Country Report

Socio-economic and Financial Implications Assessment of Climate Change on Jamaica

The Commonwealth

MHURECC
HOUSING, URBAN RENEWAL, ENVIRONMENT & CLIMATE CHANGE

CCD
CLIMATE CHANGE DIVISION

NDC PARTNERSHIP

Socio-economic and Financial Implications Assessment of Climate Change on Jamaica

Printed and published by the Commonwealth Secretariat.

Acknowledgments

This report has been developed by Dr Justin Ram, Consultant, Commonwealth Secretariat, with technical input from the Commonwealth Climate Finance Access Hub (CCFAH) for the Climate Change Division of the Government of Jamaica under the NDC Partnership Climate Action Enhancement Package (CAEP).

We acknowledge all the ministries, departments and agencies involved in the consultation processes and for the provision of technical inputs towards the completion of this study; including the Ministry of Housing, Urban Renewal, Environment and Climate Change, Planning Institute of Jamaica (PIOJ), Bank of Jamaica and Ministry of Finance – the Economic Management Unit (EM), the Public Expenditure Unit (PEX) and the Public Investment Management System Secretariat (PIMSEC).

Acronyms

CAEP	Climate Action Enhancement Program
CCD	Climate Change Division
CCMA	Climate Change Macro Accounts
CCPF	Climate Change Policy Framework
CDB	Caribbean Development Bank
DaLA	Damage and Loss Assessment
GDP	Gross Domestic Product
GEF	Global Environmental Fund
GoJ	Government of Jamaica
IMF	International Monetary Fund
MHURECC	Ministry of Housing, Urban Renewal, Environment and Climate Change
MICAF	Ministry of Industry, Commerce, Agriculture and Fisheries
MSJ	Meteorological Service of Jamaica
MWLECC	The Ministry of Water, Land, Environment and Climate Change
NAP	Jamaica's National Adaptation Plan
NDCs	Nationally Determined Contributions
NEPA	National Environmental Planning Agency
NMS	The National Meteorological Service
PIOJ	Planning Institute of Jamaica
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank

Glossary of terms

Adaptation – efforts to adjust systems and societies to withstand the current and anticipated impacts of climate change.

Climate Change – a change of climate which is attributed directly or indirectly to a human activity that alters the composition of the global atmosphere and is in addition to natural climate variability observed over comparable time periods.

Climate Impacts – consequences of climate change on natural and human systems.

Climate Variability –variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events.

Damage – the effects a disaster has on the assets of a certain sector in monetary terms. Damage includes impacts on physical assets such as buildings, machinery and equipment, systems and ports, for example.

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 by using its own resources.

Drought – the phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.

Emissions – the release of substances (e.g. greenhouse gases) into the atmosphere.

Externalities – occur when producing or consuming a good causes an impact on third parties not directly related to the transaction.

Losses – disruptions to flows resulting from a disaster. Losses are defined as goods that go unproduced and services that go unprovided from the moment a disaster occurs until full recovery and reconstruction are achieved, for example the reduction in the size of future harvests due to the flooding of farmland.

Mitigation – efforts to lower or remove greenhouse gas emissions from the atmosphere.

Resilience – the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation and the capacity to adapt to stress and change.

Vulnerability – the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.

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Executive summary

The Nationally Determined Contributions Partnership (NDCP) assists countries committed to implementing NDCs and the achievement of the 2030 Sustainable Development Goals. Through its Climate Action Enhancement Program (CAEP), the NDCP helps countries fast-track climate and development activities.

The Government of Jamaica approached the NDCP CAEP to support its work on understanding the "Socio-economic and financial implications (past and projected) of climate change (including severe weather events/cyclones/drought) in Jamaica through the development of climate expenditure and institutional analyses and modelling". In response to this request from the Jamaican government, the Commonwealth Secretariat agreed to support this request through its Commonwealth Climate Finance Access Hub (CCFAH). The CCFAH is a mechanism used by the Commonwealth Secretariat to support member countries in building their capacities to address climate change, meet their sustainable development goals, and assist in accessing climate finance.

This report was completed under the aegis of the CCFAH to assess Jamaica's climate socio-economic and expenditure implications by examining the country's climate institutional framework and modelling the economic and public financial consequences of climate change.

Jamaica's location in the Caribbean renders it a climate-sensitive small island developing state. Like many Caribbean countries, Jamaica is highly vulnerable to climate variability and natural hazards, including tropical cyclones, floods, landslides, droughts, and earthquakes. Natural hazards significantly impacted economic activities, human welfare, and natural resources in the last few decades (ECLAC 2019). These severe impacts can be attributed to where settlements and economic activity are concentrated, specifically the coast. For example, 60 per cent of the population lives in coastal areas, and 90 per cent of economic activity, GDP, such as agriculture, fisheries, and tourism, is produced in coastal areas.

Therefore, Jamaica is already witnessing the effects of climate change as evidenced by the increased occurrence of climate-induced extreme and slow onset events over the past two decades. Furthermore, the damages and losses associated with these events have negatively impacted Jamaica's productive capacity and caused social disruptions.

Climate forecasts suggest that Jamaica is likely to witness more frequent and intense climate-induced events in the future. Climate projections for Jamaica show that the mean temperatures are expected to increase by 0.49–0.57°C by the 2020s. The mean temperature is also expected to increase by 0.85–1.80°C by the 2050s; and by 0.82–3.09°C by 2081–2100, compared to the 1986–2005 baseline. Climate change projections also forecast that Jamaica's rainfall will become more variable and less predictable, with longer dry spells. These projections indicate that climate change will become a severe threat to the island's development and have more significant socio-economic impacts.

Roles and responsibilities of government institutions

Climate change government institutions

Jamaica has a comprehensive albeit complex institutional arrangement to help manage the impacts of climate change and how the country should adapt to these changes. The Ministry of Housing, Urban Renewal, Environment, and Climate Change (MHURECC)[1] is responsible for overseeing and supporting the implementation of the Climate Change Policy Framework for Jamaica. In 2012, the **Climate Change Branch (CCB) was founded to** coordinate the implementation of the climate change policy framework. Additionally, the **Environment and Risk Management Division (ERMD)** is the policy division within the MHURECC responsible for the periodic monitoring, review, and revision of the Climate Change Policy Framework along with other key agencies.

1 The MHURECC replaced the Ministry of Water, Land, Environment, and Climate Change (MWLECC) following the September 2020 General Elections.

Climate change national framework, plans and policies

The climate change policy framework (CCPF) aims to support Vision 2030 Jamaica – National Development Plan (Vision 2030 Jamaica) by reducing the risks posed by climate change to Jamaica's economy and its development goals. It creates a sustainable institutional mechanism to facilitate the development, coordination, and implementation of policies, sectoral plans, programmes, strategies, and legislation to address the impacts of climate change.

Plans and policies relating to climate change

JJamaica has adopted various climate change adaptation and mitigation policies to reduce the risks or vulnerabilities posed by climate change and increase resilience. For example, Vision 2030 (the country's aspirational planning document) provides the framework to ensure that climate change issues are mainstreamed into national policies and development activities. There are other policies that either directly or indirectly support climate change efforts (see the full report).

Integration of climate change in the Jamaica government's budgeting and planning process

In addition to reviewing how Jamaica manages its climate change obligations and resilience building, the report examines how climate change impacts the Jamaican government's budgeting and financial process. Jamaica's fiscal operations are managed under an institutional arrangement of the Financial Administration and Audit Act (FAA). The FAA provides the primary legal and institutional framework for fiscal operations. The FAA was designed to improve Jamaica's macroeconomic outlook and debt-to-GDP ratio. However, the FAA provides an exception or "escape clause" from the fiscal rules for a maximum of 2 years in the event of a natural disaster that results in a fiscal impact of 1.5 per cent of the GDP or higher.

Concerning the fiscal and financial resilience aspect of climate change, the National Public Financial Management Policy Framework and the National Disaster Risk Financing Policy underpin the actions of the Ministry of Finance and the Public Service (MFPS). Furthermore, in November 2018, the Jamaican Cabinet approved the National Public Financial Management Policy Framework for Natural Disaster Risk Financing. In August 2021, Cabinet also approved a National Disaster Risk Financing Policy. This policy framework provides the Jamaican government's vision and the enabling environment needed to ensure that adequate resources are available to address ex-post financing requirements through a mix of fiscal instruments.

Using empirical evidence, the study methodologies were developed to measure the dynamic economic impacts of natural events and the public financial implications of these events. Two economic models were built:

- The Climate Change Macro Assessment (CCMA) and
- Climate macro-fiscal model.

The Climate Change Macro Assessment model (CCMA) estimates how different climate change events impact individual sectors and the entire economy, including intermediate and final demand impacts. The estimates from the CCMA are then fed into the climate macro-fiscal model to ascertain the fiscal costs or consequences of climate change.

The climate macro-fiscal model presents a simple simulation of the macro-fiscal environment by incorporating the IMF's financial programming framework and a simplified debt sustainability tool to assess the impact of climate events on the GoJ's medium-term fiscal outlook. The tool is Excel-based and provides a range of standard IMF performance criteria, together with a complete set of consistent macroeconomic accounts for the real and public sectors of the economy.

Jamaica has integrated climate mitigation and adaptation in its economic development processes. The policy response has and continues to be comprehensive. The response relies on the coordination of numerous agencies that report and seek to implement the various climate policies of the Jamaican government. However, the review of the agencies responsible for implementing the multiple climate policies suggests that there may be a risk of duplication of efforts and creating parallel systems. Public–private partnerships should be a crucial component of the climate policy framework, and the responsibilities of climate change are not exclusive to government-only activities. It is critical that all stakeholders, such as the private sector and civil society should have clearly defined roles within the implementation framework. Engaging with and recruiting the rest of the society could be an important new focus of the climate change policy framework.

The worst of the climate change impacts could yet happen. Therefore, mainstreaming climate into policy and the Jamaican way of life is critical now. All government policies must have climate risks assessments and mitigated. The economic models provide a foundation for the government to simulate climate change impact on public expenditure and to identify the gaps and resources needed.

Technical expertise/capacity in climate modelling and forecasting is critical. Improving modelling capacity for climate change and its impacts including financial flows and mitigation and adaptation actions is required.

Background and scope of work

The Nationally Determined Contributions Partnership (NDCP) is an organisation, which assists countries committed to the implementation of NDCs and the achievement of the 2030 Sustainable Development Goals. The NDCP helps countries to fast-track climate and development activities through several approaches covering country engagement, knowledge and information sharing, and access to finance, including through its new Climate Action Enhancement Program (CAEP).

The Government of Jamaica has requested support from the NDCP CAEP for undertaking the "Socio-economic and financial implications (past and projected) of climate change (including severe weather events/cyclones/drought) in Jamaica through the development of climate expenditure and institutional analyses and modelling". The Commonwealth Secretariat responded to the CAEP request from Jamaica and agreed to provide support through its Commonwealth Climate Finance Access Hub (CCFAH). The CCFAH supports member countries in building their human and institutional capacities to address climate change and assist in accessing international and regional sources of climate finance from both the public and private sectors to meet their priority for adaptation and mitigation needs and realise their sustainable development goals.

Against this background, this assignment aims to undertake the climate expenditure analysis by collecting information and data and conducting a modelling exercise.

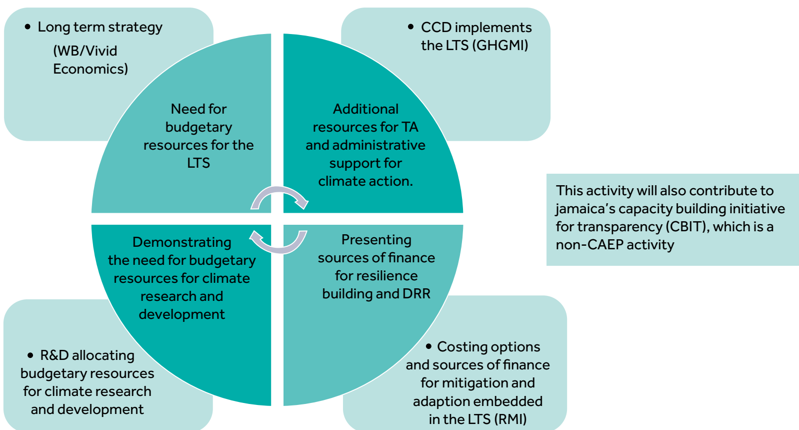
The specific objectives of this assignment within the national context include the identification of key stakeholders within the ministries, departments and agencies (MDAs) of the Government of Jamaica involved in the development of climate policy, implementation of projects and programmes that have an impact on climate action and/or climate national targets; and economic and fiscal management including the national budgeting process.

Using existing assessments, conducted by national, regional and international institutions, the study also examines the key climate-induced extreme and slow onset events of the past and their socioeconomic and fiscal implications.

The development of an analytical framework for the collection of relevant data and information from a wide range of stakeholders including both budget and climate-related data – ideally within the last 10 years where available. Such data focused on (1) climate change-induced natural disasters faced by the country, (2) data and information on damages and losses and their socioeconomic and financial implications on different sectors and segments of the society, (3) data and information on government climate change-related expenditures through the national budget and (4) flow of climate finance and development assistance focused on climate change-related issues; and identification and use of the most appropriate methodological and modelling approach for undertaking the analysis in the specific context of Jamaica.

This exercise attempts to connect with the work of the other CAEP partners and non-CAEP initiatives.

Connecting with other CAEP partners and non-CAEP initiatives



The climate vulnerability context

Jamaica is a climate-sensitive small island developing state by virtue of its location in the Caribbean Basin and its topography and geology (Heger et al., 2008; McCalla, 2012). The country is highly vulnerable to climate variability and natural hazards, including tropical cyclones, floods, landslides, droughts and earthquakes. Apart from earthquakes,[2] these natural hazards have significantly impacted economic activities, human welfare and natural resources in the last few decades (ECLAC, 2019). Jamaica has a high concentration of settlements, infrastructure and economic activity along the coast. For example, over 60 per cent of the country's population is in the coastal area, with key economic sectors (90 per cent of its GDP) such as agriculture, fisheries and tourism produced within its coastal zone (ECLAC/CCAD/SICA/UKAID, 2011; USAID, 2017; Rhiney and Ajayi, 2018). Jamaica continues to experience an increase in the frequency of natural events related to inclement weather conditions, tropical depressions, tropical storms and hurricanes – primarily floods, droughts and landslides – and between 1990 and 2020 Jamaica experienced a total damage of J$705 billion from natural hazards (including 16 major hurricanes) and several flood events.[3] As a result, it is expected that climate change will exacerbate the socio-economic and fiscal impact on these sectors and human development.

Jamaica is already witnessing the effects of climate change. Several studies cite the increased occurrence of climate-induced extreme and slow onset events, including hurricanes, storms, floods, droughts and rising sea levels, experienced within the country over the past two decades (IPCC, 2012; Rhiney et al., 2015; Fuller et al., 2020). The damages and losses associated with these events have dampened Jamaica's productive capacity and caused social disruptions, negatively impacting the country's GDP, the balance of payments, trade and fiscal position. Such frequent climate shocks have ultimately placed a tremendous financial pressure on the Government (Burns et al., 2021). For example, Hurricane Ivan in 2004 accounted for 8.0 per cent of GDP in damage. It is estimated that Hurricane Sandy in 2012 cost the Government of Jamaica J$9.7 billion (0.8 per cent of 2011 GDP) in direct and indirect damages (PIOJ, 2013; GoJ, 2015). Six storm events between 2002 and 2007 resulted in 60 fatalities and J$153 billion in damages (PIOJ, 2017).

Jamaica is likely to witness greater climate-induced events in future. Projections show rising sea temperatures, more intense hurricanes and more severe weather events such as droughts and floods. For example, climate projections show that the mean temperature is likely to increase by 0.49–0.57°C by the 2020s; 0.85–1.80°C by the 2050s; and 0.82–3.09°C by 2081–2100 with respect to a 1986–2005 baseline. In the central region of Jamaica, climate projections show a decrease in mean annual rainfall between 3 and 24 per cent by the 2030s, between 2 and 25 per cent by 2050s and between 10 and 37 per cent by 2100s with respect to the baseline. The drying trend is primarily driven by a decrease in late wet season rainfall of 1–3 per cent by 2030s and 2–20 per cent by the end of the century. Climate change projections also foresee Jamaica's rainfall becoming more variable and less predictable, with longer dry spells. The country is highly vulnerable to such changes and exposed to tropical storms and hurricanes. Changes in tropical cyclone activity are difficult to predict since they depend on location, tracks, duration and impact areas. However, the rate of tropical cyclone-related rainfall will likely increase. Such projections indicate that climate change will likely become a more severe threat to the island's development and have more significant socio-economic implications (FAO, 2013; CDB, 2018; IPCC, 2018; IDB, 2020a). These findings emphasise the importance for the Jamaican Government to implement effective disaster risk preparedness and management strategies, such as investment in hurricane-resilient infrastructure, fiscal buffers and self-insurance through the accumulation of a hurricane relief contingency fund to reduce the amount of economic damage caused by such events (Burns et al., 2021).

Past climate-extreme events have significantly impacted Jamaica's infrastructure sector. *Major hurricanes and storms* have caused damage to communication, energy, water systems and road infrastructure through blockage caused by

2 Earthquakes can affect the entire island, but most of the earthquakes recorded have occurred in the eastern section of the island.

3 Various EM-DAT and PIOJ publications.

Box 1. Damage and Loss Assessment and Post-Disaster Needs Assessment methodologies

The United Nations Economic Commission for Latin America and the Caribbean developed the Damage and Loss Assessment (DaLA) methodology for Latin America and the Caribbean (UN-ECLAC). DaLA was developed in the 1970s and since then has been customised for application by the World Bank (WB) in different areas of the world. The DaLA methodology estimates the value of assets destroyed (damages) and the changes (or losses) in the flows of the economy as a result of the disaster. The DaLA provides an estimation of the overall effects of the disaster on the affected society and economy. In 2008, the European Commission (EC), the United Nations Development Group (UNDG) and the WB adopted the Post-Disaster Needs Assessment (PDNA), which built on the quantitative analysis of the DaLA methodology by adding specific sectors and a qualitative analysis on issues of gender, environment, disaster risk reduction, livelihoods and human impacts of the disaster on people's lives and livelihoods. In 2018, the Planning Institute of Jamaica (PIOJ) adopted the PDNA methodology and trained disaster risk management professionals and sector specialists across the public sector to assess the economic, social and environmental impacts of disasters.

landslides, power lines and fallen trees (USAID, 2017). For example, the heavy winds, rainfalls and floods due to Hurricane Ivan in 2004 caused $575 million in infrastructural damages, with 62 per cent focused directly on damage to physical assets (PIOJ, 2017). Such damages also had ripple effects on various social sectors. For example, the education sector was impacted due to damaged school buildings and power lines and resulted in the closure of schools, affecting 204,000 students and contributing to a productivity loss among students (PIOJ, 2017). Damaged public infrastructure had further fiscal implications for the country through increased government expenditure required for restoration and rebuilding activities.

Table 1 summarises the average damage and loss assessments of the key climatic events that have impacted Jamaica over the past 20 years. The impact varied according to the event, with the average damage and losses due to hurricanes being the most extreme, averaging 2.7 per cent of GDP (with 1.69 per cent of GDP in damages and 1.10 per cent of GDP in losses), to 0.4 per cent of GDP for the impact of droughts. The WB (2021) estimates that, under current temperatures, Jamaica's contingent liabilities related to tropical cyclones and floods average US$121 million annually (J$17 billion) or 0.8 per cent of 2020 GDP. This is equivalent to 1.9 per cent of total government expenditures in 2020. With an annual probability of 0.4 per cent (i.e. events occurring once every 250 years), contingent liabilities would amount to at least 22.7 per cent of Jamaica's GDP.

Climate change is a significant threat to agricultural productivity and food security. The major climate events affecting the agriculture sector are hurricanes, floods, landslides, droughts and heavy winds. The PIOJ (2014) and PIOJ (2012) report that between 2001 and 2012, Jamaica's agriculture sector suffered losses amounting to J$23.48 billion (US$253.6 million, exchange rate USD 1 = J$93) because of extreme weather-related events. On average, the impact of significant climate extremes on agriculture accounts for nearly 20 per cent of the total impact on the country. Crop damage associated with the impacts of hurricanes and storms affected foreign exchange earnings and weakened the country's current account balance due to the consequent reduction in exports. For instance, Hurricane Ivan inflicted a heavy damage to coffee and banana plantations in Jamaica in 2004, resulting in production declines and a loss of livelihoods and incomes, estimated at J$8.55 billion. The Ministry of Industry, Commerce, Agriculture and Fisheries (MICAF) also reported that between July and December of 2012, the agriculture sector contracted by 2.9 per cent attributed mainly to the passage of Hurricane Sandy.

Droughts severely impact Jamaica's agriculture sector as the hot and dry conditions reduced the availability of scarce water resources and lowered crop yields. According to rainfall data from the Meteorological Service of Jamaica (MSJ), between 2009 and 2019, there were only 2 years of rainfall measurements above normal, 2 years were average and 7 years were below normal rainfall. In

Table 1. Climate events average damage and losses assessment (per cent of GDP)

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Hurricanes average damage and losses			
Social sectors	0.96	0.92	0.04
Productive sectors	1.25	0.41	0.87
Infrastructure	0.48	0.34	0.15
Environment	0.01	–	0.01
Emergency Operations	0.03	0.02	0.03
Total	**2.74**	**1.68**	**1.10**
Tropical storms average damage and losses			
Social sectors	0.15	0.10	0.06
Productive sectors	0.15	0.14	0.01
Infrastructure	1.60	1.54	0.05
Environment	–	–	–
Emergency Operations	0.01	0.01	–
Total	**1.91**	**1.79**	**0.12**
Floods average damage and losses			
Social sectors	0.010	0.008	0.002
Productive sectors	0.089	0.071	0.018
Infrastructure	0.216	0.130	0.086
Emergency Operations	0.002	0.001	0.001
Total	**0.317**	**0.21**	**0.107**
Droughts average damage and losses			
Productive sectors	–	–	–
Agriculture	0.0400	0.000	0.400

Source: DaLA various years.

3 out of 11 years, the actual rainfall was at least 20 per cent below the mean annual rainfall, which is indicative of the frequency of drought occurrence. In addition, there were fluctuations and high variability in rainfall occurrence, one year being very wet compared to the following year, which may be much drier. This is consistent with several recent prolonged droughts that have been recorded for Jamaica, such as 2004/5, 2009/10 and 2014/15. For example, during the 2010 drought, there was a 1.4 per cent fall in cash crop production and a 5 per cent decline in the overall production figures compared to 2009. Additionally, during the El Niño drought of 2004–5, the dry underbrush resulted in widespread bushfires that damaged the soil by removing moisture and caused loss of leaf litter and trees, impacting biodiversity. According to the MSJ, in 2015, Jamaica experienced the worst drought in over 50 years that resulted in a 30 per cent decline in agriculture production and losses estimated to be up to US$7.2 million. More recently, Jamaica rainfall analysis maps produced by the MSJ showed a progressive drying of the entire island between 2017 and 2020. During this same period (2017/18), MICAF reported losses in agriculture of over US$7.2 million. A recent study by the Inter-American Development Bank (IDB) (2020b) on the impact of climate change on crop yields by 2050 found that rainfed corn yields were expected to decline by 40 per cent.

Climate events also impact Jamaica's fisheries sector through damage of the marine environment. The marine environmental threats include a decline in the health of coral reefs, loss of sea-grass beds, severe beach erosion and loss of forested areas. For example, prolonged *high sea surface temperatures* in 2005 resulted in widespread bleaching of the island's corals (Creary, 2008). Additionally, the El Niño drought of 2004–5 caused a reduction of river flows, which in some places disappeared completely and adversely affected the freshwater aquatic systems (ECLAC, 2011a). Death of the coral would lead to a habitat loss for reef fish, and their eventual decline has a multiplier effect on coastal erosion since they serve as protective barriers to storm surges. Sea level rises could also reduce the sizes of fishing beaches and force them to move further inland. Furthermore, rising temperatures may affect the migratory patterns of certain species (ECLAC, 2011b). Such marine environmental threats and their consequent impacts on the fisheries sector may place a significant burden on the country's population that depends on the sea as a food source, reducing food security and seafood earnings of fishermen families and those on the lower end of the socio-economic spectrum (CDB, 2018), resulting in lower incomes.

Jamaica's tourism sector, including the infrastructure, beaches and coral reefs, is all vulnerable to climate change and variability. In the past, hurricanes have resulted in a severe damage to the hotels and restaurant infrastructure, in addition to declines in tourist arrivals. Increasing sea surface temperature also impacted the tourism sector by leading to Sargassum seaweed which covered white sandy beaches and discoloured nearshore waters in coastal areas, including hotel facilities, ultimately compromising the scenic beauty of the local tourism product (Oxenford et al., 2015). ECLAC (2011a) undertook a study to evaluate the cost of extreme events to the tourism sector in Jamaica and found that in addition to changes in the climatic suitability for tourism, climate change is also likely to have supply-side effects from extreme events and acidification of the ocean. Future climate-extreme events pose a significant concern for the tourism sector. Sea-level rise, greater intensity of rainfalls and storm surges can accelerate coastal erosion, posing substantial threats to the beaches, a primary tourism attraction (Spencer and Strobl, 2020). Additionally, increasing ocean temperatures can lead to coral bleaching, reduce the appeal of water activities such as scuba diving and snorkelling and increase exposure to beach erosion, leading to further losses of tourism-based amenities (USAID, 2018). A decline in the overall attractiveness of the country as a vacation destination can lead to a significant fall in tourist arrivals. This can have negative implications for the country's economic growth, employment levels and the country's external sector due to tourism being the country's top foreign exchange earner.

The health sector is vulnerable to climate-induced events in terms of damage to critical healthcare infrastructure and a rise in disease transmission. Past hurricanes and storms have damaged critical infrastructure for health service delivery, including health centres and hospitals, reducing access to health care for a significant proportion of the Jamaican population, particularly those amongst the poorest. For example, damage to health centres and their furnishings resulting from Hurricane Ivan amounted to J$718 million (ECLAC, 2004). These events have also caused damage to the water and sanitation sectors, reducing sanitation and access to potable water by the population and ultimately resulting in the spread of diseases. For example, the outbreak of typhoid after Hurricane Gilbert in 1988 was associated with infrastructural damage to a treatment plant and the destruction of pit latrines. Similarly, an increase in extreme hazards, such as more storms, floods and droughts, might increase disease transmission (Rahman et al., 2016). For instance, the incidence of vector-borne diseases (such as dengue fever, malaria and chikungunya) may increase as higher temperatures favour the proliferation of mosquitoes and other disease carriers (Chen, 2007; ECLAC, 2011b; GoJ, 2015; RADA, 2015). The GoJ has also found that the chances of transmission of the more severe dengue haemorrhagic fever will increase. Severe outbreaks of dengue epidemics in Jamaica may have negative economic implications as funds earmarked for social and economic development may have to be diverted from these priorities. Given Jamaica's limited fiscal space, these trade-offs may be detrimental to development (UNDP, 2018). Furthermore, predicted increasing temperatures, humidity and dust could also result in higher respiratory-related illnesses such as asthma and bronchitis.

Roles and responsibilities of government institutions

Climate change governance and institutional set-up

This chapter is an overview of the public institutions and policies focused on Jamaica's climate response. It begins by identifying the key stakeholders within the MDAs of the GoJ involved in the development of climate policy, implementation of projects and programmes that have an impact on climate action and/or climate national targets, economic and fiscal management including the national budgeting process.

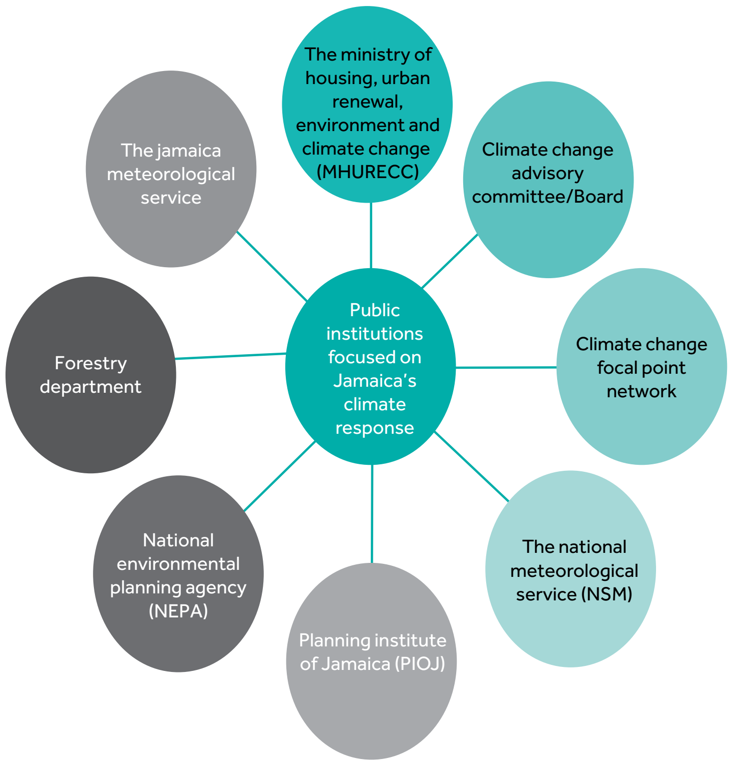
Climate change government institutions

The Ministry of Housing, Urban Renewal, Environment and Climate Change (MHURECC)[4] is responsible for overseeing and supporting the implementation of the Climate Change Policy Framework for Jamaica. The **Climate Change Branch (CCB)**, founded in 2012, coordinates existing and proposed initiatives in addressing climate change and oversees the implementation of the climate change policy framework. The **Environment and Risk Management Division (ERMD)** is the policy division within the MHURECC responsible for the periodic monitoring, review and subsequent revision of this Policy Framework, as appropriate (Figure 1).

The strategic objectives of the CCB:

- enhance resilience to climate change
- increase education, training and awareness on climate change
- improve the efficiency in the coordination on climate change strategies and activities across relevant actors

Figure 1. Public institutions involved in climate change



4 The MHURECC replaced the Ministry of Water, Land, Environment, and Climate Change (MWLECC) following the September 2020 General Elections.

- establish a monitoring and evaluation (M&E) framework for climate change adaptation and mitigation
- increase access to available climate change funding
- develop and maintain appropriate policies and administrative management mechanisms
- strengthen climate studies, scenarios and research

Climate Change Advisory Board provides a platform for the exchange of scientific and technical information on climate change and related issues of importance to Jamaica and advises the Minister and the Climate Change Department. The Forestry Department manages state-owned forested areas, which amount to approximately 25 per cent of Jamaica's forest cover, focusing on maintaining forest cover and carrying out reforestation activities.

Climate Change Focal Point Network was established to facilitate a multi-sectoral approach to climate change. Climate change focal points were appointed in all ministries, selected departments and agencies, and civil society and private group representatives. The focal points are responsible for coordinating the development and implementation of their respective sectoral strategies and actions concerning climate change and the mainstreaming of climate change considerations into their respective policies, plans and programmes.

The National Meteorological Service (NMS) within the Ministry of Land and Environment (MLE) is appointed as the Focal Point for the UNFCCC and is responsible for coordinating the preparation of the national communications. The Climate Branch of the NMS is the specialised unit on climate change. It is responsible for maintaining a current database of the climate of Jamaica and for the utilisation of this data in informing productive sectors of the country. It consists of a Data Acquisition Section that sets up and maintains an island-wide network of rainfall and climatological stations; a Data Processing Section that gathers, archives and analyses the climatological data with a view to monitoring and assessing the climate of the island; and an Applied Meteorology Section that processes the needs of clients, which include crop water requirements, design criteria for hydrologists and engineers, and climatological information for resolving weather-related legal and insurance issues.

National Environment Planning Agency (NEPA) is the lead government agency with the mandate for environmental protection, natural resource management, land use and spatial planning in Jamaica. The National Ozone Unit in NEPA works to minimise the use of ozone-depleting substances. Through its efforts, Jamaica completely phased out the use of chlorofluorocarbons (CFCs) in refrigeration in 2006 and is ahead of its 2025 schedule to phase out the use of hydrochlorofluorocarbons.

Planning Institute of Jamaica (PIOJ) is an agency of the Ministry of Finance and the Public Service (MOFPS). The PIOJ is the principal planning agency of the Government that seeks to initiate and coordinate the development of policies, plans and programmes for the sustainable development of Jamaica. Its Division of Sustainable Development and Regional Planning oversees implementation policy, strategy design and coordination for sustainable development. The organisation has played a leading role in the development of several climate change-related activities. It has been accredited as a National Implementing Agency (NIE) to the Adaptation Fund and leading research to improve climate-resilient planning. In disaster management, the organisation has also coordinated macro-socio-economic impact assessments and initial damage assessments.

In terms of economic and fiscal management, Jamaica is a member of the Coalition of Finance Ministers for Climate Action aimed at driving more decisive collective action on climate change and its impacts. The Coalition promotes national climate action, especially through fiscal policy and public finance, in terms of sharing best practices and experiences on macro-, fiscal and public financial management policies for low-carbon transformation. The **National Public Financial Management Policy Framework** and the **National Disaster Risk Financing Policy** underpin the Ministry of Finance and the Public Service (MFPS) fiscal/financial resilience aspect to climate action. Jamaica's Cabinet in November 2018 approved the National Public Financial Management Policy Framework for Natural Disaster Risk Financing. Cabinet approved a National

Disaster Risk Financing Policy on 2 August 2021. The policy framework provides the state's vision and it sets out the enabling environment needed to ensure that adequate resources are available to address ex-post financing requirements through a mix of instruments. The policy framework considers cost-effectiveness, timeliness and sound administrative arrangements for reducing the fiscal impact of natural disasters by proposing a risk-layering strategy that combines risk retention and risk transfer instruments.

Climate change national framework, plans and policies

The climate change policy framework (CCPF) for Jamaica

The CCPF aims to support Vision 2030 Jamaica – National Development Plan (Vision 2030 Jamaica) by reducing the risks posed by climate change to Jamaica's economy and its development goals. It creates a sustainable institutional mechanism to facilitate the development, coordination and implementation of policies, sectoral plans, programmes, strategies and legislation to address the impacts of climate change. The objectives of the CCPF are:

- to mainstream climate change considerations into national policies and development planning and build the country's capacity to implement climate change adaptation and mitigation activities;
- to support the institutions responsible for research, monitoring and projections on climate change to facilitate decision-making and strategic actions at all levels;
- to encourage and coordinate the national response to the impacts of climate change and promote low-carbon development;
- to improve communication at all levels on climate change impacts and also adaptation and mitigation-related opportunities;
- to mobilise climate financing for adaptation and mitigation initiatives;
- to encourage the private sector to embrace climate change imperatives and promote technologies and processes contributing to climate change adaptation and mitigation initiatives.

The CCPF provides specific strategies, legislation and policies to be adopted and implemented, including implementing the climate change mitigation and adaptation framework. Furthermore, relevant sectors are required to develop or update individual plans addressing climate change adaptation and mitigation. The framework facilitates the development of a climate financing strategy; development of research, technology, training and knowledge management; regional and international engagement and participation; promotion of consultative processes and communication to improve public participation in mitigation and adaptation response measures; strengthening climate change governance arrangements; development and incorporation of mechanisms and tools to mainstream climate change into ecosystem protection and land use and physical planning.

Plans and policies relating to climate change

Jamaica has adopted various climate change adaptation and mitigation policies and programmes to reduce the risks or vulnerabilities posed by climate change and increase resilience. For example, Vision 2030 Jamaica provides the framework to ensure that climate change issues are mainstreamed into national policies and development activities. The point of adaptation to climate change is addressed explicitly under *National Outcome #14* "Hazard Risk Reduction and Adaptation to Climate Change". The critical related national strategies are developing measures to adapt to climate change and developing mechanisms to influence the global rate of climate change. In addition, measures aimed at climate change mitigation are supported through National Outcome #10 "Energy Security and Efficiency", which addresses energy efficiency, conservation and renewable energy and National Strategy 12-5 "Promote Eco-efficiency and Green Economy", which promotes the use of clean technologies within the manufacturing sector.

The Food and Nutrition Security Policy is an integral part of the National Agriculture Policy and National Development Strategy and aims at addressing the threats and opportunities relating to food security in the country. Concerning climate change, it includes policy recommendations to improve the national community's food and nutrition security resilience to natural and socioeconomic shocks and climate change. It also emphasises disaster risk mitigation and response mechanisms by proposing a nationwide network of emergency food stocks for a minimum of 3 months, emergency food plans for vulnerable groups and households, and contingency plans for recovery and rehabilitation in areas prone to natural disasters.

The Disaster Preparedness and Emergency Management Act (1993) seeks to facilitate and coordinate the development and implementation of integrated disaster management systems. *The National Disaster Plan* sets out mitigation preparedness, response and recovery procedures for natural and man-induced hazards. *Hazard Mitigation Policy* details the Government's policy for evacuation, communications, mass casualty events, aircraft accidents, pandemics and pest infestations.

The 2015 Policy Guideline on Rainwater Harvesting and The Forest Management and Conservation Plan, and the Strategic Forest Management Plan 2010–2014 provide targets for reforestation and afforestation programmes that remove carbon dioxide from the atmosphere.

The *National Water Sector Adaptation Strategy* (draft) outlines the duties of the Government and other key stakeholder groups in helping to build the resilience of the water sector against climate change and other potential hazardous impacts.

The National Building Code provides guidelines for constructing hurricane-resistant buildings across the island, including hurricane straps and water tanks. The code outlines the building standards for construction within the coastal zone and considers physical planning standards, such as coastal setbacks.

The *National Carbon Emissions Trading Policy* (draft) establishes the guidelines and terms under which Jamaica will participate in carbon markets to assist the country in realising a portion of its quantified emission reduction targets and move it towards achieving the national sustainable development goals.

The *National Energy Policy 2009–2030* outlines priority areas that will ensure that the country mitigates volatile and rising crude oil prices, takes advantage of renewable and non-renewable resources, and promotes energy resources conservation and efficiency in all sectors of the society. It aims for 20 per cent of renewables in the energy mix by 2030.

Integration of climate change in the Jamaica government's budgeting and planning process

Jamaica has faced several climate-induced extreme and slow onset events in the past, which have had significant socio-economic and fiscal implications for the country through their direct and indirect impacts on Jamaica's vital economic sectors. Such implications have been severe, ultimately affecting the overall economy and quality of life in Jamaica. With compelling evidence suggesting that Jamaica is likely to witness greater climate-induced events in the future. Developing adequate climate change mitigation and adaptation policies and building financial resilience strategies to reduce and manage climate risks should be a priority for the Jamaican Government.

The Financial Administration and Audit Act (FAA) provides the primary legal and institutional framework for fiscal operations, the basic principles for the Consolidated Fund and the Contingencies Fund, and prescribes definitions and parameters for operating in times of emergency. While the FAA is designed to improve Jamaica's macroeconomic outlook and debt-to-GDP ratio, the FAA provides an "escape clause" from the fiscal rules for a maximum of 2 years in the event of a natural disaster that results in a fiscal impact of 1.5 per cent of the GDP or higher (sections 48C(2)(a) and 48C(3)(a)). The rules are mindful that the GoJ may subscribe to insurance facilities, and only the difference between the total value of the disaster and the insurance payout should be counted.

The National Public Financial Management Policy Framework and the National Disaster Risk Financing Policy underpin the Ministry of Finance and the Public Service (MFPS) fiscal/financial resilience aspect to climate action. Jamaica's Cabinet in November 2018 approved the National Public Financial Management Policy Framework for Natural Disaster Risk Financing. Cabinet approved a National Disaster Risk Financing Policy on 2 August 2021. The policy framework provides the state's vision. It sets out the enabling environment needed to ensure that adequate resources are available to address ex-post financing requirements through a mix of instruments. The policy framework considers cost-effectiveness, timeliness and sound administrative arrangements for reducing the fiscal impact of natural disasters by proposing a risk-layering strategy that combines risk retention and risk transfer instruments.

Jamaica includes disaster risk financing in its national budget. The Cabinet in October 2021 approved the development of a Policy on National Disaster Risk Financing. The policy is in alignment with the VISION 2030 Jamaica National Development Plan, the medium-Term Socio-economic Policy Framework (MTF) and the fiscal management strategy of the GoJ. The National Disaster Fund (NDF) is the main budget instrument for the GoJ to finance public post-disaster expenditures. As outlined in the 2021/22 national budget, the GoJ earmarked J$2.3 billion in resources to counter the risk of natural disasters. This includes a J$50.0 million allocation to the National Disaster Fund, the issuance of J$1.1 billion in Catastrophe Bonds (Cat-Bonds), J$1.0 billion in premium payments to the Caribbean Catastrophe Risk Insurance Facility (CCRIF) and a J$200 million transfer to the Contingencies Fund. The Ministry of Finance and the Public Service designates the contingency fund as the National Catastrophic Disaster Reserve Fund to improve public assets' insurance and incorporate disaster risk analysis in the public sector investments and planning.

Jamaica is also a member of the Coalition of Finance Ministers for Climate Action aimed at driving stronger collective action on climate change and its impacts.

As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and as a Non-Annex I Party to the Convention, Jamaica has played a key role in international negotiations advocating for adequate climate funding for SIDS. To date, Jamaica has received grants and financial support from various bilateral and multilateral donors. This includes:

- Global Environmental Fund (GEF) Trust Fund targeting community-based projects, over the 2008–2017 period, the GEF Small Grants Program allocated US$1.4 million.
- Special Climate Change Adaptation Fund (SCCAF) targeting community-based organisations and selected public sector entities to finance adaptation and disaster risk reduction projects. The SCCAF operates through the Environmental Foundation of Jamaica (EFJ). As of May 2019, the EFJ disbursed US$3.23 million to grant beneficiaries (Climate Change Division, 2017, GCF, 2019).
- UNFCCC Adaptation Fund for Enhancing Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security.
- Jamaica pays an insurance premium annually to the Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF SPC) for natural disasters.

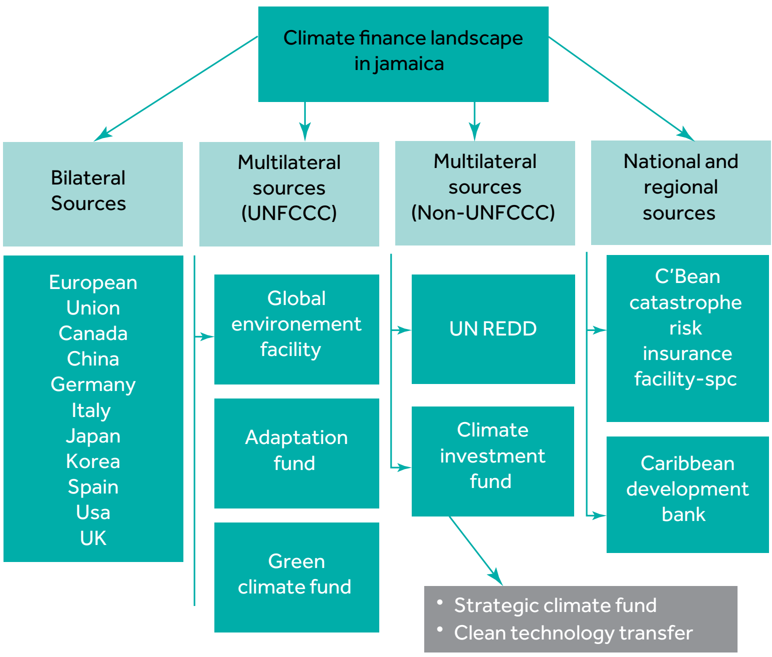
The Climate Change Division (2017) provides an outline of the climate finance landscape in Jamaica (see Figure 2).

Jamaica also receives grants from external sources to fund projects, which seek to build resilience and adapt to climate change (see Appendix A). Although limited regional and national funds are available, Jamaica receives support from the Caribbean Development Bank (CDB), which supports disaster risk reduction and management, climate change mitigation and adaptation, and renewable energy and energy efficiency in its member countries. The National Conservation Trust Fund of Jamaica Limited (NCTFJ) is a grant-making entity established to fund activities related to the conservation and management of protected areas. See Appendix B for details of how Jamaica allocates its current climate change budget.

The IDB (2020a) evaluated the climate budget of the Jamaica government by reviewing the budget set aside for five sectors, namely energy, environment, agriculture, transport and risk management. The IDB found that based on the five sectors in the 2017 budget (Table 2), 1.1 per cent of GDP (US$161.4 million) was allocated for climate change. Actual expenditure in the five sectors was greater than budgeted, with climate change outlays accounted for 1.2 per cent of GDP (US$175.1 million).

The IDB (2020b) study found that the allocations for climate change were often the last institutional priorities. The WB (2021) identified key capacity constraints to be addressed to enhance the reporting requirements of the Paris Agreement.

Figure 2. Jamaica's climate finance landscape



Source: Climate Change Division (2017).

Table 2. Climate change as per cent of budget and the GDP for Jamaica, 2017

Budget associated with climate change in the sectors under analysis, as a percentage of the total national budget (%)	Budget contrary to climate change in the sectors under analysis, as a percentage of the total national budget (%)	Budget associated with climate change in the sectors under analysis, as a percentage of the GDP (%)	Budget contrary to climate change in the sectors under analysis, as a percentage of the GDP (%)
1.7	1.9	1.1	1.2

Source: IDB.

This included the need to monitor, report and verify mitigation and adaptation actions, the collection of reliable and accurate climate-specific data and the need to generate forecasting scenarios and strategic information. Consequently, MDAs need to continue the initiatives to mainstream climate adaptation and mitigation measures in their investment and strategic plans to implement the NDCs.

Building climate resilience in the economy and budget

Climate resilience is the ability to anticipate, prepare for and respond to hazardous events, trends or disturbances related to climate. In the context of climate change, resilience is the ability of a system or community to rebound following a shock such as a natural disaster. Building resilience requires recognising potential hazards like extreme weather events and understanding the underlying vulnerabilities that may affect recovery from them (Intergovernmental Panel on Climate Change (IPCC, 2012)).

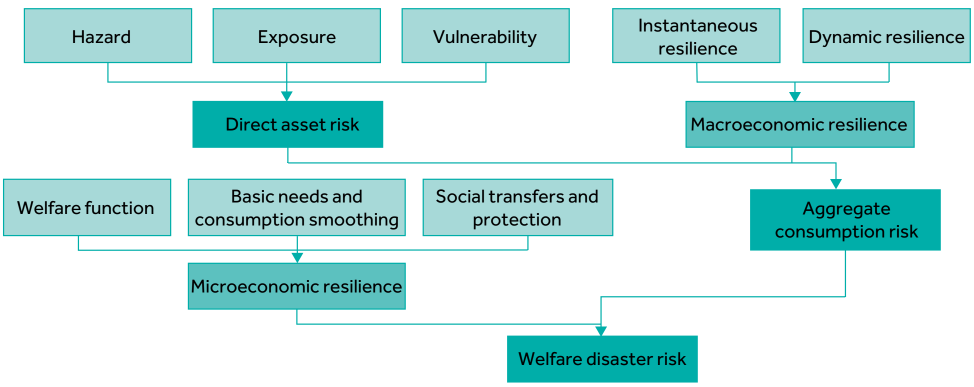
From an economic perspective, it is important to determine the economic cost associated with a natural event shock (e.g. a natural disaster) and its welfare impacts. In the case of Jamaica, it is important for policymakers/government technicians to be able to estimate the effects of a natural disaster shock on assets, production factors, output and consumption. The natural disaster affects the economic system beyond the immediate loss and damages of assets, considering indirect impacts such as the loss of output and income and loss of employment and tax revenues. In addition to human losses, these consequences must be accounted for to assess the disaster's impact on the population's welfare. From this assessment, then and only then, a true evaluation of the fiscal impacts can be conducted, and the Government's budgetary response estimated.

The theoretical framework draws from Hallegatte (2014). It starts with an examination of "disaster welfare risk", which captures both the macroeconomic and microeconomic risks such as the value of the damaged assets, losses in aggregate consumption and investment, in addition to the distribution of the losses in terms of households' pre-disaster income and their ability to smooth the shock(s) over time. From a climate resilience lens, disaster welfare risk depends on the ability to limit the magnitude of immediate production losses for a given amount of asset losses and the economy's capacity to cope, recover and reconstruct and, therefore, minimise aggregate consumption losses (macroeconomic resilience).

Conversely, microeconomic resilience will depend on the household's ability to smooth shocks over time, access to savings, borrowing, insurance and social protection programmes. As a result, disaster welfare risk in a country can be reduced by, reducing the exposure or vulnerability of people and assets (reducing asset losses), increasing macroeconomic resilience (reducing aggregate consumption losses for a given level of asset losses) or increasing microeconomic resilience (reducing welfare losses for a given level of aggregate consumption losses) (Hallegatte, 2014).

Figure 3 shows the structure of the disaster welfare risk. Welfare disaster risk only encompasses economic effects. Oceana light boxes represent the characteristics of the economy, Oceana medium boxes represent the different resilience indicators and Oceana represent the various measures of disaster risk.

Figure 3. Disaster welfare risk



Source: Hallegatte (2014).

Modelling climate economic impacts

The approach set out above and in the Appendix is the methodology followed for this project. We need to measure asset losses and output losses (measured as asset losses multiplied by the productivity function of the economy). In an ideal scenario with perfect information, we would add to productive asset losses to the losses associated with output declines. It is an attempt to measure the *disaster welfare risk* associated with an event to quantify an event's true damage and losses. However, we do not have good productivity data for all of Jamaica's industrial sectors. Therefore, to estimate the economic impacts of an event on the economy of Jamaica, we observed the DaLA for various events that Jamaica experienced in the past 20 years (2000 to present). The damage and loss assessments for hurricanes, tropical storms, floods and one drought event are presented in Chapter 1 and Appendix C. Based on these DaLA estimates and using the rule of thumb of multiplying the DaLA by the prevailing interest rate and the expected time to recover, we calculated the GDP flow impacts for the various sectors that DaLA estimates were provided. Understanding what is required to build resilience (macroeconomic and microeconomic components) is essential in knowing what should be measured concerning damages and losses.

These sectoral impacts were used to "shock" the entire economy to determine the events' whole economy or output impact.

The consultant built a climate change economic model to estimate the economic impacts of different climatic events, including slow onset events. The model shows what impact climate change has on every sector of the economy (Appendix D explained how the model was built). The model allows the Government to forecast the impact that certain events (hurricanes, tropical storms, droughts and excess rainfall) could have on the economy. The following figures provide a snapshot of the modelling methodology.

It was essential first to understand how economic activity in Jamaica is currently measured. Figure 4 shows that there is a unique set of interactions between different economic agents. The system of national accounts (SNA) tries to measure this.

From this, GDP is calculated by adding intermediate demand and final demand to get total output (Figure 5).

The consultant then utilised the most recent and current supply and use table for the Jamaican

Figure 4. The system of national accounts

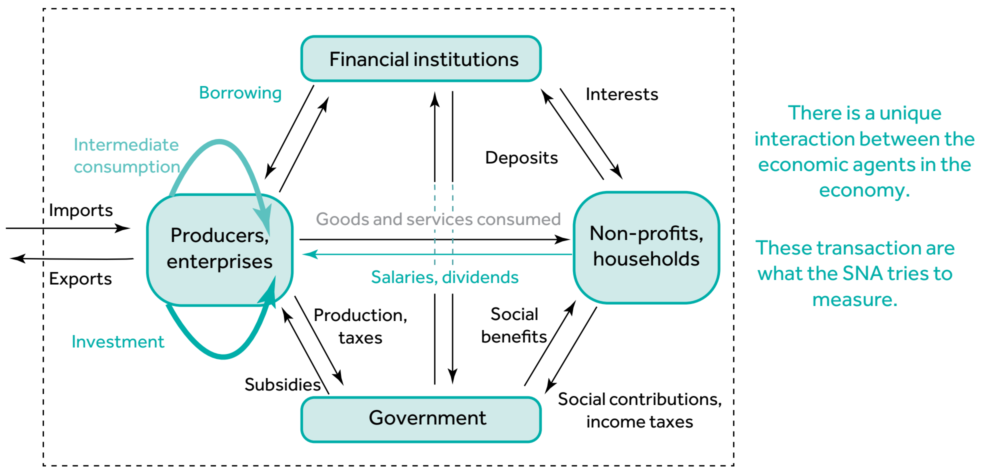


Figure 5. Calculating GDP

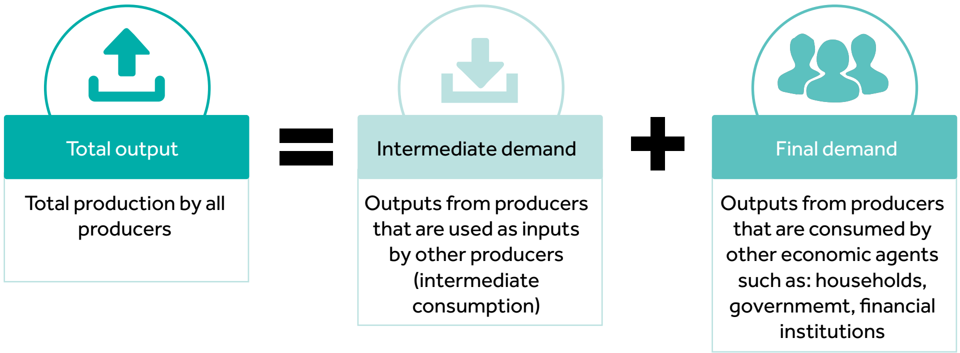
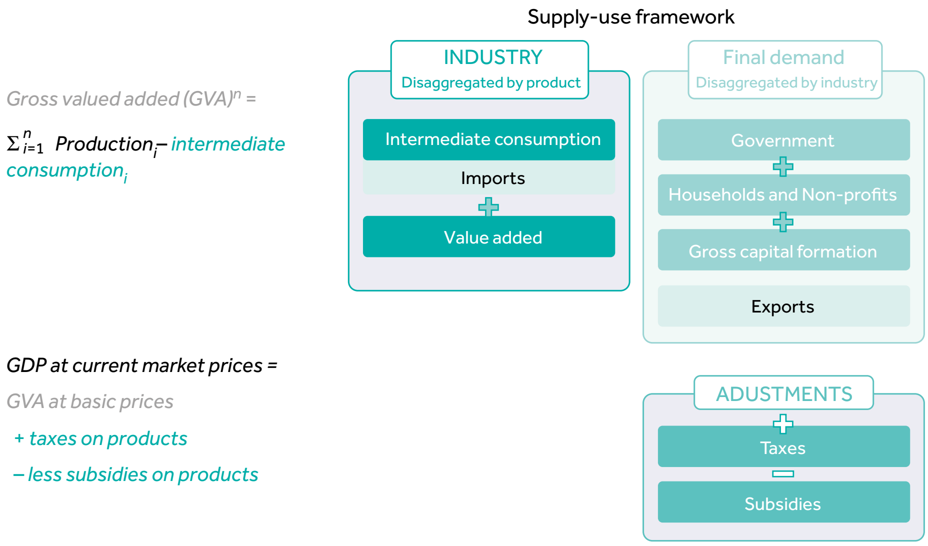


Figure 6. Supply and use framework



economy (2007), which provides a detailed overview of the intermediate and final demand between all industries within Jamaica and the rest of the world (Figure 6).

Using the supply and use framework, the consultant built a Climate change macro-account for Jamaica and integrated climate impacts within the GDP model. The approach is called climate change macro accounts (CCMA).

The CCMA estimates how different climate change events impact individual sectors and the entire economy, including intermediate and final demand impacts, as shown in Figures 7–9 (see Appendix D for further details). By estimating the effect of climatic events on the economy, these impacts can then be fed into the climate macro-fiscal model to ascertain the fiscal costs or consequences of climate change.

Figure 7. Linking climate change data to economic impacts

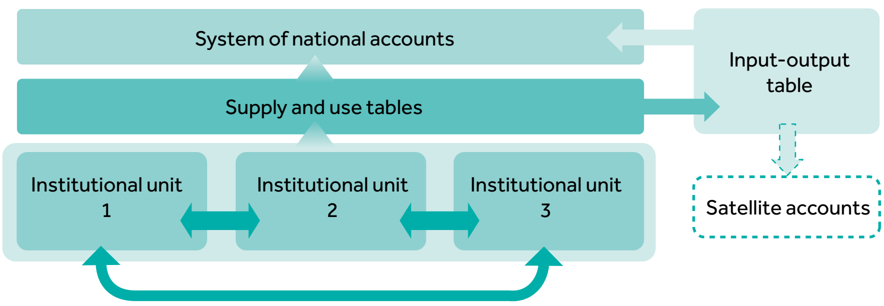


Figure 8. Impacts on various sectors

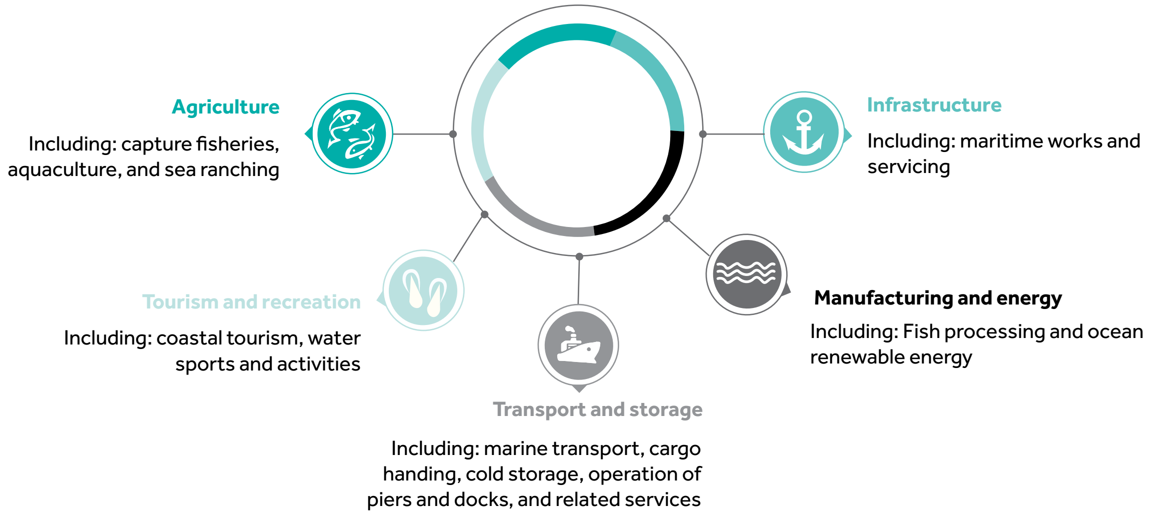
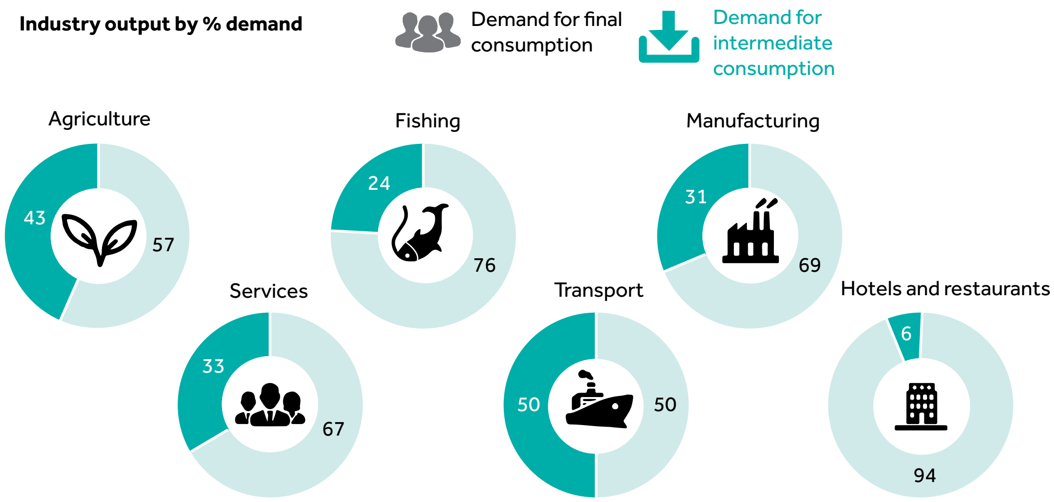


Figure 9. The impacts on intermediate demand and final demand



Climate macro-fiscal model

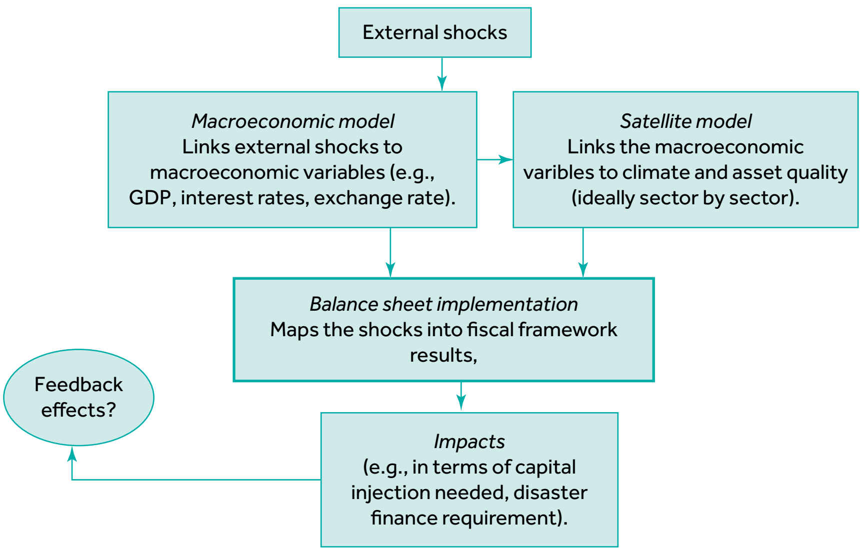
The analysis presents a simple simulation macro-fiscal model that incorporates the IMF's financial programming framework and a simplified debt sustainability tool to access the impact of climate events on the GoJ's medium term outlook. The tool is Excel based and provides a range of standard IMF performance criteria, together with a complete set of consistent macroeconomic accounts for the real and public sectors of the economy. Medium- and long-term fiscal and debt considerations are incorporated, considering climate events and their impact on key economic variables. The variables are projected with some combination of country economic knowledge, qualitative judgement and econometric equations. The tool is helpful in policy simulations and in analysing the ramifications of policy options (Figure 10).

The corresponding economic impact was then entered into the macro-fiscal model to determine the effect on the fiscal accounts resulting from the shock. The primary budgetary impact is reflected in the changes against the business-as-usual scenario in three leading indicators: Debt sustainability, impact on programming expenditures and the impact on the capital budget. Debt sustainability as measured by the debt to GDP ratio indicates the government's solvency and how climate events impact that solvency. The climate macro-fiscal model is a standalone file. Programming expenditures, which examine the spending on wages and other government programmes, such as transfers and subsidies, indicate the impact on government welfare-enhancing expenditures resulting from an event. Capital expenditure reflects the need to rebuild or enhance infrastructure resilience due to slow onset events or sudden events.

The macro-fiscal model was built to estimate the impacts of climate change on the fiscal accounts and allow the Government to potentially differentiate expenditures associated with climate action against general environmental spending. The model enables the Jamaican Government to stress-test the fiscal accounts based on various climate scenarios and estimate the impacts of current climate events.

The model results from the macro-climate model will populate an amended macro-fiscal model to provide detailed insights into climate change's fiscal impacts. This model will assist in providing recommendations for ex-ante and ex-post financing options.

Figure 10. Fiscal climate stress testing



Recommendations

Jamaica has played a key role in integrating climate mitigation and adaptation in its economic development processes. The policy response is comprehensive based on the number of agencies that report and seek to implement the various climate policies of the Jamaican Government. However, the review of the agencies responsible for implementing the numerous climate policies suggests that there may be a risk of duplication of efforts and creating parallel systems. Public–private partnerships must be a crucial component of the climate policy framework, and the responsibilities of climate change are not exclusive to government-only activities. Other key stakeholders such as the private sector and civil society are required to have clearly defined roles and active participation within the engagement and implementation framework. Private sector engagement and civil society participation must also form critical pillars of the new climate change policy environment. Therefore, deepening stakeholder engagement and coordination will be critical. An important consideration for the government is how it encourages the private sector and civil society to mainstream climate change into their daily activities and decision-making. Getting the rest of the society and economy on board could be an important new focus of the climate change policy framework.

Climate change poses an existential threat to the Jamaican standard of living and way of life. It is, therefore, everyone's responsibility. However, because many of the most severe impacts will happen in the future (although severe climatic consequences do happen now), there could be a tendency for current generation economic agents to make the minimum policy response or prepare less than sufficiently now. Therefore, mainstreaming climate into policy and the Jamaican way of life is critical now. It also means that all government policies must also be viewed through a "climate lens" to ensure the impacts of climate change have been assessed and risks have been mitigated. The models provide a foundation for the government to simulate climate change impact on public expenditure and to identify the gaps and resources needed.

Research on development strategies and disaster risk reduction highlight the importance of adopting an adaptive and iterative approach in programme implementation. Therefore, there is the need to investigate/explore the respective roles, management and governance capacity, and interactions among the MDAs responsible for climate action and to improve policy coordination and development impact. For example, is there a need for a dedicated multi-stakeholder climate change coordination and finance committee focused on implementing the climate change plan?

Strengthening technical expertise/capacity in climate modelling and forecasting, having a dedicated and central repository (easier access to data) for climate data and financial flows, and mitigation and adaptation actions will need to be addressed to enhance Jamaica's ability to respond to the reporting requirements of the Paris Agreement.

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Appendix A

Economics of natural disasters theoretical framework

Economic theory states that, at the economic equilibrium, under certain conditions, the value of an asset is the net present value (NPV) of its expected future production. In this case, the annual loss of output is equal to the value of the lost capital multiplied by the marginal productivity of capital (MPC) (which is equal to the interest rate, increased by the depreciation rate). Assuming that this equality is always verified, the output loss caused by capital loss is equivalent to the value of the lost asset.

Figure A1 illustrates this point a scenario in which no reconstruction occurs: in that case, the production that is lost because of the disaster is equal to the value of the lost assets. In estimates of disaster consequences, "asset loss" refers to the replacement value of the capital. To have the equality of asset loss and output loss, a double equality needs to be verified: replacement value must be equal to market value, and market value has to be equal to the NPV of expected output.

In such an idealised context, classical production functions take the inputs, labour (L) and capital (K), and the outputs in the production process and give the value of the production (Y):

$$Y = f(L, K)$$

In this framework, natural disasters can be modelled assuming that they reduce the stock of productive capital instantaneously ($K_0 \rightarrow K_0 - \Delta K$), where ΔK is the value of asset losses. Figure 4 illustrates this way of assessing the impact on output. The production function is the blue line linking the origin of the graph to point A. The pre-disaster situation is point A, with capital K_0 and production Y_0. For small shocks, the impact on production can be estimated using the MPC. This is shown as point B on the orange dashed line tangent to the production function at point A. The orange line gives the production level Y_1 at the X-coordinate $K_0 - \Delta K$. It is the estimated residual production if the output loss is calculated by multiplying the value of the lost capital (ΔK) by the MPC:

$$\Delta Y(t_0) = r\Delta K$$

This relationship is equivalent to assuming that the NPV of output losses equals the value of lost assets (Figure A2).

However, in a more realistic setting, this method to assess output losses may lead to significant underestimation. The following subsections introduce several modifications to this framework to better represent the impacts of disasters.

Figure A1. Production as a function of time, without disaster or in a scenario with disaster and no reconstruction

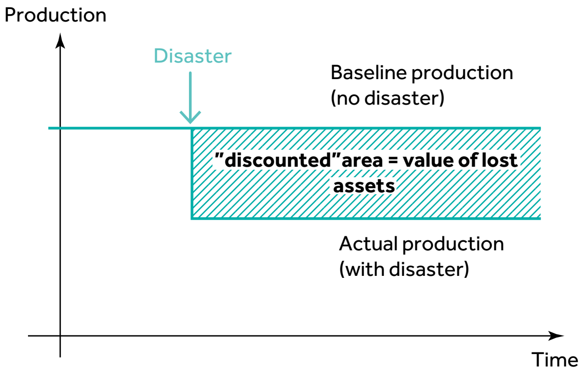
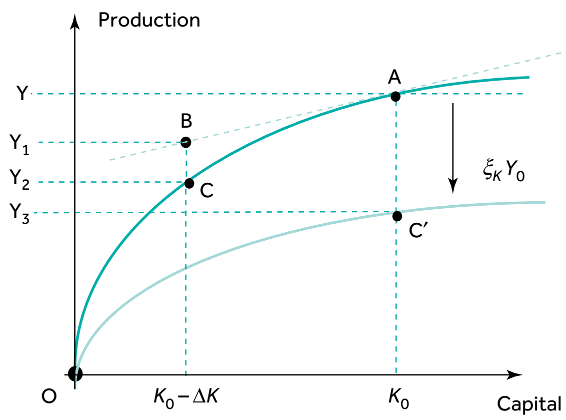


Figure A2. Production for productive capital for different modelling assumptions



Small shocks

Asset value and output are only equal for marginal changes, i.e. small shocks that do not affect the economy's structure and the relative prices of different goods and services. However, large shocks can affect prices (as the price of goods may rise due to disaster-related scarcity). At the same time, asset and output losses are often estimated assuming unchanged (pre-disaster) prices. This assumption is unrealistic if the disaster causes more than a slight shock. Thus, estimating the value of asset and output losses should consider the price change for large shocks. Compared with an assessment based on pre-disaster prices, it can significantly increase the assessed disaster cost.

To account for these effects of large shocks on the capital stock, one can use the full production function and reduce the amount of capital from K_0 to $K_0 - \Delta K$. This is shown by point C in Figure 4, which gives the value of production Y_2. In that case, output losses are larger than in the idealised framework, and Equation (A2) is replaced by:

$$\Delta Y = f\left(L, K\right) - f\left(L, K - \Delta K\right)$$

Impact on the "non-marginal" capital

Equation (A3) assumes that the destructions from the disaster affect only the least productive assets or that capital consists only in one commodity, perfectly substitutable. To account for the fact that disasters affect capital in a different way from optimal accumulation (or de-accumulation) of capital, one can modify the production function by introducing the term ξK, which is the proportion of non-destroyed capital. Thus, the effective capital is $K = \xi K \cdot K_0$, where K_0 is the potential productive capital in the absence of disaster. In Figure 4, the new production level is given by the relationship:

$$Y_3 = \xi K\ f\left(L, K_0\right) = A \xi K\ L \lambda K_0 \mu$$

With this new production function, an *x*% destruction of the productive capital reduces production by *x*%, and the loss in output is approximately equal to $1/\mu$ times the loss of asset estimated using the normal production function. In Figure 4, the new production function is the red line, and the new production Y_3 is given by the point "C".

With these assumptions, output losses are now equal to the value of lost assets multiplied by the average productivity of capital, which is larger than the marginal capital productivity. With classical values for μ, it means that output reduction at the time of shock (t_0) is about three times larger than what is suggested by the market value of damaged assets (i.e. what is estimated with Equation (A2)). As a result, production losses are then given by:

$$\Delta Y\ t_0 = ½\, r \Delta K$$

Externalities and distortions

For the replacement value and the market value to be equal, the economy needs to be at its economic optimum, i.e. the amount of capital is such that its return is equal to the interest rate. This is not always the case, especially in sectors affected by disasters such as infrastructure.

Additionally, output losses need to be estimated from a social point of view. Some assets, such as public goods that are destroyed by disasters, may exhibit positive externality, meaning that their value to society is larger than the value of the owner's expected output.

To account for these effects, the value of lost assets (ΔK) should be evaluated considering externalities and existing distortions, not from replacement costs only. If assets lost to disasters exhibit mostly positive externalities, this effect provides one additional reason to use capital productivity that is higher than the marginal productivity.

Assets that have not been affected by the hazards can also become unable to produce at the pre-event level because of indirect impacts/ripple effects (backward[5] or forward). Output losses are also due to complex interactions between businesses and production bottlenecks through supply chains of suppliers and producers.

These ripple effects across sectors are because capital components are not perfectly substitutable within a network of economic activities. The relative price of different types of capital depends on the relative quantity. Thus, the loss of one component can affect the other component and lead to higher (or lower) losses than the value of the asset loss suggests depending on the substitutability.

This problem can be illustrated by replacing the classical production function $f(L, K)$ with a function with two types of capital $f(L, K_1, K_2)$. If there are decreasing returns in K_1 and K_2, the impact of a

5 Appendix A provides a more detailed outline of the framework.

given loss $\Delta K = \Delta K_1 + \Delta K_2$ depends on how losses are distributed across the two capitals. The loss in output is larger if all losses affect only one type of capital, compared with a scenario where the two capitals are equally affected. Illustrating these effects in the extreme case where the production function has no substitution, the destruction by a disaster of a (marginal) amount of one type of capital would lead to a loss of output equal to:

$$\Delta Y\ t_0 = \left(\frac{\Sigma\alpha j}{\Sigma\alpha j - \alpha i}\right) r\Delta K_i$$

where the $\{\alpha j\}$ are parameters of the production function and describe the share of each type of capital in the total stock of capital. If αj is very small – i.e. if one capital is very small in value, but still essential in the production process – then the impact of a minimal asset loss can be very large. However, there is always some substitutability among capital types, and the assumptions used in Equation (A6) are an extreme case.

Non-affected capital, idle capacity and rescheduling

When capital cannot produce because of a lack of input, several options are available: input substitution, production rescheduling, mobilisation of existing idle resources and longer work hours when services are restored and can compensate for a significant fraction of the losses. In case of large disasters, output losses will be largely dependent on two characteristics of the economy: the adaptability and flexibility of its production processes; and its ability to channel economic production towards its most efficient uses.

Stimulus effects

Disasters lead to a reduction of production capacity and an increase in the demand for the reconstruction sector. Thus, the reconstruction acts in theory as a stimulus. However, its consequences depend on the pre-existing economic situation. If the economy is efficient and in a phase of high growth, in which all resources are fully used, the net effect of a stimulus on the economy will be negative, for instance, through diverted resources and production capacity scarcity. On the other hand, if the pre-disaster economy is depressed, the stimulus effect can yield benefits to the economy by mobilising idle capacities. However, the stimulus effect is not accounted for in disaster consequences since the same stimulus benefits could be captured in the absence of a disaster, through a classical stimulus policy, and without the negative welfare and human impacts of disasters.

A simple representation

As a result of externalities and distortions, ripple effects, and the mobilisation of idle capacity, the loss of output estimated in Equation (A5) is magnified (or reduced) by a factor $(1 + \alpha)$. The reduction in output just after the shock is thus:

$$\Delta Y\ t_0 = \left(\frac{1+\alpha}{\mu j}\right) r\Delta K$$

The parameter α represents the reduced (or increased) production of the capital that is not directly affected by the event and depends on the ability of the economic system to mobilise existing idle capacity, channel remaining production towards its most productive uses and increase imports to compensate for unavailable supplies. It is likely to be negative for relatively small disasters and become positive and then increase for larger-scale events. It is lower (and possibly negative) if there is a larger under-utilisation of production capacity and idle capacity that can be mobilised.

In the absence of more information, it is possible to assume that $\alpha = 0$, keeping in mind that we are disregarding some potentially important effects. In particular cases, different values could be used, for instance, a −20 per cent value if the shock occurs during a recession with large idle resources or +20 per cent if the transport sector is heavily affected, creating large-scale supply-chain issues.

Reconstruction dynamics and total output losses

The most common models used to assess post-disaster output losses are Input–Output (IO) or Calculable General Equilibrium (CGE) models. In these models, the economy is described as an ensemble of economic sectors, which interact through intermediate consumptions. However, these models describe how these different sectors interact with each other and how they react to shocks. For this project, an IO model was built using the latest available supply and use tables for the country. The model allows us to see how different shock scenarios, such as a hurricane or drought, impact the economy or the ripple effects.

A simple rule to assess total output losses

One dollar of direct loss in productive capital translates into more than the same amount of output losses in the framework presented here. The instantaneous decrease in output is equal to the amount of asset losses multiplied by the average productivity of capital, which is about three times the MPC (r), possibly increased by a factor $(1 + \alpha)$ that represents ripple effects.

$$\Delta Y\ t_0 = \left(\frac{1+\alpha}{\mu j}\right) r\Delta K$$

Assuming that output losses are reduced to zero exponentially and that 95 per cent of the losses are repaired in N years, then the output losses are also decreasing exponentially, with a characteristic time $N/3$. Output losses after are, thus, given by:

$$\Delta Y\ t_0 = \left(\frac{1+\alpha}{\mu j}\right) r\Delta K e^{\frac{t-t_a}{N/3}}$$

Figure 5 shows the (very) simplified representation of the return to "initial state" after a disaster. The area between the horizontal line and the actual production is the total loss of production and is given by Equation (A10). With this reconstruction pathway, total non-discounted output losses are equal to (see Figure 5):

$$\widetilde{\Delta Y} = \int_{t_0}^{+\infty} \frac{1+\alpha}{\mu} r\Delta K e^{-\frac{t-t_a}{N/3}} dt = \frac{1+\alpha}{\mu} \Delta K \frac{rN}{rN+3}$$

The parameter N is the reconstruction period, and experts can often estimate it based on experience. The reconstruction time is not when the observed output returns to its pre-disaster value but may be much longer as output is affected by other mechanisms, including changes in labour productivity, trade effects and other investments. The length of the reconstruction period will depend on many characteristics of the affected economy, such as the capacity of the sectors involved in the reconstruction process, the flexibility of the economy and its ability to mobilise resources for reconstruction, the openness of the economy and the financial strength of the public sector and its ability to access financial resources to reconstruct.

Taking an example of a disaster that makes capital losses equal to \$100 million, in a country with a 10 per cent interest rate, with a reconstruction period that is likely to span over 3 years would lead to output losses equal to \$30 million (i.e. 30 per cent of direct capital losses).

According to Hallengate, in the context of Figure 5 (hurricanes in Louisiana), this rule of thumb reproduces model results, if losses less than \$50 billion can be repaired in 1 year and that losses amounting to \$100, \$150, \$200 and \$250 billion can be repaired in 5, 10, 12 and 15 years, respectively.

With discounting at a rate r, the NPV of output losses is 12:

$$11F\widetilde{\Delta Y} = \int_{t_0}^{+\infty} \frac{1+\alpha}{\mu} r\Delta K e^{-\frac{t-t_a}{N/3}} e^{-r(t-t_0)} dt = \frac{1+\alpha}{\mu} \Delta K \frac{rN}{rN+3}$$

Appendix B

Jamaica selected climate change projects

Project	Funding Agency	Executive Agency	Objective	Start–End Date	Total Allocation to Jamaica (US$ Million)
Climate Change Action for Gender Sensitive Resilience **REGIONAL (C$15.0 million)**	Global Affairs Canada (GAC)	UNDP	To advance the development sector-level National Adaptation Plans (NAPs) and Nationality Appropriate Mitigation Actions (NAMAs), with a focus on the sectors that can give the greatest beneficial impact for women and girls	2018–22	NA
Skills to Access the Green Economy (SAGE) **REGIONAL (C$15.3 million)**	GAC	Colleges and Institutes Canada	To provide technical and vocational education training in key economic sectors associated with climate change	2018–22	NA
Building Climate Resilience of Urban Systems Through Ecosystem-based Adaptation (EbA) in Kingston, Jamaica	UNEP	Ministry of Economic Growth and Job Creation	To increase the capacity of urban to adapt to the effects of climate change through the integration of Ecosystem-based Adaptation (EbA) into urban planning in the medium- to long term	2017–21	$0.02
Jamaica – Promoting Community-based Climate Resilience in the Fisheries Sector Project	World Bank	MICAF	To increase the adoption of climate-resilient practices among targeted fishing and fish farming communities in Jamaica	2018–22	$4.8
PPCR-Improving Climate Data and Information Management Project	World Bank	PIOJ	To improve the quality and use of climate-related data and information for effective planning and action at local and national levels	2015–21	$6.8

Source: PIOJ.

Appendix C

Breakdown of selected the damage and loss assessments

See Tables C1–C11.

Table C1. Hurricane Ivan (2004) damage and loss assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**4.48**	**2.81**	**1.66**
Social sectors	**1.66**	**1.57**	**0.09**
Housing	1.36	1.27	0.08
Education and culture	0.10	0.10	0.00
Health	0.09	0.09	0.00
Public buildings	0.12	0.12	–
Productive sectors	**1.62**	**0.50**	**1.12**
Agriculture and livestock	1.04	0.41	0.62
Food processing	0.27	0.03	0.24
Mining	0.13	0.01	0.12
Tourism	0.19	0.06	0.14
Infrastructure	**0.85**	**0.43**	**0.42**
Electricity	0.17	0.07	0.10
Water supply and sanitation	0.08	0.02	0.06
Transport	0.40	0.30	–
Telecommunications	0.19	0.02	0.16
Airports	0.01	0.01	0.00
Environment	**0.31**	**0.31**	–
Emergency expenditures	**0.03**	–	**0.03**

Table C2. Hurricane Dean (2007) damage and loss assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Direct	Indirect
Total	**2.36**	**1.48**	**0.89**
Social sectors	**0.73**	**0.72**	**0.01**
Housing	0.61	0.61	–
Education and culture	0.07	0.07	–
Health	0.03	0.02	0.01
Correctional Facilities	0.01	0.01	–
Heritage Sites	0.00	0.00	–
Productive sectors	**1.20**	**0.41**	**0.79**
Domestic Crop and Agriculture crops	0.91	0.33	0.67
Livestock	0.01	0.01	–
Greenhouse/Protected Cultivation	0.01	0.01	–
Fisheries	0.04	0.03	0.01
Irrigation	0.00	0.00	–
Tourism	0.00	0.00	–
Relief Assistance (Agriculture)	0.02	0.02	–
Infrastructure	**0.37**	**0.35**	**0.02**
Electricity	0.11	0.11	–
Water supply and sanitation	0.02	0.01	0.02
Transport	0.21	0.21	–
Telecommunications	0.03	0.03	–
Environment	**0.01**	–	**0.01**
Waste Management	0.01	–	0.01
Emergency Operations	**0.06**	–	**0.06**
Government Relief Assistance	–	–	0.06
ODPEM Recovery Activities	–	–	1.00

Table C3. Hurricane Sandy (2012) damage and loss assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**0.84**	**0.80**	**0.03**
Social sectors	**0.41**	**0.40**	**0.01**
Housing	0.36	0.36	–
Education and culture	0.01	0.01	–
Health	0.03	0.02	0.01
Public buildings	0.00	–	–
Productive sectors	**0.14**	**0.13**	**0.01**
Domestic Crop and Agricultural crops	0.11	0.11	–
Livestock	0.01	0.01	–
Coffee	0.01	0.00	0.01
Spices	0.00	0.00	–
Fisheries	0.01	0.01	–
Irrigation	0.01	0.01	0.00
CASE Tutorial Farm	0.00	0.00	–
Infrastructure	**0.23**	**0.22**	**0.01**
Electricity	0.05	0.05	–
Water supply and sanitation	0.02	0.01	0.01
Transport	0.15	0.15	–
Telecommunications	0.01	0.01	–
Airports	0.00	0.00	0.00
Emergency Operations	**0.06**	**0.06**	–
Government Relief Assistance	0.05	0.05	–
ODPEM Recovery Activities	0.00	0.00	–

Table C4. Average hurricane damage and loss assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**2.74**	**1.68**	**1.10**
Social sectors	**0.96**	**0.92**	**0.04**
Housing	0.78	0.75	0.03
Education and culture	0.06	0.06	0.00
Health	0.05	0.04	0.01
Public buildings	0.06	0.06	–
Correctional Facilities	0.01	0.01	–
Heritage Sites	0.00	0.00	–
Productive sectors	**1.25**	**0.41**	**0.87**
Domestic Crop and Agricultural crops	0.68	0.28	0.43
Livestock	0.01	0.01	–
Greenhouse/Protected Cultivation	0.01	0.01	–
Fisheries	0.02	0.02	0.00
Irrigation	0.00	0.00	0.00
Tourism	0.10	0.03	0.07
Relief Assistance (Agriculture)	0.02	0.02	–
Food processing	0.27	0.03	0.24
Mining	0.13	0.01	0.12
Coffee	0.01	0.00	0.01
Spices	0.00	0.00	–
CASE Tutorial Farm	0.00	0.00	–
Infrastructure	**0.48**	**0.34**	**0.15**
Electricity	0.11	0.08	0.03
Water supply and sanitation	0.04	0.01	0.03
Transport	0.25	0.22	0.03
Telecommunications	0.07	0.02	0.05
Airports	0.01	0.01	0.00
Environment	**0.01**	–	**0.01**
Waste Management	0.01	–	0.01
Emergency Operations	**0.03**	**0.02**	**0.03**
Government Relief Assistance	0.03	0.02	0.03
ODPEM Recovery Activities	0.00	0.00	0.00

Table C5. Storm Gustav (2008) damage and loss assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**1.52**	**1.42**	**0.10**
Social sectors	**0.16**	**0.13**	**0.03**
Housing	0.10	0.09	0.01
Education and culture	0.02	0.02	–
Health	0.04	0.02	0.02
Correctional Facilities	0.00	0.00	–
Productive sectors	**0.17**	**0.17**	**0.00**
Livestock	0.00	0.00	–
Greenhouse/Protected Cultivation	0.00	0.00	–
Domestic Crop and Agricultural crops	0.15	0.15	–
Relief Assistance (Agriculture)	0.00	–	0.00
Fisheries	0.01	0.01	–
Irrigation	0.00	0.00	0.00
Infrastructure	**1.18**	**1.11**	**0.06**
Electricity	0.01	0.01	–
Water supply and sanitation	0.04	0.02	0.02
Transport	0.74	0.73	0.00
Parish Council Roads	0.39	0.35	0.04
Telecommunications	0.00	0.00	–
Environment	**0.00**	**0.00**	–
Waste Management	0.00	0.00	–
Emergency Operations	**0.00**	–	**0.00**
Government Relief Assistance	0.00	–	0.00
ODPEM Recovery Activities	0.00	–	0.00

Table C6. Tropical Storm Nicole (2010) damage and loss assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**1.79**	**1.70**	**0.09**
Social sectors	**0.14**	**0.06**	**0.08**
Housing	0.02	0.02	–
Education and culture	0.10	0.01	0.08
Health	0.02	0.02	–
Productive sectors	**0.07**	**0.06**	**0.01**
Livestock	0.03	0.03	–
Greenhouse/Protected Cultivation	0.01	0.01	–
Domestic Crop and Agricultural crops	0.05	0.05	–
Relief assistance (Agriculture)	0.00	–	0.00
Tourism	0.01	0.01	0.01
Infrastructure	**1.58**	**1.57**	**0.00**
Electricity	0.01	0.01	–
Water supply and sanitation	0.02	0.02	–
Transport	1.48	1.48	0.00
Farm Roads	0.05	0.05	–
Ports	0.00	0.00	0.00
Telecommunications	0.01	0.01	–
Environment	**0.00**	**0.00**	**0.00**
Forestry	0.00	0.00	0.00
Waste Management	0.00	0.00	–
Emergency Operations	**0.00**	**0.00**	–
PC-Drain Cleaning/Vector Control	0.00	0.00	–
ODPEM Relief Supplies	0.00	0.00	–
ODPEM Relief Transportation	0.00	0.00	–
Red Cross Activities	0.00	0.00	–

Table C7. Tropical storms average damage and losses assessment

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**1.91**	**1.79**	**0.12**
Social sectors	**0.15**	**0.10**	**0.06**
Housing	0.06	0.06	0.01
Education and culture	0.06	0.02	0.04
Health	0.03	0.02	0.01
Correctional Facilities	0.00	0.00	–
Productive sectors	**0.15**	**0.14**	**0.01**
Livestock	0.01	0.01	–
Greenhouse/Protected Cultivation	0.01	0.01	–
Domestic Crop and Agricultural crops	0.10	0.10	–
Relief assistance (Agriculture)	0.00	–	0.00
Tourism	0.01	0.01	0.01
Fisheries	0.01	0.01	–
Irrigation	0.00	0.00	0.00
Infrastructure	**1.60**	**1.54**	**0.05**
Electricity	0.01	0.01	–
Water supply and sanitation	0.03	0.02	0.01
Transport	1.11	1.11	0.00
Farm Roads	0.05	0.05	–
Ports	0.00	0.00	0.00
Telecommunications	0.01	0.01	–
Parish Council Roads	0.39	0.35	0.04
Environment	**0.00**	**0.00**	**0.00**
Forestry	0.00	0.00	0.00
Waste Management	0.00	0.00	–
Emergency Operations	**0.01**	**0.00**	**0.00**
PC-Drain Cleaning/Vector Control	0.00	0.00	–
ODPEM Relief Supplies	0.00	0.00	–
ODPEM Relief Transportation	0.00	0.00	–
Red Cross Activities	0.00	0.00	–
Government Relief Assistance	0.00	–	0.00
ODPEM Recovery Activities	0.00	–	1.0

Table C8. May floods (2002) damage and losses assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Direct	Indirect
Total	**0.400**	**0.358**	**0.042**
Social sectors	**0.016**	**0.014**	**0.002**
Housing	0.009	0.009	0.000
Education and culture	0.000	0.000	0.000
Health	0.007	0.005	0.002
Productive sectors	**0.127**	**0.094**	**0.033**
Agriculture, livestock and fisheries	0.127	0.094	0.033
Tourism	0.000	0.000	–
Manufacturing and distribution	0.000	–	0.000
Infrastructure	**0.256**	**0.249**	**0.007**
Transport	0.242	0.240	0.002
Telecommunications	0.001	0.001	–
Energy and electricity	0.000	–	0.000
Water and sewerage	0.013	0.008	0.005
Emergency Operations	**0.001**	**0.001**	**0.000**
Emergency expenditure	0.001	0.001	0.000
ODPEM Recovery Activities	–	–	–

Table C9. March–June floods (2017) assessments

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**0.226**	**0.056**	**0.170**
Social sectors	**0.002**	**0.001**	**0.001**
Housing	–	–	–
Education and culture	–	–	–
Health	0.002	0.001	0.001
Productive sectors	**0.045**	**0.044**	**0.001**
Domestic Crop and Agricultural Crops	0.040	0.040	–
Livestock	0.004	0.004	–
Irrigation	0.000	0.000	–
Grant to Farmers	0.001	–	0.001
Forestry	0.000	–	–
Infrastructure	**0.175**	**0.010**	**0.165**
Water supply and sanitation	0.006	0.002	0.004
Transport/Roads and Bridges	0.169	0.009	0.161
Emergency Operations	**0.003**	–	**0.003**
Government Relief Assistance	0.003	–	0.003
ODPEM Recovery Activities	0.000	–	1.000

Table C10. Floods average damage and losses assessment

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Total	**0.317**	**0.210**	**0.107**
Social sectors	**0.010**	**0.008**	**0.002**
Housing	0.005	0.005	0.000
Education and culture	0.000	0.000	0.000
Health	0.005	0.003	0.001
Productive sectors	**0.089**	**0.071**	**0.018**
Domestic Crop and Agricultural Crops	0.084	0.067	0.017
Livestock	0.004	0.004	–
Irrigation	0.000	0.000	–
Grant to Farmers	0.001	–	0.001
Forestry	0.000	–	–
Tourism	0.000	0.000	–
Manufacturing and distribution	0.000	–	0.000
Infrastructure	**0.216**	**0.130**	**0.086**
Water supply and sanitation	0.009	0.005	0.005
Transport/Roads and Bridges	0.205	0.124	0.081
Telecommunications	0.001	0.001	–
Energy and electricity	0.000	–	0.000
Emergency Operations	**0.002**	**0.001**	**0.001**
Government Relief Assistance	0.002	0.001	0.001
ODPEM Recovery Activities	0.000	–	0.000

Table C11. Droughts average damage and losses assessment

Sector	Damage and losses (per cent of GDP)		
	Total effect	Damage	Losses
Productive sectors			
Agriculture	0.0400	–	0.0400

Appendix D

Steps to creating the macro-climate Leontief model

1. Adjust the IO table by the DaLA coefficients (more will be explained in the section on Inputs – DaLA). The IO table adjusted allocates a multiplier to the current industry dynamic based on the existence of one of five scenarios, namely (1) no event, (2) drought, (3) hurricane, (4) excess rainfall and (5) tropical storm. Each event has shock functions identified based on empirical evidence from previous DaLAs. To change an event, select from the dropdown box in cell B1 [**worksheet: shock functions**].

2. Identify the column and row vectors (industries) from the original IO table. The original IO table is [**worksheet: IO table**]. These columns and rows are adjusted for the impact of one of the five scenarios, previously identified. The model automatically calculates an adjusted IO table considering the impacts of the scenarios. This computation applies the output shocks from DaLAs to the specific industries and activities listed in the IO table. The results of this are shown in [**worksheet: IO table adj**].

3. Based on the nature of the research/ application, the IO table must be converted into a square matrix with the same industries listed in the rows and columns. For this study, the matrix of industries was:

   Agriculture | Fishing and Aquaculture | Manufacturing | Services | Transport | Hotels and Restaurants | Government Services

4. To convert the IO table into this square matrix, firstly all outputs (industries) are summed into these industries. The applicable System of National Accounts (SNA) Framework must be applied to convert the output (column vectors) into one of these seven industries [**worksheet: Output Total**]. Next, all inputs (industries) are summed into one of the seven industries, using the same SNA framework [**worksheet: Input Total**].

5. The A-Matrix is then created showing the share of each industries' outputs that comes as inputs from one of the seven industries. Calculating this tells us what per cent of every dollar of output in a particular industry are inputs from another industry [**worksheet: A-Matrix**]. This is computed as the respective industry input divided the sum of all inputs for that respective column.

6. An Identity matrix must be identified, simply this is the same structure as the A-Matrix but with all values change to 0, except where an intersection of the same industry occurs – this is set to 1 (i.e. where the column and row industry are the same). The result of this adjustment is a matrix where the diagonal is 1's and every other value is 0's. [**worksheet: I-Matrix**].

7. The next step involved subtract the A-Matrix from the I-Matrix, using standard matrix algebra. This is automatically done using the linked worksheets from before [**worksheet: Unit Matrix**].

8. The inverse of the previous matrix is then computed to establish the relational matrix used in computing final output. This Leontief matrix applied to the demand for final consumption of an industry can be extrapolated across the total economic system to measure intermediate input from other industries [**worksheet: Lf**]. The [**worksheet: Static Lf**] provides a control where no shock took place and is used as the benchmark against which changes are computed. As such, when no event is selected – the Lf and Static Lf are equal; as a result, the per cent change in GDP is zero.

Inputs

DaLA

1. The results of DaLAs previously done are averaged based on the respective event types. Through this, there is an estimation of the total effect and damage and loss value

over the reference period (determined by the researcher) [**worksheet: Average Losses by Event Type**].

a. In cases where the DaLA is provided as a per cent of GDP, a further level of analysis is needed where you apply this per cent to the respective industry level GDP. To do this, there must be a cross-referencing of the DaLA Sector Impacted and the relevant industry defined in the SNA. In this case, the DaLA represented values as a per cent of real GDP, this value is included in [**worksheet: Average Losses by Event Type, cell J1**].

b. An industry level DaLA coefficient is then computed, where the industry's value of damage and/or loss is expressed as a share of that respective industry's total output – based on the initial IO table [**worksheet: DaLA GDP**].

2. These DaLA coefficients are used to administer the shock functions based on the event. To do this, a matching of the DaLA industries and the IO table industries is conducted. The no event scenario assumes a growth rate of 0 for each industry; for incidence of disasters, this 0 growth is reduced by the respective DaLA coefficient so that those scenarios will depict the resulting loss to GDP [**worksheet: Shock Functions**].

3. The shock functions are expressed as a per cent of GDP and can be manually adjusted by making changes to the respective values [**worksheet: Shock Functions, Columns B,C,D,E**]. The no event scenario should be kept at 0 and used as a reference variable. If changed to represent expected growth, there is no discernible way to allocate this growth and account for the natural disaster at the same time – one would have to be done before the other.

Results

1. The [**worksheet: results**] has two sets of results for the production impact showing the final demand, intermediate demand and total output. The first result shows the value of output in Jamaican Dollars and the second result shows the per cent change of this output compared to the reference (control) of no event. As such, when no event is selected, the Dollar value remains equal to the standard IO table applied to production data; in this scenario, there will be no per cent change to GDP. If any other scenario is selected, the DaLA coefficient is applied to the standard IO table and the Jamaican Dollar amount will be expressed based on this; these numbers will be different from the reference values (no event). The per cent change results will thus express the change to production (final and intermediate) between the selected scenario and the no event scenario.

Appendix E

Stakeholder Consultation List

List of Stakeholders Consulted

1. Claire Bernard – Deputy Director General, Sustainable Development, Planning Institute of Jamaica (PIOJ), Jamaica
2. Trevor C. Anderson – Actg. Principal Director, FPMB, Economic Management Division Ministry of Finance & Public Service, Jamaica
3. Claire Bernard – Deputy Director General, Sustainable Development, Planning Institute of Jamaica (PIOJ), Jamaica
4. James Stewart – Senior Director, Economic Planning, Planning Institute of Jamaica (PIOJ)
5. Nadine Brown – Director, Sustainable Development, Planning Institute of Jamaica (PIOJ)
6. Omar Alcock – Senior Technical Officer (Mitigation), Climate Change Division, Ministry of Housing, Urban Renewal, Environment and Climate Change, Jamaica
7. Le-Anne Roper – Senior Technical Officer for Adaptation, Climate Change Division, Ministry of Housing, Urban Renewal, Environment and Climate Change, Jamaica
8. Terron Francis – Ministry of Finance & Public Service, Jamaica

List of Participants – Training Session on Climate Models: Socio-economic and Financial Implications Assessment of Climate Change on Jamaica

1. Anaitee Mills – NDC Partnership
2. Andrew Schofield – Commonwealth Secretariat
3. Ashanie Long-Reid – University of the West Indies (UWI)
4. Ashley Codner – Planning Institute of Jamaica (PIOJ)
5. Beienetch Watson – University of the West Indies Eleanor Jones
6. Bilal Anwar – Commonwealth Secretariat
7. Fabrice Mugabo – Consultant
8. Giselle Hall – The Nature Conservancy
9. Hugh Morris – Planning Institute of Jamaica (PIOJ)
10. Jevanic Henry – Commonwealth Secretariat
11. Jumaine Taylor – Planning Institute of Jamaica (PIOJ)
12. Justin Ram – Consultant
13. Karelle Samuda – Ministry of Finance
14. Marcia Creary Ford – University of the West Indies – Centre for Marine Sciences
15. Mxolisi Sibanda – Commonwealth Secretariat
16. Natalie Dietrich Jones – SALISES, University of the West Indies
17. Omar Alcock – Climate Change Division, Government of Jamaica
18. Paula-Kay-Cousins – Bank of Jamaica
19. Richard Coutou – Environmental Solutions Limited
20. Sam Ogallah – Commonwealth Secretariat
21. Seveline Collins – Planning Institute of Jamaica (PIOJ)
22. Sherida Powell – University of the West Indies (UWI)
23. Theresa Rodriguez-Moodie – Jamaica Environment Trust
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