was undertaken to further built capacity for climate change adaptation in the Caribbean region
Special Program on Adaptation to Climate Change (SPACC) projects	Implements local actions that address the (i) sustainability of water resources and supply of the Vieux-Fort Region and (ii) the strengthening of critical coastal Infrastructure in the Castries Area. In the Northern part of the island, it focuses on retrofitting the Marchand Community Centre to withstand category four (4) or higher hurricanes.
Climate Change Technology Needs Assessment (CCTNA)	Determined the country's priority environmentally sustainable climate change technology needs. With regard to adaptation, the CCTNA addresses a number of sectors, namely: coastal zone, freshwater resources, tourism, agriculture, health, human settlements and disaster response. Identifies adaptation and mitigation options, development benefits, technology needs and barriers to the transfer or adoption of these technologies
Caribsave Climate Change Risk Atlas (CCCRA), Climate Change Risk Profile for Saint Lucia	Developed a climate change profile for Saint Lucia using data from a Regional Climate Model.
Flood hazard mapping of the Castries River catchment, St. Lucia	Developed a detailed hazard map of the Castries river basin and hydrographs of extreme rainfall events that could subsequently be used in the determination of the capability of the river network to safely convey the hydrograph without riverbank overtopping
An Investigation of the Applicability of Hydroinformatics in Assessing the Impact of Flooding on Castries, St. Lucia	Examined the usefulness of hydroinformatics tools such as modeling and GIS in assessing the impact of flooding on Castries, St. Lucia.

5.3 Landslide and flood vulnerability and risk in Castries

This project focuses on floods and landslides which can be triggered by rainfall and storm events. These events can have significant impact on people, infrastructure, and the country's economy. This section investigates the vulnerability of (i) settlements, and (ii) facilities and critical infrastructure that may be exposed to these hazards. The findings of this vulnerability analysis suggest the locations where stakeholders in Castries may conduct a more thorough risk assessment of future floods and landslides.

5.3.1 Approach

This section synthesizes information on Castries's landslide and flood vulnerabilities, focusing on the current physical risk, urban social and economic conditions, and institutional arrangements. This is done by conducting a vulnerability analysis for each settlement in the study area. Due to the lack of available data, the results of this analysis should be viewed as an informative screening of which settlements are more likely to be affected by landslides and floods by mid-century. A vulnerability analysis of critical infrastructure is not possible as this would require an analysis by infrastructure category (e.g., inspection of building codes, damages associated with past events, and other indicators to determine how sensitive the infrastructure is when exposed to the hazard). This analysis does, however, overlay the critical infrastructure with the settlements that are exposed to the hazards. This vulnerability analysis can then inform decision makers as they consider climate adaptation options and provide recommendations regarding the combination of hazards, settlements, and facilities that would benefit from a more intensive risk analysis.

A vulnerability analysis considers the exposure, sensitivity, and adaptive capacity of the settlement to the hazard (see Figure 5.2). Each of these components is discussed in more detail below.

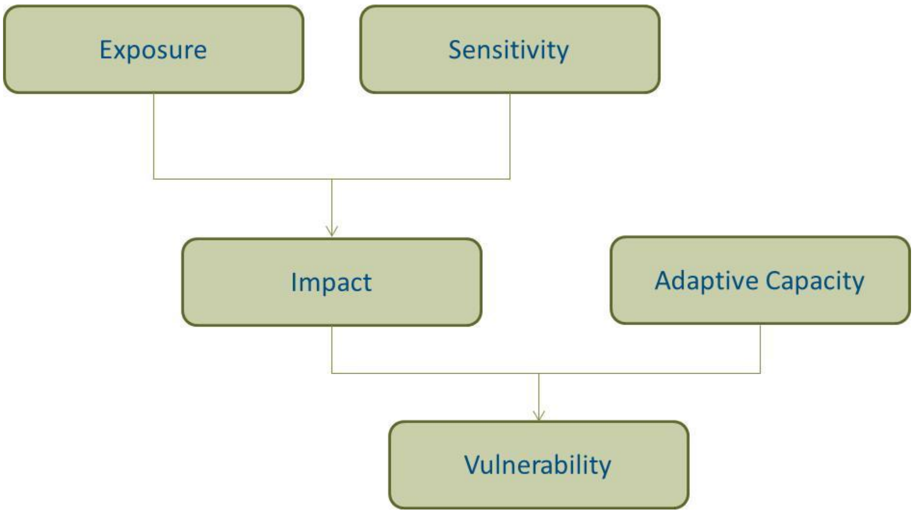


Figure 5.2 Schematic of the vulnerability analysis for landslides and floods, Source: The Authors.

Exposure. Exposure considers whether a settlement and/or facility is located in an area that is considered susceptible to the hazard. For this analysis, this is simply a "yes/no" determination based on the findings in the hazard analysis. The hazard analysis identified the regions and settlements that were exposed to a landslide and/or flood hazard and considered through the use of climate projections whether the exposure may increase or decrease by mid-century (see Box 8).

Box 8 Projected changes in hazards

Due to climate change, Castries's exposure to floods, particularly coastal flooding associated with storm surge, is projected to increase with sea level rise. This could significantly affect the country's development potential. Landslides, on the other hand, are not projected to increase.

Given the hazard analysis does not include a more intensive modelling effort (e.g., new hydrologic and hydraulic modelling driven with projections of precipitation to investigate how exposure may change), this analysis is constrained to simply considering whether the existing hazard will worsen or reduce in areas already exposed to the hazard. Because of this, this analysis cannot provide a quantitative number describing the change in flooding or landslide exposure. However, it can provide a high-level description of which settlements are exposed to the hazard and a qualitative description based on quantitative data as to how climate change may impact future exposure. Climate projections were developed to reduce various components of uncertainty (e.g., an average from an ensemble of climate models was developed for two plausible socioeconomic futures). As with any projection, there is inherent uncertainty. In addition, new climate data that is shown to produce more rigorous results should be considered to augment the results presented in this report.

Sensitivity. Sensitivity describes the degree to which a settlement that is exposed to the hazard might be affected. This step can rely on design standards, historical and geographic analogues, and/or expert opinion. Drawing from the information available as provided in the *Urban, social and economic assessment*, the percentage of households within each settlement fortified by concrete walls indicates the general sensitivity of the settlement to the hazards. This metric is really used as a proxy to suggest the proportion of houses that may be able to better withstand landslides and suffer less damage during a flood. The sensitivity is ranked at a "0" to indicate a low sensitivity to the hazard to a "4" which indicates a high sensitivity to the hazard (see Table 5.2). The percent range used to determine the ranking was developed based upon inspection of the entire range of values across settlements. Ideally, information would incorporate other factors such as the percentage of housing with a doorway height above flood level, percentage of housing using specific types of materials, number of housing damaged by past events.

Table 5.2 Ranking sensitivity

Rank	Sensitivity
0	% of households with concrete walls is over 90%
1	% of households with concrete walls is between 70% to 90%
2	% of households with concrete walls is between 40% to 70%
3	% of households with concrete walls is between 20% to 40%
4	% of households with concrete walls is less than 20%

Adaptive capacity Adaptive capacity considers how an impacted settlement (i.e., a settlement that is exposed to and potentially harmed by the hazard) may be able to cope or adapt. This may include considering what technological, economic, and social means are available to help the settlement deal with the hazard. This step draws from the findings of the *Urban, social and economic assessment* and *Institutional adaptive capacity assessment*. The institutional contribution to adapt is considered consistent across all settlements given governance is largely at the national level. The socioeconomic analysis provides a "Basic Needs" Index[16] that is used to consider the adaptive capacity of each settlement. The "Basic Needs" Index is used based upon the assumption that settlements with a high index will be less capable of responding to and/or protecting against the hazard.

Table 5.3 Ranking adaptive capacity

Rank	Adaptive Capacity
0	"Basic Needs" Index less than 13.4
1	"Basic Needs" Index between 13.4 and 16.9

[16] The "Basic Needs" Index is based on Edwin St. Catherine (2011). For more information regarding the poverty index refer to the *Urban, social, and economic assessment* or http://www.stats.gov.lc/StLuciaCommunityRanking2010.pdf

Rank	Adaptive Capacity
2	"Basic Needs" Index between 16.9 and 20.3
3	"Basic Needs" Index between 20.3 and 23.8
4	"Basic Needs" Index greater than 23.8

Vulnerability. The vulnerability analysis then applies the rankings of sensitivity and adaptive capacity from low (i.e., least vulnerable) to high (i.e., most vulnerable) for each settlement that are located in flood- and/or landslide-prone areas.

Table 5.4 illustrates how the rankings of sensitivity and adaptive capacity were used to assess potential vulnerability. The suggested responses to the potential vulnerabilities are as follows:

- Low ("L"): Stay attentive to the hazard but not necessarily change current planning and management
- Medium ("M"): Consider developing strategies to curtail impacts and consider enhancing warning systems
- High ("H"): Develop strategies to curtail impact and consider hazard vulnerability in planning.

This evaluation is applied for both the landslide and flood vulnerability analyses.

Table 5.4 Index of potential vulnerability for hazards based upon the rankings of sensitivity and adaptive capacity.

Sensitivity						
	4	M	M	H	H	H
	3	M	M	M	H	H
	2	L	M	M	M	H
	1	L	L	M	M	M
	0	L	L	L	M	M
		0	1	2	3	4
		Adaptive Capacity				

A similar ranking of potential vulnerability based on sensitivity and adaptive capacity was not conducted for critical facilities. This would require significant analysis of such information as building codes, past records of damages per landslide and/or floods, and a record of maintenance and repair. Instead, a discussion is provided regarding the number of facilities located in each settlement and the Annex 5 provides maps of each settlement and the facilities within each settlement located in landslide- and/or flood-prone areas.

5.3.2 Vulnerability screening results

Landslides. The urban and socioeconomic assessment describes the settlements prone to landslides (i.e., may potentially be exposed to landslides). These settlements are listed in Table 1.5. This table presents the findings of the vulnerability assessment as well as a description of the anthropogenic and climate triggers associated with landslides in the Castries study area.

As discussed in the hazard analysis, the future exposure to landslides may be reduced by the reduction in rainfall; however, it is not clear the degree of reduction and how that will impact the exposure. **To err on the side of caution, it is assumed the future exposure will be slightly less than that experienced today**. This analysis is not equipped to provide more detail regarding the degree of future change in exposure to landslides. For example, it is not possible to use the landslide hazard map produced by CIPA (2006) to consider how future precipitation may impact the hazard levels (e.g., whether a section may switch from a high hazard level to a low hazard level); this is because precipitation was not used in the development of this map. Table 5.5 suggests the settlements of greatest vulnerability to landslides include: Black Mallet, Bois Patat, Morne Dudon, and Pavee.

Table 5.5 Summary of settlements that are potentially vulnerable to landslides.

Settlement	Population	Stressors		Link to Climate Variability and Change	Potential Vulnerability				
		Anthropogenic Activities	Climate		Exposure Today	Future Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
Black Mallet	102	■ Road construction along steep slopes ■ Deforest-ation ■ Urban development into landslide-prone areas.	■ Rainfall, even slight events ■ Intensity and frequency of low-pressure weather systems ■ Flooding ■ Hurricanes and tropical depressions	■ Rainfall may be reduced in the 2040s in response to climate change. Reduction in the frequency of rainfall events may occur; however, it is not clear how the intensity of precipitation events may change.	Y	↓	3	3	**H**
Maynard Hill	580				Y	↓	2	3	**M**
La Pansee	448				Y	↓	1	3	**M**
Bocage	1,463				Y	↓	2	3	**M**
Bois Patat	425				Y	↓	3	3	**H**
Morne Dudon	1,284				Y	↓	3	3	**H**
Pavee	1,168				Y	↓	3	3	**H**
Entrepot	935				Y	↓	1	1	**L**

Figure 5.3 illustrates the settlements vulnerable to landslides and suggests the degree of the vulnerability. These settlements are to the west and south of the city centre of Castries. These are settlements that are both most apt to be impacted by landslides and are likely to have difficulty protecting against the impact. This figure was discussed and 'ground-truthed' during a workshop with primary stakeholders in Castries. This is an important step to ensure the rankings applied for sensitivity and adaptive capacity produce a credible vulnerability analysis. As landslide prone areas are not projected to experience a significant shift from today's baseline nor are landslides currently considered a significant threat to this study area, **decision makers may consider not implementing any strategies beyond coping with today's conditions and then re-evaluate at a future time as new climate model data becomes available.**

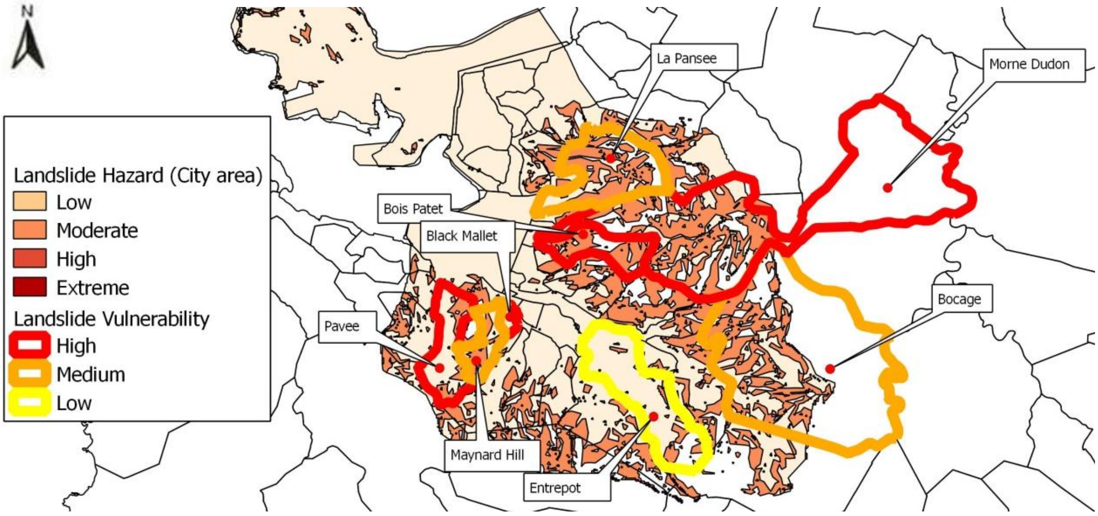


Figure 5.3 Settlements vulnerable to landslides, Source: The Authors

Floods. The *Urban, social, and economic assessment* identified the settlements prone to flooding; these settlements are listed in Table 5.6. The table provides the findings of the vulnerability assessment as well as a description of the anthropogenic and climate stressors associated with floods in the Castries study area.

The future exposure to coastal floods in the 2040s may be increased as the sea level rises leading to increased damage associated with storm surge. All coastal settlements in the study area are provided in Table 1.7. The coastal flood analysis suggests certain coastal settlements are more prone to flooding based upon coastal topography, which is indicated in Table 1.7 by a “Y” under the column “Exposure Today”. The “Y” is colored red for those settlements where inundation is suggested under the 50-Year maximum likelihood event and orange for those settlements where inundation is suggested under the 100-Year maximum likelihood event. Future projections suggest the inland flooding in the City of Castries may remain consistent with that experienced today. The settlements of greatest vulnerability to coastal flooding include: Cul de Sac, Ciceron/Monkey Town, La Toc, and Conway.

Table 5.6 Summary of settlements that are potentially vulnerable to flooding (primarily coastal flooding).

Settlement	Population	Stressors		Link to Climate Variability and Change	Potential Vulnerability				
		Anthropogenic	Climate		Exposure Today	Future Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
Coubaril	257	■ Increase in impermeable surfaces ■ Inadequate storm water drainage system ■ Inappropriate garbage disposal that block drains ■ Loss of natural vegetation	■ Periods of rain >25mm in 1 day ■ Intense storms, including hurricanes (damage water intakes, dams and reservoirs and this can result in decreased	■ Rainfall risk associated with flooding may remain about the same in the 2040s compared to today. ■ Sea level rise could increase the adverse impact associated	Y	↑	1	0	L
Cul de Sac	765				Y	↑	3	4	H
Ciceron / Monkey Town	1,016				Y	↑	3	3	H
Barre St Joseph	634				N	--	--	--	--
Marigot	792				N	--	--	--	--
La Toc	826				Y	↑	3	3	H
Tapion	133				Y	↑	4	1	M
Banannes Bay	364				Y	↑	2	3	M
Faux a Chaud	306				Y	↑	4	4	H

Settlement	Population	Stressors: Anthropogenic	Stressors: Climate	Link to Climate Variability and Change	Potential Vulnerability: Exposure Today	Future Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
Castries City	805	and increased siltation ■ Land reclaiming ■ Inadequate maintenance of existing drainage systems	water supply and quality)	with storm surge and waves.	Y	--	2	3	M
Conway	78				Y	↑	4	4	H
Vide Bouiteille	531				Y	↑	2	2	M
Vigie	211				Y	↑	1	0	L
Choc	5				Y	↑	N/A	0	N/A

Figure 5.4 illustrates the settlements vulnerable to floods and suggests the degree of the vulnerability. These settlements are located along the western coastline of the study area.

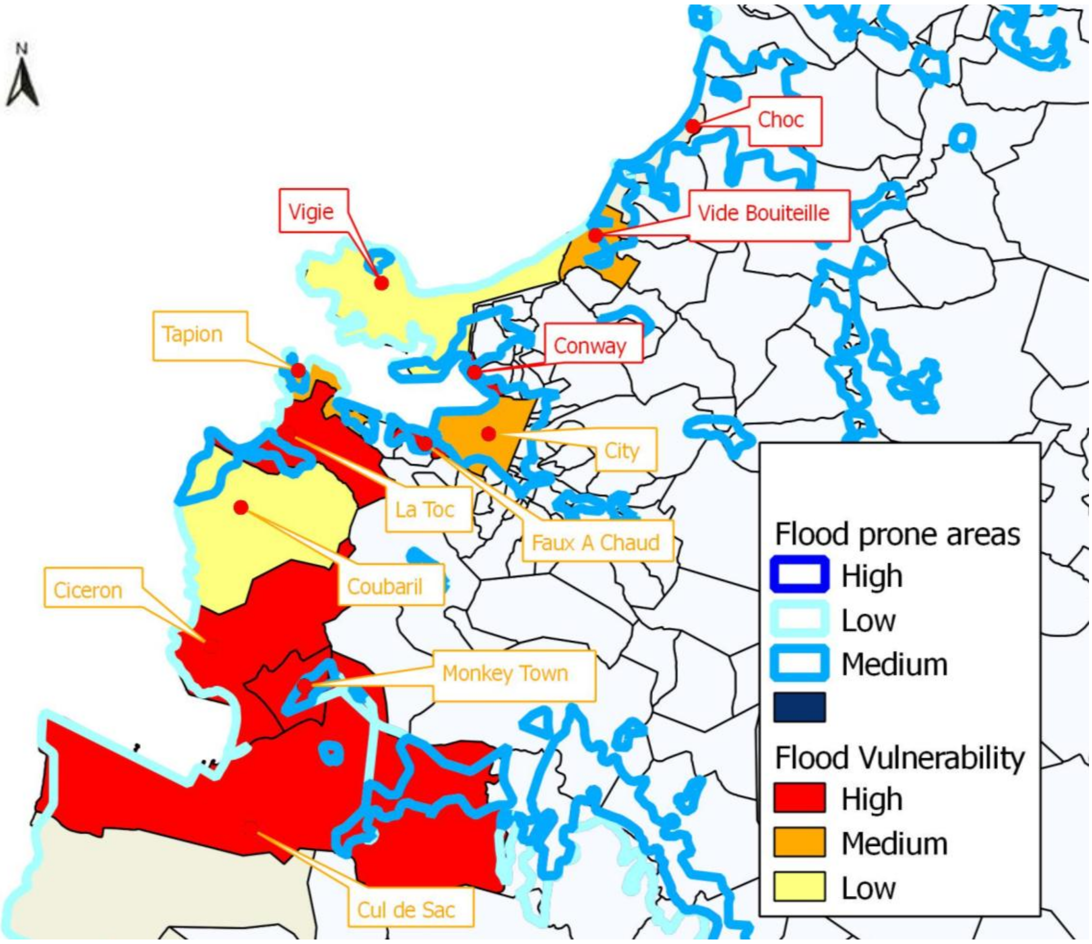


Figure 5.4 **Potential vulnerability of settlements prone to flooding as illustrated by the yellow to red shadings. Areas prone to inland and coastal flooding are identified by the blue regions. The settlements with names provided in red are locations apt to impacted by the 50-Yearcoastal flood event and settlements with names provided in orange are apt to be impacted by the 100-Year coastal flood event, Source: The Authors.**

Facilities and Critical Infrastructure

This section discusses the facilities and critical infrastructure within vulnerable settlements that may be impacted by flood and/or landslide hazards.

Box 9 Critical infrastructure

Critical infrastructure includes:

- Castries waterfront
- Transportation infrastructure (airport, port, roads)
- Energy infrastructure (power plant and substations, fuel stations, transmission cables and poles)
- Water infrastructure (water supply infrastructure and sewage lift stations).

Some key infrastructure such as the airport, port, roads, and fuel storage stations, are located along the coast or on low-lying reclaimed coastal land in the Castries study area, and are susceptible to flooding and storm surge as a result. The water and the energy supply facilities are further inland, but the distribution networks are near human settlements within the study area and are still within close proximity to the coast.

Figure 5.5 presents the infrastructure of the study region along with the areas susceptible to landslide and flood hazards. The landslide hazard identification is constrained to the information provided by the CIPA (2006) map.

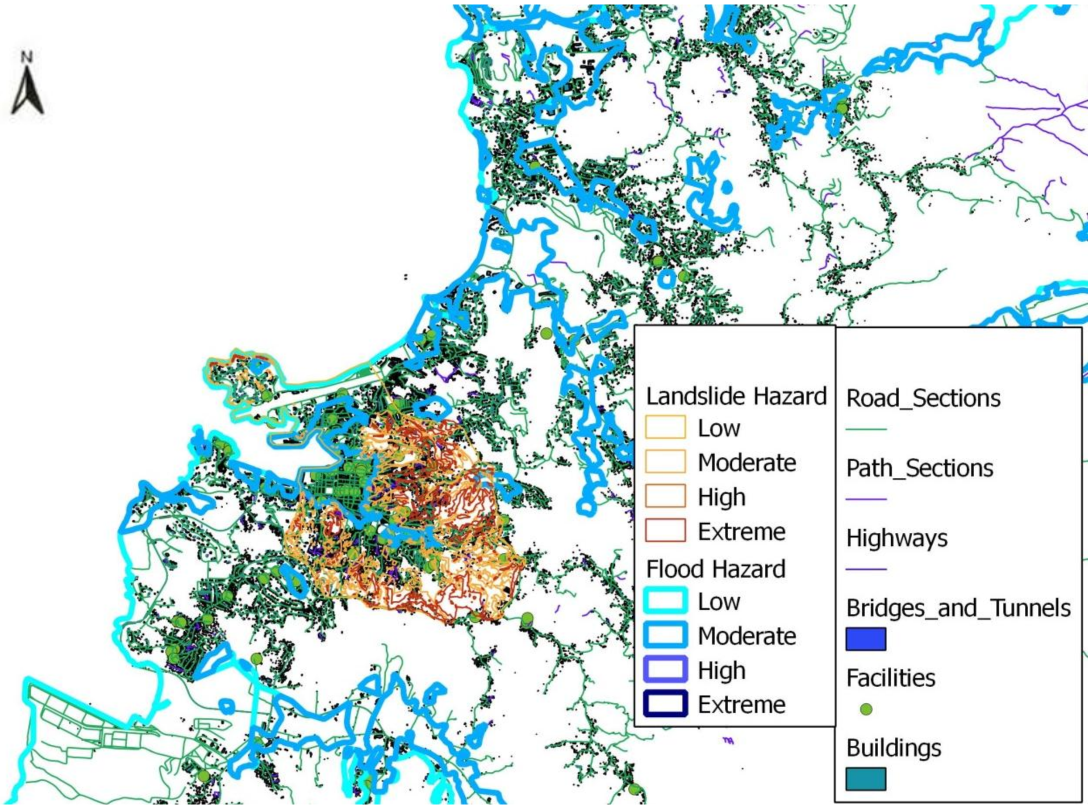


Figure 5.5 Map of the infrastructure, landslide hazard, and flood hazard for the study region, Source: The Authors.

Figure 5.6 illustrates the settlements within the study area that have been identified as vulnerable to landslides and floods overlaid with the buildings, roadways, and facilities. This provides a nexus between the most vulnerable locations and the most populated settlements. In addition, this figure suggests which of the vulnerable settlements also contain important facilities and critical infrastructure (such as schools, hospital, police stations, water facilities, electrical facilities, community centers). The Annex 5 to this document provides greater detail of this figure by breaking this figure into a series of maps by settlement.

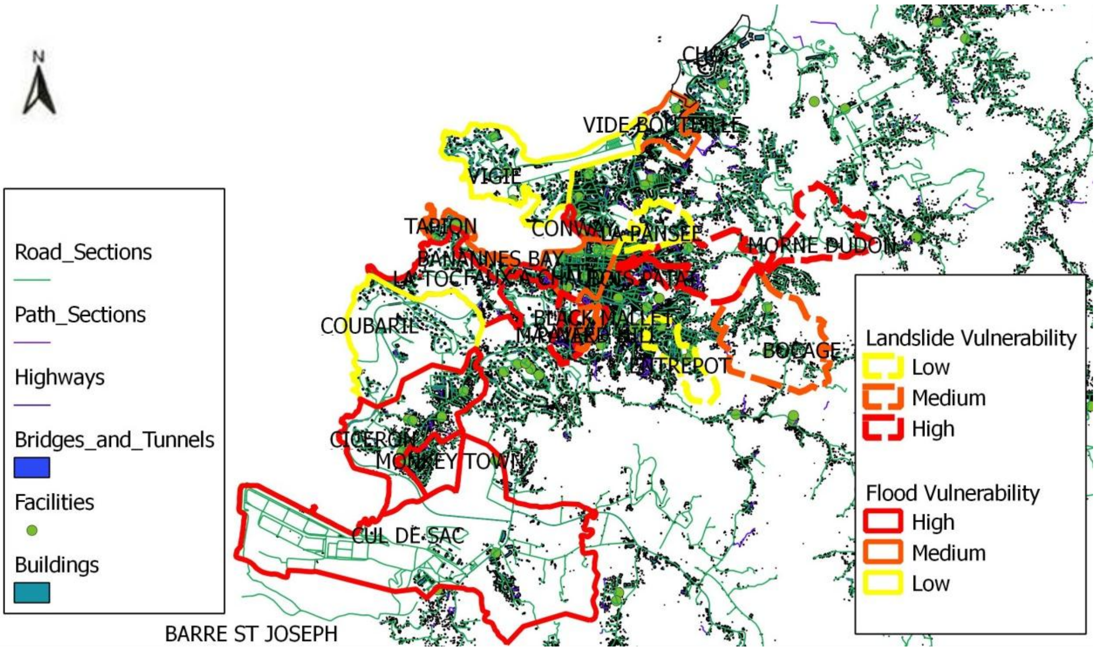


Figure 5.6 Settlements that may be vulnerable to floods and landslides. Flood vulnerability is shown with solid lines where red lines are highly vulnerable, orange lines are moderately vulnerable, and yellow lines are of low vulnerability. Landslide vulnerability is shown in dashed lines with the coloring consistent with that for flood vulnerabilities. Green circles indicate facility and critical infrastructure locations (e.g., schools, community centers, police stations, health centers), green lines indicate roadways, and blue boxes indicate buildings. Annex 5 provides a magnified view in a series of maps, Source: The Authors.

It is important to note that the vulnerability scores are based upon settlement characteristics and, hence, may not be appropriate in describing the vulnerabilities of every individual facility (see Box 10). To provide facility vulnerability scores, each type of facility would need to be considered with a number of corresponding metrics to determine facility-specific sensitivity and adaptive capacity rankings determined.

Box 10 Overlaying infrastructure and settlement vulnerability

Flood and landslide events can damage infrastructure, leading to financial losses. It is important to realize that two similar types of infrastructure may suffer differently in response to an event. This is because the potential damage and associated costs to infrastructure – particularly infrastructure built to last many decades or more – is affected by many complex factors such as building materials and design, maintenance, age of the infrastructure, past damage, and the strength and dynamics of the particular event. Therefore to analyze infrastructure vulnerability, a detailed database of these factors for each critical infrastructure is needed. Additionally, discussions with infrastructure stakeholders can assist in understanding the level of difficulty in building protective resilience into the infrastructure.

The overlay figures provided identify which infrastructure is located in an area prone to landslides and/or floods. The settlement vulnerability to the event is also included in the figures to demonstrate the potential 'social' severity if an event were to occur. For example, if a flood were to occur in a settlement that is highly vulnerable, there is a higher potential need for specific infrastructure – e.g., a hospital – to support the affected population compared to a settlement ranked at lower vulnerability. In addition, considering the criticality of the hospital to the local population is also important: Is it the only hospital within a given radius of the settlement? Are other hospitals not vulnerable to the event reachable during an event? Will necessary staff be available to support the hospital needs? These types of overlays can provide key talking points for decision makers when considering how to identify which infrastructure is critical to the local population and thereby warrant further study.

Overall, flood events appear to pose more significant risks to the key infrastructure networks of Castries than landslides. In addition, it is recommended that attention should also be paid to the urban-rural continuum, as rural (inland) areas have many critical infrastructure networks, such as energy and water supply facilities, that are important for Castries and the northwest coastal urban corridor.

Table 5.7 provides a summary of the vulnerability scoring of each settlement that are susceptible to floods and landslides. The population, facilities and critical infrastructure located within each settlement are also provided. For planning purposes, it is recommended to develop adaptation options for those densely population settlements with critical infrastructure located in potentially “high” vulnerable areas. Hence, adaptation planning could initially focus on the following settlements that may be vulnerable to coastal flooding: Cul de Sac and Ciceron/Monkey Town.

Table 5.7 Summary of settlements vulnerable to floods and landslides

Score	Settlement	Population	Facilities	Critical Infrastructure
	Floods			
High	Cul de Sac	765	■ Community center ■ School	Electrical facility
High	Ciceron/Monkey Town	1,016	■ Community center ■ Schools ■ Health center	Water facility
High	La Toc	826	-	-
High	Faux a Chaud	306	-	-
High	Conway	78	-	Water facility
Medium	Tapion	133	■ Health centers ■ Hospital ■ Schools	-
Medium	Banannes Bay	364	-	-
Medium	Castries City	805	■ Police facilities ■ Schools	Port Water facilities Electrical facility
Medium	Vide Bouiteille	531	■ School	-
Low	Coubaril	257	-	-
Low	Vigie	211	■ Police facility	Water facility Airport
	Landslides			
High	Black Mallet	102	-	-
High	Bois Patat	425	-	-
High	Morne Dudon	1,284	■ School	-
High	Pavee	1,168	-	-
Medium	Maynard Hill	580	-	-
Medium	La Pansee	448	■ School	-
Medium	Bocage	1,463	■ Schools	-
Low	Entrepot	935	■ Health centers ■ Schools ■ Community center	Water facilities

5.3.3 Considering risk

A risk assessment considers the likelihood of a hazard event occurring (typically expressed in terms of probability) and the magnitude of the consequence if the hazard event occurs. Some studies define likelihood as the probability of the occurrence of a climate hazard (NYCPCC, 2009). Our vulnerability analysis incorporated limited primary and secondary data. In order to expand this analysis to consider risk, additional data is needed to develop a quantifiable baseline understanding of the frequency, severity, and triggers of landslides and floods and how these hazards may change over time. In addition, no information was available to consider the impact of these hazards on specific critical infrastructure.

The following studies and data collection activities are suggested to continue the development of pertinent risk information for Castries:

- Sea level rise maps are based upon conservative estimates. New maps defining inundation beyond 24 cm would be useful to understand what additional areas are potentially vulnerable to future sea level rise. Coastal flood level maps were developed using the terrain height relative to mean sea level in open water and, for example, do not include local coastal drainage which could affect the behaviour of waves and flooding in a rising sea level.
- Simulations estimating how the inundation from storm surge and waves may change under rising sea levels were not available to inform this assessment. To understand how storm surge and waves may impact coastal locations, an intensive coastal storm surge analysis using models such as SLOSH or ADCIRC would reveal how the coastline may be inundated in response to various historical storms with and without projected sea level rise. This effort would demonstrate regions vulnerable to multiple scenarios of possible inundation.
- This analysis used daily precipitation data observed at a single station in the study area located in an area moderately at risk to inland flooding masking variability within the study area. Additional daily precipitation data from observation stations with records of 10 year of data or longer would provide a more holistic understanding of risk to the study area.
- Considering how the flood return periods (e.g., 2 year, 5 year, 10 year, 25 year, 50 year) may change under a changing climate would be beneficial. This would explore changes in the area currently at risk to extreme events.
- The vulnerability assessment could be enhanced by incorporating additional metrics describing sensitivity and adaptive capacity. For example, the height of the doorway floorboard may be useful in determining susceptibility to floods. In addition, considering how the values of these metrics changed with future time would create a more dynamic analysis.
- Conducting a drilled-down vulnerability analysis of carefully selected critical infrastructure would serve to identify which infrastructure is most vulnerable and arm decision makers with recommendations on how to build resilience into the system. Within this effort, outlining the costs of damage and adaptation would be particularly useful.

The choice of which activities to undertake depends on the concerns and stakeholder understanding of the hazards within Castries.

6 Strategic climate adaptation investment and institutional strengthening plan

6.1 Introduction

Present-day Castries is susceptible to flood and landslide hazards that have a substantial impact on the local population and the economy. Castries's exposure to floods, particularly coastal flooding associated with storm surge, is projected to increase with sea level rise associated with climate change. Future projections also suggest the inland flooding may remain consistent with that experienced today. Landslides, on the other hand, are not projected to increase, although urban development patterns can have an amplifying effect on existing landslide risk.

Urban development in Castries has often occurred in an unplanned manner. The urban planning system in Saint Lucia is mainly reactive, and the island lacked of a land use policy until the year 2000. As a result, due to the absence of appropriate planning instruments, settlements appeared in areas not destined for development, such as hilly slopes, often prone to landslides, or low lying and coastal areas, exposed to flooding. Although Saint Lucia has developed effective and comprehensive systems for disaster response and management through the National Emergency Management Organization (NEMO), the Castries City Council (CCC), the only functioning city level government department, has limited mandate and resources to undertake such tasks.

The purpose of the *Castries strategic climate adaptation investment and institutional strengthening plan* is to identify and then to prioritize short-, medium- and long-term adaptation interventions aimed at enhancing resilience to flooding and landslides in Castries.

6.2 Approach and tools for adaptation planning

The preceding *Climate-related vulnerability and assessment* provides the basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon in the short and medium term.

Engagement with national and local level stakeholders and decision-makers during the execution of the assignment was a very important feature which helps ensure coherence with national and local priorities and to tailor measures to fit needs.

The plan draws accordingly on the conclusions and the feedback obtained during a workshop held in Castries in February 2013. The feedback served to validate assessment findings, update or readjust them and establish a set of specific actions to be proposed based on the needs and major issues identified by stakeholders. This process helps ensure that the proposed climate change adaptation measures can be linked or incorporated into existing priorities, sectoral plans and planning instruments, and form part of an overall climate change adaptation strategy, for Castries in particular, and Saint Lucia generally.

Climate change adaptation planning is a key element of urban planning since it sets out a range of responses that can be implemented to enable communities to 'adapt' and become more resilient to climate-related change. Resilience is broadly defined as the 'ability to absorb or off-set damage and so avoid lasting harm and recover to pre-disaster status.' (da Silva et al., 2012) In the context of climate change, a more resilient system (i.e., a city) has the ability to withstand higher threshold limits in specific events, such as floods and landslides.

The steps taken to develop the *Strategic climate adaptation investment and institutional strengthening plan* for Castries were:

1. Identification of urban planning, physical, socio-economic and institutional challenges and shortcomings related to flooding and landslides, drawing from the four assessments carried out under the project.

2. Definition of planning themes that create the foundation for a climate change adaptation strategy.
3. The planning themes lead to specific structural and non-structural measures which can be implemented in Castries to manage and reduce flooding and landslide vulnerability and risk. These measures are presented in Table 6.1 and Table 6.2. Table 6.3 positions the measures within the disaster risk management (DRM) cycle.
4. Finally, a set of specific actions that can be undertaken to implement adaptation measures are proposed. These actions are presented in Table 6.4, which specifies:
   - The targeted area in the city: the area/s where the action can be enacted.
   - The institution responsible for enacting the action: this identifies the institution or institutions that have a responsibility for the proposed action.
   - The timeframe for its implementation: this allows providing a prioritization spectrum. Short-term actions are the issues with the highest priority; long-term actions are the issues with lower priority, or with high priority but with longer-roll out times.
   - An estimation of its relative cost: this is meant to give estimation on the resources to be allocated for the implementation of the action.

In the process of planning and implementation, the uncertainty associated with climate projections and its implications requires addressing, as Box 11 below describes.

Box 11 Dealing with uncertainty: addressing the risk of maladaptation

Ranger et al (2011) point out that as a degree of uncertainty is incorporated in climate projections, uncertainty is also embedded within the climate change adaptation process.

If policy-makers need to make investment decisions that will have a direct impact in the future capacity of a city to adapt to climate change, and uncertainty is embedded within the decision-making process, policy-makers face a significant challenge: *How to plan and decide on what will best help in constructing the city's resilience to climate change when the information available to advise on decision-making is limited and/or unclear?*

The major risk of not taking uncertainty into account is to take decisions that expose a society to maladaptation. This occurs when unsuitable investments are made for addressing the climate changes that actually do happen.

There are two forms:

- Under-adaptation: when the actions and adjustments made are not enough to deal with the climatic changes that do occur. For example, needing significant financial resources for replacing infrastructure built prematurely and found unsuitable to address climatic changes can be regarded as under-adaptation.
- Over-adaptation: when the adjustments made initially prove to be unnecessary, but later on they are either not adaptive or counter-adaptive. For example, when considerable financial resources are put into building a sea defense meant to withstand a sea level rise of 4 meters, but this change does not happen and the infrastructure is found unsuitable.

In dealing with maladaptation, the integration of adaptation considerations into existing planning and policy priorities can be seen as a major asset. Incorporating adaptation into the overall development process can allow the proper addressing of the existing needs of a city. The rationale is to focus on principles rather than projections. If adaptation is integrated not as an independent characteristic but as a constitutive element spanning across an integrated development strategy, the possibility of delivering an appropriate strategy taking into account present uncertainties is increased.

Furthermore, a core feature of integrated planning is to build flexibility into adaptation strategies by prioritizing long-term adaptive capacity while avoiding inflexible decisions: here, the need to have a decision support tool allowing stakeholders to make "robust" investment choices in a context of uncertainty has been advanced (Lempert et al., 2010).

"Optimal" solutions stand in contrast to "robust" ones. An "optimal" solution is only adapted for an expected future, but might be inappropriate if conditions change. "Robust" solutions might not be optimal, but they are appropriate no matter the conditions that are encountered in the future. Allowing the incorporation of new information to guide decision-making allows the effective design of an adaptation strategy in which flexibility and robustness are embedded as core elements.

6.3 Strategy and adaptation measures

Overall goal

The overreaching goal of the strategic plan is to increase resilience to floods and landslides in Castries. On the basis of planning themes, specific measures to address particular urban development challenges as well as institutional shortcomings are identified. These measures also promote a more sustainable and resilient urban development process.

From goal to planning themes

The planning themes that create the foundation for a climate change adaptation strategy to help Castries build its resilience against floods and landslides, both now and in the future, can be outlined as follows:

- **Devolved risk management and planning capacity at the city level for Castries:**
  - Strengthening of city administration and municipal functions for Castries City Council
  - Development of improved systems of urban planning in order to increase urban resilience.
  - Identification and incorporation of urban vulnerability and demographic groups at risk from climate-related hazards in planning strategies
  - Consideration of urban expansion and future demographic trends, as well as physical and climate vulnerabilities in land use management
- **Capacity building in national and city level government institutions engaged in climate change planning and risk management:**
  - Improvement of human resources capacity and infrastructure for the successful implementation of climate adaptation practices and policies.
- **Mechanisms for data collection, storage and dissemination to be created and/or improved for better climate monitoring, risk planning, and information sharing:**
  - Improvement of information, communication and policy relevant technical knowledge for assisting local actors to identify and understand impact, vulnerability and adaptation responses in order to effectively select and implement practical and high priority adaptation measures.
- **Improved insurance mechanisms and climate financing for long-term recovery and building resilience against floods and landslides:**
  - Formalized structures of cooperation with the private sector in planning and risk reduction phases for sustained and meaningful engagement.
- **Cross-scale integration of risk management practices:**
  - Promotion of local level participation in climate change adaptation and risk reduction.
  - Initiatives to engage the public and local stakeholders in adaptive actions and to improve citizen awareness regarding floods and landslides to consolidate institutional and local adaptation and provide a more holistic approach to climate change planning.
- **A shift from disaster management to long term risk reduction and climate change adaptation to ensure a proactive and forward-looking system of risk governance:**
  - Supporting efforts towards mainstreaming climate change adaptation from policy into development practice and programmes.

From planning themes to measures

An integrated strategic plan requires the use of both structural and non-structural measures for "getting the balance right" (Jha et al., 2012).

Flood and landslide risk management measures can be either structural or non-structural. In broad terms, structural measures aim to reduce risk by controlling physical processes – such as the flow of water – both outside and within urban settlements. They are complementary to non-structural measures which aim at keeping people safe from flooding or landslides through better planning and management of – in this case, urban – development. More narrowly:

- **Structural measures:** refer to physical investments that a city can institute in order to prepare its built environment for the expected effects of climate change. Structural measures are often costly investments in hard-engineered infrastructures.
- **Non-structural measures:** refer to investments other than the improvement of physical infrastructure. These measures are often less costly than structural measures, and span a wider spectrum, covering urban (for example, planning), socio-economic (for example, poverty reduction) and institutional (for example, educational campaigns) dimensions.

Tables 6.1 and 6.2 which follow present a series of disaster and climate change-related adaptation measures which can be implemented in Castries to manage and reduce flooding and landslide risk and vulnerability to these hazards – and, in so doing, enhance overall urban resilience.

Each measure is briefly described and the anticipated co-benefits over and above their flood and landslide management role are sketched.

In order to present a forward-looking view and allow the prioritization of adaptation options, two ratios are also considered:

- **Benefits relative to costs:** to allow an understanding of how the costs inherent to the measure compare with the expected benefits.
- **Robustness to uncertainties:** robustness refers to the way in which the benefits of an adaptation measure might vary with climate projections. It can be regarded as the risk of maladaptation. For example, on the left hand-side of Figure 6.2 are found "no-regret measures" (measures that will have a positive effect on adaptation, no matter the accuracy of climate projections, as for example, with awareness campaigns). On the right hand-side are located "higher-regret" measures, whose benefits are dependent on the accuracy of climate projections (for example, drainage systems or flood defences).

It is important to highlight that the robustness and cost-benefit ratios of measures are established on a case-by-case basis. It is also acknowledged that costly, long-term projects should seek "no-regret" ways to build in flexibility in order to address potential uncertainty.

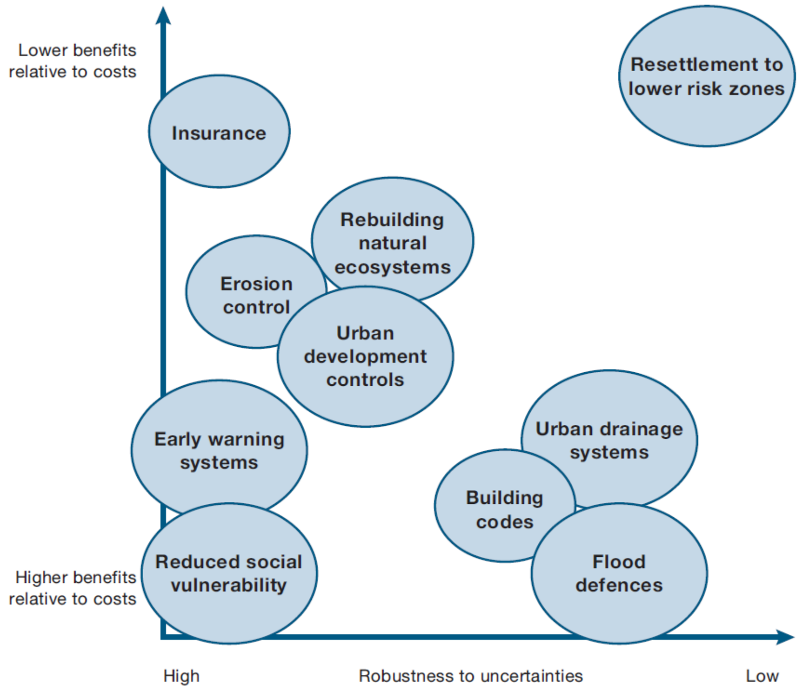


Figure 6.1 Relative costs and benefits of flood management options (based on findings for Guyana, Mozambique and UK). Source: Adapted from Ranger and Garbett-Shields 2011, in Jha, A., Bloch, R., and Lamond, J. (2012).

Table 6.1 Structural measures

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
■ More frequent, but less severe rainfall evens ■ Seal level rise ■ Storm Surges ■ Tropical storms may decrease in frequency but increase in intensity	■ Flooding from precipitation ■ Flooding from storm surge and tidal waves events ■ Flooding from sea level rise	**Sustainability of existing drainage systems**	Castries is prone to flooding from both precipitation and storm surge events due, in part, to poor drainage. Increased urban development and other challenges have reduced storm water drainage capacity to the point where even small rain events can cause flooding in the city area. Urban drainage systems need to be able to deal with both wastewater and stormwater whilst minimizing problems to human life and the environment, including flooding. Maintenance is vital, not only to remove obvious obstructions, but also cleaning out deposited sediment, and then disposing of the material so that it does not go back into the drain. The cost of operation and maintenance is a critical aspect in the long term. Realistic ways of revenue generation for sustainability and general awareness from the public and local authorities will be key issues.	■ Prevention of water pollution ■ Providing valuable habitats for wildlife in urban areas ■ Addresses landslide causes by reducing infiltration into the soil	High	Medium
■ Sea level rise ■ Storm Surges ■ Tropical storms may decrease in frequency but increase in intensity	■ Flooding from storm surge events and sea level rise ■ Shoreline erosion	**Rebuilding and protection of the natural ecosystem**	Changes in the landscape including beach erosion and the removal of a mangrove have increased the storm surge experienced in Ganters Bay within Castries Harbor. Infrastructures along the shoreline at Ganters Bay are at sea level and are extremely vulnerable to storm events. Rebuilding natural ecosystems and protection of mangroves has come to describe a basis for considering how communities are dependent upon the condition of the natural environment. Natural ecosystems contribution extends beyond the provision of goods such as food, to services which support processes such as flood and coastal erosion risk management. Mangroves, for example, have been reported to be able to help buffer against cyclones and other storms. Wetlands that provide flood protection may be valued on the basis of the cost of building man-made defenses of equal effectiveness.	■ Ecosystem goods, such as fisheries ■ Recreation and tourism ■ Climate change mitigation co-benefits	High	High

■ More frequent, but less severe rainfall evens ■ Reduction in precipitation	■ Landslides triggered by rainfall events ■ Drying soils may increase the threat of landslides	**Management of Slope Stability in Communities (MoSSaiC)**	Designed as explicitly community based, MoSSaiC provides an innovative method for delivering landslide risk reduction in the vulnerable communities. In particular, it addresses rainfall-triggered landslide hazards through community-based implementation of surface water management measures in vulnerable urban communities. MoSSaiC is already been successfully piloted in Castries as in 2004 an academic team from the University of Bristol worked in a number of communities in Castries with the support of the Government of Saint Lucia, and later continued in partnership with several international organizations, and particularly the World Bank, through the Saint Lucia Second Disaster Management Project.	■ Develops sustainable foundations for landslide risk reduction through ensuring community engagement and ownership	High	Medium
■ More frequent, but less severe rainfall events ■ Sea level rise ■ Storm Surges ■ Tropical storms may decrease in frequency but increase in intensity	■ Flooding from both precipitation and storm surge events ■ Flooding from sea level rise ■ Landslides triggered by rainfall events	**Incentivize green infrastructure projects**	Measures for reducing the amount and speed of rainwater runoff in urban areas can include green infrastructure projects. These 'greening' measures can be at a micro level, such as creation of green roofs, landscaping around buildings, and tree-lined streets. Within the context of wider urban planning, policies can be drawn up which address the need to zone natural or man-made buffer zones within and around urban areas, such as urban parks, riverside corridors, and buffers around roads in sloping areas. The creation of green spaces indirectly further reduce flooding and landslides in urban areas. From the flood management point of view the key purpose green infrastructure projects is to act as flood retention basins and hence reduce the flood risk to built-up urban areas. Green infrastructure projects can also help control the soil and stabilize stream banks providing protection against substantial erosion and landslides. The success of such initiatives will depend on considerable support from local communities and businesses.	■ Reduction of the 'urban heat island' effect ■ Benefits to flora and fauna habitats ■ Reduction of the level of CO2 ■ Reduction of run-off together with the enhancement of ground water storage by more infiltration through the soil	High	High
■ More frequent, but less severe rainfall evens ■ Reduction in precipitation	■ Flooding from precipitation ■ Increased chance of drought	**Rainwater harvesting**	Rainwater harvesting can be seen as an innovative measure to prevent urban flooding. It usually forms part of a sustainable drainage system and can simultaneously be used for non-drinking purposes, resulting in water conservation. One useful advantage of rainwater harvesting is that much of the technology used is flexible and incremental with relatively little effort required for construction, operation and maintenance. In addition, such systems tend to fail gracefully: that is, if water is initially stored in a dispersed way at source, overtopping will probably not cause more problems than if the system were not installed. Therefore some improvements can be achieved quickly and cheaply even without full understanding of the system. There are different types of rainwater harvesting systems. Roof systems are the most common. They can be simple small roof collection systems for single households and larger roof collection systems for large commercial buildings.	■ Water conversation	High	High

Table 6.2 Non-structural measures

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
■ More frequent, but less severe rainfall evens ■ Seal level rise ■ Storm Surges ■ Tropical storms may decrease in frequency but increase in intensity	■ Flooding from both precipitation and storm surge events ■ Flooding from sea level rise ■ Landslides triggered by rainfall events	**Prioritize and enhance civil society's awareness to risk**	Flood risk awareness is the cornerstone of non-structural flood and landslide risk management. All actions to minimize the impact of flooding and landslides hinge upon stakeholders becoming aware these are both necessary and desirable. A low level of public awareness and education on risk is observable in Castries, and Saint Lucia in general, with most community level knowledge emerging out of learning through past disaster events and experiences. Various measures can be advanced to enhance flood and landslide risk awareness, for example: (i) the use of communications media, such as television, radio and newspapers, as well as new media, like Twitter, Facebook for targeting to ensure the 'message' reaches a large proportion of the population; (ii) environmental awareness campaigns to improve citizen awareness on hazardous practices such as illegal waste disposal and construction in high risk zones; and (iii) public awareness in school system, given that education is the first step for a better understanding of risk, the possible consequences it can have, and the deployment of attached prevention and mitigation strategies.	■ Better understanding of risk ■ Improved environmental conditions ■ Increased deployment of risk prevention and mitigation measures	Very High	Very High
		Capacity building in national and city level government institutions engaged in climate planning and risk	Capacity building in national and city level government institutions engaged in climate planning and risk management is needed for improved human resources capacity and infrastructure for the successful implementation of climate adaptation practices and policies. In order to determine capacity needs and precise training requirements for meeting climate change challenges, targeted capacity needs assessments of key institutions should be carried out at the national as well as local levels.	■ Better climate change adaptation planning ■ Shift from a reactive and response-led system to a proactive system	Very High	Very High

	Improved mechanisms for data collection, storage and dissemination	Mechanisms for data collection, storage and dissemination should be created and or improved for better climate monitoring, risk planning, and information sharing. Technical knowledge generation and data management systems are key challenge in formulating risk reduction policies in Castries. Critical information and data to orient decisions at the sub-national and local level, as well as for the elaboration of climate change induced socio-economic scenarios, is lacking in Saint Lucia. There is no analysis of trends or patterns of loss, and low data resolution prevents the use of these inventories as a basis for informing decision-making and practice. Existing data sets do not contain sufficient information to monitor climate change or assess effectiveness of adaptation strategies. Without better information, it is impossible to undertake local adaptation activities that rely on the downscaling of climate change models and climatic data. These initiatives need to be integrated into a more strategic and consistent engagement with developing risk identification and data management systems. Both the robustness of information, as well as the systems for information management needs to be improved. Platforms for information dissemination across government agencies as well as the private sector can also help improve data accessibility and inform decision-making.	■ Better climate monitoring ■ Better flood and landslide risk planning ■ Better information sharing	Very High	Very High
	Develop an early warning system (EWS) for Castries	There is only one early warning information and prediction system for Saint Lucia. This is located outside Castries. It is NEMO's intention to mobilize external resources to finance an early warning and prediction system for Castries. The purpose of early warning systems (EWS) is simple. They exist to give advance notice of an impending flood and/or landslide, allowing emergency plans to be put into action. EWS, when used appropriately, can save lives and reduce other adverse impacts. It is important to note, however, that the utility of EWS is crucially dependent on the underlying forecasting system, the quality of emergency plans and the level of preparedness of the community at risk. Setting up a warning system may be a low cost option and is often seen as the first line of defense for that reason. The cost will be lowest in Saint Lucia because of the existing forecasting and monitoring services. Once established the service will require continuous investment in manpower, data and other resources in order to be functionally useful. Recruitment and retention of qualified personnel, continuity of funds and operations and maintenance of monitoring, modeling and dissemination equipment can be key challenges in the long term sustainability of the EWS.	■ Effective disaster prevention ■ Reduces loss of life ■ Reduces the disruption of economic activity ■ Reduces damage of property and critical infrastructures	Very High	Very High

	Oversight and enforcement of land use planning regulations	Even when land use planning takes flood and landslide risk into consideration, the implementation and enforcement of guidelines and regulations often remains problematic. To overcome these constraints and facilitate the implementation of land use management, possible incentives and disincentives may include (ADPC, 2010): (i) offering land development subsidies in some areas and levy development overhead charges in others; (ii) encouraging the location of industries and housing in safe areas by prioritizing in those areas the installation of utilities and urban services; and (iii) encouraging the use of certain areas through differential land pricing (in the case of undeveloped or underdeveloped land) or by subsidizing transportation from those areas to areas of employment, shops and businesses.	■ Better urban planning and management ■ Effective disaster prevention	High	High
	Integrated land use planning and risk-sensitive zoning	Land use planning provides a policy and regulatory mechanism that enables diverse and often conflicting objectives to be integrated and addressed in a development framework – with this process and its output, is referred to as 'integrated land use planning'. Integrating flood and landslide risk management objectives and principles into land use planning is an essential component of flood and landslide risk management. Through its formulation and implementation, land use planning: ■ Identifies appropriate area(s)/location(s) for specific land uses ■ Determines what risks are associated with specific land uses in specific locations ■ Determines and identifies sensitive or important societal or environmental features ■ Details minimum requirements/expectations of particular land use types. ■ Put simply, it determines what urban development is required and where it should go. The interaction between land use planning and flood and landslide risk management is mutual. Urban land use plans should ideally be integrated within a suite of flood and landslide management plans which may include river basin management plans, coastal management plans and surface water management plans. Such plans are likely to be the responsibility of different governmental departments or agencies and the urban use plan will be informed by these dedicated flood and landslide management tools.	■ Increased resilience and establishment of a pattern of sustainable urbanization	High	High

	Improved budgetary resources and climate financing	Stakeholders recognized that Castries's limited financial capabilities are a major challenge in any possible actions to be undertaken in climate change adaptation. Whether it is for financing new infrastructure, expanding the local DRM system, or engaging new actors in it, Castries is confronted with a lack of resources. This is not to be underestimated, as it could hinder the potential long-term capacity to address climate hazards. Increased resources for climate finance could thus help the city expand its capabilities in coping with climate change hazards. Specific municipal budget allocations in climate change would enhance the city's capacity in designing strategies targeting a particular output in climate change adaptation action. The underlying question is to figure out where the new resources could come from. Innovative solutions involving different scales in government, including local and national authorities, might be necessary to ensure that possible increased budgetary allocations are at disposal.	■ Enhanced capabilities in designing and implementing climate change adaptation actions – risk identification, risk reduction, adaptive governance	High	High
	Formalized structures of cooperation with the private sector in planning and risk reduction	Further attention can be paid to the level of engagement and liaison between the government and private sector in both risk management and climate change adaptation. Progress is being made in attracting private sector investment through the concessional loan facility. Stakeholders acknowledged that the involvement of various private sector actors could be improved. This would allow the establishment of a more integrated and participatory strategy in climate change adaptation and the DRM system overall. Stakeholders specifically targeted: The private sector could also be engaged in climate change adaptation through a Corporate Social Responsibility (CSR) schemes. Private companies, notably in the tourism industry, can undertake innovative measures in climate change adaptation and mitigation.	■ Improved integration of the DRM and climate change adaptation system ■ Elaboration of a more integrated approach in climate change adaptation action taking into account lessons and ideas from various stakeholders	High	High
	Mortgage finance or security backed loans for climate change adaptation activities	Individuals and communities, or businesses, may acquire funds for property level adaptation or local community schemes. This may be based on mortgage finance or security backed loans to dependent on 'elevation house' (for floods) and on 'retaining walls' (for landslides). However, many individuals and communities world have difficulty in accessing finance via traditional market-based routes, and may rely on microfinance. Microfinance arrangements have the potential to empower individuals and communities to implement flood and landslide risk management solutions for themselves. Microfinance can be supplied by market based financial institutions (MFIs), and also by NGOs for the poorest sectors of the population.	■ They can form a vital part of development strategy for poor individuals and micro enterprises	Medium	High

	Improved insurance mechanisms and climate financing for long-term recovery and building resilience against climate change hazards	Saint Lucia has made efforts to improve its insurance system to cope with the aim of improving its response to natural disasters. Insurance have two main purposes in the management of flood and landslide risk. Firstly, and most obviously, the provision of these financial mechanisms can be used by those at risk to offset their financial risk from flooding and landslide. Although these financial tools obviously do not prevent flooding or landslides, they allow recovery without placing undue financial burdens on those impacted by flood and landslide disasters. Purchase of insurance is highly dependent on a number of factors, including its availability and cost, the level of the provision of disaster relief, general risk awareness, and attitudes to collective and individual risk. Micro-insurance can be a solution offered to the urban poor. Below the poverty line, micro-insurance schemes will need some government or donor intervention. Expansion of insurance coverage and financial instruments, such as those outlined above, could thus contribute to alleviate financial pressure on the government during recovery and adaptation phases.	■ Disaster recovery can be expedited and funds are not diverted from other priorities such as development	Medium	High

Note: For comprehensive, forward-looking operational guidance on how to manage the risk of floods in a rapidly transforming urban environment and changeable climate see Jha, A., Bloch, R., and Lamond, J. (2012) “Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century.” Available at: https://www.gfdrr.org/urbanfloods. For guidance on community-based landslide risk reduction see Anderson, M. G. and Holcombe, E. (2013) “Community-Based Landslide Risk Reduction: Managing Disasters in Small Steps.” Available at: https://openknowledge.worldbank.org/handle/10986/12239. Highland, L.M., and Bobrowsky, P. (2008) “The landslide handbook—A guide to understanding landslides.” Reston, Virginia, U.S. Geological Survey (USGS) Circular 1325, is a useful resource for policy makers and technical specialists concerned with landslide risk reduction. Available at: http://pubs.usgs.gov/circ/1325/

Proposed measures and the disaster risk management (DRM) cycle

Under the disaster risk management (DRM) cycle, the structural and non-structural measures above can also usefully be classified as: (i) risk reduction, (ii) risk transfer or share, (iii) preparedness, and, (iv) response and recovery (Mitchell and Harris, 2012). Table 6.3 below locates the proposed structural and non-structural measures in the DRM cycle.

Table 6.3 Risk management options

Risk reduction (preventing hazard/shock, reducing exposure and vulnerability)	Risk transfer or share	Disaster preparedness	Disaster response and recovery
Incentivize green infrastructure projects	Improved insurance mechanisms	Develop an early warning system for Castries	Improved budgetary resources and climate financing
Rainwater harvesting	Mortgage finance or security, backed loans for climate change adaptation activities	Prioritize and enhance civil society's awareness to risk	Formalized structures of cooperation with the private sector
Rebuilding and protection of the natural ecosystem		Capacity building in national and city level government institutions	
Sustainability of existing drainage systems		Improved mechanisms for data collection, storage and dissemination	
Management of slope stability in communities			
Oversight and enforcement of land use planning regulations			

6.4 Action plan: from measures to action

Table 6.4 presents a set of specific actions that can be undertaken to implement the adaptation measures above. It illustrates the areas targeted by the action, the institution/s responsible for putting it in place and giving it life, the expected time-frame (short, medium, or long-term), as well as the relative costs. The purpose of this is to present activities that the city could consider and to present how these could be implemented.

Table 6.4 Castries action plan

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
Incentivize green infrastructure projects	Incentivize 'greening' measures at the micro level, such as creation of green roofs, landscaping around buildings, and tree-lined streets	City-wide; prioritize low-income high-risk neighborhoods	■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Ministry of Physical Development Environment and Housing ■ Ministry of Infrastructure, Port Services & Transport				High
	Zone natural or man-made buffer zones within and around urban areas, such as urban parks, riverside corridors, and buffers around roads in sloping areas						
Rainwater harvesting	Determine the type of rainwater harvesting system depending on the size and nature of the catchment available	City-wide; prioritize low-income high-risk neighborhoods	■ Ministry of Physical Development Environment and Housing ■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Castries City Council				Medium
	Allocate roles and responsibilities at both individual and community levels						
Rebuilding and protection of the natural ecosystem	Call for an expert meeting on protection and restoration of mangroves and other coastal ecosystems as strategies for climate change mitigation and adaptation	Coastal areas	■ Ministry of Physical Development Environment and Housing ■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Ministry of Infrastructure, Port Services & Transport ■ Castries City Council				High
	Develop and implement ecosystems and mangrove protection policies and legislation to halt further degradation and promote mangrove restoration activities						
Sustainability of existing drainage systems	Carry out detailed studies for the water basins of the city to assist decision making for future drainage infrastructure investments	City-wide	■ Ministry of Infrastructure, Port Services & Transport ■ Castries City Council ■ Civil Society				High

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule: Short-term (1-5 years)	Schedule: Medium-term (5-10 years)	Schedule: Long-term (10-20 years)	Relative costs
	Develop a comprehensive maintenance strategy to sustain the overall condition of the drainage infrastructure		Organizations; NGOs; and Private Sector				
Management of Slope Stability in Communities (MoSSaiC)	Confirm and evaluate the relative landslide exposure and vulnerability of specific communities	Landslide prone areas; prioritize low-income high-risk neighborhoods	■ Ministry of Physical Development Environment and Housing ■ Castries City Council ■ Civil Society Organizations; NGOs; and Private Sector				Medium
	Design and implement the landslide hazard reduction measures						
Prioritize and enhance civil society's awareness to risk	Define target audience(s), for example, the public, professionals, hard to reach groups	City-wide	■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Castries City Council ■ Civil Society Organizations; NGOs; and Private Sector				Medium
	Choose the message and determine communications channels. Using more than one channel						
Capacity building in national and city level government institutions engaged in climate planning and risk	Devise a schedule and mechanism for relevant key officials and adaptation experts to engage with one another to share understanding, experience and visions for urban adaptation planning	City-wide	■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Castries City Council ■ Civil Society Organizations; NGOs; and Private Sector				Low
	Support strategic capacity building for urban adaptation planning and knowledge exchange through practitioner networks and global events						

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
Improved mechanisms for data collection, storage and dissemination	Database generation using actual event data, historical data, socio-economic and physical data	City-wide	■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Civil Society Organizations; NGOs; and Private Sector ■ Castries City Council	■			Medium
	Develop a computer-aided well-integrated system of data collection, monitoring and information dissemination			■			
Develop an early warning system (EWS) for Castries	Needs and applicability analysis for an early warning system (EWS) for Castries	City-wide	■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Castries City Council ■ Civil Society Organizations; NGOs; and Private Sector	■			Medium
	Operationalize warning service. Generate a parallel program of wider community engagement with the warring system			■			
Oversight and enforcement of land use planning regulations	Identify and assess possible inceptives and disincentives that could facilitate the implementation of land use management	City-wide	■ Ministry of Physical Development Environment and Housing	■	■	■	Low
Integrated land use planning and risk-sensitive zoning	Undertake a strategic assessment of Castries to understand what land uses exist and identify natural features, infrastructures, and the built form	City-wide	■ Ministry of Physical Development Environment and Housing ■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Castries City Council	■			Medium
	Improve land use planning and zoning by incorporating flood and landslide risk management				■	■	
Improved budgetary resources and climate financing	Integrate climate risk reduction across the budgets and projects of government departments or crate a distinct budget for climate risk reduction	City-wide	■ Ministry of Finance, Economic Affairs, Planning & Social Security		■	■	High

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
	Identify and assess possible ways for climate finance, including through private sector contributions		■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Castries City Council				
Formalized structures of cooperation with the private sector in planning and risk reduction	Inclusion of the private sector in flood and landslide risk management may involve the utilization of the financial and human resources of businesses	City-wide	■ Ministry of Finance, Economic Affairs, Planning & Social Security ■ Ministry of Public Service, Sustainable Development, Science, Energy and Technology ■ Private Sector				Low
	Identify and assess possible climate change adaptation solutions through Corporate Social Responsibility (CSR) schemes, for example in the tourism industry						
Mortgage finance or security backed loans for climate change adaptation activities	Identify and assess possible market-based products for individuals and communities, or businesses to implement flood and landslide risk management solutions	City-wide	■ Ministry of Finance, Economic Affairs, Planning & Social Security ■ Civil Society Organizations; NGOs; and Private Sector				High
	Identify and assess possible micro-finance arrangements for low-income individuals and communities, or micro-businesses to implement flood and landslide risk management solutions						
Improved insurance mechanisms and climate financing for long-term recovery and building resilience against climate change hazards	Identify and assess possible market-based insurance products for individuals and communities, or businesses	City-wide	■ Ministry of Finance, Economic Affairs, Planning & Social Security ■ Civil Society Organizations; NGOs; and Private Sector				High
	Identify and assess possible micro-insurance schemes for low-income individuals and communities, or micro-businesses						

6.5 Conclusion

Climate change adaptation is a continuous process: the resilience of a city can be enhanced over time through various measures in different time-scales (short-term, medium-term, long-term). The *Castries Strategic Climate Adaptation and Institutional Strengthening Investment Plan* presents an overview of measures that the city can implement to enhance disaster risk management and adaptation planning. This is done following a holistic approach: the different elements that constitute Castries as an urban area are taken into account, and effort is put into assessing what initiatives are already in place and how new strategies can contribute to improve what is in existence. This would ultimately strengthen institutional capabilities.

As discussed in this report, Saint Lucia has undertaken, or is in the process of undertaking, projects that have generated policy outputs or that demonstrate clear policy stances on climate-relevant issues. These include the Caribbean Planning for Adaptation to Climate Change (CPACC), Adapting to Climate Change in the Caribbean (ACCC) and Special Programme on Adaptation to Climate Change (SPACC) projects. Further, the 2002 National Climate Change Policy and Adaptation Plan (NCCPAP) is the first policy instrument formulated to specifically address climate change. Since then, climate change elements have been incorporated in several national policy documents.

Overall, a relatively elaborate institutional set up for climate change adaptation and disaster risk management operates primarily at national level and is reinforced by regional (Caribbean-level) initiatives. Enhancing the risk management and planning capabilities of the City Council, or establishing new city level agencies to address adaptation and planning would be a means of promoting local level adaptive capacity in the context of the city. Until then, climate change adaptation planning for Castries necessarily focuses on national level agencies engaged in disaster risk management and climate change adaptation planning.

For the Castries Plan we acknowledge and recommend the potential for utilizing the output of this project for inclusion in current and future urban planning and management activities in Castries in particular, and Saint Lucia in general, notably the potential links with the World Bank-funded Pilot Program for Climate Resilience (PPCR) and the ensuing proposed Disaster Vulnerability Reduction Project (DVRP) for Saint Lucia, which are designed to provide programmatic finance for climate resilient development plans.

Similarly to what we are proposing here, the Saint Lucia DVRP follows a “no-regrets” approach. In particular, investments will be chosen based on a high risk of structural failure to the 10-year event (Category 1 Hurricane) in the case of buildings and bridges, or where annual flooding occurs in the case of flood management and urban drainage. DVRP also intends to finance activities for institutional strengthening and regional collaboration for capacity-building and knowledge-building around geospatial data management, risk analysis, and climate change adaptation planning, including developing and enforcing the use of harmonized infrastructure codes and standards. In addition, the Government of Saint Lucia will establish a line of credit, an ‘Adaptation Loan Facility’ that will provide concessional loans to businesses, community groups and households for investments and/or livelihood activities that supports disaster vulnerability reduction and climate change adaptation.[17]

Actions decided and implemented in the present can play a central role in shaping the future exposure to climate hazards, such as floods and landslides. Understanding the linkages between conventional urban development and climate change adaptation is key in reducing climate-related vulnerability in Castries.

The main challenge for policy- and decision-makers is to implement a climate change adaptation process that considers the trade-offs between current development priorities and long-term climate risks and embraces uncertainty, as the timing and scale of local climate change impacts affects the types of measures to be adopted and prioritization of investments

[17] World Bank (2012) “Saint Lucia Disaster Vulnerability Reduction Project” Project Concept Note.

and action. In the end, the ability and willingness of key actors to address climate change impacts will be of utmost importance.

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ANNEXES

Annex 1 Methodology of climate-related hazard assessment

This analysis utilizes existing planning tools, data and resources (in short, tools) used by Saint Lucia's government to consider how flood and landslide hazards may change in the Castries study area by approximately mid-century (more specifically, the 2040s). To effectively inform future disaster risk and urban planning, it is important our approach be appropriately aligned with the available local data and planning procedures.

The steps taken to consider how climate changes by the 2040s may impact the timing and frequency of future landslide and flood events are:

1. Reviewing available information describing the physical system such as hydrology and geomorphology to understand the drivers that affect landslides and floods.
2. Collecting and investigating data on past landslide and flood events in Castries to assess the degree of impact per event and the conditions that precipitate events.
3. Assessing available tools used by the municipality to describe zones susceptible to landslides and floods, and inform emergency planning.
4. Assessing available future precipitation and temperature data for the 2040s.
5. Assessing the application of three distinct approaches that consider how climate change may impact the tools investigated in Step 3.

Each step is discussed in greater detail below.

Step 1: Review the physical system. It is important to first understand the physical system specific to Castries that affects the nature and location of landslides and floods. To do this, the thematic maps of local terrain, geology, and hydrology developed by the Saint Lucia government were reviewed. To investigate local climate, two data sources were analysed:

- WorldClim data was processed to consider how observed mean annual precipitation varies across Saint Lucia (Hijmans et al., 2005). Worldclim data was generated through the interpolation of average monthly climate data from weather stations at a 1 km^2 resolution.[18] A figure is included in this analysis to illustrate the large variability in precipitation across the mountainous region.
- Daily precipitation records were provided by the Saint Lucia Meteorological Services for two coastal stations and were used to construct climatic averages of monthly precipitation and extreme events for 1989 to 2010.

The results of this step are presented in Section 2.3.

Step 2: Catalogue past events. A collage of past flood and landslide events was compiled based on: (1) discussions with stakeholders during the field visit; (2) government reports; and (3) online material including local newspaper reports. This information was collected to explore answers to these specific questions: Do floods and/or landslides occur concurrently? Is the hazard more apt to occur during specific times of year? Is there regularity to the occurrence of the events or is the time series of events punctuated by a few events over a long time period? Answers to these questions helped illuminate the flood and landslide trends in Castries.

The results of this step are presented in Sections 2.4 and 2.5.

Step 3: Review resources that inform flood and landslide management. As this analysis is to inform planners, planning and emergency management, a survey of available information led to the collection of materials (e.g., maps, plans, weather indicators) that are used as tools by the local

[18] For observation data, this dataset uses a number of major climate databases such as the Global Historical Climatology Network (GHCN), the FAO, the WMO, the International Center for Tropical Agriculture (CIAT), R-HYdronet, and a number of additional minor databases for Australia, New Zealand, the Nordic European Countries, Ecuador, Peru, Bolivia, among others. It also uses the SRTM elevation database. The ANUSPLIN program interpolates noisy multi-variate data using thin plate smoothing splines (using latitude, longitude, and elevation as independent variables). At a minimum, averages were calculated for 1960 to 1990 where at least 10 years of data where available. After removing stations with errors, WorldClim used precipitation records from 47,554 locations.

stakeholders to gage landslide and flood hazards. Using these resources allows this analysis to be developed drawing from sources of information that local planners are intimately knowledgeable with. In addition, the materials may have defined spatial and temporal scales for the precipitation data that were deemed acceptable, and, as such, replicating future projections as close to the scales of data as possible ensures the results of this analysis are within an acceptable scale of uncertainty to inform future plans (understanding that working with climate projections introduces additional uncertainty as discussed in Step 4). A review was conducted to investigate if precipitation data informed these collective tools. For example: Is the flood and/or landslide early warning system triggered by a specific precipitation threshold? Were the flood and/or landslide hazard maps developed based on precipitation metrics?

For this analysis, the tools available include coastal flood hazard maps, inland flood hazard maps, and landslide hazard maps. The meteorological and oceanographic parameters used in these maps were identified. There was no information linking emergency response to meteorological conditions. The Saint Lucia Meteorological Services did describe an emergency warning system that is enacted on a storm-by-storm basis (i.e., no formal meteorological thresholds or criteria are used to formally enact the warning system).

Discussion of the findings of this step is presented in Sections 2.4 and 2.5.

Step 4: Assess climate projections. We reviewed sources that provide precipitation and temperature projections. For replicability across other cities and as no locally tailored data was available, data sources that provide global projections of climate were considered.

Considerations in identifying and developing appropriate projections. The following approach was adopted to develop robust projections from the available projections to inform this analysis (see Box 12 for term definitions and additional discussion of uncertainty in climate projections):

- **Time period:** The 2040s were chosen as the relevant time period for this analysis.
- **Spatial scale:** The data sources of climate projections available include global climate model projections with and without the application of statistical downscaling. Given the small-size of the island nation and the gaps that exist in the observational network of the Caribbean islands, the use of statistically down-scaling the projections may introduce more uncertainty into the projections than add to the robustness of the projections. Because of this, the preferred option was to work directly with the global climate model projections.
- **Natural Variability:** To reduce this uncertainty, 30-year averages are preferred centered at the 2040s; however, only 10-year averages were readily available. Hence, the use of the 10-year averages introduces some uncertainty as such a short time period will not reduce the influence of natural variability.
- **Model uncertainty:** To reduce the contribution associated with model uncertainty, projected change was calculated as an average for the climate model ensemble (i.e., the average values across all climate model results) for a given emission scenario. This is consistent with the approach recommended by the broader community of climate scientists as the most robust indication of how climate may change in the future when considering adaptation responses (Knutti et al., 2010). To illustrate the range of values projected across the climate models, the maximum and minimum projections from the individual climate models were also provided.
- **Scenario uncertainty:** Given it is unclear how global society may evolve over the coming decades, this analysis considered low (B1) and moderately-high (A2) greenhouse gas emission scenarios for developing potential futures.

Box 12 Uncertainty in climate projections

There is considerable confidence in the capability of climate models to simulate temperature projections[1] particularly at the continental scale, but less confidence in climate models ability to project precipitation. This difference in confidence should be qualitatively considered when incorporating risk and vulnerability assessment results into future planning.

There are three main sources of uncertainty in climate model simulations:

1. Natural variability (the unpredictable nature of the climate system)
2. Model uncertainty (the ability to accurately model the Earth's many complex processes)
3. Scenario uncertainty (the ability to project future societal choices such as energy use)

The relative contribution of each uncertainty component to the climate model simulation's overall uncertainty varies with time. In the near term, Hawkins and Sutton (2009) suggest scenario uncertainty is relatively minimal while model uncertainty and natural variability are dominant contributors by near-term and mid-century. These uncertainties also change relative to each other for projections on different spatial scales. Natural variability becomes a greater source of uncertainty at finer scales. This is one reason why incorporating downscaled projections expands the potential uncertainty in climate projections.

There are a few methods adopted within the climate modelling and impact science community to capture the breadth of uncertainty associated with each of the three main sources. To understand the uncertainty associated with natural variability, climate model results may be averaged over long-term periods of time (e.g., 30 years) or driven with variations in input data to simulate various sources of natural variability differently. A collection of results across climate models that rely on variations in parameterizations and other components within climate models can provide some breadth of the uncertainty component associated with climate models. And considering various emission scenarios reflecting differences in how our society may change in the future provide some degree of quantification of the scenario uncertainty.

Climate datasets used in the analysis. For simplicity, this analysis refers to the climate model ensemble mean under the B1 emission scenario as Scenario 1 and the climate model ensemble mean under the A2 emission scenario as Scenario 2 (see Boxes 12 and 13).

Box 13 Scenarios for this analysis

Scenario 1: The climate model ensemble average under the low (B1) emission scenario

Scenario 2: The climate model ensemble average under the moderately-high (A2) emission scenario

Box 14 Emission scenarios

The A2 emission scenario family assumes a population that continuously increases and regional economic development with technology change more fragmented than other scenarios. The B1 emission scenario describes a global population that peaks in mid-century and declines thereafter, and an emphasis on global solutions to economic, social, and environmental sustainability (IPCC, 2007).

For the Castries analysis, we decided to collect two sets of data described in Table A1.1:

- Annual projections for precipitation were gathered from the website managed by United Nations Environment Program (UNEP) and United Nations Development Program (UNDP) for the 2040s relative to a 1970 to 1999 baseline (McSweeney et al., 2010). This data provide projections of 15 climate models under the low (B1) and moderately-high (A2) emission scenarios.[19]
- The UNEP/UNDP site also provides extreme precipitation projections for the 2060s under the low (B1) and moderately-high (A2) emission scenarios. Though this time period is less than ideal, it is the only source of available extreme precipitation projections needed for this analysis.

[19] As recommended by the scientific community, this analysis considers the average across model grid cells around the Castries study area (i.e., not just at the grid cell that overlays Castries). This increases the statistical confidence of the results (Girvertz, 2009).

Table A1.1 Catalogue of climate projections for the 2040s used in this analysis.

Dataset / Report	Precipitation Projections	Downscaled?	Spatial Resolution	Emission Scenarios	Climate Models
UNDP[20] (McSweeney et al,. 2010)	Annual, Extreme Events (2060s)	No	250 km	B1 A2	15 global climate models used to inform the IPCC Fourth Assessment

For this analysis, we assumed all projections were equally plausible rather than assigning ranks or weights to a given climate model or emission scenario.

The projected changes in climate based upon these two datasets for the two scenarios described in Box 13 are provided in Section 2.6.

Step 5: Assess approaches to consider climate change impacts on floods and landslides. As described below, we considered three approaches and tested the viability of implementing each one based on available information:

- **Approach 1.** This approach identifies and investigates the development of flood and landslide hazard maps used by local stakeholders in planning and emergency management. Any precipitation metrics used to develop the flood and landslide maps are identified. An analysis is done to quantify how these precipitation metrics may change in the future and a discussion of the implications of these changes on the frequency and/or intensity of future flood and landslide events is provided.
- **Approach 2.** Using regional meteorological events that have caused floods and/or landslides can be a useful approach in developing precipitation event thresholds. How floods and/or landslides may change in the future can then be investigated by looking at future daily precipitation projections to see how often these thresholds might be crossed in the future.
- **Approach 3.** When observational data and/or records are very limited, global datasets of precipitation projections can provide insight as to how changes in the nature of precipitation may impact future floods and landslides in Castries.

Table A1.2 provides a succinct discussion of each approach along with a description of the data requirements, the assumptions and limitations for applying the approach in the Castries study area. The level of detail in the findings for use by the municipality reduces from the first approach to the third approach, moving from a more quantitative analysis to one that is more qualitative. Given the constraints on the available information, we largely adopted Approach 1 to investigate how landslides and floods may change in the future for Castries.

As this study was not intended as an intensive vulnerability and risk analysis, we did not consider a sophisticated and time-consuming model-intensive approach for Castries. This would include conducting hydrologic and hydraulic modelling driven by projected changes in precipitation to consider changes in the flood hazard. Additionally, analysis to understand better today's relationships between storm events and hazards could also be conducted. This, for example, could potentially provide a robust statistical relationship between storm events and landslides that could be used to tailor future precipitation projections to consider changes in future landslide hazards. The findings of our analysis based on the more simpler approaches, however, can provide guidance regarding the best use of funds for conducting such a vulnerability and risk analysis (e.g., which hazards are likely to worsen, are there potential hotspots where hazards may get even worse, amongst others).

[20] http://country-profiles.geog.ox.ac.uk

Table A1.2 Description and considerations of approaches to investigate how changes in precipitation may impact floods and landslides in Castries.

Approaches to investigate future changes in floods and landslides				
Approach	Description	Requirements	Assumptions	Discussion/Limitations
1. Identify precipitation metrics used in developing local flood and landslide hazard maps for local planners. Consider how these precipitation metrics may change in the future.	Investigate the methodology used to develop local flood and landslide hazard maps that inform local planners (e.g., 100 year flood, maps that identify areas that are prone to flooding, etc.). Determine what precipitation metrics were used in the map development. Identify appropriate source(s) for the projections of the precipitation metrics within the temporal and spatial resolution required and use these data to consider future change in hazard. In addition, through stakeholder discussions determine if additional anecdotal information or emergency flood and/or landslide warning systems are used and tied to precipitation thresholds.	■ Local flood hazard maps ■ Local landslide hazard maps ■ Information underlying the emergency flood warning systems ■ Information underlying the emergency landslide warning system ■ Local expertise in flood events ■ Local expertise in landslide events ■ Projections of identified precipitation metrics	The findings of this approach describing future conditions would not create new flood and landslide hazard locations. This method is constrained to consider whether the flood and landslide hazard locations identified by the flood and landslide maps are projected to intensify or lessen; though qualitative reasoning can be applied to broaden the identified future hot spots.	Local stakeholders use flood and landslide maps as described in Sections 2.4, 2.5, and 2.6 to identify areas prone to floods and landslides. These maps are linked to meteorological and oceanographic thresholds that can be used in this analysis. The 100-year flood map was not provided for this analysis; however, this analysis is not structured to support a re-analysis of the 100-year flood maps using sophisticated hydrological and hydraulic models.
2. Identify precipitation thresholds. Consider how these precipitation thresholds may change in the future.	Use past events described in research/academic/government literature and local newspapers to identify the dates of past flood and/or landslide events. Using these identified dates, construct a table with the daily precipitation observed at a local weather station. If there are enough events to consider, investigate the strength of the precipitation threshold(s) in predicting flood events (e.g., construct a scatterplot between precipitation and flood, investigate whether there were other days that crossed a specific precipitation	■ Collection of past flood events ■ Collection of past landslide events ■ Local meteorological data ■ Daily downscaled precipitation projections	This approach assumes that precipitation thresholds represent a consistently strong driver for like-floods and landslides. This assumes other future changes across the city remain static such as changes in land use, construction and maintenance in sewage/drainage systems, and housing.	Saint Lucia Meteorological Services provided daily precipitation data for two coastal observation stations. Though Saint Lucia does keep records of past events that would be useful for this approach, these information was not made available for this analysis. Future work could include linking the past landslide and flood events on records with the precipitation amounts and storm surge to consider relevant meteorological and oceanographic thresholds. This option also is difficult to

Approaches to investigate future changes in floods and landslides

	thresholds but did not lead to flooding); similarly for landslide events. This effort can be conducted for the entire study area or divided into smaller regions dependent on the scale of data available. Use daily downscaled precipitation projections to consider how the frequency of the precipitation threshold(s) may change in the future.			apply as it assumes daily downscaled precipitation data is available in a ready-to-use format for this analysis - this is not the case for Castries.
3. Construct / leverage future precipitation projections and qualitatively consider the impact on floods and landslides.	Identify sources of recent precipitation projections for Castries (i.e., projections developed ideally using modelling of IPCC AR4 or later) and the associated metrics (e.g., time periods, emission scenarios, climate models). Construct a catalogue of precipitation projections and determine the best projections to use for the flood and landslide analysis. Ideally, the data would include changes in annual, monthly, and daily precipitation. If daily is not available, then 'processed' projections that are available should be considered (e.g., changes in the 5-percentile of precipitation; changes in the 100 year precipitation return period).	■ Precipitation projections ■ Local landslide hazard maps (if available) ■ Local flood hazard maps (if available)	This assumes other future changes across the city remain static, including: land use, construction and maintenance in sewage/drainage systems, and housing. Also assumes flood and landslide maps may or may not be available.	The precipitation projections will not be developed specifically focusing on precipitation flood and landslide drivers in Castries.

Annex 2 Hazard maps

This appendix contains two landslide hazard maps that have been develop for Saint Lucia. They are provided for comparison with the landslide hazard map developed by CIPA (2006) based on DeGraff (1985). The hazard maps are as follows:

- Figure A2.1: Saint Lucia debris flow risk map, developed by Rogers (1997).
- Figure A2.2: Saint Lucia landslide susceptibility map, developed by Quinn (2012) in a draft paper submitted to the Canadian Geotechnical Journal in April 2011.

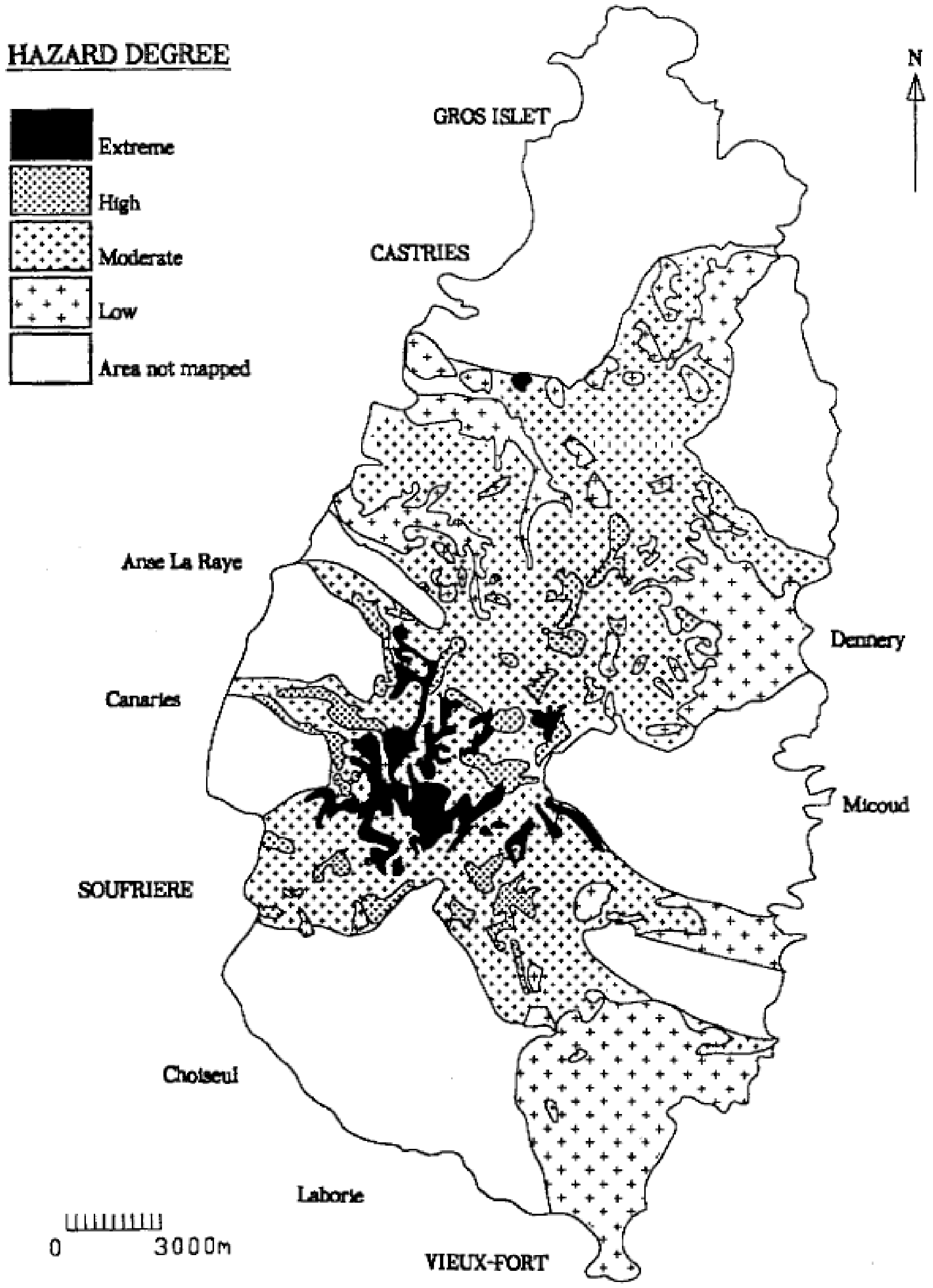


Figure A2.1 Debris flow hazard map, Source: Rogers 1997.

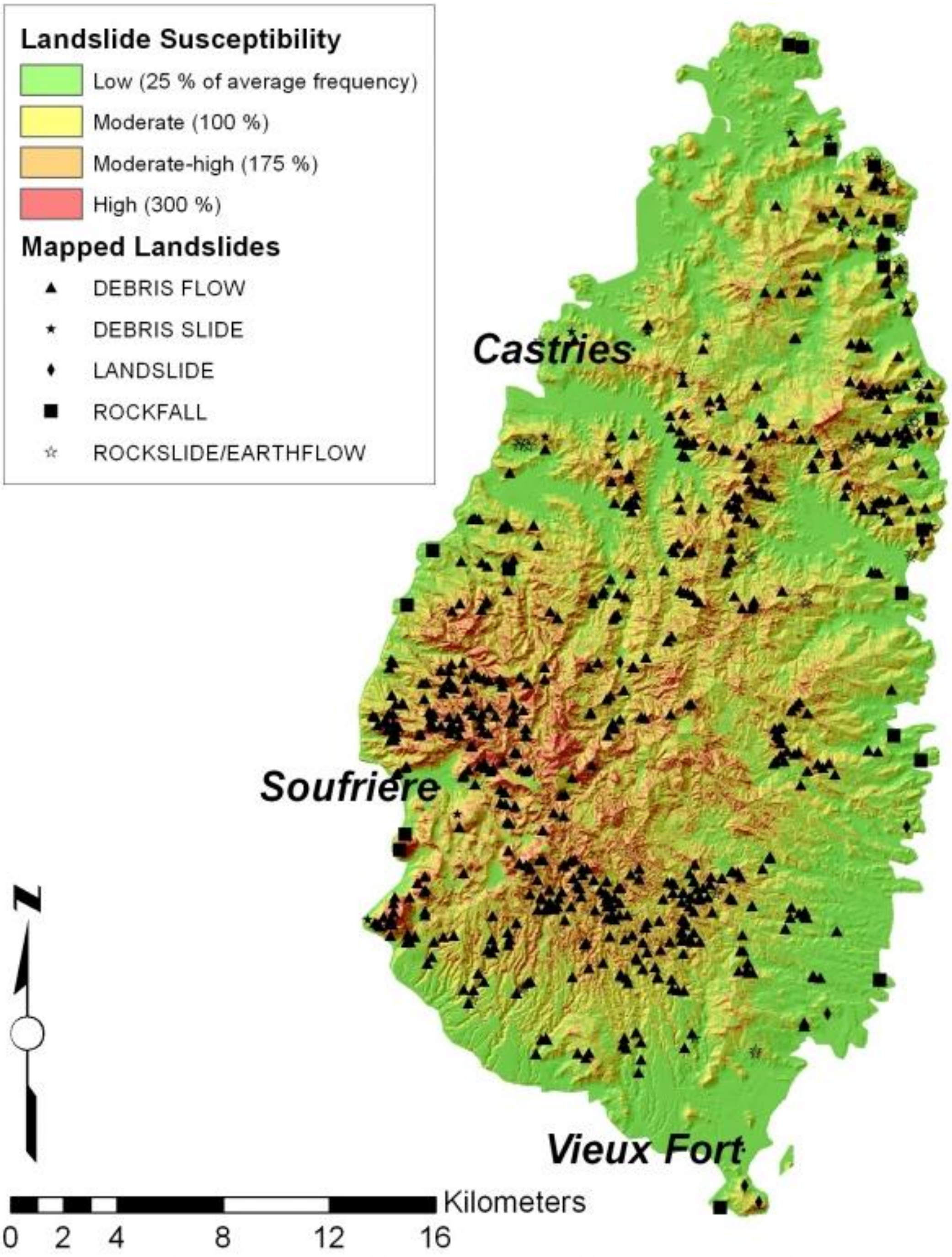
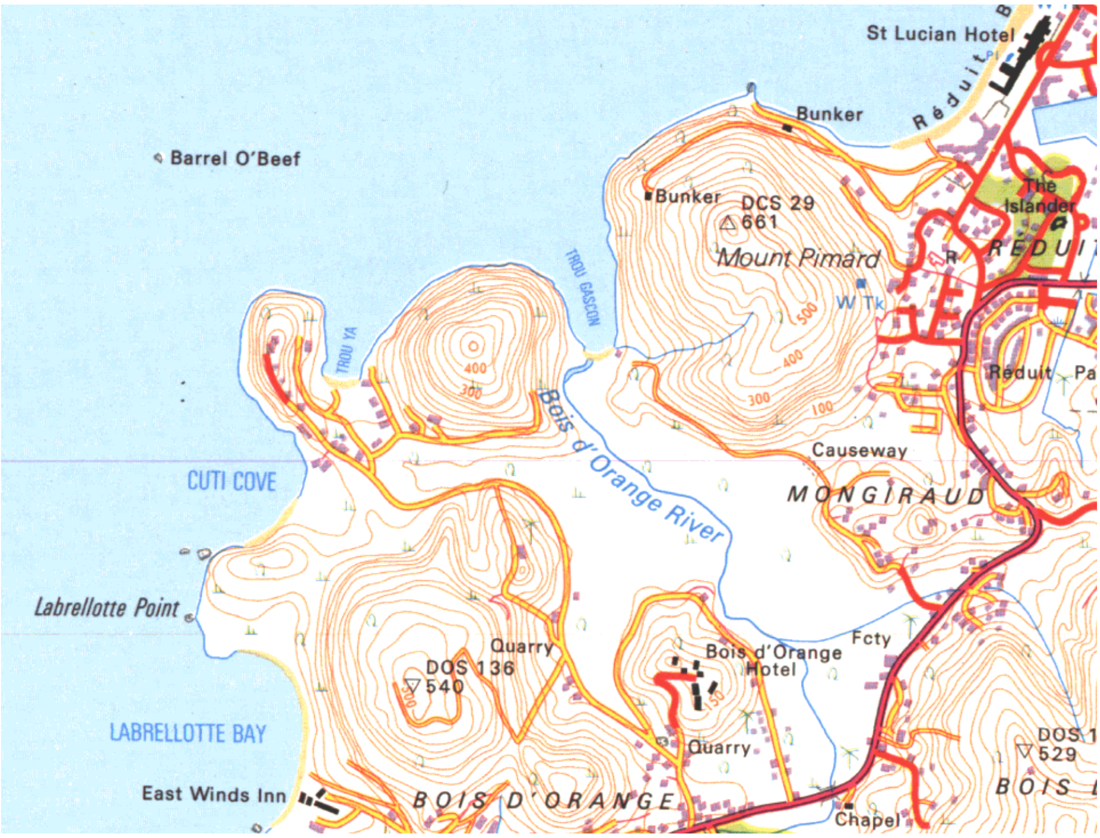
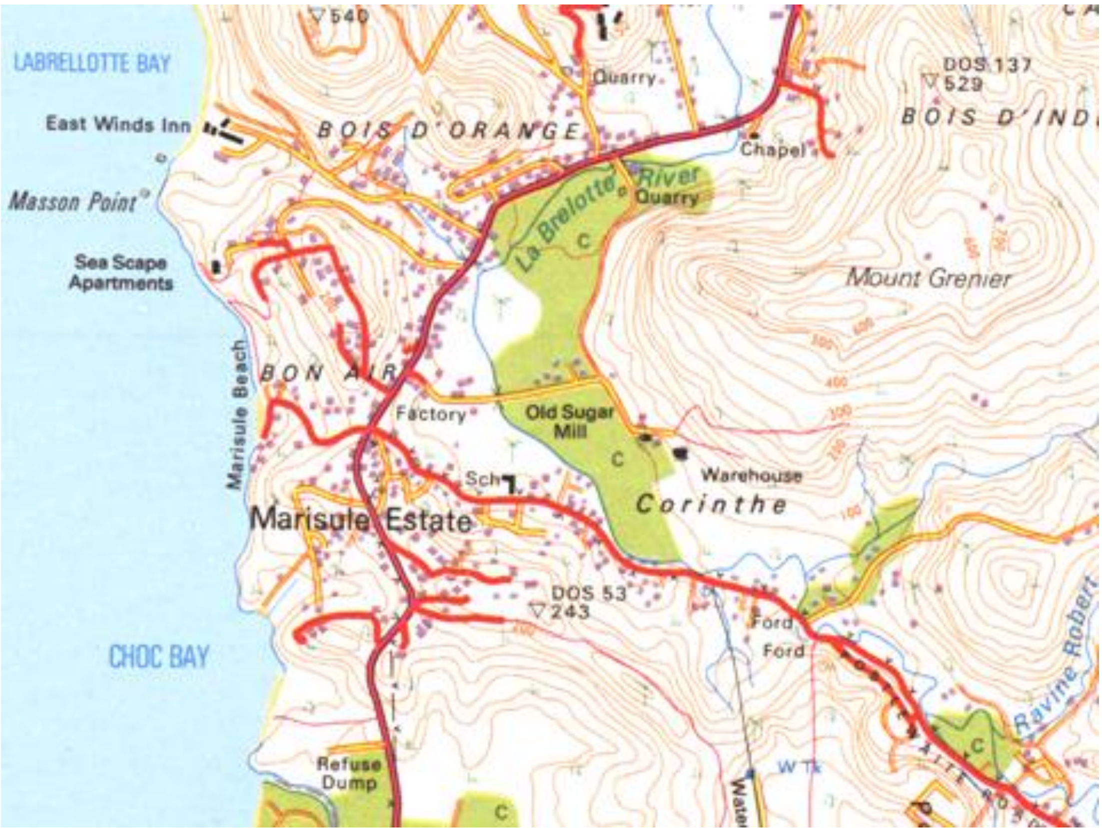


Figure A2.2 Landslide susceptibility map of Saint Lucia, Source: Quinn 2012.

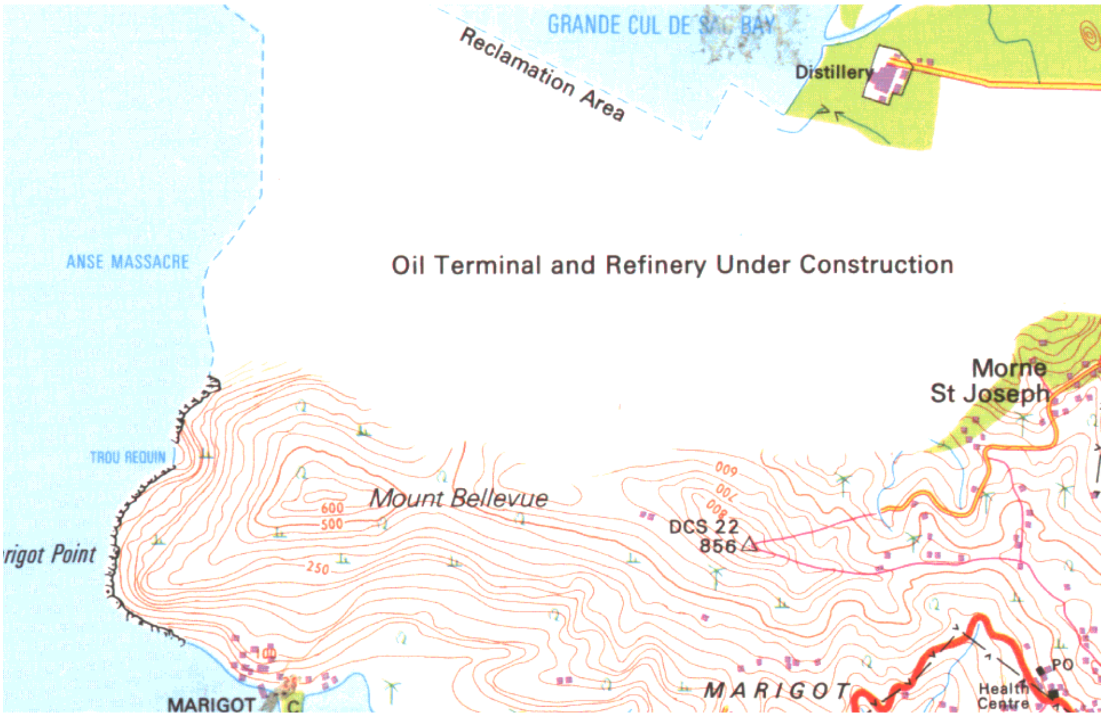
Annex 3 Topographic maps



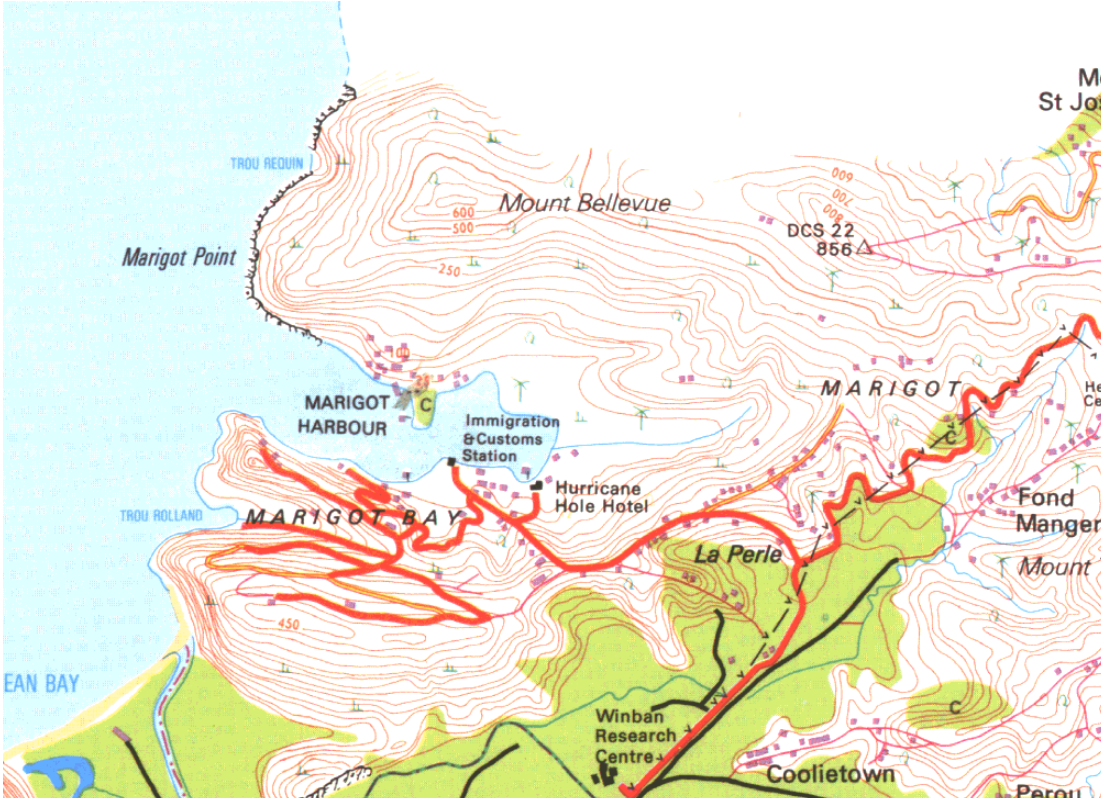



Refuse Dump
Choc Beach
Rat Island
DOS 63
Vide Bouteille Point
Halcyon Beach Club
CHOC
Factory
Brick Factory
Sunny Acres
Sch
DOS 52
Vigie Beach
Summersdale
Couples Hotel
Fcty
DOS 51
Cem
BISÉE
Quarry
Industrial Area
Residence
Kiwanies Beach
Vigie Airport
Terminal Building
LA CARRIÈRE
DOS 50


St Mary's College
Teachers Residence
D'Estrées Point
Light House
DOS 31
VIGIE
Vigie Beach Hotel
Kiwanies Beach
Vigie Airport
Terminal Building
Air Cargo
DOS 50
Hanger
PORT CASTRIES
Tapion Rock
Ships Beacon
Causeway
Pointe St Victor
Quarry
PETIT CARENAGE
DOS 61
Prison Farm
Mental Hosp
Cocoa Nut Point
Pointe Serafin
SANS SO
CASTRIES
LA TOC BAY
Jetty
Bunger
Pointe Bananes
Customs Office
Fire Sta & Port Police
La Toc Point
Yellow Sands Beach
La Toc Hotel
Tennis Courts
Victoria Hosp
Port Authority
PWD
Law Courts
Library
BELLA ROSA


GRANDE CUL DE SAC BAY
Reclamation Area
Distillery
ANSE MASSACRE
Oil Terminal and Refinery Under Construction
Morne
St Joseph
TROU REQUIN
Mount Bellevue
DCS 22
856
rigot Point
MARIGOT
Health
Centre
PO


La Toc Hotel
Tennis
Courts
Golf
Course
Govt
House
Coubaril Estate
DOS 56
351
Coubaril Point
Cut Line
Water Pipeline
REDOUBT
ANSE FERE
Reservoir
Ch
Ciceron Point
LA BELLE VIE
DOS 55
383
Mount Ciceron
Ciceron


Mount Bellevue
Marigot Point
TROU REQUIN
DCS 22
856
MARIGOT
MARIGOT HARBOUR
Immigration
&Customs
Station
Hurricane
Hole Hotel
TROU ROLLAND
MARIGOT BAY
La Perle
Fond
Manger
Mount
EAN BAY
Winban
Research
Centre
Coolietown

Annex 4 Planning guidelines

Lot Densities

Low Density	7,000 sq. ft. minimum
Medium Density	3,000 sq. ft. to 6,999 sq. ft.
High Density	below 3,000 sq. ft.

Lot Frontages and Mean Depth

	Lot frontages	Mean Depth
Low Density- 7,000 sq. ft. min. (Detached House)	60 ft.	80 ft.
Medium Density- 3,000 sq. ft. to 6,999 sq. ft. (Detached or Semi- Detached and Duplex)	40 ft.	60 ft.
High Density- below 3,000 sq. ft. (Attached dwelling Units for Urban areas only	12 ft.	50 ft.

Room Densities

Apartments, Condominiums and Villas	50 Bedrooms per acre
Hotels and Guest Houses	75 Bedrooms per acre

Plot Coverage

	Description	%
Residential (Single Family)	Low Density 7,000sq.ft. min.	25
	Medium Density 3,000 sq. ft. to 6,999 sq. ft.	30
	High Density below 3,000 sq. ft.	50
Residential (Multi Family)	Apartments, Condominiums, Villas	30
Commercial (not within CBD)	Minimum 10,000 sq. ft.	60
Commercial (CBD not corner lot)		80
Commercial (CBD Corner Lot)		100

	Description	%
Industrial	Minimum 10,000 sq. ft.	60
Touristic	Minimum 10,000 sq. ft.	60

Set Backs

Set Backs	Category	Requirements
Front Set Backs	Footpath Residential Access (27 ft. and 20 ft.) Residential Collector (30 ft.) Secondary and Primary roads (Highway)	10 ft. min. 10 ft. min. 15 ft. min. 20 ft. min. (*for all classes except industrial which is 30 ft.)*
Side Set Backs	Low Density 7,000 sq. ft. min. Medium Density 3,000 sq. ft. to 6,999 sq. ft High Density below 3,000 sq. ft.	8 ft. min. 6 ft. min. 4 ft. min. NB: *1 ft. must be added to standard set back for each additional floor of building*
Rear Set Backs		8 ft. min.
Soakaway		10 ft. min. from boundary
Set Backs from the High Water Mark (HWM)	Cliffs and Slopes of 1:1 Slopes of 1:4, 1:20 Slopes of 1:2	25 ft. from the HWM 50ft from the HWM 100 ft. from HWM
WASCOs Pipeline Reserve		6 ft. on either side of the Pipeline
River and Ravine Buffer	River Buffer Ravine Buffer	50 ft. on either side of river 15 ft. on either side of ravine

Annex 5 Maps of flood and landslide vulnerability

Maps of flood vulnerability. This section presents maps of the settlements that are potentially vulnerable to floods both today and in the 2040s. For many of these settlements, the exposure is projected to increase over the next few decades. Flood vulnerability is shown with solid lines where red lines are highly vulnerable, orange lines are moderately vulnerable, and yellow lines are of low vulnerability.

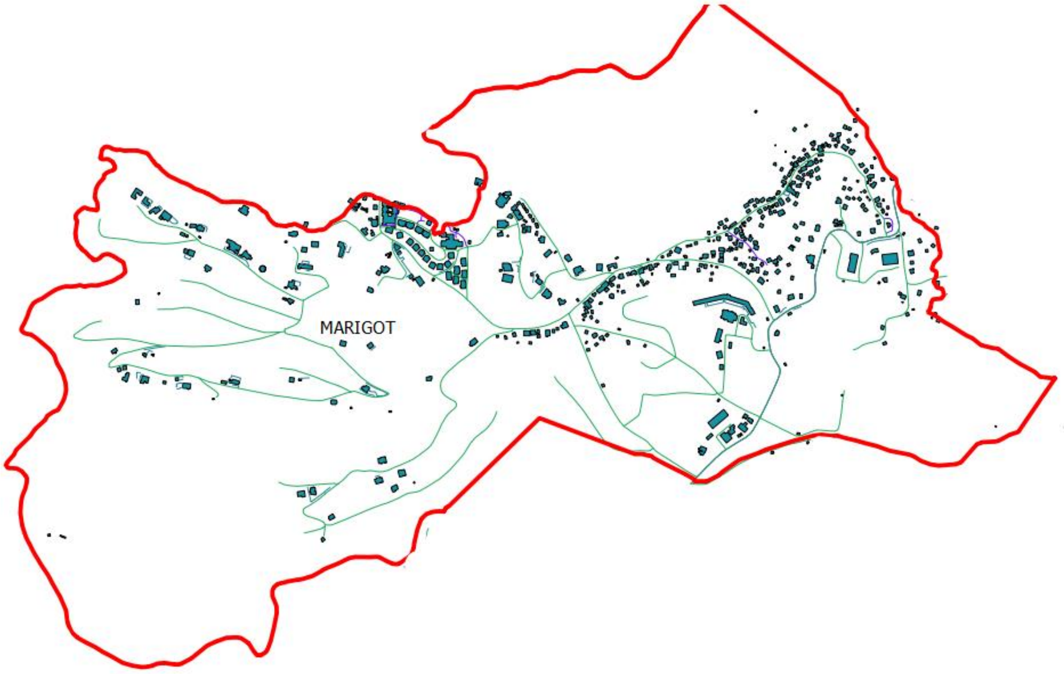


Figure A5.1 Map of Marigot, potentially at high flood risk both today and in the 2040s. Green lines indicate roadways, and blue boxes indicate buildings.

Figure A5.2 Map of Barre St Joseph, potentially at high flood risk both today and in the 2040s. Green circle indicates electricity facility, green lines indicate roadways, and blue boxes indicate buildings.

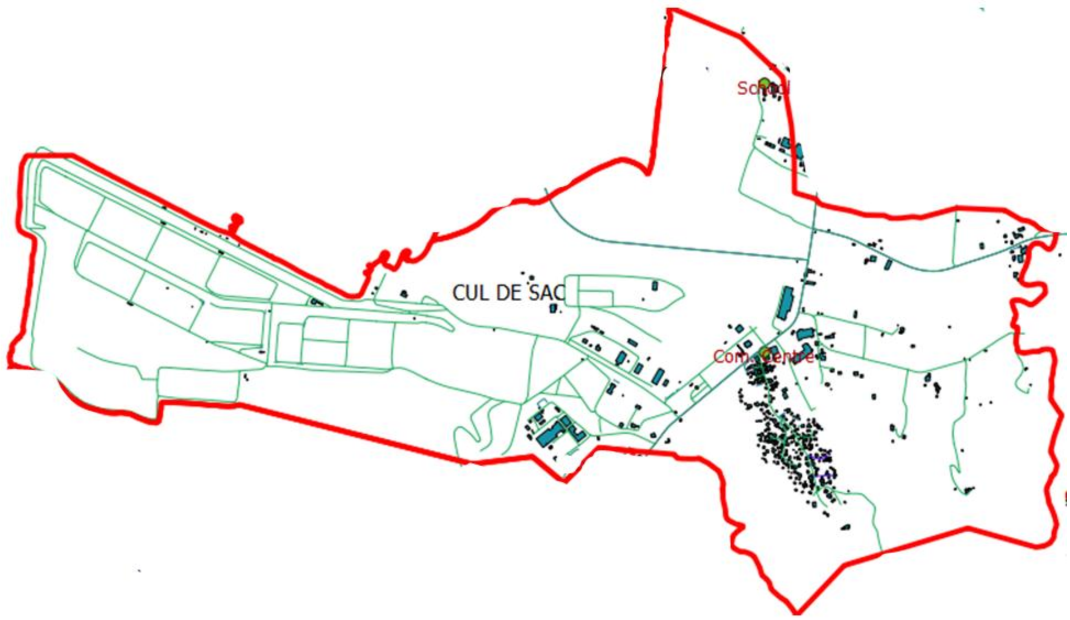


Figure A5.3 Map of Cul de Sac, potentially at high flood risk both today and in the 2040s. Green circles indicate a community center and school, green lines indicate roadways, and blue boxes indicate buildings.

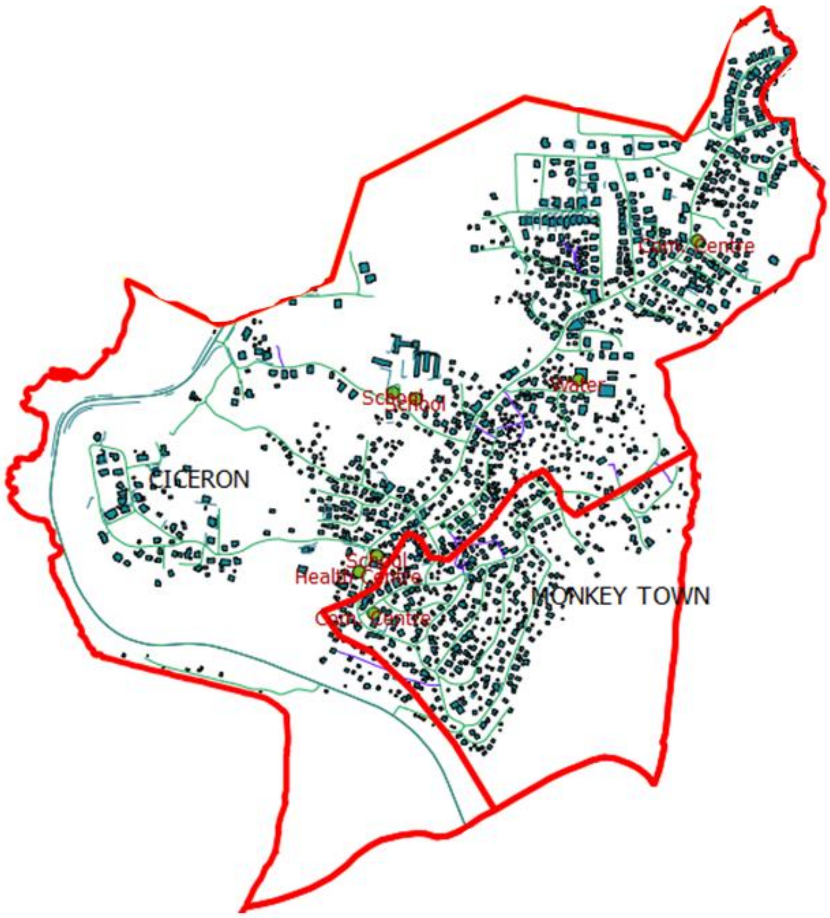


Figure A5.4 Map of Ciceron and Monkey Town, potentially at high flood risk both today and in the 2040s. Green circles indicate a community center, schools, health center, and water facility, green lines indicate roadways, and blue boxes indicate buildings.

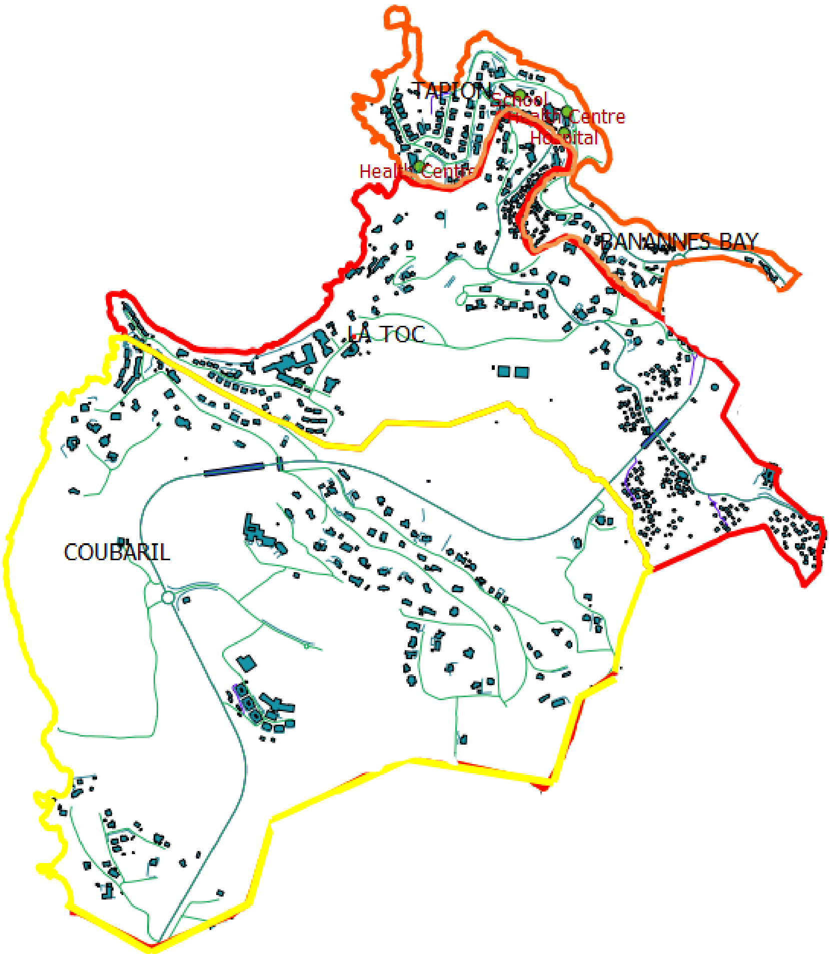


Figure A5.5 Map of Coubaril, La Toc, Tapion, and Banannes Bay, potentially at low to high flood risk both today and in the 2040s. Green circles indicate a hospital, schools, health center, green lines indicate roadways, and blue boxes indicate buildings.

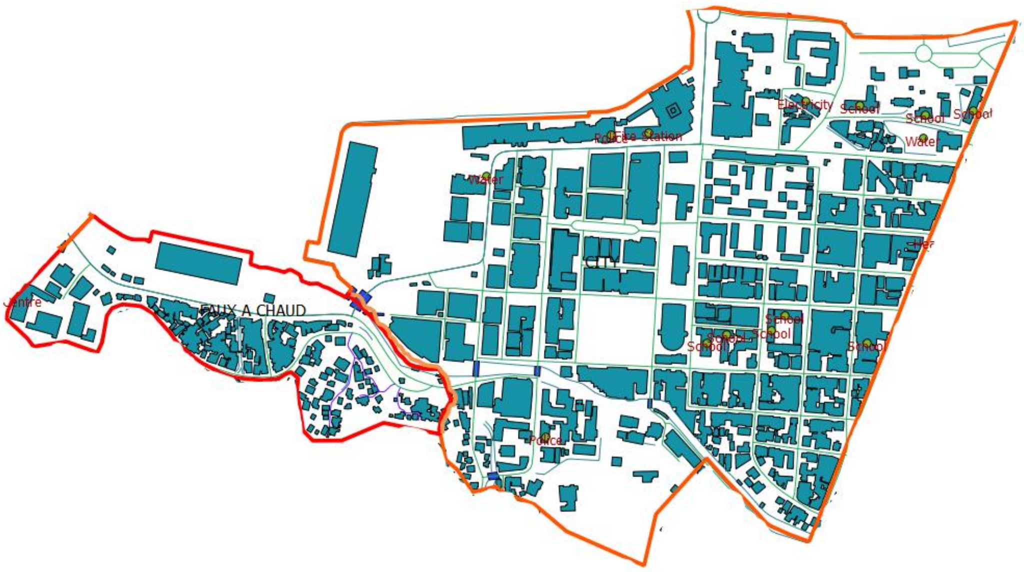


Figure A5.6 Map of Faux a Chaud and City of Castries, potentially at moderate to high flood risk both today and in the 2040s. Green circles indicate a police facilities, schools, water facilities, and electrical facility, green lines indicate roadways, and blue boxes indicate buildings.

Figure A5.7 **Map of Vigie and Conway, potentially at low to high flood risk both today and in the 2040s. Green circles indicate a police facility, school, and water facility, green lines indicate roadways, and blue boxes indicate buildings.**

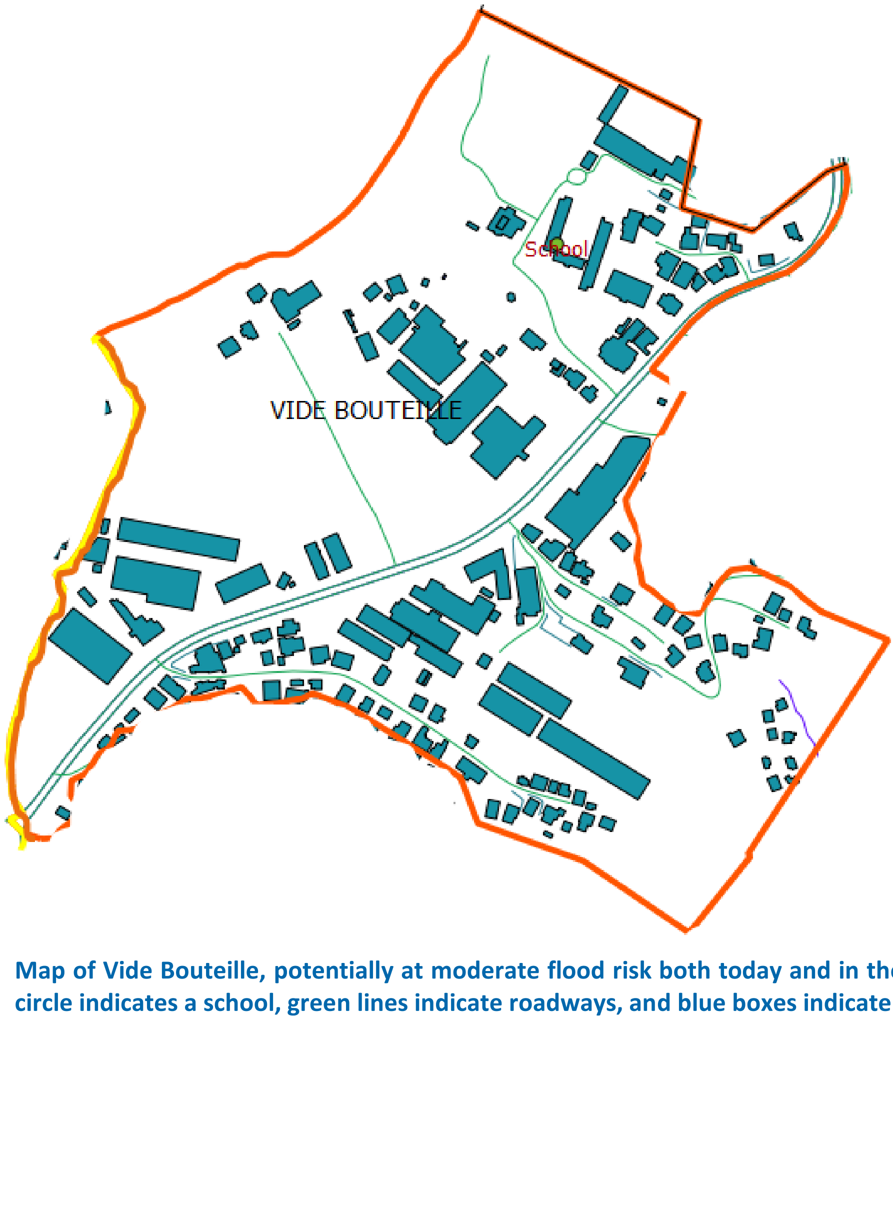


Figure A5.8 **Map of Vide Bouteille, potentially at moderate flood risk both today and in the 2040s. Green circle indicates a school, green lines indicate roadways, and blue boxes indicate buildings.**

Maps of landslide vulnerability. This section presents maps of the settlements that are potentially vulnerable to landslides. Landslide exposure is projected to reduce in the 2040s, but it is not clear the degree of reduction that may be experienced. Landslide vulnerability is shown with solid lines where red lines are highly vulnerable, orange lines are moderately vulnerable, and yellow lines are of low vulnerability.

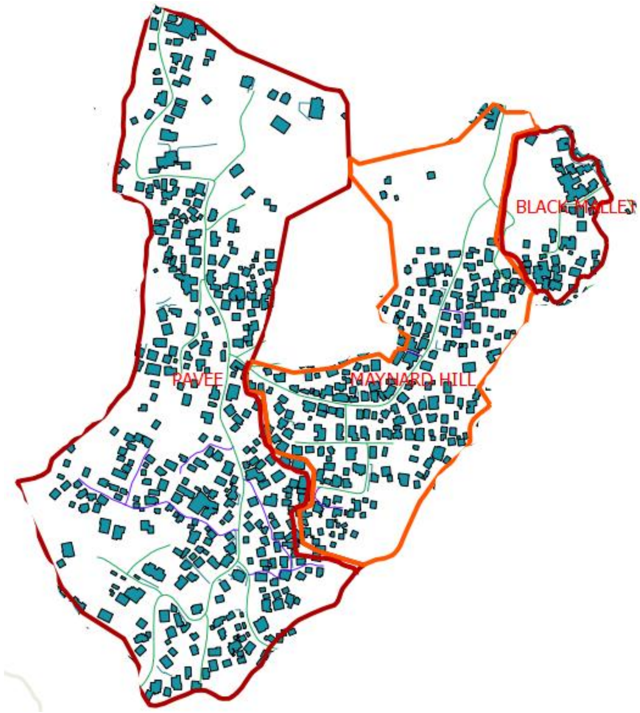


Figure A5.9 Map of Pavee, Maynard Hill, and Black Mallet potentially at moderate to high landslide risk both today and in the 2040s. Green lines indicate roadways, and blue boxes indicate buildings.

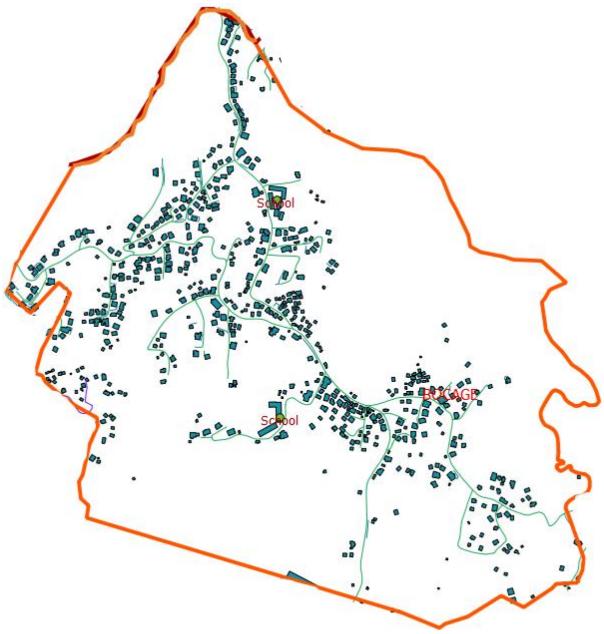


Figure A5.10 Map of Bocage potentially at moderate landslide risk both today and in the 2040s. Green circles indicate schools, green lines indicate roadways, and blue boxes indicate buildings.

Figure A5.11 Map of Entrepot potentially at low landslide risk both today and in the 2040s. Green circles indicate health centers, water facilities, schools, and community center, green lines indicate roadways, and blue boxes indicate buildings.

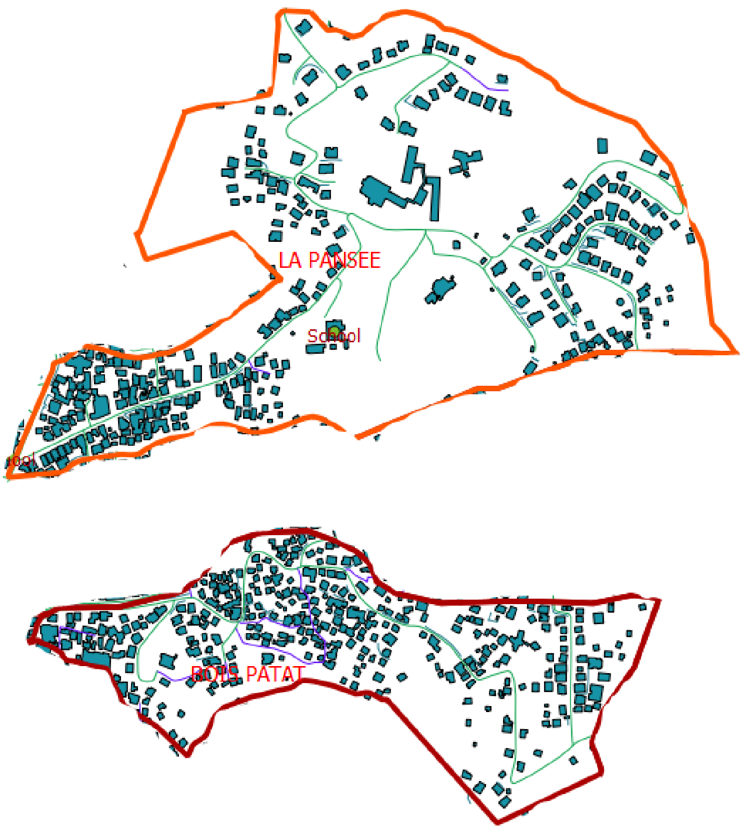


Figure A5.12 Map of La Pansee and Bois Patat potentially at moderate to high landslide risk both today and in the 2040s. Green circle indicates a school, green lines indicate roadways, and blue boxes indicate buildings.

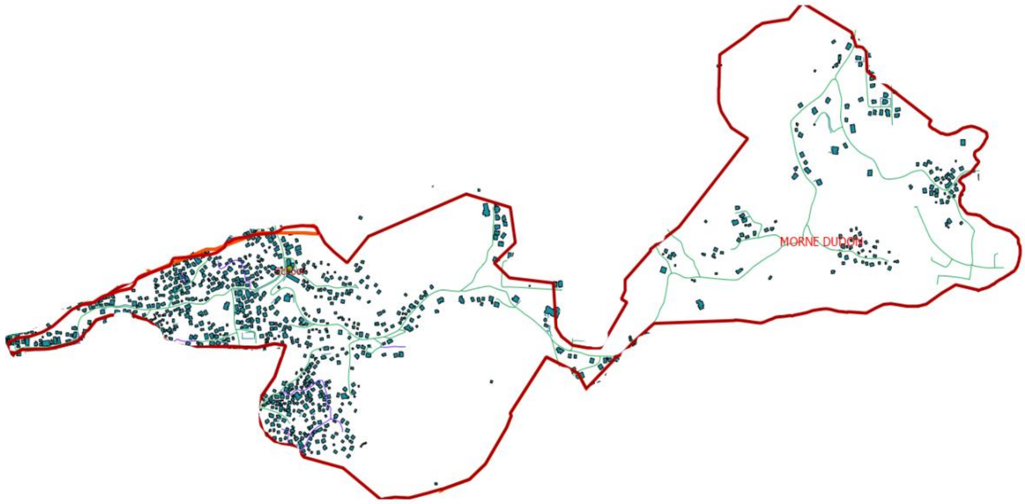


Figure A5.13 Map of Morne Dudon potentially at high landslide risk both today and in the 2040s. Green lines indicate roadways, and blue boxes indicate buildings