

# Towards Resilient Public Finance

**National Assessment of Fiscal Risks  
in Critical Infrastructure Sectors  
in Mauritius**



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# Foreword



## Amit Prothi

Director General  
Coalition for Disaster Resilient Infrastructure

Mauritius' location in the Indian Ocean makes it highly vulnerable to cyclones, floods, and storm surges, all of which have inflicted recurrent human and economic losses. Single events, such as Cyclone Dina in 2002 and Cyclone Berguitta in 2018, have disrupted critical services and imposed substantial repair and recovery costs. With climate change intensifying rainfall extremes and raising sea levels, the frequency and severity of disasters are projected to increase, increasing risks to infrastructure, coastal settlements, and key sectors like tourism and energy. These shocks place mounting pressure on public finances, widening fiscal gaps and diverting resources from long-term investment to short-term recovery. Strengthening financial preparedness and resilience is therefore an urgent priority, not only to safeguard lives and assets, but also to sustain Mauritius' growth trajectory and protect its position as a small island state striving for climate-resilient development.

As part of the Coalition for Disaster Resilient Infrastructure's (CDRI) commitment to strengthening resilience in infrastructure systems globally, we launched a model disaster risk finance study in four countries to evaluate fiscal risks associated with disasters in critical infrastructure sectors. This study for Mauritius represents one of the first efforts in the region to systematically connect disaster-related impacts on infrastructure to fiscal outcomes. It also offers key recommendations towards enhancing disaster risk financing strategies and strengthening institutional capacities for managing contingent liabilities in infrastructure.

The study aims to establish a benchmark for disaster risk financing by providing a methodology to understand the economic and fiscal implications of disasters, evaluates the performance of existing financing mechanisms, and highlight the critical importance of forward-looking, risk-informed public investment and budgeting practices. We expect this assessment to be a useful tool for policymakers, financial planners, and development partners working to strengthen fiscal resilience in Mauritius and other similarly vulnerable economies.

We are grateful to our consultant, the Asian Disaster Preparedness Center (ADPC), and to the Government of Mauritius for its guidance and leadership throughout the process. As we collectively move toward resilient and sustainable development pathways, it is imperative that disaster risk finance is integrated into the core of public financial decision-making. This report is a step in that direction.

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# Executive Summary

**Mauritius, a small island developing state (SIDS) located in the South-West Indian Ocean,** is among the countries highly vulnerable to natural hazards, particularly cyclones, floods, and storm surges. Disasters occur regularly on the island, disrupting economic activity and critical infrastructure, such as power and transport systems, while also causing significant fiscal shocks. This report, prepared under the Coalition for Disaster Resilient Infrastructure's Finance for Resilient Infrastructure Programme (FRIP), assesses the fiscal impacts of disasters in Mauritius, evaluates risk financing options, and proposes measures to strengthen institutional and financial preparedness.

**Mauritius' hazard profile is dominated by cyclones and torrential rains, often triggering flash floods and landslides.** Between 1980 and 2024, various disaster events have repeatedly caused spikes in mortality, displacement, and damages exceeding millions of US dollars. Cyclones Dina (2002), Berguitta (2018), and Belal (2024) have been among the most disruptive. EM-DAT and DesInventar data indicate that while mortality rate fluctuates, the economic burden of these disasters, primarily from cyclones and floods, remains substantial.

**The fiscal effects are visible in the sharp increases in expenditure and the rising contingent liabilities.** Revenues, which were 22.1 percent of gross domestic product (GDP) in 2019, experienced a slight decline in 2020 due to the combined impacts of disasters and COVID-19. However, by 2022–2023, revenues rebounded to over 24 percent of GDP. Public debt, meanwhile, surged from 81.1 percent of GDP in 2019 to 91.9 percent in 2020, underscoring the reliance on borrowing during crisis years. Fortunately, this trend moderated, with public debt decreasing to 78.3 percent of GDP by 2023. In 2020, expenditure reached 40.4 percent of GDP, nearly double the revenue, leading to persistent fiscal imbalances despite the subsequent recovery.

**The energy sector, managed by the Central Electricity Board (CEB), has faced recurrent damage from cyclones, floods, and storm surges.** Cyclones Berguitta (2018) and Calvinia (2019) caused widespread power outages, damaging lines and substations. Additionally, floods in March 2013 disrupted distribution networks. Coastal power stations remain particularly vulnerable to storm surges. The prolonged outages that follow these disasters lead not only to repair costs but also to indirect losses for both industries and households.

**The road sector faces similar risks. Cyclones and heavy rainfall often block or damage roads through flooding, landslides, and debris.** The 2013 Port Louis flash floods caused widespread traffic disruption and road erosion, while Cyclone Berguitta damaged critical surfaces and bridges. Each cyclone season demands substantial government expenditure on clearance and repairs, straining the national budget and raising long-term maintenance costs.





**Economic modelling results confirm that disasters consistently increase government expenditure, with significant coefficients at the 5 percent level.**

Debt levels show smaller, statistically insignificant increases, despite fiscal shocks from recurrent natural events, suggesting that the government finances its contingency needs through budget allocations and concessional external borrowings. Severe events, such as Cyclone Berguitta, were estimated to increase expenditure by around 0.10 percent of GDP (~MUR<sup>1</sup> 150 million), while debt rose by 0.08 percent of GDP (~MUR 314 million). Most fiscal impacts are concentrated in the year of the event, highlighting the immediate strain disasters place on public finances.

**Looking ahead, catastrophe modelling for cyclones, floods, and landslides shows that climate change is likely to amplify hazard frequency and severity, raising potential losses in the power and road sectors.**

Replacement cost assessments estimate that Mauritius' installed power generation capacity is 1,139 MW and its transmission networks span ~157 km, alongside extensive road networks that face risks from coastal and inland flooding. Probable maximum loss (PML) and average annual loss (AAL) calculations underscore the scale of prospective fiscal exposure, with climate change projected to substantially increase costs unless resilience investments are prioritized.

**Current post-disaster financing in Mauritius still relies heavily on budget reallocations, contingency funds, and international aid.**

Mechanisms such as the Prime Minister's Relief Fund, the National Environment Fund, and the Sugar Insurance Fund Board offer limited, sector-specific coverage. Recent innovations, such as sustainable bonds introduced by the Bank of Mauritius, signal progress towards diversified financing, but allocations for disaster risk reduction remain modest and volatile.

The report concludes with key recommendations:

**1**

Expand and stabilize budget allocations for disaster risk reduction.

**2**

Institutionalize contingency financing and pre-arranged funds for immediate response.

**3**

Strengthen insurance mechanisms, particularly for non-sugar agriculture and critical infrastructure.

<sup>1</sup> Mauritian Rupee

4

Integrate disaster-linked liabilities into debt management strategies.

5

Improve exposure and loss data to support fiscal forecasting and risk models.

6

Enhance infrastructure standards in the power and transport sectors to reduce recurrent damage.

By adopting these measures, Mauritius can strengthen its policy objective of gradually moving away from reactive to proactive disaster financing, as laid out under the National Disaster Risk Reduction and Management Policy (2020-2030), ensuring more predictable, efficient, and sustainable responses to climate shocks while safeguarding development gains.

Mauritius has been cited as a global best practice in IMF's C-PIMA handbook (Box 4.7)<sup>2</sup> for its strategic planning and budget framework that enables strong coordination and decision making on climate change-related projects across the public sector. This framework facilitates public investment in infrastructure projects to achieve national climate objectives, particularly in the energy, water, and transport sectors.

<sup>2</sup><https://www.imf.org/en/-/media/files/publications/books/2025/english/cpimaea.pdf>





Chapter 1

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**Introduction**



## Introduction

**Mauritius faces considerable disaster risks due to its geographic position in the South-West Indian Ocean and its status as a small island developing state (SIDS).** The country is vulnerable to a wide range of hazards, including cyclones, heavy rainfall, tidal surges, floods, droughts, and landslides. Although situated on the edge of the Indian Ocean cyclone belt, Mauritius experiences recurrent storm impacts that damage infrastructure, disrupt trade and port activities, and cause major flooding. Flooding ranks as the second most significant hazard after cyclones, while landslides—driven by deforestation and unregulated development—are emerging as a growing threat. Climate change is amplifying these risks through rising sea levels, coastal erosion, biodiversity loss, and more frequent and intense weather extremes, jeopardizing both lives and infrastructure.



The country's economic and social profile amplifies these vulnerabilities. As a small, open economy dependent on sectors such as coastal tourism, agriculture, and trade, Mauritius is highly vulnerable to external shocks and climate variability. Rapid urbanization and the conversion of agricultural land for residential and commercial use have increased hazard exposure, while inadequate drainage systems contribute to recurrent flash flooding in urban centres. Projections of a temperature rise of up to 3.8°C by 2100, combined with decreasing rainfall and more intense cyclones, pose risks to water security, public health, and infrastructure. These pressures have direct fiscal implications: disasters repeatedly force the government to divert funds towards emergency response and reconstruction, generating disaster-related contingent liabilities that, without adequate planning, can increase debt burdens and destabilize fiscal stability.

The 'National-Level Assessment of Fiscal Risk Due to Disasters in Critical Infrastructure Sectors' project is a Coalition for Disaster Resilient Infrastructure (CDRI) initiative. CDRI is committed to supporting member countries in developing coherent disaster risk financing (DRF) strategies. These strategies aim to address the financial needs for rebuilding resilient infrastructure during both the pre-disaster mitigation and post-disaster recovery and reconstruction phases through the 'Finance for Resilient Infrastructure Programme (FRIP)'.

This report assesses the fiscal risks associated with disasters in Mauritius' critical infrastructure sectors, with a specific focus on power and transport. The aim is to support evidence-based policymaking and improve financial preparedness for future events.

Mauritius has taken significant steps to strengthen disaster risk management and financing through recent policy and institutional reforms. The National Disaster Risk Reduction and Management Policy and Strategic Framework (2020–2030) outline a comprehensive agenda for risk governance, resilience investment, preparedness, and recovery. Complementary measures such as the Land Drainage Authority Act (2017) and the Mauritius Meteorological Services Act (2019) further integrate hazard assessment, climate services, and flood risk management into national planning. At the institutional level, the National Disaster Risk Reduction and Management Centre (NDRRMC) plays a central role in coordinating these efforts and consolidating disaster-related data. This report builds on these priorities by analysing fiscal risks associated with disasters and presenting options to strengthen Mauritius' financial preparedness, safeguard development gains, and promote resilient growth amid escalating climate challenges.

## Fiscal Risk Assessment Framework

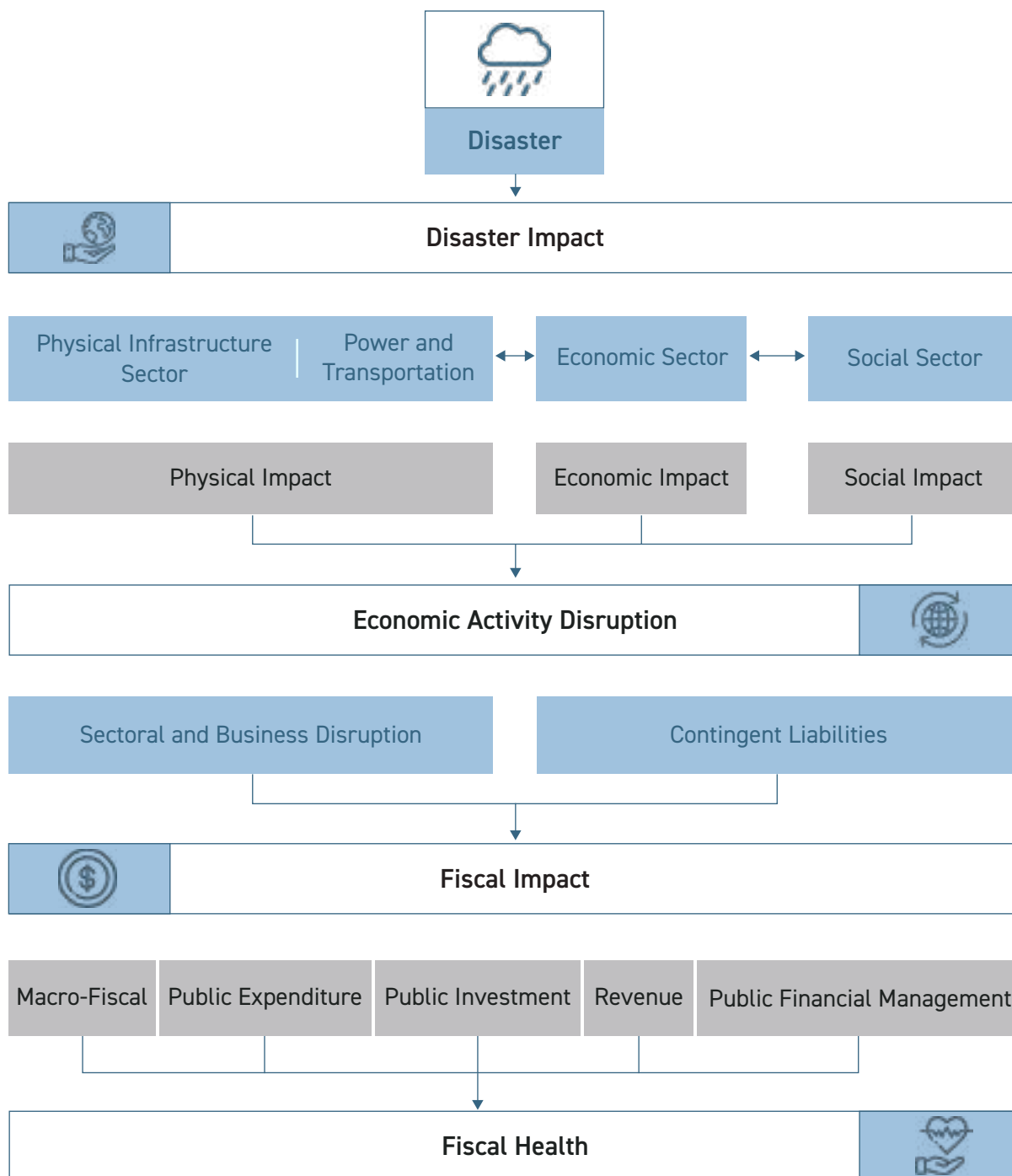
The International Monetary Fund (IMF) defines fiscal risk as the economic factors that may cause actual fiscal outcomes to differ from projected or expected fiscal outcomes (International Monetary Fund 2016). The OECD characterizes fiscal risks as changes in the expected fiscal outcomes outlined in an economy's annual budget or forecasting documents (Organisation for Economic Co-operation and Development 2019). Fiscal risks can stem from macroeconomic shocks or contingent liability obligations triggered by uncertain events. Governments need to comprehend these risks and prepare for them by conducting financial risk assessments to ensure the effective allocation of resources in the event of a disaster. Fiscal risks can originate from various sources, including macroeconomic shocks, financial sector crises, legal issues, subnational government liabilities, and problems with state-owned enterprises (SOEs). Disasters can cost anywhere from 1.5 percent of gross domestic product (GDP) on average to 6 percent in extreme circumstances (Albala-Bertrand 1993), making them a significant source of fiscal risk. Public-private partnerships and liabilities of private non-financial companies are additional sources that may necessitate government bailouts. According to a study by Bova et al. (2016), disasters caused the second-highest fiscal costs, averaging 1.6 percent of GDP, after financial sector shocks, which accounted for 9.7 percent. Maintaining sound budgetary management and ensuring the government's ability to respond effectively during a crisis depends on recognizing and managing these risks.

Disasters cause significant fiscal burdens on governments. According to the Inter-American Development Bank (IDB), fiscal impact channels can be categorized into macro-fiscal, revenue-related, public expenditure, public investment, and public financial management impact (Inter-American Development Bank 2017). Understanding these channels is essential for policymakers to effectively manage the fiscal repercussions of disasters.

Figure 1.1 presents a structured framework adopted in this report. The framework illustrates the cascading effects of disasters on economic and fiscal stability, beginning with the disaster impact that affects physical infrastructure, as well as economic and social sectors. These disruptions cause interruptions in economic activity, including sectoral and business disturbances, and create contingent liabilities for the government. As economic activities suffer, fiscal consequences emerge, falling under the fiscal impact category, affecting macro-fiscal stability, public expenditure, public investment,

revenue, and public financial management. These cumulative fiscal pressures ultimately influence the overall fiscal health of the government.

Figure 1.1: Framework for Assessing Fiscal Risk Arising from Disasters



Source: Asian Disaster Preparedness Center – Author's illustration



## Chapter 2

# Financial Risk Assessment based on Historical Data



## Financial Risk Assessment based on Historical Data

**Climate-induced disasters, such as floods, cyclones, and other hazards, can have a severe impact on human lives, economies, and fiscal accounts.** A disaster can result in loss of life, displacement of people, and damage to infrastructure, leading to reduced economic output and increased demand for emergency services, reconstruction, and social welfare and protection programmes. Climate-induced extreme weather events cause an average increase in the fiscal deficit of 0.8 percent and 0.9 percent of GDP in lower-middle-income and low-income countries, respectively (International Monetary Fund 2023). From a fiscal perspective, the frequency and severity of climate-related disasters can pose a higher risk of negative fiscal shocks as they strain public fiscal accounts, leading to budget deficits and debt accumulation, and weakening fiscal stability due to the negative impacts of revenue and expenditure channels, increased public debt, delayed investment projects, and cyclical fiscal policies.



Disasters can also have a significant impact on government revenues, mainly by hindering economic activity. This often results in lower tax and non-tax revenues, disruptions to international trade, and fewer labour hours. However, there can also be a post-disaster recovery boost that encourages economic activity and causes short-term increases in foreign aid or tax revenue. Disasters also influence the government's assets and obligations, beyond the immediate changes in revenue and expenditure. Damage to public infrastructure, for instance, increases the cost of repair or replacement. Yet, many governments do not maintain comprehensive balance sheets that include non-financial assets, making fiscal impact evaluations more difficult.

Between 1994 and 2013, disasters resulted in an estimated \$2.6 trillion<sup>3</sup> in economic losses globally, equivalent to 4 percent of the global GDP in 2015 (Guha-Sapir, Below, and Hoyois 2016). On average, across a sample of events between 1990 and 2014, the financial impact of disasters on a country's economy was 1.6 percent of its GDP. In some cases, the cost was much higher, with the most severe disasters resulting in costs equivalent to up to 6 percent of GDP (Bova et al. 2016). The study by the International Monetary Fund revealed that the maximum fiscal cost identified was 6 percent of GDP. Numerous studies have shown that disasters and economic growth are negatively correlated, often indicating that disasters lower GDP over the long and short terms. To prepare governments for the worst and avoid underestimating the financial impact of such events, it is essential to improve future damage predictions and conduct more detailed research into low-frequency, high-impact disasters.

<sup>3</sup> All figures in \$ refer to US dollars unless otherwise specified.

Figure 2.1 summarizes how disasters impact government finances through several key fiscal channels. These include macro-fiscal effects such as increased spending and reduced revenues that strain the fiscal balance, often leading to higher public debt and the activation of sovereign guarantees. Revenue is further impacted by declines in production, trade disruptions, and loss of labour hours, all of which decrease tax and customs income. On the expenditure side, governments face rising costs for emergency responses and humanitarian aid and may also need to support local governments through cost-sharing mechanisms. Understanding these interconnected channels is essential for policymakers to effectively plan for and manage the fiscal consequences of disasters.

Figure 2.1: Fiscal Impact Channels of Disasters



Source: Asian Disaster Preparedness Center – Author's illustration

As governments borrow money to fund recovery, this could lead to budget deficits and an increase in public debt. Disasters can result in production losses, disrupt trade, and reduce tax collections due to lost labour hours and business earnings, significantly affecting revenue. Governments must allocate funds promptly for emergency response and recovery, often sharing disaster costs with local governments, which necessitates additional assistance. Public financial management faces challenges in guaranteeing the effective use of disaster funds and maintaining transparency. Public investment is also impacted, with funds diverted from future projects to rebuild damaged infrastructure.

## Overview of Impact of Disasters in Mauritius

Mauritius has a long history of encountering natural hazards, most notably tropical cyclones, torrential rainfall, flooding, and droughts. Its location in the South-West Indian Ocean makes it highly vulnerable to severe weather patterns. At the same time, environmental pressures such as deforestation, rapid urbanization, and unregulated development on steep slopes have increased the incidence of landslides and flash floods. Climate change is amplifying these risks through rising sea levels, coastal erosion, and projections of more intense cyclones, placing both communities and infrastructure under increasing strain.

The country's small size and dependence on key sectors such as tourism, agriculture, and trade mean that disasters quickly cascade into broader economic disruption. Coastal settlements, power grids, and transport hubs are particularly vulnerable, and storm-related damage often causes port closures, power outages, and blocked roads that spread through the economy. Urban flooding has become a recurring hazard, primarily caused by land conversion and poor drainage, while droughts pose a significant threat to food and water security, accounting for the majority of long-term economic losses.

Over the past four decades, the frequency and effects of disasters in Mauritius have been significant. EM-DAT data show large fluctuations in the number of people affected and killed by disasters since 1980, as presented in Figure 2.2 (total affected persons) and Figure 2.3 (total deaths). These trends highlight how a single cyclone or flood can impact tens of thousands, resulting in spikes in mortality and displacement. Economic costs are also substantial. Figure 2.4 shows the damages in US dollars (nominal values) from historical disasters, underlining the heavy fiscal burden that recurring events impose on government finances.



Recent history provides stark examples. Tropical cyclone Belal (2024) affected an estimated number of 2,548 households and around 8,154 people directly. Cyclone Freddy (2023) displaced at least 370 families and resulted in one death, while Cyclone Batsirai (2022) prompted evacuations and damaged power lines across Port Louis and Plaine Wilhems. Flooding in March 2022 affected Port Louis, killing one person and sweeping away vehicles, while April 2021 floods and landslides prompted multiple evacuations in the south. Earlier cyclones—including Berguitta (2018), Gelena and Joaninha (2019), and Bansi (2015)—also caused widespread displacement, infrastructure damage, and power outages across Mauritius and Rodrigues.

Long-term statistics confirm the scale of impacts. Between 1990 and 2014, cyclones and torrential rains caused over 32 percent of disaster-related mortality, while flash floods accounted for more than 26 percent. The 2013 Port Louis flash flood alone resulted in 11 deaths, underscoring the vulnerability of urban centres. Landslides have repeatedly destroyed homes in high-risk areas such as Chitrakoot and Chamarel, and droughts, exacerbated by rising temperatures, have caused more than 96 percent of recorded economic losses in that period. These figures illustrate the multi-hazard nature of Mauritius' disaster profile and the significant fiscal liabilities disasters impose on the state.

Figure 2.2 Time series of Natural Disasters Statistics, Mauritius 1980-2024: total affected (persons) (EM-DAT data)

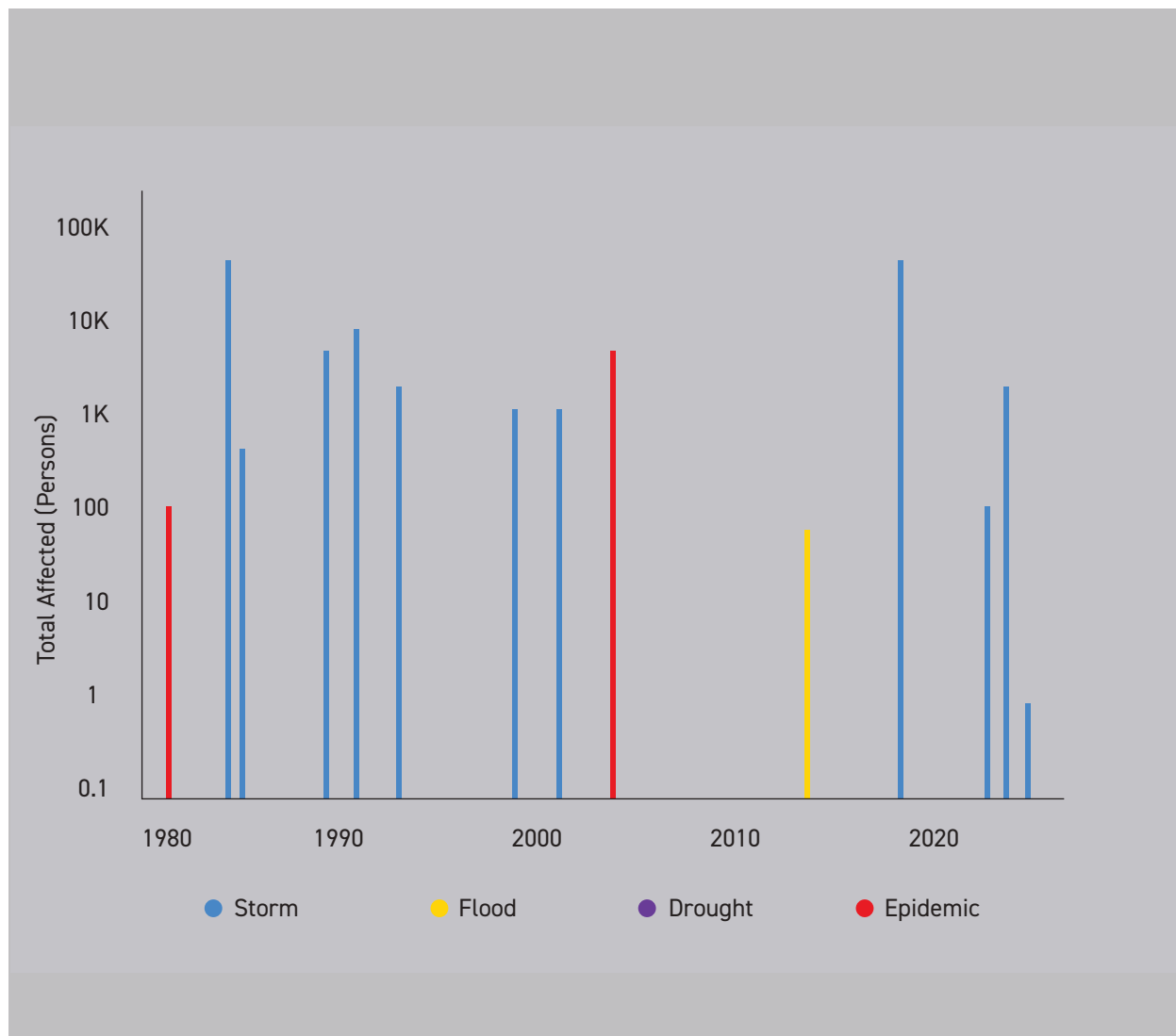
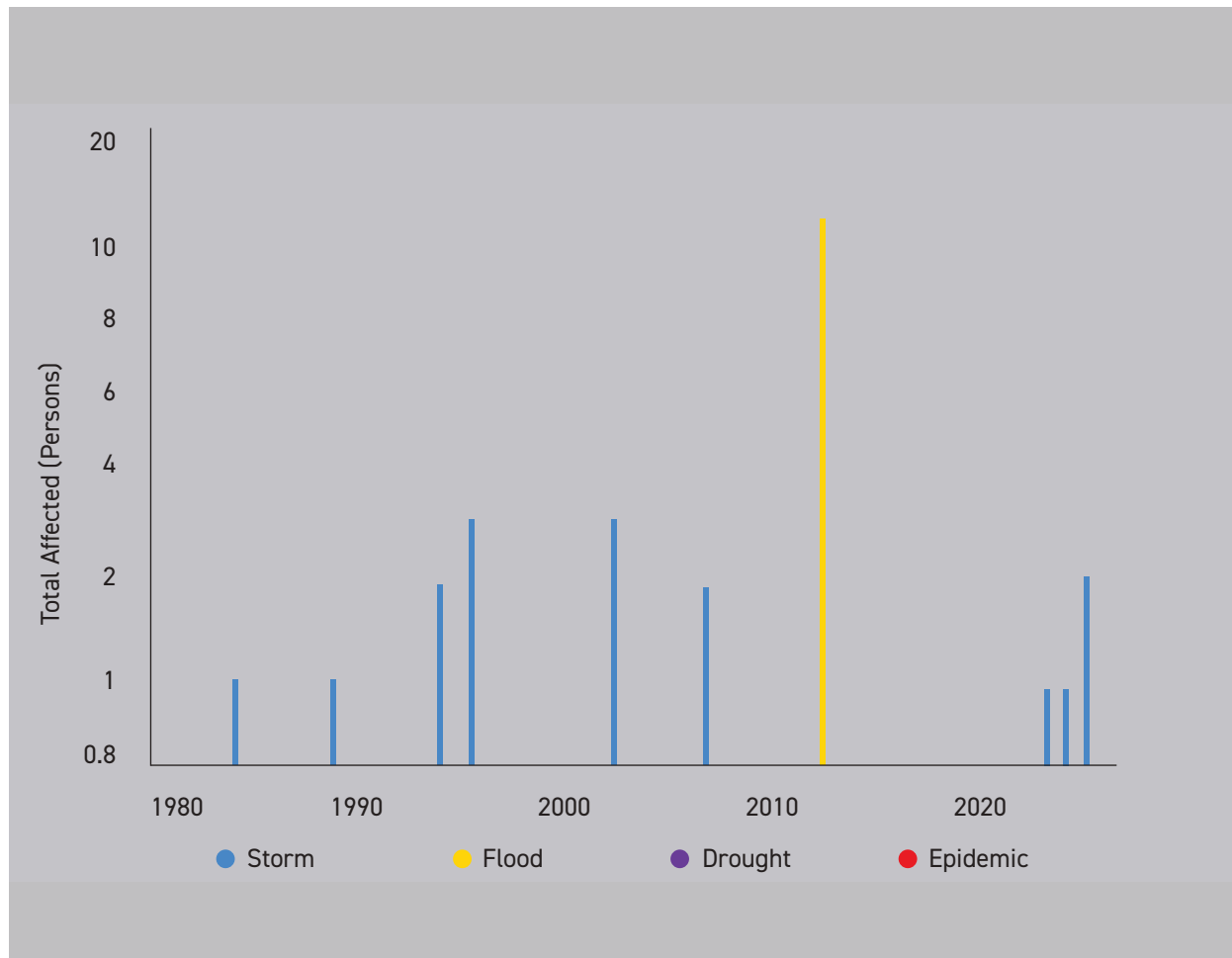


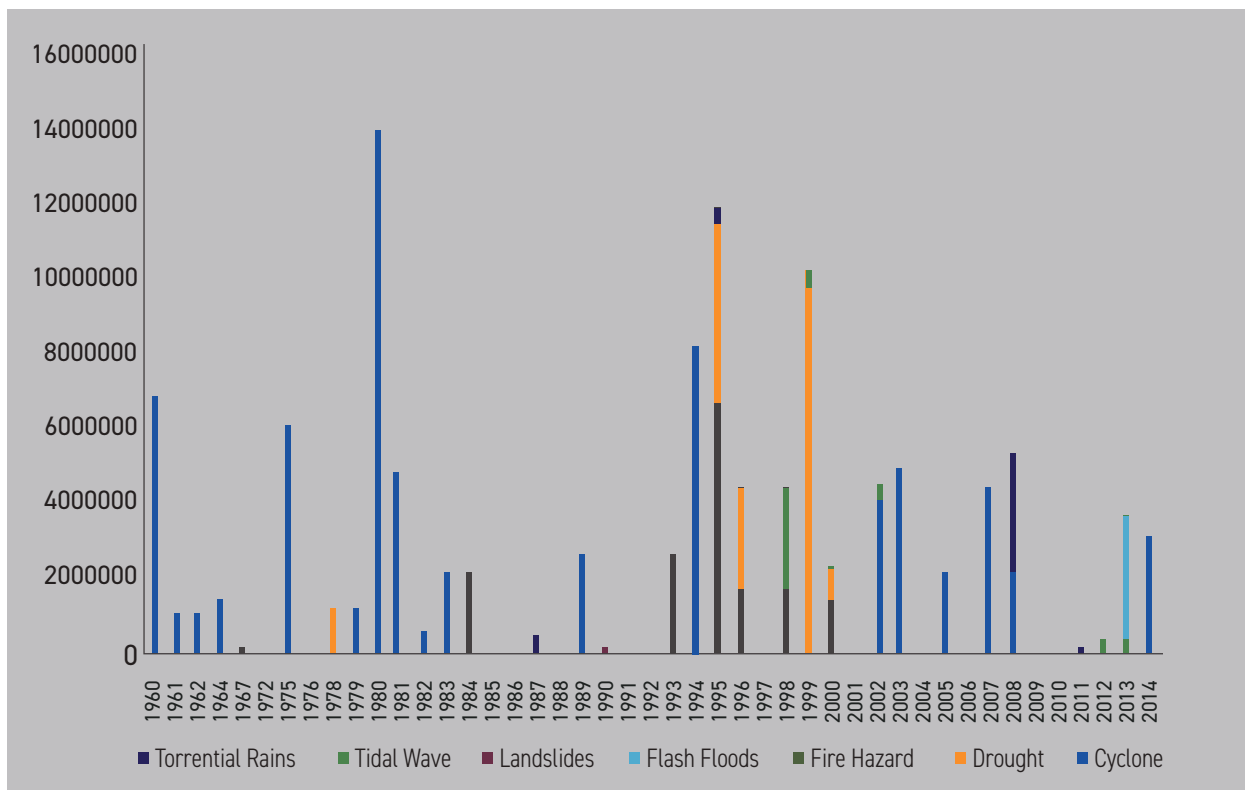
Figure 2.3 Time series of Natural Disasters Statistics, Mauritius 1980–2024: total affected (persons) (EM-DAT data)



From 1960 to 2014, data on losses from disasters have been recorded by the United Nations Office for Disaster Risk Reduction (UNDRR) DesInventar Sendai programme, indicating cyclones as the most impactful disaster. The damage by disaster type, per year, between 1960 and 2014 is presented in Figure 2.4, where the losses are nominal US dollar values, converted from local current values using the average exchange rate of the given year.



Figure 2.4 Damages in \$ (nominal values of the given year) of historical disasters in Mauritius



Source: DesInventar

Damage refers to the replacement value of physical assets that are wholly or partly destroyed, built to the same standards that prevailed before the disaster. Losses represent the foregone economic flows resulting from the temporary absence of the damaged assets and/or any other disruption of economic activity caused by the disaster (Economic Commission for Latin America and the Caribbean [ECLAC] 2003, United Nations Development Programme, European Union, and World Bank 2013).

While data specific to damage and loss by sector were not available at the time of development of this report, the impact of disasters on the road and power sectors has been documented qualitatively across various sources.

### Impact of Disasters on Power Infrastructure

Over the past decade, Mauritius has faced numerous disasters that have significantly impacted its power sector, including cyclones, floods, and storm surges. The following is a summary of the impacts.

#### Cyclones

Situated within the cyclone belt of the Indian Ocean, Mauritius is particularly susceptible to cyclones, especially from November to April. Notable cyclones such as Cyclone Berguita (2018) and Cyclone Calvinia (2019) caused widespread power outages due to strong winds and heavy rainfall. These cyclones damaged power lines and transmission systems, disrupting electricity supply across large areas of the island.



Cyclones often cause damage to power lines and poles, resulting in extended power outages. The process of recovery and repair can take several days or even weeks, contingent upon the extent of the damage. The Central Electricity Board (CEB), the national utility provider, has been forced to undertake extensive restoration efforts following such incidents.

### **Flooding**

Mauritius has experienced significant rainfall events that have caused flash floods, particularly during the cyclone season. These floods have damaged power generation facilities, particularly those located near rivers or in low-lying regions. For example, flooding can submerge power stations, substations, and transformers, leading to short circuits, equipment malfunctions, and considerable damage.

In March 2013, Mauritius experienced severe flash floods that caused extensive damage to infrastructure, including the power sector. The floodwaters affected electricity distribution networks and power stations, leading to widespread power outages.

### **Storm Surges**

Several power stations in Mauritius are located along the coast, rendering them susceptible to storm surges during cyclones. Such surges can result in the inundation of these facilities, leading to operational disruptions and damage to equipment. For instance, storm surges linked to Cyclone Hollanda have had detrimental effects on coastal power stations (ReliefWeb 1994).



## Impact of Disasters on Roads

Over the past decade, disasters in Mauritius, particularly cyclones, intense rainfall, and flooding, have significantly affected the road sector. The road infrastructure is often susceptible to these extreme weather conditions, leading to damage, disruptions, and increased maintenance costs. The following is a summary of the impacts, supported by citations.

### Cyclones

Mauritius is subjected to cyclones nearly every year, bringing strong winds and heavy rainfall. Notable cyclones such as Berguitta (2018) and Calvinia (2019) caused considerable damage to the road infrastructure (ReliefWeb 2018, BBC 2024), including uprooted trees, landslides, and flooding that blocked roads and rendered them impassable. The repercussions on the road networks often result in transportation delays, particularly in rural regions.

Debris from fallen trees and landslides caused by cyclones often obstructs roadways, necessitating urgent clearance efforts. For example, Cyclone Berguitta caused extensive road blockages and damaged road surfaces, requiring significant repairs.



### Flooding

Mauritius has faced numerous flash floods, especially during the cyclone season. The floods of March 2013 are a notable example, where heavy rainfall caused widespread flooding across the island. Many roads were submerged, leading to traffic disruptions and damage to the road surfaces. Some roads became entirely impassable due to the force of the water, and the subsequent repairs were both expensive and protracted (BBC 2013).

Intense rainfall often leads to soil erosion and landslides, weakening the structural integrity of roads and possibly leading to their collapse. In certain instances, entire sections of roads have been washed away. The 2013 Port Louis floods, for example, caused substantial damage to road infrastructure, with several critical roads being eroded or obstructed by landslides.

## Storm Surges

A significant number of roads in Mauritius are located near the coastline, making them susceptible to the effects of storm surges. These surges can weaken the structural integrity of the road foundation, leading to cracking and potential collapse. Coastal roads are at increased risk during cyclonic events, when powerful waves, storm surges, and severe winds coincide with heavy rainfall. The resultant damage to these roads often necessitates immediate repairs to ensure continued connectivity.

## Fiscal Impact

The frequent damage caused to roads by disasters imposes a considerable financial strain on the government for repair and maintenance. Each cyclone season typically requires a large portion of the national budget to be allocated towards road restoration efforts. The ongoing requirement for maintenance, particularly for coastal and rural roads, has become a significant economic burden.

The impact on road infrastructure leads to broader economic consequences, including disruptions in the movement of goods and individuals. Such disruptions can cause delays in supply chains, higher transportation costs, and a slowdown in economic activity within the affected regions.

The economic ramifications of disasters on Mauritius' power sector include the expenses related to repairing and reconstructing damaged infrastructure, as well as the economic losses stemming from prolonged power outages. Such outages can disrupt various industries, businesses, and essential services, resulting in wider economic consequences.

In summary, the power sector in Mauritius has faced significant challenges due to disasters over the past decade, leading to intensified efforts to bolster resilience and ensure a more reliable power supply in the face of rising climate-related risks.

## Revenue Trends

Government revenues in Mauritius have demonstrated resilience over the past five years, despite the dual pressures of recurrent cyclones and the COVID-19 pandemic. Revenues (including grants) stood at 22.1 percent of GDP in 2019, fell slightly to 21.6 percent in 2020 as the pandemic disrupted trade and domestic activity, and then rebounded strongly to over 24 percent of GDP from 2021 onwards (International Monetary Fund 2024a). This rebound was driven primarily by tax receipts linked to consumption and imports, along with improved compliance efforts. Non-tax revenues and grants contribute less significantly compared to tax income, but one-off inflows (e.g., higher dividends from state-owned enterprises) supported the fiscal position during crisis years (International Monetary Fund 2024a).

## Public Debt Trajectory

Mauritius' public debt has risen sharply in recent years, driven by disaster-related expenditures and pandemic response costs. Debt levels increased from 81.1 percent of GDP in 2019 to a peak of 91.9 percent in 2020. Although the ratio moderated to 85.9 percent in 2021 and further to 78.3 percent by 2023, this improvement mainly resulted from post-pandemic GDP growth rather than fiscal consolidation (International Monetary Fund 2024a). The debt is divided between domestic borrowing and concessional external loans, with the government increasingly relying on the latter to cushion fiscal shocks.



## Fiscal Health Context

The growing gap between revenue and expenditure remains a key vulnerability. Expenditure reached 40.4 percent of GDP in 2020—almost twice the revenue ratio—as the government financed pandemic relief, disaster response, and social protection schemes. Although expenditures dropped below 30 percent of GDP by 2022–23, they continue to outpace revenues, creating persistent fiscal deficits. This imbalance has necessitated high levels of borrowing, raising concerns about the sustainability of debt. At the same time, the ability to mobilize revenues above 24 percent of GDP in recent years demonstrates a relatively strong domestic resource base compared to many small island economies. Strengthening fiscal buffers, improving expenditure efficiency, and broadening the tax base will be essential for Mauritius to maintain its resilience in the face of climate-related shocks and global economic volatility. Refer to Table 2.1.

Table 2.1: Data on GDP, total revenue and grants, expenditure, and public sector debt between 2019 and 2023

Year	GDP (\$ millions)	Total Revenue and Grants (% GDP)	Total Expenditure, excl. Net Lending (% GDP)	Public Sector Debt (% GDP)
2019	14,436	22.1	33.5	81.1
2020	11,408	21.6	40.4	91.9
2021	11,484	24.1	31.0	85.9
2022	12,928	24.3	29.2	81.2
2023	14,397	24.2	28.9	78.3

Source: International Monetary Fund, 2024b



An aerial photograph of a coastal road. The road is paved and curves along the shoreline. To the left of the road is a small, crescent-shaped bay with clear, turquoise water and a sandy beach. To the right is a larger body of water, also with turquoise water. The surrounding landscape is lush with green vegetation, including palm trees and other tropical plants. The sky is clear and blue. The overall scene is a beautiful coastal landscape.

## Chapter 3

# Institutional Frameworks and Provisions for Financing Post-Disaster Losses

## Institutional Frameworks and Provisions for Financing Post-Disaster Losses

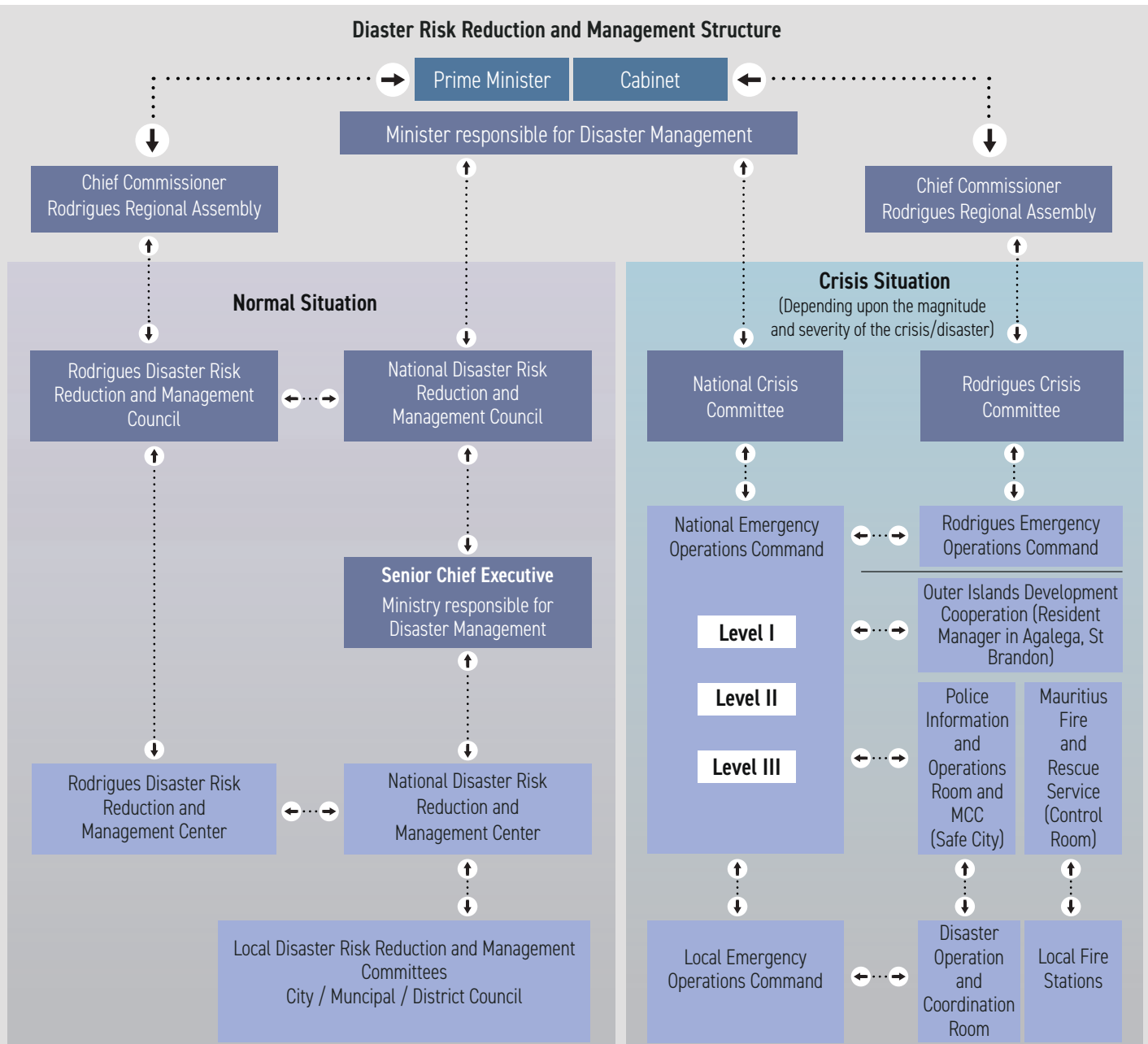
**This section of the report reviews the different DRF plans and policies of the national and state governments that provide funding mechanisms for post-disaster response and recovery efforts.** It aims to understand the current DRF environment, including the specific mechanisms and processes in place, as well as the hazards, assets, or activities covered by the current national framework, and the available funding. It provides detailed information on the review of the existing budgetary provisions and government funding sources. Additionally, this section provides a historical account of the disaster-related expenditure of different government and non-government sources.



### Institutional Framework for Disaster Risk Management

Mauritius has developed a relatively comprehensive framework for disaster risk management, based on the Disaster Risk Reduction and Management Act of 2016. This act established the National Disaster Risk Reduction and Management Council, responsible for steering multi-hazard risk assessments, promoting scientific research, and ensuring that disaster risk information is shared across governments. Additional legislation complements this core framework. The Environmental Protection Act (2002) incorporated disaster risk considerations into the environmental impact assessment process, while the Planning Development Act (2004) requires risk analysis for investments in hazard-prone areas. More recent measures—the Land Drainage Authority Act (2017) and the Mauritius Meteorological Services Act (2019)—have strengthened the country's capacity for flood mapping, drainage impact assessments, climate monitoring, and early warning issuance. The NDRRMC is at the heart of this system. It is responsible for gathering and analysing disaster data, coordinating preparedness and response efforts, and developing a national disaster information management system. Under the authority of the council, the NDRRMC functions as the main point of coordination in both normal and crisis situations (refer to Figure 3.1), with its organizational structure detailed in Figure 3.2.

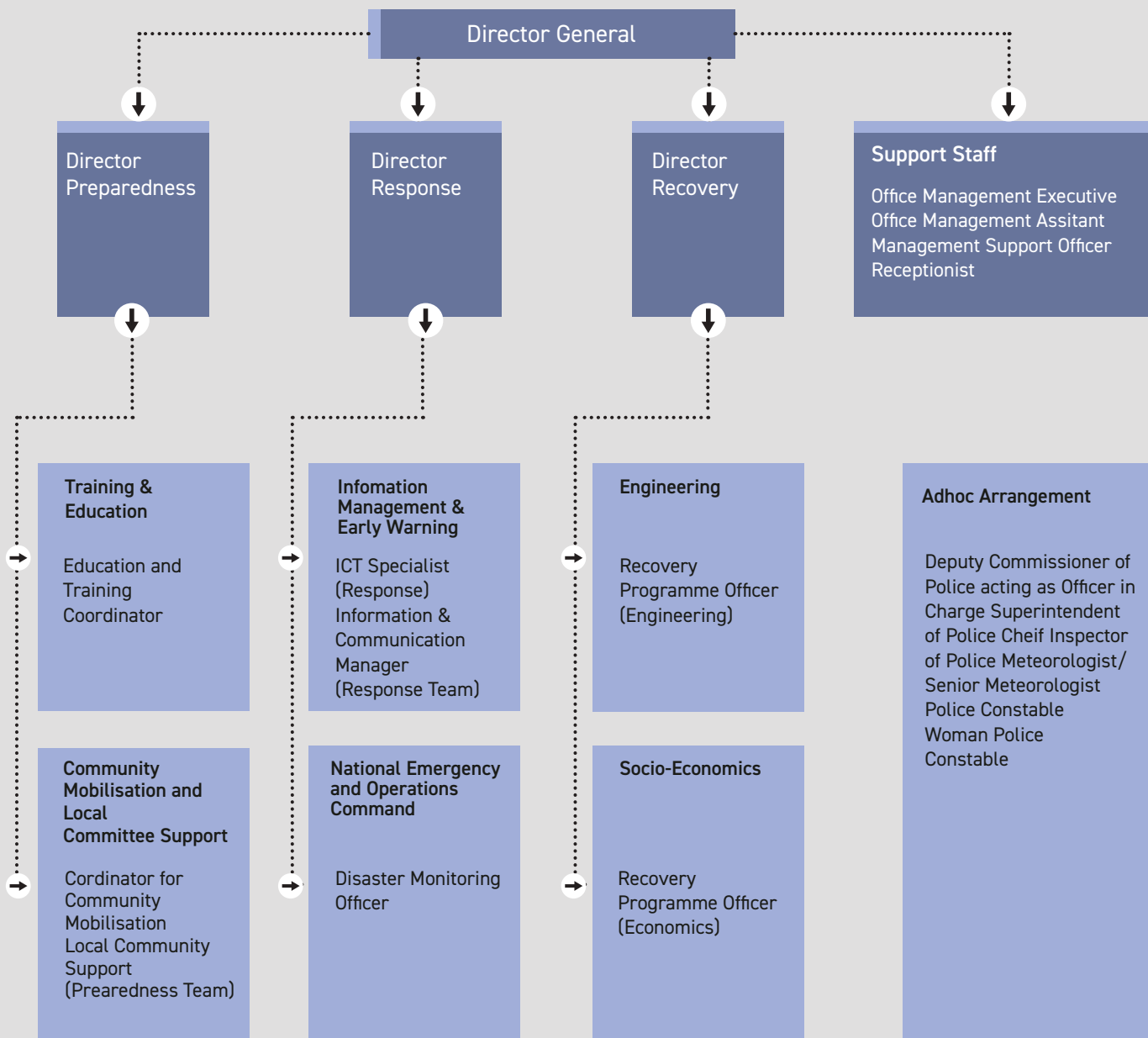
Figure 3.1: Disaster Risk Reduction (DRR) and management operational structure in normal and crisis situations



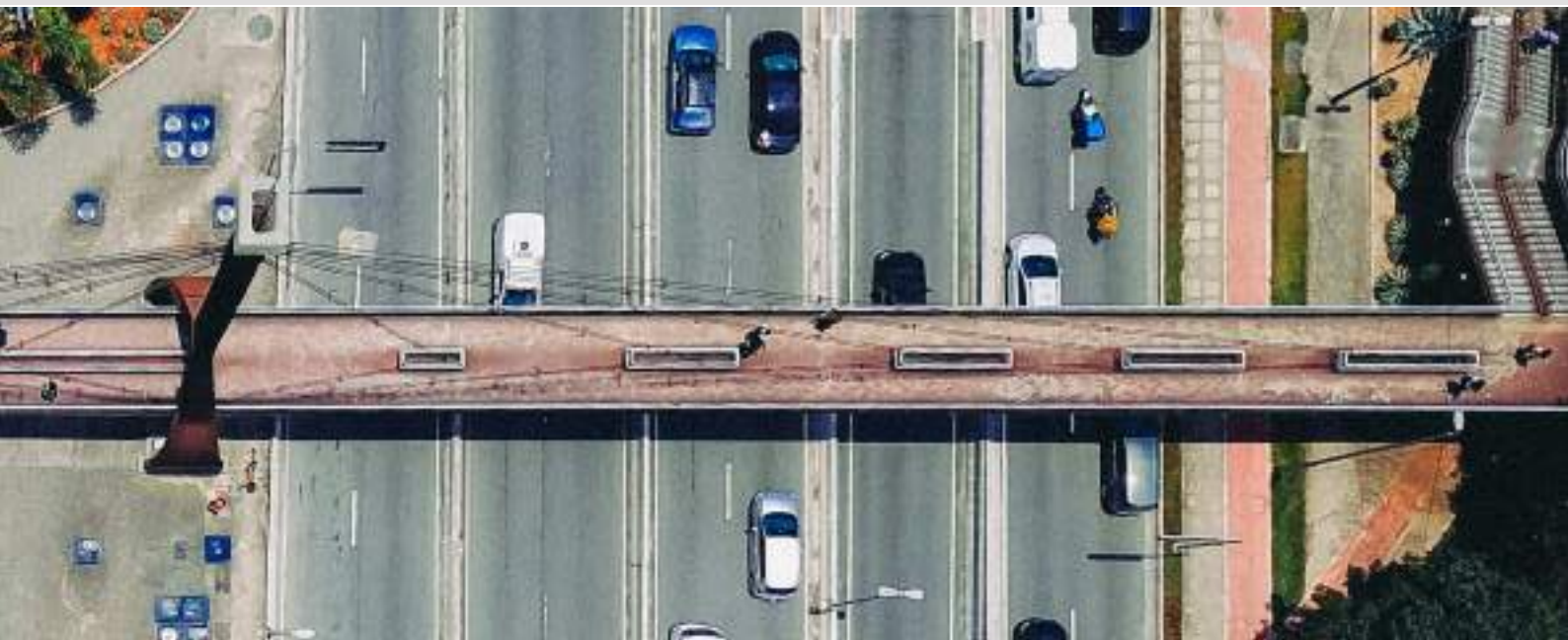
Source: PreventionWeb (2021)



Figure 3.2: Organizational structure of NDRRMC



Source: PreventionWeb (2021)



A range of ministries and agencies play supporting roles. The Ministry of Housing and Land Use Planning provides topographic and hydrographic data to identify landslide-prone areas. The Mauritius Meteorological Services issues weather forecasts and cyclone warnings. The Ministry of Environment, Solid Waste Management, and Climate Change monitors risks such as coastal erosion and oil spills, while the Ministry of Social Integration, Social Security, and National Solidarity provides data on social vulnerability. Statistics Mauritius underpins decision-making through data collection and analysis. Other key actors include the Ministry of Agro-Industry and Food Security, which manages risks to agriculture and food systems; the Ministry of Energy and Public Utilities, which oversees dam safety and water resources; and the Ministry of Health and Wellness, responsible for health surveillance during disasters.

Together, these laws, policies, and institutions create a solid framework for disaster risk management in Mauritius. By embedding risk considerations into environmental planning, infrastructure development, and social protection, the system encourages a multi-sectoral approach to resilience, with the NDRRMC acting as the central coordinating body.



## Disaster Risk Financing Mechanisms in Mauritius

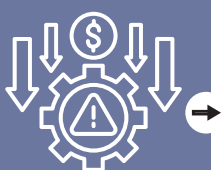


**Historical Perspective of Disaster Risk Financing:** The historical context of disaster risk financing in Mauritius shows the nation's increasing recognition and adaptation to the increasing threats posed by disasters. Initially, the country's approach to disaster risk was predominantly reactive, with the government relying on emergency funds and budget adjustments to manage the consequences of disasters. This reactive strategy was particularly pronounced during significant cyclonic occurrences, such as Cyclone Claudette in 1979 and Cyclone Dina in 2002, which inflicted considerable economic losses and underscored the weaknesses in the prevailing financial systems.

As the economic impact of these disasters became clearer—exemplified by the \$52 million in damages from Cyclone Dina—the government acknowledged the necessity for a more organized strategy to disaster risk financing. This realization led to the development of specialized frameworks and institutions, including the NDRRMC established in 2013, followed by the passing of the National Disaster Risk Reduction and Management Act in 2016. These measures marked a transition towards a proactive and cohesive approach, focusing not only on immediate responses but also on long-term recovery and resilience.

In terms of economic data, the losses incurred by Mauritius from disasters have consistently highlighted the significance of these advancements. For example, the damage inflicted by Cyclone Claudette in 1979 represented roughly 20 percent of the nation's GDP at that time. This economic burden, along with the increasing frequency of such disasters, has compelled Mauritius to explore both domestic and international financing options. The introduction of sustainable bonds by the Bank of Mauritius in 2021, which conforms to global standards, is one such initiative aimed at attracting private investment funding for disaster risk financing.

Considering the current climate change projections, Mauritius must prepare to address their potential adverse effects. The Indian Ocean SIDS—Comoros, Maldives, Mauritius, and Seychelles—show the highest rise in exposure to flooding among world regions, with 13–17 times more people exposed by 2100 compared to the present day, depending on emissions scenario. Meanwhile, damages are expected to be 113–152 times higher.



**Current Disaster Risk Finance Mechanism:** The NDRRMC plays a pivotal role in planning, coordinating, and overseeing disaster risk management initiatives. This centre operates under a legal framework established by the National Disaster Risk Reduction and Management Act of 2016, which encourages an integrated approach to disaster risk management that includes prevention, preparedness, response, recovery, and rehabilitation. To finance these initiatives, Mauritius has been actively seeking to mobilize both domestic and international resources. Nevertheless, the nation faces obstacles due to its constrained fiscal capacity and

the complex process of accessing international climate funding. The Bank of Mauritius has taken steps to develop a sustainable finance ecosystem, which includes guidelines for issuing sustainable bonds. These initiatives aim to attract private sector investment and align with global standards to ensure transparency and accountability in fund allocation. Despite these progressions, Mauritius continues to depend significantly on international assistance to meet its climate adaptation and disaster risk management objectives.

### Ex Ante Disaster Risk Financing Mechanisms



**Contingency Funds:** The government utilizes the 'contingencies and reserves' allocated under Sub Programme 2703: Contingencies and Reserves, which is designed to address unforeseen circumstances that budgeted programmes cannot manage. This provision is not restricted to disasters; it also covers emergencies that necessitate extraordinary expenditures. Consequently, this 'contingency fund' was used for flood relief and response efforts in 2013, for landslide management in 2014 (specifically at Macondé), and for tackling the mosquito-borne viral disease Chikungunya in 2006. For the fiscal year 2014, the amount allocated for 'contingencies and reserves' is MUR 1.6 billion (\$52 million), representing 1.4 percent of the performance-based budgeting (PBB). The maximum limit for each fiscal year is set at 2 percent in accordance with the Finance Audit Act. Since the establishment of NDRRMC, allocation needs to be budgeted under the ministry for DRR activities. In the annual report of the Ministry of Local Government and Disaster Risk Management, in the 2020–21 budget, MUR 38,000,000 was budgeted for national DRR. In the 2022–23 annual report, the budgeted amount for national DRR was MUR 26,400,000. In 2023–24 annual report, the national DRR budgeted amount was MUR 26,300,000. The budget voted under the NDRRMC is limited to covering its recurrent expenditure, in line with its role as a coordinating body. Expenditures related to Disaster Risk Reduction (DRR) are, however, implemented and financed across various Ministries and Departments through their respective budgets.

In order to obtain a comprehensive and consolidated view of public spending on Disaster Risk Reduction, Government has introduced a green tagging mechanism in FY 2025/2026 in a phased manner. This initiative will enable the identification, tagging, tracking and monitoring of green expenditures, including climate adaptation expenditures and climate related post-disaster DRR expenditures across the public sector.

As at date the Budget of the NDRRMC falls under Programme 0208: National Disaster Risk Reduction and Management which falls under the Prime Minister's Office. Details of allocation in the three years to other segments of the ministry, also relevant to DRR, are presented in Table 3.1.



Table 3.1: Budget allocation to DRM under the Ministry of Local Government and DRM as per the annual performance reports available

Sub-department	2020–21 (MUR)	2022–23 (MUR)	2023–24 (MUR)
National Disaster Risk Reduction	38,000,000	26,400,000	26,300,000
Mauritius Fire and Rescue Service	945,000,000	810,000,000	735,000,000
Mauritius Meteorological Services	109,000,000	121,900,000	127,000,000

Source: Ministry of Local Government and Disaster Risk Management (n.d.)

## Special Funds

Various special funds exist to support different aspects of disaster response, management, and risk reduction. While these funds can serve multiple purposes, they can also be utilized specifically for disaster response. Such funds, along with the potential DRM activities they can support, include the following:

- **National Environment Fund:** Disaster risk reduction, landslide management, environmental monitoring.
- **Climate and Sustainability Fund:** Disaster risk reduction, landslide management, and environmental monitoring.
- **Project Development Fund:** Contributions towards social housing and post-cyclone repairs.
- **Poverty Reduction Fund:** Social support, relief, and disaster-related projects.
- **Lotto Fund:** Rehabilitation of national heritage sites and support of victims of natural calamities.

Table 3.2 presents the estimated spending, along with the expected and planned spending of these funds for activities related to disaster response, recovery, and mitigation, based on the 2020 budget estimates and the 2024–25 budget estimates.

It is to be noted that the National Environment Fund is being phased out and, accordingly, no budgetary provision has been made for FY 2025/26. Expenditures pertaining to its activities are being accommodated under the Climate and Sustainability Fund.



Table 3.2: Budget allocation to DRM-related activities from special funds as per the budget allocation reports available (MUR million)

Fund	2018/19 Estimates	2019/20 Estimates	2020/21 Estimates	2021/22 Planned	2022/23 Planned	2023/24 Estimates	2024/25 Estimates	2025/26 Planned	Details
National Environment Fund	-	1,950	2,327	1,045	-	1,144	603	-	DRR, landslide management
Climate and Sustainability Fund	-	-	-	-	-	-	3,202	3,011	DRR, landslide management
Projects Development Fund	-	-	6,000	4,500	-	1,700	250	250	Social housing post-cyclone repairs, flood management, post-cyclone repairs
Lotto Fund	30	35	35	35	35	28	25	25	Rehabilitation of heritage sites

Source: Ministry of Finance (2017, 2020, 2024)

### Insurance

In various economic sectors, specific insurance funds or dedicated grants and loans have been established to address damages resulting from disasters. The Small Farmers Welfare Fund includes an insurance initiative known as the Agricultural Calamity Solidarity Scheme, which is accessible to registered small-scale farmers and breeders. This scheme provides financial assistance to those facing challenges following disasters such as cyclones, heavy rainfall, droughts, and floods. The Sugar Insurance Fund Board (SIFB) is a parastatal body operating under the aegis of the Ministry of AgroIndustry, Food Security, Blue Economy and Fisheries (Agro-Industry & Food Security Division). The SIFB functions as a contingency financing mechanism, offering coverage to all insured sugar planters for losses incurred due to weather-related events, including cyclones, droughts, and excessive rainfall. Established by the government in collaboration with sugar producers, the SIFB operates under the Ministry of Finance and Economic Development and is entirely funded by the sugar industry. Compensation is provided only to insured planters in years when crop loss exceeds 20 percent due to adverse climatic conditions.

Additionally, the fund includes provisions for fire insurance. For instance, in Crop Year 2012, compensation of MUR 7.6 million (\$0.25 million) was disbursed to insured planters for losses resulting from inter-crop fires that destroyed cane plantations, while MUR 6.01 million (\$0.19 million) was paid in Crop Year 2013. Furthermore, eligible insured planters received transport allowances of MUR 0.3 million (\$10,622) in Crop Year 2012 and MUR 1.4 million (\$45,710) in 2013 for transporting burnt canes during the harvest season outside their designated factory areas. However, the SIFB operates solely as a fund and does not offer re-insurance, which may limit the compensation available in particularly severe years. Additionally, the government has often introduced special schemes managed by the Development Bank of Mauritius (DBM) to support small-scale farmers in sectors other than sugar cane (United Nations Office for Disaster Risk Reduction 2015a).

## Post-Disaster Financing Sources of the Country

### The Prime Minister's Disaster Relief Fund

The Prime Minister's Relief to Victims of Accidents and Injuries Fund was established by Regulations made on 13 August 1997 under Section 24 of the Finance and Audit Act. The regulations were gazetted as Government Notice No. 111 of 1997. The board set up to administer the fund has been operational since December 1997 and consists exclusively of ex officio members, operating under the Chairmanship of the Secretary to the Cabinet or their representative.

Following the regulations 2006 made under the Finance and Audit Act, the appellation of the Prime Minister's Relief Fund for Victims of Accidents and Injuries has been changed to the Prime Minister's Relief and Support Fund as of 15 July 2006.

In 2013, further regulations were enacted under the Finance and Audit Act, changing the appellation of the 'Prime Minister's Relief and Support Fund' to 'Prime Minister's Relief Fund' (the fund) from 21 June 2013.

Historical data on funds in the Prime Minister's relief fund following disasters is limited, with one record from the Bank of Mauritius referring to a donation of MUR 5 million in the aftermath of the 2013 floods (Prime Minister Relief and Support Fund n.d.).

### International Assistance

Various international institutes, such as the World Bank, the United Nations Development Programme (UNDP), the African Development Bank, and the European Union, have supported Mauritius in the aftermath of disasters through loans, grants, and technical assistance. Specific data on the level of assistance is not available at the time of preparing this report.

## Trend Analysis of Disaster Risk Financing in Mauritius

The trajectory of disaster risk financing in Mauritius reflects a gradual yet uneven shift from a reactive, ad hoc system to a more structured approach. In the past, major cyclones such as Claudette (1979) and Dina (2002) compelled the government to rely almost entirely on emergency reallocations and contingency funds. Losses were substantial—Cyclone Claudette caused damages amounting to nearly one-fifth of GDP, while Cyclone Dina resulted in an estimated \$52 million in losses—exposing the limitations of purely post-disaster funding arrangements.

Reforms over the past two decades have created a stronger institutional basis for financing. The creation of the NDRRMC (2013) and the Disaster Risk Reduction and Management Act (2016) introduced a more proactive approach, incorporating prevention, preparedness, and recovery into the financing framework. Since then, budgetary allocations have been earmarked for disaster risk reduction activities within the Ministry of Local Government and Disaster Risk Management, although the amounts remain modest and have fluctuated—MUR 38 million in 2020–21 compared to MUR 26.4 million in 2022–23. Larger recurrent allocations support frontline services such as the Mauritius Fire and Rescue Service and the Meteorological Services, but these funds are largely for operations rather than for contingencies.

In parallel, Mauritius has drawn on a set of special-purpose funds for disaster-related spending. These include the National Environment Fund, the Climate and Sustainability Fund, the Project Development Fund, and the Lotto Fund. Their allocations vary widely year by year, often influenced by broader fiscal priorities. For example, the National Environment Fund peaked at over MUR 2.3 billion in 2019–20 but then declined sharply in subsequent years, while new allocations to the Climate and Sustainability Fund only commenced in 2023. This variability limits predictability and complicates long-term planning.

Insurance mechanisms play an important role in protecting specific sectors. The Agricultural Calamity Solidarity Scheme offers small farmers limited protection against crop and livestock losses, while the SIFB offers more structured coverage for cane planters against cyclones, drought, and excess rainfall. However, the SIFB lacks reinsurance support, constraining its ability to cover losses in catastrophic years. Similar gaps exist for non-sugar farmers, where temporary schemes through the Development Bank of Mauritius address some needs but remain ad hoc in nature.



Ex post mechanisms remain central. The Prime Minister's Relief Fund, established in 1997 and reformed in 2013, continues to be the principal vehicle for post-disaster assistance to households. However, information on its inflows and outflows is limited. Records suggest modest mobilization—for example, MUR 5 million donation to the fund after the 2013 floods—underscoring its supplementary rather than systemic role. International assistance also remains a critical element of the financing landscape, with aid from the World Bank, UNDP, the African Development Bank, and the EU in the form of grants, loans, and technical support.

Recently, Mauritius has begun experimenting with innovative financing instruments. The introduction of sustainable bond guidelines by the Bank of Mauritius in 2021 signals an effort to attract private capital for climate adaptation and resilience. Although still in its early stages, this move highlights recognition that domestic resources alone are not enough and that diversified financing—such as insurance, bonds, contingency funds, and international support—will be needed to address rising risks.

Table 3.3: Trends in disaster risk financing allocations in Mauritius (selected years, MUR million)

Year/Period	National DRR Budget (MoLGDRM)	Fire and Rescue Service	Meteorological Services	Contingencies and Reserves (Example FY2014)	Selected Special Funds (DRR-related)	Notes on Disaster Context
2013	-	-	-	Contingency funds used for flood relief	PM's Relief Fund received MUR 5 million donation	Major floods in Port Louis
2014	-	-	-	MUR 1,600 (1.4% of budget)	-	Landslide management at Macondé
2020-21	38	945	109	-	Project Development Fund: MUR 4,500	Allocations begin to appear for the National DRR line item
2021-22	-	-	-	-	No clear allocation	Transition period in reporting
2022-23	26.4	810	121.9	-	National Environment Fund: MUR 1,144	Lower DRR budget compared to 2020-21
2023-24	-	-	-	-	Climate and Sustainability Fund: MUR 3,202	New climate related fund allocations begin
2024-25	-	-	-	-	Climate and Sustainability Fund: MUR 3,011; NEF MUR 603; Lotto Fund MUR 28	Expansion of sustainable finance instruments

Overall, Mauritius' disaster risk financing demonstrates a clear progression—shifting from reactive budget reallocations towards a multi-instrument system. However, allocations remain small, special funds are volatile, and sectoral insurance is only partially effective. The system is therefore still marked by underfunding and dependence on external support, even as new instruments suggest a more forward-looking and diversified approach. It should, however, be noted that allocations for Disaster Risk Reduction (DRR) activities are largely embedded within the budgets of various Ministries and Departments, and Special Funds. As such, the aggregate level of Government expenditure on DRR is not readily captured in a single framework, making it difficult to ascertain the total resources allocated to these activities.

In this context, the introduction of a disaster (green) tagging mechanism is expected to significantly enhance the identification, aggregation and monitoring of climate related DRR expenditures across the public sector.

An aerial photograph of a city street, likely in a developing country, showing a mix of residential and commercial buildings, trees, and a road with a dashed white line down the center. In the background, there are mountains under a cloudy sky. The image is partially overlaid by a red banner on the left and a white geometric pattern on the top left and bottom left.

## Chapter 4

# Economic Modelling

## Economic Modelling

**To assess the economic implications of disasters in Mauritius, a panel econometric approach was adopted.** This method was selected due to the availability of consistent macroeconomic data, whereas other methods, such as Input–Output models, Computable General Equilibrium (CGE) models, and agent-based models, were not feasible due to the lack of detailed micro-level and sectoral data. National accounts data from the World Bank and IMF provided the most comprehensive source of fiscal and economic variables, making a panel model the most appropriate option.

The model links government fiscal indicators to a derived measure of disaster intensity, based on established approaches in the disaster economics literature (e.g., Noy 2016). Fiscal variables include government expenditure, revenue, and debt, all expressed relative to GDP. These are analyzed in relation to sudden-onset events such as cyclones, floods, and related hazards. As in comparable cross-country studies, a fixed-effects model was used, incorporating both country-specific characteristics that remain constant over time and time effects that account for global or regional shocks. By combining data from multiple countries and years and comparing outcomes before and after disasters, the model identifies the fiscal consequences of shocks in Mauritius within a broader peer group of middle-income economies.

All modelling was conducted in R using the PLM (panel linear model) package (Croissant and Millo 2008). The package allows estimation of fixed-effects models and provides tools for hypothesis testing of both individual (country) and time effects. Using this framework, the study isolates the impact of disaster severity on fiscal balances while controlling for broader macroeconomic trends.

This approach offers insight into the indirect costs of disasters, which often persist beyond immediate damage to infrastructure and livelihoods. By connecting disaster intensity to fiscal outcomes, the model highlights how disasters influence expenditure patterns, debt accumulation, and revenue mobilization in Mauritius.

### Economic Panel Model and Data

This section outlines the datasets used to construct the panel model and assess the fiscal impacts of disasters in Mauritius. The data covers the years 2000 to 2019 and combines fiscal indicators with disaster impact variables, supported by a standardized severity measure.

#### **Countries Included in the Model**

The countries were selected for the panel model based on their income level because previous research (IMF 2023) has found that a country's income level can influence the economic impact of a disaster. As Mauritius is a middle-income country, we included all middle-income countries in our model. The 69 middle-income countries included in the economic panel model are listed in Table 4.2.

Table 4.1: Summary of panel country sample (middle income; n = 69)

Component	2023–24 (MUR)
Country Group	69 middle-income countries
Basis of Inclusion	Income classification (IMF 2023)
Mauritius' Status	Middle-income; included in panel

Table 4.2: Middle-income countries included in the panel model (n = 69)

Albania	Georgia	Namibia
Angola	Ghana	Mauritius
Argentina	Guatemala	Nicaragua
Armenia	Honduras	North Macedonia
Azerbaijan	India	Pakistan
Bangladesh	Indonesia	Papua New Guinea
Belarus	Iran, Islamic Rep.	Paraguay
Bolivia	Iraq	Peru
Bosnia and Herzegovina	Jamaica	Philippines
Botswana	Jordan	Senegal
Brazil	Kazakhstan	Serbia
Cambodia	Kenya	South Africa
Cameroon	Kyrgyz Republic	Sri Lanka
China	Lao PDR	Tajikistan
Colombia	Lebanon	Tanzania
Congo, Rep.	Lesotho	Thailand
Costa Rica	Malaysia	Timor-Leste
Dominican Republic	Mauritius	Tunisia
Ecuador	Mexico	Ukraine
Egypt, Arab Rep.	Moldova	Uzbekistan
El Salvador	Mongolia	West Bank and Gaza
Eswatini	Morocco	Zambia
Gabon	Myanmar	Zimbabwe

## Fiscal Variables and Sources

Fiscal data for Mauritius was obtained from the World Bank for the period 2000–19. The indicators used in the analysis were expense (as a percentage of GDP), revenue excluding grants (as a percentage of GDP), and central government debt (as a percentage of GDP). To enable year-on-year comparisons, GDP in current US dollars was used to convert these ratios into absolute values. A first-order differencing method was then applied to address autocorrelation across years, ensuring a clearer relationship between disaster shocks and fiscal outcomes. These fiscal variables provided the basis for modelling how government finances in Mauritius respond to disasters. Refer to Table 4.3.

Table 4.3: Fiscal variables and sources for Mauritius

Component	Details
Source	World Bank
Indicators	Expense (% GDP), revenue excl. grants (% GDP), central government debt (% GDP), GDP (current \$)
Coverage	2000–19
Processing	Converted to absolute values; first-order differencing applied to remove autocorrelation



## Disaster Variables and Sources

Disaster data were obtained from the EM-DAT International Disaster Database for the period 2000–19. The analysis focused on sudden-onset hazards—cyclones, floods, and flood-induced landslides—while rare catastrophic events such as earthquakes and tsunamis were excluded to avoid distortion. Three variables were considered: fatalities, population affected, and monetary damages. Missing values were addressed using quantile imputation to maintain the statistical distribution of impacts.

To quantify severity consistently, these variables were combined into the life years lost (LYL) index, adapted from the WHO's DALY framework (Noy 2016). For Mauritius, the average annual LYL was 814, with Cyclone Berguitta in 2018 (10,275 LYL) and Cyclone Dina in 2002 (4,984 LYL) being the most severe events. Disaster damages were also expressed as a percentage of GDP to give a direct indication of economic disruption. Refer to Table 4.4.

Table 4.4: Disaster variables and sources for Mauritius

Component	Details
Source	EM-DAT (International Disaster Database)
Indicators	Fatalities, population affected, monetary damages
Hazard Types	Cyclones, floods, flood-induced landslides
Coverage	2000–19
Derived Measure	Life years lost (LYL), adapted from WHO DALY (Noy 2016); Damages also expressed as percent of GDP

## Economic Modelling Results

The econometric analysis assessed the relationship between disaster intensity and fiscal performance in Mauritius using two measures of disaster impact: LYL and total monetary damage (% of GDP). In both models, government expenditure (% of GDP) increased significantly following disasters, while central government debt (% of GDP) showed positive but statistically insignificant changes. For expenditure, coefficients were significant at the 5 percent level ( $p = 0.023\text{--}0.045$ ), emphasizing the consistent fiscal response to disaster shocks. The coefficients and significance levels for each fiscal variable are presented in Tables 4.5 and 4.6.



Table 4.5: Coefficients and significance (p value) for each fiscal variable included in the panel model for LYL

Fiscal Variable	LYL Coefficient	p Value	Standard Error
Source	0.000,204,88	0.500,9	0.000,304,10
Central government debt, total (% of GDP)	0.000,248,39	0.044,75*	0.000,123,58

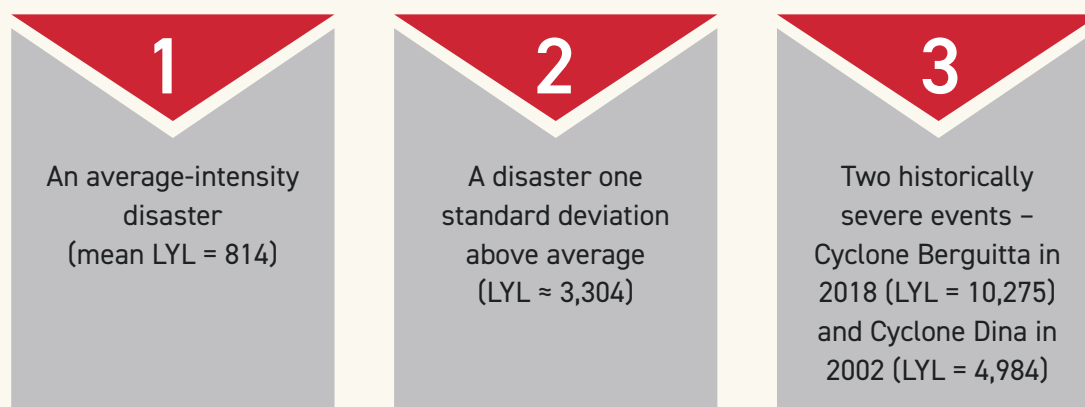
\* Significant at the 5 percent level.

Table 4.6: Coefficients and significance (p value) for each fiscal variable included in the panel model for damage as a percentage of GDP

Fiscal Variable	Total Damage (% of GDP) Coefficient	p Value	Standard Error
Central government debt, total (% of GDP)	0.000,650,33	0.380,2	0.000,740,13
Expense (% of GDP)	0.000,695,40	0.023,92*	0.000,307,37

\* Significant at the 5 percent level.

To illustrate the scale of these effects, modelled impacts were estimated for the following:



For an average disaster, central government debt was projected to increase by 0.06 percent of GDP while expenditure rose by 0.07 percent of GDP. When expressed in monetary terms, this corresponds to an increase of MUR 228 million in debt and MUR 109 million in expenditure.

In the event of a disaster one standard deviation above average, the model estimated an increase of 0.07 percent of GDP in debt and 0.09 percent of GDP in expenditure. This corresponds to increases of MUR 275 million in debt and MUR 132 million in expenditure based on 2019 fiscal values.

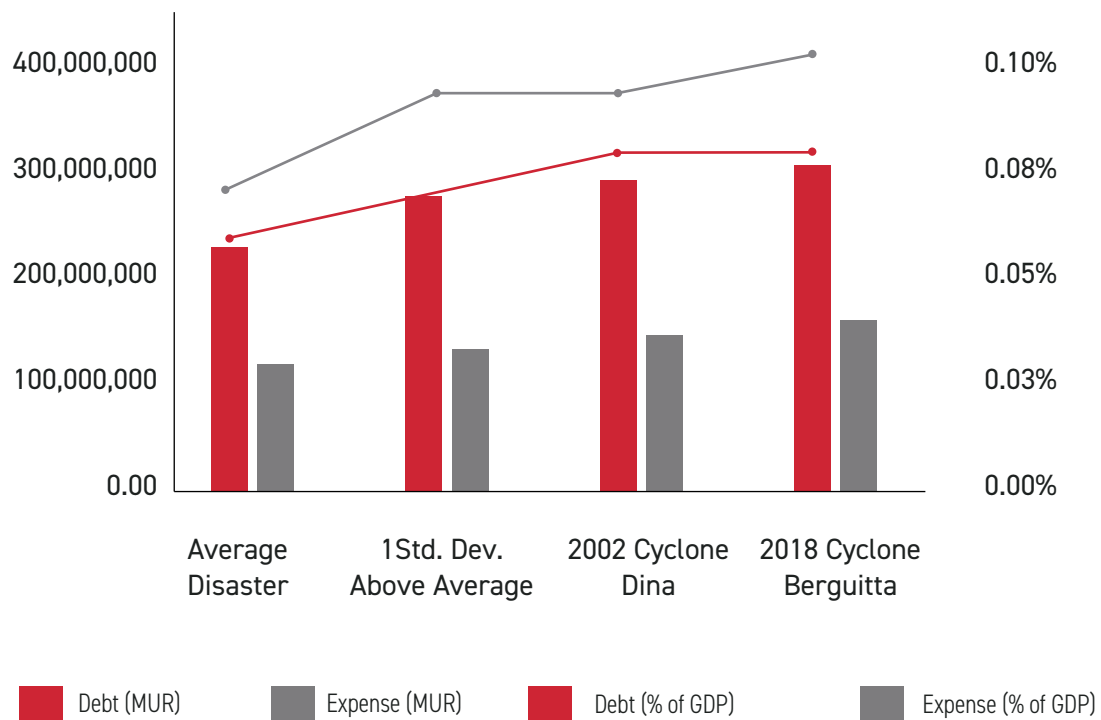
High-severity events amplify these effects. For Cyclone Berguitta in 2018, debt was projected to rise by 0.08 percent of GDP ( $\approx$  MUR 314 million) and expenditure by 0.10 percent of GDP ( $\approx$  MUR 150 million) (Table 4.7). Cyclone Dina in 2002 produced a similar pattern, with debt increasing by 0.08 percent of GDP ( $\approx$  MUR 289 million) and expenditure by 0.09 percent of GDP ( $\approx$  MUR 138 million).

Table 4.7: Modelled fiscal impacts of disasters in Mauritius (average, above average, and high-severity events)

Event/Scenario	Fiscal Variable	Change (%)	Change (MUR)
Average Disaster (LYL = 814)	Debt (% of GDP)	0.06%	227,794,604
	Expense (% of GDP)	0.07%	108,835,697
1 Std. Dev. Above Avg. (LYL ≈ 3,304)	Debt (% of GDP)	0.07%	275,398,670
	Expense (% of GDP)	0.09%	131,579,966
Cyclone Berguitta (2018) (LYL = 10,275)	Debt (% of GDP)	0.08%	313,962,372
	Expense (% of GDP)	0.10%	150,004,930
Cyclone Dina (2002) (LYL = 4,984)	Debt (% of GDP)	0.08%	289,370,060
	Expense (% of GDP)	0.09%	138,255,216

Table 4.7 and Figure 4.1 summarize these results, combining percentage changes (lines) with absolute monetary impacts (bars). The visual comparison across average disasters, above-average events, and severe historical cyclones highlights that government expenditure consistently increases in response to disasters, while debt effects are more muted and statistically insignificant.

Figure 4.1: Modelled fiscal impacts of disasters in Mauritius



The temporal analysis using a dynamic panel model further revealed that fiscal impacts are largely realized within the year of the disaster, with limited persistence into the following years. This indicates that immediate post-disaster recovery costs place the greatest pressure on public finances, while medium-term fiscal adjustments are less pronounced.



## Key Findings



### Expenditure Pressure

Disaster shocks consistently cause increased government spending, with statistically significant results.



### Debt versus Expense

Debt levels show positive but statistically insignificant changes, indicating Mauritius finances post-disaster costs more through budget reallocations and external aid rather than borrowing.



### Magnitude of Losses

Severe events such as Cyclone Berguitta (2018) increased expenditure by approximately MUR 150 million (~0.1% of GDP), underscoring the fiscal stress major disasters impose.



### Immediate Impact

Most fiscal impacts are concentrated in the year of the event, with little evidence of carry-over effects.



## Chapter 5

# Probabilistic Assessment of Future Fiscal Risks through Catastrophe Modelling

## Probabilistic Assessment of Future Fiscal Risks through Catastrophe Modelling

**As climate change intensifies the frequency and severity of natural hazards, catastrophe modelling analysis helps** us understand how return periods develop. This understanding is crucial to ensure that disaster risk management plans remain effective and meet current needs. By modelling the potential costs ahead of a major disaster, we can more effectively plan and prepare for such events. This includes analysing the breakdown of losses contributing to disasters, enabling a more tailored disaster risk finance strategy. This section of the report presents the results of the catastrophe modelling used to estimate the future impact of disasters on the power and road sectors and their subsequent effects on the fiscal health of the state.



### Hazard Model

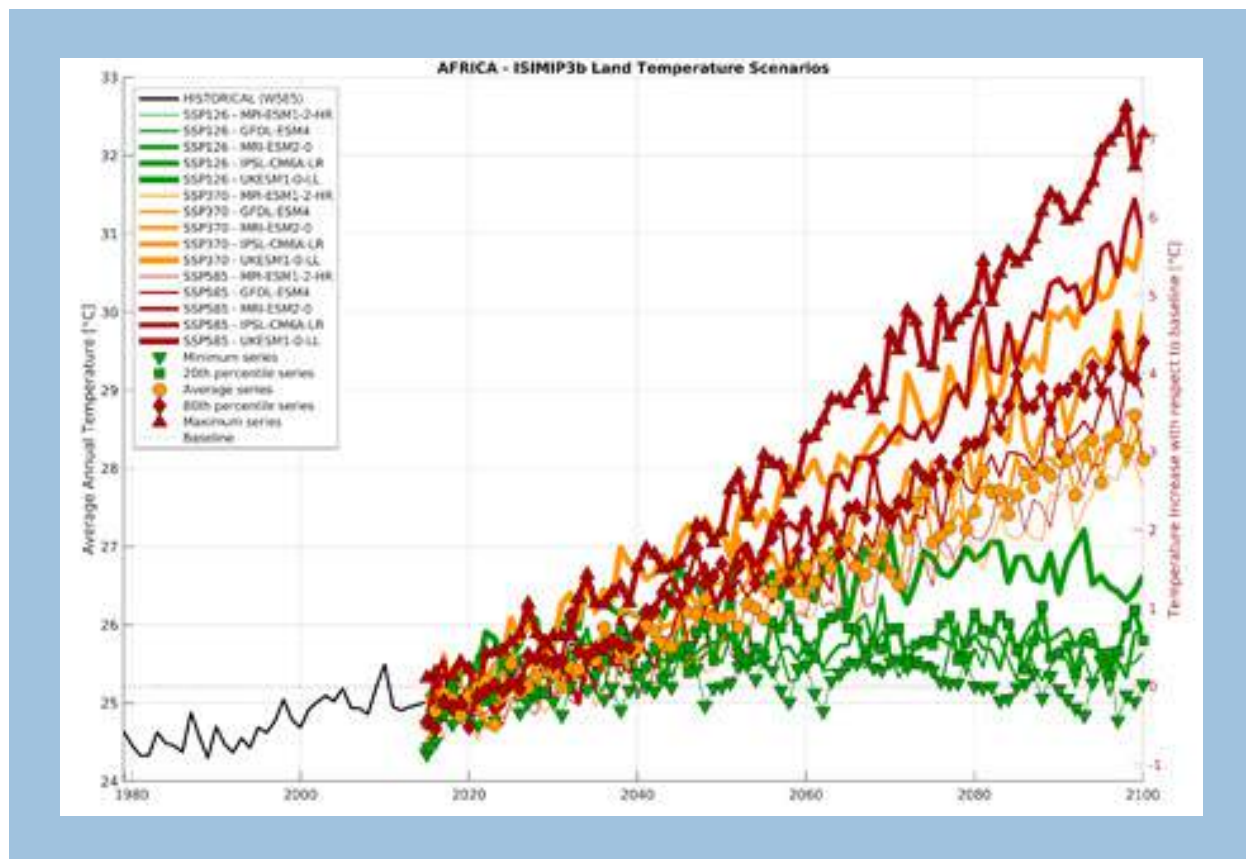
For the fiscal risk assessment of Mauritius, three hazards are considered: tropical cyclones, floods, and landslides. These natural hazards are represented as a collection of events. Each event is a single manifestation of the hazard (i.e., one tropical cyclone), which produces some intensity at the location of the infrastructure elements and has a certain probability of occurrence. The complete set of events (i.e., all the simulated tropical cyclones) fully represents the possible ways each hazard can occur. In the following sections, we will describe the different hazard models utilized in this assignment.

## Climate Models

### Model for Flood and Landslide Hazards

The climate models considered for this assignment are the same as those defined for developing the Global Infrastructure Risk Model and Resilience Index (GIRI) model of CDRI (Cardona et al. 2023). Multiple projections of Global Circulation Models included in CMIP6 (Climate Model Intercomparison Project 2023a) were verified, including anthropogenic forcings expressed as combined scenarios of SSP (shared socio-economic pathways) and RCP (representative concentration pathways), as defined by the IPCC (AR6). Figure 5.1 shows the spatial average of various future projections of surface temperature, up to 2100, obtained from the ISIMIP3b (Climate Model Intercomparison Project 2023b) database for Africa, compared to the average historical series obtained from the W5E5 (Climate Model Intercomparison Project 2023c) dataset.

Figure 5.1: Average of future climate projections obtained from CMIP6 global circulation models



Cardona et al. (2023) selected the 20th and 80th percentiles of climate variation as indicative projections of lower and upper bounds. Those percentiles correspond to projections provided by the IPSL-CM6A-LR model from the Institut Pierre-Simon Laplace, with a lower-bound scenario (SSP1-RCP2.6) and an upper-bound scenario (SSP5-RCP8.5).

Hydrometeorological phenomena are modelled from the meteorological forcing (precipitation, temperature, etc.) of a historical period, called the base climate, which corresponds to the period 1980–2010, i.e., a recent 30-year interval used as the climate norm. Climate projections are employed

to modify the base climate using the Delta method, which simply adjusts the meteorological forcing in the base climate to match the 30-year average in a projected future climate. From this modified forcing, hydrometeorological hazards are recalculated.

### Model for Tropical Cyclone Hazard

Cyclogenesis is a mesoscale process that requires high-resolution inputs from climate models. Therefore, not all climate models included in CMIP6 are suitable for cyclone hazard modelling. Only a few CMIP6 models have sufficient spatial resolution to be used for projecting future cyclone tracks. These models are all part of the PRIMAVERA High Resolution Project within CMIP6. For this assignment, we are using four high-resolution models: CMCC-CM2-VHR4, CNRM-CM6-1-HR, EC-Earth3P-HR, and HadGEM3-GC31-HM. The mentioned models consider only an emissions scenario SSP5-RCP8.5; therefore, for tropical cyclones only, the model is built based on a single trajectory rather than two bounds of climate variation, as is done for other hydrometeorological hazards.

### Flood Hazard Model

For the fiscal risk assessment (FRA) of Mauritius, the global flood hazard model developed by Alferi et al. (2023) was used. This is the same model employed for the GIRI assessment of CDRI (Cardona et al. 2023). The model's spatial resolution is suitable for this assignment. In this section, we present a summary of the model. Further details can be found in the original reference.

The model is based on defining inflows to various parts of the tributary basin upstream of various points on the main rivers and streams, to hydraulically move the flows within the channels. These inflows vary depending on the sub-basins that comprise the main channel basin. In this way, and at an intermediate resolution, it is possible to cover all the rivers in the country and identify flood areas and depths caused by overflow.

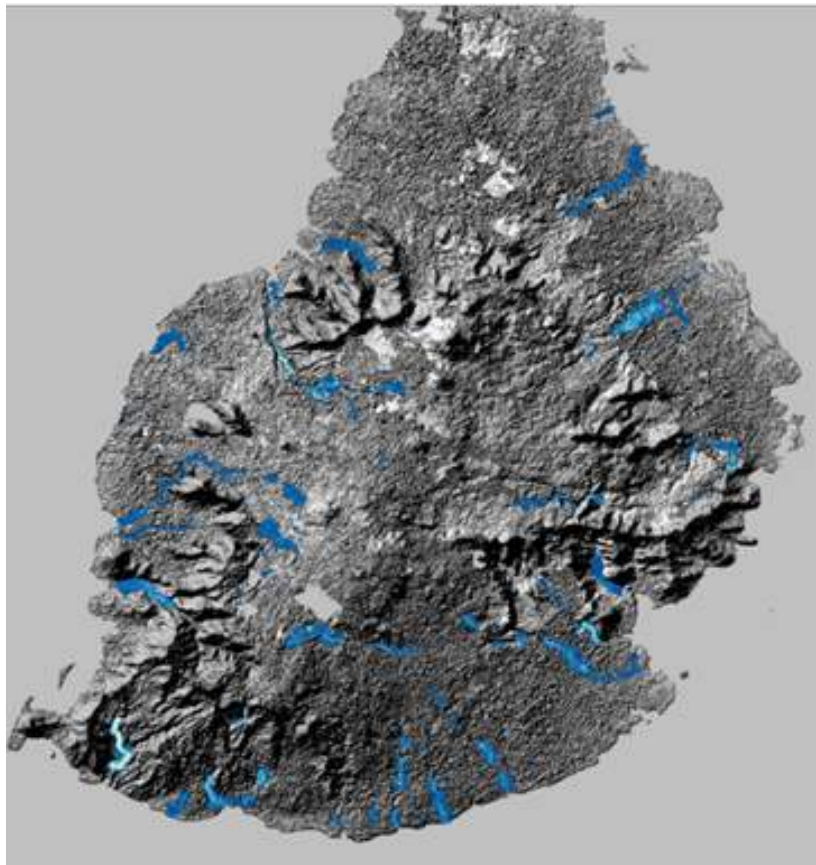


For the development of the global flood model, from which the hazard for Mauritius is derived, a global database of flows was compiled from different sources, comprising nearly 8,000 gauging stations worldwide with time series long enough to conduct a statistical analysis of extreme values. Data were collected on a daily basis; however, most of the available data were at a monthly scale. Therefore, stochastic techniques were employed to adjust the time series to a daily scale while maintaining their statistical properties. This algorithm was calibrated in regions with available daily time series.

Flood discharge magnitude is estimated using methods based on statistical analysis of data from the hydrological region. The method applied in this case was regional frequency analysis. The proposed methodology examines statistical data from a homogeneous region identified using the index flood method (IFM) to estimate flood frequency at the site with the highest possible confidence, even for quantiles with very low frequencies. This approach enables the sample size to be increased, as time series from homogeneous groups can be combined to form a longer, dimensionless time series, reducing uncertainty in estimating outlier quantiles.

A continuous, distributed physical hydrological model was employed to improve regression across climatic variables and to provide insight into areas where discharge rates cannot be derived from observations. When discharge quantiles are obtained, these results originate from the input data used in the simplified hydraulic flood model. The model constructs hydraulic cross sections where the flood stage is calculated from the flow value by solving the Manning equation. These stages are interpolated based on local relative morphology, with modifications included to account for longitudinal hydraulic connectivity between sections, especially in large floodplains. Figure 5.2 presents the uniform flood hazard map for a 100-year return period for Mauritius.

Figure 5.2: Flood hazard map for 100-year return period for present climate conditions in Mauritius

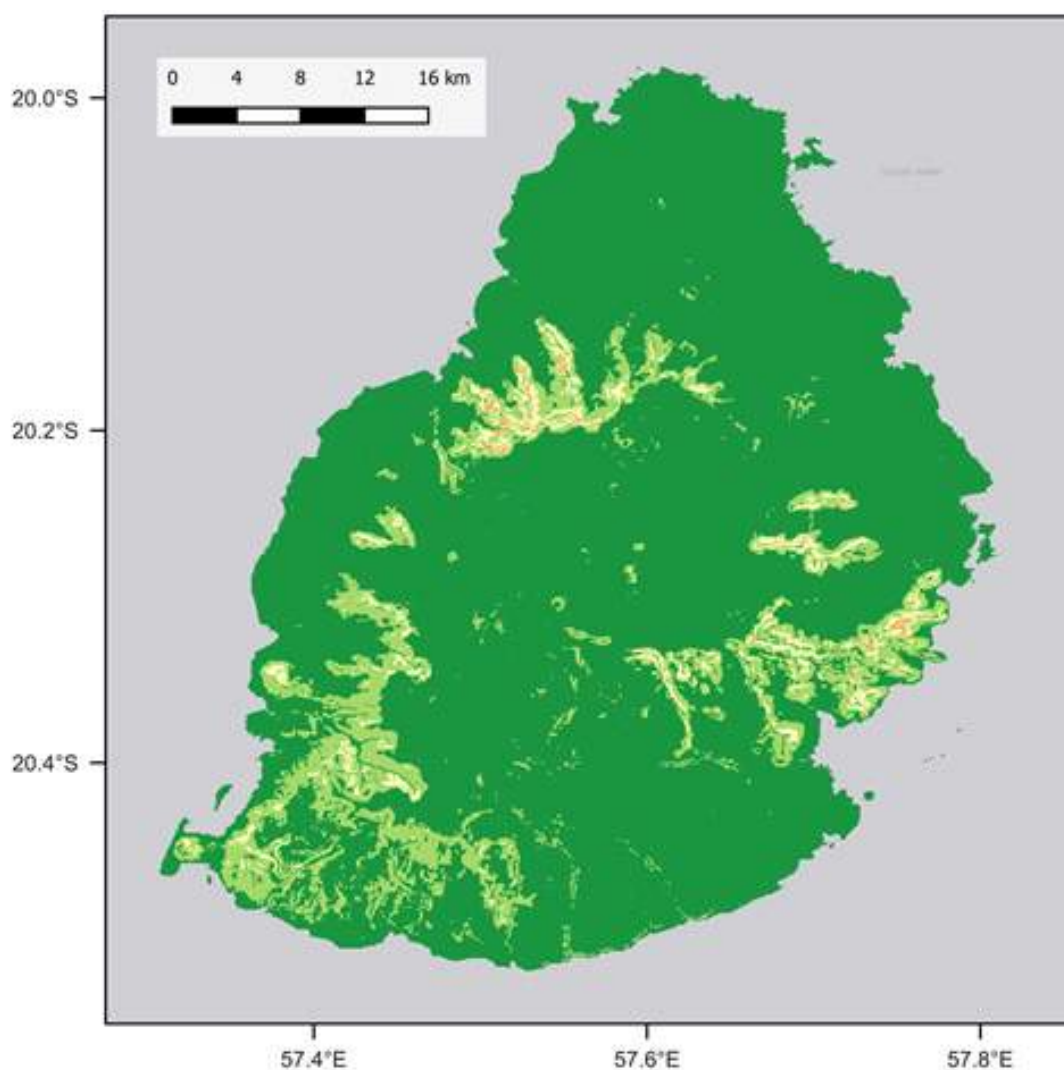


## Landslides Hazard Model

For the FRA of Mauritius, the global susceptibility model and rainfall thresholds developed by Nadim et al. (2023) were used, along with the landslide hazard model developed by Cardona et al. (2023). These are the same model components used for the GIRI of CDRI. The spatial resolution of the model is appropriate for this assignment. Here, we present a brief summary of the model.

The susceptibility to landslides worldwide was modelled by Nadim et al. (2023). Susceptibility is estimated heuristically as a function of slope, lithology, vegetation cover, and soil moisture. Each of these characteristics is assigned a susceptibility factor (an integer between 0 and 5) and weighted according to its expected impact. The overall susceptibility is calculated as the weighted sum of these features involved at each mountainous location in the territory. Local modifiers, such as population density or road density, are incorporated to reflect anthropogenic influence on landslides. The susceptibility map has a spatial resolution of 30 meters and is expressed with values between 0 and 5. More details about the model can be found in Nadim et al. (2023). Figure 5.3 shows the landslide susceptibility map for Mauritius.

Figure 5.3: Landslide susceptibility of Mauritius



Source: Nadim et al. (2023)

Landslide hazard depends not only on susceptibility but also on triggering factors, which are external influences that locally increment instability, triggering a landslide event. For Mauritius, such a factor is solely excess rainfall. The rainfall trigger is obtained directly from climate modelling (see Section on Model for Flood and Landslide Hazards). Nonetheless, landslide thresholds are necessary to determine the corresponding triggering intensity. In this assignment, we use the thresholds proposed by Nadim et al. (2023), presented in Table 5.1.

Table 5.1: Rainfall threshold for landslide hazard

Range of $P_n$	Susceptibility				
	Susc. 1	Susc. 2	Susc. 3	Susc. 4	Susc. 5
$P_n < 0.3$	0%	0%	0%	0%	0%
$0.3 \leq P_n < 2.0$	0%	1%	2%	3%	5%
$2.0 \leq P_n < 3.7$	0%	2%	3%	5%	10%
$3.7 \leq P_n < 5.0$	0%	3%	5%	10%	15%
$P_n > 5.0$	0%	5%	10%	15%	20%

Source: Nadim et al. (2023)

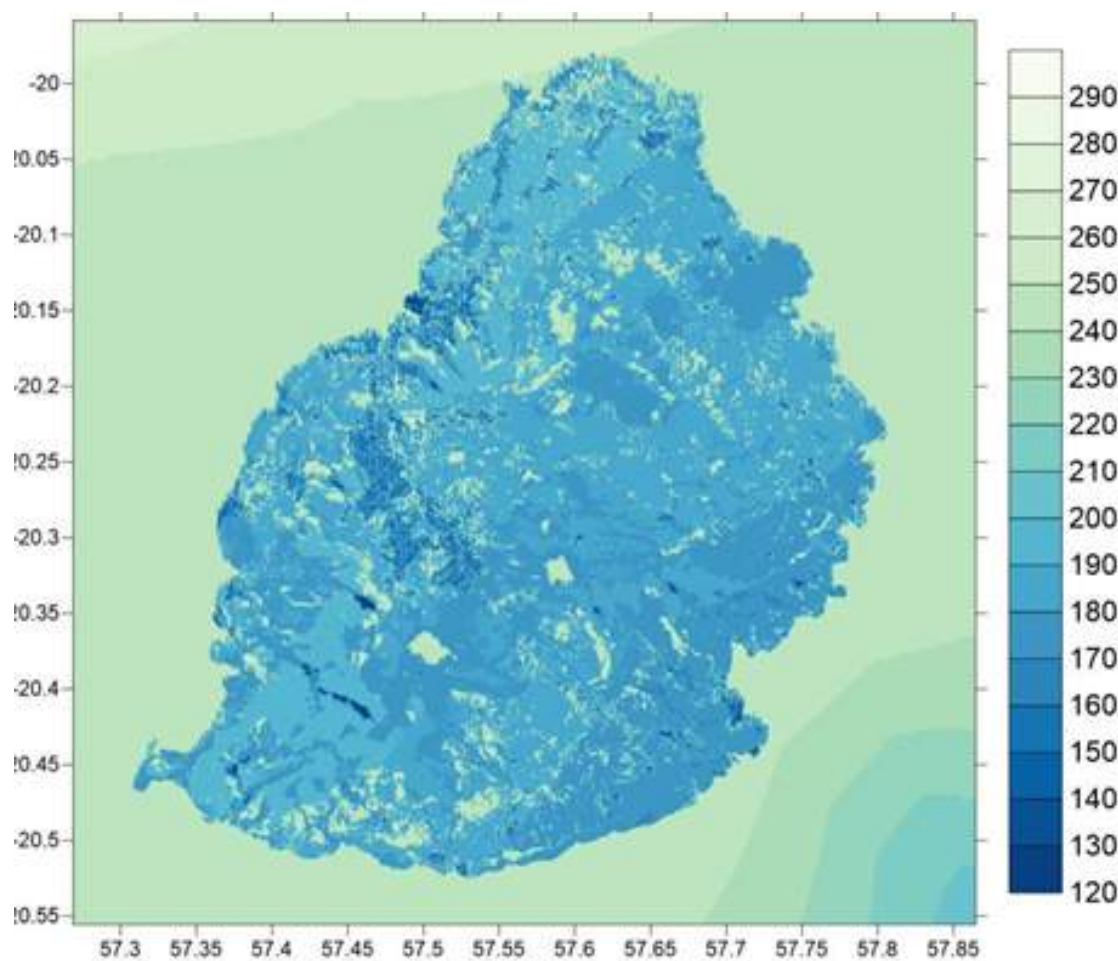
Based on susceptibility and thresholds, the model estimates the probability of a landslide according to the simulated triggering rainfall. It should be noted that landslides are assumed to be events of very high local energy, which is why the vulnerability of any exposed element becomes saturated, leading to a total loss. Therefore, vulnerability functions are not developed for this phenomenon.

### Tropical Cyclones Hazard Model

For this assignment, the tropical cyclone hazard was updated to include the latest cyclone trajectories up to 2024. The calculation method is the same as that used by Cardona et al. (2023) for the GIRI of CDRI and Cardona et al. (2014) for the GAR Global Risk Model of UNDRR. The method is implemented in the CAPRA ROBOT software module TCHM (Bernal 2014). Detailed information on the methodology can be found in Cardona et al. (2014).

The hazards for both strong winds and storm surge were assessed for this project using an updated catalogue that includes 775 historical tropical cyclones from the South Indian Ocean basin. Completeness periods were recalculated to determine the frequency of historical cyclone occurrences. For each historical track, a family of associated 'children' tracks was generated using a bi-dimensional Wiener process. Strong wind speeds and storm surge flooding were calculated for each cyclone child track, and these results were used to compute probability moments of wind speed and coastal flooding for each historical track. The results are presented as a geographical distribution of peak wind speed (3-second gusts) for strong winds, as well as the distribution of maximum surge run-up and its associated flooding along the shorelines of storm surge. This analysis was repeated across all historical and future cyclone tracks. The hazard assessment result is a set of probabilistic wind fields and storm surge flood scenarios. Figure 5.4 shows the map of the 500-year return period for strong winds in Mauritius.

Figure 5.4: Cyclone wind hazard in Mauritius for 500-year return period (intensity is wind velocity in km/h)



## Exposure Model

The database of exposed elements is defined as the collection of physical components that constitute an infrastructure system, with at least three properties established: its geographic location, its physical value or replacement cost of the asset, and a constructive or archetypal class that relates to its vulnerability. It is common that some, or even all, of these three fundamental characteristics are not available within the existing information in the country, which is why estimates are often needed to approximate or account for this inventory of exposed elements. For this assignment, exposure for Mauritius is limited to the energy and roads sectors.

## Energy Sector

In this assignment, the energy sector refers to the existing infrastructure for generating, transmitting, and distributing electricity within the territory. Oil and gas infrastructure, considered by some authors as part of the energy sector, is not included.

The energy sector is therefore subdivided into three subsectors: generation, transmission, and distribution. Each subsector requires an independent exposure model that considers its unique characteristics. For example, elements in the generation subsector are typically power plants that are extremely diverse in terms of the type of energy converted, the plant capacity, or the components that comprise the facility. On the other hand, transmission lines, although also diverse, are far more

constrained in terms of the number of typologies to consider. This makes the energy sector one of the most complex for risk assessment models.

Power generation in Mauritius is highly diverse. According to data from the World Resources Institute (WRI) and OpenStreetMap (OSM), there is more than 1,000 MW of installed capacity, distributed across seven different types of energy conversion, as shown in Table 5.2. Regarding transmission, there are around 160 km of transmission lines in Mauritius. Table 5.3 displays the total length of transmission lines at different operational voltages.

Table 5.2: Installed capacity of the generation sector in Mauritius

Source Energy	Capacity (MW)	% share
Bioenergy (biomass, waste, etc)	102	8.9%
Coal	225	19.7%
Gas	75	6.6%
Hydro	51	4.5%
Oil (petroleum derivatives)	466	40.9%
Solar (photovoltaic)	113	9.9%
Wind	107	9.4%
<b>Total general</b>	<b>1,139</b>	

Table 5.3: Transmission lines voltages and lengths in Mauritius

Voltage (kV)	Capacity (MW)	% share
<110	151.6	96.5%
110 – <220	5.4	3.4%
220 o >220	0.1	0.1%
<b>Total</b>	<b>157.1</b>	

The procedure for determining the replacement cost of energy sector components follows the approach proposed by Cardona et al. (2023) and is used for valuing exposed elements in the GIRI model of CDRI.

## Generation

The approximation of the replacement cost for the exposed elements in the generation subsector is based on information from the Global Power Plant Database (WRI) and the Power Plant Database (OSM). It is worth noting that no official information was received during the execution of this assignment. The procedure for estimating the cost of generation infrastructure is described next.

First, the raw data is cleaned by removing elements that lack information about the energy source or generation capacity. Then, the data on energy sources is reclassified into one of the basic categories presented in Table 5.4. Next, the capacity of each plant is verified using the existing information. If there is no data on plant capacity, it is randomly assigned based on a probability distribution of capacities for the same type of energy source (see Cardona et al. 2023 for further details). Finally, the replacement cost is assigned using the cost indicators from Cardona et al. (2023), as defined by IRENA (International Renewable Energy Agency 2023), and then multiplied by the plant capacity.

Table 5.4: Basic energy source classes and unitary costs

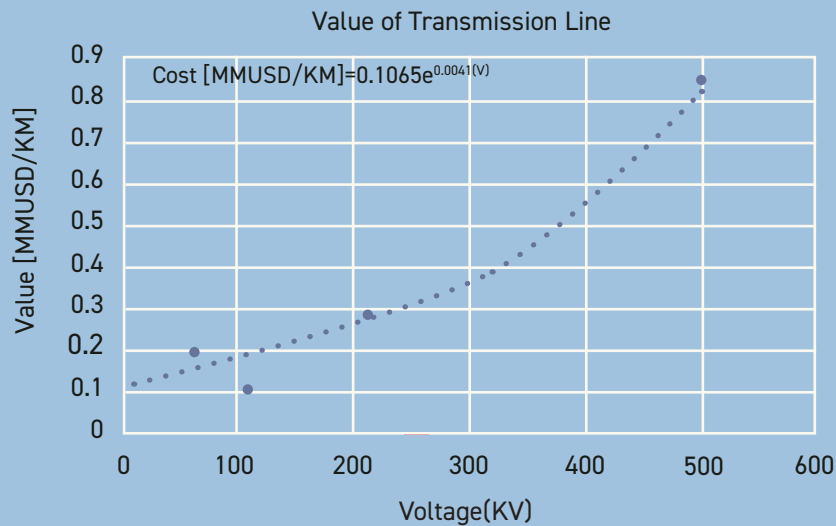
Energy Source	% share
Bioenergy (biomass, waste, etc.)	2,353
Battery (storage)	758
Coal	875
Gas	1,116
Geothermal	3,991
Hydro	2,135
Nuclear	3,782
Oil (petroleum derivatives)	795
Solar (photovoltaic)	857
Wave and tidal	7,038
Wind	1,325
Other	1,134

## Transmission

For the transmission subsector, the raw data is obtained from the Power Lines Database and Power Substations Database, both maintained by OSM. No official information was received during the execution of this assignment. The procedure for estimating the cost of transmission infrastructure is described next.

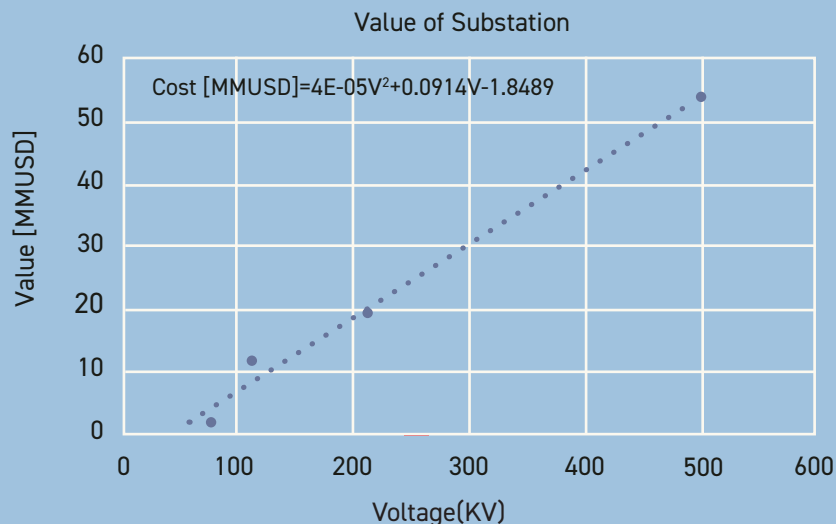
For the transmission lines, the length of each element is first determined from the raw spatial data. Long elements are cut into segments of 150 m or less. Then, the line voltage is used to calculate the cost indicator in accordance with the price function proposed by Cardona et al. (2023), which is shown in Figure 5.5. Finally, the overall cost of the segment is obtained by multiplying the corresponding cost indicator by the segment length.

Figure 5.5: Pricing function (based on transmission line voltage)



For substations, the initial step involves cleaning the raw data to eliminate substation elements that do not correspond to transmission or distribution networks. Afterwards, the cost is assessed based on the operational substation voltage using the pricing function proposed by Cardona et al. (2023) and presented in Figure 5.6.

Figure 5.6: Pricing function (based on voltage at substation)



## Distribution

Distribution networks are closely linked to population density. They tend to be denser where populations are more concentrated. Furthermore, data on the actual locations and characteristics of distribution network components (such as cable posts, buried lines, and transformers) often lack availability or do not exist at all. It is worth mentioning that no official information was received during the execution of this assignment. As a result, we will utilize the framework developed by Cardona et al. (2023) to create an exposure proxy for the distribution network based on population data.

Cardona et al. (2023) propose that the valuation of the distribution subsector should be considered as a factor of the transmission subsector<sup>4</sup>. This approach results in a total valuation that must be distributed geographically using the raster grid of population data provided by the Global Human Settlement Layer (GHSL) (European Commission, Joint Research Centre 2023). This population grid is then adapted to reflect the number of people with access to electricity. For Mauritius, the World Bank reports that 99.6 percent of the total population has access to electricity (World Bank 2023a). Consequently, this method results in higher exposure values in areas with denser populations and establishes an overall infrastructure value that is consistent with actual access to electricity.



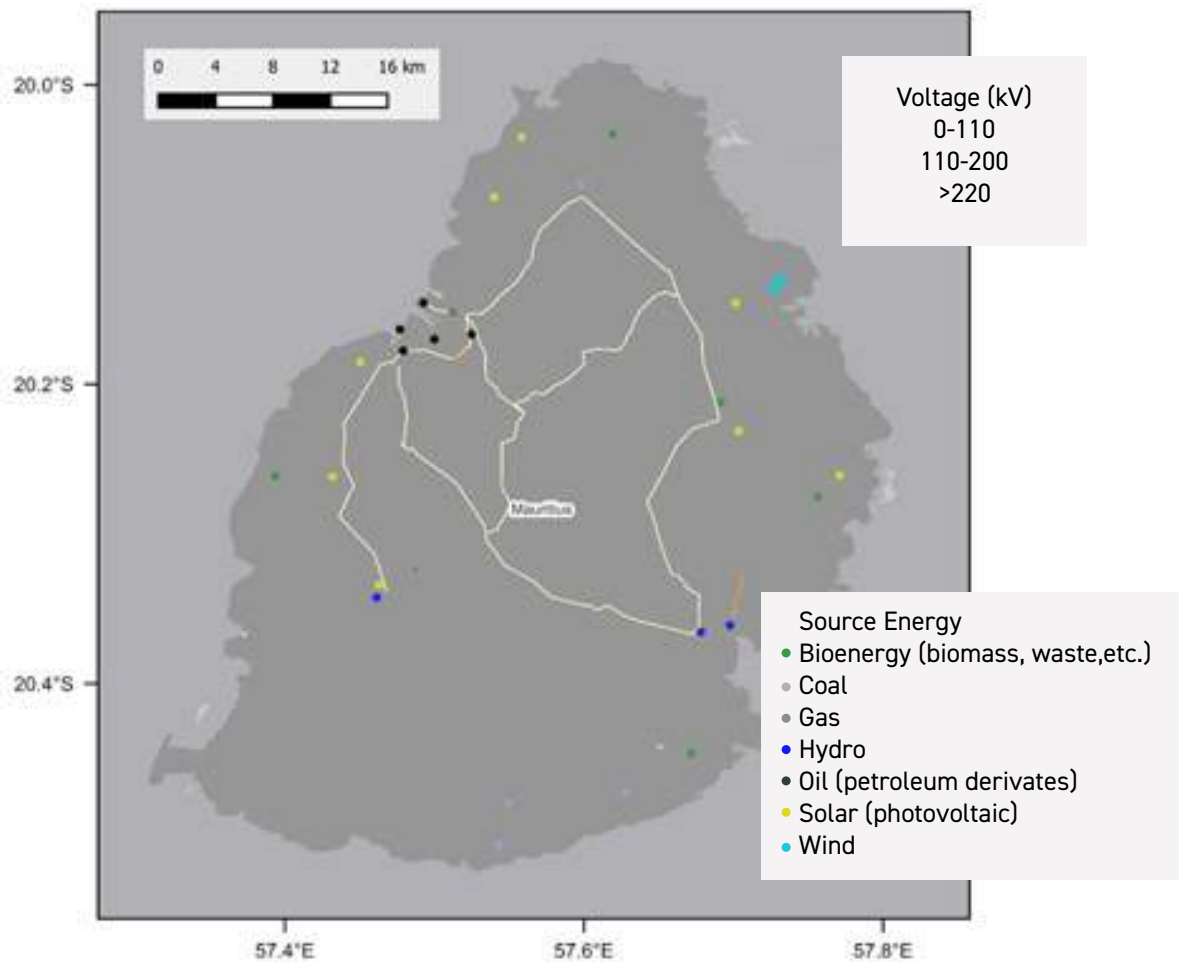
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<sup>4</sup>The factor is 2.26. See Cardona et al. (2023) for further details.

## Exposure Database

The resulting exposure model comprises geolocated vector entities with attributes that are useful for risk evaluation. Key fields such as the replacement cost and the archetype of each element are included to effectively characterize the exposure. Figure 5.7 provides a general overview of the sector in Mauritius.

Figure 5.7: Map of the exposure database for energy sector in Mauritius



## Roads Sector

The roads sector discussed in this assignment pertains to highway infrastructure. Road infrastructure differs depending on design conditions, such as topography, weather, and traffic. Furthermore, highway segments comprise various elements, including pavement structures, retaining walls, gutters, and box culverts. Similarly, bridges are unique; while they could be classified into archetypes, each bridge is distinct and lacks standardized typification. In addition, the available data is severely limited. It is important to note that no official data was received during the execution of this assignment. Therefore, the exposure model generated is only a good enough approximation of the sector for the purpose of risk assessment.

According to the information in the OSM dataset, Mauritius has more than 6,000 km of roads, including primary, secondary, tertiary, residential, and minor roads. In addition, there are 17 km of bridges that fall within these same road categories. Private roads and bridges are not included in this assignment.

## Road Segments

The procedure for determining the replacement cost of components in the road sector follows the method proposed by Cardona et al. (2023) and is used for the valuation of exposed elements in the GIRI model of CDRI. This procedure employs the Global Roads Network dataset from OSM, which is used and processed to eliminate incorrect or incomplete records. Roads are segmented into sections of a maximum length of 300 m to increase the model's granularity. The basic value of each segment is evaluated based on its length and a nominal cost of \$1.09 million per kilometre.

The basic value of the segment is adjusted based on four main features: road type, number of lanes, pavement type, and slope. Each feature has a multiplication factor that modifies the segment's basic value.

Road type describes the operational level of a road within a country's transportation network. It is an important modifier that influences variations in replacement cost based on the road's overall significance. The corresponding multiplication factor is presented in Table 5.5.

Table 5.5: Road-type multiplier

Road Type	Factor
Primary	1.00
Secondary	0.83
Tertiary, residential, and Unclassified	0.67

Source: Cardona et al. (2023)

The number of lanes on a road segment is an indicator of the demand that the road can accommodate. We use the factor proposed by Cardona et al. (2023), which is calculated as half the total number of lanes in the segment. Therefore, a two-lane road serves as the basic condition, with a multiplication factor of 1. Roads with a greater number of lanes result in an amplified exposure value relative to the basic replacement cost.

Pavement type also modifies the cost of the segment. It is evident that replacing a segment of the paved road would be more costly than replacing a segment of affirmed gravel. We use the factors proposed by Cardona et al. (2023), which categorize roads into three general types: paved, affirmed, and loose. The factors are presented in Table 5.6.

Table 5.6: Pavement-type multiplier

Pavement Type	Factor
Paved	1.00
Affirmed	0.34
Loose	0.18

Source: Cardona et al. (2023)

Finally, slope is a strong modification of the segment value. Replacing a road segment with similar characteristics in steep terrain would be far more costly than replacing it in flat terrain. Furthermore, some critical elements, such as retaining walls, are far more likely to be necessary in steep terrain, whereas they may not be necessary in flat terrain. We use the slope factors proposed by Cardona et al. (2023), which are detailed in Table 5.7.

Table 5.7: Slope multiplier

Slope Type	Slope Angle (°)	Factor
Plain	0–10	1.00
Rolling	10–15	1.43
Hilly/mountainous	15–25	1.82
Steep	>25	2.16

Source: Cardona et al. (2023)

## Bridges and Tunnels

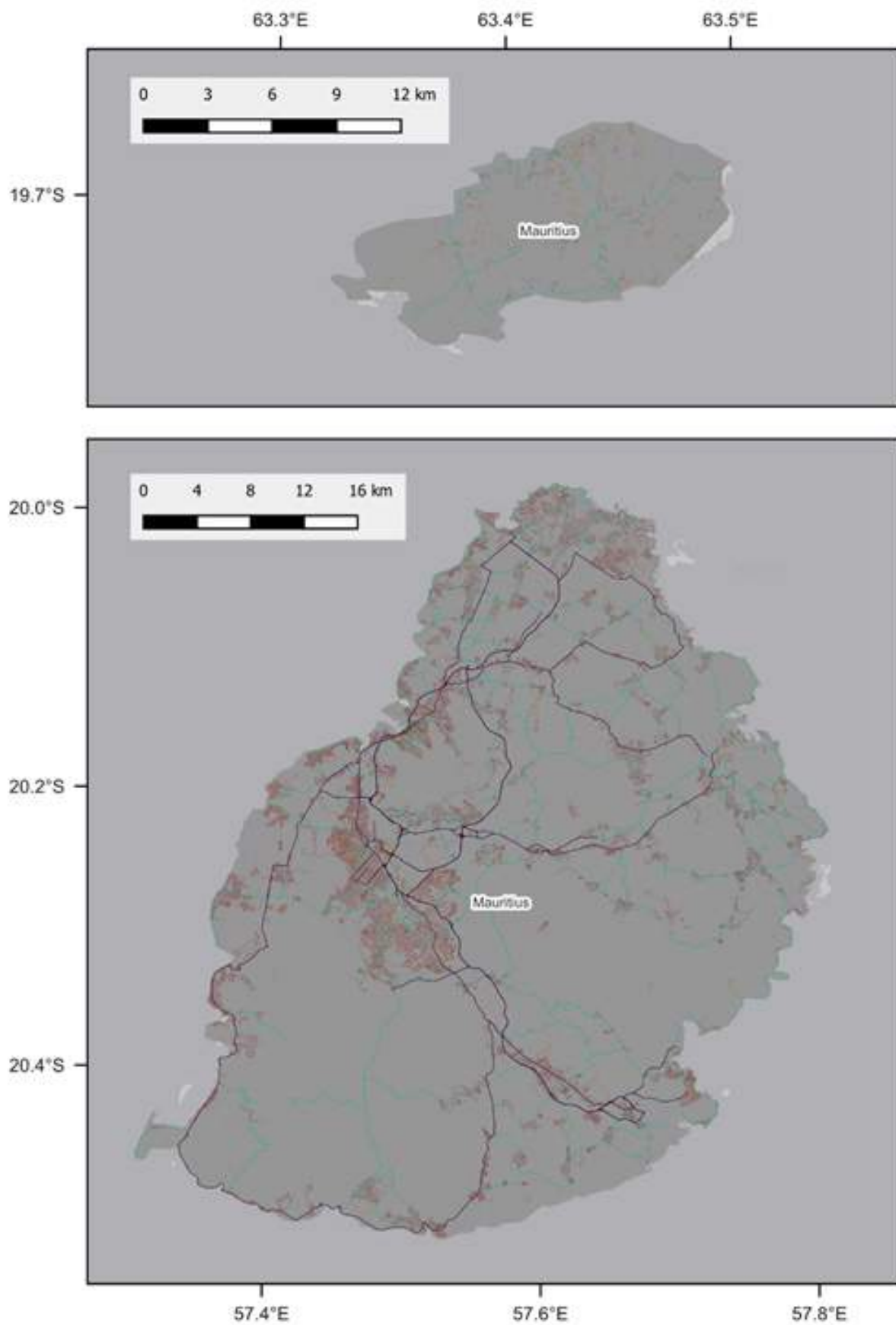
Bridges are infrastructure elements that are particularly difficult to typify. It can be said, with high confidence, that there are as many bridge types as there are bridges worldwide. This, of course, complicates any attempt to classify bridges. However, given the current state of available data, such classification is impossible because the available information is insufficient to distinguish among different structural features of existing bridges. Properties such as span, gauge, support type, number of pillars, abutments, foundation, and board structure, among many others, are unknown. The available data from the OSM dataset only allows for the identification of the bridge's length. We use this attribute to estimate the replacement cost, including the cost indicator proposed by Cardona et al. (2023), which is \$9.84 million per kilometre.

Finally, tunnels are included. They share some of the difficulties highlighted for bridges in terms of the impossibility of a good generalization and the lack of detailed information. Nonetheless, based on the length of each identified tunnel in the OSM dataset, the estimated value is approximated from the average price indicator proposed by Cardona et al. (2023), which is \$19.8 million per kilometre.

## Exposure Database

The resulting exposure model comprises geolocated vector entities, each featuring attributes that are valuable for risk evaluation. Key fields, such as replacement cost and archetype, are included for each element to effectively characterize the exposure. Figure 5.8 provides a general overview of the sector in Mauritius.

Figure 5.8: Map of exposure database for road sector in Mauritius



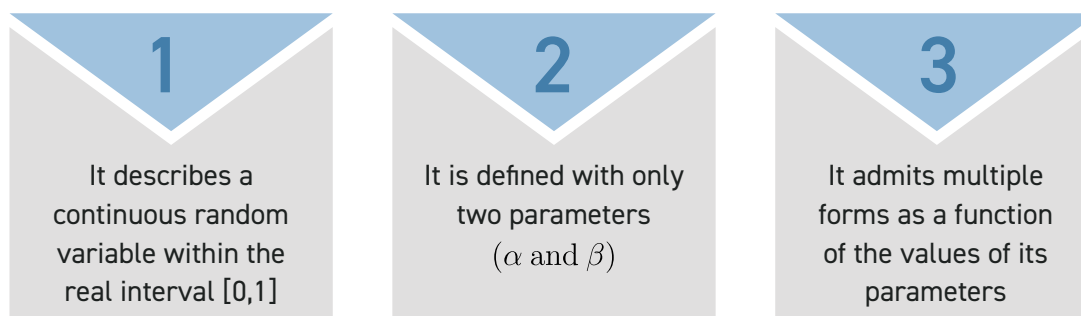
## Vulnerability Models

The physical vulnerability of exposed elements can be mathematically represented using vulnerability functions. These functions effectively capture the complexity of the loss generation process when these exposed elements are subjected to a hazardous event. Additionally, vulnerability functions express potential loss in a probabilistic manner, enabling the application of a conceptual framework for risk assessment.

## Probability Model for the Loss

In catastrophic risk modelling, losses are treated as random variables. This approach enables the direct factoring of the uncertainty inherent in the amounts of loss caused by any hazard into the calculations. Vulnerability is assessed on an element-by-element basis within the exposure portfolio, meaning that the losses referred to here pertain to a single exposed element. To generalize, loss can be defined as a variable ranging from 0 to 1, which represents 0 percent to 100 percent of the exposed value of the element (e.g., the replacement value of a property or an infrastructure element). Consequently, when discussing vulnerability, the term 'loss' always refers to a relative loss based on the degree of damage. In other words, it represents a fraction of the exposed value.

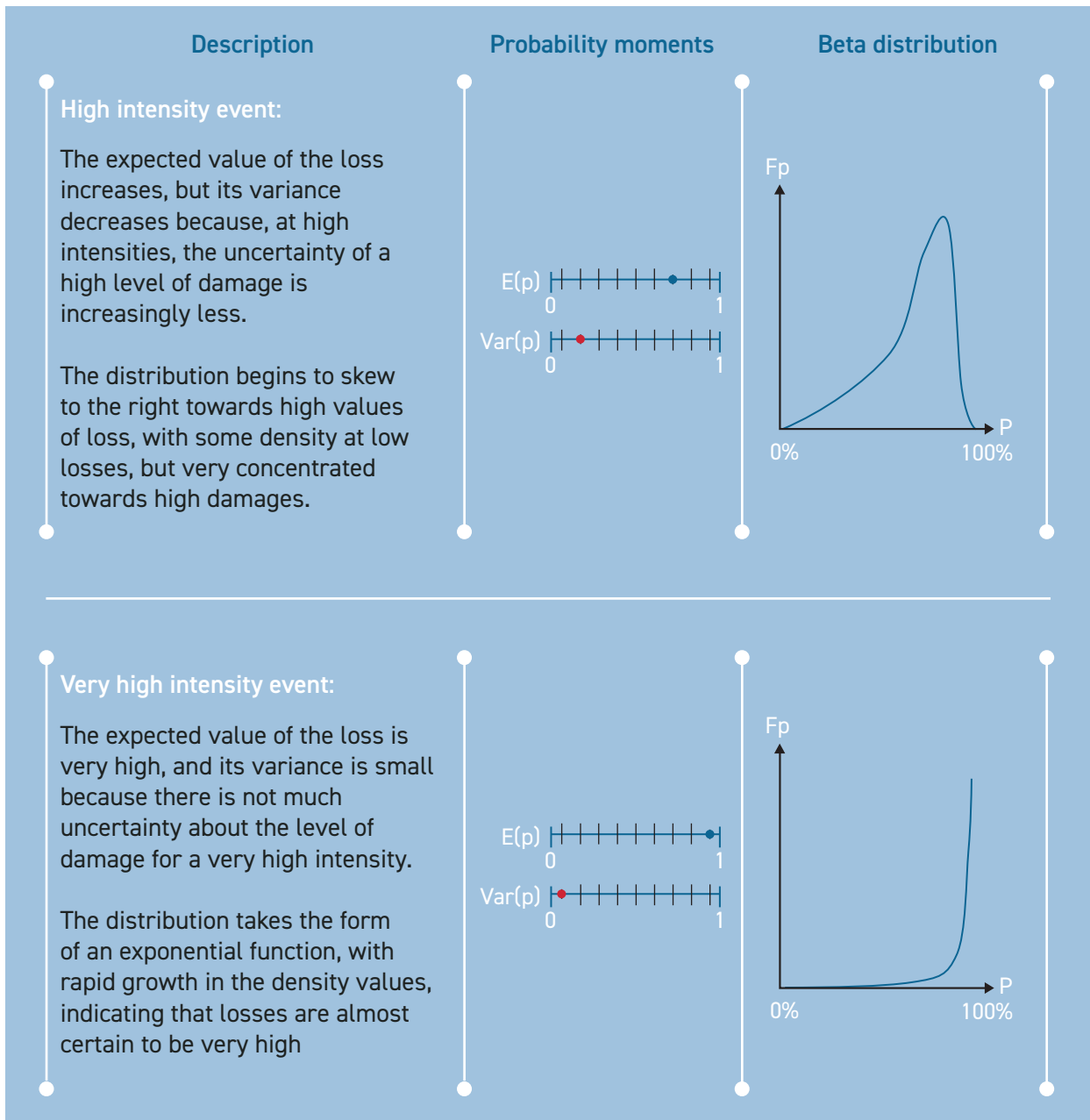
In general, there is insufficient information on the damage and losses caused by historical events to adjust a probability model based on statistical estimates of those losses. Therefore, defining a probability model that reflects the randomness of loss is considered reasonable and appropriate, but it inevitably involves some degree of arbitrariness. The most widely used model is the Beta distribution, initially proposed by Anne Kiremidjian and other authors in the development of the ATC-13 document and its commentary, ATC-13-1 (ATC 1985, 2002). This work aimed to establish probability models for damage caused by earthquakes in California. Since then, the Beta distribution has been widely adopted as a probability model for loss worldwide, applicable to various hazards and types of exposed elements. It is favoured due to its practicality under the following criteria:



As the Beta distribution is a two-parameter distribution, it requires two probability moments to be fully characterized. This implies that vulnerability models must incorporate at least two probability moments, which are estimated through the vulnerability models in terms of the expected value and the variance of the loss. The shape of the Beta distribution changes based on the values of these probability moments, which are estimated through the vulnerability model. As mentioned, the ability of the Beta distribution to adjust its shape within its defined interval makes it a popular choice in catastrophe risk modelling. Table 5.8 illustrates the expected shapes of the Beta distribution for different combinations of expected value and variance for the loss. The table includes a general description of anticipated outcomes for hazard events of different intensity levels, specific values for the expected value and variance within the interval  $[0,1]$ , and a visual representation of the expected shape of the Beta distribution. It can be concluded that the Beta distribution effectively represents the distributions of loss expected from events with different characteristics.

Table 5.8: Illustration of the variation of the Beta distribution in response to events of different intensity levels

Description	Probability moments	Beta distribution
<p><b>Very low intensity event:</b></p> <p>A low-loss value is expected with low dispersion. That is, if the intensity is very low, it is known that the loss will be low without much variability.</p> <p>The distribution exhibits negative exponential behaviour, with rapid decrease. That is, the highest probability density is concentrated near zero loss, as expected for a very low intensity.</p>		
<p><b>Low intensity event:</b></p> <p>The expected value of the loss increases, and its variance also increases (i.e., the loss is more uncertain).</p> <p>The distribution is wider, centred more to the right, but still skewed towards low losses.</p>		
<p><b>Intermediate intensity event:</b></p> <p>The expected value of the loss is much higher, and the variance is also as high as possible.</p> <p>The distribution is now symmetrical, bell-shaped, and as wide as possible, indicating that this is the point of greatest possible variability for the loss.</p>		

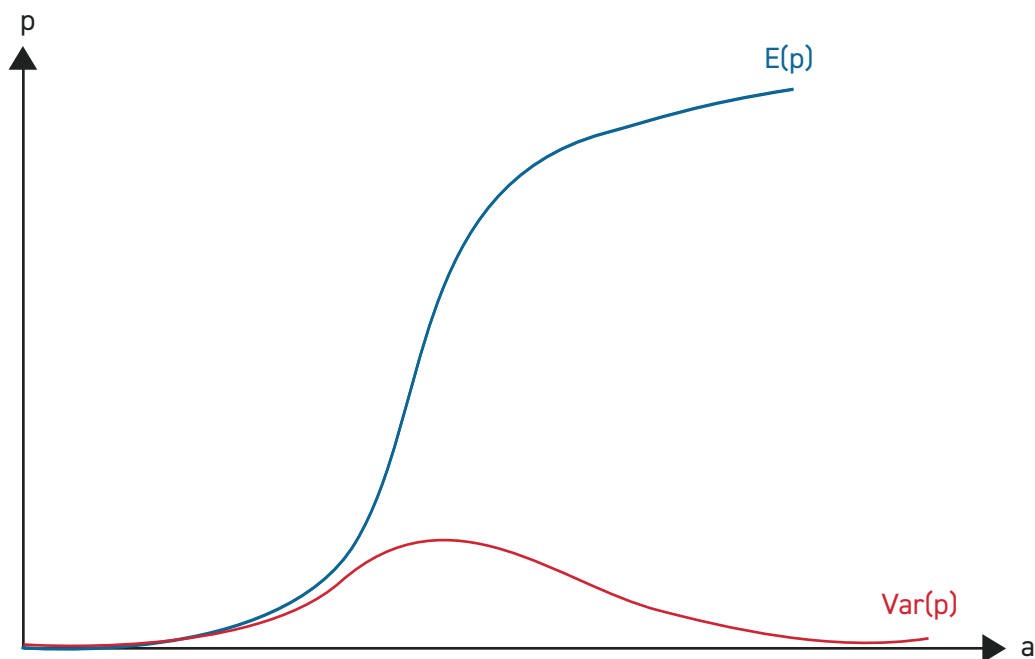


### Vulnerability Functions

Vulnerability functions mathematically represent physical vulnerability and consist of two different components. The first component describes how the expected value of loss varies with the intensity of a phenomenon, while the second component outlines the variation of the variance. Vulnerability functions are the preferred vulnerability model for property or infrastructure elements in catastrophe risk assessments because they adequately describe the loss.

The expected value and variance functions are not entirely free. In general, what is illustrated in Table 5.8 must be fulfilled; that is, the expected value function is necessarily increasing, while the variance function should initially increase and then decrease. This behaviour is necessary to accurately reflect the expected variability in relation to the intensity of the phenomenon. Figure 5.9 illustrates a typical shape of vulnerability functions.

Figure 5.9: Illustration of a vulnerability function



Vulnerability functions are determined and established for various types of exposed elements, based on some categorization. This means that a single function can describe the behaviour of multiple exposed elements within the same category. This approach is sensible given the probabilistic nature of these functions, which can effectively capture the behaviour of multiple exposed elements within the same category. The typification or categorization of exposed elements is typically established within the exposure model based on the construction or functional characteristics of those elements.

The vulnerability functions developed by Cardona et al. (2023) for various infrastructure archetypes are used for this assignment. These functions are the same ones utilized in the GIRI model of CDRI. The GIRI library, which contains archetype functions, is currently the most comprehensive resource for infrastructure vulnerability models used in catastrophe risk assessment. In this assignment, the vulnerability functions applied to the risk assessment of Mauritius are presented in Figures 5.10 to 5.15. As previously mentioned, no vulnerability functions are employed in landslide hazard assessment. This is based on the assumption that the occurrence of the landslide inherently results in the destruction of the infrastructure element. This assumption is particularly valid for road infrastructure, which is the only one subjected to landslides in this assignment.

## Energy Infrastructure

Figure 5.10: Earthquake vulnerability functions for the infrastructure of the energy sector

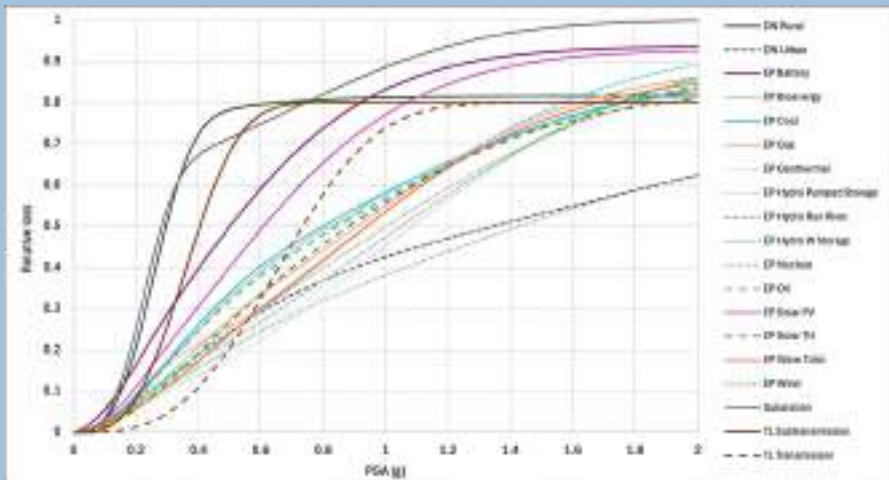


Figure 5.11: Flood vulnerability functions for the infrastructure of the energy sector

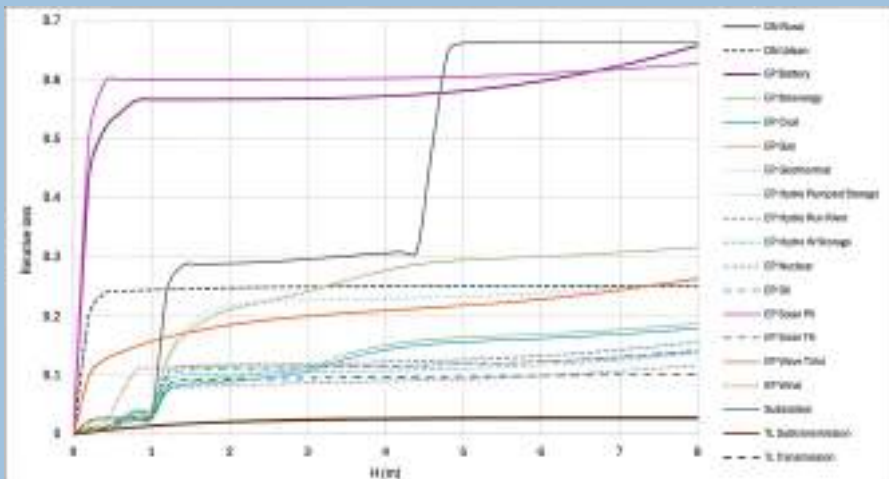
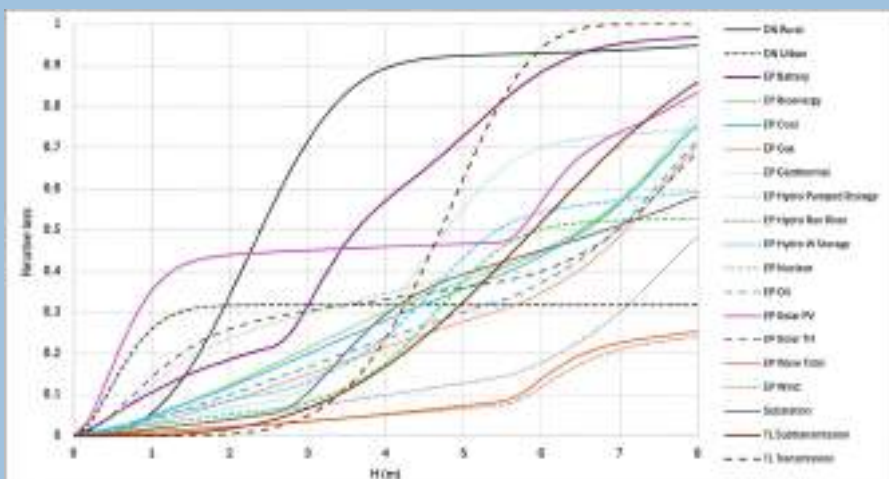
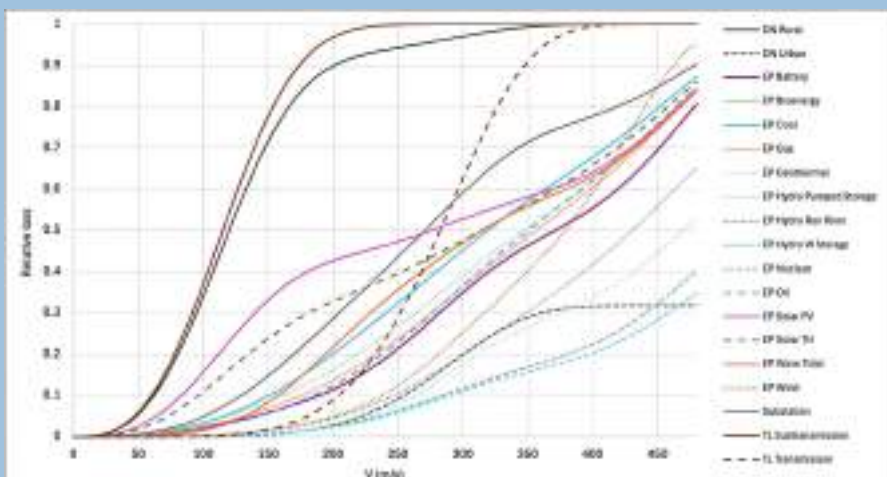


Figure 5.12: Storm surge (cyclone) vulnerability functions for the infrastructure of the energy sector



Note: EP - Energy Production, TL - Transmission Line, DN - Distribution Network

Figure 5.13: Wind (cyclone) vulnerability functions for the infrastructure of the energy sector



Note: EP = energy production; TL = transmission line; DN = distribution network

### Road Infrastructure

Figure 5.14: Earthquake vulnerability functions for infrastructure of the road sector

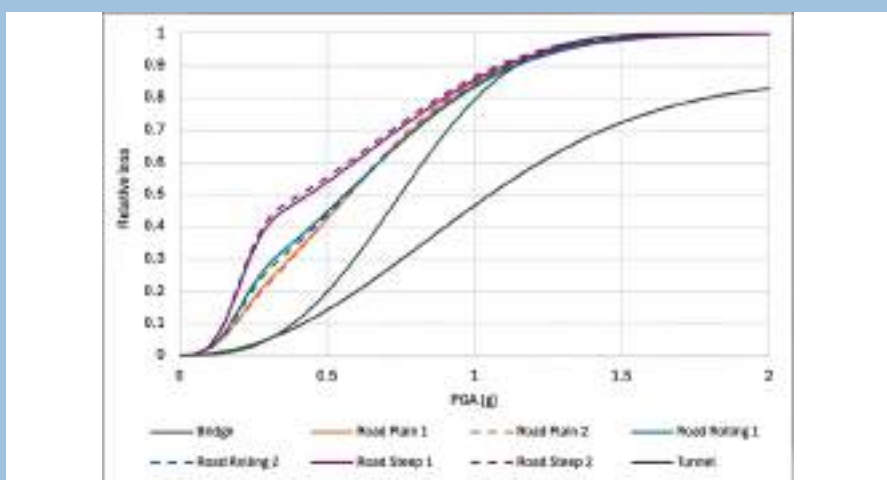
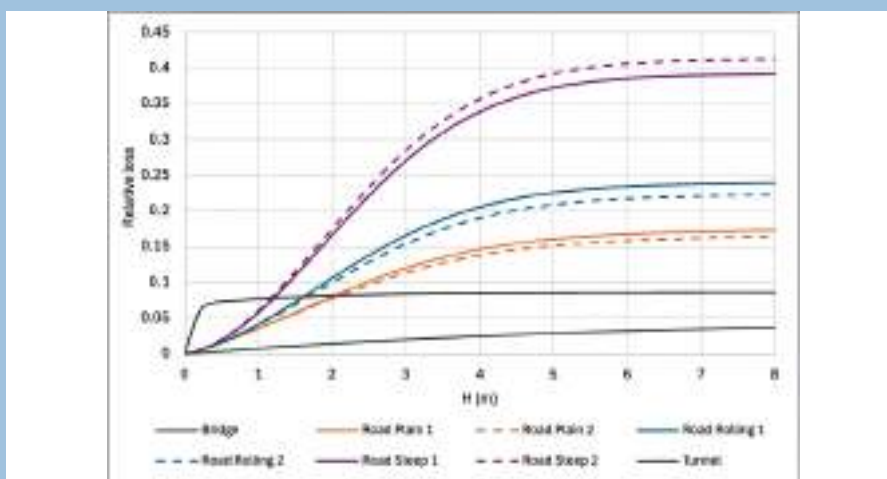


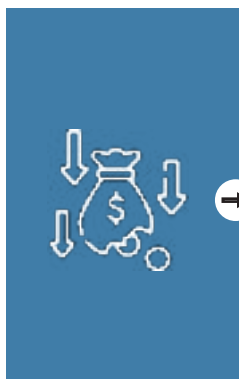
Figure 5.15: Flood vulnerability functions for infrastructure of the road sector



Note: EP - Energy Production, TL - Transmission Line, DN - Distribution Network

## Risk Assessment Results

Risk results are expressed in terms of average annual loss and probable maximum loss, which are standard risk metrics commonly used in catastrophe risk assessments and the insurance industry. While these metrics are formally defined in Product 1 of this consultancy, we provide their definitions here for the reader's convenience.



### Average Annual Loss:

The average annual loss (AAL) is an important indicator because it integrates the effect, in terms of loss, of hazard scenario occurrences over vulnerable exposed elements into a single value. It is considered as the most robust risk indicator, not only because it summarizes the loss-time process into a single number but also due to its low sensitivity to uncertainty. The AAL corresponds to the expected value of the annual loss and indicates the annual value to be paid to compensate all future losses in the long term. In a simple insurance scheme, the AAL would be the annual pure premium.



### Probable Maximum Loss:

This refers to a loss that does not occur frequently, that is, a loss usually associated with long return periods. There is not a single probable maximum loss (PML) value, but a complete curve (loss versus return period). However, it is common practice to define a PML value by fixing a specific return period. There are no universally accepted standards to define what is meant by 'not very frequently'. In the insurance industry, for example, the return periods used to define the PML range from 200 to 2,500 years.

The AAL is presented as totalized for each combination of hazard and sector and disaggregated by subsector and other important features. Furthermore, the AAL is disaggregated in risk maps that illustrate the geographical variation of the expected losses. In all these types of results, AAL values may be presented as absolute or relative. Absolute AAL refers to the modelled amount of the metric in monetary units. Relative AAL is the same amount but divided or normalized by the exposure value under consideration. For example, if the AAL presented is the total for a specific sector in the territory, then the relative AAL is normalized by the total exposed value of that sector. On the other hand, if the AAL reported pertains to a single exposed element (such as in risk maps), the relative AAL is normalized by the exposure value of that element alone. In this report, relative AALs are always expressed as per-thousand fractions with the symbol ‰.

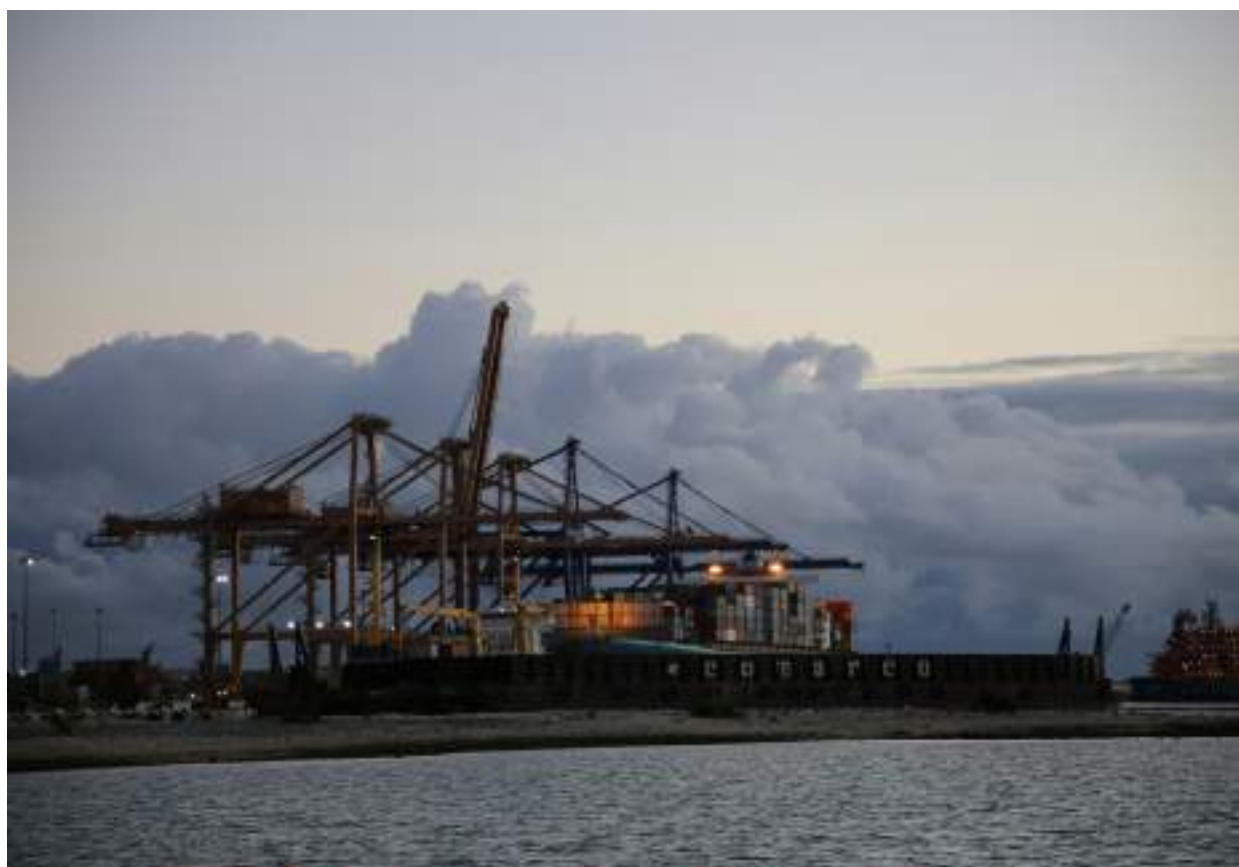
The PML is presented as a function of loss versus return period for each hazard and sector. Both absolute and relative PML values are included. Relative PML values are presented to help facilitate comparison among hazards. As for the AALs, absolute PMLs are the calculated amounts, while relative PMLs are normalized by the exposed value of the sector. Given that PMLs are obtained from large quantiles in probability distributions, they cannot be disaggregated to present maps. In this report, relative PMLs are always presented as per-hundred fractions, denoted by the symbol %.

## Energy Infrastructure

Table 5.9 presents the AAL for Mauritius' energy sector concerning the hazards considered in this assessment, both in absolute and in relative terms. The significant impact of tropical cyclones on the catastrophic risk of Mauritius is evident, with AALs for the energy sector exceeding those for floods by more than one order of magnitude. This discrepancy is further exacerbated under an SSP56-RCP8.5 climate scenario. Floods pose a moderate risk to the sector, with an increased metric for the same climate scenario as cyclones.

Table 5.9: Absolute and relative average annual loss for the energy sector infrastructure

Hazard	Average annual Loss	
	\$	%
Flood	688,000	0.50
Flood (RCP2.6)	668,000	0.49
Flood (RCP8.5)	1,062,000	0.78
Tropical cyclone	14,929,000	10.93
Tropical cyclone (RCP8.5)	17,345,000	12.70



The relative AAL among subsectors is distributed as shown next. For floods (see Figure 5.16), the largest AAL occurs in the generation subsector, followed by the distribution subsector. For transmission, the AAL is low, which is expected since the majority of this subsector, primarily transmission lines, are elevated. In addition, a marked increase in AAL due to climate change is visible across all subsectors when considering scenario SSP5-RCP8.5. AALs for tropical cyclones (see Figure 5.17) show a greater contribution from the Generation subsector, with lower values for Transmission and Distribution, although still within the same order of magnitude. This is due to the higher wind sensitivity of power plants and facilities, owing to the nature of their components, compared to the lower wind sensitivity of Transmission or Distribution infrastructure, such as transmission towers or substations.



Figure 5.16: Relative average annual loss from flood for the energy infrastructure portfolios

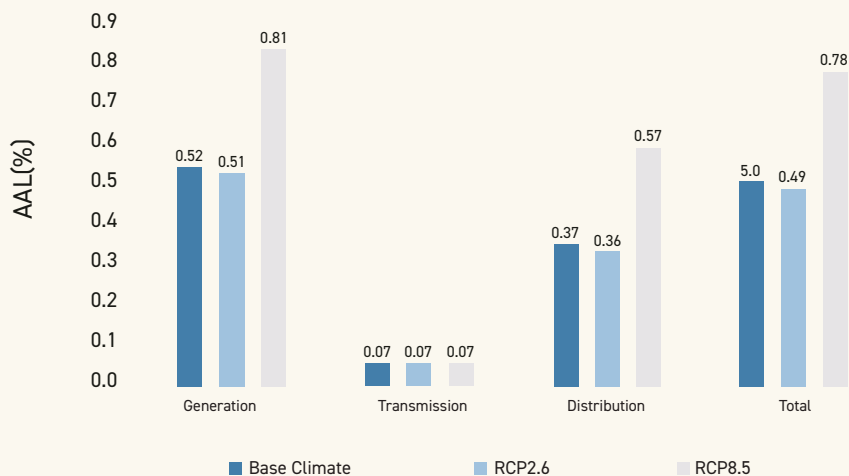
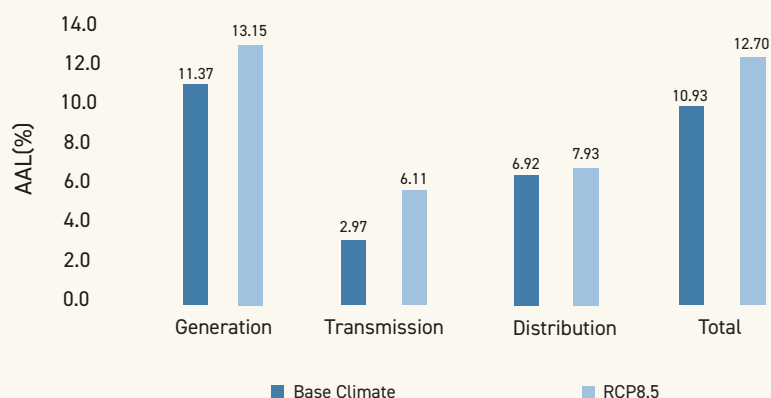


Figure 5.17: Relative average annual loss from tropical cyclone for the energy infrastructure portfolios



The AAL of each subsector is calculated by aggregating the individual losses for each exposed element. Each element in the exposure portfolio has a unique combination of location, price, and vulnerability, making its risk assessment distinct. AAL is further disaggregated by element to illustrate these differences and the individual characteristics within the risk landscape. The maps presented next demonstrate the variation in the relative AAL among the exposed elements. From Figures 5.18 to 5.22, the relative AALs are displayed for elements in the energy sector, across all hazards and climate scenarios considered.

It is noteworthy that a comprehensive dataset containing the geolocated vector information of exposed elements will be delivered to the Asian Disaster Preparedness Center (ADPC), enabling further consultation on the extensive set of results generated.



Figure 5.18: Map of relative average annual loss from floods for the energy portfolios

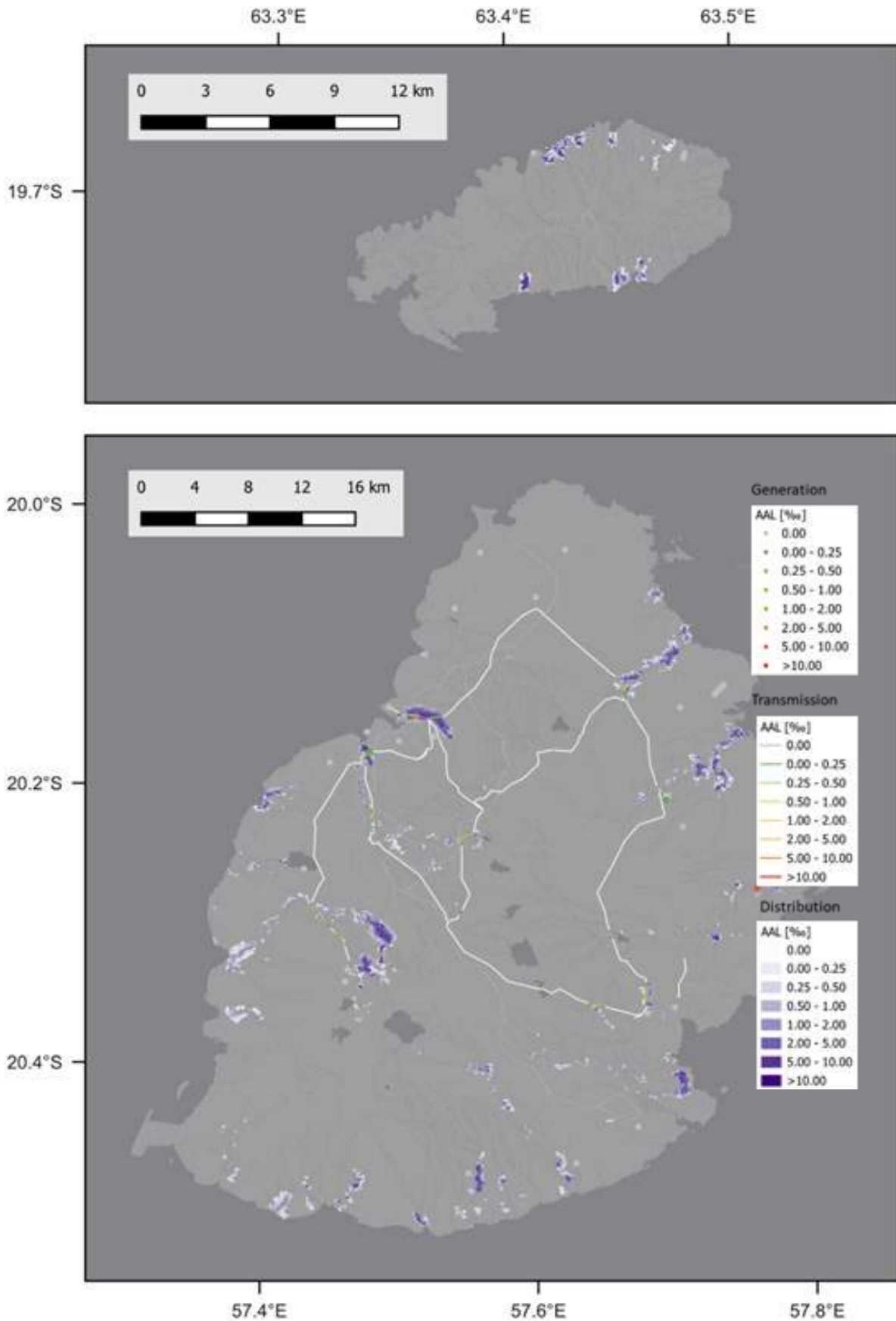


Figure 5.19: Map of relative average annual loss from floods (SSP1-RCP2.6) for the energy portfolios

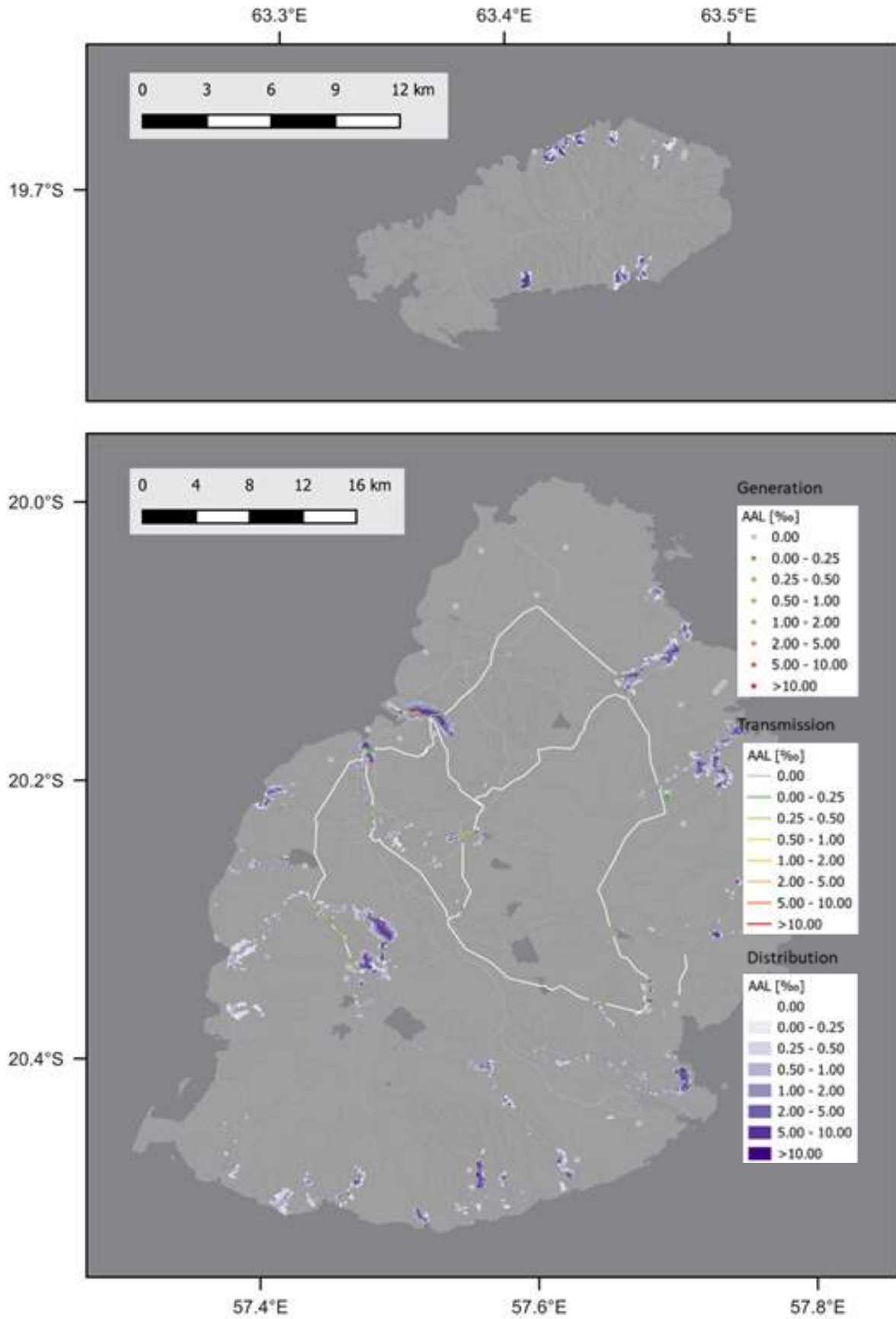


Figure 5.20: Map of relative average annual loss from floods (SSP5-RCP8.5) for the energy portfolios

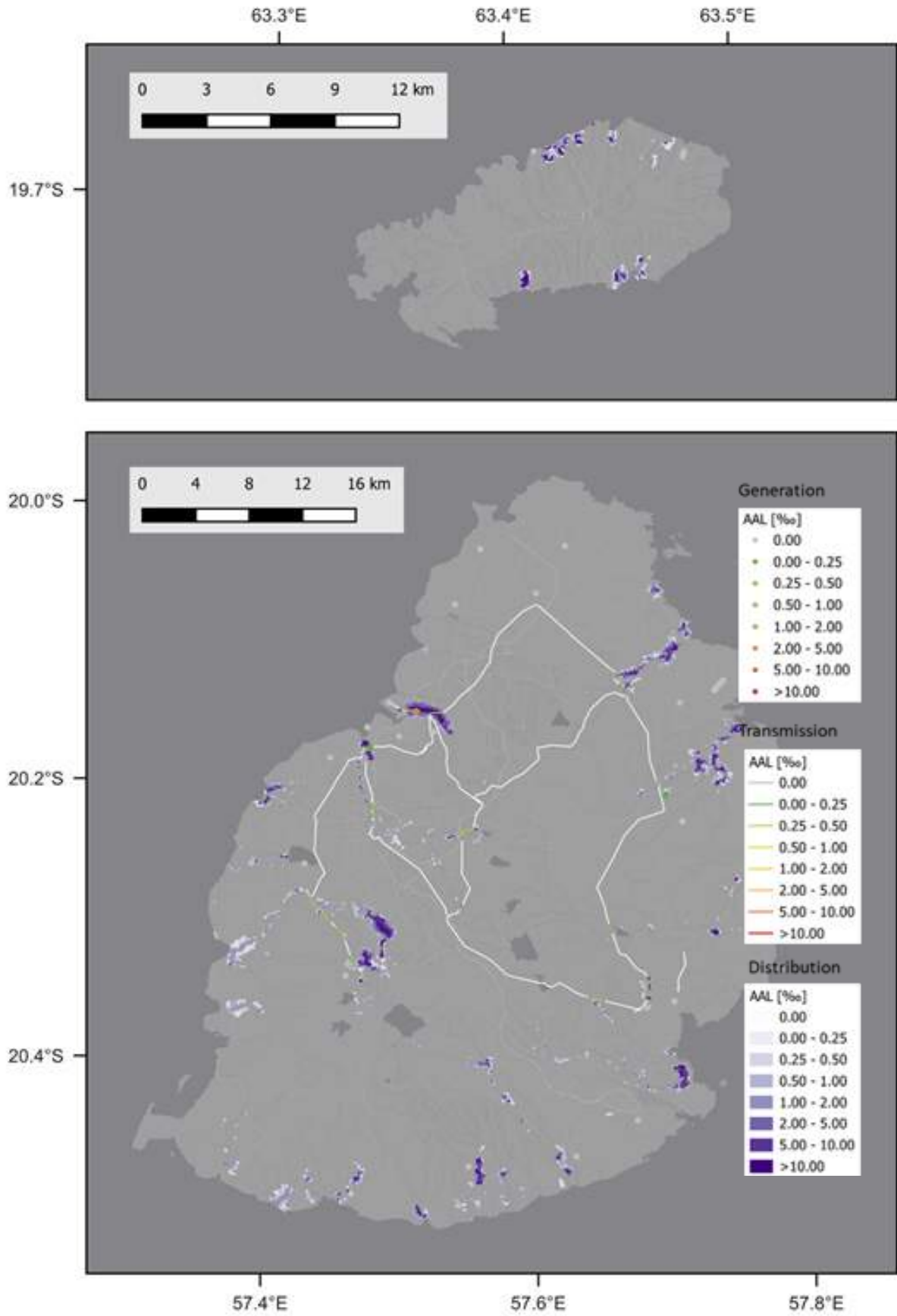


Figure 5.21: Map of relative average annual loss from tropical cyclones for the energy portfolios

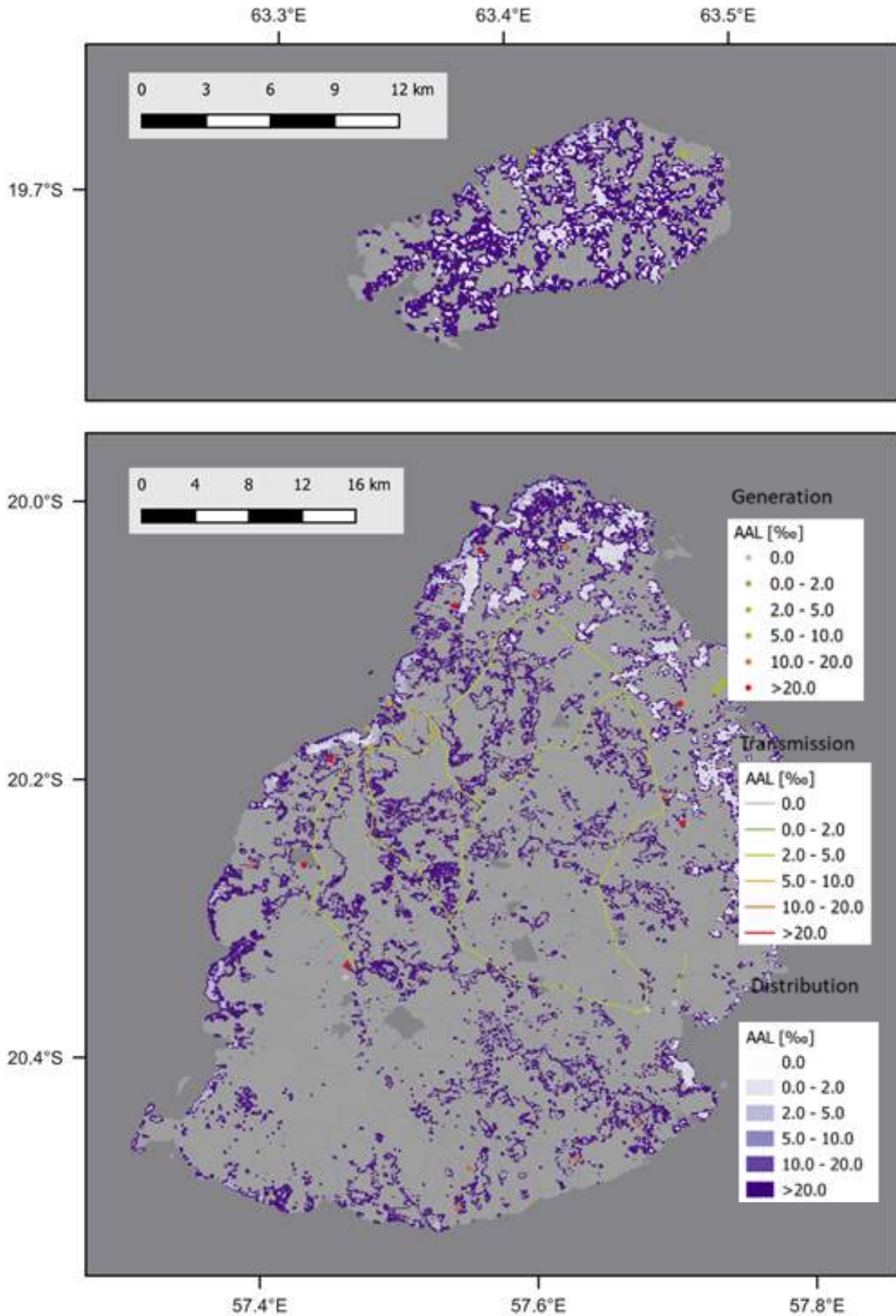


Figure 5.22: Map of relative average annual loss from tropical cyclones (SSP5-RCP8.5) for the energy portfolios

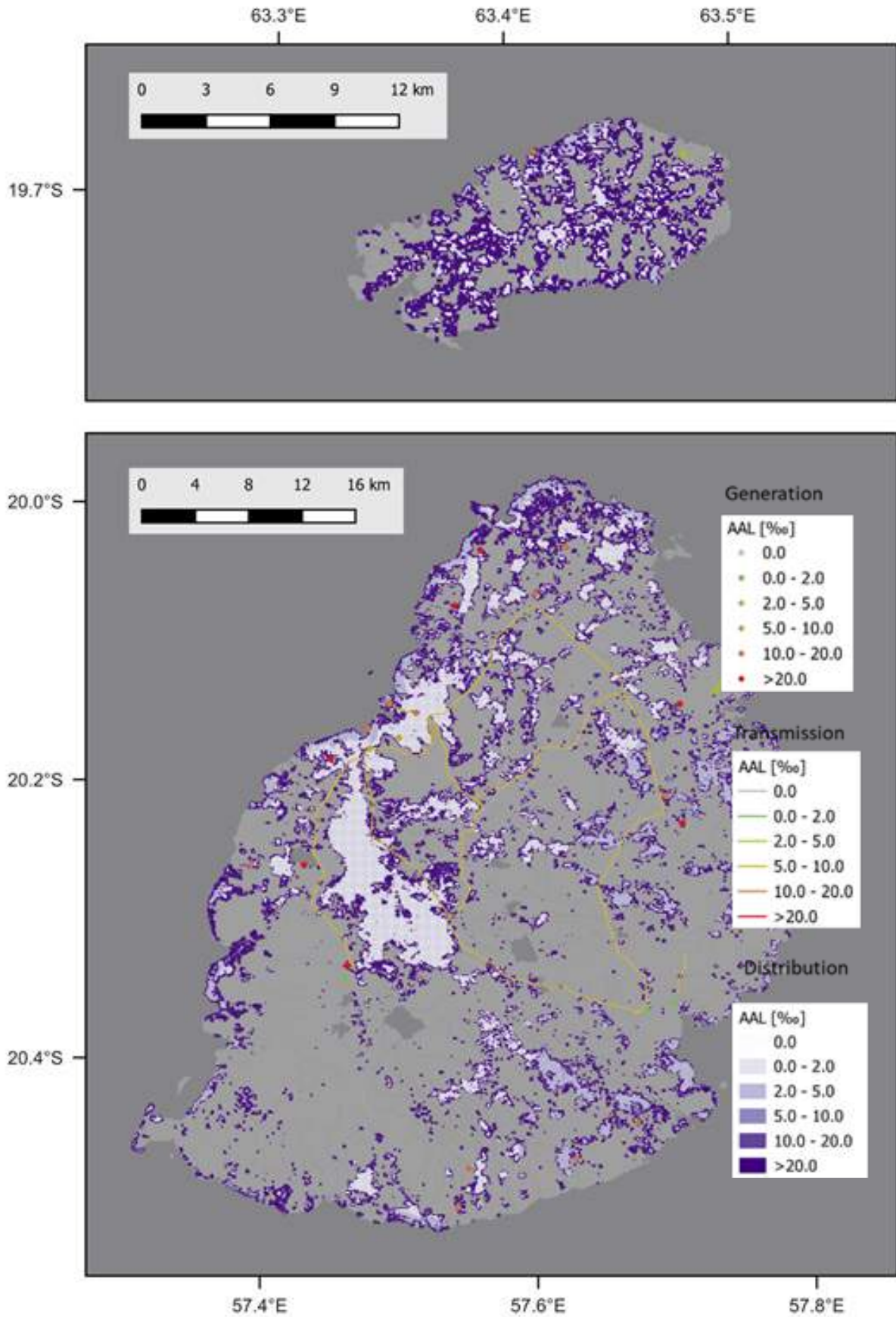
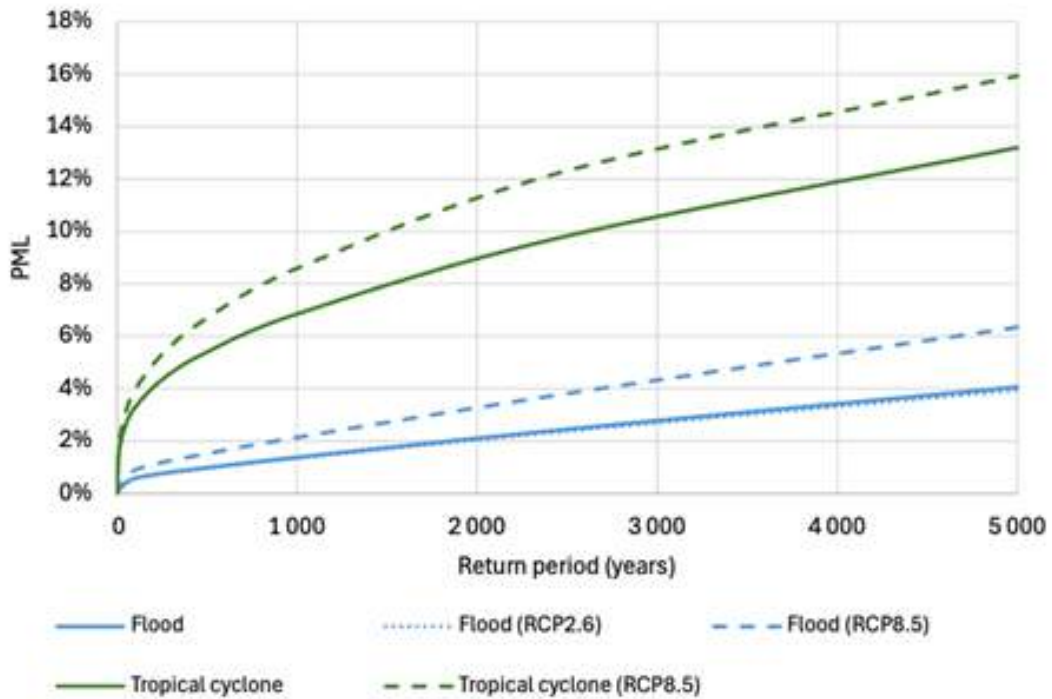


Table 5.10 presents the PML values for the energy sector of Mauritius, by hazard and for some selected return periods. PMLs are always higher in magnitude than AALs due to how they are defined and calculated. These PMLs are presented in relative terms in Figure 5.23 as PML curves, illustrating the full extent of variation of the metric with the return period. It is evident that tropical cyclones dominate the PML curve across all return periods, with a consistent increase under the SSP5-RCP8.5 climate scenario. Although flood risk is not insignificant, it remains considerably lower than the risk posed by tropical cyclones, which is expected for a territory like Mauritius.

Table 5.10: Probable maximum loss for energy sector infrastructure (values in \$)

Return period (years)	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Tropical cyclone	Tropical cyclone (RCP8.5)
10	\$1,281,000	\$1,244,000	\$1,977,000	\$19,477,000	\$22,651,000
25	\$3,048,000	\$2,960,000	\$4,705,000	\$28,223,000	\$33,242,000
50	\$5,394,000	\$5,238,000	\$8,327,000	\$35,977,000	\$42,797,000
100	\$7,926,000	\$7,696,000	\$12,241,000	\$44,843,000	\$53,913,000
250	\$10,452,000	\$10,150,000	\$16,159,000	\$59,309,000	\$72,478,000
500	\$13,416,000	\$13,029,000	\$20,773,000	\$73,758,000	\$91,377,000
1,000	\$18,836,000	\$18,294,000	\$29,226,000	\$93,575,000	\$117,362,000
2,500	\$33,465,000	32509000	52097000	\$134,214,000	\$168,243,000
5,000	\$55,556,000	53975000	86711000	\$180,229,000	\$217,639,000

Figure 5.23: Probable maximum loss curve for energy sector infrastructure



## Road Infrastructure

Table 5.11 presents the AAL for Mauritius' road sector for the hazards considered in this assessment, both in absolute and in relative terms. Note that the losses are quite similar across all hazards. The largest AAL under current climate conditions is caused by rain-triggered landslides, but under a climate scenario SSP5-RCP8.5, the highest value is for floods. This illustrates the rather non-linear relationship between greenhouse gas emissions and disaster risk, even for a small territory like Mauritius.

Table 5.11: Absolute and Relative AAL for the Roads and Bridges Infrastructure

Hazard	Average annual Loss	
	\$	%
Flood	\$1,478,000	0.18
Flood (RCP2.6)	\$1,433,000	0.18
Flood (RCP8.5)	\$2,283,000	0.28
Landslide - Rain	\$1,888,000	0.23
Landslide - Rain (RCP2.6)	\$1,948,000	0.24
Landslide - Rain (RCP8.5)	\$1,949,000	0.24

For floods (see Figure 5.24), the AAL values are relatively uniform across subsectors, with a steep increase for the climate scenario SSP5-RCP 8.5 and a slight decrease for SSP1-RCP2.6. This contrasts with the AALs for rain-triggered landslides (see Figure 5.25), which are less uniform across subsectors, with a higher incidence on tertiary and unclassified roads (likely due to concentration in rural areas), and more uniform across climates, with only negligible variations.

Figure 5.24: Relative average annual loss from flood for the road and bridges infrastructure portfolios

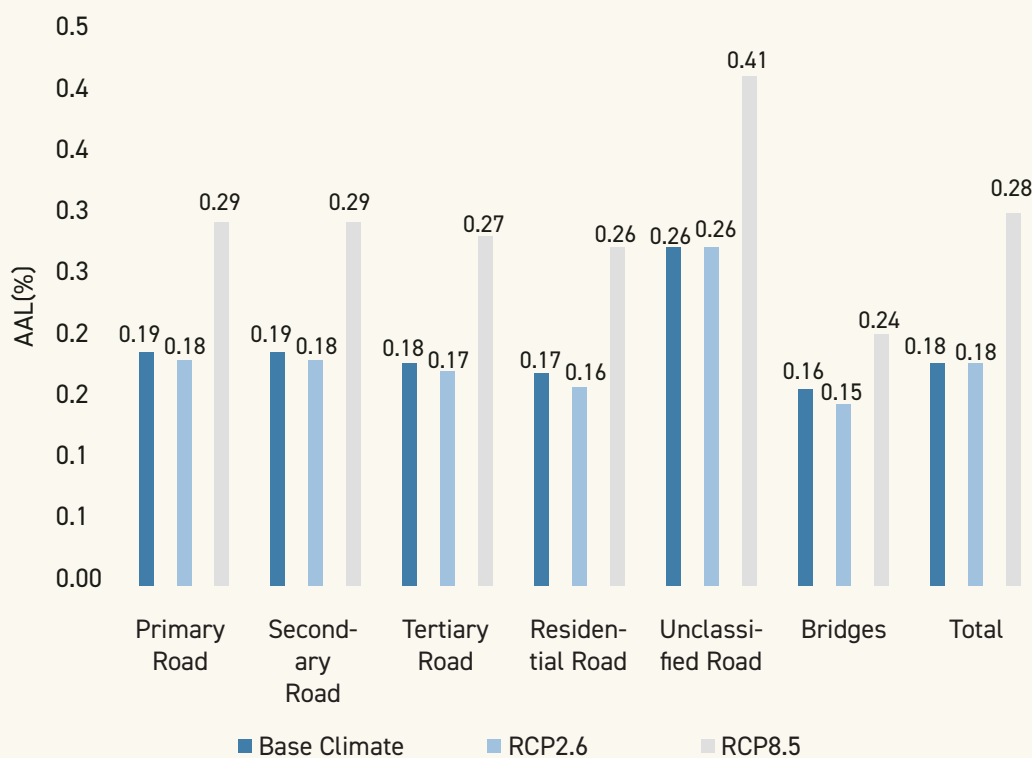
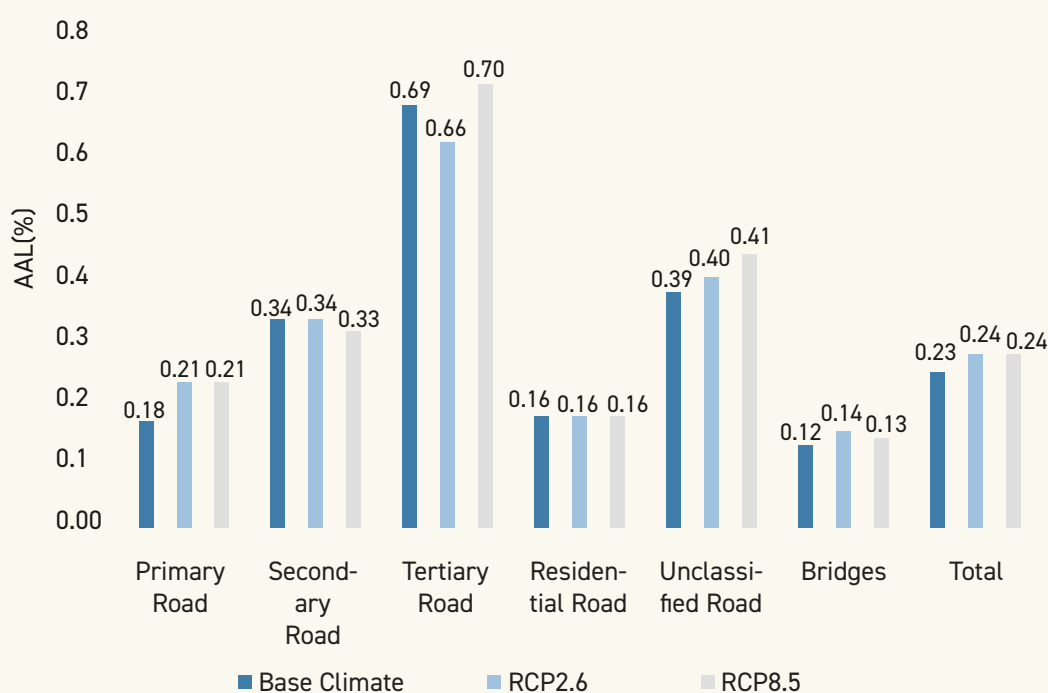


Figure 5.25: Relative average annual loss from rain-triggered landslides for the road and bridges infrastructure portfolios



The AAL of each road segment in the model is presented in Figures 5.26 to 5.31, for each hazard. The maps effectively depict the variation in the relative AAL among the exposed elements of the road network, despite the large size of the country. As mentioned earlier, a comprehensive geolocated dataset will be provided to ADPC, enabling more detailed consultation.

Figure 5.26: Map of relative average annual loss from floods for the road portfolios

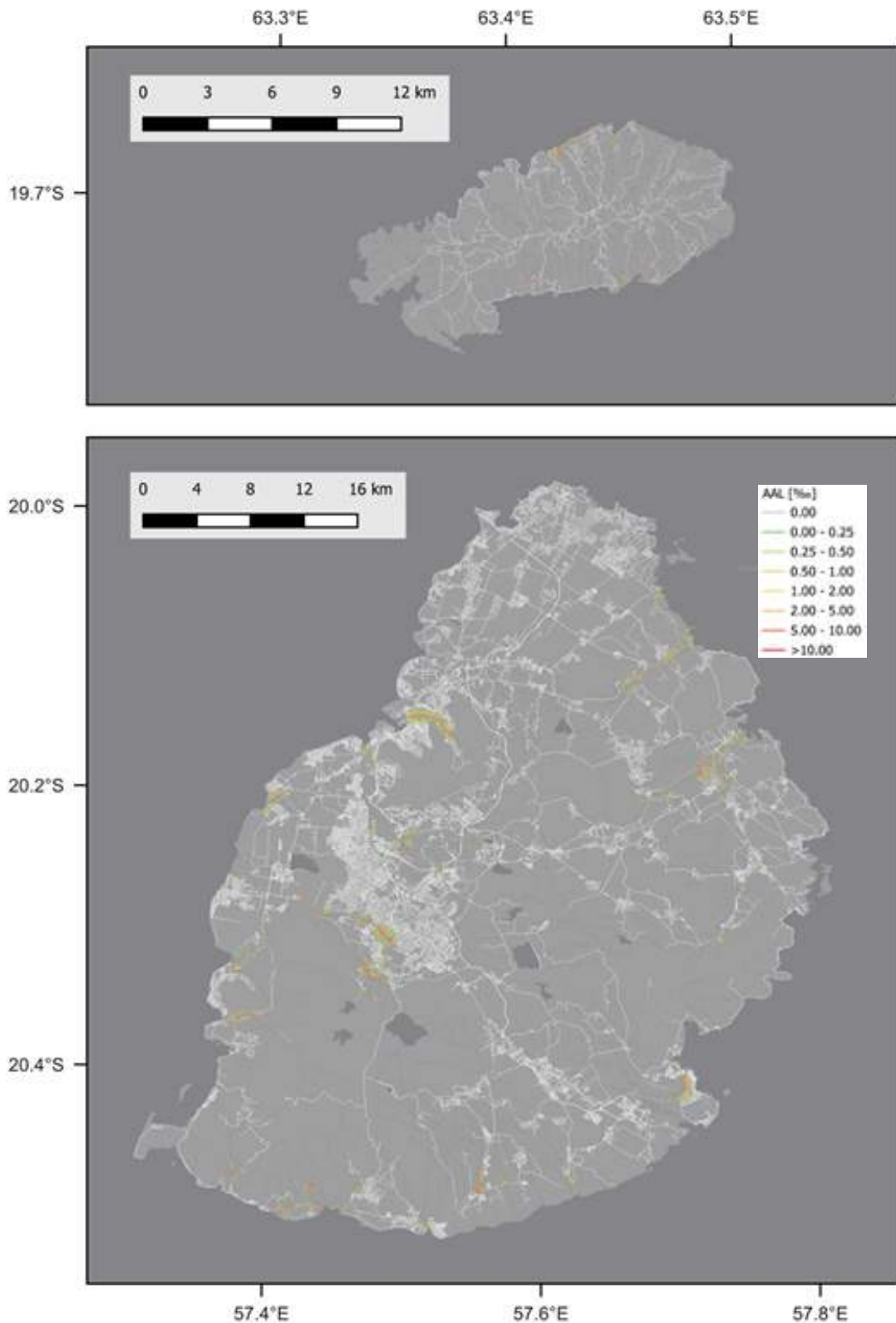


Figure 5.27: Map of relative average annual loss from floods (SSP1-RCP2.6) for the road portfolios

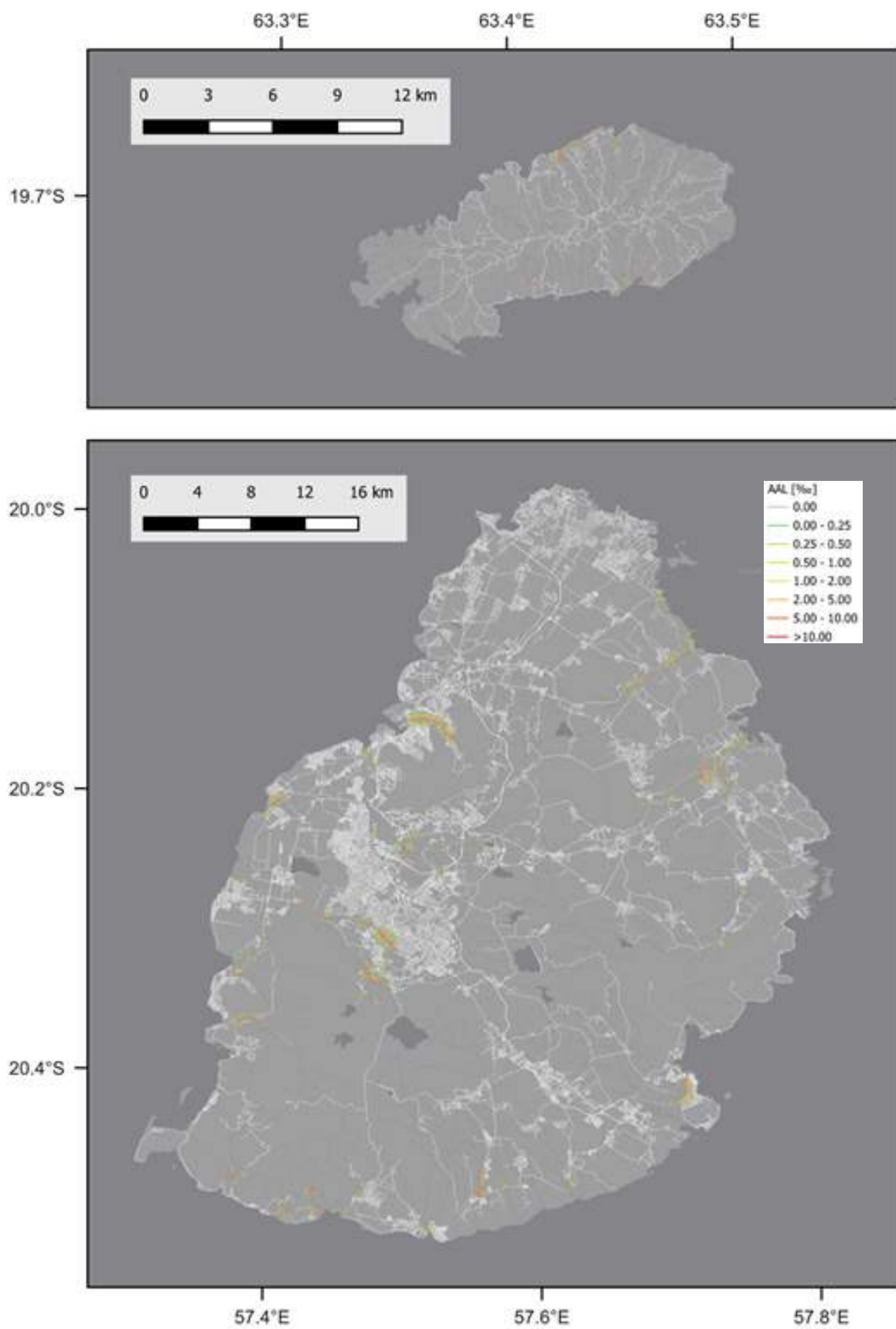


Figure 5.28: Map of relative average annual loss from floods (SSP5-RCP8.5) for the road portfolios

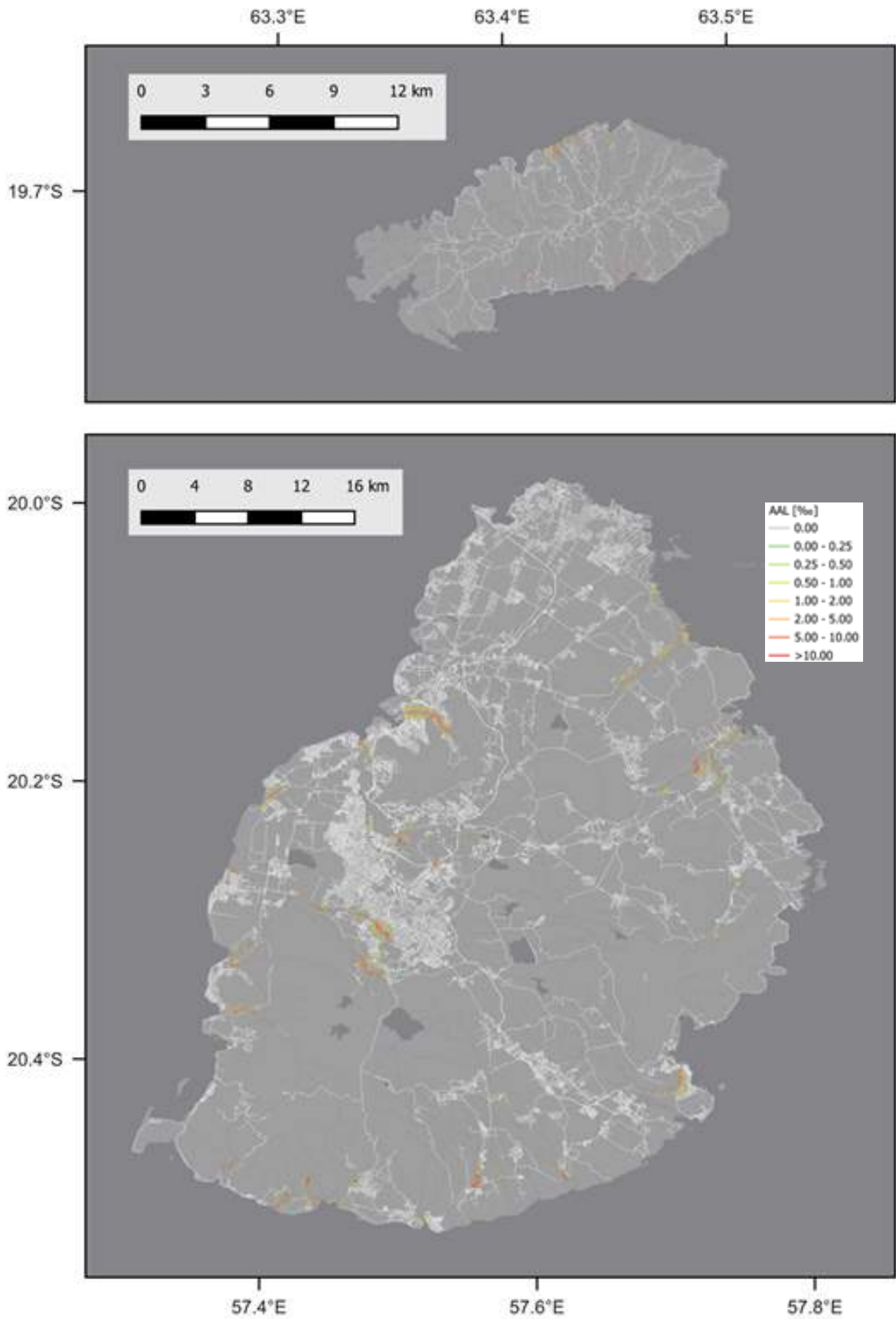


Figure 5.29: Map of relative average annual loss from rain-triggered landslides for the road portfolios

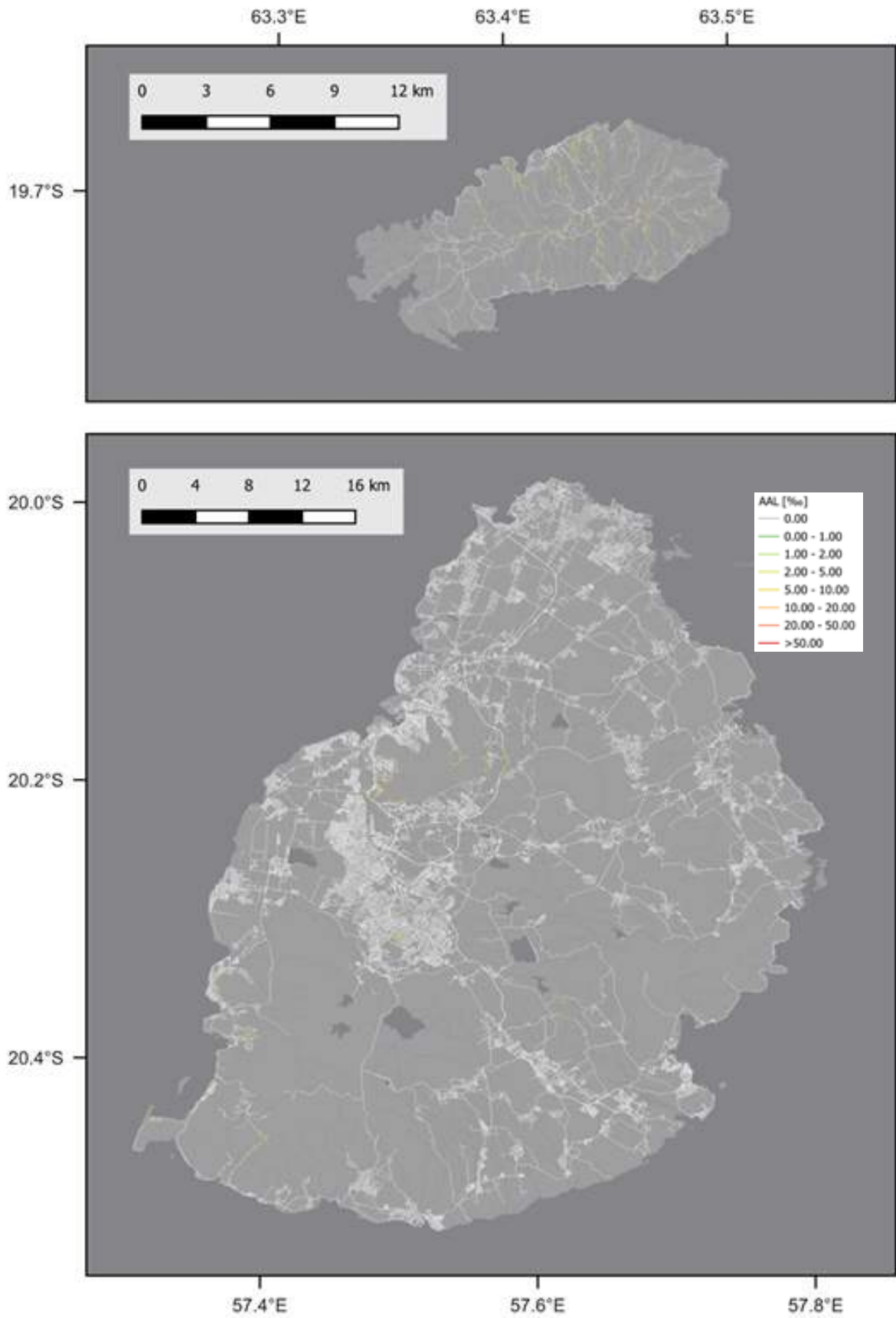


Figure 5.30: Map of relative average annual loss from rain-triggered landslides (SSP1-RCP2.6) for the road portfolios

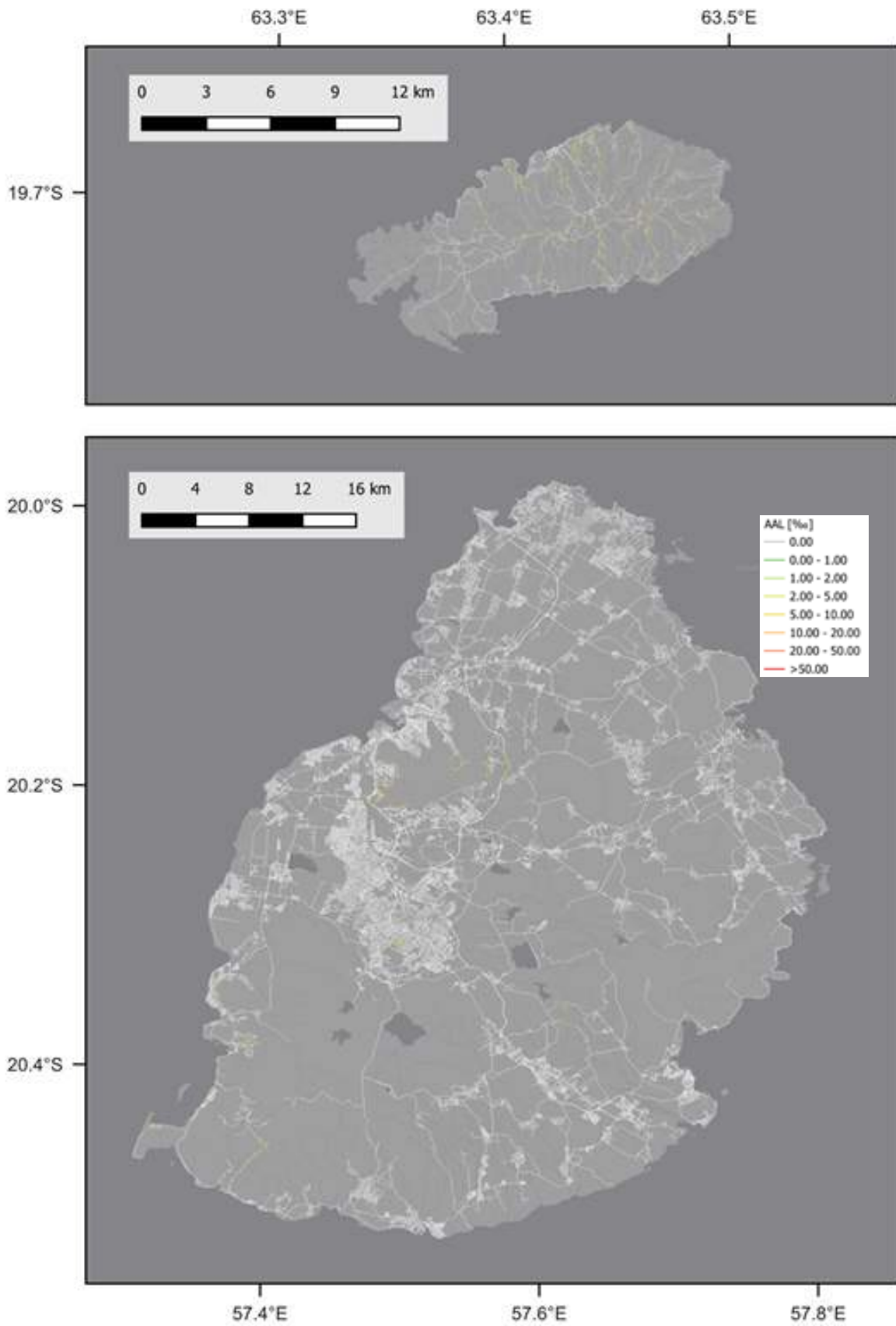


Figure 5.31: Map of relative average annual loss from rain-triggered landslides (SSP5-RCP8.5) for the road portfolios

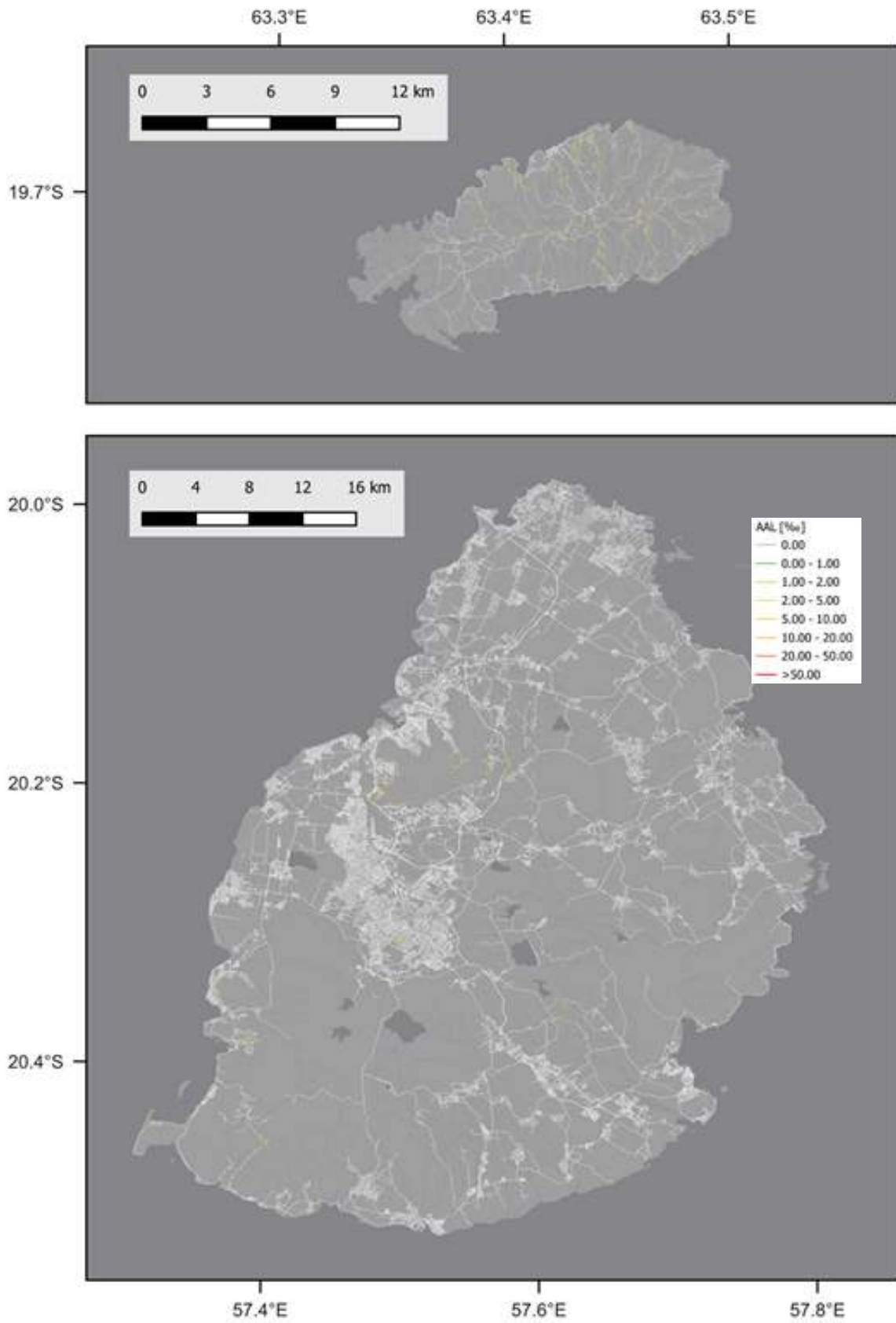


Table 5.12 presents the PML values for the Road sector of Mauritius, categorized by hazard and for some selected return periods. As mentioned, PMLs are consistently higher in magnitude than AALs across all the calculated return periods.

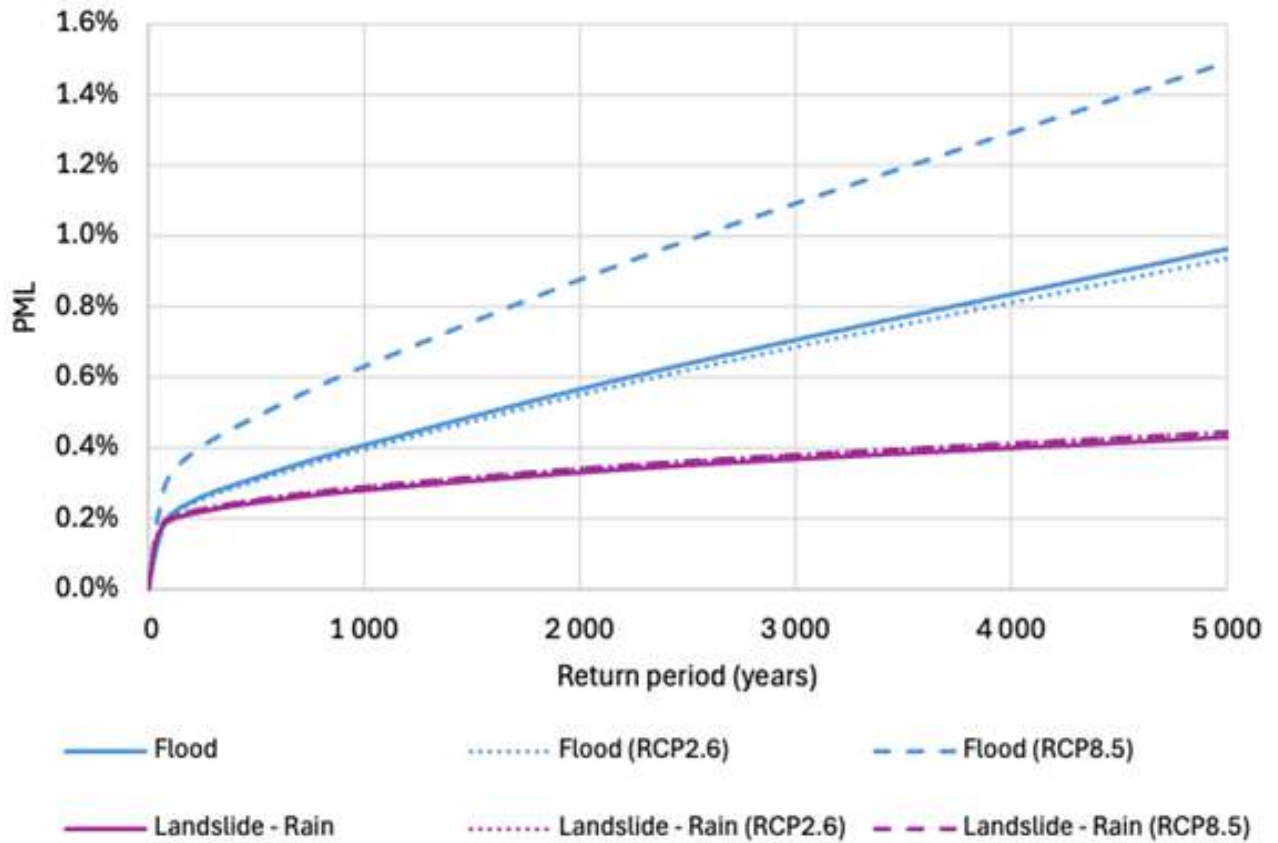
Table 5.12: Probable maximum loss for the roads and bridges infrastructure (values in thousand \$)

Return period (years)	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide - Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	\$2,809	\$2,724	\$4,340	\$3,926	\$4,050	\$4,053
25	\$6,623	\$6,422	\$10,232	\$8,535	\$8,805	\$8,812
50	\$11,622	\$11,270	\$17,956	\$13,015	\$13,427	\$13,438
100	\$16,819	\$16,310	\$25,986	\$15,728	\$16,226	\$16,238
250	\$21,128	\$20,492	\$32,652	\$17,698	\$18,257	\$18,272
500	\$25,452	\$24,691	\$39,347	\$19,723	\$20,347	\$20,363
1000	\$32,877	\$31,905	\$50,847	\$22,589	\$23,304	\$23,322
2500	\$51,488	\$49,997	\$79,682	\$28,279	\$29,173	\$29,196
5000	\$77,696	\$75,488	\$120,300	\$34,691	\$35,788	\$35,816

Figure 5.32 presents the relative PML curves for all the hazards considered. For the roads sector, flood risk is the most significant one in Mauritius, dominating the curve across all return periods. Furthermore, note that the rate of increment of the flood PML functions is much higher than the PML curve for rain-triggered landslides; the latter appears relatively flat. This is due to the frequency of individual events.



Figure 5.32: Probable maximum loss curve for the roads and bridges infrastructure



An aerial photograph of a densely populated urban area. A central street runs vertically through the middle of the frame. The buildings are multi-story and packed closely together. There are some green spaces and trees interspersed among the structures. The overall scene depicts a typical city street view from an elevated perspective.

## Chapter 6

# Post-Disaster Funding Gap Assessment

## Post-Disaster Funding Gap Assessment

Post-disaster funding gap assessment is a systematic process that identifies the available financial resources for recovery and reconstruction and estimates additional funding requirements. Conducting a timely funding gap assessment is critical to ensure affected sectors receive the necessary resources to rebuild and recover effectively and efficiently. As it is a multi-faceted process, it requires multiple perspectives to ensure fiscal resilience. There are advantages to undertaking a funding gap assessment. Funding gap assessments do the following:

**1**

Supply decision-makers with the essential data to make informed choices about where to allocate resources at different stages of recovery. By identifying funding gaps and understanding the financial requirements for various recovery initiatives, stakeholders can systematically prioritize projects and redirect funds to address new or escalating needs for efficiency and impact.

**2**

Provide a structured and data-driven approach to understanding specific financial needs for recovery. The information helps decision-makers, governments, and organizations effectively mobilize resources by advocating for additional funding from various sources, including government budgets, international donors, private sector partnerships, grants, and loans.

**3**

Can be used to advocate for additional funding from governments, international organizations, donors, and the private sector. Resource mobilization is a pivotal component of ensuring efficient disaster recovery, and funding gap assessments play a crucial role in this process. It also guides stakeholders in identifying which resources are most critical and how they can be leveraged strategically to support recovery initiatives.

**4**

Enhance transparency and accountability during the recovery process. Stakeholders can monitor how funds are allocated and utilized, reducing the risk of corruption and mismanagement.

**5**

Help ensure that there are no unnecessary bottlenecks in funding availability, enabling a quicker and more efficient response to recovery needs without delay.

**6**

Enable international donors and humanitarian organizations to target their aid and donations more effectively. They can channel their resources to areas with the greatest need, maximizing the impact of their assistance.

Disasters pose serious fiscal risks to Mauritius. Unexpected shocks can cause significant challenges that may disrupt the government's finances, severely impacting the economy's smooth functioning.

### Fiscal Risks from Disasters in Mauritius

The contingencies and reserve component is part of Mauritius' national budget set aside to cover unforeseen expenditures, such as hazard-related disasters or economic shocks, including emergency relief (food, shelter, rescue) and post-disaster reconstruction and rehabilitation. During the recent devastating disaster in the country, tropical cyclone Belal in January 2024, where severe flooding turned streets into rivers, particularly in Port Louis, the estimated total damages amounted to approximately MUR 5.8 billion (around \$131 million), with the agricultural sector incurring losses of about MUR 1.8 billion (approximately \$40.7 million).

### Estimating Future Funding Gaps for Power, Roads and Bridges

#### Government Reserves

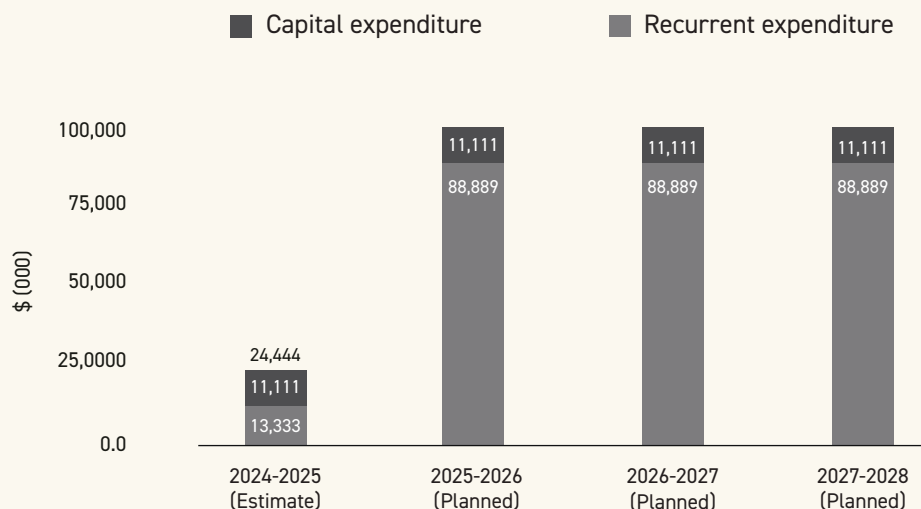
The government allocated MUR 1 billion (about \$22.6 million) to support victims and repair infrastructure (Wikipedia 2025). Apparently, government reserves are insufficient to meet all post-disaster needs. In subsequent years, the government has allocated contingencies and reserves as shown in Table 6.1 and Figure 6.1.

Table 6.1: Total contingencies and reserves in the budget (at \$ = 45 MUR)

Year	Contingencies and Reserves	
	MUR (000)	\$ (000)
2024–25 (Estimate)	1,100,000	24,444
Recurrent expenditure	600,000	13,333
Capital expenditure	500,000	11,111
2025–2026 (Planned)	4,500,000	100,000
Recurrent expenditure	4,000,000	88,889
Capital expenditure	500,000	11,111
2026–2027 (Planned)	4,500,000	100,000
Recurrent expenditure	4,000,000	88,889
Capital expenditure	500,000	11,111
2027–2028 (Planned)	4,500,000	100,000
Recurrent expenditure	4,000,000	88,889
Capital expenditure	500,000	11,111

Source: Ministry of Finance, Economic Planning and Development, Mauritius (n.d.)

Figure 6.1: Total contingencies and reserves in the Mauritius budget (at \$ = 45 MUR)



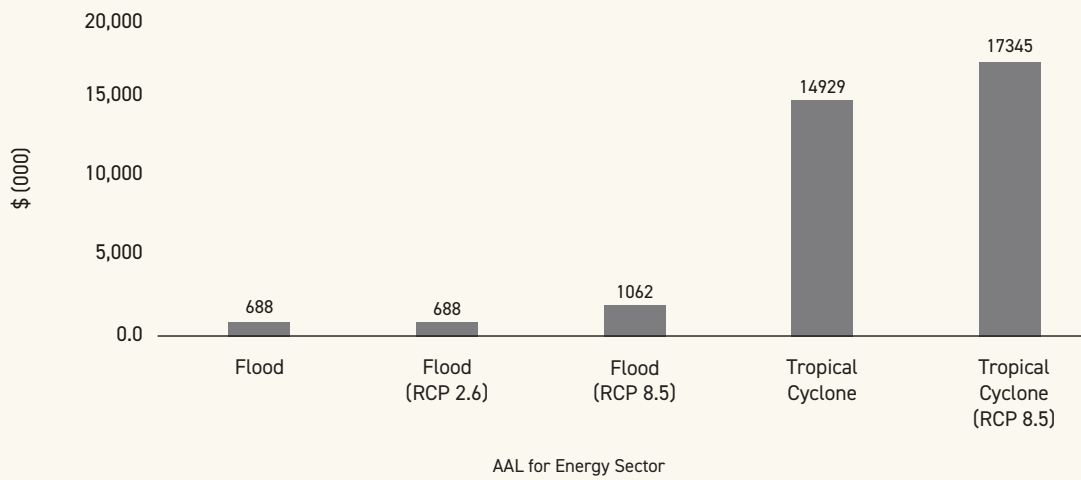
The contingencies and reserves component of the budget is a provision for urgent and unforeseen expenditures, including disasters or other emergencies requiring exceptional spending (Republic of Mauritius 1973). As there is no specific breakdown of expenditures for this component, the analysis in this report will consider the total amount of contingencies and reserves, as well as separately analyze the capital expenditure in relation to post-disaster needs.

As mentioned in the catastrophe model section, the average annual loss for the energy sector in Mauritius is shown in Table 6.2 and Figure 6.2.

Table 6.2: AALs from various hazards in Mauritius for the energy sector

Average Annual Loss (in \$ '000)					
Hazard	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Tropical Cyclone	Tropical Cyclone (RCP8.5)
AAL Value	688	688	1,062	14,929	17,345

Figure 6.2: Average annual loss for energy sector by hazard and climate change scenario (in \$ '000)

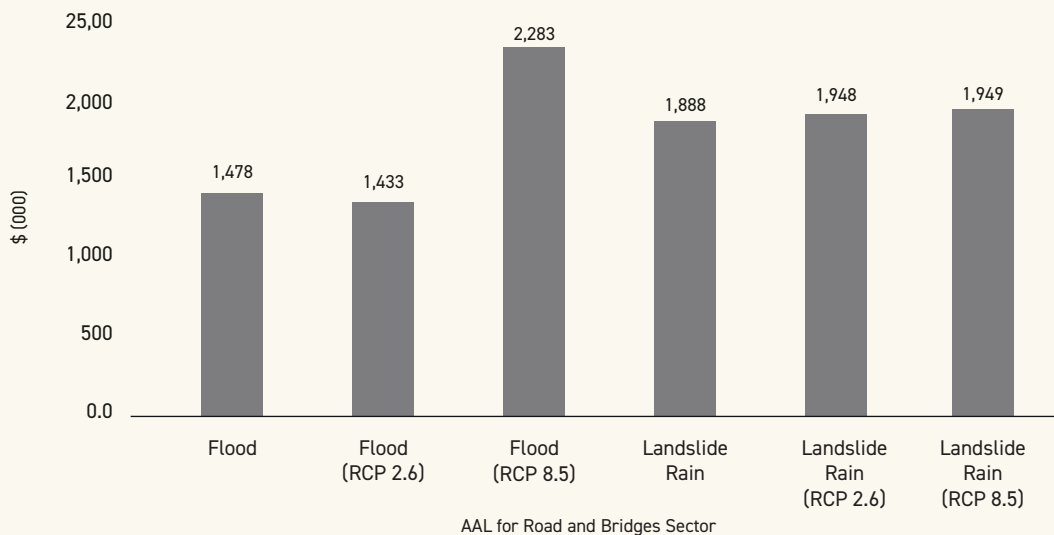


On the other hand, the AALs for various hazards to roads and bridges are shown in Table 6.3 and Figure 6.3.

Table 6.3: AALs from various hazards in Mauritius for roads and bridges sector

Average Annual Loss (in \$ '000)						
Hazard	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide - Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
AAL Value	1,478	1,433	2,283	1,888	1,948	1,949

Figure 6.3: Average annual loss for roads and bridges sector by hazard and climate change scenario (in \$ '000)



To analyze the potential funding gap on an annual basis, the following cases are considered:

#### Case 1.

The total allocated budget for contingencies and reserves is available to fund the post-disaster needs of the energy and roads and bridges sectors.

#### Case 2.

Only the capital expenditure component of the total budget allocated for contingencies and reserves may be utilized for the post-disaster needs of the two sectors.

#### Case 3.

Tropical cyclones will cause the highest AAL for the energy sector, while for roads and bridges, it will be rain-induced landslides.

#### Case 4.

It is assumed that climate change will not affect the intensity of the hazards.

Based on the information above, Table 6.4 shows the gap/surplus.

Table 6.4: Funding gap with total contingency reserve vs capital expenditure

Year	Contingencies and Reserves		Energy AAL	R&B AAL	Gap/Surplus	
	MUR (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)	MUR (000)
2025–26 (planned)	4,500,000	100,000	14,929	1,888	83,183	3,743,235
Recurrent expenditure	4,000,000	88,889				
Capital expenditure	500,000	11,111	14,929	1,888	-5,706	-256,765

Table 6.4 shows that the total government budget for contingencies and reserves will be sufficient to meet the post-disaster needs of the energy, roads, and bridges sectors. However, there will be a significant funding gap if only the capital expenditure component of the contingencies and reserves budget is used for post-disaster activities.

However, if the total contingencies and reserves increase by 10 percent annually, the funding gap will be bridged by the allocation of the corresponding capital expenditures by 2031, as shown in Table 6.5.

Table 6.5: Funding difference with 10 percent annual increase in contingency reserves and capital expenditure with the AALs for energy and roads and bridges

Year	Source of Funds		Annual Average Loss		Gap/Surplus	
	Total Contingencies and Reserve	Capital Expenditures Allocation	Energy	Roads and Bridges	With Total Contingencies and Reserve	With Capital Expenditures
	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)
2026–27	100,000	11,111	14,929	1,888	83,183	-5,706
2027–28	110,000	12,222	14,929	1,888	93,183	-4,595
2028–29	121,000	13,444	14,929	1,888	104,183	-3,373
2029–30	133,100	14,789	14,929	1,888	116,283	-2,028
2030–31	146,410	16,268	14,929	1,888	129,593	-549
2031–32	161,051	17,894	14,929	1,888	144,234	1,077
2032–33	177,156	19,684	14,929	1,888	160,339	2,867
2033–34	194,872	21,652	14,929	1,888	178,055	4,835
2034–35	214,359	23,817	14,929	1,888	197,542	7,000

## Extreme Cases

When analysing extreme cases, the potential post-disaster funding gaps are estimated using the values in the PML. The PMLs caused by various hazards across different return periods are presented in Table 6.6 and Figure 6.4.

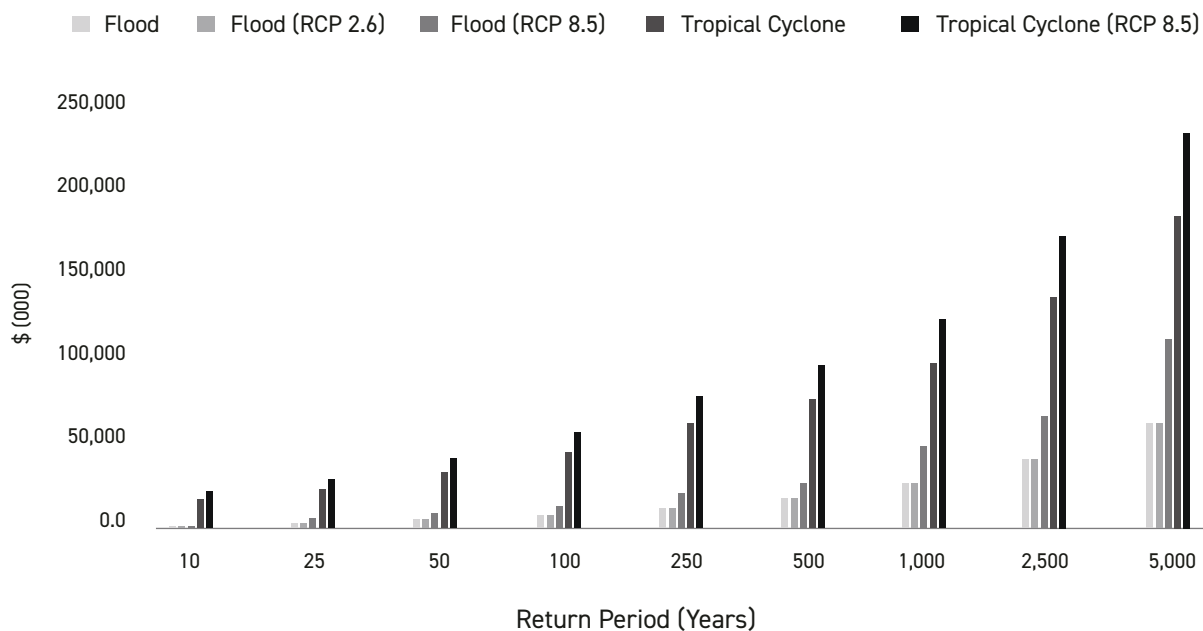
The highest PMLs for the energy sector are expected to be caused by tropical cyclones, especially in the context of climate change at RCP8.5, as shown in Table 6.6.



Table 6.6: Probable maximum loss for the energy sector infrastructure (in \$ '000)

Return Period (years)	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Tropical Cyclone	Tropical Cyclone (RCP8.5)
10	1,281	1,244	1,977	19,477	22,651
25	3,048	2,960	4,705	28,223	33,242
50	5,394	5,238	8,327	35,977	42,797
50	7,926	7,696	12,241	44,843	53,913
250	10,452	10,150	16,159	59,309	72,478
500	13,416	13,029	20,773	73,758	91,377
1,000	18,836	18,294	29,226	93,575	117,362
2,500	33,465	32,509	52,097	134,214	168,243
5,000	55,556	53,975	86,711	180,229	217,639

Figure 6.4: Probable maximum loss for energy sector by hazard type (in \$ '000)

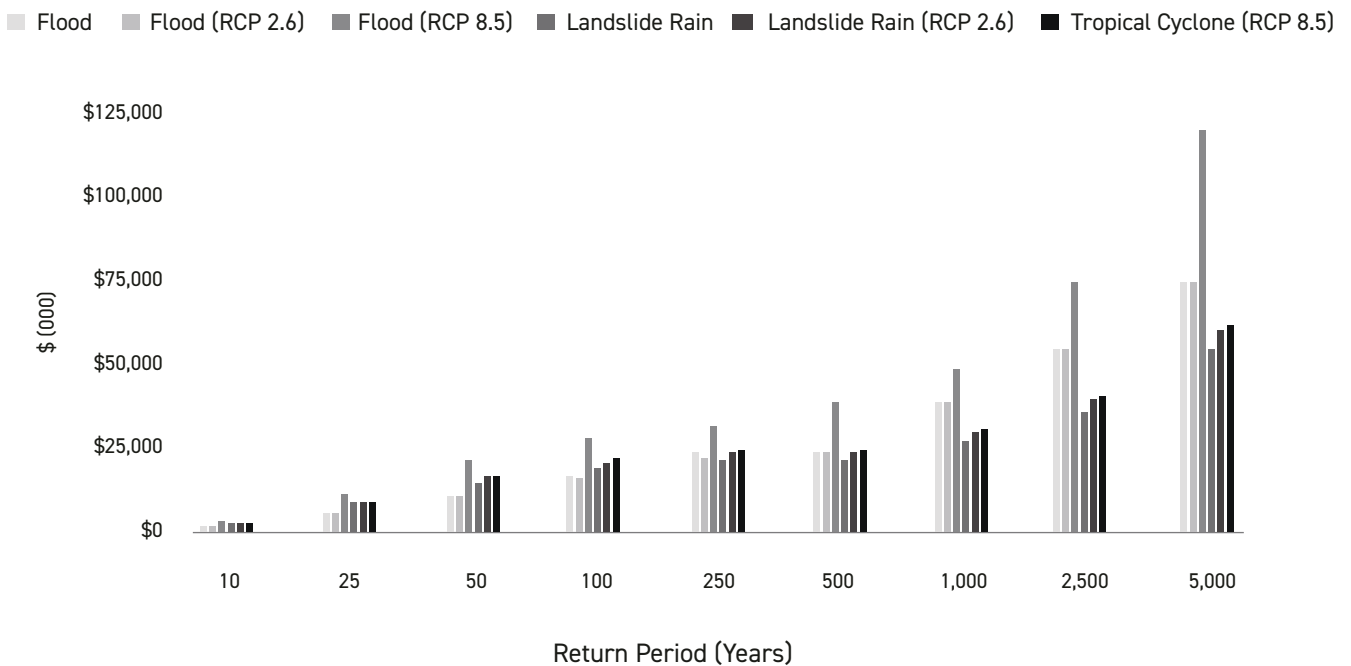


The PML for the roads and bridges sector will be caused by rain-induced landslides with return periods of 10 to 50 years, while floods with return periods of more than 50 years have higher PMLs, especially with the effect of climate change at RCP8.5, as shown in Table 6.7 and Figure 6.5.

Table 6.7: Probable maximum loss for roads and bridges (in \$ '000)

Return Period (years)	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide - Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	2,809	2,724	4,340	3,926	4,050	4,053
25	6,623	6,422	10,232	8,535	8,805	8,812
50	11,622	11,270	17,956	13,015	13,427	13,438
50	16,819	16,310	25,986	15,728	16,226	16,238
250	21,128	20,492	32,652	17,698	18,257	18,272
500	25,452	24,691	39,347	19,723	20,347	20,363
1,000	32,877	31,905	50,847	22,589	23,304	23,322
2,500	51,488	49,997	79,682	28,279	29,173	29,196
5,000	77,696	75,488	120,300	34,691	35,788	35,816

Figure 6.5: Probable maximum loss for roads and bridges by hazard (in \$ '000)



In analysing the potential post-disaster funding gap by PML, the following scenarios are considered.

### Scenario 1.

Hazards with a return period of 10 years, excluding climate change effects that occur in the same year, say 2026–27. The following assumptions are considered.

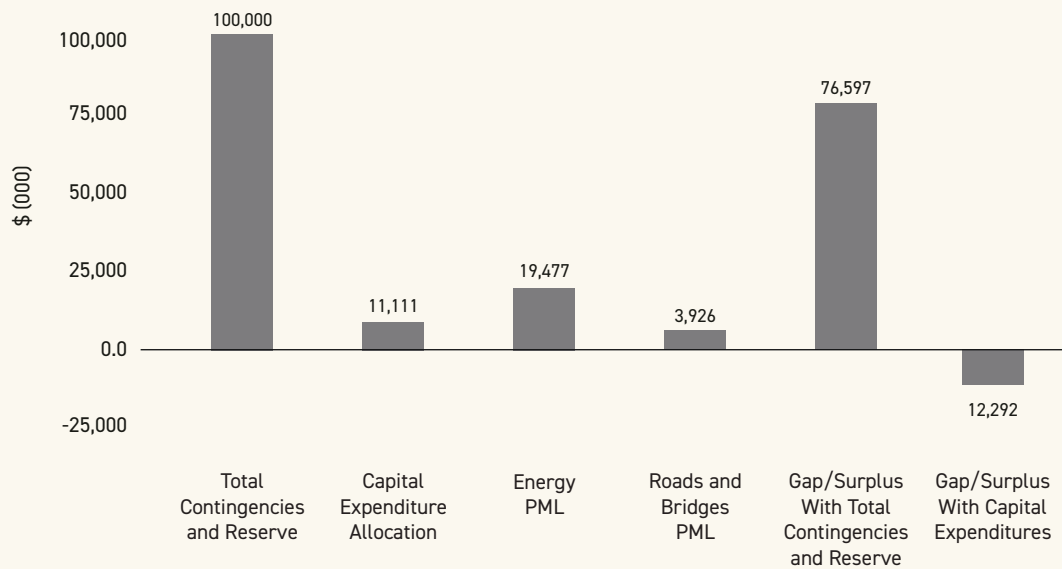
- The highest PML for the energy sector is expected to be caused by tropical cyclones, valued at around \$19,477,000, which could increase to \$22,651,000 under the RCP8.5 scenario with a return period of 10 years.
- Landslides caused by rain have the highest PML for roads and bridges for hazards with a return period of 10 years, amounting to about \$3,926,000, which could reach \$4,053,000 under the RCP8.5 scenario.
- The total value of contingencies and reserves, as well as the capital expenditures, was used separately and compared to the PMLs.

Using the figures mentioned above (tropical cyclones for the energy sector and landslides due to rain for roads and bridges), Table 6.8 illustrates that the total contingency reserves can accommodate the PMLs for the energy and roads and bridges sectors for hazards with a 10-year return period. On the other hand, a significant funding gap (\$12 million or MUR 553 million) will exist if only the capital expenditures allocation is designated for post-disaster response.

Table 6.8: Funds and PMLs for energy, roads and bridges with 10-year return period

Year	Source of Funds		Probable Maximum Loss		Gap/Surplus	
	Total Contingencies and Reserve	Capital Expenditures Allocation	Energy	Roads and Bridges	With Total Contingencies and Reserve	With Capital Expenditures
	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)
2026–27	100,000	11,111	19,477	3,926	76,597	-12,292

Figure 6.6: Funds and PMLs for energy and roads and bridges with 10-year return period



Scenario 2.

Hazards with different return periods occurring without climate change projected effects, and with the highest PMLs occurring in the same year. This considers the following:

- Hazards with the highest PMLs by different return periods occurring in the same year affecting the energy and roads and bridges sectors. For the energy sector, tropical cyclones with various return periods will have the highest PMLs. For roads and bridges, rain-induced landslides with return periods of up to 50 years will have the higher PMLs, but floods with return periods of 100 to 5,000 years will have the highest PMLs.
- The gap or surplus is calculated separately based on the total contingencies and reserves budget of \$100 million, and the capital expenditure of only \$11.111 million.

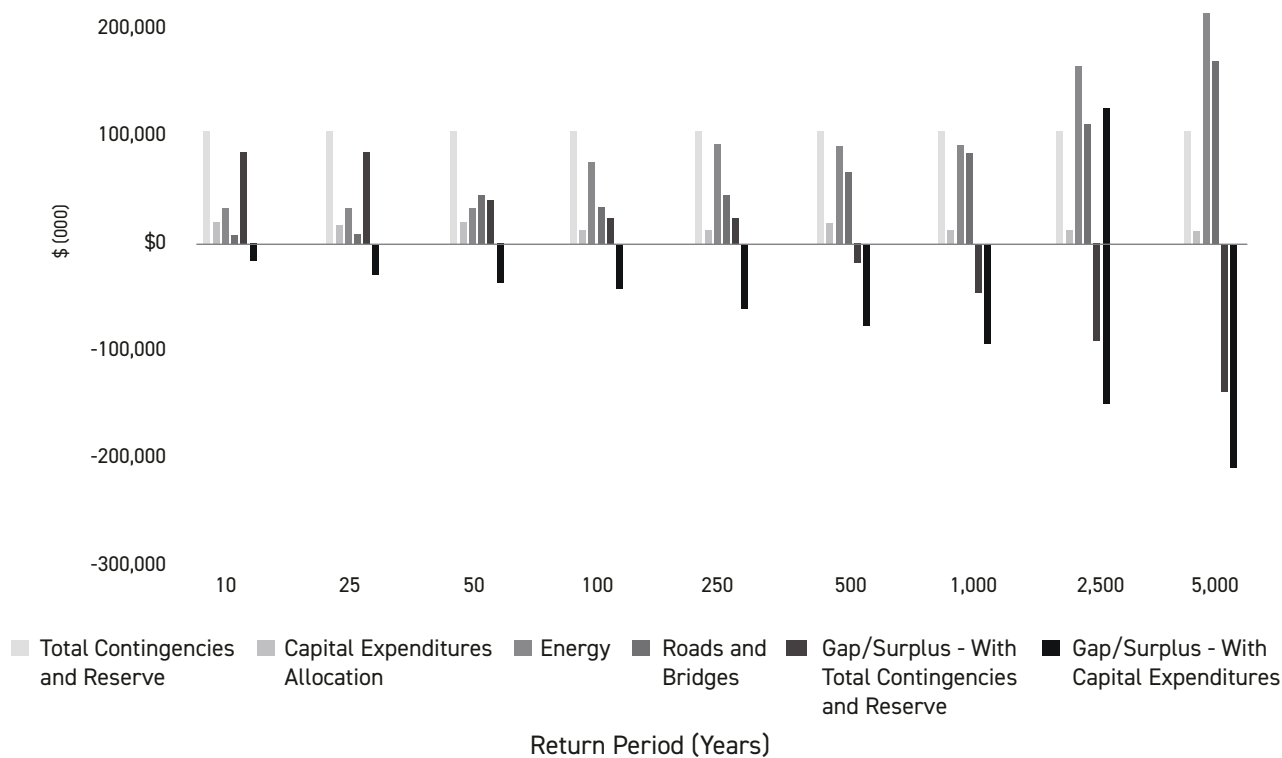
Table 6.9 shows the funding gap for hazards (without climate change impacts) with the highest PMLs by return period.



Table 6.9: Funding gap based on highest PMLs by return period (no climate change)

Return Period  Years	Source of Funds		Probable Maximum Loss		Gap/Surplus	
	Total Contingencies and Reserve	Capital Expenditures Allocation	Energy	Roads and Bridges	With Total Contingencies and Reserve	With Capital Expenditures
	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)
10	100,000	11,111	19,477	3,926	76,597	-12,292
25	100,000	11,111	28,223	8,535	63,242	-25,647
50	100,000	11,111	35,977	13,015	51,008	-37,881
100	100,000	11,111	44,843	16,819	38,338	-50,551
250	100,000	11,111	59,309	21,128	19,563	-69,326
500	100,000	11,111	73,758	25,452	790	-88,099
1,000	100,000	11,111	93,575	32,877	-26,452	-115,341
2,500	100,000	11,111	134,214	51,488	-85,702	-174,591
5,000	100,000	11,111	180,229	77,696	-157,925	-246,814

Figure 6.7: Funding gap based on highest PMLs by return period (no climate change)



Based on the above estimates, the total budget allocated for contingencies and reserves seems sufficient to address the post-disaster needs of the energy and roads and bridges sectors, up to hazards with a 500-year return period. However, the capital expenditure allocation alone will not be sufficient to cover the post-disaster requirements of these two sectors.

### Scenario 3.

The contingency reserves and capital expenditures allocations for disasters in Mauritius will increase by 10 percent annually. This scenario considers the following:

- As mentioned earlier, the total contingency reserve is \$100,000,000, and the capital expenditure for Mauritius totals \$11,111,000.
- The hazards with 10-year return periods with the highest PMLs (without climate change effects) will occur in the same year.

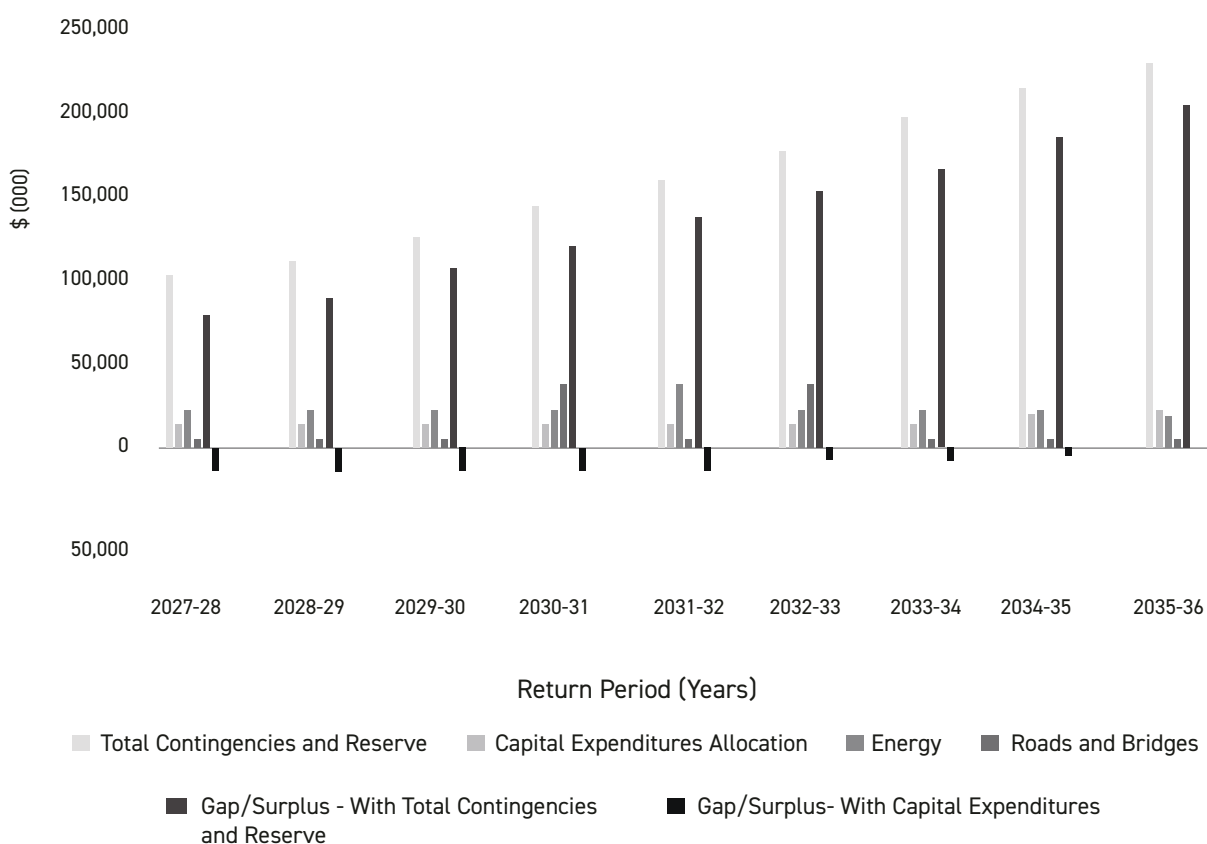
Based on these assumptions, Table 6.10 shows that the total contingencies and reserves would be more than sufficient to meet the post-disaster needs of the energy and roads and bridges sectors. However, if capital expenditure were the only funding source, even with a 10 percent annual increase, the gap between post-disaster needs and available funds would not be closed until 2035–36.

Table 6.10: Funding difference with 10 percent annual increase in contingency reserves and capital expenditure with the PMLs for energy and roads and bridges

Years	Source of Funds		Probable Maximum Loss		Gap/Surplus	
	Total Contingencies and Reserve	Capital Expenditures Allocation	Energy	Roads and Bridges	With Total Contingencies and Reserve	With Capital Expenditures
	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)
2027–28	100,000	11,111	19,477	3,926	76,597	-12,292
2028–29	110,000	12,222	19,477	3,926	86,597	-11,181
2029–30	121,000	13,444	19,477	3,926	97,597	-9,959
2030–31	133,100	14,789	19,477	3,926	109,697	-8,614
2031–32	146,410	16,268	19,477	3,926	123,007	-7,135

2032-33	161,051	17,894	19,477	3,926	137,648	-5,509
2033-34	177,156	19,684	19,477	3,926	153,753	-3,719
2034-35	194,872	21,652	19,477	3,926	171,469	-1,751
2035-36	214,359	23,817	19,477	3,926	190,956	414

Figure 6.8: Funding difference with 10 percent annual increase in contingency reserves and capital expenditure with the PMLs for energy and roads and bridges



Scenario 4.

The contingency reserves and capital expenditure allocations for disasters in Mauritius will increase by at least 10 percent annually, with hazards of various return periods and the highest PMLs occurring in the same year. This scenario considers the following:

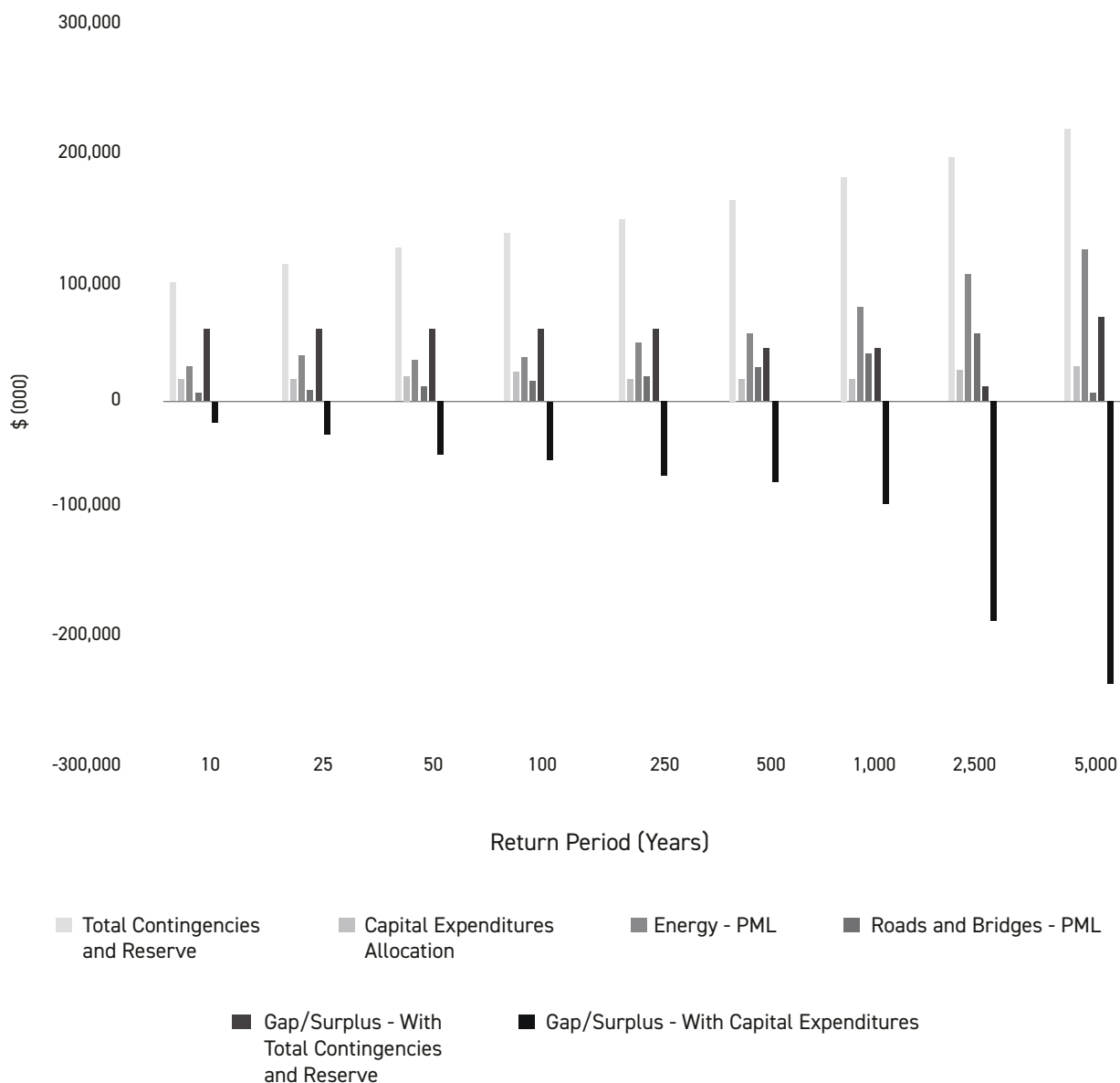
- The total contingency reserve is \$100,000,000, and the capital expenditure of Mauritius, amounting to a total of \$11,111,000, will increase by 10 percent annually.
- The hazards with different return periods with the highest PMLs (excluding climate change effects) will occur in the same year.

Based on these assumptions, Table 6.11 demonstrates that total contingencies and reserves would be adequate to meet the post-disaster needs of the energy and roads and bridges sectors, even in hazards with return periods of 2,500 years occur within the same year. Conversely, if capital expenditure were the only funding source, a gap between post-disaster needs and available funds would persist every year, despite a 10 percent annual increase.

Table 6.11: Funding gap based on highest PMLs by return period and a 10 percent increase in total contingencies and capital expenditure allocation

Return Period (Years)	Source of Funds		Probable Maximum Loss		Gap/Surplus	
	Total Contingencies and Reserve	Capital Expenditures Allocation	Energy	Roads and Bridges	With Total Contingencies and Reserve	With Capital Expenditures
	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)	\$ (000)
10	100,000	11,111	19,477	3,926	76,597	-12,292
25	110,000	12,222	28,223	8,535	73,242	-24,536
50	121,000	13,444	35,977	13,015	72,008	-35,548
100	133,100	14,789	44,843	16,819	71,438	-46,873
250	146,410	16,268	59,309	21,128	65,973	-64,169
500	161,051	17,894	73,758	25,452	61,841	-81,316
1,000	177,156	19,684	93,575	32,877	50,704	-106,768
2,500	194,872	21,652	134,214	51,488	9,170	-164,050
5,000	214,359	23,817	180,229	77,696	-43,566	-234,108

Figure 6.9: Funding gap based on the highest PMLs by return period and a 10 percent increase in total contingencies and capital expenditure allocation



In summary, the overall budget allocated for contingencies and reserves seems sufficient to address the post-disaster needs of the energy and roads and bridges sectors even under the high-impact RCP8.5 climate scenario. However, if only the capital expenditure allocation of \$11.11 million is available, the country will fall short of meeting the post-disaster requirements of both sectors. Given that the capital expenditure allocation within the contingency reserve is insufficient to cover loss thresholds associated with natural hazards, Mauritius should explore alternative disaster risk financing instruments to ensure an effective and timely post-disaster response and strengthen its financial resilience.



## Chapter 7

# Recommendations

## Recommendations

**Based on the analysis presented in this report, the following recommendations are proposed to help** mitigate fiscal risks associated with disasters impacting critical infrastructure sectors, specifically energy and roads, and bridges, in Mauritius. These recommendations are interconnected and directly informed by the financial data and findings detailed throughout the report.

### 1 Increase disaster response funds

- a** The government should further examine the amount allocated for disaster response. If only the capital expenditure allocation of \$11.11 million is accessible for post-disaster response—out of the \$100 million contingency reserve, which is 0.629 percent of Mauritius's 2024 GDP estimated at approximately \$15.89 billion in nominal terms (International Monetary Fund 2024c)—the said amount is insufficient. The disaster response fund should cover at least the emergency needs from frequently recurring disasters.

International experience and disaster risk finance principles suggest that pre-arranged reserves or contingent credit lines are more cost-effective than ex post budget reallocations or emergency borrowing, particularly for recurrent events that generate predictable, moderate fiscal pressures. Such instruments reduce response delays, avoid disruption to planned development spending, and lower the risk of higher financing costs associated with post-disaster debt issuance.

### 2 Assess and improve the structural integrity of infrastructure, especially the power grid, and roads and bridges

- a** Building more resilient infrastructure with higher design standards would enable power grids and road networks to withstand higher intensity hazards. Although this may incur higher cost, it will, in the long term, cut down on repair expenses, service interruptions, and frequent maintenance. For instance, Tonga, which faces significant cyclone risks, has begun upgrading its power grid by replacing its low-voltage overhead network with aerial-bundled conductors (ABCs), installing underground service cables to customer premises, and adopting new smart meters (Nicolas et al. 2019). Additionally, the structural designs for roads and bridges should be reviewed to ensure that they can handle the projected effects of climate change in terms of higher intensities and more frequent natural hazards. Preventive maintenance of infrastructure within the power grid and roads and bridges should likewise be conducted on a regular basis to ensure that their vulnerabilities have not increased.

### 3 Update and upgrade hazard maps

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- a Upgraded and updated hazard maps will improve the accuracy of estimating potential damage to identified critical infrastructure. Such estimates will also guide the government in budgeting for emergency response. Moreover, hazard maps are necessary in encouraging insurance companies to expand their disaster-related insurance coverage since they are vital in risk assessment, pricing, underwriting, among other aspects. Identifying high-risk areas prone to floods, earthquakes, cyclones, and other disasters enables insurers to determine risk levels, coverage eligibility based on the risk exposure of a property, design customized policies for different risk zones, estimate potential losses, maintain adequate financial reserves or reinsurance, and set appropriate premiums for policyholders (FasterCapital 2025).
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### 4 Update building codes and regulations

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- a Mainstream disaster and climate risks in development planning and investment decisions to minimize adverse disaster effects and impacts. To institutionalize social and economic resilience, it is essential to update and enforce building codes, land-use plans, and zoning regulations, by integrating these standards into the planning and design of both public and private investments. Disaster risk management and the projected impacts of climate change should be systematically incorporated into national and local development strategies, as well as into investment decisions across sectors. This approach ensures that all new public infrastructure is designed to withstand extreme weather events with disaster-resilient features. For example, constructing elevated roads, climate-resilient bridges, and enhanced drainage systems should be thoroughly evaluated for their effectiveness in reducing flood risks and transport disruptions.

Such forward-looking investments are critical not only for ensuring public safety and continuity of services but also for reducing the long-term fiscal burden associated with repeated infrastructure damage. Furthermore, existing assets and older structures may require retrofitting to improve their structural integrity and resilience. Strengthening critical infrastructure in this way reduces vulnerability to future hazards and supports a more sustainable recovery process. In addition, climate-resilient infrastructure can attract better insurance terms—such as higher coverage limits, lower deductibles, or more comprehensive policies—thereby improving financial protection while lowering long-term costs. Also, since insurers often rely on reinsurance to protect themselves, activities that reduce the vulnerability of infrastructure can lead to reinsurers offering better terms, indirectly lowering overall insurance costs (Swiss Re Institute 2024).

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## 5 Build a nationwide disaster risk database

- a The government should establish a comprehensive digital disaster database that consolidates historical data on disaster impacts, including detailed assessments of fiscal expenditures and infrastructure damages. Such a database would be instrumental in macroeconomic analysis of disaster effects across sectors and in developing accurate catastrophe risk models. Moreover, by mapping essential infrastructure and analysing their exposure to frequent and severe disasters, the government can better assess inter-sectoral vulnerabilities and design appropriate risk financing and management strategies. For example, it could help identify critical infrastructure vital to the tourism sector—a key pillar of the Mauritian economy, contributing approximately 13.6 percent to GDP in 2023 (projected to reach 22% in 2024), supporting 10 percent of the workforce, and generating MUR 88.7 billion (\$1.89 billion) in revenue (Shore Africa 2025). Protecting assets vital to tourism would strengthen economic resilience. A robust digital disaster risk database will enable the government to conduct informed risk assessments, enhance budget planning for contingencies, and improve national disaster preparedness.

## 6 Integrate fiscal consolidation agenda into Disaster Risk Financing framework

- a Mauritius needs to pursue integration of fiscal consolidation with disaster risk financing to strengthen fiscal resilience against recurrent climate related natural hazards. For this purpose the report recommends pre-arranged financing instruments like contingency credit lines, catastrophe bonds and insurance that will help to finance recovery from natural events without putting pressure on fiscal balances.

## 7 Explore the possibility of establishing contingent credit lines

- a Related to the above, an assessment of the potential impacts of hazards on critical infrastructure can inform the government whether contingent credit is necessary. A contingent credit line like the Catastrophe Deferred Drawdown Options (Cat DDO) is designed to provide immediate liquidity to countries in the aftermath of disasters, aiding in rapid response and recovery efforts. It is most effective when integrated into a comprehensive disaster risk management framework. For instance, Madagascar, which faces an average annual disaster loss of \$100 million just from cyclone and flood risks, has received a \$50 million disaster risk management policy grant from the International Development Association (IDA) with a Cat DDO. Morocco has received a \$275 million Disaster Risk Management Development Policy Loan containing a Cat DDO from the World Bank. Other African nations with Cat DDO in place include Seychelles, Kenya, Malawi, and Cabo Verde (Artemis 2025).

## 8 Explore other options to finance disaster risks

- a As the contingency reserve is intended to cover the needs of all sectors, it cannot be relied upon solely for the needs of the energy and roads and bridges sectors. Some risk financing options, as shown in Table 7.1, can be considered by the government.

Table 7.1: Disaster risks by return period and possible financing strategies

Return Period (years)	Energy and Roads and Bridges PML (\$ '000)	Possible Disaster Risk Financing Strategy
10	23,403	Contingency reserve; budget reallocation; private sector assistance; international assistance
25	36,758	
50	48,992	Contingency reserve; budget reallocation; private sector assistance; contingent credit (CatDDO); international assistance
100	61,662	
250	80,437	
500	99,210	Risk transfer: insurance-linked securities; insurance reinsurance; international assistance
1,000	126,452	
2,500	185,702	
5,000	257,925	

Mauritius should consider conducting a detailed cost-benefit analysis of transferring disaster-related risks to the capital markets for public assets such as power grids, roads, and bridges. Risk transfer mechanisms may include traditional insurance, parametric insurance (which pays out when specific triggers are met—such as temperature or rainfall thresholds), reinsurance arrangements, or disaster-contingent instruments like catastrophe bonds.

Given that such instruments often involve high costs, they are best suited for low-probability but high-impact events, those with severe potential fiscal consequences and limited immediate access to financing. Conversely, Mauritius may choose to retain risks that occur more frequently but have a relatively limited impact on public finances (The International Bank for Reconstruction and Development/The World Bank 2019).

## 9 Accelerate Implementation of financing facilities outlined in NDC 3.0 (2025)

- a Mauritius in its NDC 3.0, 2025 has pledged to set up a Climate and Sustainability Fund, introduce a corporate climate responsibility levy, initiate climate budget tagging and pursue blended finance through Public Private Partnerships. Along with this a Climate Finance Unit is to be set up and a National Carbon Market framework will be prepared. These initiatives will accelerate the mobilization of private capital and facilitate flow of concessional finance from multilateral agencies to proactively mitigate the impact of climate events.

Annexed is a list of disaster risk financing mechanisms.





Chapter 8

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**Annexure**



## Annexure

### Annex A: Disaster-related Insurance Schemes in Selected Countries

## Sri Lanka<sup>5</sup>

Recently, the global advisory, broking, and solutions company WTW (NASDAQ: WTW) launched Asia's first four-peril parametric insurance to protect Sri Lanka's shrimp farms against weather-related risks, marking a crucial turning point in Asia's aquaculture development. The unique solution was designed and implemented for Taprobane Seafood Group, Sri Lanka's largest seafood company, helping them meet a critical condition to secure \$15 million in project financing from the Dutch entrepreneurial development bank FMO.

Shrimp farming is associated with a diverse range of risks and uncertainties, most prominently weather-related risks across coastal regions where farms are traditionally located. To safeguard Taprobane against such vulnerabilities and remove potential bottlenecks hindering the inflow of much-needed capital, WTW has structured the region's first four-peril parametric insurance solution that covers four key weather risks: **earthquake, typhoon, excess rainfall, and heat stress**. This also enabled Taprobane Seafood Group to meet a critical condition for securing \$15 million in project financing from the Dutch entrepreneurial development bank FMO.

The WTW also recently launched Nitrogen Risk Insurance, the world's first parametric insurance solution that allows sugarcane farmers in Queensland, Australia, to hedge against yield shortfalls caused by reduced applications of nitrogen fertilizer on ratoon crops.



<sup>5</sup> "WTW Launches Asia's First 4-Peril Parametric Insurance Solution to Unlock Financing for Aquaculture Development," Press Release, July 2023, <https://www.wtwco.com/en-ph/news/2023/07/wtw-launches-asias-first-4-peril-parametric-insurance-solution-to-unlock-financing-for-aquaculture>.

## Thailand<sup>6</sup>

Since 2011, the Thailand Rice Disaster Relief Top-up Crop Insurance Scheme, which uses weather index insurance for rice, has been available to farmers. The 'Remote-sensing-based information and insurance for crops in emerging economies' project is a public-private partnership being implemented by the Swiss Agency for Development and Cooperation, the German Agency for International Cooperation, and others, to reduce the vulnerability of smallholder rice farmers. In cooperation with the Geo-Informatics and Space Technology Development Agency, the project is linking remote sensing technology to sophisticated crop yield modelling technology to develop a rice production monitoring system that provides accurate and timely information on rice areas, yield, and disaster-affected rice areas.

## India

### Modified Area Crop Insurance Scheme of India (2010)

The National Agricultural Insurance Scheme (NAIS), established by the Government of India, is the world's largest crop insurance programme, covering approximately 25 million farmers and managed by the Agriculture Insurance Company of India (AICI). It provides insurance for food crops, oilseeds, and select commercial crops using an area yield-based approach.<sup>7</sup> By comparing current crop yields with historical data, this indexed strategy provides indemnity payouts to insured farmers in specific locations when actual yields fall below historical levels.

In addition to addressing issues associated with small landholdings, the plan lessens moral hazard and adverse selection. NAIS, however, is dependent on government contributions made after a disaster and subsidized premiums. As a result, the government faces unlimited financial risk, and delays in claims settlement could cause hardship for farmers. To enhance the programme's effectiveness and tackle these challenges, the government collaborated with AICI and sought technical assistance from the World Bank in 2005 to modify and improve insurance coverage.

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<sup>6</sup> United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), *Disaster Risk Transfer Mechanisms: Issues and Considerations for the Asia-Pacific Region* (Bangkok: UNESCAP, 2017).

<sup>7</sup> World Bank, *Disaster Risk Financing and Insurance Case Study – National Agricultural Insurance Scheme in India* (Washington, DC: World Bank, 2011), [https://www.farm-d.org/app/uploads/2019/05/DRFI\\_India\\_mNAIS\\_Jan11](https://www.farm-d.org/app/uploads/2019/05/DRFI_India_mNAIS_Jan11).



### India's First Weather Index Insurance Pilot by ICICI Lombard General Insurance Company (2003)

The first weather insurance product in India, and indeed in the developing world, was a rainfall insurance contract underwritten in 2003 by ICICI-Lombard General Insurance Company for groundnut and castor farmers associated with Hyderabad-based micro-finance institution BASIX's water user associations in the Mahabubnagar district of Andhra Pradesh. This innovative insurance scheme provided coverage based on rainfall levels, helping farmers mitigate risks associated with unpredictable weather conditions. It functions as a significant mechanism for disaster risk financing and insurance by offering innovative coverage linked to weather indices. This pilot programme offers protection to farmers against adverse weather conditions, such as droughts or excessive rainfall, which can lead to crop losses and financial instability. By utilizing weather indices as triggers for payouts, the insurance scheme ensures timely compensation to farmers, enabling them to mitigate the economic impact of climate-related disasters. Since then, weather-based crop insurance has evolved considerably in India, with various programmes and approaches aimed at supporting farmers during adverse weather events. For instance, newer initiatives include heat-linked parametric insurance systems that offer a lifeline to Indian women in the informal sector.<sup>8,9</sup> This approach not only promotes resilience among agricultural communities but also helps stabilize livelihoods and fosters sustainable development in vulnerable regions. Additionally, by pioneering such initiatives,

ICICI Lombard contributes to the evolution and expansion of weather index insurance markets, paving the way for broader adoption and enhanced disaster risk management strategies across India.

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<sup>8</sup> Daniel J. Clarke, Olivier Mahul, Kollu N. Rao, and Niraj Verma, Weather-Based Crop Insurance in India, Policy Research Working Paper 5985 (Washington, DC: World Bank, 2012), <https://documents1.worldbank.org/curated/en/693741468269445619/pdf/WPS5985.pdf>.

<sup>9</sup> ICICI Foundation for Inclusive Growth, "Financial Inclusion," ICICI Foundation. <https://www.icici.bank.in/ms/icici-esg/foundation-for-inclusive-growth.html>

## Pradhan Mantri Fasal Bima Yojana (PMFBY) in India (2016)

A flagship agricultural insurance programme in India, the Pradhan Mantri Fasal Bima Yojana (PMFBY) uses an 'area approach basis'<sup>10</sup> to provide farmers with reasonably priced crop insurance against inevitable natural risks from pre-sowing to post-harvest. The programme includes oilseeds, food crops, horticulture, and commercial crops. Farmers without institutional credit are not required to participate, but those who have bank loans are required to do so. The Ministry of Agriculture oversees the programme, which has been redesigned to expedite the processing and payment of claims, improve technology interventions, and provide states more freedom in choosing risk covers and the distribution of premium subsidies. PMFBY aims to stabilize farm revenue, facilitate farmers' self-sufficiency in risk management, and encourage the adoption of contemporary farming techniques. The plan does not cover losses from riots, war, or nuclear hazards, but it does cover a variety of disasters and pests. It also seeks to use smartphones and remote sensing technology to speed up crop loss estimation.<sup>11</sup> In general, PMFBY aims to promote contemporary farming methods, stable farmer income, encourage sustainable agricultural production, and guarantee the flow of financing to the agriculture sector for competitiveness and food security. Through its comprehensive coverage and government support, PMFBY plays a significant role in mitigating the financial impact of agricultural disasters on farmers and promotes sustainable agricultural production in India.



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<sup>10</sup> Government of India, "PM Fasal Bima Yojana," MyGov.in, 2020, <https://www.mygov.in/campaigns/pmfbby/>.

<sup>11</sup> Sandeep Kaur, Hem Raj, Harpreet Singh, and Vijay Kumar Chattu, "Crop Insurance Policies in India: An Empirical Analysis of Pradhan Mantri Fasal Bima Yojana," *Risks* 9, no. 11 (2021): 191, <https://doi.org/10.3390/risks9110191>.

# Philippines<sup>12</sup>

Aside from the multiple-peril crop insurance (MPCI), the country also has an all-peril property cover for public assets, which is provided by the Government Service Insurance System General-Insurance Group (GSIS-IG), a state-owned entity. The insurance covers all property in which the government has an interest (e.g., government offices, hospitals, schools, and public markets).

Contingent credit for disasters is also in place, and insurance for public assets is in use. On 17 November 2021, the World Bank approved the Fourth Disaster Risk Management Development Policy Loan with a Catastrophe-Deferred Drawdown Option (CAT-DDO 4) of \$500 million for the Government of the Philippines. Through a Cat DDO, the Philippines can access funds upon the declaration of a national state of calamity due to an imminent or occurring natural catastrophe or a declaration of a state of public health emergency. The loan is available for a period of three years and can be renewed for up to a total period of 15 years. The past Cat DDOs have all been successfully disbursed to propel the Philippines towards recovery in the aftermath of disasters such as Tropical Storm Washi (2011) and Tropical Cyclone Mangkut (2018), as well as the COVID-19 pandemic. The latest CAT-DDO 4 has also been disbursed after Typhoon Rai, which battered the

country in December 2021. On 16 November 2023, a \$500-million development policy loan for the country was approved by the WB/IBRD to finance the Philippines Disaster Risk Management and Climate Development Policy Loan with a Catastrophe Deferred Drawdown Option (DDO), which has set aside \$500 million that the Philippine government can immediately draw upon in times of natural disasters and health crises, mitigating their impact on the economy. The funds can be disbursed when the president declares a state of calamity in response to a disaster or public health emergency.

**Catastrophe Bond:**<sup>13</sup> In November 2019, the World Bank issued two tranches of catastrophe bonds to capital market investors, providing the Philippines with insurance coverage of up to \$225 million (\$75 million for earthquakes and \$150 million for tropical cyclones) for a three-year period. The type of events that will trigger a payout is predefined based on the requirements of the Philippines. If and when a qualifying event occurs, the Philippines will issue a notice to an independent calculation agent to determine the insurance payouts. The World Bank will transfer the payouts to the Philippines as soon as a calculation report is available, within approximately one month for earthquake and five months for tropical

cyclone events, without the need to assess the actual losses incurred by the country. The Philippines pays an insurance premium for the coverage, which the World Bank transfers to the cat bond investors. The premium is fixed during the life of the bond, removing the uncertainty of the cost.

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<sup>12</sup> Department of Finance, Republic of the Philippines, Department of Finance Publications (Manila: Government of the Philippines, 2023).

<sup>13</sup> World Bank, "Case Study: The Philippines—Transferring the Cost of Severe Natural Disasters to Capital Markets." (Washington, DC: World Bank, n.d.).

# Mongolia

In 2006, the Government of Mongolia, with assistance from the World Bank, implemented a pilot programme in three provinces for an index-based insurance programme to address death rates in the livestock population. Shocks to the well-being of animals have devastating implications for the rural poor and for the overall economy. The scheme combines self-insurance, market-based insurance, and social insurance. Herders pay a premium rate for a commercial risk product (base insurance product), which has specified trigger percentages for livestock mortality rates, while the government finances and provides a social safety net product (disaster response product). In addition, a syndicated pooling arrangement for insurance companies protects the domestic insurance market since the government fully covers insured losses beyond the financial capacity of the pool through a reinsurance treaty with the World Bank.



# Mexico<sup>14</sup>

Mexico has a considerable capacity for financial resilience and disaster response based on a wide range of financial instruments for risk management and risk transfer, among which several different insurance schemes and the following funds and trusts stand out: Natural Disaster Fund (Fondo de Desastres Naturales, FONDEN) consists of the Emergency Fund (Fondo para la Atención de Emergencias FONDEN), the Natural Disaster Fund Programme of the Branch of the Federal Budget, and the Natural Disaster Fund Trust. The Emergency Fund is a financial instrument for immediate and timely disaster response, providing relief, aid, and assistance to severely affected populations. Funds from FONDEN could be used for the rehabilitation and reconstruction of (i) public infrastructure at the three levels of government (federal, state, and municipal); (ii) low-income housing; and (iii) certain components of the natural environment (e.g., forestry, protected natural areas, rivers, and lagoons).

Natural Disaster Prevention Fund (Fondo para la Prevención de Desastres Naturales, FOPREDEN) includes the Preventive Trust (Fideicomiso preventivo, FIPREDEN), aimed at promoting and strengthening preventive actions for DRR, diminishing the effects and impacts of natural phenomena, as well as fostering DRR research. FIPREDEN provides resources to the agencies and federal and state units for unscheduled preventive actions.

The Fund for Rural Assistance to Climatic Contingencies (Fondo de Apoyo Rural por Contingencias Climatológicas) is operated by the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) within its Natural Disaster Assistance Programme for the agricultural, livestock, and fisheries sectors (Programa Atención a Desastres Naturales en el Sector Agropecuario y Pesquero, CADENA) as one of the components of the Disaster Management Prevention Programme (Programa de Prevención y Manejo de Desastres). This fund aims to assist, through insurance, to limit the negative effects of disasters on agricultural, livestock, aquaculture, and fisheries activities. The legal foundation for this fund is established under the Sustainable Rural Development Law, e.g., Article 129, among others.

The Federal Budget Law requires that an amount of no less than 0.4 percent of the annual federal budget should be available to FONDEN, FOPREDEN, and the Agricultural Fund for Natural Disasters at the beginning of each fiscal year.

FONDEN resources are leveraged with market-based risk transfer instruments. Despite its stable annual budget appropriation, funding needs related to the occurrence of one or multiple disasters can cause a shortfall in any given year. To manage the volatility of demand on its resources, FONDEN is allowed to transfer risks through insurance and other risk transfer mechanisms, such as catastrophe bonds. FONDEN is, however, not allowed to contract debt.

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<sup>14</sup> United Nations Development Programme (UNDP), Mexico: Country Case Study Report – How Law and Regulation Support Disaster Risk Reduction (June 2014) and World Bank, FONDEN: Mexico's Natural Disaster Fund – A Review (Washington, DC: World Bank, 2012).

## Mexico's First Sovereign Catastrophe Bond (2006)

The FONDEN applies a variety of tools to assist local governments and organizations in responding to disasters, such as risk transfer programmes and reserve funds. To transfer Mexico's seismic risk to the global capital markets, FONDEN issued a \$160 million catastrophe bond (CatMex) in 2006. Mexico decided to further diversify its coverage by pooling multiple risks across multiple regions after CatMex attained maturity in 2009. Using the World Bank's recently formed MultiCat Program, which assists sovereign and sub-sovereign entities in pooling multiple perils in multiple regions and lowering insurance costs, it issued a multiperil cat bond in October 2009.<sup>15</sup> With this bond, Mexico transferred a pool of disaster risk to the market for the first time; secured multi-year protection for the covered risks at a fixed price; and reduced potential pressure on public budgets. By leveraging the expertise of the insurance-linked securities market, Mexico effectively diversifies its risk and ensures access to timely funds for disaster management, reducing reliance on traditional post-disaster financing mechanisms.<sup>16</sup> This sovereign catastrophe bond not only enhances Mexico's financial resilience to disasters but also sets a precedent for other countries seeking innovative approaches to disaster risk financing and insurance.

## Component for the Attention of Natural Disasters (CADENA) Mexico (2003)

In Mexico, disasters, particularly affecting agriculture, have increased in frequency and severity, with over 80 percent of economic losses occurring in the agricultural sector in the past two decades. Challenges include the fragmentation of the farming sector, where small-scale farmers form a significant portion but face difficulties accessing affordable insurance due to high transaction costs. To address this, the Mexican government has categorized farmers into three groups and developed tailored agricultural insurance programmes: commercial farmers requiring insurance for financing, farmers able to pool risks and access credit, and small-scale, vulnerable farmers lacking access to credit or insurance. The CADENA programme, launched in 2003, operates as a crucial mechanism for disaster risk financing and insurance by providing formal parametric crop and livestock insurance solutions at the state level, primarily targeting small-scale, vulnerable farmers lacking access to traditional insurance or credit. It utilizes macro-level catastrophe climatic agricultural index products to provide social safety net coverage, thereby replacing traditional post-disaster relief schemes with formal insurance solutions at the state level under the Ministry of Agriculture, Livestock, and Fisheries (SAGARPA).<sup>17</sup> In doing so, it replaces ad hoc post-disaster relief schemes with a structured insurance approach, mitigating the financial impacts of disasters on agriculture. This programme not only offers financial protection but also promotes resilience among vulnerable farming communities, thereby contributing to Mexico's overall disaster preparedness and response capabilities.

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<sup>15</sup> The World Bank, A Case Study of Insuring Against Natural Disaster Risk in Mexico (Washington, DC: The World Bank, 2015), <https://documents1.worldbank.org/curated/en/170311468056076924/pdf/81172-REVISED-Mexico-MultiCatBond-2015.pdf>.

<sup>16</sup> World Bank, Disaster Risk Financing and Insurance Case Study – Mexico MultiCat Bond (Washington, DC: World Bank, 2013), <https://openknowledge.worldbank.org/handle/10986/16191>.

<sup>17</sup> World Bank, Mexico Agriculture Insurance Market Review (Washington, DC: World Bank, 2013), <https://documents1.worldbank.org/curated/pt/124521468287160777/pdf/881000BRI0P1300urance04Pager0Cadena.pdf>.

## Mexico Indemnity-based Excess of Loss Insurance for Public Assets

Mexico has established an innovative insurance scheme to lessen the financial damage that natural catastrophes cause to public property. This programme evaluates fiscal risks for the government by quantifying both explicit and implicit contingent liabilities. It does this by fusing historical data with information from simulated losses. It has an excess-of-loss insurance component based on indemnification that activates when demands linked to disasters reach a certain threshold. In order to increase resilience to disasters, Mexico's programme works in combination with risk reduction initiatives, such as bolstering early warning systems, in addition to its primary goal of protecting the government budget.<sup>18</sup> The indemnity-based coverage takes effect when disaster-related costs exceed a certain threshold, thereby shielding the government from excessive financial burdens. Moreover, the programme's integration with risk reduction measures, such as supporting early warning systems, enhances resilience to disasters, further emphasizing its role in comprehensive disaster risk management and financial protection.



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<sup>18</sup> World Bank, *Quantifying Contingent Liabilities Associated with Natural Disasters* (Washington, DC: World Bank, 2013), <https://documents1.worldbank.org/curated/en/672271467997574054/pdf/97977-BRI-Box391499B-PUBLIC-Short-Note-1-Risk-Assessment-04Nov2013.pdf>.

# Türkiye

## Turkish Catastrophe Insurance Pool (TCIP-2000)

The Turkish Catastrophe Insurance Pool (TCIP) functions as a pivotal mechanism for disaster risk financing and insurance, providing coverage against disasters such as earthquakes, floods, and landslides. In 2000, the Turkish government instituted a mandatory earthquake insurance system for all residential structures on registered urban land. This initiative aimed to shift the financial burden from the government to private insurers. To facilitate this transition, the World Bank provided crucial financial and technical support for the establishment of the TCIP. The TCIP stands as a pioneering endeavour, becoming the world's first national catastrophe insurance pool among the World Bank client countries. It offers standalone earthquake insurance coverage to homeowners and small- to medium-sized enterprises, marking a significant step in bolstering disaster resilience and easing the strain on government resources in the face of seismic risks. By transferring risk from individuals and businesses to a pooled system, TCIP significantly contributes to Turkey's disaster preparedness and recovery efforts, ensuring swift and effective responses in times of crisis while fostering long-term resilience and sustainability.<sup>19</sup>

# Taiwan

## Taiwan Residential Earthquake Insurance Programme (2002)

The Taiwanese government established and promoted the Taiwan Residential Earthquake Insurance Programme (TREIP) in response to the 1999 Chi-Chi Earthquake. TREIP offers basic insurance protection against earthquakes starting from 1 April 2002. The programme serves as a vital mechanism for disaster risk financing and insurance by providing coverage tailored specifically to earthquakes for residential properties. Homeowners who have experienced earthquake damage can obtain financial assistance to improve the stability of their properties. The government established the Taiwan Residential Earthquake Insurance Fund (TREIF) and designated it as the central organization of this statutory insurance programme and the managing entity for the Risk Spreading Mechanism of Residential Earthquake Insurance in order to implement TREIP and give homeowners basic earthquake insurance protection<sup>20</sup>. This not only facilitates financial protection for individual homeowners but also contributes to overall community resilience by encouraging earthquake-resistant construction practices and facilitating rapid recovery in the aftermath of seismic events. By pooling resources and spreading risk across a broad base, the programme enhances Taiwan's disaster preparedness and response capabilities, ultimately fostering a more resilient society.

<sup>19</sup> World Bank, Disaster Risk Financing and Insurance Case Study – Turkish Catastrophe Insurance Pool (Washington, DC: World Bank, n.d.), <https://www.gfdrr.org/drfi>.

<sup>20</sup> Taiwan Residential Earthquake Insurance Fund (TREIF), “About TREIF,” <https://www.treif.org.tw/>.



### Caribbean Catastrophe Risk Insurance Facility (CCRIF-2007)

The Caribbean Catastrophe Risk Insurance Facility, the world's first multi-country risk pool, was established in 2007 and developed the first insurance product to successfully use parametric policies backed by both traditional and capital markets. To enable the offering of new products and expansion into new geographic areas, the facility underwent a restructuring in 2014. It became a segregated portfolio company (SPC), which is now known as CCRIF SPC. It is registered, owned, and operated in the Caribbean. The CCRIF SPC helps governments in the Caribbean and Central America mitigate the financial impact of natural hazard catastrophes by promptly supplying short-term liquidity when a policy is triggered. For tropical cyclones, earthquakes, excessive precipitation, the fisheries industry, and public utilities, CCRIF provides parametric insurance coverage. Through its parametric approach, CCRIF triggers payouts based on predetermined parameters such as wind speed or rainfall intensity, enabling a swift and efficient response to disasters. By providing timely financial assistance, CCRIF helps member countries bridge the gap between immediate humanitarian needs and long-term recovery efforts, ultimately promoting resilience and sustainable development in the Caribbean. Moreover, CCRIF's risk pooling and reinsurance mechanisms enhance the affordability and availability of disaster insurance for small island states with limited resources, thus bolstering their capacity to manage and mitigate the impacts of disasters.<sup>21</sup>

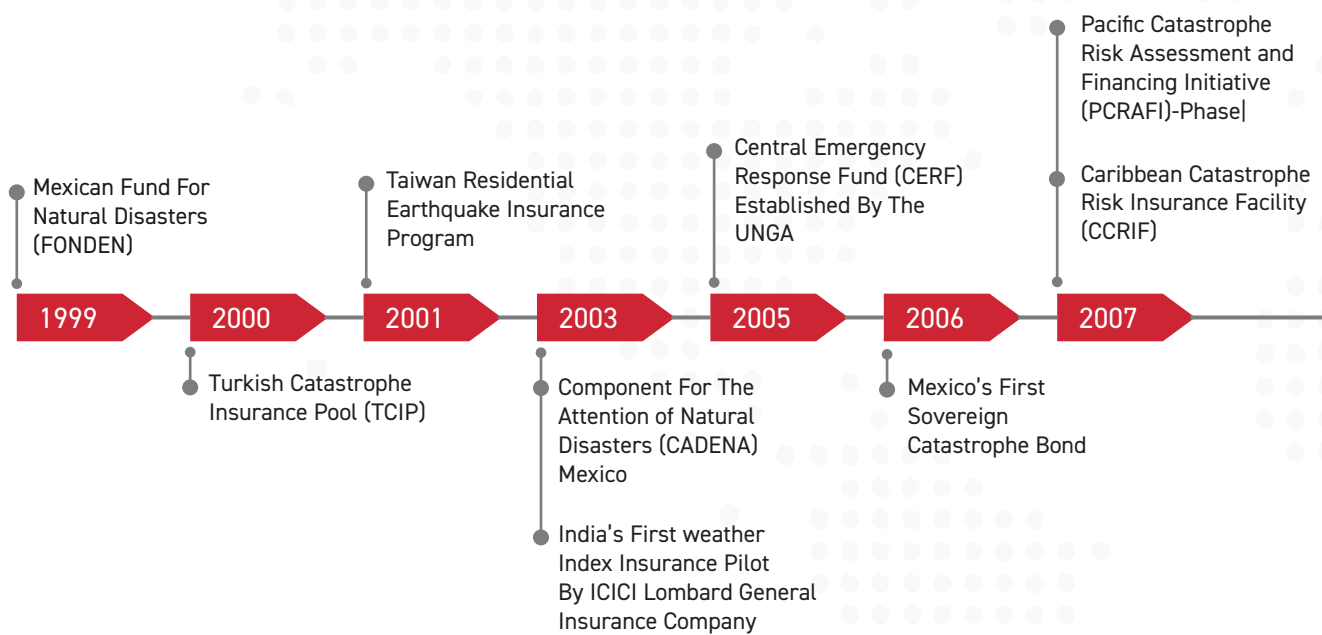


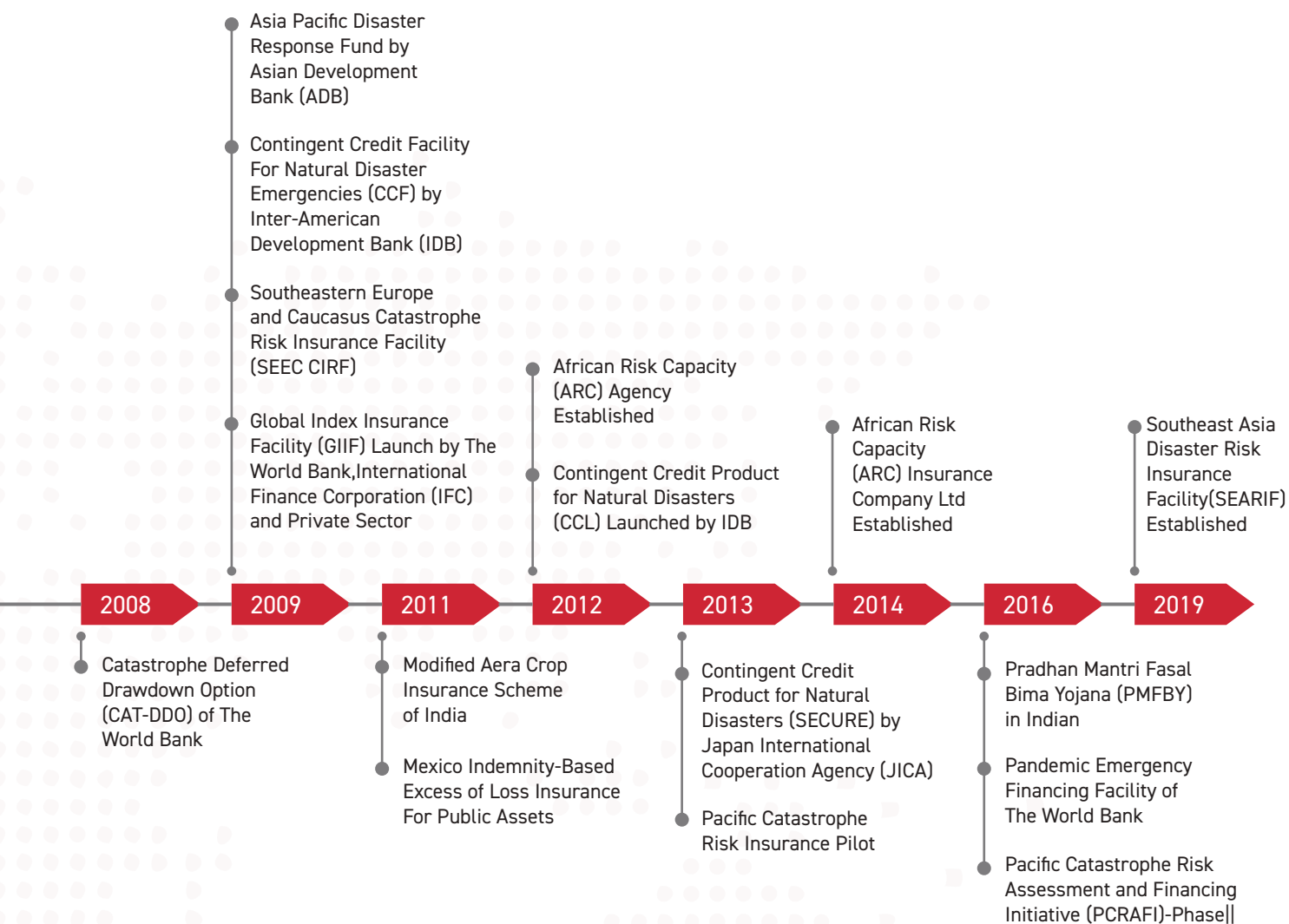
### Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI-2007)

A regional initiative called the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) Programme was launched in 2007 to strengthen the Pacific region's financial resilience to risks of disaster and climate change. The PCRAFI Facility and the PCRAFI Technical Assistance programme are the two main pillars of Phase II, which was started in April 2016. The holistic approach of PCRAFI enables countries to better understand and quantify their vulnerability to natural hazards by facilitating the development of risk assessment tools like the Pacific Risk Information System (PacRIS). The Secretariat of the Pacific Community is undertaking a project under the Technical Assistance programme focusing on capacity-building for the Hazard and Exposure Database. Through in-country surveys, improved data collection capabilities, and case studies highlighting the value of risk information, this project aims to update data in the PacRIS and ultimately empower nations to independently impact data and improve their future exposure.<sup>22</sup>

<sup>21</sup> Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC), Annual Report 2022–2023 (2023), [https://www.ccrif.org/sites/default/files/publications/annualreports/CCRIFSPC-Annual-Report-2022-2023\\_lowres.pdf](https://www.ccrif.org/sites/default/files/publications/annualreports/CCRIFSPC-Annual-Report-2022-2023_lowres.pdf).

<sup>22</sup> World Bank, Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI): Catastrophe Risk Assessment Methodology (Washington, DC: World Bank, 2013), <https://reliefweb.int/report/world/pacific-catastrophe-risk-assessment-and-financing-initiative-pcrafi-risk-assessment>.







### Catastrophe Deferred Drawdown Option (CAT-DDO) of the World Bank (2008)

An IBRD Flexible Loan product, called the Drawdown Option (CAT-DDO), is designed to improve countries' crisis preparedness and responsiveness to natural catastrophes and public health emergencies. It offers swift disbursement contingency finance in the event of a disaster, providing liquidity upfront while additional funding is raised. Approved before a disaster event, the Cat DDO offers immediate liquidity once triggered, serving as early budget support while additional funds are mobilized. By disbursing quickly and efficiently, the Cat DDO helps mitigate the financial impact of disasters, enabling governments to respond promptly to emergencies. This mechanism complements existing risk retention and transfer tools, providing early budget help as part of a larger risk management plan. The Disaster Risk Management Development Policy Loan with a Catastrophe-Deferred Drawdown Option (CAT DDO) Project aims to improve technical capacity, support policy reforms, and fortify Serbia's institutional and legal framework for managing the financial and physical impacts of disasters. The CAT-DDO also helps Serbia's catastrophe insurance industry grow by offering financial safety nets and short-term funding for emergency response.<sup>23</sup>



### Asia Pacific Disaster Response Fund by Asian Development Bank (2009)

Established in 2009, the Asia Pacific Disaster Response Fund (APDRF) provides developing member countries (DMCs) of the Asian Development Bank (ADB) with loans that can be disbursed promptly for life-saving measures in the immediate aftermath of significant natural catastrophes. This funding helps DMCs augment relief from other donors during emergencies and help restore life-saving services to impacted individuals. This mechanism enhances countries' crisis response capabilities, particularly when emergencies exceed their capacity to address immediate expenses. Additionally, APDRF supports DMCs in mitigating the financial impacts of disasters by providing essential funding for urgent relief efforts, thereby contributing to the broader objectives of disaster risk management and resilience building in the Asia-Pacific region.<sup>24</sup> Assistance is eligible if certain emergency requirements are met, such as a disaster occurring, an official declaration of emergency beyond the nation's ability to respond, and the UN humanitarian/resident coordinator (H/RC) confirming the scope and consequences of the disaster. The geographic scope of the damage, preliminary estimates of the number of dead and displaced, response capability, and the cumulative effect of previous catastrophes on the country's ability to respond are among the factors that influence the size of the award.<sup>25</sup>

<sup>23</sup> World Bank, Product Note on IDA Catastrophe Deferred Drawdown Option (Cat-DDO) (Washington, DC: World Bank, 2018), <https://thedocs.worldbank.org/en/doc/563361507314948638-0340022017/original/productnotecatddoenglish2018.pdf>.

<sup>24</sup> Asian Development Bank (ADB), "Funds and Resources – Asia Pacific Disaster Response Fund," Asian Development Bank, <https://www.adb.org/what-we-do/funds/asia-pacific-disaster-response-fund-apdrf>.

<sup>25</sup> NDC Partnership, "Asia Pacific Disaster Response Fund," Knowledge Portal, <https://ndcpartnership.org/knowledge-portal/climate-funds-explorer/asia-pacific-disaster-response-fund-apdrf>.



### Contingent Credit Facility for Natural Disaster Emergencies (CCF) by Inter-American Development Bank (IDB) (2009)

One of the Inter-American Development Bank's (IDB) most important tools for assisting member nations in managing the financial risks associated with disasters is the Contingent Credit Facility for Natural Disaster Emergencies (CCF). It serves as a critical mechanism for disaster risk and financing insurance by providing member countries of the IDB with access to contingent loans following verified disaster events. It provides contingent loans that are reimbursed in event the of a catastrophic occurrence, allowing for the provision of essential amenities and humanitarian relief. Countries must have a Comprehensive Natural Disaster Risk Management Program (CDRMP) in place to be eligible for the CCF. The CCF, which incorporates parametric triggers based on preset event characteristics, symbolizes the IDB's approach towards proactive disaster risk management. It focuses on giving prompt financial support during the emergency phase of disasters.<sup>26</sup>



### South-eastern Europe and Caucasus Catastrophe Risk Insurance Facility (SEEC CRIF) (2009)

To address the lack of insurance coverage for natural hazards in Southeast Europe (SEE), a region highly vulnerable to disasters, Europa Reinsurance Facility Ltd. collaborated with the World Bank to establish the Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (CRIF). The project is now operational, offering small enterprises and homeowners with catastrophe insurance through regional providers, with funding exceeding \$12 million.<sup>27</sup> Its goals are to develop new insurance products for weather and catastrophe risks, simplifying insurance processes, and increase public awareness of disaster risks in SEE member nations. The project comprises two parts: participating in the SEEC CRIF, which supports countries in their efforts to join Europa Re, and receiving technical assistance from donors, delivered by Europa Re. This assistance includes risk mapping, product design, weather monitoring, and legislative reforms.<sup>28</sup> The project's ultimate goal is to make financial insurance against climate change and geological risks in the area more accessible to government agencies, businesses, farmers, and households.

<sup>26</sup> Guido Collich, Raúl Rosillo, José Martínez, David J. Wald, and Juan J. Durante, "Financial Risk Innovation: Development of Earthquake Parametric Triggers for Contingent Credit Instruments," in *Natural Disasters and Climate Change*, ed. Juan Durante and Raúl Rosillo (Cham: Springer, 2020), 1–15, [https://doi.org/10.1007/978-3-030-43708-4\\_1](https://doi.org/10.1007/978-3-030-43708-4_1).

<sup>27</sup> Global Environment Facility (GEF), "Regional – Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (CRIF)," (2012), <https://www.thegef.org/newsroom/news/regional-southeastern-europe-and-caucasus-catastrophe-risk-insurance-facility-crif>.

<sup>28</sup> World Bank, "Southeast Europe and Caucasus Catastrophe Risk Insurance Facility (Serbia and Macedonia)," (2024), <https://projects.worldbank.org/en/projects-operations/project-detail/P110910>.



### Global Index Insurance Facility (GIIF) launched by the World Bank, International Finance Corporation (IFC), and Private Sector (2009)

The European Union, Japan, and the Netherlands support the Global Index Insurance Facility (GIIF), which is managed by the World Bank Group and aims to improve access to financing for microfinance institutions, small-scale farmers, and microentrepreneurs in developing nations. GIIF was established in 2009 with a primary focus on sub-Saharan Africa, the Caribbean, and the Asia-Pacific region. It uses index insurance solutions to manage catastrophic risks in agriculture, food security, and catastrophe risk reduction.<sup>29</sup> Through its initiatives, GIIF has enabled billions of dollars in funding, millions of contracts that affect tens of millions of people globally, and promoted resilience and financial inclusion in disadvantaged communities.<sup>30</sup> A crucial part of GIIF is index-based insurance, which eliminates the difficulties involved in estimating individual losses by relying on predetermined indices to initiate payouts and ensuring faster claims processing. Index-based insurance can help mitigate catastrophic risks associated with agriculture, food security, and disaster risk reduction. This approach enables faster claims processing and ensures timely financial assistance to those affected by disasters, thereby promoting resilience and economic inclusion in vulnerable communities worldwide.



### African Risk Capacity Agency (ARC) (2012)

The African Risk Capacity (ARC) Group is composed of ARC Agency, a Specialized Agency of the African Union founded in 2012, and ARC Insurance Company Limited (ARC Ltd), a hybrid mutual insurer and the commercial affiliate of the Group, founded in 2014. The ARC Group, comprising ARC Agency and ARC Ltd, was founded with the aim of improving the ability of African governments to plan, prepare for, and respond to epidemics and disasters triggered by extreme weather events. With an emphasis on inclusivity and gender equality, ARC offers member states facilities for risk pooling and transfer, early warning systems, and capacity building, to increase resilience against natural catastrophes, such as tropical cyclones and droughts. ARC seeks to establish pan-African climate response systems that transfer the cost of climate risks from governments to ARC, guaranteeing more prompt and equitable disaster aid by utilizing contemporary financing methods like risk pooling and transfer.<sup>31</sup> Through ARC,

<sup>29</sup> World Bank, "Global Index Insurance Facility – Overview," (2024), <https://www.indexinsuranceforum.org/overview>.

InsuResilience Global Partnership, "The Global Index Insurance Facility (GIIF) – InsuResilience Global Partnership," (2017),

<sup>30</sup> <https://www.insuresilience.org/>.

<sup>31</sup> African Risk Capacity (ARC), "About ARC," <https://www.arc.int/about>.

member states can access readily available funds for response, reducing reliance on external aid and ensuring timelier and more equitable disaster relief. By merging traditional disaster relief approaches with modern financial mechanisms like risk pooling and transfer, ARC offers a sustainable African-led strategy for managing extreme climate risks and disease outbreaks, thereby promoting resilience and reducing the financial burden on governments and vulnerable populations.



### Southeast Asia Disaster Risk Insurance Facility (SEADRIF) (2019)

Through SEADRIF, ASEAN nations can improve their financial resilience to climate and catastrophe risks and access finance options for disaster risk. SEADRIF was founded in Singapore as a trust to own a general insurance business. It offers financial and consultancy services for rapid post-disaster funding, with an emphasis on flood risks in Myanmar, Cambodia, and the Lao PDR. The organization also aims to extend its financial solutions to other ASEAN nations with middle-class incomes, such as Indonesia.<sup>32</sup> SEADRIF facilitates cooperative approaches to improve preparedness for climate and disaster risks and helps member countries prevent catastrophes from escalating into crises by pooling resources and knowledge. With the COVID-19 pandemic adding to the stress of disasters and climate change intensifying extreme weather events, SEADRIF offers customized programmes and products that cater to a range of demands in the ASEAN area at varying stages of development. Through initiatives like the ASEAN+3 Disaster Risk Financing Initiative, SEADRIF also provides a forum for information sharing, developing technical solutions, and exploring insurance and other financial products.<sup>33</sup>



<sup>32</sup> World Bank, "Southeast Asia Disaster Risk Insurance Facility (SEADRIF): Technical Briefing for Japanese Insurance Industry," (2019), <https://www.worldbank.org/en/news/feature/2019/01/17/southeast-asia-disaster-risk-insurance-facility-seadrif-technical-briefing-for-japanese-insurance-industry-drmhubtokyo>.

<sup>33</sup> World Bank, Project Information Document: Southeast Asia Disaster Risk Insurance Facility (SEADRIF) – Strengthening Financial Resilience in Southeast Asia (2019), <https://documents1.worldbank.org/curated/en/772221601306153071/pdf/Project-Information-Document-Southeast-Asia-Disaster-Risk-Insurance-Facility-SEADRIF-Strengthening-Financial-Resilience-in-Southeast-Asia-P170913.pdf>.



## Pandemic Emergency Financing Facility of the World Bank (2016)

The Pandemic Emergency Financing Facility (PEF)—a financing mechanism that was officially closed and managed by the World Bank—was designed to provide an additional source of financing to help the world's poorest countries respond to cross-border, large-scale outbreaks. The PEF complemented the larger role that IDA, the World Bank's fund for the poorest countries, and other international organizations and donors played in financing outbreak response. The PEF's design was unique in that it allowed payments to be sent directly through its cash window or, once triggered, through its insurance window to governments and frontline responder organizations that had been pre-approved, such as UNICEF and WHO.<sup>34</sup>



## Central Emergency Response Fund (CERF) established by the UNGA (2005)

The Central Emergency Response Fund (CERF), established by the United Nations General Assembly (UNGA) in 2005, serves as the United Nations' global emergency response fund, enabling humanitarian actors to provide life-saving assistance to the most vulnerable people at the most appropriate time and location. CERF funding enables UN agencies and partners to jointly initiate relief efforts in emerging or escalating crises before other funding sources become available.<sup>35</sup> It operates as a crucial mechanism for disaster risk financing and insurance, providing rapid and predictable funding for humanitarian responses to sudden-onset emergencies. Additionally, CERF is a strategic tool for addressing significant budget gaps in emergencies that receive insufficient funding. Furthermore, the flexible financing mechanism of CERF enables the quick allocation of resources based on assessed needs, thereby enhancing the effectiveness and efficiency of humanitarian interventions in disaster-affected areas.<sup>36</sup> Through its proactive approach to financing emergency response, CERF plays a vital role in strengthening global disaster preparedness and resilience, ultimately contributing to more effective disaster risk management worldwide.

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<sup>34</sup> World Bank and World Health Organization (WHO), Pandemic Emergency Financing Facility (PEF) Framework Report (2022), <https://thedocs.worldbank.org/en/doc/24dce6fdf04a1313a07f7c24f539f4c7-0240012017/pandemic-emergency-financing-facility-pef-framework.pdf>.

<sup>35</sup> United Nations Central Emergency Response Fund (CERF), "UN Central Emergency Response Fund," <https://cerf.un.org/>.

<sup>36</sup> United Nations, Annual Report of the Central Emergency Response Fund (CERF) (2022), [https://cerf.un.org/sites/default/files/resources/CERF\\_ARR\\_2022\\_20230904.pdf](https://cerf.un.org/sites/default/files/resources/CERF_ARR_2022_20230904.pdf)

## Annex B: Various Risk Financing Mechanisms, Their Usage, Advantages, and Disadvantages

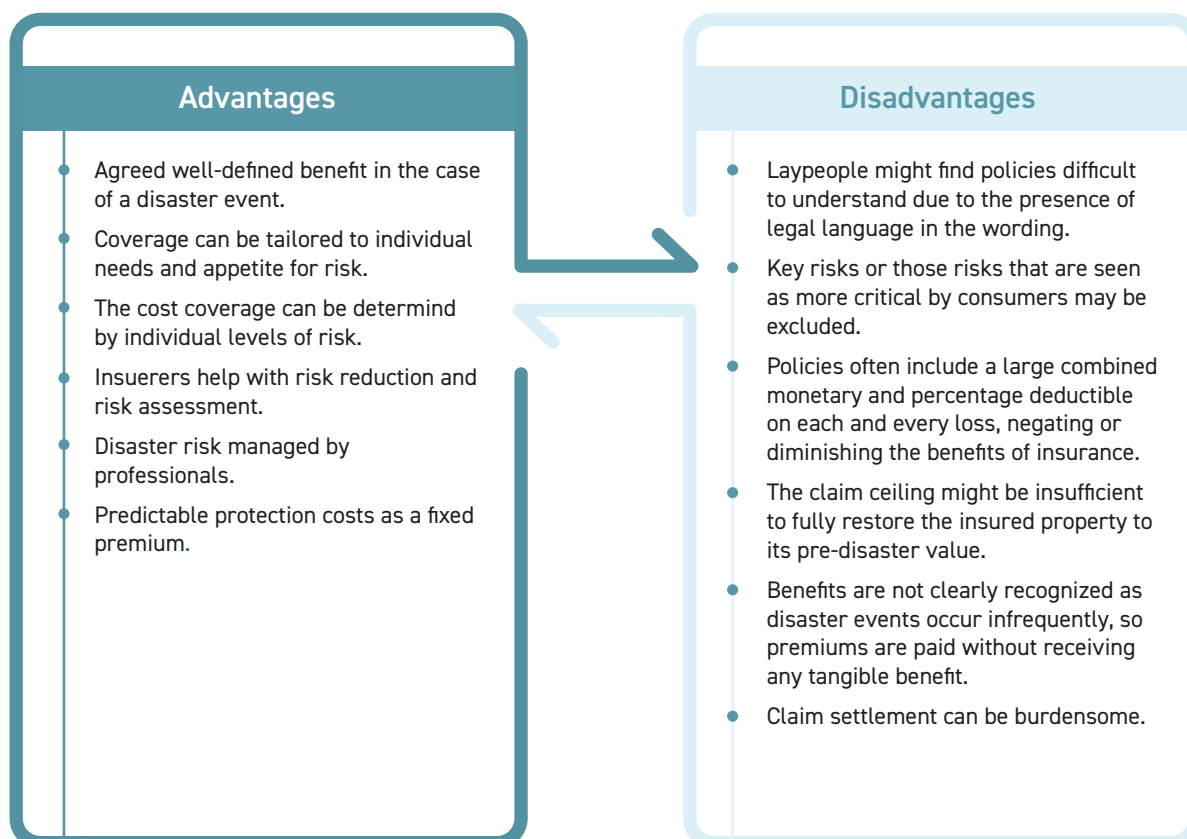
### 1 Disaster Insurance

#### Definition

Insurance is a financial transaction by which the insured, a physical or legal person, transfers to an insurer their natural hazard risk in exchange for a payment (insurance premium). Providers of insurance are licensed and supervised insurance companies, captive insurers, and insurance pools, which are entities exclusively dedicated to the insurance activity. In some jurisdictions, non-licensed insurance activity exists. Depending on how this activity is controlled, it could result in an inability to fulfil the claim payment after a disaster due to insufficient funds by the entity acting as an unlicensed insurer.

#### Main usage

Major disaster risk entails a low-frequency, high-severity event (earthquake, flood, cyclone, tsunami, drought, etc.). Although exposure and vulnerability to these events can be reduced, significant residual risk may remain, so transferring the risk through insurance is appealing as a valid risk management strategy.



### Preconditions

- Disaster risk awareness.
- Supporting government policy on developing disaster insurance instruments, which may include mandatory insurance cover and tax benefits on premiums.
- Availability and affordability of disaster risk product, including those for corporates, individual households, and low-income populations.
- Credibility of the insurance sector, including with regard to the regulatory environment, the solvency and reputation of the insurance markets, and the availability of support from professionals such as actuaries, risk assessors, auditors, brokers, and loss adjusters.
- Complementary social protection solutions, allowing low-income populations to enjoy social protection or support in the acquisition of insurance, while avoiding the crowding out of insurance solutions for people who can afford premiums.
- No unlicensed competition. Insurance credibility and resilient insurance providers are essential and can only be achieved if all insurance providers are licensed and supervised by the insurance regulator.

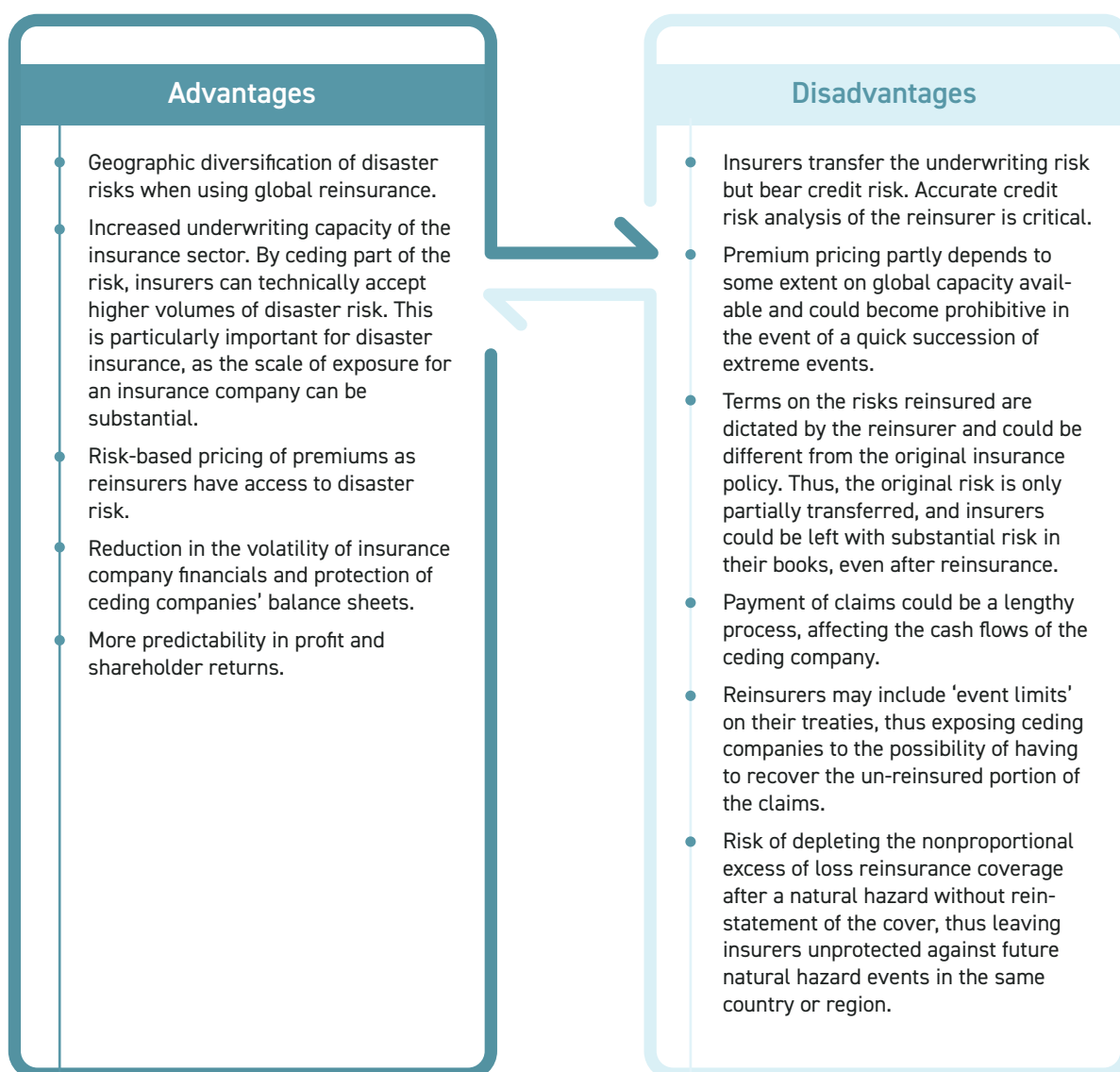
## 2 Disaster Reinsurance

### Definition

Reinsurance is a financial transaction by which disaster risk and other insured risks assumed by an insurer in the original insurance policy are transferred (ceded) from the insurance company (cedent) to a reinsurance company (reinsurer) in exchange for a payment (reinsurance premium). The providers of reinsurance are professional reinsurers, which are entities exclusively dedicated to the activity of reinsurance. In most jurisdictions, however, insurance companies are also allowed to participate in reinsurance (Wehrhahn 2009). Reinsurers can effectively assume massive amounts of disaster risk by diversifying their portfolios to accept risks from around the world and maintaining substantial capital to support these assumed risks.

## Main usage

Major disaster risk entails a low-frequency, high-severity event (earthquake, floods, cyclone, tsunami, drought, etc.). This risk is difficult to diversify at the primary insurer level. Hence, without additional risk transfer possibilities, insurers would not be in a financially viable position to accept this type of risk on their own. Insurers assuming disaster risk protect their balance sheet by entering into reinsurance agreements.



### Preconditions

- Sound supervision of the insurance and reinsurance markets to guarantee effective products and timely claims payments.
- Availability of international reinsurers interested in acting in the given country.
- Availability of data and risk maps.
- Minimum credit rating of the reinsurers by reputable rating agencies such as AM Best, Fitch, and Standard & Poor's Global Ratings.
- Proper oversight of reinsurance brokers operating within the region or country.

## 3 Insurance-Linked Securities

### Definition

Insurance-linked securities (ILS) are investment instruments that transform insurance risk into transparent and tradable capital market products. Investors assume insurance risk in exchange for a higher rate of return compared to other securities that are free from that risk. The insurance risk materializes in the event that a predefined disaster event occurs, such as an earthquake or tropical cyclone of a certain intensity. ILS include categories of vehicles such as catastrophe bonds, longevity or mortality bonds, fully collateralized reinsurance agreements, and industry loss warranties.

### Main usage

Catastrophe or cat bonds and other types of ILS are typically issued to provide (re)insurance protection for insurers, reinsurers, governments, and corporations. ILS offers coverage from new pools of capital separate from traditional reinsurers, such as hedge funds and pension funds. Investor capital provides collateralized cover. The capital is held in a segregated collateral account with dedicated funds available to make a payment in the event of a qualifying event occurring. This virtually eliminates the credit risk inherent in traditional (re)insurance (Swiss Re 2012).

### Advantages

- Immediate access to funds once the trigger event is confirmed.
- Limited concern about counter party credit in the event of an extremely huge event, as the claim amount is fully collateralized.
- Predictable budgetary costs for the issuer of the bonds.
- Tailor-made triggers to address specific disaster risk contexts.
- A diversified source of disaster risk financing, which is especially beneficial when there is shortage of retrocession capacity or complex pricing cycles in traditional reinsurance markets.
- Multiyear pricing stability (terms of three to five years are typical for cat bonds).
- For investors, a source of investment that remains uncorrelated with broader cycles in financial market performance, thereby increasing portfolio diversification.

### Disadvantages

- Complexity of the product. Securities are already complex, and including the triggers related to the underwriting risks adds complexity to the instrument's structure.
- Costs can be relatively high if the issuance volume is small. Transaction sizes range from approximately \$100 million to either \$750 million or \$1 billion (Swiss Re 2012).
- Basis risk exists as the triggers might not be totally correlated with the actual loss incurred.
- Investor appetite may differ from the desired triggers.
- Triggers may be difficult to assess.

### Preconditions

- Sophisticated securities markets that can issue ILS.
- Sophisticated investors looking to diversify their investments away from traditional forms of market risk.
- Transparent product structures.
- Transparent and robust disaster risk models.
- Clearly defined triggers.
- An enabling government policy including tax benefits for ILS investors, regulations that allow insurers, and reinsurers to use ILS for capital relief, among others.
- Attractive returns for investors in the ILS markets.
- Credibility of the securities sector, including with regard to the associated regulatory environment, credibility and reputation of sponsors, and the availability of professionals such as broker-dealers, rating agencies, actuaries, and auditors.

## 4 Agricultural Indemnity Insurance

### Definition

Agricultural indemnity insurance is a type of insurance that indemnifies the insured person against pure agricultural losses (i.e., crop or livestock). A loss assessment process verifies the loss. The insured person could be a farmer, a farmer group, or an agricultural lender whose delinquency risks depend on the outcome of agricultural output.

The following forms of agricultural indemnity insurance products are presently popular:

- 1 **Single-risk insurance:** Covers against one peril or risk (e.g., drought).
- 2 **Combined (peril) insurance:** Covers a combination of several risks (two or more risks, mostly with hail as basic cover). In some countries, this type of insurance is also referred to as multi-risk insurance.
- 3 **Yield insurance:** Offers a yield guarantee based on either regional average yield or individual historic yield, covering key risks affecting yield (e.g., drought). In some countries (e.g., the United States), this type is also known as combined or multiperil insurance.
- 4 **Revenue insurance:** Combines yield and price risks coverage in a single insurance product. It can be product-specific or farm-wide.
- 5 **Farm-income protection insurance:** Covers losses to future income (e.g., future droughts) based on investments in long-term production, thereby reducing reliance on government assistance in times of need and building farmers' business resilience. It includes yields and price risks, as well as production costs. Usually, this type of insurance is not product-specific, instead covering whole-farm income.
- 6 **Whole-farm insurance:** Consists of a combination of guarantees for different agricultural types of production on a farm. Depending on the scope of the guarantees, it can cover whole-farm yield, revenue, or income insurance (EU 2008).

### Main usage

Agricultural indemnity insurance covers farmers and agrarian lenders against the loss of crop or livestock. When purchased by agricultural lenders, it can also increase their risk appetite to lend to farmers who are not otherwise creditworthy and at better terms than uninsured risks.

### Advantages

- **Low basis risk:** Indemnity insurance has low basis risk compared to index insurance (i.e., the claim amount nearly matches the actual loss suffered).
- **Less data requirement:** Indemnity insurance requires less data compared to index insurance for designing and developing products.
- **Reasonably transparent verification processes:** Losses are verified on the ground, usually in the presence of the insured farmers, although involving some degree of subjectivity.
- **Transparent settlements:** Payouts depend on the scale of damage and losses incurred, making settlements easy to understand and communicate.

### Disadvantages

- **Onerous assessment processes:** As a claim is paid after assessing each loss, the loss assessment process can be onerous and costly. However, modern and affordable technology can reduce the time for loss assessment, keeping costs in check. Technology-based tools can also provide corroborative information to reinforce human loss assessment activities.
- **Costly assessments:** The onerous loss assessment process implies high assessment costs.
- **High risk of adverse selection and moral hazard:** Claim payments often rely on crop-cutting experiments, leaving room for manipulation. Adverse selection (i.e., the purchase of insurance by farmers who are more likely to experience claims) is more likely with indemnity than with index-based insurance. Moral hazard (i.e., farmers acting in a manner that leads to greater chances of the claim becoming payable) is also more likely with indemnity than with index-based insurance.

### Preconditions

- **Historical loss, modelled loss, and exposure data:** This information is required for several aspects of the product design, product evaluation, and product pricing processes. Insurance can be effective for risks with low frequency and high values. Still, the product needs to be designed such that risks with higher frequency and lower values are not transferred to the insurer but instead retained—and hopefully reduced—through the farmer's risk reduction efforts.
- **Subject specialists:** Worthy products are usually developed with assistance from subject specialists. It is therefore important to ensure that the product development team has access to the required types of expertise, either internally or externally (e.g., agronomists, modellers, underwriters, and actuaries).
- **Distribution channels:** Efficient distribution channels help minimize administrative costs for underwriting and claim settlement. It is possible that the insurer may have a captive distribution channel (e.g., its own sales force to distribute credit-linked insurance for agricultural risks). The insurance product's sales process often needs to be embedded into the main business activities of the insured persons.

- **Availability of reinsurance:** Crop and livestock claims depend upon weather and other natural hazards, which can affect the entire region of coverage in a relatively short time span. This can result in substantial and often covariate losses for the insurer, leading to higher demands on capital to demonstrate solvency. Reinsurers can accept such risks by covering geographically diverse regions over long periods of time within their already diversified lines of business. Therefore, reinsurance capacity becomes necessary for agricultural insurance, which inherently faces large and covariate risks.
- **Regulatory support:** Regulation can support agricultural index-based insurance in many ways: (i) by setting lighter solvency requirements due to the extremely short tailed losses, if not already covered under the existing solvency requirements; (ii) by offering a prompt redress mechanism on claim settlement; or (iii) by establishing data infrastructure and coordinating investment in data as a public good.



## 5 Agricultural Index and Parametric Insurance

### Definition

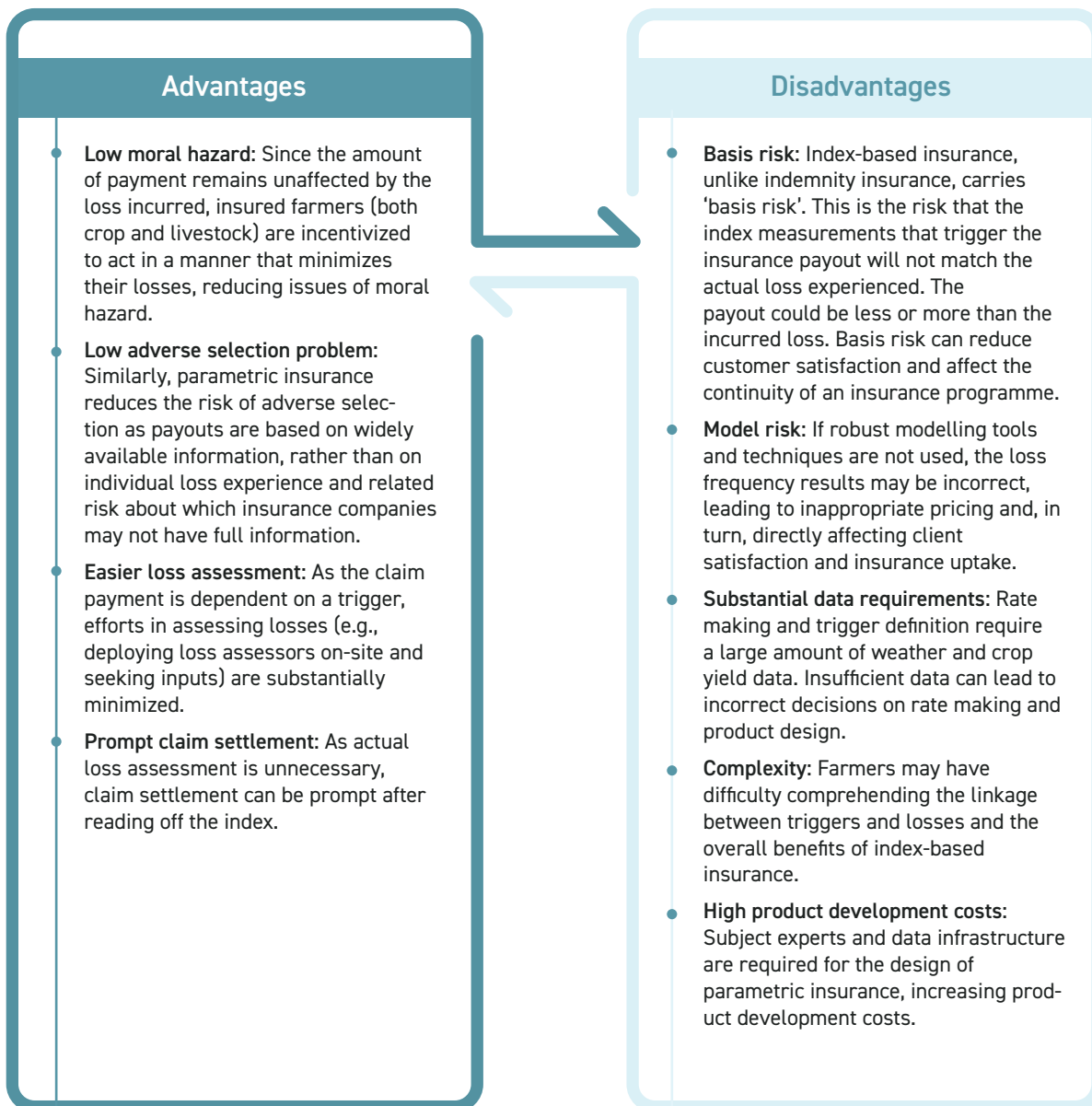
Agricultural parametric insurance is a form of insurance that *ex ante* agrees to make a payment upon the occurrence of a trigger observation or event linked to the loss, rather than indemnifying the pure agricultural loss (i.e., crop or livestock). The trigger observation could be a decrease in average yield or prices in a predefined area, such as an area yield index insurance or a trigger event based on weather-based indexes, satellite images, and other factors. In developing such products, it is necessary to understand the fine line between parametric insurance and index-based insurance. A parametric insurance product typically works on a binary parameter with only two possible outcomes (e.g., death or contracting a critical illness). In such cases, either a full payout or no payout is made as only two outcomes are possible. In contrast, index-based insurance is offered on parameters that most likely have multiple outcomes (such as wind velocity and precipitation levels) and can result in a graded scale of payouts. In such cases, claims are often linked to the trigger gradually (e.g., the farther above the observation from the trigger, the higher the claim payout) until a pre-agreed ceiling is reached. The insured person could be a farmer, a farmer group, or a lender whose delinquency risks depend on the outcome of agricultural output.

The following forms of agricultural indemnity insurance products are presently popular:

- 1 **Area yield index insurance:** Indemnities are computed from the decrease in the average yield over an area without ascertaining the crop output of individual farmers.
- 2 **Area revenue index insurance:** Indemnities are calculated based on the decline in overall production of the average yields and prices in an area (EU 2008), without determining the crop output and prices of individual farmers.
- 3 **Indirect index insurance:** Indemnities are based on indexes of yields or vegetation that are computed from weather-based indexes, satellite images, and other sources (EU 2008).

### Main usage

Agricultural parametric insurance provides security to farmers and agricultural lenders by eliminating the element of subjectivity in loss verification and reducing the time to settle claims. When purchased by agricultural lenders, it can also encourage them to lend to farmers who are otherwise not creditworthy and to provide better terms for farmers.



### Preconditions

- **Historical and modelled weather data:** This information is required for several stages of product design, evaluation, and pricing. If such information is unavailable, designing a robust product will not be feasible.
- **Subject experts:** Valuable products are usually designed with assistance from subject specialists. It is important to ensure that the product development team is multiskilled (e.g., in crop agronomy and statistical modelling) and has the necessary experience and expertise to develop the required products.
- **Historical and modelled loss data:** Especially for area yield index insurance, historical and modelled loss data are essential in pricing the product and determining the trigger.

- **Real-time hazard data:** Real-time hazard data are required to provide prompt payouts and maintain customer satisfaction.
- **Product design capabilities:** High-quality product design capabilities must be available to the insurer, either internally (in the long run) or externally (in the short run).
- **Regulatory and supervisory support:** Regulation can support agricultural index-based insurance in many ways:
  - By setting lighter solvency requirements due to the extremely short-tailed losses, if it is not the case in the existing regulations.
  - By recognizing index insurance, which could otherwise be argued as a 'derivative' product.
  - By setting up data infrastructure and coordinating investment in data as a public good.
  - By setting up a supervisory mechanism that emphasizes the education of farmers on parametric products.
- **Distribution channels:** Proper distribution channels are required to help ensure low administrative costs for underwriting and claim settlement.
- **Availability of reinsurance:** Index insurance is typically employed to transfer covariant risks that can affect a whole country or region at the same time, necessitating access of insurers to sufficient reinsurance capacity.
- **Weather infrastructure:** A sufficient network of tamper-proof weather stations and satellite imaging infrastructure is required to capture data regularly and accurately.
- **Animal mortality rates:** In the case of mortality index-based livestock insurance, historical animal mortality rates (including exposure and death events) by species, time, and geography are necessary.



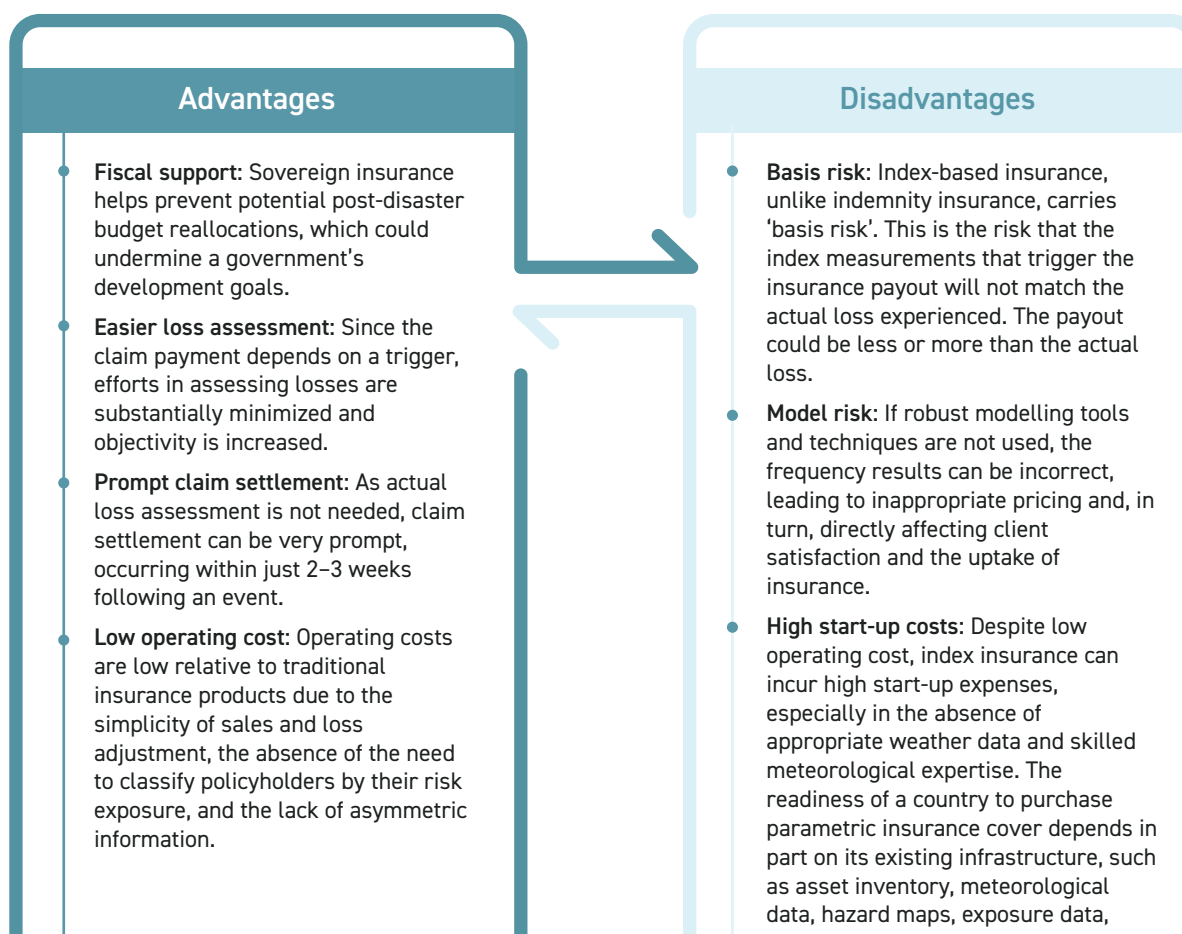
## 6 Sovereign Parametric Insurance

### Definition

Like any parametric insurance, sovereign parametric insurance *ex ante* agrees to make a payment when a trigger observation or an event linked to the loss occurs, rather than indemnifying the pure loss. It may be purchased by the government of a sovereign state and works on the usual insurance principles of premium payment to cover risks. The trigger observations can be specified intensities of natural hazards in a designated location (e.g., rainfall level, wind speed, seismic shocks as measured on a Richter scale) as assessed by an independent agency. Claim payouts could be linear (i.e., gradually increasing claims paid as the actual observation moves beyond the parametric trigger) or categorical (i.e., payment of a fixed sum on the breaching of the defined parametric trigger).

### Main usage

Parametric insurance can be used to provide security to a country's fiscal position while reducing subjectivity in loss verification and time to settle claims. It also reduces the post-disaster fiscal stress on the insured country, hence smoothing government spending. Parametric cover is most suitable for low-frequency, high-severity events.



- **Low moral hazard:** As the amount for payouts is unaffected by the loss experienced, governments are incentivized to act in ways that minimize losses, thereby reducing issues of moral hazard.

vulnerability analyses, historical disaster data, and disaster risk models..

- **Data requirements:** Rate making and trigger definition require extensive data, including exposed assets (including public assets), past and modelled hazard events, and weather information. The absence of data can lead to incorrect decisions on rate making and product design.

### Preconditions

- **Understanding of disaster risk:** Parametric cover is best applicable to very low frequency, high-severity events.
- **Data infrastructure:** Weather and seismology-related information is required for several stages of product design, evaluation, pricing, and implementation. This information should be capable of independent verification using different tools. For example, satellite images can complement primary weather station information regarding precipitation. If this type of information is unavailable, it may hinder the development of an appropriate product.
- **Subject experts:** Valuable products are usually designed with assistance from subject specialists. It is important to ensure that the product development team is multiskilled and has the required experience and expertise. Often, there is a need to involve reinsurance companies interested in underwriting the cover to provide domain expertise.
- **Historical and modelled loss data:** Historical and modelled loss data are essential in pricing the product as well as in defining the trigger. Insufficient or inappropriate data may lead to gaps in coverage or other serious product-related issues.
- **Real-time hazard data:** In the absence of real-time data, it is difficult to gauge the amount of claim payment promptly.
- **Frequency and accuracy of recording data:** Weather stations and satellite imaging infrastructure need to capture data regularly and accurately, while being highly resistant to any form of tampering. This type of infrastructure is critical to assessing whether a particular area has breached the trigger.

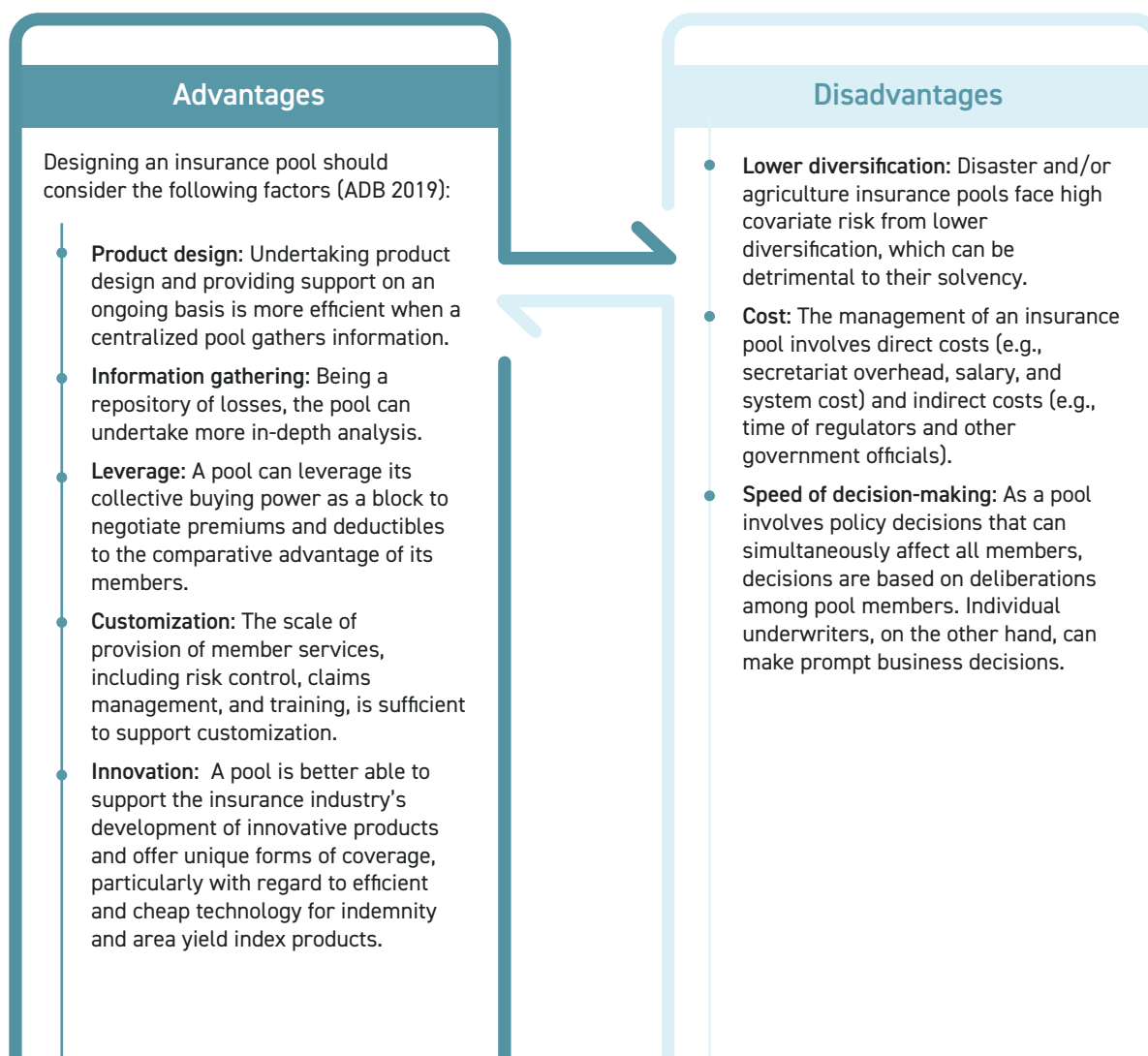
## 7 Insurance Pool

### Definition

An insurance pool is a multiple-member risk-sharing arrangement where organizations (often primary underwriters) pool their funds together to finance an exposure, liability, risk, or some combination of the three. Pools may include multiple layers of coverage, such as insurance, excess insurance, and different deductibles for different members.

### Main usage

**An insurance pool can create capacity at multiple dimensions:** Supply of insurance for business lines that face high risks from unfavourable outcomes, underwriting of large risks by pool members, technical capacity for development of complex insurance products, advice and information gathering for loss assessment, stability of underwriting results, and reduction of the impact of single and large risks.



- **Flexibility:** A pool is better able to respond to the needs of individual insurers through variable deductibles, self-insured retention levels, and special coverage.
- **Subsidy policy:** A pool can provide data that could be useful to guide policy on premium subsidies, which, in principle, should be restricted to the cost of underwriting systemic risks.
- **Credibility:** By involving many key public sector stakeholders (e.g., the regulator and other government departments), pool members can demonstrate higher credibility to supply insurance.
- **Pricing stability:** Pools can involve a layer of capital to cover the first layer of losses, reducing the use of reinsurance and resulting in greater price stability.
- **Reinsurance:** Economies of scale facilitate the purchase of reinsurance at a more competitive price.

## Preconditions

- **Reinsurance:** An agriculture or disaster insurance pool will have high covariate risks. It is imperative to have proper reinsurance arrangements to maintain the solvency of the pool.
- **Regulatory framework:** Insurance pools involve many stakeholders and underwrite large, collective risks. To prevent conflict, it is necessary to have rules or regulations in place to demarcate the rights and duties of all the stakeholders.
- **Subject experts:** Managing a pool's risks and information keeping requires subject specialists. Often, it requires involving subject specialists who have a strong understanding of the specific risks being pooled, as well as an in-depth understanding of the pool's reinsurance arrangements.
- **Medium- and long-term strategy:** As insurance pools are often created to address a market need in the medium (3–5 years) and long term (5–10 years), a well-planned strategy is necessary to envisage future functioning. For example, a strategy may consider winding up a pool after certain performance parameters have been achieved.
- **Information systems:** Adequate information technology systems are needed to record data, settle distribution costs and claims, and demonstrate solvency.

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