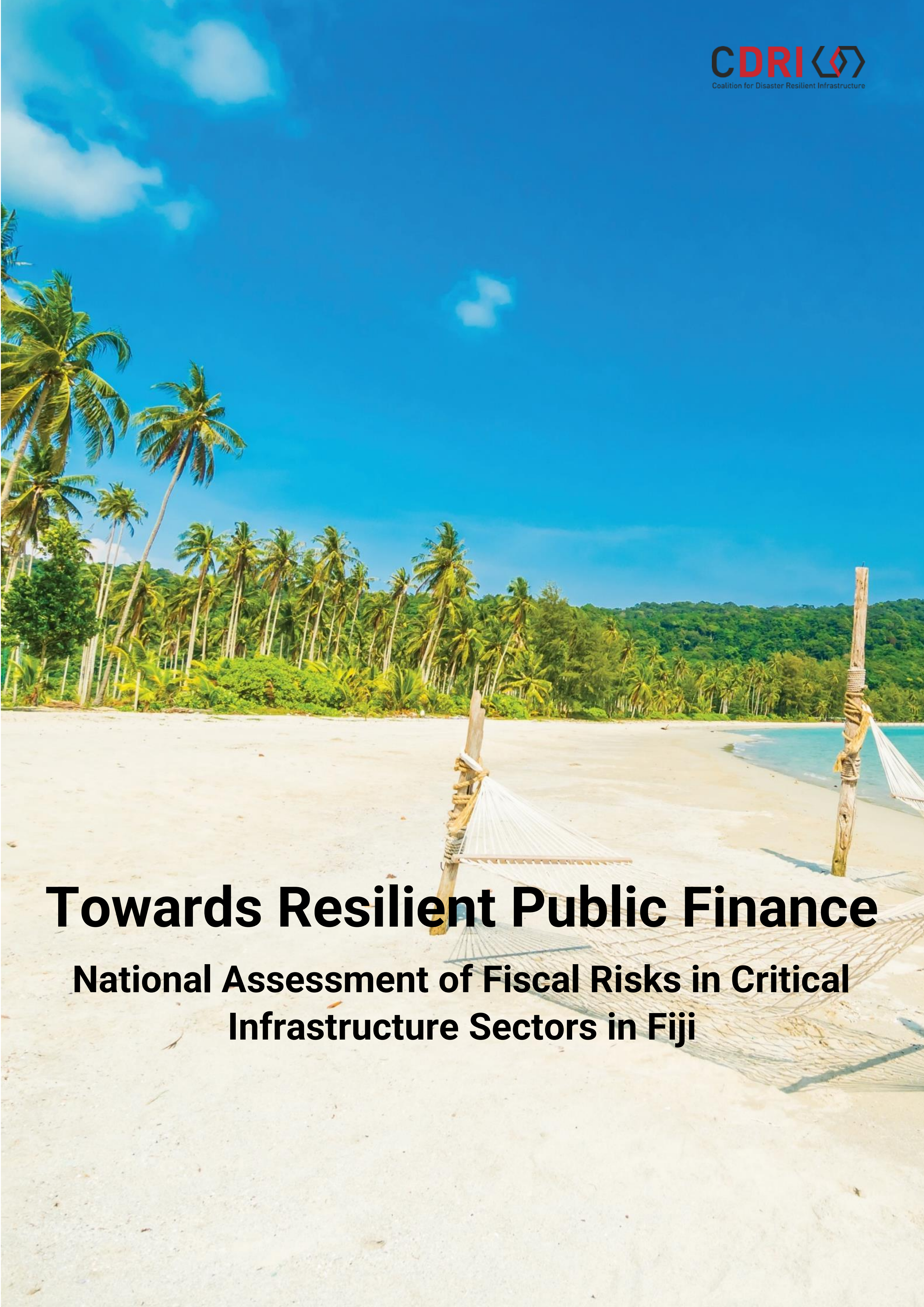

Towards Resilient Public Finance

National Assessment of Fiscal Risks in Critical Infrastructure Sectors in Fiji

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Foreword

Fiji, like many Small Island Developing States (SIDS), faces complex and growing risks emanating from climate-related threats such as tropical cyclones, floods, and rising sea levels, and geological hazards including earthquakes and tsunamis. Among these, the accelerating frequency and intensity of climate hazards, driven by rising global temperatures, are placing unprecedented strain on the country's infrastructure and public finances. Each successive shock not only undermines critical infrastructure and disrupts essential services but also erodes hard-won development gains. The cumulative fiscal pressure limits the government's ability to respond rapidly, recover sustainably, and invest in future resilience. Building financial preparedness for such compounding risks is no longer optional – it is essential for safeguarding national 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 assess fiscal risks associated with disasters in critical infrastructure sectors. This study for Fiji represents one of the first efforts in the Pacific region to systematically link disaster-related impacts on infrastructure to fiscal outcomes. Key recommendations are towards enhancing disaster risk financing strategies and strengthening institutional capacities for managing contingent liabilities in infrastructure are also suggested.

The study is intended to become a benchmark for disaster risk financing by providing a methodology to understand the economic and fiscal implications of disasters, the performance of existing financing mechanisms, and the critical importance of forward-looking, risk-informed public investment and budgeting practices. We hope this assessment will serve as a useful tool for policymakers, financial planners, and development partners working to build fiscal resilience in Fiji and other similarly vulnerable economies.

We are grateful to our consultant, Asian Disaster Preparedness Center (ADPC), and to the Government of Fiji 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 heart of public financial decision-making. This report is a step in that direction.

Amit Prothi
Director General
Coalition for Disaster Resilient Infrastructure

Table of Contents

Executive Summary

Fiji, recognized as one of the most disaster-prone Small Island Developing States (SIDS), faces significant fiscal risks from natural hazards, particularly from tropical cyclones, floods, and rising sea levels. Disasters occur nearly every year, resulting in substantial economic shocks, particularly to critical infrastructure sectors like power and transport. This report, developed under the Coalition for Disaster Resilient Infrastructure's Finance for Resilient Infrastructure Programme (FRIP), offers a thorough evaluation of the fiscal consequences of disasters in Fiji, suggests evidence-based risk financing solutions, and puts forth measures for institutional strengthening to improve fiscal resilience.

Fiji is listed among the top 15 countries most impacted by extreme weather worldwide. The growing frequency and intensity of disasters have led to extensive economic effects, such as disruptions to businesses, a shrinking tax base, and rising public spending needed for recovery. This report proposes a detailed fiscal risk framework that demonstrates how disasters impact convert into fiscal liabilities through decreased economic activity, diminished revenue, and heightened emergency expenditure. From 1931 to 2022, Fiji encountered 45 tropical cyclones, resulting in cumulative losses amounting to $3.96 billion, with an average loss of $88[1] million per cyclone. Cyclone Winston alone caused damages that represented 6.9 percent of GDP, while following events like Cyclones Yasa and Harold, together with the COVID-19 pandemic, placed additional strain on public finances. Fiscal analysis indicated sharp decreases in tax revenues, from $200.5 million in 2019–20 to $135 million in 2020–21, while public debt rose from $611.6 million to $906.4 million between 2020 and 2024. These patterns highlight the mounting fiscal pressure resulting from recurrent disasters.

The power sector, managed by Energy Fiji Limited and the Department of Energy, suffered damages exceeding $41 million from Cyclone Winston alone. Cyclones have repeatedly damaged rural electrification infrastructure, particularly diesel-based mini-grids and solar home systems. In the transport sector, the Fiji Roads Authority reported damages exceeding $129.5 million for roads and bridges due to Winston, along with recurring damages from Cyclones Harold, Yasa, and Ana. These persistent losses raise maintenance expenses and hinder planned advancements.

Currently, Fiji's post-disaster financing primarily depends on budget adjustments, international assistance, and preferential borrowing. Existing mechanisms, including the Disaster Rehabilitation and Containment Facility, Fiji National Provident Fund (FNPF) withdrawals, and donor-supported flash funds, have been applied irregularly. The National Disaster Relief and Rehabilitation Fund (NDRRF) receives yearly funding but lacks structured disbursement rules. From 2017 to 2023, the NDRRF averaged only $352,000 annually, a significant shortfall compared to estimated damage costs. Despite Fiji having access to a $75 million standby loan from the Japan International Cooperation Agency (JICA) and a $40 million Catastrophe Deferred Drawdown Option (Cat DDO) from the World Bank, these resources are not yet incorporated into a comprehensive risk-layering strategy.

Economic modelling based on GDP fluctuations post-disaster (especially after Cyclone Winston) reveals that sectors such as forestry, agriculture, energy, and services experienced losses greater than 30 percent in certain instances, delaying recovery times. For instance, the forestry sector's GDP dropped by over 30 percent in 2016, and it took two years to recover. These losses have also contributed to wider macroeconomic instability and a decline in the current account balance.

Leveraging catastrophe models, this report evaluates Fiji's prospective risks from tropical cyclones, floods, landslides, and seismic occurrences. Exposure models were established for both the power and road sectors, quantifying replacement costs and pinpointing vulnerabilities using global and local datasets. For example, the power sector's replacement value was assessed using data on energy

[1] All monetary values in this report are in US dollars ($), except where specified otherwise.

generation, transmission lines, and substation information, while road valuations considered road types, slopes, and bridge/tunnel lengths. This modelling equips Fiji with a foundation for crafting risk-informed insurance and budget planning initiatives.

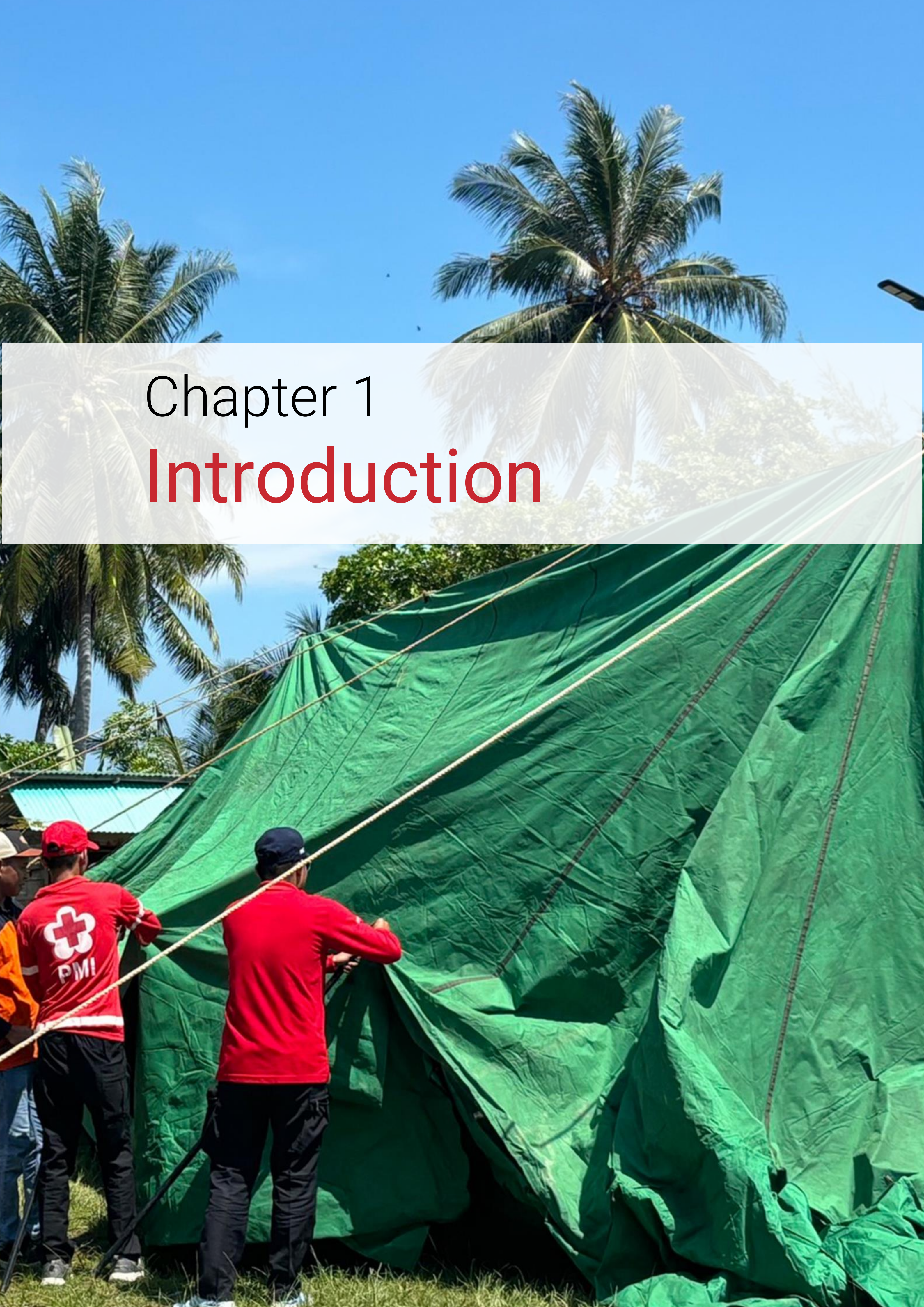
The gap in post-disaster funding remains substantial. For significant cyclones, the actual disaster-related damages have significantly surpassed budget allocations. In 2020, damages from Cyclone Yasa amounted to $155.4 million, while total disaster funding for that year was merely $5.8 million. For the power and road sectors, future funding deficits are anticipated to expand due to climate change-induced increases in hazard severity unless pre-arranged financing and resilient infrastructure investments are enhanced.

The report concludes with essential recommendations:

- Upgrade infrastructure standards in public and private investments
- Adequately allocate post-disaster funds, particularly for emergency humanitarian response
- Expand and Formalize the Use of Risk Layering through a Multi-Tiered Financing Framework
- Institutionalize Pre-Arranged Disaster Response Funds at National and Subnational Levels
- Strengthen Exposure and Loss Data for Fiscal Forecasting and Disaster Analytics, solutions are as reliable as the risk models that support them and risk models are only as good as the data and the capacity required to develop them
- Integrate Disaster-Linked Liabilities into Public Debt Management Strategy
- Creating an evidence-based allocation for the ongoing Contingent Budget Line for Immediate Recovery
- Expanding Sector-Specific Insurance Based on Loss Patterns

These measures aim to shift Fiji from reactive disaster financing to proactive fiscal risk management, ensuring more predictable, efficient, and sustainable responses to climate shocks.

Chapter 1
Introduction



Fiji is highly vulnerable to disasters, underscored by its ranking of 115th out of 191 countries in the 2019 INFORM Risk Index. This vulnerability is largely due to its geographic location in the South Pacific, which exposes it to frequent cyclones, floods, and rising sea levels. The increasing frequency and intensity of these events pose serious threats to lives, livelihoods, and infrastructure, making disaster preparedness and climate resilience critical priorities for the country. The destruction of physical and human assets by disasters disrupts businesses and reduces the tax base, resulting in significant financial strain. This situation necessitates substantial government spending on post-disaster response, recovery, and reconstruction efforts. The problem is further intensified by the interconnected nature of critical infrastructure, especially in the power and transport sectors. Disruptions in these areas can have a cascading effect across the economy, destabilizing supply chains and various economic activities. In recent decades, disaster-related economic losses have risen, highlighting the urgent need for a comprehensive disaster risk financing (DRF) strategy to improve the state's fiscal resilience.

The 'National-Level Assessment of Fiscal Risk Due to Disasters in Critical Infrastructure Sectors' project is part of the Coalition for Disaster Resilient Infrastructure's (CDRI) initiative. The Coalition is committed to supporting Member Countries in developing coherent 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 Fiji's critical infrastructure sectors, explicitly focusing on power and transport. The aim is to support evidence-based policymaking and enhance financial preparedness for future events.

The report aligns with Fiji's Medium-Term Fiscal Strategy, which is in accordance with the new National Development Plan (NDP) for 2025-2029 and Vision 2050. The NDP serves as a strategic framework that combines a three-year and five-year plan with a 25-year vision for Fiji's national development, laying the groundwork for long-term economic growth. Additionally, the report offers detailed insights into various fiscal risk mitigation strategies that can be implemented. These strategies aim to enhance the state's capacity to withstand financial shocks resulting from disasters, thus promoting greater resilience and preparedness for future emergencies. Ultimately, this comprehensive analysis seeks to provide policymakers with the necessary tools to safeguard Fiji's fiscal health and ensure resilient development in the face of natural hazards.

Fiscal Risk Assessment Framework

The International Monetary Fund (IMF) defines fiscal risk as the economic factors that may cause actual fiscal outcomes to diverge from projected or expected fiscal outcomes. The OECD articulates fiscal risks as changes in the expected fiscal outcomes outlined in an economy's annual budget or forecasting documents. Fiscal risks can arise from macroeconomic shocks or contingent liability obligations triggered by uncertain events.[2] Governments must comprehend these risks and prepare for them by performing financial risk assessments for the effective allocation of resources in the event of a disaster.

Fiscal risks can emerge 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 GDP on average to 6 percent in extreme circumstances, making them a significant source of fiscal risk. Public-private partnerships (PPPs) and private non-financial company liabilities are additional sources that may lead to government bailouts.

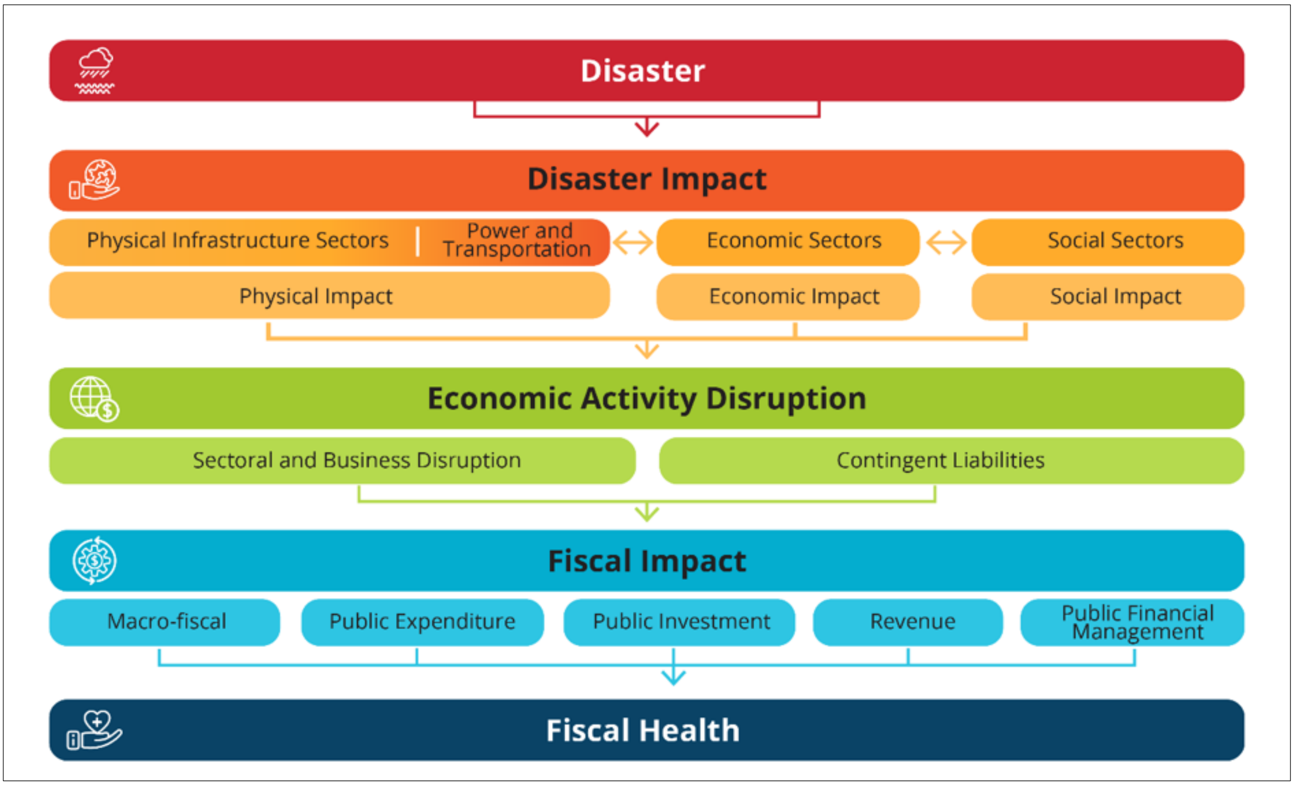
[2] IMF, 2016, Analyzing and Managing Fiscal Risks: Best Practices, https://www.imf.org/external/ np/pp/eng/2016/050416.pdf

According to a study by Bova et al.,[3] disasters imposed the second-highest fiscal costs, accounting for 1.6 percent of GDP on average, after financial sector shocks, which accounted for 9.7 percent. Maintaining sound fiscal management and guaranteeing the government's capacity to respond effectively during a crisis depends on recognizing and controlling these risks.

Disasters cause profound fiscal implications for 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. Understanding these channels is essential for policymakers to effectively manage the fiscal consequences of disasters.

Figure 1 presents a structured framework adopted for this report. The framework illustrates the cascading effects of disasters on economic and fiscal stability, beginning with the disaster impact, which affects physical infrastructure, economic, and social sectors. These disruptions lead to economic activity disruption, including sectoral and business disruptions, and the creation of contingent liabilities for the government. As economic activities suffer, fiscal consequences emerge, categorized under the fiscal impact, affecting macro-fiscal stability, public expenditure, public investment, revenue, and public financial management. These cumulative fiscal pressures ultimately determine the overall fiscal health of the government.

Figure 1. Framework for Assessing Fiscal Risk Arising from Disasters



(Source: ADPC)

[3] Bova et al. (2016). The Fiscal Cost of Contingent Liabilities: A New Dataset, IMF Working Paper. https://www.imf.org/external/pubs/ft/wp/2016/wp1614.pdf

Chapter 2

Financial Risk Assessment Based on Historical Data

Climate-induced disasters, such as floods, cyclones, and other hazards, can severely affect 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 programme. 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. From a fiscal perspective, the frequency and intensity of climate-related disasters can create a higher risk of negative fiscal shock as they strain public fiscal accounts, leading to budget deficits and debt accumulation, resulting in weakness in fiscal stance due to the negative impacts of revenue and expenditure channels and increased public debt, postponed investment projects and a cyclical fiscal policy.

Disasters can also have a significant impact on government revenues, particularly by negatively affecting economic activity. This usually results in reduced tax and non-tax revenues due to lower tax revenues, disruptions to international trade, and reduced labour hours. However, there might also be a post-disaster recovery boost that stimulates economic activity and results in short-term rises in foreign aid or tax revenue. Disasters also influence the government's assets and obligations, in addition to the immediate changes in revenue and spending. Damage to public infrastructure, for instance, raises the cost of repair or replacement. Yet, many governments lack complete balance sheets that consider non-financial assets, making fiscal impact evaluations more difficult.

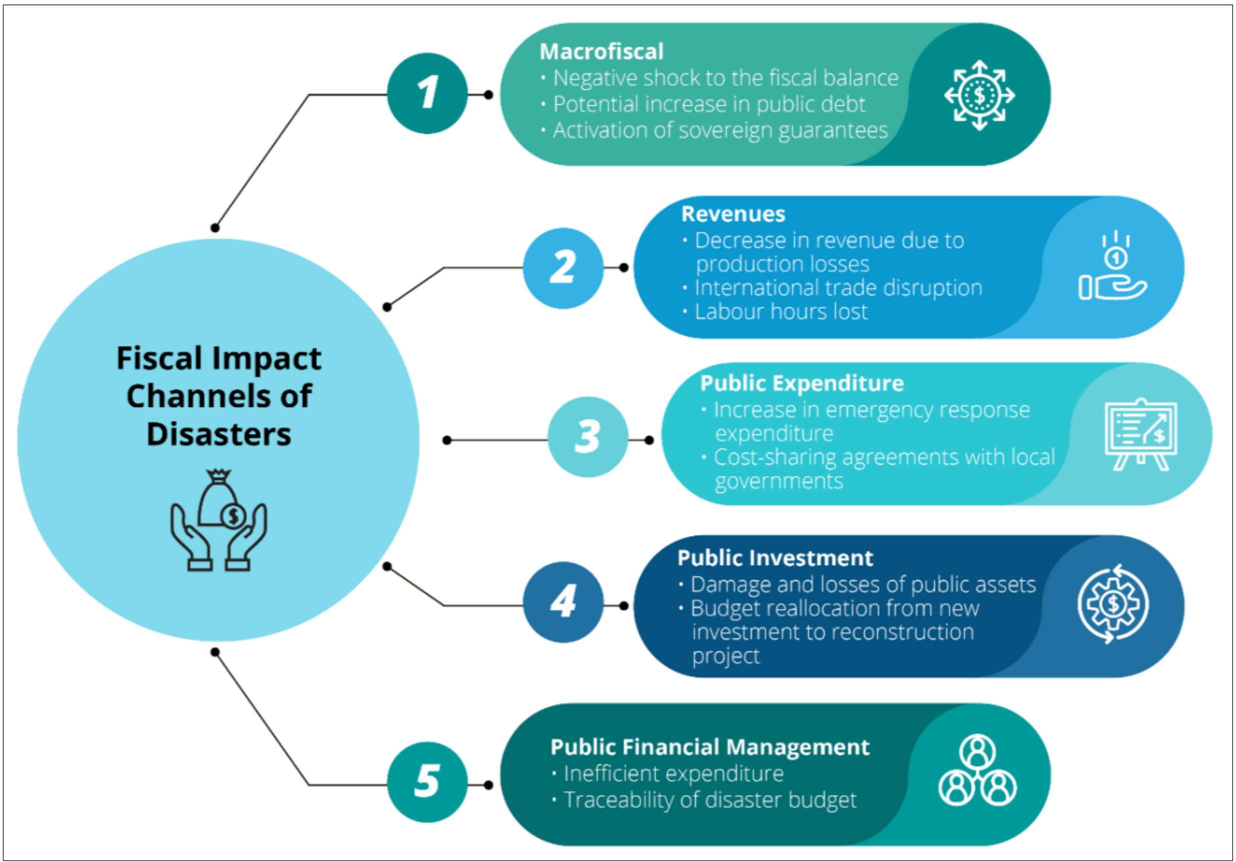
Between 1994 and 2013, disasters caused an estimated $2.6 trillion in economic losses globally, equivalent to 4 percent of the world's GDP in 2015.[4] On average, across a sample of events between 1990 and 2014, the cost to a country's finances due to disasters was 1.6 percent of its GDP. In some cases, the cost was much higher, with the most significant disasters resulting in costs of up to 6 percent of GDP.[5] The study by the International Monetary Fund revealed that the maximum fiscal cost identified was 6 percent of GDP. Disasters and economic growth are negatively correlated in various studies, with the majority demonstrating that disasters lower GDP over the long and short terms. To ensure that governments are ready for the worst and do not undervalue the financial cost of such occurrences, future damage predictions and better study of low-frequency, high-impact disasters are crucial.

[4] Guha-Sapir, Below, and Hoyois (2016), Annual Disaster Statistical Review: The Numbers and Trends. https://www.emdat.be/sites/default/files/adsr_2016.pdf

[5] Bova et al. (2016). The Fiscal Cost of Contingent Liabilities: A New Dataset, IMF Working Paper. https://www.imf.org/external/pubs/ft/wp/2016/wp1614.pdf

Figure 2 *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 resulting in higher public debt and the activation of sovereign guarantees. Revenue is further affected by declines in production, trade disruptions, and loss of labour hours, all of which decrease tax and customs income. On the expenditure side, governments encounter rising emergency response and humanitarian aid costs and may also need to support local governments through cost-sharing mechanisms. Understanding these interconnected channels is crucial for policymakers to effectively plan for and manage the fiscal consequences of disasters.*

Figure 2. Fiscal Impact Channels of Disasters



(Source: ADPC)

As governments borrow money to fund recovery, this could result in budget deficits and increased public debt. Disasters can result in production losses, disrupt trade, and lower tax collections due to lost labour hours and business earnings, significantly influencing revenue. Governments must set aside funds for emergency response and recovery promptly, and they frequently split the expenses of disasters with local governments, necessitating further assistance. Public financial management faces difficulties in guaranteeing the effective use of disaster funds and upholding openness. Public investment is also harmed, with money taken from future projects to rebuild damaged infrastructure.

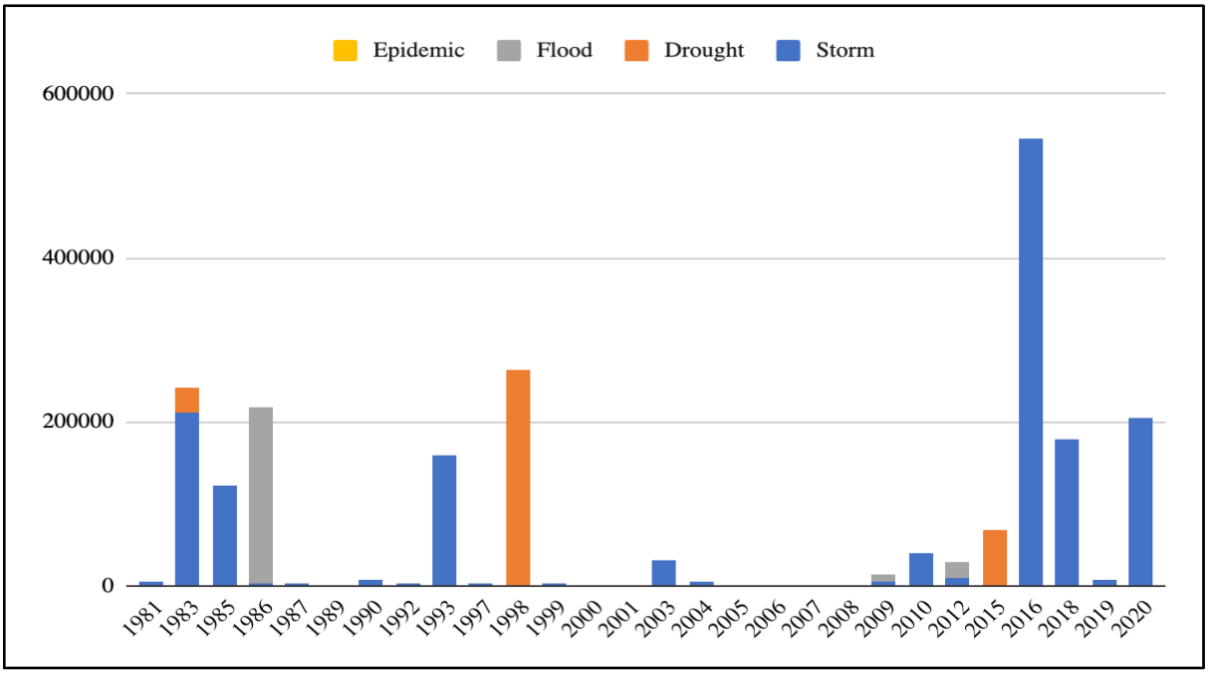
Overview of Impact of Disasters in Fiji

Fiji, a small island developing state (SIDS), is highly exposed to natural hazards such as cyclones, floods, earthquakes, tsunamis, and drought. Disaster risk in Fiji is increased due to its high social vulnerability levels and low coping capacity. Also, it is noted from the review of the Post-disaster Needs Assessment (PDNA) developed by the Government of Fiji that primary disasters, such as cyclones, generate cascading impacts leading to secondary disasters, such as floods and landslides, which further exacerbate the effects and impacts of a disaster.

The country is situated in the vicinity of the Pacific Ring of Fire, which means that earthquakes, earthquake-induced tsunamis, and landslides are common occurrences. Cyclones, heavy rain, and flooding are yearly occurrences, and the most common disasters in the past have been the result of high-impact hydro-meteorological events. The majority of the population (91 percent) and infrastructure are located near the coast, which results in heightened exposure to sea-level rise and weather-related hazards.[6]

The frequency of tropical cyclones is also of major economic significance in Fiji, costing around 5 percent of GDP annually.[7] According to EM-DAT, Fiji has been exposed to several hazards between 1931 and 2022; the most catastrophic events included tropical cyclones (45 events, 1.9 million affected), floods (12 events, 0.3 million affected), droughts (3 events, 0.4 million affected), and earthquakes (Figure 3). Tropical cyclones occur nearly every two years on average, with costs averaging $88 million per event and a total cost of US $3,964 million (2021 values). Floods and droughts occur approximately every 8 to 30 years, with average costs reaching $37 million and $75 million, totaling $445 million and $224 million, respectively.

Figure 3. Number of People Impacted by Major Disasters in Fiji in the Last Four Decades



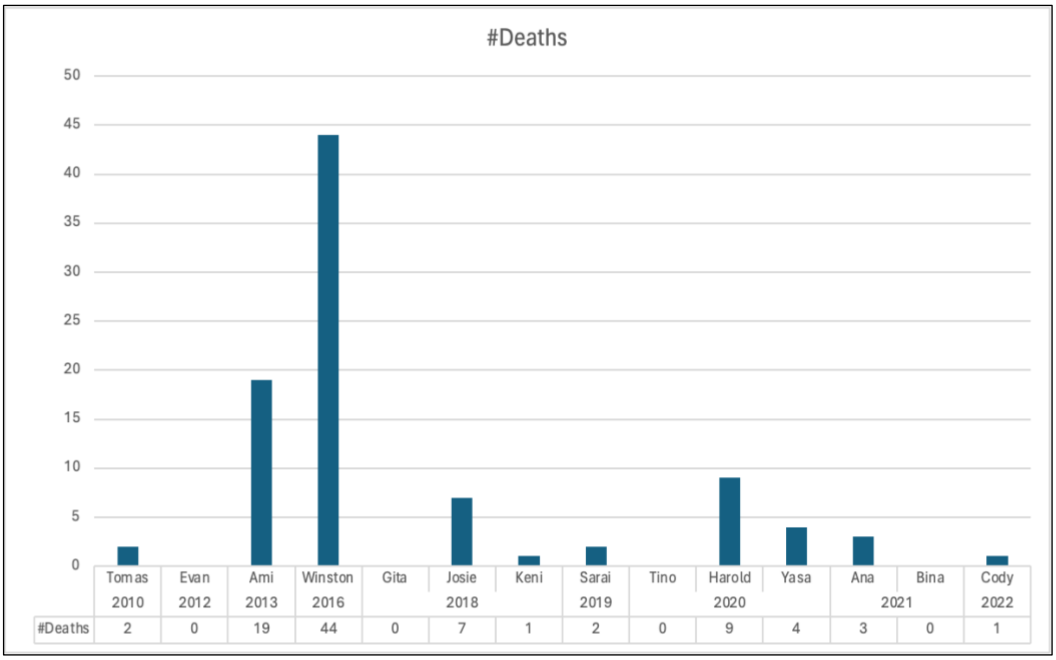
(Source: World Bank, n.d)

Some of the most devastating cyclones to hit Fiji in recent history include Cyclone Winston (2016), the strongest cyclone ever recorded in the Southern Hemisphere, Cyclone Yasa (2020), which was the second-strongest cyclone on record to make landfall in Fiji, and Cyclone Harold (2020). In the past decade, the impact of the key disasters can be observed in Figure 4.

[6]Australian Agency for International Development. *Pacific Risk Profile: Fiji*. 2024. https://www.dfat.gov.au/sites/default/files/pacific-risk-profile_fiji.pdf

[7] World Bank. (2022). *Fiji Critical Bridges Resilience Project (P180979)*. World Bank. https://documents1.worldbank.org/curated/en/099111524183515769/pdf/P180979-2e8e89f7-0fda-4ee0-a58d-4ac97837057f.pdf

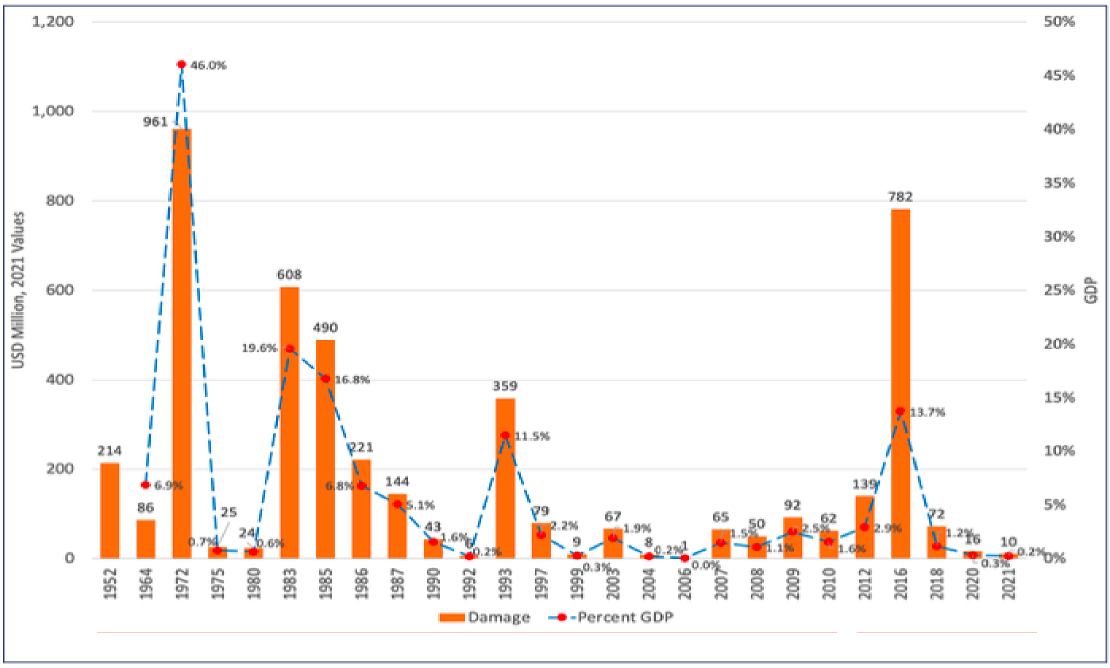
Figure 4. Number of Deaths per Major Cyclone in the Past Decade



(Source: Fiji data compiled by the authors)

A report on the disaster financial preparedness analysis of Fiji, prepared by the United Nations Development Programme (UNDP) and the Asian Development Bank (ADB),[8] estimates the damage from historical events using EMDAT data, as presented in Figure 5.

Figure 5. Damages in $ (2021 Values) of Historical Disasters in Fiji



(Source: UNDP, 2023)

[8] United Nations Development Programme. *Disaster Financial Preparedness Analysis Report*. New York: United Nations Development Programme, 2023. https://www.undp.org/sites/g/files/zskgke326/files/2023-12/undp-pacific-disaster-financial-2023.pdf.

Damage is the replacement value of physical assets wholly or partly destroyed, built to the same standards that prevailed before the disaster. Losses are the foregone economic flows resulting from the temporary absence of the damaged assets and/or due to any other disruption of economic activity caused by the disaster (ECLAC 2003[9]; UNDP 2013[10]).

Impact of Disasters on Power Infrastructure

Energy Fiji Limited (previously the Fiji Electricity Authority), is a government-owned statutory agency that is responsible for the generation, transmission, distribution, and retail sale of electricity in Fiji. It operates four separate power grids on Viti Levu, Vanua Levu (Labasa and Savusavu) and Ovalau, and produces electricity from a mix of diesel, hydropower, and wind. As of 2021, 92.1 percent of the population has access to electricity. The Department of Energy (DoE) provides power to a number of rural areas either through diesel-based mini-grids or solar home systems.[11]

Diesel-based mini-grids are installed by DoE and progressively transferred to community ownership. Since 1976, DoE has installed approximately 419 diesel-based mini-grids in rural areas, most of which have been transferred to local communities for operation and maintenance. Solar home systems for rural households are owned by DoE and are rented to the households for a fee. DoE supplies approximately 4,534 solar home systems to rural households. While these numbers reflect historical installations, their current operational status is subject to the impact of recent disasters (e.g., Tropical Cyclones - TC Winston and TC Keni) and ongoing maintenance challenges.

Fiji's energy sector has been shaped by the demands of Fiji's growing economy as well as by Fiji's natural environment, tropical climate, and traditional practices. The future of Fiji's energy sector will continue to be shaped by these factors. Today, as much as 60 percent of Fiji's electricity generation is derived from hydropower, while remote islands and some rural areas are largely dependent on energy production powered by imported fossil fuels.

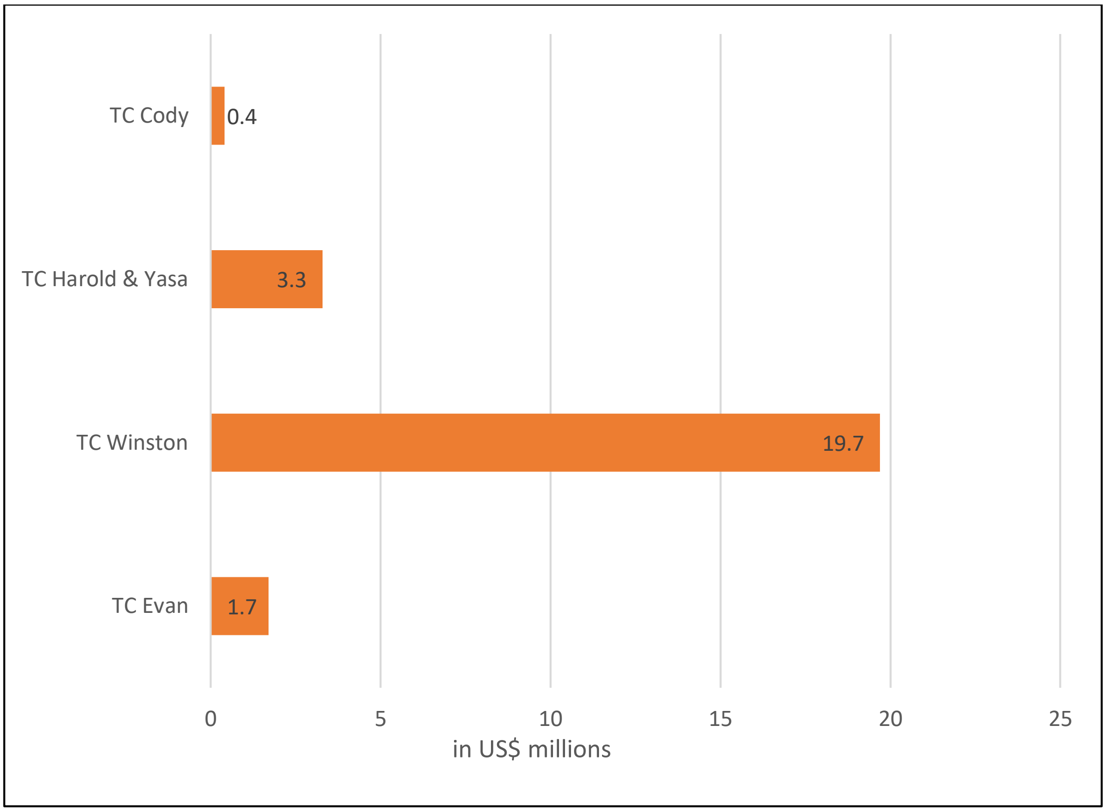
The impacts of climate change pose several threats to Fiji's energy security. Disaster events, such as cyclones, that continue to be intensified by climate change, have increased pressure on Fiji's energy infrastructure and have led to increased current and projected expenditure on improving infrastructure resilience. Energy Fiji Limited recorded over $19 million in damages to energy infrastructure following Cyclone Winston in 2016. Power sector damage from tropical cyclones in Fiji can be mainly observed from TC Winston's damage estimates. In recent years, TC Yasa has documented damage to the power sector, but the documented damage has reduced considerably. Figure 6 presents the available data on power sector damages from disasters in Fiji.

[9] Economic Commission for Latin America and the Caribbean (ECLAC). (2003). *Handbook for Estimating the Socio-economic and Environmental Effects of Disasters*. Santiago, Chile: ECLAC.

[10] United Nations Development Programme (UNDP), European Union, & The World Bank. (2013). Post-Disaster Needs Assessment Guidelines Volume A. Washington, DC: World Bank Publications.

[11] Fiji Ministry of Economy, and Global Facility for Disaster Reduction and Recovery (GFDRR). *Fiji: Disaster Recovery Framework*. Suva, Fiji: Fiji Ministry of Economy, 2016. https://www.gfdrr.org/sites/default/files/publication/Fiji%20DRF.pdf.

Figure 6. Power Sector Estimated Damages from Past Disasters



(Source: Fiji data compiled by the authors)

Impact of Disasters on Roads, Bridges, and Ports

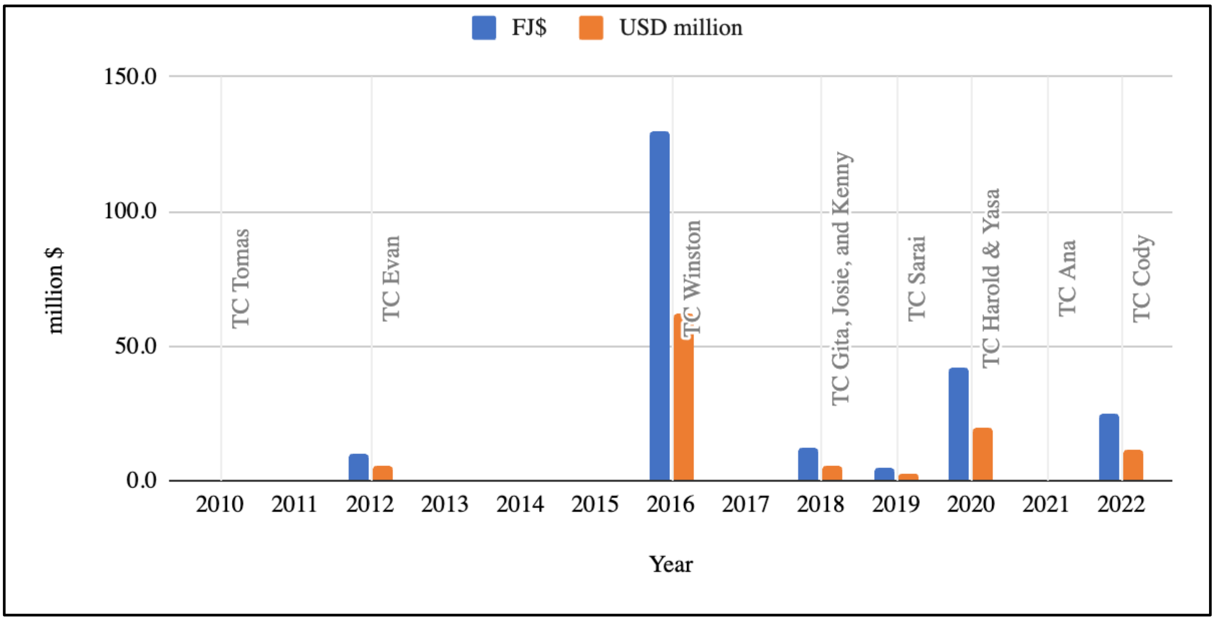
Transport infrastructure and services underpin Fiji's economic growth and social development. Critical industries, such as sugar cane farming, forestry, agriculture, and tourism, rely on road access (e.g., from plantations to processing plants). Remote rural and island communities in Fiji depend on rural access roads, jetties, and safe and reliable maritime and aviation routes in order to access economic opportunities and social services. Tourism is Fiji's primary foreign exchange earner and relies on safe and efficient mobility, internal freight distribution, and increasingly, port facilities, safe and well-charted shipping lanes, and access to island destinations. Fiji's topography has restricted the road network to the spine or circumferential main roads along the coast, with feeder roads and a few alternate routes. In the main urban areas, many lower-level municipal roads and bridges have suffered from neglect and are in poor condition.

The Ministry of Public Works, Meteorological Services, and Transport is responsible for the management of policy, administration, and regulatory activities of all transport modes. The Fiji Roads Authority (FRA) manages the country's road assets and bridges, as well as the country's wharves and domestic jetties, excluding international ports. The FRA's funding requirements are currently met by government capital and operating grants and loan financing.[12]

Historical disasters that have caused significant damage to the road sector include TC Winston in 2016, and TC Harold, Yasa, and Anan in the 2020–2021 timeframe. Other cyclones have also caused damage, although relatively less than those caused by these disasters. The damage estimates are presented in Figure 7.

[12] Fiji Ministry of Economy, and Global Facility for Disaster Reduction and Recovery (GFDRR). *Fiji: Disaster Recovery Framework*. Suva, Fiji: Fiji Ministry of Economy, 2016. "https://www.gfdrr.org/sites/default/files/publication/Fiji%20DRF.pdf.

Figure 7. Road Sector Estimated Damages from Past Disasters
(FJ$ & $ (in million))



(Source: Fiji data compiled by the authors)

Fiscal Impact

Frequent and severe disasters in Fiji have placed a considerable strain on the country's fiscal health, increasing expenditures while disrupting revenue generation. The need for emergency response, infrastructure restoration, and economic recovery creates a fiscal burden, often requiring reallocations from (existing and future) development-focused sectors. The gap between disaster-related spending and revenue inflows widens, affecting the country's long-term economic stability. Figure 8 presents an analysis of Fiji's fiscal revenue streams and public debt from the fiscal year 2019–2020 to 2023–2024.

Revenue Trends

Tax Revenue experienced a significant decline from $455.74 million in 2019–2020 to $306.91 million in 2020–2021, primarily due to the economic fallout from the COVID-19 pandemic. However, a steady recovery followed, with tax revenues reaching $619.58 million by 2023–2024, surpassing pre-pandemic levels. Non-Tax Revenue peaked at $152.34 million in 2020–2021, reflecting one-time inflows or adjusted policies. This revenue stream then declined and stabilized at around $109.88 million in 2023–2024. Grants-in-aid saw a sharp increase in 2020–2021 to $61.73 million, likely reflecting donor support during the crisis period. The amount declined in subsequent years, settling at $39.01 million in 2023–2024.

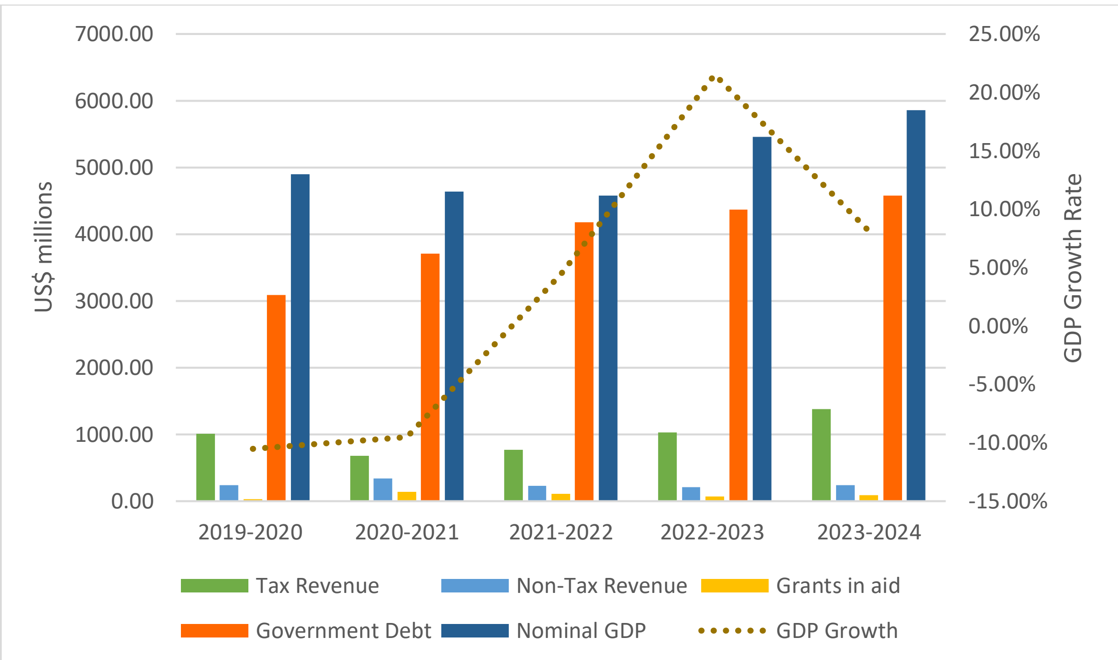
Public Debt Trajectory

Government debt showed a persistent upward trend throughout the five years, growing from $1.39 billion in 2019–2020 to $2.06 billion in 2023–2024. This consistent increase suggests continued reliance on debt-to-finance fiscal deficits, support recovery programmes, and maintain essential public services.

Fiscal Health Context

The widening gap between revenue and debt is a key concern. In 2023–2024, total revenue (tax & non-tax) stood at approximately $729.46 million, while public debt was nearly three times higher at $2.06 billion. Although revenue recovery is evident, the elevated debt levels indicate a structurally imbalanced fiscal position that may require long-term fiscal consolidation measures. The data highlights the importance of improving domestic revenue mobilization, enhancing expenditure efficiency, and managing debt sustainability as Fiji moves toward post-pandemic economic stabilization. The sources of revenue for the Government of Fiji are summarized in Figure 8.

Figure 8: Sources of Government's Revenue



(Source: Fiji data compiled by the authors)

The compiled data on disaster damages is presented in the table below. The data obtained in FJ$ is converted to $ using the exchange rate for that year, hence calculating the nominal $ values of the damages. The exchange rates are sourced from reliable financial data providers, including OANDA, XE, and OFX, which provide historical currency exchange rates.

Table 1. Historical Data of Fiji - GDP, Total Estimated Damages, and Damages by Sector *(nominal $ Values)*

Year	GDP (IMF)	Total Budget Expenditure (Budget Reports)		Budget Allocation for Disaster Response (Budget estimate reports)		Budget Expenditure for DRR (Data from Fiji compiled datasets)		Total Estimated Damage (Public source datasets)		Damage to Roads (Public source datasets)		Damage to Power (Public source datasets)		Exchange Rate
	$ million	FJ$ million	$ million	FJ$ million	$ million	FJ$	$ million	FJ$	$ million	FJ$	$ million	FJ$	$ million	
2010	7,374	NA	NA	NA	NA	NA	NA	84.3	44.0	NA	NA	NA	NA	0.52
2011	7,729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.56
2012	8,283	2,078	1,161	3.8	2.1	NA	NA	194.9	108.9	9.9	5.5	3.0	1.7	0.56
2013	8,942	2,327	1,272	3.0	1.6	NA	NA	NA	NA	NA	NA	NA	NA	0.55
2014	9,832	2,883	1,534	10.3	5.5	NA	NA	NA	NA	NA	NA	NA	NA	0.53
2015	10,782	3,336	1,598	7.7	3.7	NA	NA	NA	NA	NA	NA	NA	NA	0.48
2016	11,020	3,415	1,637	6.8	3.3	NA	NA	199.9	95.9	129.5	62.1	41.1	19.7	0.48
2017	11,784	4,357	2,117	18.9	9.2	23.7	11.5	NA	NA	NA	NA	NA	NA	0.49
2018	12,513	4,651	2,235	35.5	17.1	19.0	9.1	1.2	0.6	12.0	5.8	NA	NA	0.48
2019	12,649	3,841	1,783	5.1	2.3	10.4	4.8	10.3	4.8	5.0	2.3	NA	NA	0.46
2020	10,632	3,675	1,696	13.2	6.1	NA	NA	353.2	163.0	42.0	19.4	7.2	3.3	0.46
2021	10,577	3,715	1,796	NA	NA	7.5	3.6	NA	NA	NA	NA	NA	NA	0.48
2022	13,588	3,812	1,743	NA	NA	7.5	3.4	NA	NA	25.0	11.4	0.8	0.4	0.46

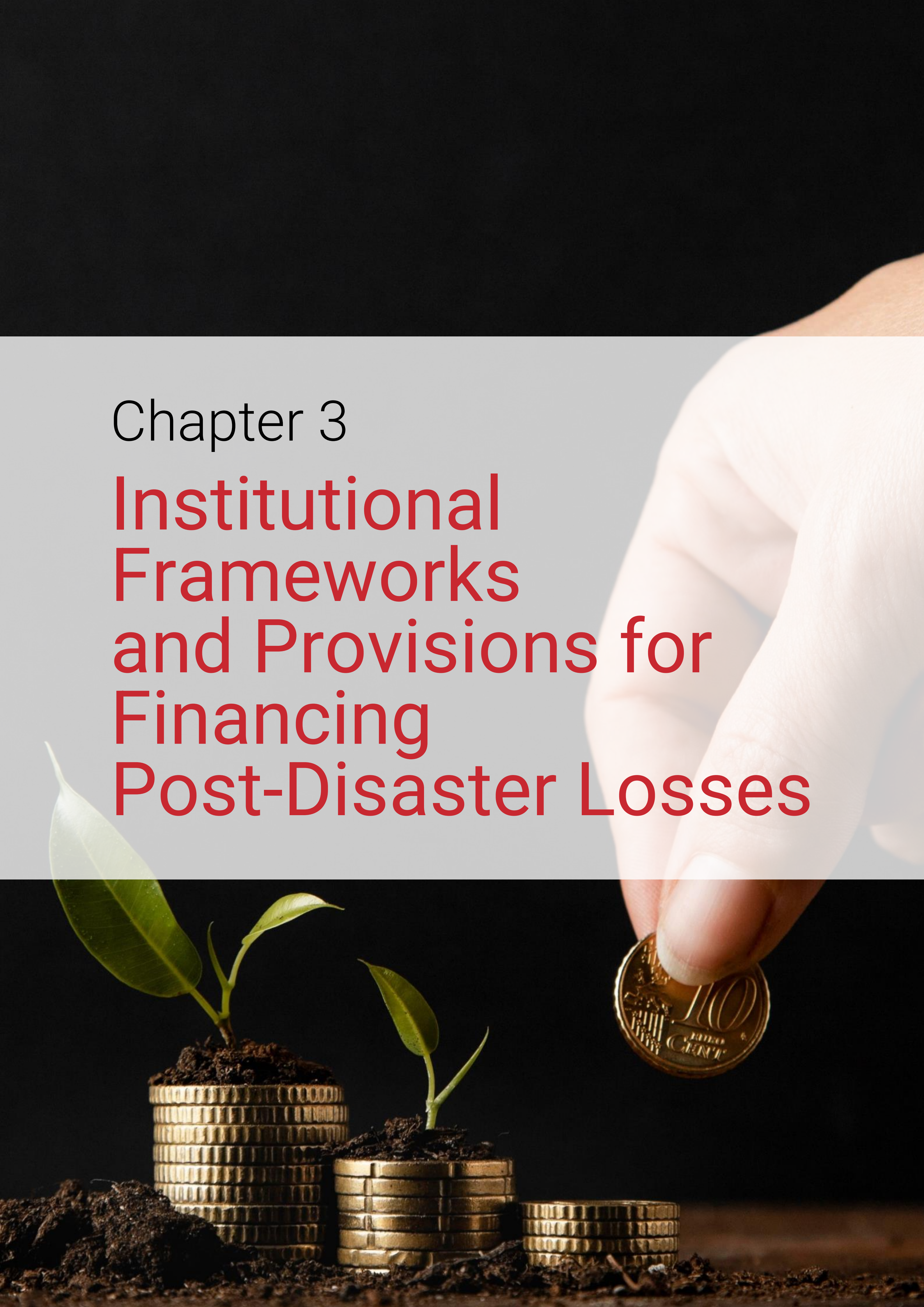
(Source: Fiji data compiled by the authors)

The combined effect of rising expenditure and declining revenues creates a fiscal gap that threatens Fiji's economic resilience. Key trends include:

- Increase in Debt Burden: debt-to-GDP ratio rises post-disaster as the country borrows more to finance recovery,
- Diversion of Developmental Funds: essential infrastructure projects face delays due to funds being redirected for post-disaster repairs and servicing of debts,
- Dependence on Foreign Aid: Fiji increasingly relies on official development assistance (ODA) and international NGOs' grants, which are often insufficient to cover full recovery costs.

Chapter 3

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 measures to understand the current DRF environment, including the specific mechanisms and processes in place, the hazards and assets or activities covered by the current national framework, and the amount of funding available. It provides detailed information on the review of the existing budgetary provisions and government funding sources. A historical record of the disaster-related expenditure of different government and non-government sources is also detailed in this section.

Institutional Framework for Disaster Risk Management

Fiji has a well-structured Disaster Risk Management (DRM) framework. The National Disaster Management Act (NDMA), enacted in 1998, introduced the concept of national disaster management in Fiji (Laws of Fiji 2018). The National Disaster Management Council (NDMC) serves as the central body responsible for policy alignment. The NDMC is chaired by the Minister of Rural and Maritime Development and Disaster Management (MRMDDM), while each government ministry has a permanent secretary responsible for implementing disaster policies within their respective areas.

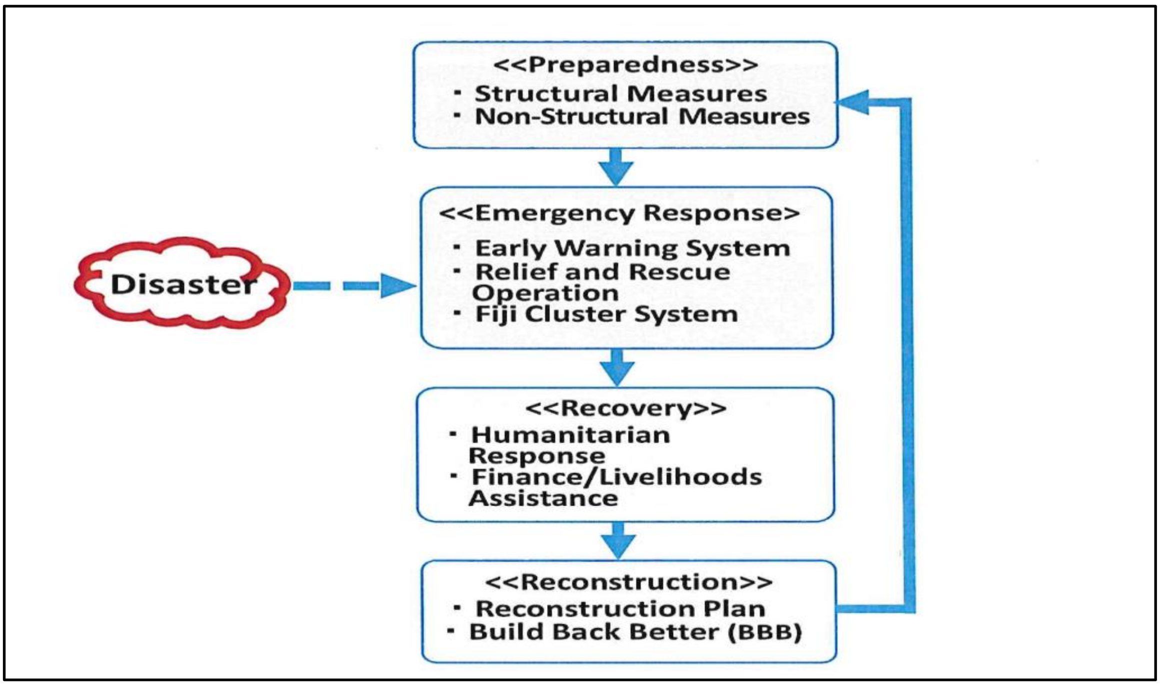
The National Disaster Management Office (NDMO) is the primary agency overseeing disaster risk management and response. It coordinates efforts, advises the Cabinet, NDMC, and National Disaster Controller (NDC) on policy matters, and plays a critical role in disaster planning, training, risk management, and policy research. Operating under the MRMDDM, the NDMO serves as the central coordination hub, ensuring seamless collaboration between government agencies, donors, and stakeholders for an effective disaster response.

The Permanent Secretary of MRMDDM typically serves as the NDC, who assumes command during disasters, directing response actions through the NDMO and the National Emergency Operations Centre (NEOC). However, since many emergency response efforts are managed at the local level, the Ministry of Local Government, Housing, and Community Development (MOLG) works closely with city and town councils to ensure their Emergency Operations Centers (EOCs) are effectively coordinated with national authorities.

The National Disaster Risk Reduction Policy 2018-2030, released in 2018, aligns with Fiji's Natural Disaster Management Act 1998, aiming to integrate disaster risk reduction with poverty alleviation and sustainable development.[13] This policy underscores good disaster risk governance, prioritizes better risk assessment, sets clear future action priorities, and emphasizes monitoring. It leverages Fiji's existing systems and cultural heritage, drawing from past experiences and lessons to enhance planning and adapt effective disaster risk reduction practices. The NDRRP highlights the key actions and measures across the DRR cycle as presented in the Figure 9.

[13] Republic of Fiji. (2018). *National Disaster Risk Reduction Policy 2018-2030*. HYPERLINK "https://www.google.com/search?q=https://www.preventionweb.net/files/70367_fijinationaldisasterriskreductionpol.pdf" https://www.preventionweb.net/files/70367_fijinationaldisasterriskreductionpol.pdf

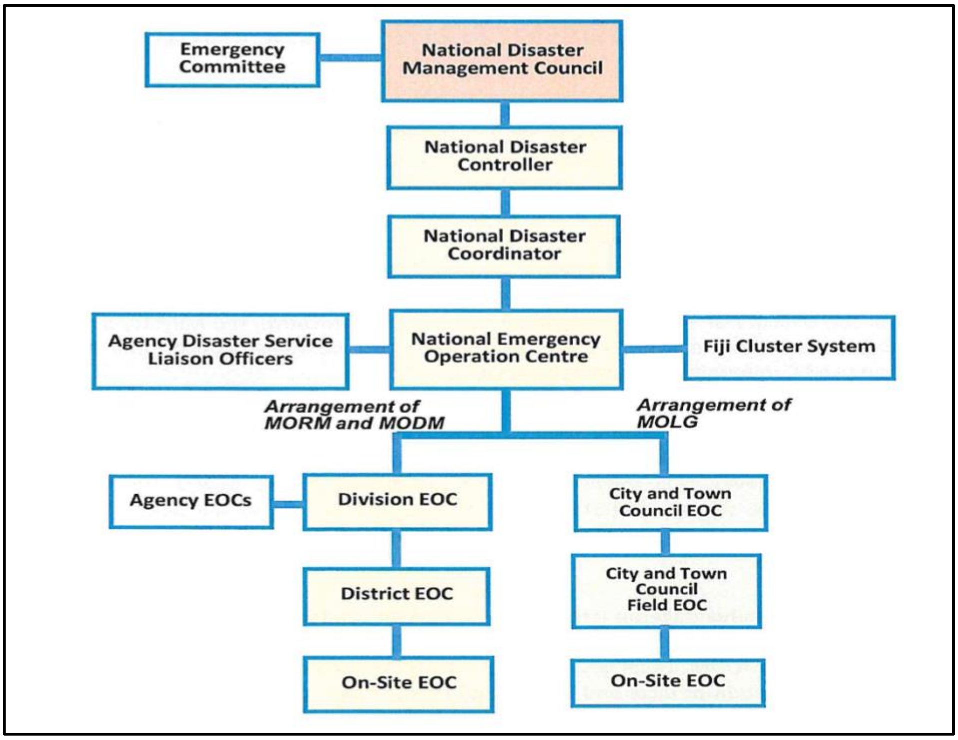
Figure 9. Disaster Risk Reduction Cycle and Associated Actions



(Source: Republic of Fiji 2018)

The current machinery of national disaster management in terms of governance and institutional arrangements is indicated in Figure 10.

Figure 10. Disaster Machinery in Terms of National Disaster/ Emergency



(Source: Republic of Fiji, 2018)

components under consideration are the clearly defined roles and responsibilities of the national and local governments, and the introduction of disaster insurance, and developing guidelines for the Fiji Cluster System as a coordination mechanism for foreign assistance in national disasters.

Disaster Risk Financing Mechanisms in Fiji

Ex-post financing mechanisms focus on post-disaster financial arrangements and funding mechanisms. These mechanisms are activated after a disaster occurs and aim to provide financial support for recovery, rehabilitation, and reconstruction. The main source of post-disaster financing for Fiji is through budget reallocations and external funding sources such as bilateral banks.

Post-disaster Budget Reallocations

The redeployment of funds is done in accordance with Section 24 of the Financial Management Act 2004 and requires cabinet approval. The Government of Fiji reallocates its budget after major disasters both by halting capital works programmes where contracts are not yet functioning and through loan receipts. After Tropical Cyclone Winston in 2016, $33 million was reallocated for the Help for Homes programme administered by the Ministry of Women, Children, and Poverty Alleviation to assist households affected. Additional support included income relief through the Poverty Benefit Scheme, Care and Protection Scheme, and the Social Pension Scheme, which delivered three months' worth of benefits quickly to those affected. Emergency and humanitarian relief costs were estimated at $15 million.

Disaster Rehabilitation and Containment Facility

The facility provided by Reserve Bank of Fiji provides access to lending institutions to lead at concessional rates for rebuilding after a declared disaster. The facility gets activated in the aftermath of a major disaster. Following Tropical Cyclone Winston, it assisted 37 businesses and 60 homeowners, with a total of $9 million advanced by the end of July 2016.

The facility was originally named Natural Disaster and Rehabilitation Facility. In 2020, the Reserve Bank of Fiji (RBF) expanded the coverage of the Natural Disaster and Rehabilitation Facility to include businesses affected by health epidemics or pandemics such as COVID-19. The expanded facility was also renamed as the Disaster Rehabilitation and Containment Facility (DRCF). As of 2023 guidelines, The Reserve Bank of Fiji (RBF) has expanded the coverage of the DRCF to include any lending to micro, small and medium-sized enterprises (MSMEs) and large businesses. The facility is available through 'approved lenders' including the commercial banks, Fiji Development Bank (FDB) and licensed credit institutions (LCIs). The interest rate charged on these advances is 0.25 percent per annum. The approved lenders can borrow from RBF at this rate and on-lend to eligible applicants at a maximum rate of 3.99 percent per annum for a maximum term of up to five years. The total amount available under this Facility is FJ$414.6 million. This facility is effective immediately and will be subject to ongoing review.[14]

Fiji National Provident Fund (FNPF) Withdrawals

The FNPF is a defined contribution fund that provides superannuation services to its members. The membership base of the FNPF is 417,886, which accounts for 47 percent of the population of Fiji. FNPF is required under its enabling Act to assist its members. In 2016, Tropical Cyclone Winston, a Category 5 cyclone, the strongest cyclone in the Southern Hemisphere, crossed Fiji's main islands. The FNPF activated the scheme of Natural Disaster Assistance in 2016 through which it assisted 182,571 members.[15]

[14] Reserve Bank of Fiji. "Disaster Rehabilitation and Containment Facility." https://www.rbf.gov.fj/category/disaster-rehabilitation-and-containment-facility/.

[15] Fiji National Provident Fund. "Practices in Managing Natural Disasters - Delivery of Service in Time of Need." International Social Security Association, 2018. https://iskm.issa.int/node/6066.

Flash Fund Appeals

The government launches flash fund appeals with tax incentives, such as a 200 percent tax deduction, to encourage donations from the business community and the general population. Following Tropical Cyclone Winston, this mechanism resulted in $4.7 million in donations from the Fiji business community.

International Assistance

Institutions like the World Bank, Asian Development Bank (ADB), among others provide financial support through grants, concessional loans, and technical assistance. Appeals for external assistance from bilateral and multilateral agencies resulted in approximately $10.5 million in aid in kind and around $16.7 million in cash after Tropical Cyclone Winston. Major contributions included $11.2 million from the European Union and additional support from various UN agencies.

Authorized by Section 59 of the Financial Management Act 2004, the Minister of Finance can borrow funds for rehabilitation work following a disaster. After Tropical Cyclone Winston, concessional loans were secured extensively from the ADB and World Bank.

Recently, Fiji successfully negotiated a $75 million Disaster Fund Facility with the Japan International Cooperation Agency (JICA), designed to enable rapid disbursement of funds immediately upon the declaration of a disaster. In addition, Fiji has secured a Catastrophe Deferred Drawdown Option (Cat-DDO) from the World Bank, providing the government with swift access to approximately $40 million in emergency financing to support disaster response and recovery efforts.[16]

Trend Analysis of Disaster Risk Financing in Fiji

This section provides a trend analysis of the allocation and expenditure of primary disaster financing sources in Fiji. Based on available, though limited, data, it has been noted that funding for disaster risk management is increasing. The Prime Minister's Fund, also known as the National Disaster Relief and Rehabilitation Fund (NDRRF), is an annual appropriation to the National Disaster Management Office (NDMO). The NDRRF is the post-disaster funding backbone for the Government of Fiji, from which budgetary resources and donor funding are received and allocated for disaster relief funding needs. Between 2017 and 2023, a yearly average of FJ$ 0.8 million (approx. $0.4 million) was allocated from the budget to the NDRRF Fund.[17]

The budget for the Ministry of Disaster Management and Meteorological Services, subsequently the Ministry of Rural and Maritime Development and Disaster Management (MRMDDM), has averaged FJ$14.5 million (approx. $6.8 million) from 2017–2023.[18] As capital and operating expenses are included in MRMDDM expenditures, a specific reserve is not allocated for contingencies due to catastrophic events. Ministry resources are primarily allocated to operations. For the 2024-2025 budget and the Ministry of Rural and Maritime Development and Disaster Management is allocated $37.9 million, an increase of $8.8 million from the previous year; $1 million is designated for constructing new evacuation centers and retrofitting existing ones and $2 million is allocated for disaster recovery initiatives.[19]

Although Fiji is not entirely dependent on international aid, it relies on it during large-scale disasters. The government takes the lead in immediate response and preparedness, but foreign assistance is crucial for long-term recovery and rebuilding efforts. International aid is still a major source of post-disaster assistance for Fiji. For example, according to the OCHA Financial Tracking Service, Fiji received

[16] The Fiji Times. Minister Tabuya supports disaster risk management legislation https://www.fijitimes.com.fj/minister-tabuya-supports-disaster-risk-management-legislation/?utm_source=chatgpt.com Oct. 16, 2024

[17] Fiscal year budget for 2017–2021, Republic of Fiji

[18] Ibid.

[19] Government of Fiji. 2024-2025 NATIONAL BUDGET ADDRESS

$21.8 million of $38.6 million required in 2016 after TC Winston.[20] Organizations like the United Nations (UN), World Bank (WB), European Union (EU), Australia, New Zealand, and the Asian Development Bank (ADB) frequently provide financial and logistical support. Based on available records, the following table shows the tropical cyclones that affected Fiji from 2010 to 2022.

Table 2. Historical Disasters in Fiji and Their Estimated Effects

Year	Total Budget Expenditure [21] (FJ$ '000)	Budget Allocation for Disaster Response (FJ$)	Budget Expenditure for DRR (FJ$)	Disaster(s)	Total Estimated Damage (FJ$)	Damage to Roads (FJ$)	Damage to Power (FJ$)
2010				TC Tomas	84,300,000[22]		
2012	2,077,929	3,800,000		TC Evan	194,900,000[23]	9,917,453[24]	3,049,152[25]
2013	2,327,385	3,000,000					
2014	2,883,261	10,296,674					
2015	3,336,292	7,727,000					
2016	3,414,537	6,800,000		TC Winston	199,900,000[26]	129,500,000[27]	41,086,479[28]
2017	4,356,831	18,900,000	23,747,590				
2018	4,650,546	35,500,000	18,991,605	TC Gita, Josie, and Kenny	1,200,000	12,000,000[29]	
2019	3,840,929	5,054,977	10,404,824	TC Sarai	10,300,000[30]	5,000,000[31]	
2020	3,674,604	13,200,000		TC Tino, Harold, and	353,200,000[32]	42,000,000[33],	7,230,000[35]

[20] ** "Fiji 2016 | Financial Tracking Service," n.d. https://fts.unocha.org/countries/74/summary/2016.
[21] Ministry of Finance. "Budget Documents - Ministry of Finance," February 6, 2023. https://www.finance.gov.fj/budget-documents/.
[22] The Parliament of The Republic of Fiji. Parliament debates. https://www.parliament.gov.fj/wp-content/uploads/2020/08/DAILY-HANSARD-TUESDAY-28TH-JULY-2020.pdf
[23] "Fiji: Post-disaster Needs Assessment - Cyclone Evan | GFDRR," n.d. https://www.gfdrr.org/en/fiji-post-disaster-needs-assessment-cyclone-evan.
[24] ibid., 22
[25] ibid., 22
[26] Tropical Cyclone Winston 2016 Fiji Post-Disaster Needs Assessment. https://www.preventionweb.net/publication/tropical-cyclone-winston-2016-fiji-post-disaster-needs-assessment
[27] ibid., 25.
[28] ibid., 25
[29] Silaitoga, Serafina. "$12m Cyclone Damage." The Fiji Times, May 1, 2018. https://www.fijitimes.com.fj/12m-cyclone-damage/.
[30] Government of Fiji. *Fiji: Tropical Cyclone Sarai - Post-Disaster Needs Assessment*. Suva, Fiji: Government of Fiji, 2020.
[31] Rawalai, Luke. "FRA Yet to Complete post-TC Sarai Damage Assessment." The Fiji Times, January 8, 2020. https://www.fijitimes.com.fj/fra-yet-to-complete-post-tc-sarai-damage-assessment/.
[32] RNZ News. "Cyclone Yasa Damage to Fiji Worth Nearly $US250m." *RNZ*, February 15, 2021. https://www.rnz.co.nz/international/pacific-news/436485/cyclone-yasa-damage-to-fiji-worth-nearly-us250m.
[33] Fij ivillage. "TC Harold: Over $27 Million of Damages to Fiji's Agricultural Sector While FRA Infrastructure Took a $22 Million Hit - PM," April 20, 2020. https://www.fijivillage.com/news/TC-Harold-Over-27-million-of-damages-to-Fijis-agricultural-sector-while-FRA-infrastructure-took-a-22-million-hit---PM-8frx54/.
[35] Energy Fiji Limited 2021 Annual Report. https://www.parliament.gov.fj/wp-content/uploads/2022/08/Energy-Fiji-Limited-Annual-Report-2021.pdf

				Yasa		[34]	
2021	3,715,081		7,473,911	TC Ana			
2022	3,812,130		7,473,911	TC Cody		25,000,000[36]	800,000[37]

Table 2 shows total estimated damages from the tropical cyclones far exceed the country's allocation for disaster response. Based on budget statement documents, ADB reports, and data from the OECD, it appears that international aid is relied upon to fund response and recovery activities. For instance, the Stand-by Yen Loan for Disaster.

Recovery and Rehabilitation support from the Japan International Cooperation Agency (JICA) provided up to $50 million for post-disaster needs. The loan was targeted to meet the financial demands of a post-disaster recovery and the rehabilitation phase, together with mainstreaming policies related to disaster risk reduction in Fiji. Australia established the Emergency Preparedness and Response (EPR) ($1.7 million 2022-23) to support locally led disaster preparedness and response in Fiji. The EPR allows Australia to quickly disburse funds to the Government of Fiji and Civil Society Organizations in the event of a disaster. It also supports long-term preparedness activities. The country also supported the Cyclone Yasa recovery ($28.5 million, 2021-24) with a focus on rehabilitating nine schools and two hospitals.[38] ADB provided Emergency Assistance for Recovery from TC Winston ($50 million), the World Bank with Post-Winston Emergency loan ($50 million), and the EU Budget Support with $23 million. In September 2024, the Stand-by Loan for Disaster Recovery and Rehabilitation (Phase 2), amounting to 5 billion yen, was signed by the governments of Fiji and Japan.[39]

The figure below shows the ODA received by Fiji each year from public and private donors based on data from the OECD organization. The data has been transformed to constant price with 2022 as the base year. There was a substantial increase in public funding in 2012 and 2016, suggesting funding increased following TC Evan and TC Winston. In 2017 and 2018, there was also private assistance, which was not present in the years prior. Australia is supporting the Cyclone Yasa recovery ($28.5 million, 2021-24) with a focus on rehabilitating damaged or destroyed school infrastructure for up to nine schools and two hospitals.[40]

[34] Fijivillage. "FRA Suffers $20 Million Worth of Damages Due to TC Yasa," December 24, 2020. https://www.fijivillage.com/news/FRA-suffers-20-million-worth-of-damages-due-to-TC-Yasa-4rxf58/.

[36] International Federation of Red Cross and Red Crescent Societies (IFRC). *Fiji: Tropical Cyclone Cody - Final Report, DREF Operation n° MDRFJ006*. ReliefWeb, 2022. https://reliefweb.int/report/fiji/fiji-tropical-cyclone-cody-final-report-dref-operation-ndeg-mdrfj006.

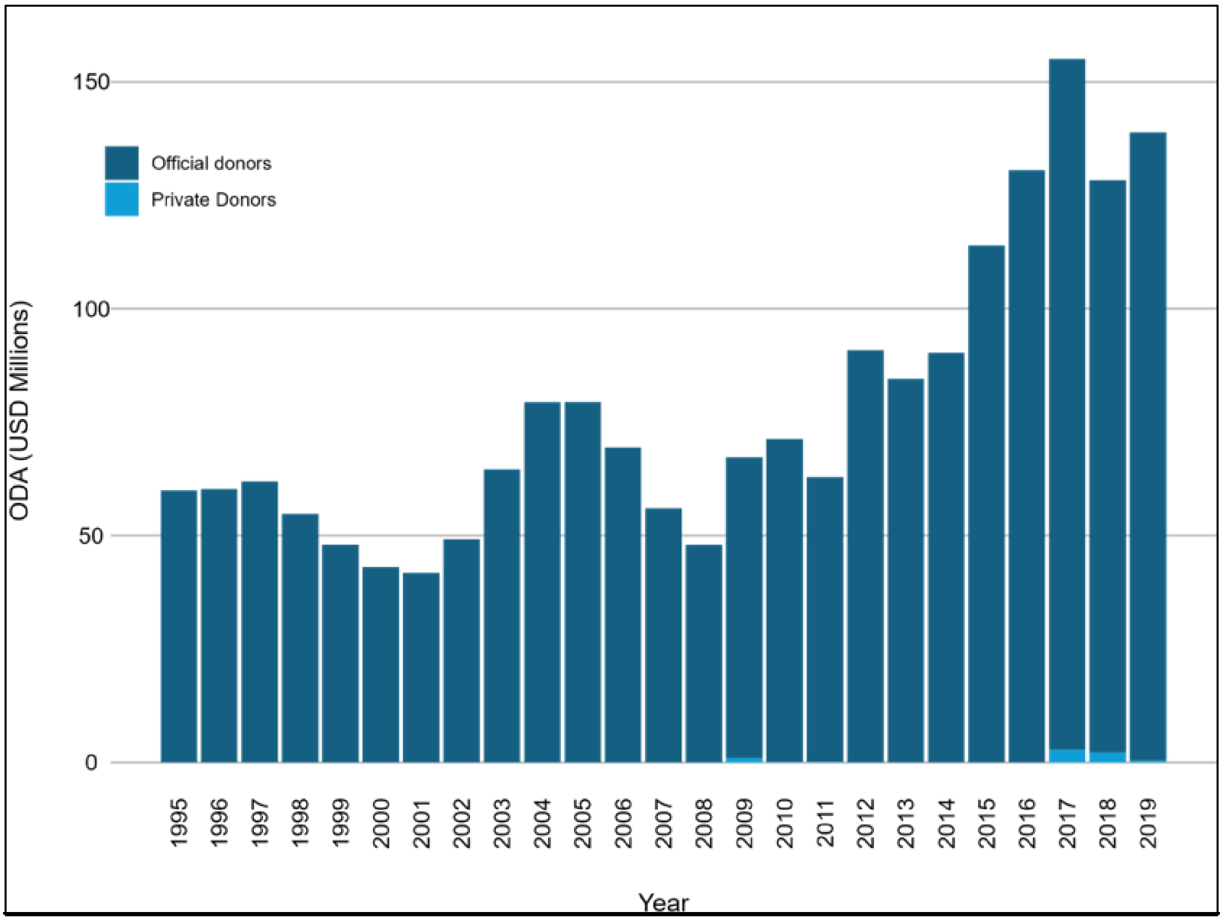
[37] Kotobalavu, Josefa. "Combined Damage to Infrastructure Exceeds $27m with FRA Hard Hit." Mai TV (Fiji), January 20, 2022. https://maitvfiji.com/combined-damage-to-infrastructure-exceeds-27m-with-fra-hard-hit/.

[38] Government of Australia. https://www.dfat.gov.au/about-us/publications/fiji-australias-commitment-to-strengthening-climate-and-disaster-resilience-in-the-pacific

[39] Ministry of Foreign Affairs of Japan. https://www.mofa.go.jp/press/release/pressite_000001_00589.html

[40] Australian Government Department of Foreign Affairs and Trade. "Fiji - Australia's Commitment to Strengthening Climate and Disaster Resilience in the Pacific," n.d. https://www.dfat.gov.au/about-us/publications/fiji-australias-commitment-to-strengthening-climate-and-disaster-resilience-in-the-pacific.

Figure 11: Official Development Aid Flowing to Fiji per Year
($ Millions, constant prices)

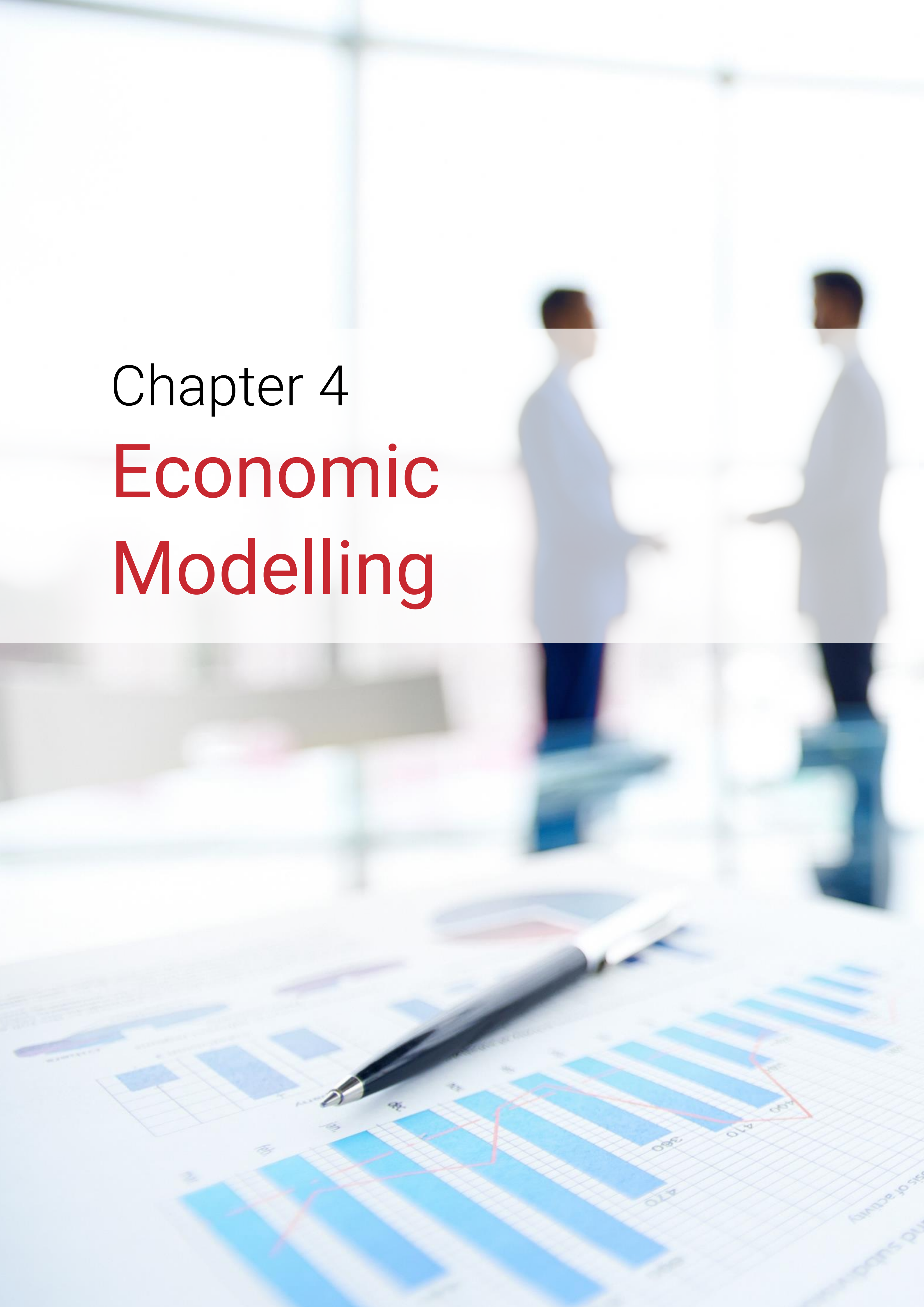


(Source: OECD)

Budget statement documents, ADB reports, and data from the OECD all agree that international aid is relied upon to fund response and recovery activities. Without this aid, there would be a serious shortfall in funds available for post-disaster needs and recovery despite the reallocation of budget allocations.

Chapter 4

Economic Modelling



To assess the economic impact of disasters in Fiji, a case study approach was used. The methodology included reviewing reports, articles, and datasets associated with disaster-related economic impacts in Fiji, acquired from online literature reviews and Government of Fiji statistics. Website sources of information spanned several platforms, including but not limited to Relief Web,[41] Prevention Web,[42] OECD,[43] and the International Monetary Fund,[44] Government of Fiji statistics and budget statements. An analysis of the actual expenditure under the budget line item "Special expenditure" of the Disaster Management Department within the relevant ministry was conducted. This analysis spanned the years 2010 to 2023 using data from the Ministry of Finance. The focus was on expenses specifically allocated for managing the aftermath of significant events such as TCs. Key terms such as “Disaster”, “Tsunami”, “Flood”, “Tropical cyclone," "TC," "Evans," "Winston," "rehabilitation," "relief," "recovery" were used to track budget allocations and actual expenditures over this period. This approach ensured that all relevant financial data related to disaster management efforts was captured and analysed to provide a comprehensive view of the government's financial response to disasters.

Data for Total GDP, Gross Value Added (GVA), and GDP per sector was available for the period 2014 to 2022 from the Reserve Bank of Fiji. The GDP in total and for each sector was plotted and a linear model was fitted to the data for years 2014 to 2019. For each year the percentage deviation from the trendline was calculated. TC Winston, a category 5 TC and the most intense TC in the Southern Hemisphere on record[45] occurred in 2016. The percentage deviation for the financial year 2016, was examined to understand which sectors were the most impacted by the event. Figure 12 shows the plot with trendline for total GDP as an example.

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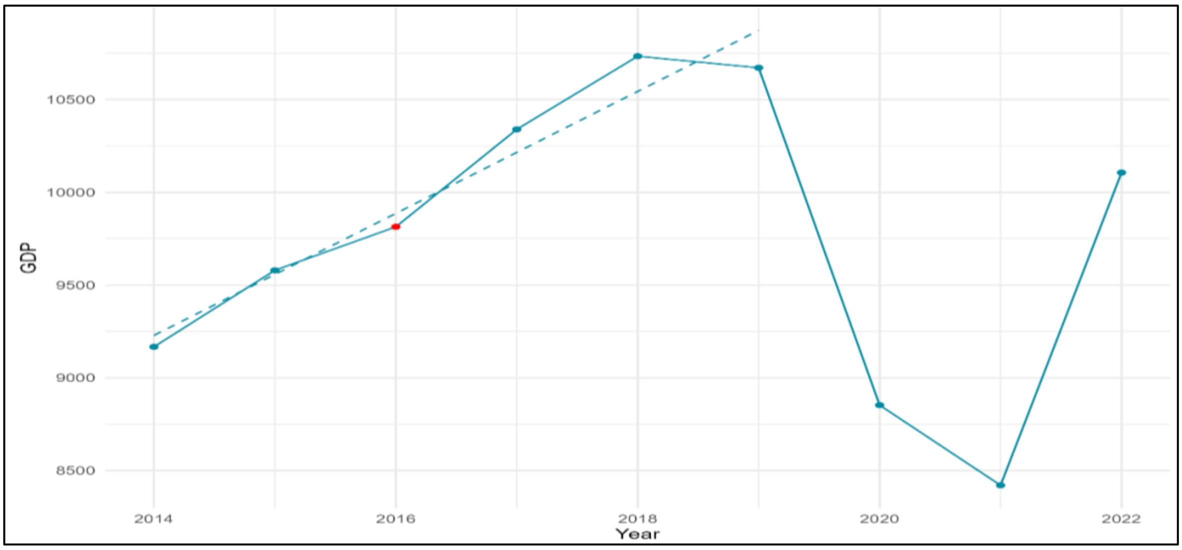
[41] United Nations Office for the Coordination of Humanitarian Affairs. "ReliefWeb." https://reliefweb.int.
[42] United Nations Office for Disaster Risk Reduction (UNDRR). "PreventionWeb." https://www.preventionweb.net
[43] Organisation for Economic Co-operation and Development. "OECD." https://www.oecd.org.
[44] International Monetary Fund. "International Monetary Fund." https://www.imf.org.
[45] Government of Fiji. 2016. "Post-disaster Needs Assessments CYCLONE WINSTON Fiji 2016." Global Facility for Disaster Reduction and Recovery. https://www.gfdrr.org/sites/default/files/publication/Post%20Disaster%20Needs%20Assessments%20CYCLONE%20WINSTON%20Fiji%202016%20(Online%20Version).pdf

Figure 12: Total GDP per Year with 2014-2019 Trendline



(Source: Reserve Bank of Fiji)

Economic Model and Data

The data period studied was the 25 years from 1995 to 2019. Data was sourced from the EM-DAT disaster database,[46] the Government of Fiji, the Asian Development Bank (ADB), the World Bank, and the OECD. Post-Disaster Needs Assessment (PDNA) reports for Tropical Cyclone (TC) Winston and TC Evan, and reports from Fiji's National Disaster Management Office were also available.

Table 3: Data Available for the Study by Source

Source	Data Available	No. Years (1995-2019)
EM-DAT	Disaster Impact per country per year	25 (1995-2019)
Fiji Government	GDP per Sector	6 (2016-2019)
World Bank	Trade in Services	Varies by country (1995-2019)
	Foreign Direct Investment	
	Current Account Balance	
	Remittances	
	Revenue	
	Expenditure	
OECD	Official Development Aid	25 (1995-2019)

Table 3 shows the data available for Fiji economic analysis by source. The data from international organisations has the most data points but the majority of this data is at a national level. The reserve bank of Fiji provides the most disaggregated data in that data is reported per sector, but the data is at the national level, there was no sub-national time-series data available.

[46] Center for Research on the Epidemiology of Disasters (CRED). "EM-DAT: The International Disaster Database." EM-DAT. https://www.emdat.be.

The ADB provides key indicators for Asia and Pacific countries[47] including government fiscal statistics such as revenue and expenditure.

Table 4 shows the fiscal data available for Pacific Island countries. All data from ADB can be downloaded from https://kidb.adb.org. The ADB data starts in 2000 so there was a maximum of 19 years available for any indicator. No country had data for all indicators for all years. Only Fiji and the Cook Islands had 19 years of data for any indicator. At least half of the countries had very limited data (1 to 8 years).

Table 4: Number of Years of Data Available per Country and Economic Indicator from ADB for the Period 1995-2019

	Revenue				Expenditure	
Country	**Total**	**Taxes**	**Grants**	**Other**	**Total**	**Social Benefits**
Cook Islands	19	19	19	19	19	10
Fiji	19	19	12	19	19	0
Kiribati	8	8	8	8	8	8
Marshall Islands	15	15	15	15	15	0
Micronesia (Fed. States of)	14	14	14	14	14	0
Samoa	7	7	7	7	7	7
Solomon Islands	11	11	11	11	11	11
Tonga	3	3	3	3	3	3
Tuvalu	7	4	4	4	7	4
Vanuatu	8	8	1	8	8	8

Table 5 shows the post-disaster reports available for all the TCs that occurred during 1995-2020. As Fiji experiences TCs in most years, only the major TCs have official reports or PDNA surveys. The only economic data available was from the two PDNA reports following TC Evan and TC Winston.

Table 5: TCs and Reference Material

TC name	Year	Report name	Report Source
Tomas	2010	TC Tomas Report 2010	(National Disaster Management Office, 2010)
Evan	2012	Fiji Post-Disaster Needs Assessment TC Evan, 17th December 2012	(Government of Fiji, 2013)
Winston	2016	Fiji Post-Disaster Needs Assessment TC Winston, February 20, 2016	(Government of Fiji, 2016)
Gita	2018	TC Gita Report	(National Disaster Management Office, 2018)
Josie	2018	Tropical Cyclone Keni/Josie Report	(Office of the Commissioner Northern, 2018)
Keni	2018	TC Keni Report 2018	(The Office of the Divisional Comissioner Eastern, 2018)
Sarai	2019	TC Sarai Report	(Government of the Republic of Fiji, 2019)
Tino	2020	No information available	
Harold	2020	TC Harold Report 2020	(National Disaster Management Office, 2020)

[47] Asian Development Bank. "Key Indicators Database." https://kidb.adb.org.

TC name	Year	Report name	Report Source
Yasa	2020	TC Yasa Report 2021	(National Disaster Management Office, 2021a)
Ana	2021	TC Ana Report 2021	(National Disaster Management Office, 2021b)

Economic Modelling Results

To access additional funds, the government reallocates planned capital spending to disaster recovery activities and total government expenditure is largely unchanged. Secondly, Fiji, like all Pacific Island countries, is heavily dependent on aid for post-disaster reconstruction. Therefore, most of the funding for relief reconstruction comes from international assistance and the majority is not channeled through the government so it is not registered in the government fiscal accounts. In looking at the impacts of TC Winston in 2016, percentage deviations from the fitted trendline of total GDP, Gross Value Added, and GDP per sector were analyzed. All graphs have the same axis values so that the graphs are directly comparable.

Figure 13: Percentage Deviation from Fitted Trendline from the Services Sectors with Decreased GDP Following TC Winston

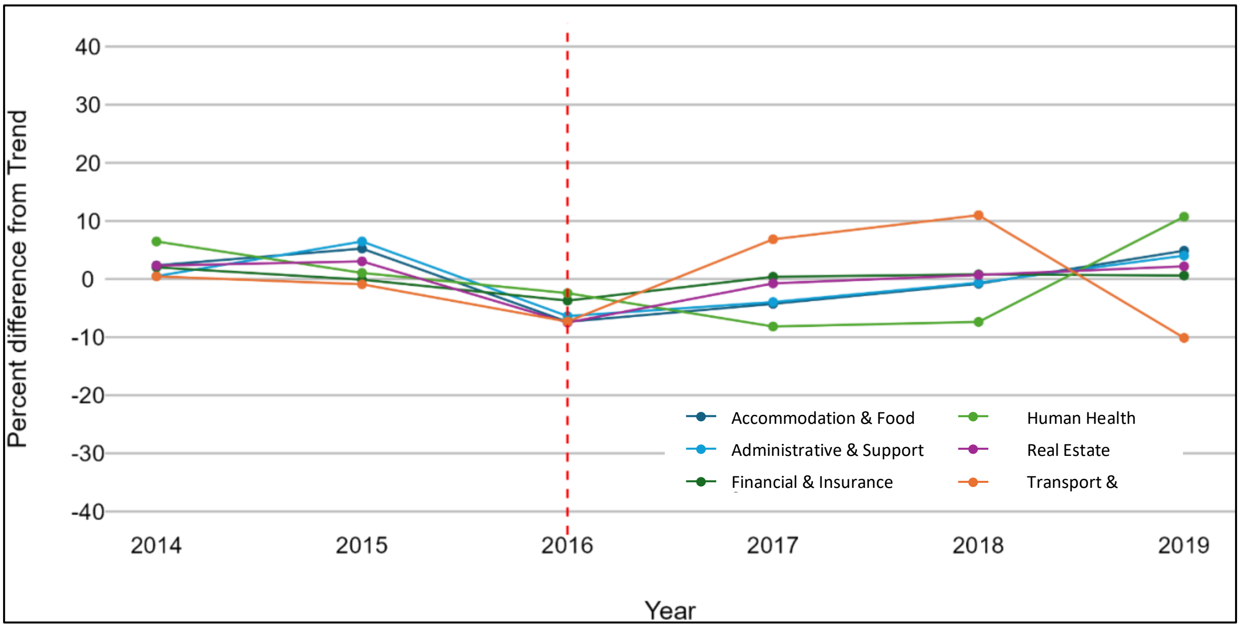
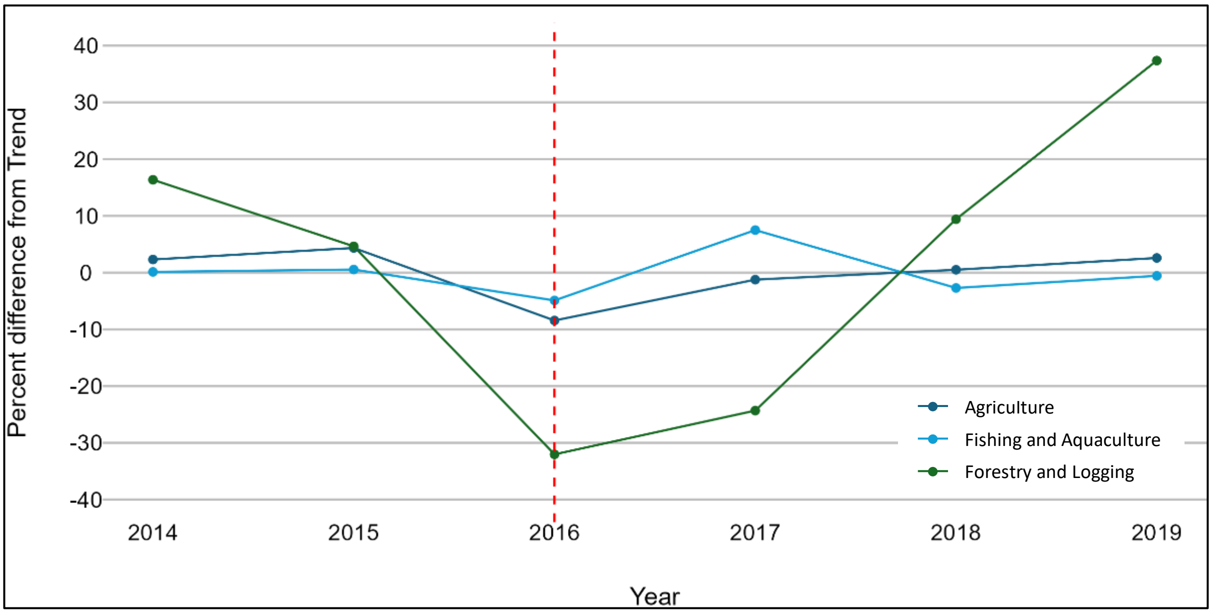


Figure 13 shows that all the sectors were GDP values were lower than expected for 2016. Of the 22 sectors analysed, half (11) saw a decline in GDP, 8 saw an increase, and 3 showed no change. The biggest impact was in the primary sector where all sector's GDP were lower than expected, particularly Forestry and logging, where GDP was more than 30 percent lower than expected. Agriculture, and Fishing, and Aquaculture all recovered to expected levels by 2017, and Forestry and Logging recovered by 2018. Total GDP and GVA were lower than expected, but the effect was small at less than 1 percent and GDP was fully recovered by 2017, and the reduction in 2016 was in line with fluctuations in values for the time period.

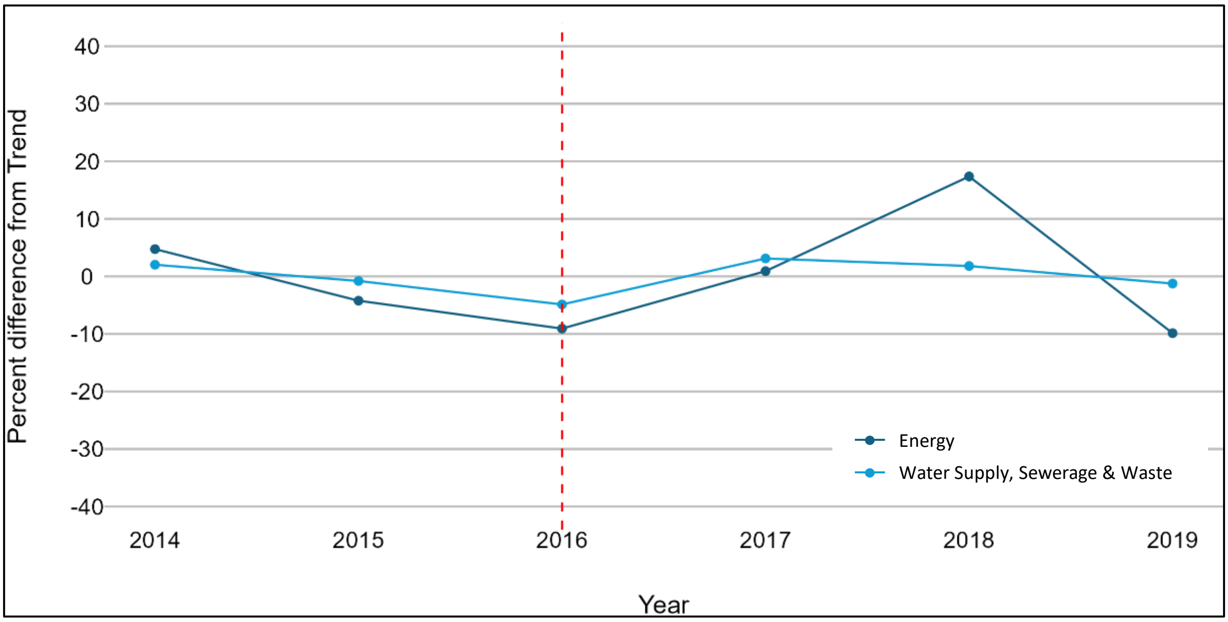
Figure 14. Percentage Deviation from Fitted Trendline from Primary Sectors with Decreased GDP Following TC Winston



(Source: Reserve Bank of Fiji and Tonkin + Taylor)

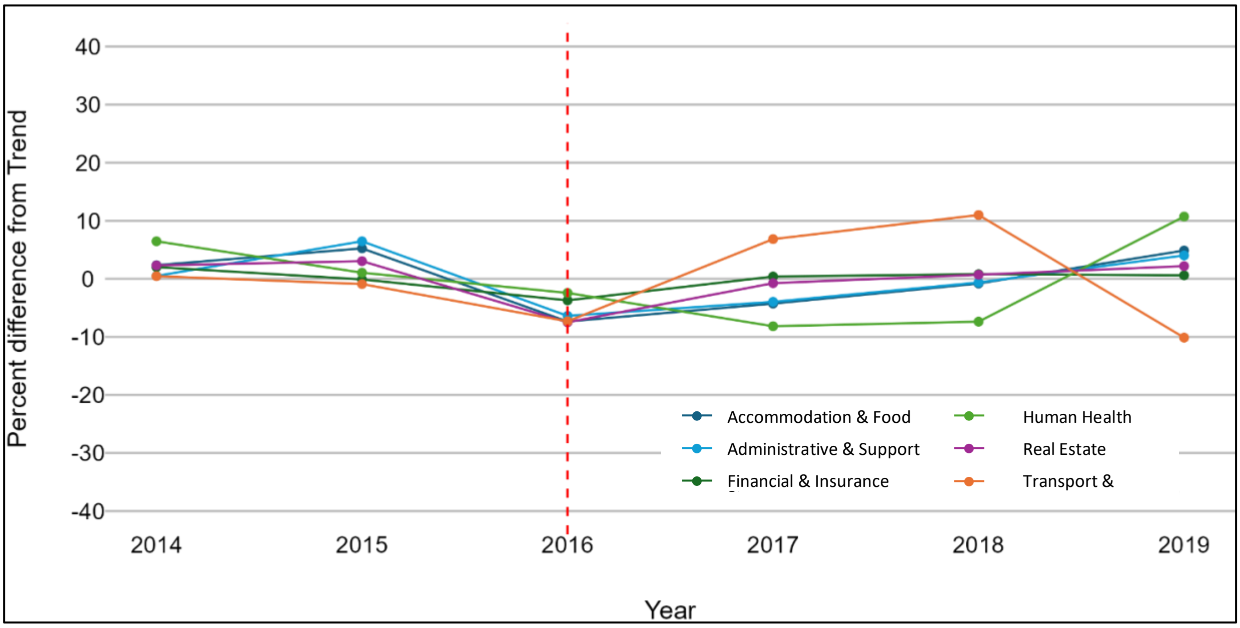
Energy and Water Supply sectors also experienced a decline in 2016 as shown in Figure 15.

Figure 15. Percentage Deviation from Fitted Trendline from the Energy Sectors with Decreased GDP Following TC Winston



(Source: Reserve Bank of Fiji and Tonkin + Taylor)

Figure 16. Percentage Deviation from Fitted Trendline from the Services Sectors with Decreased GDP Following TC Winston

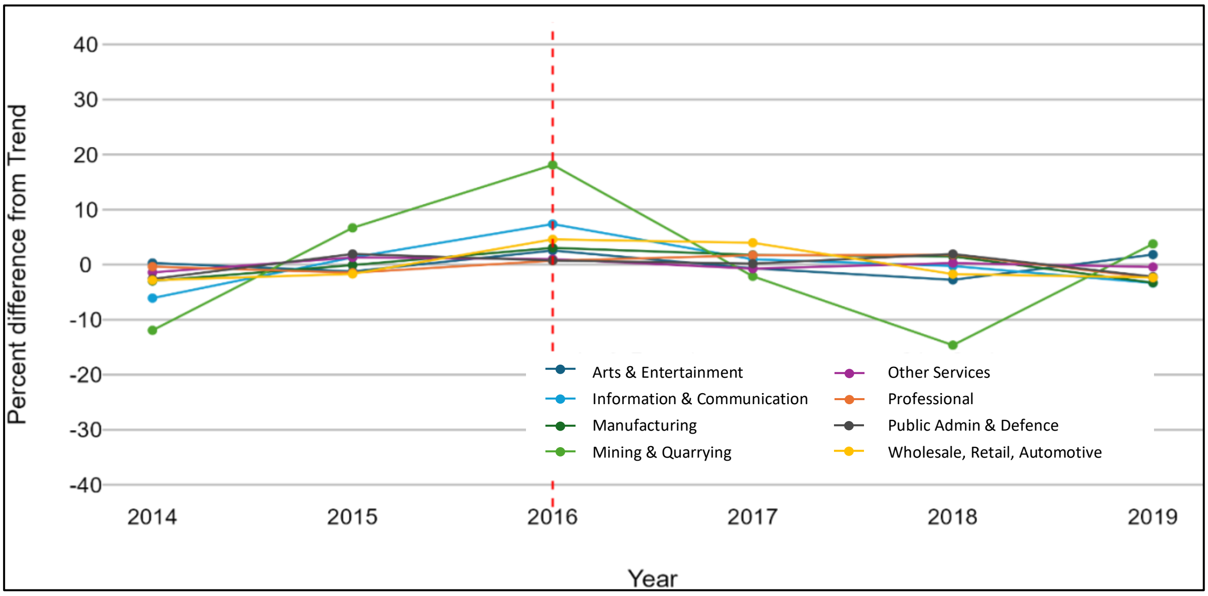


(Source: Reserve Bank of Fiji and Tonkin + Taylor)

Figure 16 shows all GDP values in the services sector. Both the energy and services sectors experienced lower GDP than expected of between 2.5 percent and 9.8 percent of GDP. The energy sectors recovered back to the trendline by 2017, but the services sector took longer to recover.

There were some sectors that experienced an increase in GDP. However, these effects were short lived with GDP returning to the trendline in 2017 as shown in Figure 17 below.

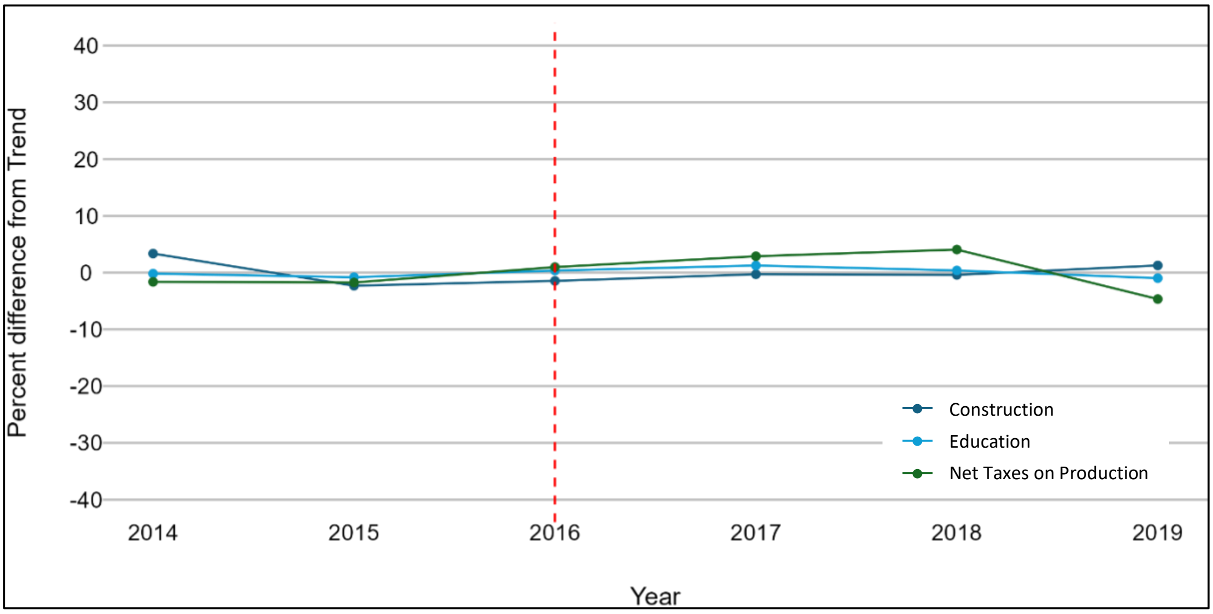
Figure 17. Percent Difference from Linear Trend Line for Sectors with Increased GDP Following TC Winston



(Source: Reserve Bank of Fiji and Tonkin + Taylor)

The Mining and Quarrying sector showed the largest increase in GDP. According to the 2017-18 Government Budget report, the mining and quarrying sector GDP increased in 2016 due to increased gold production. In addition, the PDNA report for TC Winstone found that one company sustained most of the damage, and this company was fully insured. According to the Ministry of the Economy, reconstruction and rehabilitation activities drove growth in the wholesale & retail trade sector; while government spending supported growth in the public administration & defense, education and health sectors. All other sectors did not show any substantial deviation from the fitted trendline (Figure 18).

Figure 18. Percent Difference from Linear Trend Line for Sectors not Affected by TC Winston



(Source: Reserve Bank of Fiji and Tonkin + Taylor)

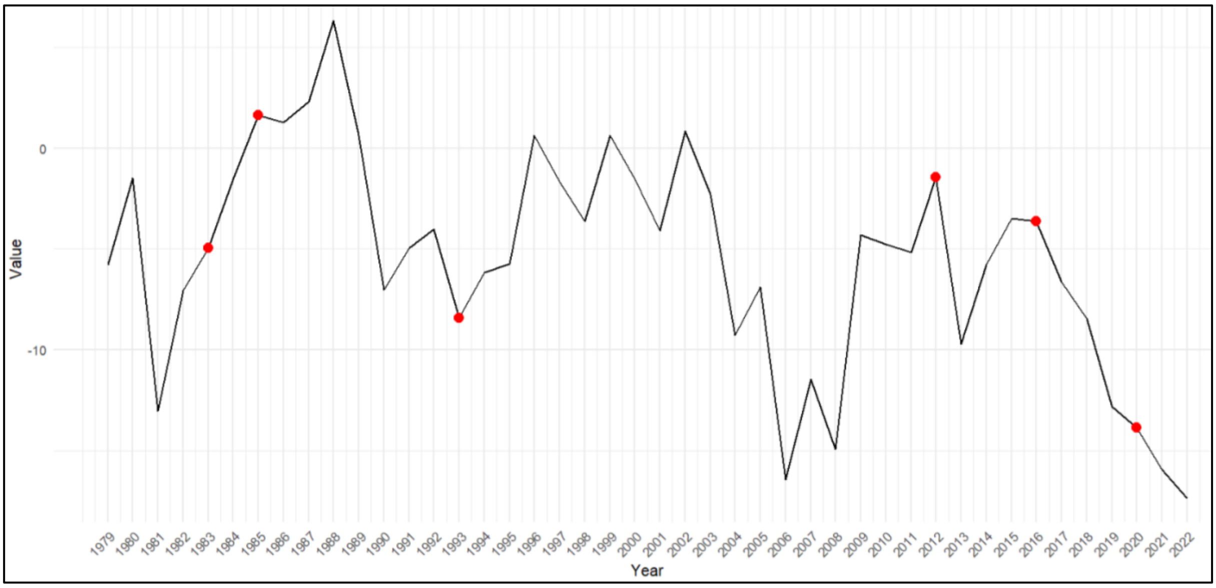
Table 6 provides a summary of the modelled deviations from expected GDP for each sector. However please note that the changes were relatively small as shown in Table 6.

Table 6. Summary of Modelled Deviations from Trendline for GDP per Sector

<table>
<tr><th>Impact on GDP based on deviations from Trend</th><th>Sectors</th></tr>
<tr><td rowspan="9">Decline in Sector GDP</td><td>Agriculture, forestry and logging</td></tr>
<tr><td>Fishing and aquaculture</td></tr>
<tr><td>Electricity, gas, steam and air conditioning supply</td></tr>
<tr><td>Water supply, sewerage, waste management and remediation activities</td></tr>
<tr><td>Transport and storage, accommodation and food service activities</td></tr>
<tr><td>Financial and insurance activities</td></tr>
<tr><td>Human health and social work activities</td></tr>
<tr><td>Real estate activities</td></tr>
<tr><td>Administrative and support services</td></tr>
<tr><td rowspan="5"></td><td>Arts, entertainment and recreation activities</td></tr>
<tr><td>Information and communication</td></tr>
<tr><td>Manufacturing</td></tr>
<tr><td>Mining and quarrying</td></tr>
<tr><td>Other service activities</td></tr>
</table>

Impact on GDP based on deviations from Trend	Sectors
Increase in Sector GDP	Professional, scientific and technical activities
	Public administration and defense
	Compulsory social security,
	Wholesale and retail and repair of motor vehicles and motor cycles
No Change	Construction
	Education

Figure 19: Fiji Current Account Balance (% of GDP) per Year



(Source: World Bank)

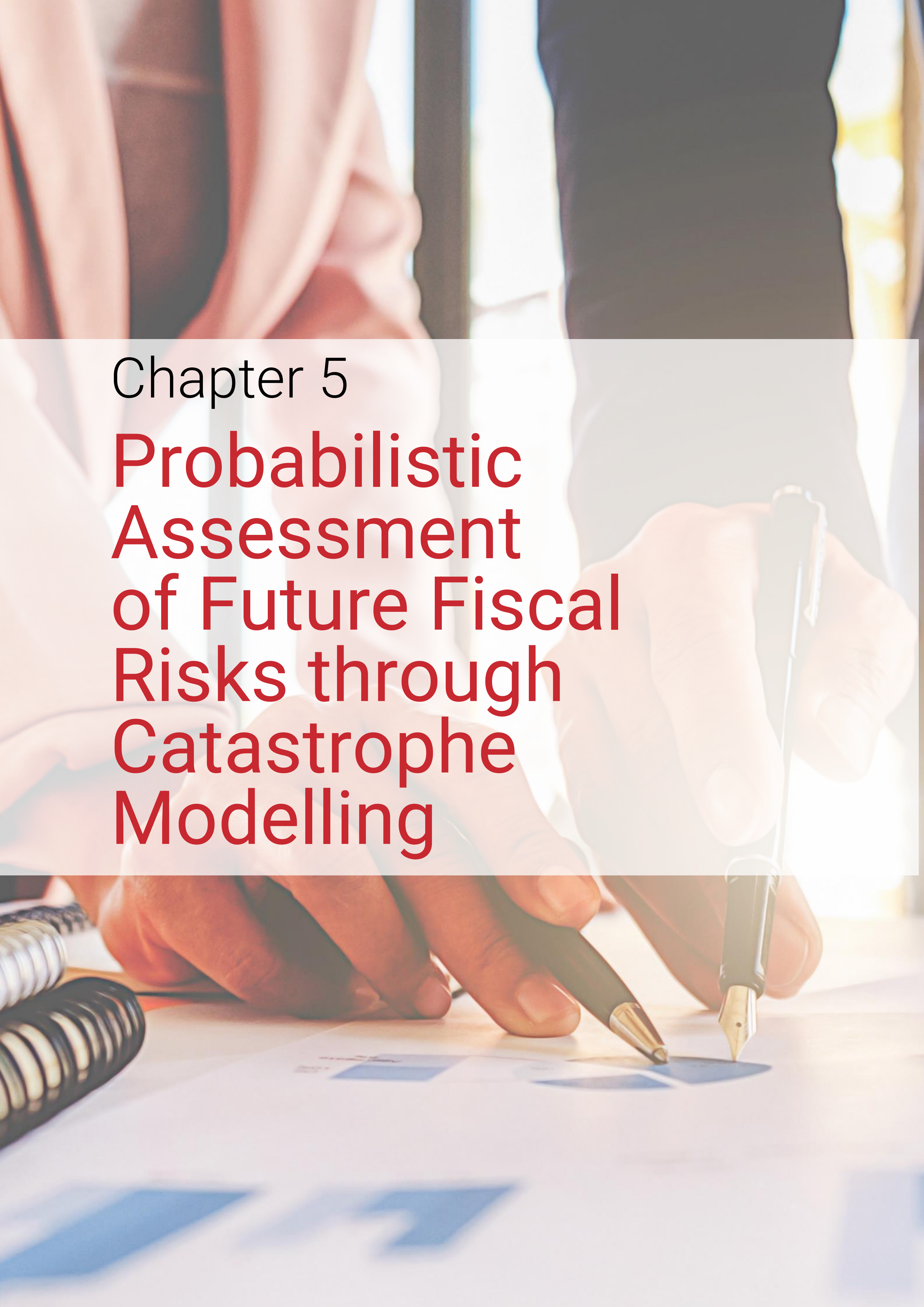
According to the PDNA report for TC Winston the total loss of the disaster is estimated to be around FJ$710 million, or 6.90 percent of GDP.[48] Similar to TC Evan, the economic impacts TC Winston were an estimated slower growth, deterioration in the Balance of Payments and Current Account, and reduction in wages (particularly for the agriculture sector).

[48] Government of Fiji. *Fiji: Post-Disaster Needs Assessment, Tropical Cyclone Winston, February 20, 2016*. Suva, Fiji: 2016. https://www.gfdrr.org/sites/default/files/publication/Fiji-Post-Disaster-Needs-Assessment-Online-Version.pdf.

The agriculture sector, which provides direct and indirect income to 37 percent of Fijians and contributes 6.4 percent to the GDP, was severely impacted. These figures highlight the long-term economic burden that disasters impose on the agriculture sector, affecting employment and income levels.

Following the TC, the Government of Fiji allocated $33.7 million (0.68 percent of GDP) for residential homes rehabilitation and assistance programme. It was noted that the diversion of funds into relief, recovery and reconstruction will reduce funds available for the government’s existing development programmes.

The Climate Finance Strategy (CFS) estimated that 79 percent of Fiji's annual climate finance was dedicated to rebuilding schools, roads, and other public infrastructure damaged by TC Winston. From 2016 to 2019, $68 million per year, or 73 percent of actual climate finance expenditures, was spent on recovery efforts, highlighting the extensive indirect costs associated with disasters.



Chapter 5

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 evolve. This understanding is crucial to ensure that disaster risk management plans remain effective and do not fall short of current needs. By modelling the potential costs ahead of a major disaster, we can more effectively plan and prepare for such events. This includes analyzing the breakdown of losses that contribute to disasters, allowing for a more tailored disaster risk finance strategy. This section of the report presents the results of the catastrophe modelling used to assess the future impact of disasters on the power and road sectors and their subsequent effects on the fiscal health of the state.

Hazard Models

For catastrophe modelling of Fiji, four hazards are considered: earthquakes, 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), that produces some intensity at the location of the infrastructure elements and has some probability of occurrence. The complete set of events (i.e., all the simulated tropical cyclones) fully represents how each hazard may occur.

Climate Models

As part of climate modelling, multiple projections of Global Circulation Models included in CMIP6[49] were verified, including anthropogenic forcings expressed as combined scenarios of SSP (Shared Socioeconomic Pathways) and RCP (Representative Concentration Pathways), as defined by the IPCC (AR6). Hydrometeorological phenomena are modelled from the meteorological forcing (precipitation, temperature, etc.) of a historical period, named Base climate, that corresponds to the period 1980-2010, i.e., a recent period of 30 years as climate norm. Climate projections are used to modify the Base climate using the Delta method, which simply alters 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 Hazards

Cyclogenesis is a mesoscale process that requires high-resolution inputs from climate models. Therefore, not all the climate models included in CMIP6 are suitable for cyclone hazard modelling. Only a few CMIP6 models have enough spatial resolution to be utilized for the projection of future cyclone tracks. Those models are all part of the PRIMAVERA High Resolution Project of CMIP6. We are using for this assignment 4 high-resolution[50] models: CMCC-CM2-VHR4,[51] CNRM-CM6-1-HR,[52] EC-Earth3P-HR,[53] HadGEM3-GC31-HM.[54] The mentioned models have projects only considering an emissions scenario SSP5-RCP8.5, therefore, for tropical cyclones only, the model is built based on a single trajectory and not two bounds of climate variation as for the other hydrometeorological hazards.

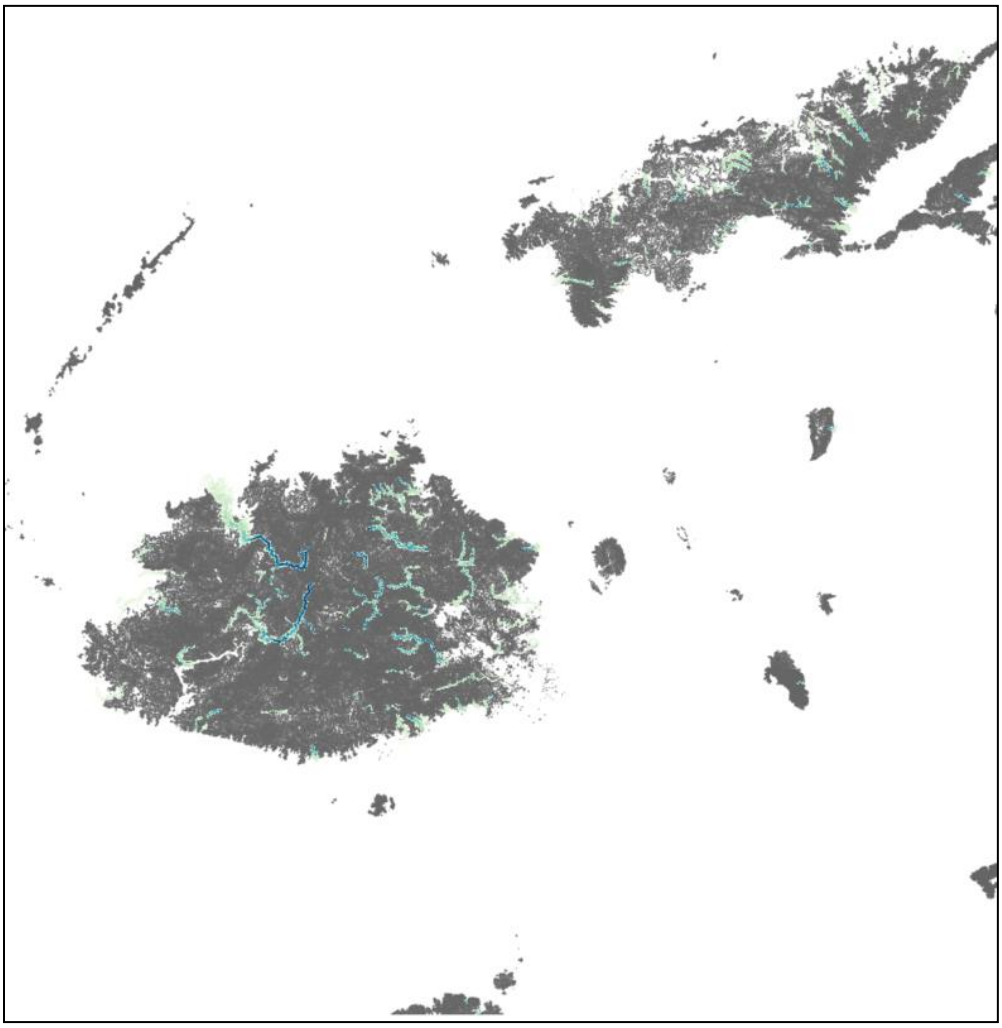
[49] Climate Model Intercomparison Project version 6.
[50] In the context of climate modelling, high resolution refers to a spatial grid of 50 km in pixel size.
[51] Centro Euro-Mediterraneo sui Cambiamenti Climatici
[52] Centre National de Recherches Météorologiques. Meteo France.
[53] Earth Consortium
[54] Hadley Centre Global Environment Model

Flood Hazard Model

A new flood model was developed, due to the unavailability of results from the global flood hazard modeled used for the GIRI assessment of CDRI. The model is based on the approximation of flows in tributary basins upstream of various points on the main rivers and streams, in order to hydraulically move the flows within the channels, with various inflows depending on the sub-basins that make up the main channel basin. In this way, and at an intermediate resolution, it is possible to cover all the rivers in the country and determine flood areas and depths due to overflow.

Flood discharge magnitude is estimated from approximated hydrological methods based on physical features of the basin. The method implemented in this case was the Modified Clark Hydrograph. Once discharge is obtained, it is used as input for the simplified hydraulic flood model. The model draws hydraulic cross sections where the flood stage is calculated from the flow value by solving the Manning equation. These stages are interpolated based on the local relative morphology and modifications are included to consider longitudinal hydraulic connectivity between sections. Figure 20 presents the uniform flood hazard map for 100 years return period for Fiji.

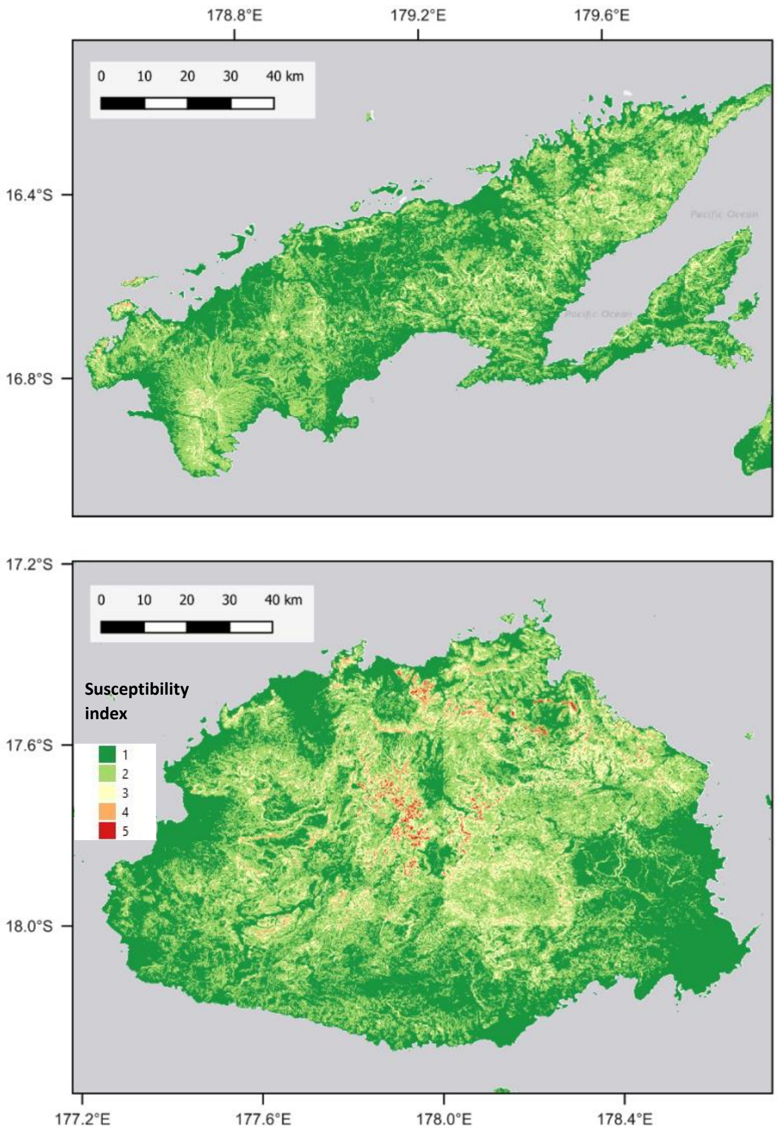
Figure 20. Flood Hazard Map for 100 Years Return Period for Present Climate Conditions in Fiji



Landslide Hazard Model

For the FRA of Fiji, the global susceptibility model and rainfall thresholds developed by Nadim et al. (2023)[55] was used, along with the landslide hazard model developed by Cardona et al. (2023)[56]. Susceptibility is modeled heuristically as a function of slope, lithology, vegetation cover and soil moisture. Each of the previous characteristics is mapped to a susceptibility factor (an integer number between 0 and 5) and weighted according to the expected influence on the susceptibility. The result is the weighted sum of the characteristics involved, at each mountainous location in the territory. Local modifiers such as population density or roads density are incorporated to account for the anthropogenic influence on landslides. The susceptibility is mapped at a spatial resolution of 30 meters, expressed as an integer number between 0 and 5. Figure 21 shows the landslide susceptibility map for Fiji.

Figure 21. Landslide Susceptibility of Fiji



(Source: Nadim et al., 2023)

Landslide hazard depends not only on susceptibility, but on triggering factors, which are external forcings that locally increment instability, triggering a landslide event. In this assignment, such factors

55 Farrokh Nadim et al., *Global Landslide Susceptibility and Rainfall Thresholds: Methodology and Data* (World Bank, 2023).

56 Omar D. Cardona et al., *A New Global Landslide Hazard Model* (World Bank, 2023).

are excess rainfall and seismic acceleration. The rainfall trigger is obtained directly from the climate modelling above, and the earthquake trigger is simulated from the seismic hazard model below. Nonetheless, landslide thresholds are required to set the corresponding triggering intensity. In this assignment, we are using the thresholds proposed by Nadim et al. (2023), presented in Tables 7 and 8.

Table 7. Rainfall Threshold for Landslide Hazard

Range of P_n[57]	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)

Table 8. Seismic Acceleration Threshold for Landslide Hazard

Range of PGA[58]	Susceptibility				
	Susc. 1	Susc. 2	Susc. 3	Susc. 4	Susc. 5
$0.05 \leq PGA < 0.15$	0%	0%	0%	0.1%	0.5%
$0.15 \leq PGA < 0.25$	0%	0%	0.1%	0.5%	1%
$0.25 \leq PGA < 0.35$	0%	0.1%	0.5%	1%	5%
$0.35 \leq PGA < 0.45$	0%	0.5%	1%	5%	10%
$PGA \geq 0.45$	0%	1%	5%	10%	40%

(Source: Nadim et al., 2023)

Based on the susceptibility and thresholds, the model estimates the probability of landslide according to the simulated triggering rainfall or seismic acceleration.

Tropical Cyclones Hazard Model

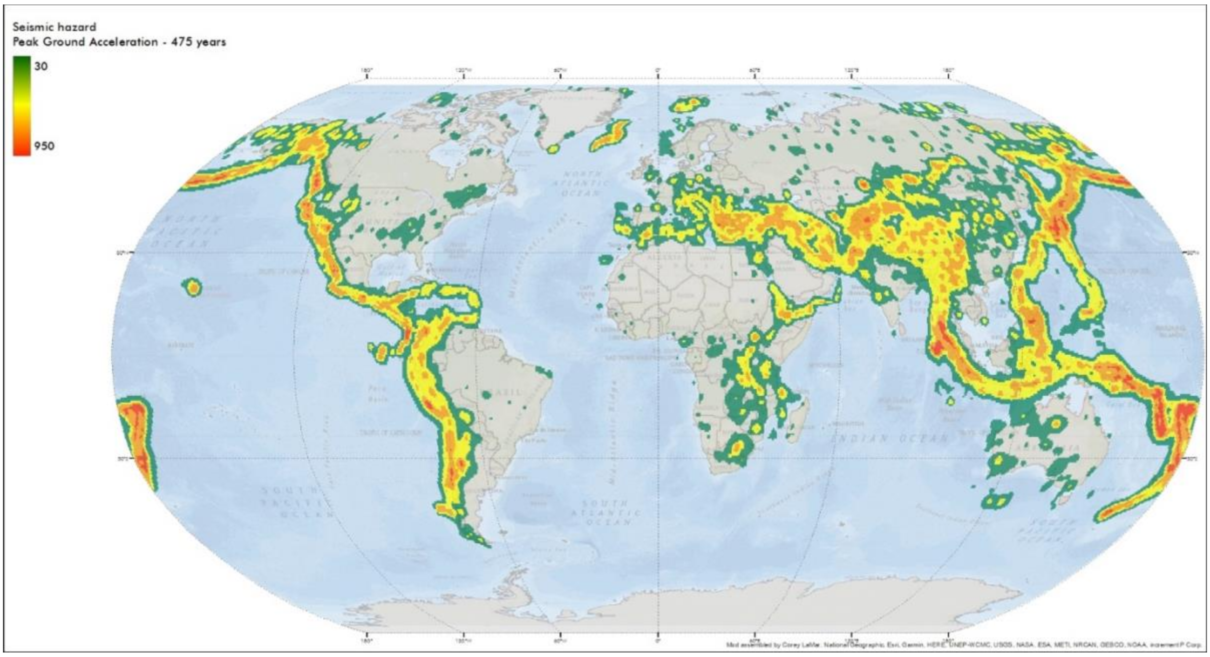
For this assignment, the tropical cyclones hazard was updated, including the latest cyclones trajectories up to 2024. The method is implemented in the CAPRA ROBOT software module TCHM (Bernal 2013).[59] Detailed information on the methodology can be found in Cardona et al. (2014).[60] Hazard for both strong winds and storm surge was assessed for this project using as input an updated catalogue including 381 historical tropical cyclones for the South Pacific Ocean basin. The results are expressed, for the strong winds, in terms of the geographical distribution of the peak wind speed of 3-seconds gusts, and for the storm surge, as the distribution along the shorelines of the maximum surge run-up and its associated flooding. This analysis was repeated for all historical and future cyclone tracks. The hazard assessment result is the set of probabilistic wind fields and storm surge floods.

Seismic Hazard Model

[57] P_n is the 24-hour normalized rainfall, expressed in mm.
[58] PGA is the peak ground acceleration expressed as a fraction of g (g=9.81 m/s^2).
[59] Bernal, G. (2013). *[A specific technical document or report on the Tropical Cyclones Hazard Modeler (TCHM) module for the CAPRA platform]*. Ingeniar Risk.
[60] Omar D. Cardona et al., *Tropical Cyclone Hazard Assessment for the South Pacific Island Countries* (Ingeniar Risk, 2014).

Seismic hazard has no relation to climate and therefore is considered stationary. For the FRA of Fiji, the global seismic hazard modeled developed by Cardona et al. (2014) was used. The seismic hazard at bedrock level is calculated based on historical information recorded in seismic catalogues. Using said information which is related to the magnitude and the location of the hypocenter of each earthquake, the intensity of the events is calculated by a set of stochastic scenarios, mutually exclusive and collectively exhaustive, each with a geographical distribution of probability. An in-depth description of the seismic hazard model can be found in Cardona et. al. (2014). Figure 22 shows an example of a seismic hazard map calculated for a 475-year return period of the peak ground acceleration at bedrock level (i.e., Vs30[61]=1,100 m/s).

Figure 22. Seismic Hazard Map for Peak Ground Acceleration and 475-year Return Period



Exposure Model

The database of exposed elements is defined as the collection of physical elements that make up an infrastructure system, and for which three properties are established as a minimum: its geographic location, its physical value or replacement cost of the asset, and a constructive or archetypal class that allows its vulnerability to be related.

[61] Vs30 is the shear wave velocity of the top 30 meters below the surface. It is a parameter commonly used to account for subsurface materials stiffness.

Energy Sector

The Energy sector refers to the existing infrastructure for the generation, transmission, and distribution of electricity within the territory. Oil and Gas infrastructure, which is considered part of the Energy sector by some authors, is not included.

The Energy sector is therefore subdivided into three subsectors: Generation, Transmission and Distribution. Each subsector requires an independent exposure model that accounts for the unique characteristics that make up its elements.

Power Generation in Fiji is diverse. According to data from Global power plant database (WRI)[62] and Open Street Map (OSM)[63], there are around 2 thousand MW of installed capacity of generation, distributed among 6 different types of energy conversion, as shown in Table 9. Regarding Transmission, there are more than 500 km of transmission lines in Fiji.

Table 9. Installed Capacity of the Generation Sector in Fiji

Source Energy	Capacity [MW]	[-]
Bioenergy (biomass, waste)	24	1.4%
Hydro	331	18.4%
Oil (petroleum derivates)	124	6.9%
Other	1,291	71.7%
Solar (photovoltaic)	19	1.0%
Wind	10	0.6%
Total general	**1,799**	

Table 10. Transmission Lines Voltages and Lengths in Fiji

Voltage (kV)	Length (km)	[-]
<110	220.3	40.8%
110 - <220	319.7	59.2%
220 o >220	0.0	0.0%
Total	**540.0**	

Generation

The approximation of the replacement cost for the exposed elements on the Generation subsector is based on the information contained in the WRI and the Power plant database from OSM. The data on energy source is reclassified to one of the basic classes presented in Table 11. Next, the capacity of each plant is verified within the existing information. If there is no data on plant capacity, it is randomly assigned from a probability distribution of capacities of the same type of energy source (see Cardona

[62] Global Energy Observatory, Google, KTH Royal Institute of Technology in Stockholm, Enipedia, and World Resources Institute. *Global Power Plant Database, version 1.3.0*. Published on Resource Watch and Google Earth Engine, 2021.https://datasets.wri.org/dataset/globalpowerplantdatabase.

[63] OpenStreetMap Foundation. "About OpenStreetMap." OpenStreetMap. Last modified August 7, 2025. https://www.openstreetmap.org/about.

et al. 2023[64] for further details). Finally, the replacement cost is assigned using the cost indicators used by Cardona et al. (2023) and defined by IRENA[65], multiplied by the plant capacity.

Table 11. Basic Energy Source Classes and Unitary Costs

Energy source	**Cost indicator (USD/kW)**
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 derivates)	795
Solar (photovoltaic)	857
Wave and tidal	7,038
Wind	1,325
Other	1,134

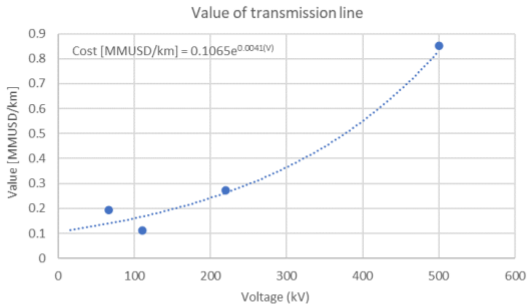
Transmission

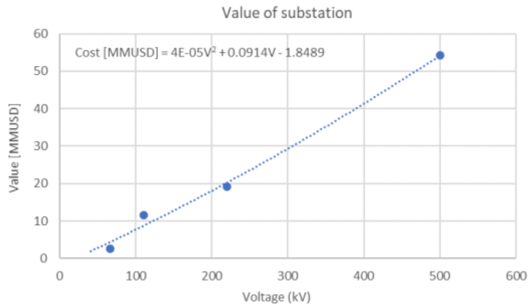
For the Transmission subsector, the raw data is obtained from the Power Lines Database and Power Substations Database, both by OSM. For the transmission lines, first the length of each element is determined from the raw spatial data. Long elements are trimmed into segments of 150 m or less. Then, the line voltage is used to determine the cost indicator in accordance with the price function proposed by Cardona et al. (2023) that is shown in Figure 23. Finally, the overall cost of the segment is obtained from the multiplication of the corresponding cost indicator and the segment length. For substations, first the raw data is debugged to eliminate substation elements that don't correspond to transmission or distribution networks. Finally, the cost is evaluated from the working substation voltage using the pricing function proposed by Cardona et al. (2023) and presented in Figure 24.

[64] ibid., 49

[65] International Renewable Energy Agency (IRENA). *Renewable Power Generation Costs in 2023*. Abu Dhabi: International Renewable Energy Agency, 2024. https://www.irena.org/publications/2024/Mar/Renewable-power-generation-costs-in-2023.

Figure 23 and Figure 24. Pricing Function Based on Transmission Line Voltage (Left) and Based on Voltage at Substation (Right)





Distribution

Distribution networks are highly correlated to the density of population. They are commonly denser where the populations are more concentrated, and vice versa. Since the data on the real location and characteristics of the elements of the distribution network (such as cable posts, buried lines, transformers, etc.) is unavailable or doesn't exist, we apply the framework developed by Cardona et al. (2023) to create an exposure proxy for the distribution network based on population.

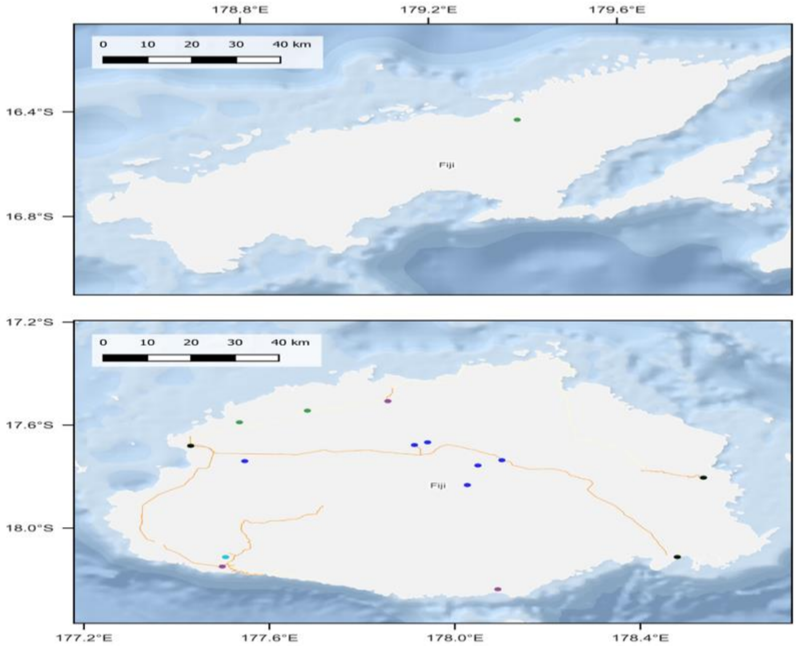
Cardona et al. (2023) propose the valuation of the distribution subsector as a factor of the transmission subsector.[66] This results in a bulk valuation that needs to be distributed geographically using the raster grid of population from the Global Human Settlements Layer (GHSL).[67] This population grid is transformed into a population with access to electricity, which for Fiji is 92 percent of the total population according to the World Bank data.[68] This procedure results in higher exposure values where the population is denser, and a bulk infrastructure value that is consistent with the real access to electricity.

Exposure Database

The resulting exposure model is composed of geolocated vector entities with attributes useful for risk evaluation. The replacement cost and the archetype of each element are included as key fields to characterize the exposure.

[66] The factor is 2.26. See Cardona et al. (2023) for further details.
[67] Global Human Settlements Layer. Available at https://human-settlement.emergency.copernicus.eu/ghs_pop.php
[68] World Bank. "Access to electricity (% of population)." World Bank Data. Accessed August 1, 2025. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

Figure 25. Shows a General Overview of the Sector for Fiji.



Roads Sector

The Roads sector in this assignment refers to highway infrastructure. Road infrastructure differs depending on design conditions such as topography, weather, and traffic. Furthermore, highway segments are composed of many elements, such as pavement structure, retaining walls, gutters, box culverts, etc. A similar situation occurs for bridges, where each bridge is totally different from the others. Although they could be classified into archetypes, bridges are among the few infrastructure elements that defy typification. In addition, the available data has strong limitations. 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, in Fiji there are around 10,000 kms of roads, considering Primary, Secondary, Tertiary, Residential, and minor roads. In addition, there are 15 kms of bridges within the same road types. Private roads and bridges are not included in this assignment.

Road Segments

The procedure to define the replacement cost of the components of the Road sector is the one proposed by Cardona et al. (2023) and used for the valuation of exposed elements in the GIRI model of CDRI. In this procedure the Global Roads Network dataset from OSM is used and processed to eliminate wrong or incomplete records. The roads included are segmented to a length of maximum 150 m to increase the granularity of the model. The basic value of each segment is evaluated from its length and a nominal cost of $1.09 million/km.

The basic value of the segment is modified by the approximation to four main features: road type, number of lanes, pavement type, and slope. Each feature implies a multiplication factor that modifies the basic value of the segment. Road type refers to the operational level of the road within the network of the country. It is an important modifier to account for variations in replacement cost depending on the overall importance of the road. The corresponding multiplication factor is presented in Table 12.

Table 12. 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* is an indicator of the demand supplied by the road segment. We use the factor proposed by Cardona et al. (2023), which is calculated as half the number of lanes in the segment. Therefore, a 2-lane road is considered as the basic condition with a multiplication factor of 1. Roads with higher numbers of lanes imply an amplification of the exposure value from the basic replacement cost.

Pavement type also modifies the cost of the segment. It is evident that replacing a segment of paved road would be more costly than replacing a segment of affirmed gravel. We use the factors proposed by Cardona et al. (2023), considering three general categories: paved, affirmed, and loose. The factors are presented in Table 13.

Table 13. 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 modifier of the segment value. Replacing a road segment of similar characteristics in a steep terrain would be far more costly than replacing it in a plain terrain. Furthermore, some critical elements, like retaining walls are far more likely to be present in a steep terrain than in plain terrain where those would not exist. We use the slope factors proposed by Cardona et al. (2023) that are presented in Table 14.

Table 14. 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

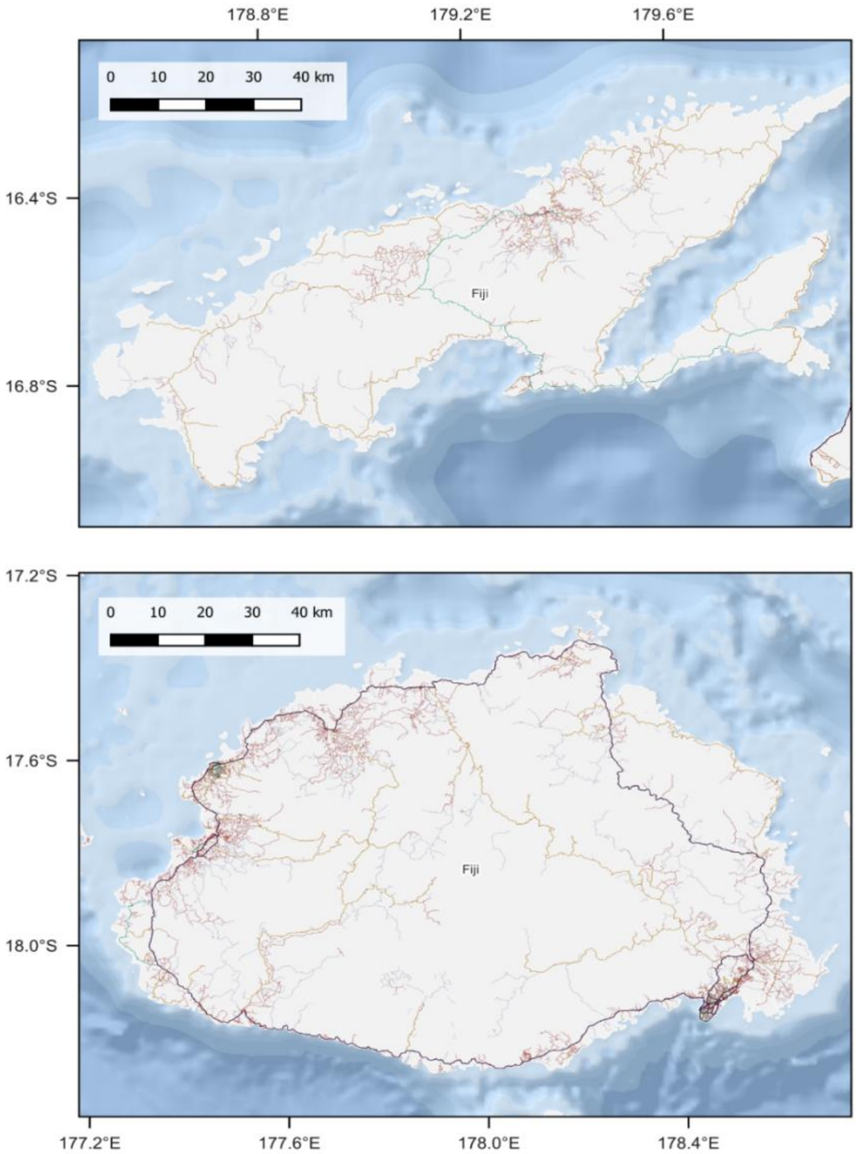
Bridges are infrastructure elements that are particularly difficult to typify. It could be said, with high confidence, that there are as many bridge types as there are bridges in the world. This, of course, makes quite difficult any attempt to classify bridges. However, given the current state of data available, such classification attempt is impossible, because the available information is insufficient to differentiate structural differences in existing bridges. Properties such as span, gauge, support type, number of pillars, abutments, foundation, broad structure, among many others, are unknown. The available data from the OSM dataset allows for the identification of the bridge length only. We use this attribute to estimate the replacement cost, including the cost indicator proposed by Cardona et al. (2023), which is $9.84 million/km.

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, from the length of each identified tunnel in the OSM dataset, the exposed value is approximated from the average price indicator proposed by Cardona et al. (2023), which is $19.8 million/km.

Exposure Database

The resulting exposure model is composed of geolocated vector entities with attributes useful for risk evaluation. The replacement cost and the archetype of each element are included as key fields to characterize the exposure. Figure 26 shows a general overview of the sector for Fiji.

Figure 26. Map of the Exposure Database for Road Sector in Fiji



Vulnerability Models

The physical vulnerability of the exposed elements can be represented mathematically by means of vulnerability functions, which sufficiently represent the complexity of the loss generation process when subjecting the exposed elements to the impact of a dangerous event. Additionally, vulnerability functions express the loss in a probabilistic way, allowing the application of the conceptual framework for risk assessment.

Probability Model for the Loss

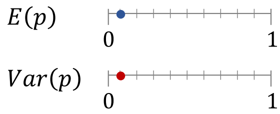
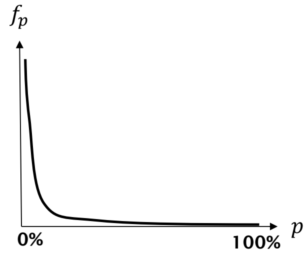
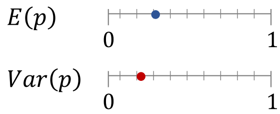
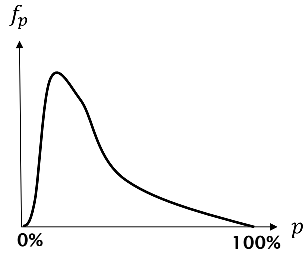
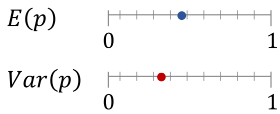
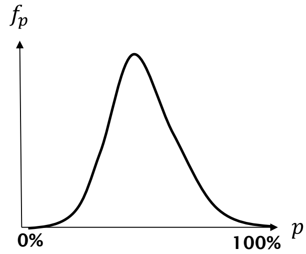
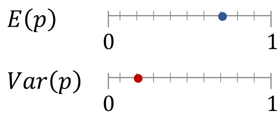
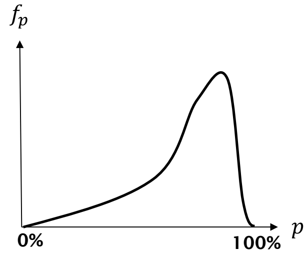
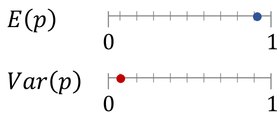
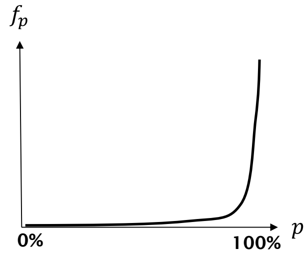
In catastrophe risk modelling, losses are treated as random variables. To generalize, loss can be defined as a variable in the range of 0 to 1, that is, from zero to 100 percent of the exposed value of the element (e.g., the replacement value of a property or an infrastructure element). This means that, from now on, and in general, when talking about vulnerability, the loss always corresponds to a relative loss according to the degree of damage; that is, it is a fraction of the exposed value.

In general, there is not enough information on damage and losses caused by historical events to allow a probability model to be adjusted to the loss based on statistical estimates. Therefore, the definition of a probability model that describes the randomness of the loss is a decision that is considered reasonable and appropriate, but it is inevitably arbitrary. The most widely used model corresponds to a Beta distribution, proposed by Anne Kiremidjian and other authors in the development of the ATC-13 document and its commentary ATC-13-1 (ATC, 1985, 2002), whose objective was the definition of probability models for the damage caused by earthquakes in California. Since then, the use of the Beta distribution as a probability model for loss has been generalized worldwide for all hazards and all types of exposed elements, as it is a practical model under the following criteria:

- It describes a continuous random variable within the real interval [0,1].
- It is defined with only two parameters (α and β).
- It admits multiple forms as a function of the values of its parameters.

Since this is a two-parameter distribution, two probability moments are required to characterize it. This implies that vulnerability models must account for at least two probability moments. It is common to define vulnerability models in terms of the *expected value* and *variance* of the loss. The way the Beta distribution changes shape then depends on the values of the probability moments that are estimated by means of the vulnerability model. As mentioned, the ability of the Beta distribution to alter its shape within the interval in which it is defined, is one of the criteria by which it is widely used in catastrophe risk modelling. Table 15 illustrates the expected shapes of the Beta distribution for different combinations of expected value and variance of the loss. The table includes a general description of what is expected for hazard events of different intensity levels, an illustration of quantities for the expected value and variance within the interval [0,1], and an illustration of the expected shape of the Beta distribution. It can be concluded that the Beta distribution appropriately fits the shapes in which the loss is expected to be distributed for events of different characteristics.

Table 15. Illustration of the Variation of the Beta Distribution in Response to Events of Different Intensity Levels

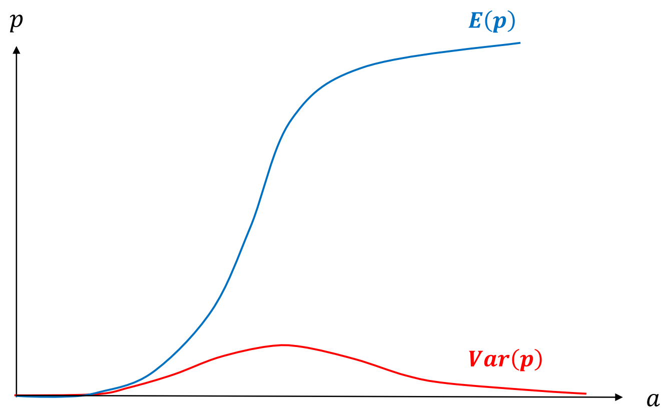
Description	Probability Moments	Beta Distribution
<u>*Very low intensity event:*</u> *A low loss value is expected with a low dispersion. That is, if the intensity is very low, it is known that the loss will be low without much variability.* *The distribution exhibits negative exponential behavior, with a rapid decrease. That is, the highest probability density is concentrated near zero loss, as expected for a very low intensity.*		
<u>*Low intensity event:*</u> *The expected value of the loss increases and its variance also increases (i.e., the loss is more uncertain).* *The distribution is wider, centered more to the right, but still skewed towards low losses.*		
<u>*Intermediate intensity event:*</u> *The expected value of the loss is much higher and the variance is also as high as possible.* *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.*		
<u>*High intensity event:*</u> *The expected value of the loss increases but its variance decreases because at high intensities the uncertainty of a high level of damage is increasingly less.* *The distribution begins to skew to the right towards high values of loss, with some density at low losses, but very concentrated towards high damages.*		
<u>*Very high intensity event:*</u> *The expected value of the loss is very high and its variance is small because there is not much uncertainty about the level of damage for a very high intensity.* *The distribution takes the form of an exponential function, with rapid growth in the density values, indicating that losses are almost certain to be very high.*		

Vulnerability Functions

Vulnerability functions are a mathematical representation of physical vulnerability, which is actually composed of two different functions: one function describing the variation of the *expected value* of the loss with the intensity of the phenomenon and another describing 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 form of the expected value and variance functions is not entirely free. In general, what is illustrated in Table 15 must be fulfilled, that is, the expected value function is necessarily increasing, while the variance function must first be increasing and then decreasing to properly account for its expected variability with the intensity of the phenomenon. Figure 27 shows an example of the typical shape of vulnerability functions.

Figure 27. Illustration of a Vulnerability Function



Vulnerability functions are determined and established for types of exposed elements, following some categorization. This means that a single function can describe the behavior of multiple exposed elements that belong to the same category. This makes sense given the probabilistic nature of probability functions, which allows capturing the behavior of similar exposed elements. The typification or categorization of exposed elements is established in the exposure model based, typically, on the construction or functional characteristics of the elements.

The vulnerability functions developed by Cardona et al. (2023) for infrastructure archetypes are used for this assignment. These are the same functions utilized in the GIRI model of CDRI. The GIRI library of archetype functions is the most complete resource of infrastructure vulnerability models for catastrophe risk assessment available at present. The vulnerability functions used for the risk assessment of Fiji in this assignment are presented in Figure 28 to Figure 33. As mentioned previously, no vulnerability functions are used for landslide hazard under the assumption that the occurrence of the landslide necessarily implies the destruction of the infrastructure element. This assumption works particularly well for road infrastructure, which is the only one subjected to landslides in this assignment.

Energy Infrastructure

Figure 28. Earthquake Vulnerability Functions for the Infrastructure of the Energy Sector

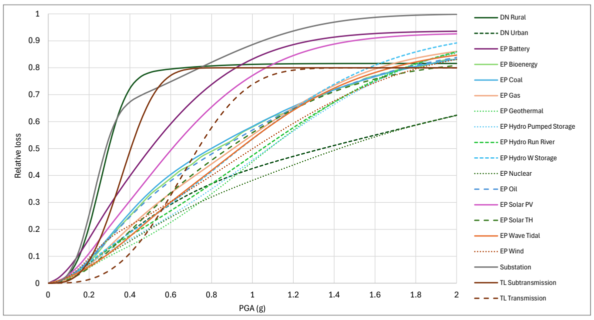


Figure 29. Flood Vulnerability Functions for the Infrastructure of the Energy Sector

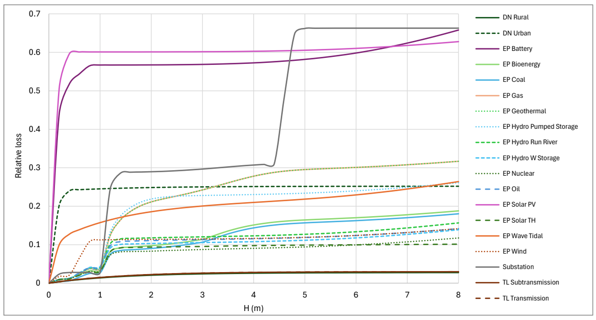


Figure 30. Storm Surge (Cyclone) Vulnerability Functions for the Infrastructure of the Energy Sector

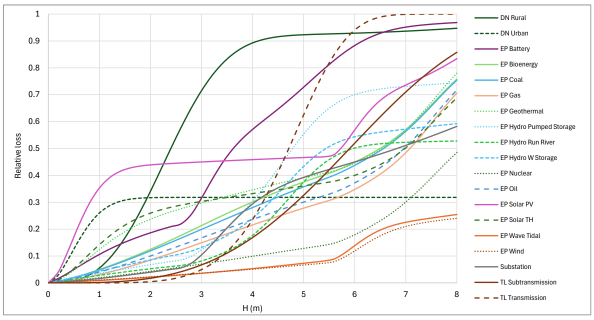
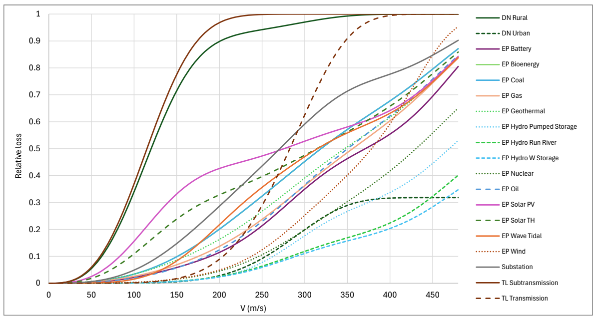


Figure 31. Wind (Cyclone) Vulnerability Functions for the Infrastructure of the Energy Sector



Road infrastructure

Figure 32. Earthquake Vulnerability Functions for Infrastructure of the Road Sector

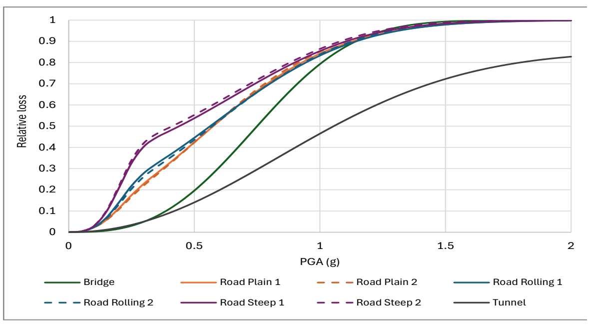
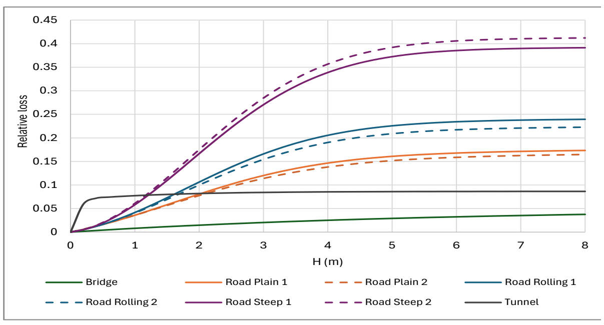


Figure 33. Flood Vulnerability Functions for Infrastructure of the Road Sector



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 in the insurance industry.

- *Average Annual Loss (AAL):* Average Annual Loss (AAL) is an important indicator because it integrates into a single value the effect, in terms of loss, of the occurrence of hazard scenarios over vulnerable exposed elements. It is considered as the most robust risk indicator, not only for its ability to resume the loss-time process in a single number but for having low sensitivity to uncertainty. The AAL corresponds to the expected value of the annual loss. It indicates the annual value to be paid to compensate in the long term for all future losses. In a simple insurance scheme, the AAL would be the annual pure premium.

- *Probable Maximum Loss (PML):* This is a loss that does not occur frequently, that is, a loss usually associated with long return periods. There is not a single PML value, but a complete curve (loss vs. return period). However, it is common practice to define a PML value by fixing a 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 up to 2,500 years.

The AAL is presented as the total 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 is the modeled 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 some sector in the territory, then the relative AAL is normalized by the total exposed value of the sector. On the other hand, if the AAL reported is of one single exposed element (like in risk maps, for example), the relative AAL is normalized by the exposure value of that element alone. In this report, relative AALs are always presented as per-thousand fractions with the symbol %.

The PML is presented as functions of loss versus return period, for each hazard and sector. The absolute PML values are included, while the relative PML values are presented to facilitate comparison among hazards. As for the AALs, absolute PMLs are the calculated amount while relative PMLs are normalized by the sector's exposed value. 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 with the symbol %.

Energy Infrastructure

Table 16 presents the AAL for Fiji's Energy sector for the hazards considered in this assessment, both absolute and relative. It is noteworthy that the highest losses are due to tropical cyclones, the climate scenario SSP5-RCP8.5 being the one that implies the higher losses. Evidently, the exposure of the country to cyclonic activity is reflected in higher risk metrics. Next follow earthquakes, with a much lower but not negligible AAL. Floods provide a much lower AAL in comparison to the other hazards. Fiji is subjected to high levels of catastrophe risk, controlled by large events, like tropical cyclones, with the capacity to correlate with losses in different locations.

Table 16. Absolute and Relative Average Annual Loss for the Energy Sector Infrastructure

Hazard	Average Annual Loss	
	USD ($)	‰
Earthquake	$5,523,000	1.39
Flood	$1,863,000	0.47
Flood (RCP2.6)	$2,291,000	0.58
Flood (RCP8.5)	$1,674,000	0.42
Tropical cyclone	$64,439,000	16.25
Tropical cyclone (RCP8.5)	$94,251,000	23.77

The relative AAL among subsectors is distributed as shown next. In the case of earthquake hazard, the AAL values are quite similar among sectors. Although the highest value is for Transmission, it falls very close to Generation and Distribution. This is expected in a country with highly concentrated infrastructure that can be impacted by the same event. For floods, the largest AAL is of Transmission and Distribution, followed by the Generation subsector. Distribution is highly correlated with population density, which explains the large AAL around river margins. In the case of Transmission, substations suffer the highest impact in Fiji, adding significant losses to the AAL of the sector. In addition, the influence of climate change in flood risk is evident, increasing for the scenario SSP1-RCP2.6, and decreasing for SSP5-RCP5. Although it may seem counterintuitive, this situation responds to the highly non-linear relationship between GHG emissions and risk. Finally, the AALs for tropical cyclones are the highest for the sector, with a large increase for an SSP5-RCP-8.5, further emphasizing the non-linearity of the risk-GHG emissions relationship (See Figure 34).

Figure 34: Relative Average Annual Loss from (A) Earthquake (B) Flood and (C) Tropical Cyclones for the Energy Infrastructure Portfolios

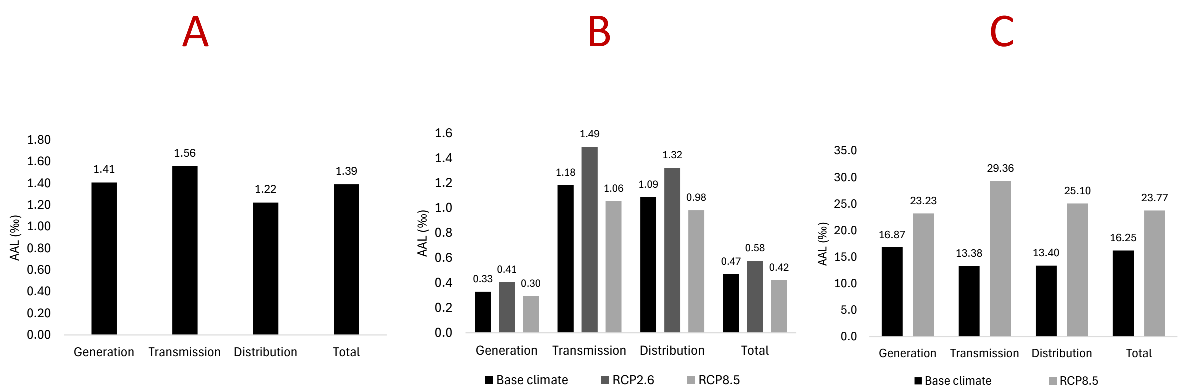
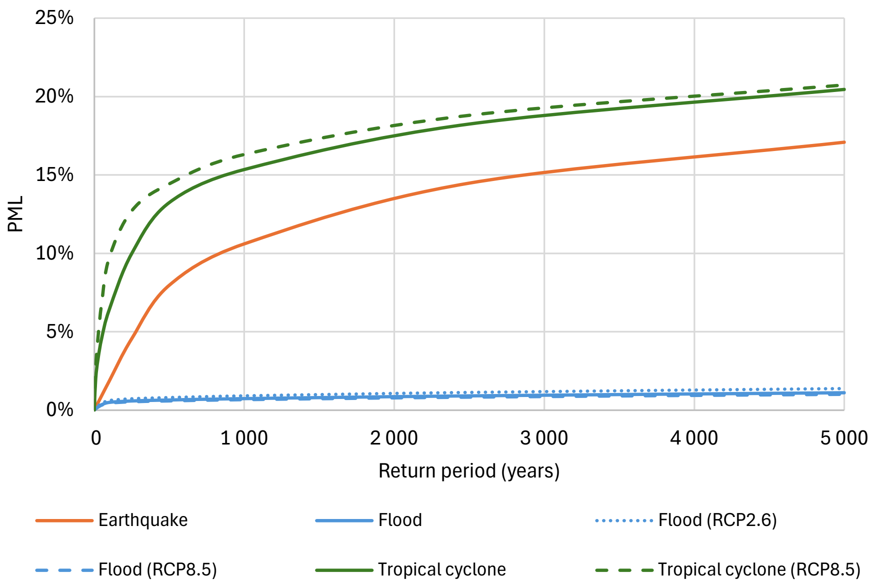


Table 17 presents the PML values for the Energy sector of Fiji, by hazard and for some selected return periods. PMLs are always higher in magnitude than AALs due to their definition and the nature of their calculation. Those PMLs are presented in relative terms in Figure 39 as PML curves, showing the full variation of the metric with the return period. Tropical cyclone risk dominates the PML curve for all return periods. Note how PML for large return periods of tropical cyclones under the current climate comes very close to the PML considering the SSP5-RCP8.5 scenario. Furthermore, earthquake risk contributes significantly as well for all return periods. Finally, flood risk is significantly lower as expected for Fiji.

Table 17. Probable Maximum Loss for Energy Sector Infrastructure (Values in $)

Return period (years)	Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Tropical cyclone	Tropical cyclone (RCP8.5)
10	$7,356,000	$3,605,000	$4,432,000	$3,238,000	$79,927,000	$107,536,000
25	$18,388,000	$8,119,000	$9,983,000	$7,294,000	$128,550,000	$183,305,000
50	$36,755,000	$13,871,000	$17,054,000	$12,461,000	$182,128,000	$271,231,000
100	$73,353,000	$19,582,000	$24,075,000	$17,591,000	$253,831,000	$385,649,000
250	$180,682,000	$23,206,000	$28,531,000	$20,846,000	$396,008,000	$504,230,000
500	$315,867,000	$25,684,000	$31,577,000	$23,072,000	$524,817,000	$572,357,000
1,000	$420,648,000	$29,188,000	$35,885,000	$26,220,000	$608,452,000	$646,727,000
2,500	$574,409,000	$36,183,000	$44,484,000	$32,504,000	$723,504,000	$745,798,000
5,000	$677,898,000	$44,110,000	$54,228,000	$39,626,000	$811,030,000	$822,589,000

Figure 35. Probable Maximum Loss Curve for the Energy Sector Infrastructure



Road Infrastructure

Table 18 presents the AAL for Fiji's Road sector for the hazards considered in this assessment, both absolute and relative. The highest losses are due to earthquakes, which are expected to be due to the geographical location of the country. Losses from other hazards fall within similar values. It is relevant to see that for floods, the highest losses come with the SSP1-RCP-2.6 scenario, while for landslides they are related to the SSP5-RCP8.5 scenario. As mentioned above, this high non-linearity is normal in climate risk analysis.

Table 18. Absolute and Relative Average Annual Loss for the Road and Bridge Infrastructure

Hazard	Average Annual Loss	
	USD	‰
Earthquake	$7,851,000	1.75
Landslide - Earthquake	$1,062,000	0.24
Flood	$2,846,000	0.64
Flood (RCP2.6)	$3,462,000	0.77
Flood (RCP8.5)	$2,566,000	0.57
Landslide - Rain	$3,575,000	0.80
Landslide - Rain (RCP2.6)	$2,968,000	0.66
Landslide - Rain (RCP8.5)	$3,364,000	0.75

The relative AAL among subsectors is distributed as shown next. In the case of earthquake hazard, all AALs are similar, except for bridges, that is about half the value for the other subsectors. Exposure to earthquakes in Fiji is total, resulting in a relatively uniform risk among sectors. Bridges probably hold higher standards in engineering and therefore exhibit lower losses. The shape of the distribution is not like the one of earthquake-triggered landslides. This is because, in Fiji, the susceptibility to landslides changes abruptly inside the territory, ending the uniformity in loss values (See Figure 36).

For floods, the AAL values are again rather uniform among subsectors, with a steep increase for climate scenario SSP1-RCP 2.6, and a decrease for SSP5-RCP8.5. This contrasts with the AALs for rain-triggered landslides, which are less uniform with higher incidence on unclassified and tertiary roads, probably due to concentration in rural areas. Furthermore, in this case the climate scenario SSP1-RCP2.6 is related to the lower losses, with higher losses for the current climate. This highlights the fact that risk is mainly due to exposure and vulnerability, meaning that the conditions are set already in the territory with a level of risk already emplaced that does not depend on, and may not be exacerbated by, a changing climate (see Figure 37).

Figure 36. Relative Average Annual Loss from Earthquake (A) and Earthquake-Triggered Landslides (B) for the Road and Bridge Bridges Infrastructure Portfolios

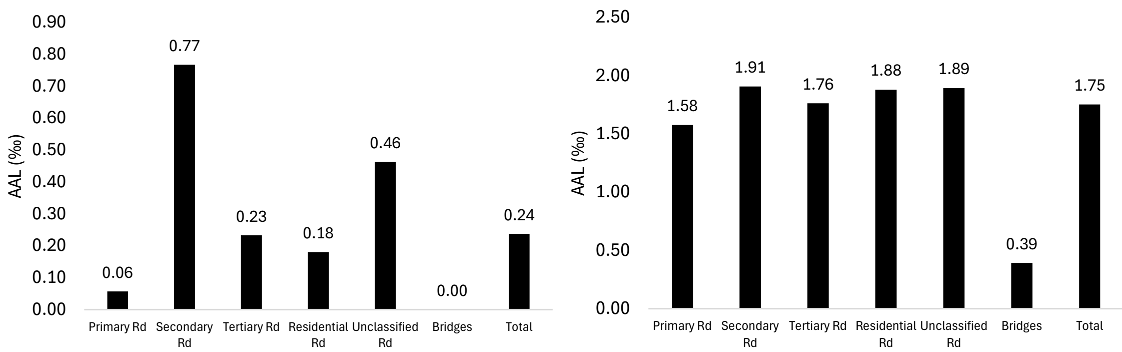


Figure 37. Relative Average Annual Loss from Flood (C) and Rain Triggered Landslides (D) for the Road and Bridge Infrastructure Portfolios

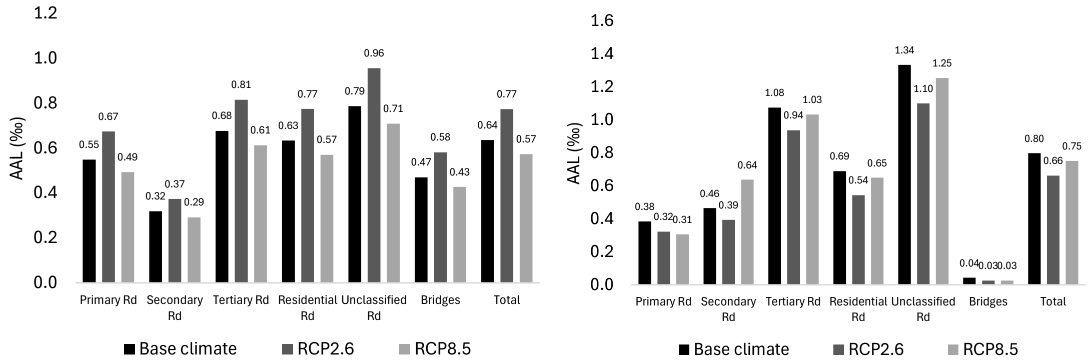


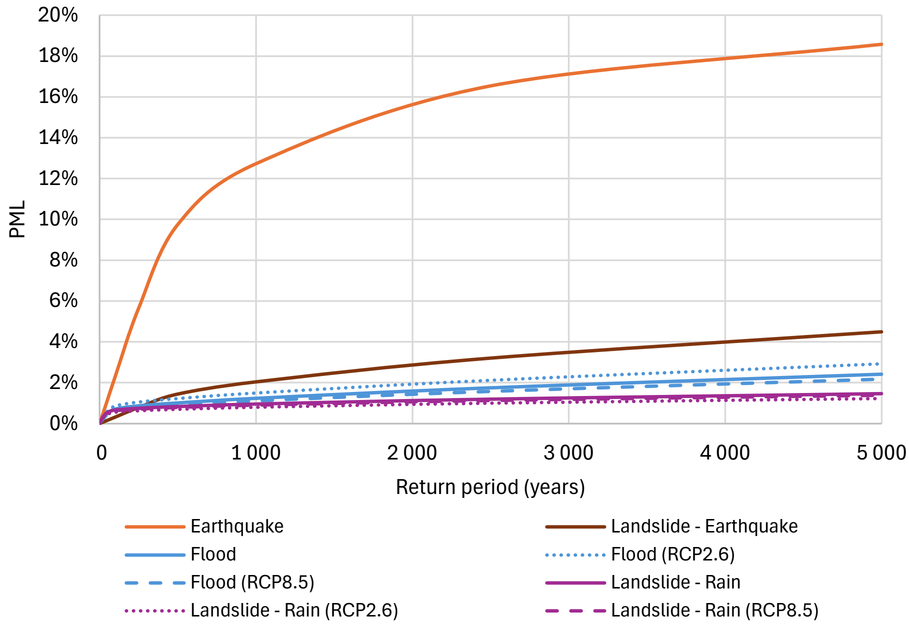
Table 19 presents the PML values for the Road sector of Fiji, by hazard and for some selected return periods. As mentioned, PMLs are always higher in magnitude than AALs for all the return periods calculated.

Table 19. Probable Maximum Loss for the Road and Bridge Infrastructure (Values in thousands of $)

Return period (years)	Earthquake	Landslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide - Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	$10,428	$1,409	$5,462	$6,645	$4,924	$7,434	$6,173	$6,994
25	$26,064	$3,523	$12,680	$15,425	$11,433	$16,160	$13,419	$15,205
50	$52,085	$7,046	$22,040	$26,811	$19,874	$24,643	$20,463	$23,186
100	$103,818	$14,093	$31,601	$38,440	$28,495	$29,779	$24,728	$28,019
250	$253,593	$35,232	$38,775	$47,162	$34,967	$33,508	$27,824	$31,527
500	$436,656	$64,610	$45,063	$54,803	$40,641	$37,342	$31,008	$35,135
1,000	$569,714	$91,324	$55,087	$66,979	$49,689	$42,769	$35,514	$40,241
2,500	$740,213	$143,411	$78,097	$94,920	$70,463	$53,541	$44,459	$50,376
5,000	$831,472	$201,119	$107,912	$131,110	$97,387	$65,682	$54,541	$61,800

Figure 38 presents the relative PML curves for all the hazards considered. Earthquake risk clearly dominated the problem among all return periods. It is possible to see that, although earthquake-induced landslides have the lower AALs, in terms of PMLs this risk surpasses the floods and rain-triggered landslides for return periods beyond 200 years, showing the higher influence this hazard has on the risk for large or catastrophic events. As mentioned above, the speed of increment of the earthquake and earthquake-triggered PML functions is far higher than the PML curve for rain-triggered landslides and floods.

Figure 38. Probable Maximum Loss Curve for the Road and Bridge Infrastructure



Highlights of the Model

The study reveals that for the energy sector, tropical cyclones in Fiji can cause the highest absolute AAL at about $64 million (FJD XXX at an exchange rate of $1 = FJ$2.3). Under the climate RCP8.5 scenario, the AAL can reach $94 million. The PML from a tropical cyclone with a return period of 10 years is about $80 million and $129 million for cyclones with a return period of 25 years. The PMLs can increase from $108 million to $183 million under the climate scenario RCP8.5 with 10 and 25 years return periods, respectively. (The longer the return period, the higher the PML). Table 20 shows the AALs and PMLs from various hazards for the energy infrastructure sector.

Table 20. Summary of AALs and PMLs from Various Hazards in Fiji for the Energy Sector

Average Annual Loss (in $ '000)						
Hazard	**Earthquake**	**Flood**	**Flood (RCP2.6)**	**Flood (RCP8.5)**	**Tropical cyclone**	**Tropical cyclone (RCP8.5)**
AAL Value	$5,523	$1,863	$2,291	$1,674	$64,439	$94,251
Probable Maximum Loss for the energy sector infrastructure (in $ '000)						
Return period (years)	**Earthquake**	**Flood**	**Flood (RCP2.6)**	**Flood (RCP8.5)**	**Tropical cyclone**	**Tropical cyclone (RCP8.5)**
10	$7,356	$3,605	$4,432	$3,238	$79,927	$107,536
25	$18,388	$8,119	$9,983	$7,294	$128,550	$183,305
50	$36,755	$13,871	$17,054	$12,461	$182,128	$271,231
100	$73,353	$19,582	$24,075	$17,591	$253,831	$385,649
250	$180,682	$23,206	$28,531	$20,846	$396,008	$504,230

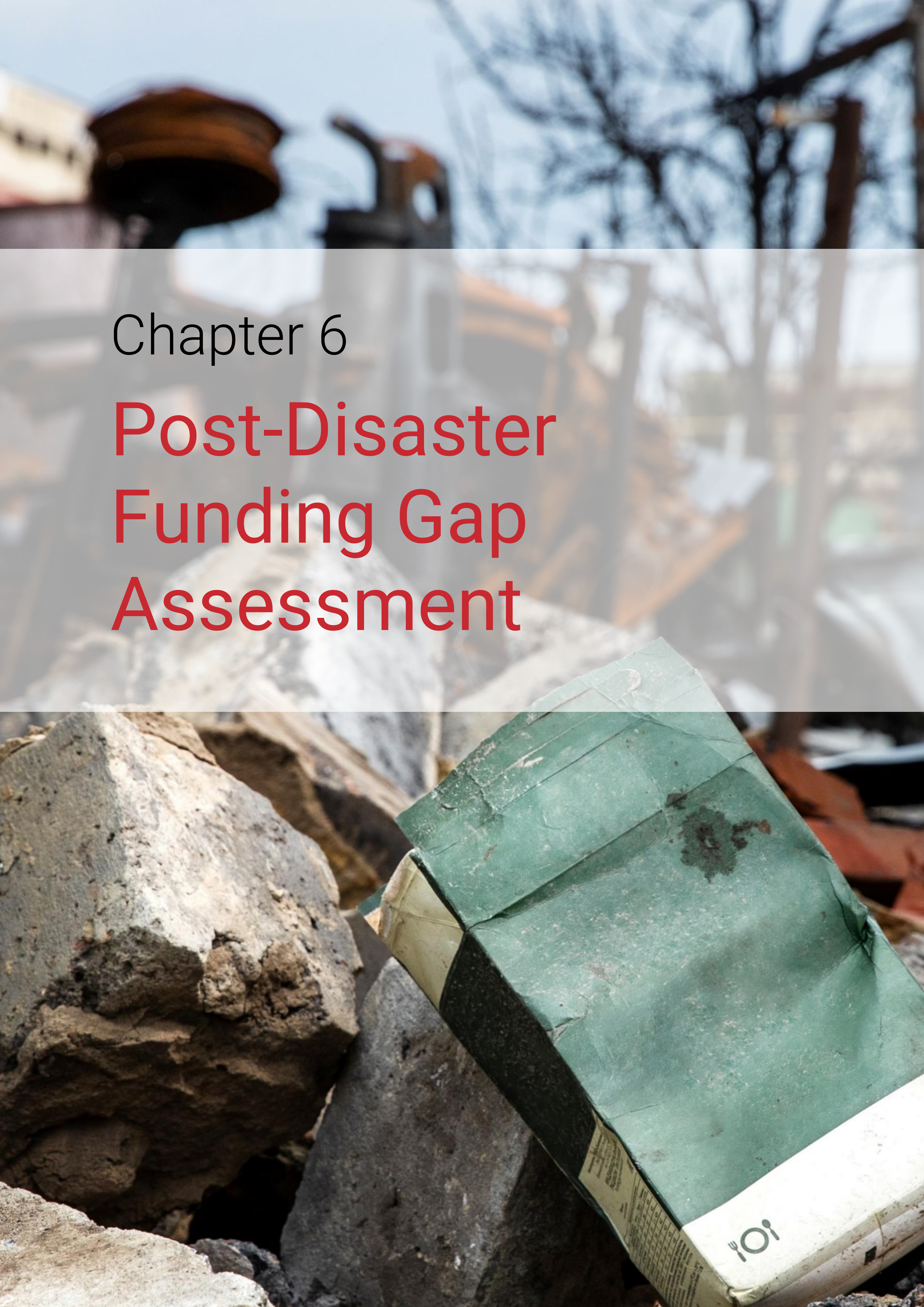
500	$315,867	$25,684	$31,577	$23,072	$524,817	$572,357
1,000	$420,648	$29,188	$35,885	$26,220	$608,452	$646,727
2,500	$574,409	$36,183	$44,484	$32,504	$723,504	$745,798
5,000	$677,898	$44,110	$54,228	$39,626	$811,030	$822,589

For the roads and bridges, earthquakes can cause an AAL of about $ 7.8 million and landslides due to rain and flood at around $3 million each. Earthquakes will also have the highest estimated PML for roads and bridges at $10 million for those with a return period of 10 years and $26 million for those with a return period of 25 years. (The longer the return period, the higher the PML).

Table 21. Summary of AALs and PMLs From Various Hazards in Fiji for Roads and Bridges

Average Annual Loss (in $ '000)								
Hazard	**Earthquake**	**Landslide - Earthquake**	**Flood**	**Flood (RCP2.6)**	**Flood (RCP8.5)**	**Landslide - Rain**	**Landslide - Rain (RCP2.6)**	**Landslide - Rain (RCP8.5)**
AAL Value	$7,851	$1,062	$2,846	$3,462	$2,566	$3,575	$2,968	$3,364
Probable Maximum Loss for roads and bridges (in USD '000)								
Return period (years)	**Earthquake**	**Landslide - Earthquake**	**Flood**	**Flood (RCP2.6)**	**Flood (RCP8.5)**	**Landslide - Rain**	**Landslide - Rain (RCP2.6)**	**Landslide - Rain (RCP8.5)**
10	$10,428	$1,409	$5,462	$6,645	$4,924	$7,434	$6,173	$6,994
25	$26,064	$3,523	$12,680	$15,425	$11,433	$16,160	$13,419	$15,205
50	$52,085	$7,046	$22,040	$26,811	$19,874	$24,643	$20,463	$23,186
100	$103,818	$14,093	$31,601	$38,440	$28,495	$29,779	$24,728	$28,019
250	$253,593	$35,232	$38,775	$47,162	$34,967	$33,508	$27,824	$31,527
500	$436,656	$64,610	$45,063	$54,803	$40,641	$37,342	$31,008	$35,135
1,000	$569,714	$91,324	$55,087	$66,979	$49,689	$42,769	$35,514	$40,241
2,500	$740,213	$143,411	$78,097	$94,920	$70,463	$53,541	$44,459	$50,376
5,000	$831,472	$201,119	$107,912	$131,110	$97,387	$65,682	$54,541	$61,800

The assessment of Fiji's capacity to meet the financial demands due to disasters is presented in the following section.



Chapter 6

Post-Disaster Funding Gap Assessment

Post-Disaster Funding Gap Assessment is the systematic process to determine the available financial resources for recovery and reconstruction and estimating the additional funding requirements.

Undertaking timely funding gap assessment is critical in ensuring that affected sectors receive the necessary resources to rebuild and recover effectively and efficiently. Since it is a multi-faceted process, it requires various perspectives to ensure fiscal resilience. There are advantages in undertaking funding gap assessment. Funding gap assessments can:

- provide 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.
- provide a structured and data-driven approach to understanding the specific financial needs for recovery. The information provides decision-makers, governments, and organizations to effectively mobilize resources by advocating for additional funding from various sources, including government budgets, international donors, private sector partnerships, grants, and loans.
- 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.
- enhance transparency and accountability in the recovery process. Stakeholders can monitor the allocation and utilization of funds, reducing the risk of corruption and mismanagement.
- help ensure that there are no unnecessary bottlenecks in funding availability, enabling a more rapid and efficient response to recovery needs without delay.
- enable international donors and humanitarian organizations in targeting their aid and donations effectively. They can channel their resources to areas with the greatest need, maximizing the impact of their assistance.

Disasters pose serious fiscal risks to Fiji. The unexpected shocks can create significant challenges that can disrupt the government's finances, severely impacting the smooth functioning of the economy.

Fiscal Risks from Disasters in Fiji

Several studies have revealed the risks from disasters that Fiji may experience in the future. According to the WB-GFDRR[69], Fiji is expected to incur, on average over the long term, annual losses of FJ$158 million ($85 million) due to earthquakes and tropical cyclones. It is further estimated that in the next 50 years Fiji has a 50 percent chance of experiencing a loss exceeding FJ$1,500 million ($806 million) and a 10 percent chance of a loss exceeding FJ$3,000 million ($1.6 billion). With climate change, Fiji will experience more intense cyclones like Tropical Cyclone Winston (2016), Gita (2018), Harold (2020), Yasa (2020) and Ana (2021), which caused extensive costly damage.[70] A 2018 Climate Vulnerability

[69] WB. Country Note: Fiji-Disaster Risk Financing and Insurance. February 2015. https://reliefweb.int/report/fiji/country-note-fiji-disaster-risk-financing-and-insurance-february-2015

[70] Government of Australia. https://www.dfat.gov.au/about-us/publications/fiji-australias-commitment-to-strengthening-climate-and-disaster-resilience-in-the-pacific

Assessment led by the Government of Fiji with support of the World Bank, indicated that Fiji suffers average asset losses of around FJ$500 million (approximately $225 million), or five percent of GDP each year due to floods and tropical cyclones.[71] Absent significant improvements in resilience, damages and losses from tropical cyclones and floods could increase by up to 50 percent by 2050, reaching more than 6.5 percent of GDP.[72]

Financing Gap from Past Disasters

The following table shows the budget allocation for disaster response, and the total estimated damage and the funding gap from selected tropical cyclones in Fiji.

Table 22. Funding Gap due to Tropical Cyclones over Selected Years

Year	Total Budget Expenditure (FJ$ '000)	Budget Allocation for Disaster Response (FJ$)	Disaster(s)	Total Estimated Damage (FJ$)	Funding Gap	
					(FJ$)	$
2012	2,077,929	3,800,000	TC Evan	194,900,000	-191,100,000	- 83,086,957
2016	3,414,537	6,800,000	TC Winston	199,900,000	-193,100,000	- 83,956,522
2018	4,650,546	35,500,000	TC Gita, Josie, and Kenny	1,200,000	34,300,000	14,913,043
2019	3,840,929	5,054,977	TC Sarai	10,300,000	-5,245,023	- 2,280,445
2020	3,674,604	13,200,000	TC Tino, Harold, and Yasa	353,200,000	-340,000,000	- 147,826,087

Table 22 shows that there is a huge gap between the budget allocation for disaster response and the post-disaster estimated damages from past disasters. For the years where there is no data on disaster damage, the cost of emergency expenses can be estimated using the average humanitarian needs per capita. Based on the experience from TC Winston that affected around 540,414 people or 62 percent of the total population, the emergency humanitarian "Flash" of the government and UN was estimated to be $38.6 million for the first three months of the disaster response. Needs identified for this appeal included the provision of emergency shelter; access to health, water and sanitation; food and livelihood support; access to education and rehabilitation of schools; and protection and support to vulnerable groups.[73] Therefore, the emergency need per capita can be estimated at $.

[71] Ibid.
[72] WB: FIJI PUBLIC EXPENDITURE REVIEW Towards Fiscal Sustainability and Improved Spending Quality, March 2023
[73] Government of Fiji. Disaster Recovery Framework for TC Winston: 2016

Estimating Future Funding Gaps for Power, Roads, and Bridges

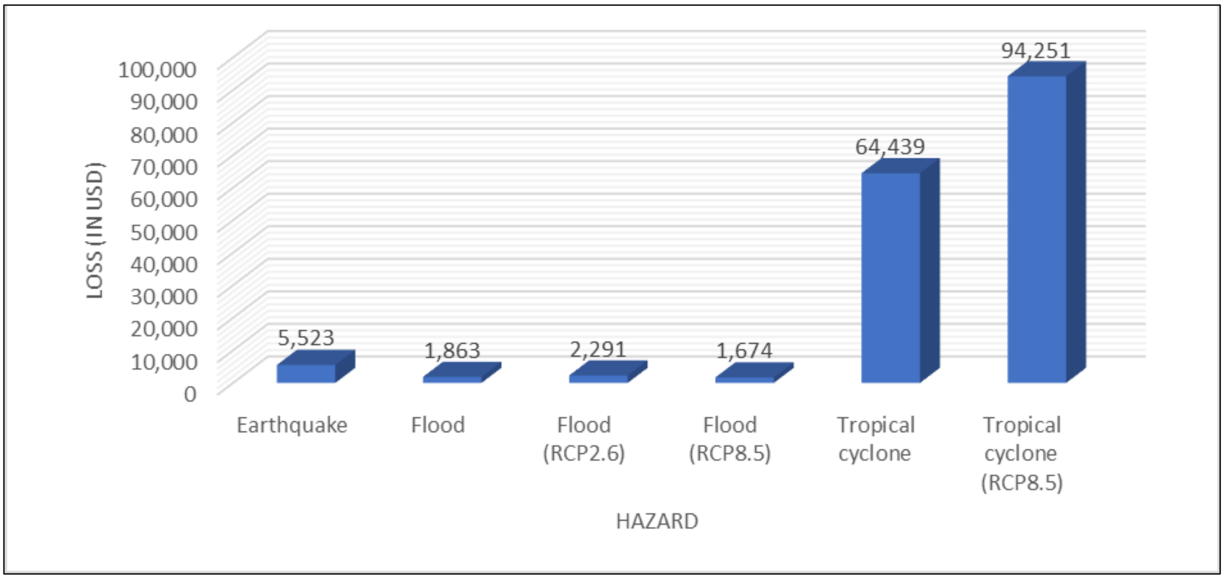
Power

Based on the catastrophe model, the annual average losses (AAL) to the energy/power sector due to tropical cyclone is $64 million which can be aggravated by climate change (RCP8.5) up to $94 million as shown in Table 23 and Figure 39.

Table 23. Summary of AALs from Various Hazards in Fiji for Energy Sector

Average Annual Loss (in $ '000)						
Hazard	**Earthquake**	**Flood**	**Flood (RCP2.6)**	**Flood (RCP8.5)**	**Tropical cyclone**	**Tropical cyclone (RCP8.5)**
AAL Value	$5,523	$1,863	$2,291	$1,674	$64,439	$94,251

Figure 39. Average Annual Loss for Energy Sector by Hazard
(in $ 000)



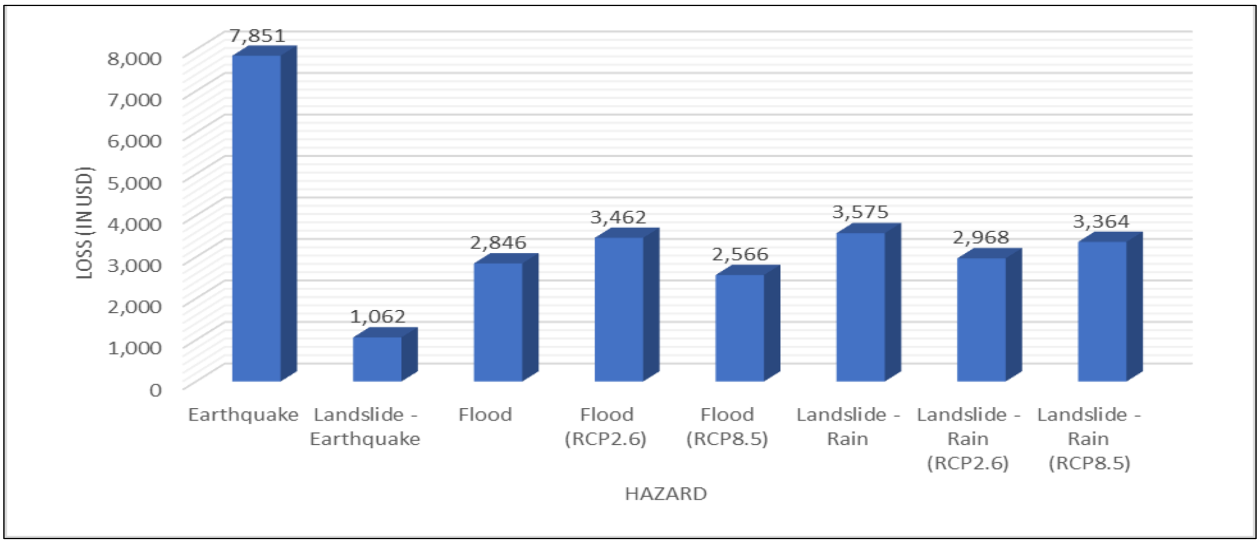
Roads and Bridges

On the other hand, the AALs from various hazards for the roads and bridges are shown in the table and figure below.

Table 24. Summary of AALs from Various Hazards in Fiji for Roads and Bridges

Average Annual Loss (in $ '000)								
Hazard	**Earthquake**	**Landslide - Earthquake**	**Flood**	**Flood (RCP2.6)**	**Flood (RCP8.5)**	**Landslide - Rain**	**Landslide - Rain (RCP2.6)**	**Landslide - Rain (RCP8.5)**
AAL Value	$7,851	$1,062	$2,846	$3,462	$2,566	$3,575	$2,968	$3,364

Figure 40. Average Annual Loss for Roads and Bridges by Hazard (in $ 000)



It should be noted that earthquakes have the highest AAL for roads and bridges. Using the $1 million for Fund Rehabilitation and Relief Disaster[74] allocated by Fiji (as part of the 2023 expenditure amounting to $ 4,339,870,900), the following table shows the difference. It is assumed in the table below that climate change will not affect the intensity of the hazards. The highest AAL for the energy sector will be due to tropical cyclones, while for roads and bridges, it will be earthquakes.

Table 25. Funding Gap without Climate Change Effects

Year Basis	Disaster Fund	Energy AAL	R&B AAL	Gap/Surplus	
	$ (000)	$ (000)	$ (000)	$ (000)	FJ$ (000)
2023	1,000	64,439	7,851	-71,290	- 163,967

Table 25 shows that the allocated disaster relief fund of the government will not be enough to cover the post-disaster needs of the energy, roads, and bridges sectors even without the effects of climate change. On the other hand, with the $75 million quick disbursement Disaster Fund Facility from Japan

[74] FIJI ESTIMATES BUDGET 2023-2024: https://www.parliament.gov.fj/wp-content/uploads/2023/06/Budget_2023-2024.pdf

International Cooperation Agency (JICA) and the $40 million (FJ$89.6 million) Catastrophe Deferred Drawdown Option (CatDDO) from the World Bank.[75] Table 26 shows the difference.

Table 26. Funding Gap from AAL without Climate Change Effects with Contingent Credit

Fiji Disaster Fund	JICA DFF	WB Cat-DDO	Energy AAL	R&B AAL	Gap	
$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	FJ$ (000)
1,000	75,000	40,000	64,439	7,851	43,710	100,533

Table 26 shows that funds are sufficient to cover the combined AALs of the energy, and roads and bridges with the JICA and WB contingent assistance. It must be noted, however, that these funds are intended for all the sectors, not just energy, and roads and bridges.

Extreme Cases

In analyzing extreme cases, the potential post-disaster funding gaps will be estimated using the values in the PML. The PMLs due to various hazards in various return periods are shown in the following tables and figures.

Energy

The PML for the energy sector is shown in the table below.

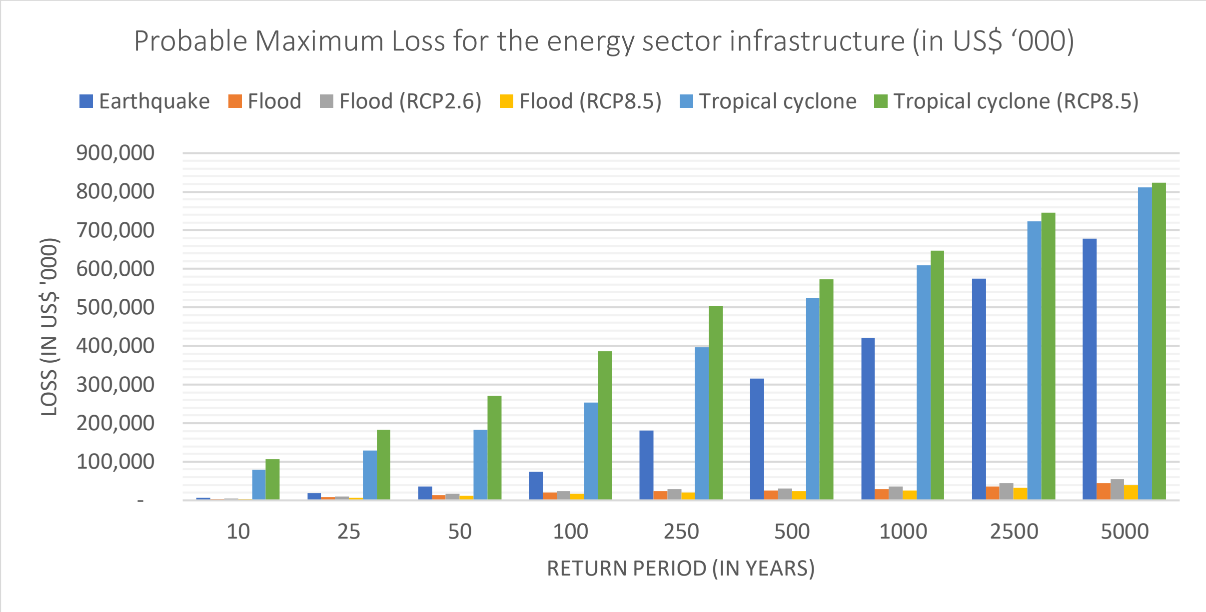
Table 27. Probable Maximum Loss for the Energy Sector (In $ '000)

Return period (years)	Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Tropical cyclone	Tropical cyclone (RCP8.5)
10	$7,356	$3,605	$4,432	$3,238	$79,927	$107,536
25	$18,388	$8,119	$9,983	$7,294	$128,550	$183,305
50	$36,755	$13,871	$17,054	$12,461	$182,128	$271,231
100	$73,353	$19,582	$24,075	$17,591	$253,831	$385,649
250	$180,682	$23,206	$28,531	$20,846	$396,008	$504,230
500	$315,867	$25,684	$31,577	$23,072	$524,817	$572,357
1,000	$420,648	$29,188	$35,885	$26,220	$608,452	$646,727
2,500	$574,409	$36,183	$44,484	$32,504	$723,504	$745,798
5,000	$677,898	$44,110	$54,228	$39,626	$811,030	$822,589

Figure 41 shows the graphical distribution of the PMLs by hazards and return periods.

[75] Rakesh Kumar. "Minister Tabuya supports disaster risk management legislation." Fiji Times, January 17, 2025. https://www.fijitimes.com.fj/minister-tabuya-supports-disaster-risk-management-legislation/?utm_source=chatgpt.com.

Figure 41. Probable Maximum Loss (PML) for the Energy Sector by Hazards and Return Periods



The PML for the energy sector will be caused by tropical cyclones, especially with the effect of climate change at RCP8.5.

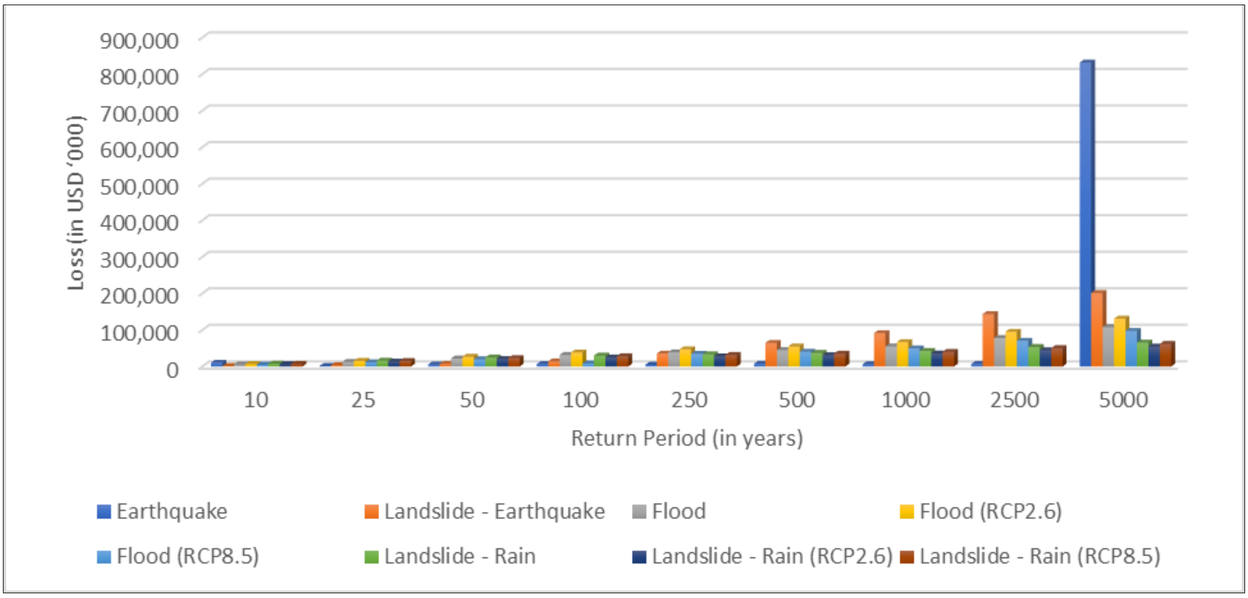
Roads and Bridges

The PML for the roads and bridges sector will be caused by earthquakes especially those with longer return periods as shown in the table below.

***Table 28. Probable Maximum Loss for Roads and Bridges** (In $ '000)*

Return period (years)	Earthquake	Landslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide - Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	$10,428	$1,409	$5,462	$6,645	$4,924	$7,434	$6,173	$6,994
25	$26,064	$3,523	$12,680	$15,425	$11,433	$16,160	$13,419	$15,205
50	$52,085	$7,046	$22,040	$26,811	$19,874	$24,643	$20,463	$23,186
100	$103,818	$14,093	$31,601	$38,440	$28,495	$29,779	$24,728	$28,019
250	$253,593	$35,232	$38,775	$47,162	$34,967	$33,508	$27,824	$31,527
500	$436,656	$64,610	$45,063	$54,803	$40,641	$37,342	$31,008	$35,135
1,000	$569,714	$91,324	$55,087	$66,979	$49,689	$42,769	$35,514	$40,241
2,500	$740,213	$143,411	$78,097	$94,920	$70,463	$53,541	$44,459	$50,376
5,000	$831,472	$201,119	$107,912	$131,110	$97,387	$65,682	$54,541	$61,800

Figure 42. Probable Maximum Loss (PML) for Roads and Bridges (in $ '000)



In analyzing the potential post-disaster funding gap due to PML, the following scenarios are considered.

Scenario 1: Hazards with a return period of 10 years without climate change effects. This assumes the least-cost scenario since hazards with longer return periods have higher PMLs.

- The higher PML for the energy sector is about $80 million due to tropical cyclones with a return period of 10 years.
- Earthquakes with a return period of 10 years can cause the highest probable maximum loss (PML) for roads and bridges which is about $ 10 million.

Using the above-mentioned figures, Table 29 shows that without the support of JICA and the WB, the disaster fund of Fiji will not be able to respond to the probable maximum losses for the energy, roads and bridges sector for hazards with a return period of 10 years.

Table 29. Funding Gap from PML without Climate Change Effects for Hazards with 10-Year Return Period

Fiji Disaster Fund	JICA DFF	WB Cat-DDO	Energy PML	R&B PML	Gap with contingent credit	Gap without contingent credit
$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)
1,000	75,000	40,000	80,000	10,000	26,000	-89,000

Scenario 2*:* Hazards with a return period of 10 years under the RCP8.5 scenario. This assumes the potential impact of climate change.

Using the higher figures of tropical cyclones (for the energy sector) at RCP8.5 estimates, Table 30 shows that funds will be insufficient even with the JICA and WB standby assistance.

Table 30. Funding Gap from PML under RCP8.5 Effects, for Hazards with 10 Years Return Period

Fiji Disaster Fund	JICA DFF	WB Cat-DDO	Energy PML	R&B PML	Gap with contingent credit	Gap without contingent credit
$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)
1,000	75,000	40,000	108,000	10,000	-2,000	-117,000

Scenario 3: Hazards with a return period of 25 years under the climate change scenario of RCP8.5. Under this scenario, the energy sector can have a PML of about $183 million from tropical cyclones and the roads and bridges sector can have a PML of about $26 million from earthquakes.

Table 31. Funding Gap from PML under RCP8.5 Effects, 25 Years Return Period

Fiji Disaster Fund	JICA DFF	WB CatDDO	Energy PML	R&B PML	Gap with contingent credit	Gap without contingent credit
$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)
1,000	75,000	40,000	183,000	26,000	-133,000	-208,000

Table 31 shows that even with the JICA and WB standby assistance, there will still be a wide funding gap if and when the above-mentioned hazards occur.

Scenario 4: Hazards without climate change projected impacts and with the highest PMLs occurring in 2026. This considers tropical cyclones for the energy sector and earthquakes for roads and bridges by various return periods with the highest PMLs, and the government fund, and JICA and WB contingency credit. Table 32 shows the funding gap for hazards (without climate change impacts) with the highest PMLs by return period if they occur in 2026.

Table 32. Funding Gap Based on Highest PMLs by Return Period (no Climate Change)

Return period (Years)	Probable Maximum Loss		Source of post-disaster funds			Gap
	Energy	Roads and bridges	Fiji	JICA	WB	
	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)
10	79,927	10,428	1,000	75,000	40,000	25,645
25	128,550	26,064	1,000	75,000	40,000	-38,614
50	182,128	52,085	1,000	75,000	40,000	-118,213
100	253,831	103,818	1,000	75,000	40,000	-241,649
250	396,008	253,593	1,000	75,000	40,000	-533,601
500	524,817	436,656	1,000	75,000	40,000	-845,473
1,000	608,452	569,714	1,000	75,000	40,000	-1,062,166
2,500	723,504	740,213	1,000	75,000	40,000	-1,347,717
5,000	811,030	831,472	1,000	75,000	40,000	-1,526,502

Table 32 indicates that the government allocation and the JICA and WB support is adequate to cover the Probable Maximum Losses (PMLs) of the energy and roads and bridges from tropical cyclones and earthquakes with return period of 10 years. Beyond that, there will be a huge funding gap. It should be noted that the above table is only concerned about energy and roads and bridges.

Scenario 5. *Probabilistic loss in the next 50 years.* According to the Climate Vulnerability Assessment led by the Government of Fiji with support of the World Bank[76], Fiji is expected to incur average annual losses over the long term of FJ$158 million ($84 million) due to earthquakes and tropical cyclones. This amount can be covered by the contingent credit from JICA and WB.

However, in the next 50 years Fiji has a 50 percent chance of experiencing a loss over FJ$1,500 million ($806 million) and a 10 percent chance of a loss exceeding FJ$3 billion ($1.6 billion).[77] Considering the 50 percent chance event, Table 33 shows the post-disaster funding gap.

Table 33. Funding Gap Based on 50% Chance Event in the Next 50 Years

Estimated loss	Source of post-disaster funds			Gap
	Fiji	JICA	WB	
$ (000)	$ (000)	$ (000)	$ (000)	$ (000)
806,000	1,000	75,000	40,000	-690,000

Findings

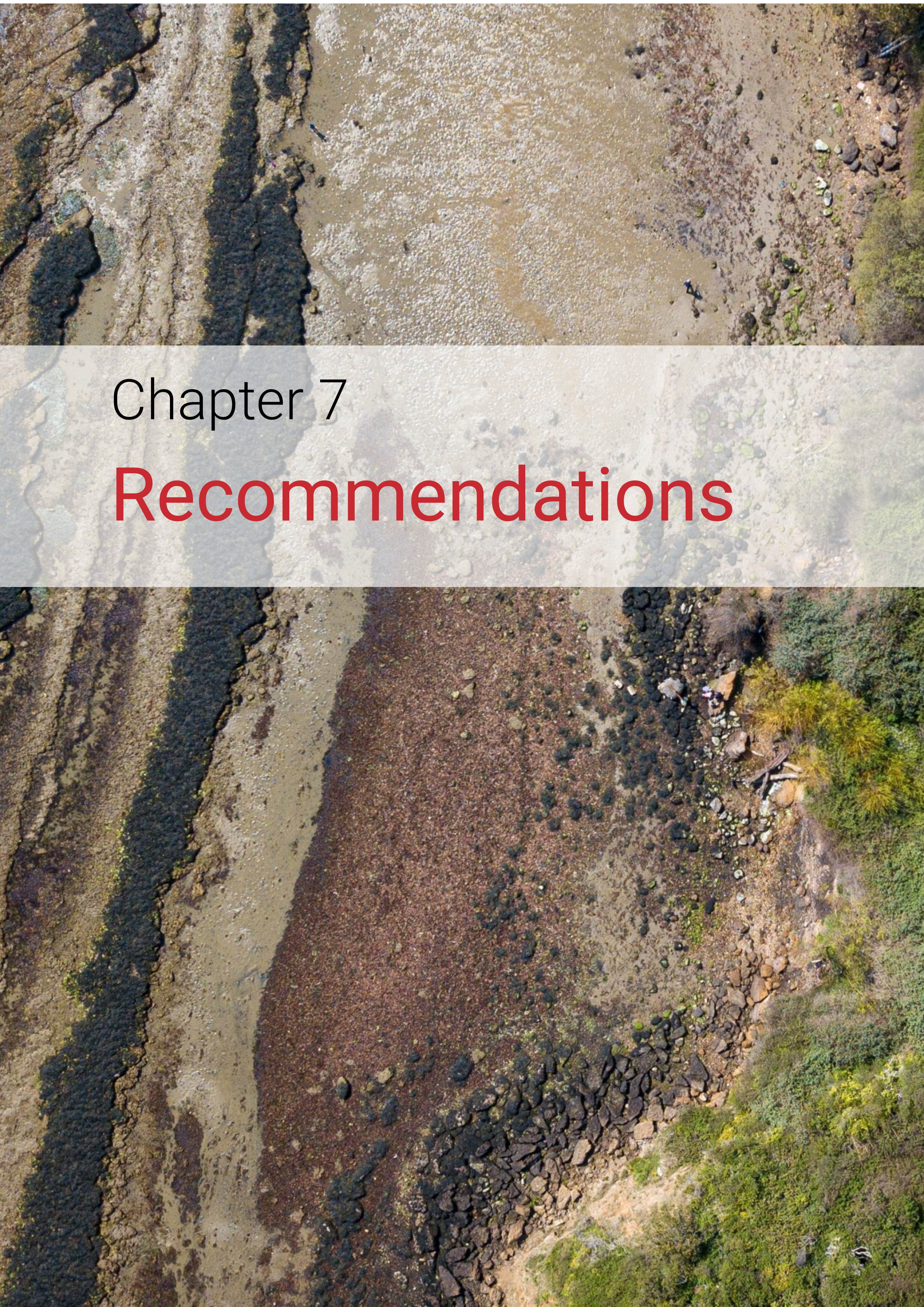
The following are the summary of findings.

1. Without climate change effects, the government allocation and the JICA and WB support are adequate to cover the Probable Maximum Losses (PMLs) of the energy and roads and bridges from tropical cyclones and earthquakes with 10 years return period. Beyond that, there will be a huge funding gap.
2. Without the contingent credit from JICA and the WB, the disaster fund of Fiji will not be able to respond to the probable maximum losses for the energy, roads and bridges sector for hazards with a return period of 10 years.
3. Funds will be insufficient even with the JICA and WB standby assistance for tropical cyclones with 10 years return period at RCP8.5 estimates.
4. For hazards with a return period of 25 years under the climate change scenario of RCP8.5, there will be a wider funding gap even with the JICA and WB standby assistance,

It must be noted, however, that these funds are intended to for all the sectors, not just the energy and roads and bridges. Since the existing ex-post financing funds will be not be sufficient to cover certain thresholds, especially for hazards with longer return periods, Fiji should consider other options for financing the disaster risks.

[76] Government of Fiji, World Bank, and Global Facility for Disaster Reduction and Recovery. 2017. "Fiji 2017: Climate Vulnerability Assessment - Making Fiji Climate Resilient." World Bank, Washington, DC

[77] Ibid.



Chapter 7

Recommendations

The Government of Fiji recognizes that the constant threat of climate change and natural hazards that result in disasters is one of the factors that may affect the economic outlook of the country.[78] Based on the above discussions, the following are some recommendations that the Government of Fiji can consider reducing the fiscal risks from disasters.

1. **Upgrade infrastructure standards in public and private investments**.

   The government should prioritize the review and the enforcement of existing building codes (including the principle of 'build back better'), roads and bridges designs, land use plans and zoning regulations, among others, to incorporate best practices for disaster resilience including wind and flood resistance to increase their resilience to disasters and reduce potential damages. Supplementing this effort is the need for investments in strengthening and the enhancement of existing enforcement mechanisms and regulatory bodies (e.g. FRA) through increasing trained inspectors and the provision of on-going trainings and capacity building to these resources to ensure that they have the right skill sets and expertise to access compliance. There is also a need for the responsible Ministries and agencies to increase public awareness and engagement on the importance of adhering to building standards across the wider section of Fiji communities. Moreover, where relevant, Fiji needs to explore the possibility of ensuring its key road network and assets to mitigate potential damages and continued functionality of the country's transportation network after disasters. In particular, the country must prepare for tropical cyclones, considering that the return periods of destructive earthquakes are longer compared to tropical cyclones.

2. **Adequately allocate post-disaster funds particularly for emergency humanitarian response**. Disaster response funds must be adequately provided for in the budget, especially those for emergency humanitarian assistance. The country cannot depend most of the time on foreign assistance for post-disaster response. There are uncertainties in foreign aid in terms of amount and timing. Countries and international organizations may not have enough funds for Fiji all the time. Foreign aid may also take longer to reach affected people and communities, so the government must be prepared to provide at least humanitarian needs immediately. Collaboration and coordination with other humanitarian agencies and partners including Civil Society Organizations (CSOs) is also critical to avoid duplication of efforts and efficient flow of humanitarian funds and responses. Given shrinking funding resources, Fiji will need to invest in better data and monitoring systems to improve decision making on needs-based allocation and also to track the effectiveness of humanitarian interventions to ensure value for money. Moreover, learning from the practices of other PICs such as Tonga, Fiji could consider the setting up of a dedicated National Emergency Fund (NEF) within the national budget and is supported by an annual budget allocation, interest and donations, and is specifically designed to be used exclusively for timely and efficient response and recovery in an event of a disaster. Similar to Tonga, such mechanism will need clearly defined access protocols and replenishment strategies (e.g. Tonga NEF has annual allocation of USD 2.1 million). It has been the practice of the government to reallocate budget intended for capital spending to recovery and response after a disaster. This deferred spending will potentially result in an infrastructure deficit and will adversely impact on the growth of Fiji over the long term.

[78] Statement By the Chairman Of The Macroeconomic Committee And Governor Of The Reserve Bank Of Fiji - Press Release No. 12/2024 https://www.rbf.gov.fj/press-release-no-12-macroeconomic-projections-for-the-fiji-economy-2024-2026/

3. Expand and Formalize the Use of Risk Layering through a Multi-Tiered Financing Framework

Findings from Chapters 3 and 6 reveal heavy reliance on ex-post budget reallocations and international assistance, with limited pre-arranged financing and growing post-disaster funding gaps, particularly in the power and transport sectors. The government may adopt a three-tier risk layering framework:

a) Low-risk/high-frequency events: Budget contingencies and dedicated reserve funds (e.g., enhance the National Disaster Relief and Rehabilitation Fund with ring-fencing and automatic trigger rules).
b) Medium-risk/moderate-impact events: Expand parametric insurance coverage under PCRIC or explore sub-national pooling models with island divisions.
c) High-risk/low-frequency catastrophic events: Secure contingent credit lines (e.g., Cat-DDO) and standby loans (e.g., JICA's facility) for rapid liquidity.

Additionally, mandate annual risk-layering reviews as part of the budget process, integrated into the Ministry of Finance's fiscal strategy. Importantly, Fiji needs to urgently finalize its National Disaster Risk Financing Strategy taking similar pathways such as Tonga, Samoa and Solomon Islands who have formalize such policy in strengthening the financial protection of their country against disasters. These DRF Strategies provide clarity on the financial solutions that are targeted to countries' respective risk profile that needs to be put in place so that critical infrastructure and the most vulnerable in society are protected.

4. Institutionalize Pre-Arranged Disaster Response Funds at National and Subnational Levels

Chapters 3.2 and 7 highlight delays in fund disbursement and scope to enhance local-level response capacity resulting from centralized and reactive financing mechanisms. Therefore, it is important to legislate pre-arranged disbursement rules for the National Disaster Relief and Rehabilitation Fund (NDRRF), linking disbursement thresholds to hazard triggers. Additionally, establishing decentralized contingency funds for municipal and provincial councils with predefined allocation formulas with annual top-ups to NDRRF as a budget line item, based on risk-layer modelling of expected annual losses. Fiji will therefore need to prioritize finalizing its National DRF Strategy as it will not only articulate the targeted solutions relevant to its risk profile and challenges, but also the processes on how these financial solutions are to be set up.

5. Strengthen Exposure and Loss Data for Fiscal Forecasting and Disaster Analytics – solutions are as reliable as the risk models that support them and risk models are only as good as the data and the capacity required to develop them.

Chapter 5 emphasizes the importance of high-resolution exposure models in forecasting losses that is underpin by complete and reliable data. Fiji can integrate infrastructure and asset-level data systems. Therefore, establishing a comprehensive National Infrastructure Exposure Database is essential for effectively managing and safeguarding critical assets across various sectors, including transportation (roads), utilities (power), and other infrastructure sectors such as public health and educational facilities. This database should be meticulously integrated with Geographic Information System data and corresponding replacement values to enable precise asset tracking and risk assessment. To enhance the accuracy and reliability of the database, it is recommended that all relevant governmental ministries and state-owned enterprises (SOEs) adequately invest in their respective capacity, capabilities, systems and processes so that can report their infrastructure inventories annually, along with associated vulnerability data. Given that data sharing across agencies is a real challenge in Fiji, increase engagement and awareness across agencies on the importance of collaboration and sharing complete, up-to-date and reliable risk related data needs to be encouraged and prioritized- and this need to be driven from the top from the ultimate decision makers and championed by the Ministry of Finance. Establishing a systematic and integrated reporting approach will facilitate a holistic understanding of the nation's infrastructure landscape and its susceptibility to various risks. Moreover, leveraging outputs from robust probabilistic risk assessments, such as return periods and loss exceedance curves, will provide valuable insights that can inform and calibrate annual reserve allocations as well as insurance pricing strategies. This data-driven approach will ensure that financial resources are allocated efficiently, ultimately contributing to the nation's infrastructure system's resilience and sustainability.

6. Integrate Disaster-Linked Liabilities into Public Debt Management Strategy

Rising debt levels post-disaster increase fiscal stress, with disaster-linked borrowing becoming a key instrument. Current debt sustainability assessments do not explicitly include disaster risks. To enhance Fiji's fiscal resilience, a crucial step involves a more sophisticated approach to public debt management. This necessitates explicitly integrating disaster-linked contingent liabilities into public debt sustainability analyses, acknowledging the increasing fiscal strain caused by post-disaster borrowing. Establishing a dedicated fiscal buffer within medium-term fiscal frameworks will provide a crucial mechanism for absorbing immediate disaster shocks. Furthermore, a strategic evaluation and potential utilization of risk transfer instruments as part of the sovereign debt portfolio should be undertaken to reduce the reliance on debt accumulation in the aftermath of disasters. These integrated measures will contribute to a more robust and sustainable fiscal framework for Fiji in the face of increasing climate-related risks. A formalized DRF strategy for Fiji is therefore critical in integrating these solutions within the PFM. Given that the Ministry of Finance should be the lead driver of DRR planning, a well-designed DRF strategy will provide clarity to the Ministry of Finance on the nature and the scale of the impact of disasters, their relevance to financial, economic and fiscal management strategies that fall under their purview. A DRF strategy can also support the need of rethinking the nature of information that must be considered when planning the long-term development of the country. Within the broader context of the PFM, a DRF Strategy can provide the clarification to the Ministry of Finance on how Fiji can effectively manage the financial consequences of future disasters, the financial gaps, and the impacts to the vulnerable sectors and stakeholders.

7. Creating an evidence-based allocation for ongoing Contingent Budget Line for Immediate Recovery

The report highlights that development programmes are often disrupted due to the diversion of funds toward disaster response. Following Tropical Cyclone Winston, for example, the government redirected $14.52 million to the Help for Homes initiative. To ensure timely and effective disaster response, Fiji must significantly reassess its current contingency fund allocation, which remains at FJ$1 million in the 2025–2026 national budget.

Based on historical evidence, this budget line should be strengthened with an annual allocation of approximately $22 million to $44 million. Such a provision would enable rapid restoration of essential services, reduce delays in infrastructure repairs, and support fiscal discipline across the broader budget framework.

8. Expanding Sector-Specific Insurance Based on Loss Patterns

The report indicates that ongoing losses in key infrastructure sectors are often lacking sufficient insurance coverage. Agencies like Energy Fiji Limited and the Fiji Roads Authority often fail to ensure the protection of their public assets despite facing significant damage. To enhance financial protection, Fiji should expand the implementation of sector-specific insurance schemes based on historical loss data. For example, parametric insurance for energy distribution and main road networks can be customized with cyclone or flooding loss information. Additionally, the government might explore subsidizing insurance premiums for state-owned enterprises and critical public infrastructure. Establishing insurance as a norm would guarantee prompt access to funds post-major events, lessen the fiscal pressure on the government, and foster improved risk-sharing between public and private sectors.

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Annexure

Annex A: Disaster-related Insurance Schemes in Selected Countries

Sri Lanka.[79] Very recently, the global advisory, broking, and solutions company WTW (NASDAQ: WTW) has launched Asia's first 4-peril parametric insurance to protect Sri Lanka's shrimp farms against weather risks, marking a crucial turning point in Asia's aquaculture development. The unique solution was designed and placed for Taprobane Seafood Group, Sri Lanka's largest seafood company, helping them to meet a critical condition to secure $15 million in project financing from Dutch entrepreneurial development bank FMO.

Shrimp farming is associated with a diverse range of risks and uncertainties, most prominently the exposure to weather risks across coastal regions where farms are traditionally located. To safeguard Taprobane against such vulnerabilities and unwind potential bottlenecks that constrain the injection of much needed capital, WTW has structured the region's first 4-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 to secure $15 million in project financing from 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 cover the risk of yield shortfall from reduced applications of nitrogen fertilizer on ratoon crops.

Thailand.[80] Since 2011, the Thailand Rice Disaster Relief Top-up Crop Insurance Scheme, using 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 that is 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 GeoInformatics and Space Technology Development Agency, the project is linking remote sensing technology to sophisticated crop yield modelling technology in order to build 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 is managed by the Agriculture Insurance Company of India (AICI), provides insurance for food crops, oilseeds, and a few commercial crops using an area yield-based approach[81]. By comparing current crop yields with historical data, this indexed strategy provides indemnity payouts to farmers who are insured in specific locations in the event that actual yields are lower than historical levels. In addition to addressing issues with tiny landholdings, the plan lessens moral hazard and adverse selection. NAIS, however, is dependent on government contributions provided after a disaster and premiums that are subsidized. As a result, the government has an unlimited financial risk and claims settlement delays could lead to hardship for farmers. To enhance the program's effectiveness and address these challenges, the government collaborated with AICI and sought technical assistance from the World Bank in 2005 to modify and improve insurance coverage.

[79] Press Release: "WTW launches Asia's first 4-peril parametric insurance solution to unlock financing for aquaculture development" 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

[80] UNESCAP. Disaster risk transfer mechanisms: issues and considerations for the Asia-Pacific region.2017.

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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 of Hyderabad-based micro-finance institution BASIX's water user associations in the Mahabubnagar district of Andhra Pradesh. This innovative insurance programme 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 providing innovative coverage based on 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 significantly in India, with various programmes and approaches aimed at supporting farmers during adverse weather events. For instance, more recent initiatives include heat-linked parametric insurance systems that offer a lifeline to Indian women in the informal sector.[82],[83] 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.

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"[84] 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 speed up 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.[85] In general, PMFBY seeks to uphold 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.

Philippines.[86] Aside from the multiple-peril crop insurance (MPCI), the country has also 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 against all property in which the government has an interest (e.g., government offices, hospitals, schools, public markets).

Contingent credit for disasters is also in place and insurance for public assets is in use. On November 17, 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

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[82] Clarke.D.J, Mahul. O, Kolli N. Rao, Verma.N. 2012. Policy Research Working Paper – *Weather Based Crop Insurance in India*. https://documents1.worldbank.org/curated/en/693741468269445619/pdf/WPS5985

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[85] Kaur, Sandeep, Hem Raj, Harpreet Singh, and Vijay Kumar Chattu. 2021. *Crop Insurance Policies in India: An Empirical Analysis of Pradhan Mantri Fasal Bima Yojana*. Risks 9: 191. https://doi.org/ 10.3390/risks911019

[86] Philippines, Department of Finance:2023

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 aftermaths 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 November 16, 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 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 caused by extreme weather or geophysical hazard.

Catastrophe Bond.[87] In November 2019, the World Bank issued to capital market investors two tranches of cat bonds that provide the Philippines with insurance coverage of a maximum of $225 million ($75 million for earthquakes and $150 million for tropical cyclones) for three years. The type of events that will trigger a payout are 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 real 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.

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.[88] 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), consisting of the Emergency Fund (Fondo para la Atención de Emergencias FONDEN), the Natural Disaster Fund Programme of 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-incoming housing; and (iii) certain components of the natural environment (e.g., forestry, protected natural areas, rivers, and lagoons).

[87] World Bank; Case Study: The Philippines: Transferring the Cost of Severe Natural Disasters to Capital Markets
[88] UNDP: "MEXICO: COUNTRY CASE STUDY REPORT | How Law and Regulation Supports DRR" June 2014; WB: "FONDEN Mexico's Natural Disaster Fund – A Review" 2012

- 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, 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 sector (Programa Atención a Desastres Naturales en el Sector Agropecuarioy Pesquero, CADENA) as one of the components of the Disaster Management Prevention Programme (Programa de Prevención y Manejo de Desastres). This fund aims to provide assistance, by means of insurance, in order to limit the negative effects caused by disasters on agriculture, livestock, aquaculture and fisheries activities. The legal foundation for this fund is established under the Sustainable Rural Development Law, e.g., Art. 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.

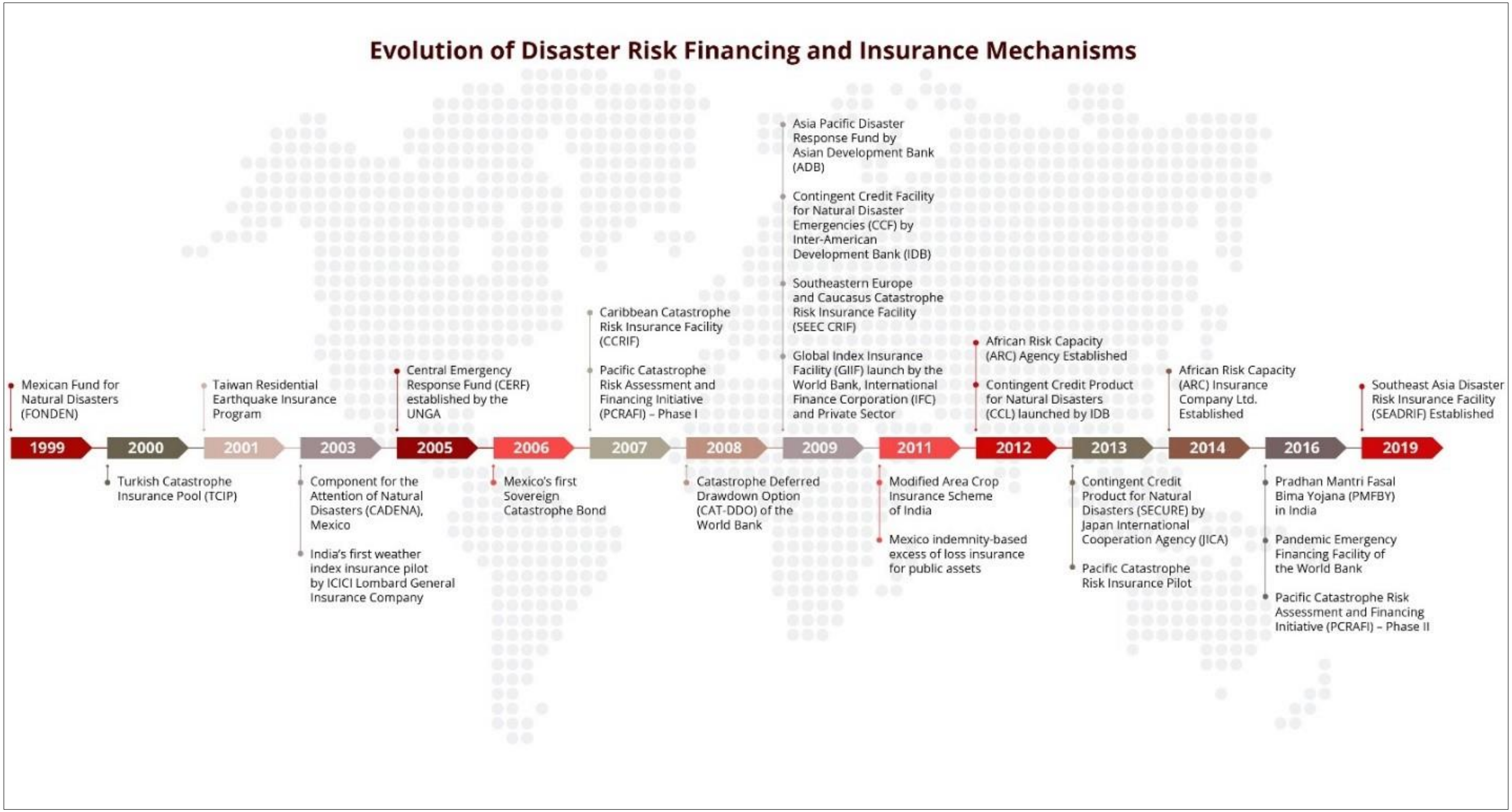
FONDEN resources are leveraged with market- based risk transfer instruments. Despite its stable annual budget appropriation, funding needs related to the occurrence of one or multiple disasters can cause a shortfall in any given year. To manage the volatility of demand on its resources, FONDEN is allowed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

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 made the decision to further diversify its coverage by pooling multiple risks in multiple regions after the CatMex attained maturity in 2009. Using the World Bank's recently formed MultiCat Programme, 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[89]. 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.[90] 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.

[89] The World Bank. 2015. *A Case Study of Insuring Against Natural Disaster Risk in Mexico*. https://documents1.worldbank.org/curated/en/170311468056076924/pdf/81172-REVISED-Mexico-MultiCatBond-2015

[90] The World Bank. 2013. *Disaster Risk Financing and Case Study –Mexico MultiCat Bond*. https://openknowledge.worldbank.org/server/api/core/bitstreams/42f4a9ed-6f3d-5bbb-bb5b-e5c2cc6703ae/content



Evolution of Disaster Risk Financing and Insurance Mechanisms
1999
Mexican Fund for Natural Disasters (FONDEN)
2000
Turkish Catastrophe Insurance Pool (TCIP)
2001
Taiwan Residential Earthquake Insurance Program
2003
Component for the Attention of Natural Disasters (CADENA), Mexico
India's first weather index insurance pilot by ICICI Lombard General Insurance Company
2005
Central Emergency Response Fund (CERF) established by the UNGA
2006
Mexico's first Sovereign Catastrophe Bond
2007
Caribbean Catastrophe Risk Insurance Facility (CCRIF)
Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) – Phase I
2008
Catastrophe Deferred Drawdown Option (CAT-DDO) of the World Bank
2009
Asia Pacific Disaster Response Fund by Asian Development Bank (ADB)
Contingent Credit Facility for Natural Disaster Emergencies (CCF) by Inter-American Development Bank (IDB)
Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (SEEC CRIF)
Global Index Insurance Facility (GIIF) launch by the World Bank, International Finance Corporation (IFC) and Private Sector
2011
Modified Area Crop Insurance Scheme of India
Mexico indemnity-based excess of loss insurance for public assets
2012
African Risk Capacity (ARC) Agency Established
Contingent Credit Product for Natural Disasters (CCL) launched by IDB
2013
Contingent Credit Product for Natural Disasters (SECURE) by Japan International Cooperation Agency (JICA)
Pacific Catastrophe Risk Insurance Pilot
2014
African Risk Capacity (ARC) Insurance Company Ltd. Established
2016
Pradhan Mantri Fasal Bima Yojana (PMFBY) in India
Pandemic Emergency Financing Facility of the World Bank
Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) – Phase II
2019
Southeast Asia Disaster Risk Insurance Facility (SEADRIF) Established

(Source: ADPC)

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

In Mexico, disasters, particularly ones affecting agriculture, have increased in frequency and severity, with over 80 percent of economic losses occurring in the agricultural sector over the past two decades. Challenges include the segmentation 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 Programmes, 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 who lack access to traditional insurance or credit. It utilizes macro-level catastrophe climatic agricultural index products to provide social safety net coverage, thus replacing traditional post-disaster relief schemes with formal insurance solutions at the state level under the Ministry of Agriculture, Livestock, and Fisheries (SAGARPA).[91] By 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 provides financial protection but also promotes resilience among vulnerable farming communities, contributing to Mexico's overall disaster preparedness and response capabilities.

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 on 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.[92] The indemnity-based coverage kicks in when disaster-related costs exceed a certain threshold, shielding the government from excessive financial burdens. Moreover, the program'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.

Turkish Catastrophe Insurance Pool (TCIP-2000)

The Turkish Catastrophe Insurance Pool (TCIP) functions as a pivotal mechanism for disaster risk financing and insurance by 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 away from the government and onto private insurers. To facilitate this transition, the World Bank provided crucial financial and technical support for the establishment of the Turkish Catastrophe Insurance Pool (TCIP). The TCIP stands as a pioneering endeavour, becoming the world's first national catastrophe insurance pool among 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 contributes

[91] The World Bank. 2013. *Mexico Agriculture Insurance Market Review*. https://documents1.worldbank.org/curated/pt/124521468287160777/pdf/881000BRI0P1300urance04Pager0Cadena

[92] The World Bank. 2013. *Quantify Contingent Liabilities Associated with Natural Disaster*. https://documents1.worldbank.org/curated/en/672271467997574054/pdf/97977-BRI-Box391499B-PUBLIC-Short-Note-1-Risk-Assessment-04Nov2013

significantly to Turkey's disaster preparedness and recovery efforts, ensuring swift and effective response in times of crisis while fostering long-term resilience and sustainability.[93]

Taiwan Residential Earthquake Insurance Program (2002)

The Taiwanese government established and promoted the Taiwan Residential Earthquake Insurance Program (TREIP) in response to the 1999 Chi-Chi Earthquake. TREIP offers basic insurance protection against earthquakes starting from April 1, 2002. The program serves as a vital mechanism for disaster risk financing and insurance by providing coverage specifically tailored to earthquakes for residential properties. Homeowners who experienced earthquake damage are able to get 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.[94] 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.

Caribbean Catastrophe Risk Insurance Facility (CCRIF-2007)

The Caribbean Catastrophe Risk Insurance Facility, the first multi-country risk pool in the world, was established in 2007 and was the first insurance product to successfully develop parametric policies backed by both traditional and capital markets. In order to enable the offering of new products and expansion into new geographic areas, the Facility underwent a restructuring in 2014 and 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 hazards 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 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.[95]

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 with the aim of strengthening 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 helps countries 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 (SPC) is undertaking a project under the Technical Assistance Programme that focuses 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

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[93] The World Bank. *Disaster Risk Financing and Case Study – Turkish Catastrophe Insurance Pool*. www.gfdrr.org/drfi
[94] *About TREIF*. Webpage of Taiwan Residential Earthquake Insurance Fund. https://www.treif.org.tw/
[95] CCRIF SPC. 2023. *The Annual Report of CCRIF SPC (2022-2023)*. https://www.ccrif.org/sites/default/files/publications/annualreports/CCRIFSPC-Annual-Report-2022-2023_lowres

information, this project seeks to update data in the Pacific Risk Information System (PacRIS) and eventually empower nations to independently impact data and improve their future exposure.[96]

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 catastrophes and public health emergencies. It offers swift disbursement contingency finance in the case of a disaster, providing liquidity up front while additional funding is raised. Approved prior to 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 and provides 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 effects 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.[97]

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 catastrophes. These funding help 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[98]. Assistance is eligible if certain emergency requirements are satisfied, such as a disaster induced by extreme weather or geophysical hazard, 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.[99]

Contingent Loan for Natural Disaster Emergencies by Inter-American Development Bank (IDB) (2009)

One of the Inter-American Development Bank's (IDB) most important tools for assisting member nations in successfully managing the financial risks connected to catastrophes is the Contingent Credit Facility (CCF). It functions as a critical mechanism for disaster risk and financing insurance by providing member countries of the Inter-American Development Bank (IDB) with access to contingent loans following verified disaster events. It provides contingent loans that are reimbursed upon the occurrence of a catastrophic event, giving money for the provision of essential amenities and humanitarian relief. Countries need to have a Comprehensive Disaster Risk Management Program (CDRMP) in place in order to be eligible for the CCF. The CCF, which incorporates parametric triggers

[96] The World Bank. 2013. *PCRAFI Catastrophe Risk Assessment Methodology*. https://reliefweb.int/report/world/pacific-catastrophe-risk-assessment-and-financing-initiative-pcrafi-risk-assessment
[97] The World Bank. 2018. *A Product Note of IDA Catastrophe Deferred Drawdown (Cat-DDO)*. https://thedocs.worldbank.org/en/doc/563361507314948638-0340022017/original/productnotecatddoidaenglish2018
[98] Webpage of Asian Development Bank. *Funds and Resources – Asia Pacific Disaster Response Fund*. https://www.adb.org/what-we-do/funds/asia-pacific-disaster-response-fund-apdrf
[99] Webpage of NDC Partnership. *Asia Pacific Disaster Response Fund*. https://ndcpartnership.org/knowledge-portal/climate-funds-explorer/asia-pacific-disaster-response-fund-apdrf

based on preset event characteristics, symbolizes the IDB's approach toward proactive disaster risk management. It focuses on giving prompt financial support during the emergency phase of disasters.[100]

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

In order to address the lack of insurance coverage for natural hazards in Southeast Europe (SEE), a region that is extremely vulnerable to disasters, Europa Reinsurance Facility Ltd. collaborated with the World Bank to implement the Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (CRIF). The project launches operations to provide small enterprises and homeowners with catastrophic insurance coverage through regional insurance providers with the funding totaling more than $12 million.[101] The project's goals are to provide new insurance products for weather and catastrophe risk, streamline insurance procedures, and raise public awareness of disaster risk in the SEE member nations. The project is composed with two components: taking part in the SEEC CRIF, which supports countries in their efforts to join Europa Re, and receiving technical assistance from donors that is carried out by Europa Re. This assistance includes risk mapping, product design, weather monitoring, and legislative reforms.[102] The project's ultimate goal is to make financial insurance against climate change and geological risks in the area more accessible to government organizations, businesses, farmers, and households.

Global Index Insurance Facility (GIIF) launch 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 financing accessibility for microfinance institutions, small-scale farmers, and microentrepreneurs in developing nations. GIIF was established in 2009 as 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.[103] Through its initiatives, GIIF has enabled billions of dollars in funding, millions of contracts affecting tens of millions of people globally, and the promotion of resilience and financial inclusion in disadvantaged communities.[104] 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. The index-based insurance can help to 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 financial inclusion in vulnerable communities worldwide.

African Risk Capacity Agency (ARC) (2012)

The African Risk Capacity (ARC) Group is comprised 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, which consists of ARC Agency and ARC Ltd, was founded with the aim of improving the ability of African governments to plan, prepare, and respond to epidemics and natural catastrophes that are caused by extreme weather events. With an emphasis on inclusivity and gender equality, ARC offers member states facilities for

[100] Collich, G., Rosillo, R., Martínez, J., Wald, D.J., Durante, J.J. (2020). *Financial Risk Innovation: Development of Earthquake Parametric Triggers for Contingent Credit Instruments*. In: Durante, J., Rosillo, R. (eds) Natural Disasters and Climate Change. SpringerBriefs in Economics. Springer, Cham. https://doi.org/10.1007/978-3-030-43708-4_1
[101] Webpage of GEF. 2012. *Regional - Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (CRIF).* https://www.thegef.org/newsroom/news/regional-southeastern-europe-and-caucasus-catastrophe-risk-insurance-facility-crif
[102] Webpage of The World Bank. 2024. *South East Europe and Caucasus Catastrophe Risk Insurance Facility (Serbia and Macedonia).* https://projects.worldbank.org/en/projects-operations/project-detail/P110910
[103] The World Bank. 2024. *Global Index Insurance Facility – Overview*. https://www.indexinsuranceforum.org/overview
[104] InsuResilience Global Partnership. 2017. *The Global Index Insurance Facility*. The Global Index Insurance Facility (GIIF) - InsuResilience Global Partnership

risk pooling and transfer, early warning systems, capacity building, and risk pooling and transfer in order 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.[105] Through ARC, 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 finance 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 have access to 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. It is also aiming to take its financial solutions to other ASEAN nations with middle-class incomes, such as Indonesia.[106] SEADRIF facilitates cooperative methods for improving preparedness for climate and disaster risks and helps member countries prevent catastrophes from becoming crises by combining resources and knowledge. With the COVID-19 pandemic adding to the stress of catastrophes 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 programmes like the ASEAN+3 Disaster Risk Financing Initiative, SEADRIF also provides a forum for information sharing, the development of technical solutions, and the investigation of insurance and other financial products.[107]

Pandemic Emergency Financing Facility of the World Bank (2016)

The Pandemic Emergency Financing Facility (PEF) – a financing mechanism had now officially closed, that was 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 much 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 UNICEF and WHO.[108]

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[105] Webpage of African Risk Capacity. https://www.arc.int/about

[106] The World Bank. 2019. *Southeast Asia Disaster Risk Insurance Facility (SEADRIF) Technical Briefing for Japanese Insurance Industry*. https://www.worldbank.org/en/news/feature/2019/01/17/southeast-asia-disaster-risk-insurance-facility-seadrif-technical-briefing-for-japanese-insurance-industry-drmhubtokyo

[107] The World Bank. 2019. *Project Information Document on Southeast Asia Disaster Risk Insurance Facility (SEADRIF): Strengthening Financial Resilience in Southeast Asia*. 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

[108] The World Bank, World Health Organization. 2022. *Report on Pandemic Emergency Financing Facility (PEF) Framework*. https://thedocs.worldbank.org/en/doc/24dce6fdf04a1313a07f7c24f539f4c7-0240012017/pandemic-emergency-financing-facility-pef-framework

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

The Central Emergency Response Fund (CERF), which was established by the United Nations General Assembly (UNGA) in 2005 as the United Nations global emergency response fund, enables 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.[109] It operates as a crucial mechanism for disaster risk financing and insurance by providing rapid and predictable funding for humanitarian response 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 allows for quick allocation of resources based on assessed needs, enhancing the effectiveness and efficiency of humanitarian interventions in disaster-affected areas.[110] 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.

Pacific Catastrophe Risk Insurance Company (PCRIC)

PCRIC is a regional insurance facility headquartered in Fiji, offering parametric insurance solutions to help Pacific Island countries manage the financial risks associated with disasters and climate change. As both a member country and the host of PCRIC's operational base, Fiji provides a strategic location that enhances the company's engagement with key regional stakeholders. This positioning supports PCRIC's mission to expand and strengthen financial protection mechanisms across the highly vulnerable Pacific region.

[109] Webpage of UN Central Emergency Response Fund. https://cerf.un.org/

[110] United Nations. 2022. *Annual Report of CERF*.https://cerf.un.org/sites/default/ files/resources/ CERF_ARR_2022_20230904

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 its natural hazard risk in exchange of 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 fulfill 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 the transfer of the risk through insurance is appealing as a valid risk management strategy.

Advantages

- Agreed well-defined benefit in case of a disaster event.
- Coverage can be purchased based on individual needs and risk appetite.
- Cost of coverage can be based on individual levels of risk.
- Insurers help with risk reduction and risk assessment.
- Disaster risk managed by professionals.
- Predictable costs for the protection in the form of a fixed premium.

Disadvantages

- Laypersons may find policies hard to understand because the policy wording contains legal language.
- Key risks or those risks that are seen as more important by consumers may be excluded.
- Policies often include a large combined monetary and percentage deductible on each and every loss, negating or diminishing the benefits of insurance.
- The claim ceiling may be insufficient to replace the insured property to the same pecuniary state enjoyed before the disaster event.
- Benefits are not clearly perceived as disaster events occur infrequently, so for many years the premium is paid but no tangible benefit is obtained.
- Claim settlement can be burdensome.

Preconditions

- Disaster risk awareness.
- Enabling government policy with respect to the development of disaster insurance instruments, potentially including mandatory insurance cover and tax benefits on the premium payments.
- Disaster risk product availability and affordability, including products 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 of 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 that can afford premiums.
- No unlicensed competition. Insurance credibility and resilient insurance providers are important 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 of a payment (reinsurance premium). Providers of reinsurance are professional reinsurers, which are entities exclusively dedicated to the activity of reinsurance. In most jurisdictions, however, insurance companies also are allowed to participate in reinsurance (Wehrhahn 2009). Reinsurers are able to effectively assume huge amounts of disaster risk because they diversify by accepting risks from around the world and maintain substantial amounts of capital to support the 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 an economic position to accept this type of risk on their own. Insurers assuming disaster risk protect their balance sheet by entering into reinsurance agreements.

Advantages

- Geographic diversification of disaster risks when using global reinsurance.
- Increased underwriting capacity of the insurance sector. By ceding part of the risk, insurers can technically accept higher volumes of disaster risk. This is particularly important for disaster insurance as the scale of exposure of an insurance company can be very large.
- Risk-based pricing of premiums as reinsurers have access to disaster risk.
- Reduction in the volatility of insurance company financials and protection of ceding companies' balance sheets.
- More predictability in profit and shareholder returns.

Disadvantages

- Insurers transfer the underwriting risk but assume credit risk. Proper credit risk analysis of the reinsurer is critical.
- Premium pricing depends to some extent on global capacity available and could become prohibitive in the event of a quick succession of extreme events.
- Terms on the risks reinsured are dictated by the reinsurer and could be different from the original insurance policy. Thus, the original risk is only partially transferred, and insurers could be left with substantial risk in their books, even after reinsurance.
- Payment of claims could be a lengthy process, affecting the cash flows of the ceding company.
- Reinsurers may include "event limits" on their treaties, thus exposing ceding companies to the possibility of having to take back the un-reinsured portion of the claims.
- Possibility of exhausting the nonproportional excess of loss reinsurance protection after a natural hazard without reinstatement of the cover, thus leaving insurers unprotected against subsequent natural hazard events in the same country or region.

Preconditions

- Sound supervision of the insurance and reinsurance markets to guarantee effective products and timely payments of claims.
- Availability of international reinsurers interested in acting in the given country.
- Availability of data and risk maps.
- Minimum credit rating of the reinsurers by reputed rating agencies such as AM Best, Fitch, and Standard & Poor's Global Ratings.
- Appropriate supervision of reinsurance brokers acting in the region/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 take on insurance risk in exchange for a higher rate of return as compared with other securities free of 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 usually issued in order to provide (re)insurance protection to insurers, reinsurers, governments, and corporations. ILS offer protection from new pools of capital separate from traditional reinsurers, such as hedge funds and pension funds. Investor capital provides collateralized cover. The capital sits in a segregated collateral account with dedicated funds available to make a payment should a qualifying event occurs. This virtually eliminates the credit risk inherent in traditional (re)insurance (Swiss Re 2012).

Advantages

- Immediate access to funds once the trigger event has been confirmed.
- Limited concern about counterparty credit in the event of an extremely large event as the claim amount is fully collateralized.
- Predictable budgetary costs for the issuer of the bonds.
- Tailor-made triggers to cover individual disaster risk contexts.
- A diversified source of disaster risk financing, which is especially beneficial when there is shortage of retrocession capacity or hard pricing cycles in traditional reinsurance markets.
- Multiyear pricing stability (terms of 3–5 years are typical for cat bonds).
- For investors, a source of investment that is uncorrelated to broader cycles in financial market performance, resulting in a higher degree of portfolio diversification.

Disadvantages

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

Preconditions

- Sophisticated securities markets that are able to 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 allows insurers and reinsurers to use ILS for capital relief, etc.
- 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 loss (i.e., crop or livestock). The loss is verified by a loss assessment process. The insured person could be the farmer or 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:

- Single-risk insurance: Covers against one peril or risk (e.g., drought).
- 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.
- Yield insurance: Provides a yield guarantee, based on regional average yield or on individual historic yield, covering the main risks affecting yield (e.g., drought). In some countries (e.g., United States), this type is also called combined or multiperil insurance.
- Revenue insurance: Combines yield and price risks coverage in a single insurance product. It can be product specific or whole farm.
- 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 and also considers the costs of production. Usually, this type of insurance is not product specific, instead covering whole-farm income.
- Whole-farm insurance: Consists of a combination of guarantees for different agricultural types of production on a farm. Depending on the coverage of the guarantees, it can be whole-farm yield, revenue, or income insurance (EU 2008).

Main Usage

Agricultural indemnity insurance provides coverage to farmers and agricultural 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 in comparison with index insurance has low basis risk (i.e., the claim amount nearly matches the actual loss suffered).
- Less data requirement: Indemnity insurance requires less data, as compared with index insurance, for the design and development of products.
- Reasonably transparent verification processes: Losses are verified on the ground, usually in the presence of the insured farmers, although entailing some level of subjectivity.
- Transparent settlements: Payouts are based on the scale of damage and losses experienced, 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 that 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, modeled loss, and exposure data: This information is required for several aspects of the product design, product evaluation, and product pricing processes. Insurance can work for risks with low frequency and higher values, but the product needs to be designed such that the risks with higher frequency and lower values are not transferred to the insurer but instead retained—and hopefully reduced—through risk reduction efforts of the farmer.
- Subject specialists: Worthy products are usually developed with assistance from subject specialists. It is therefore important to make sure that the product development team has access to the required types of expertise, either internally or externally (e.g., agronomists, modelers, underwriters, and actuaries).
- Distribution channels: Efficient distribution channels lead to low 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 lead to large and often covariate losses for the insurer and can lead 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 that is not the case under the existing solvency requirements; (ii) by providing a prompt redress mechanism on claim settlement; or (iii) by setting up 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—area yield index insurance or a trigger event based on weather-based indexes, satellite images, and so on. In developing such products, it is necessary to understand the thin dividing 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 (wind velocity, precipitation levels, etc.) and can result in a graded scale of payouts. In such cases, claims are often linked to the trigger in a gradual manner (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 the farmer or farmer group or lender whose delinquency risks depend on the outcome of agricultural output.

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

- Area yield index insurance: Indemnities are computed from the decrease in the average yield over an area without ascertaining crop output of individual farmers.
- Area revenue index insurance: Indemnities are computed from the decrease in the production of the average yields and prices in an area (EU 2008), without ascertaining crop output and prices of individual farmers.
- Indirect index insurance: Indemnities are based on indexes of yields or vegetation that are computed from weather-based indexes, satellite images, and others (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 increase their appetite to lend to farmers who are not otherwise creditworthy and to lend on better terms for farmers.

Advantages

- Low moral hazard: Since the amount of payment is unaffected by the loss experienced, insured farmers (both crop and livestock) have an incentive to act in a manner that minimizes their losses, reducing issues of moral hazard.
- Low adverse selection problem: Similarly, parametric insurance reduces the risk of adverse selection as payouts are based on widely available information, rather than on individual loss experience and related risk about which insurance companies may not have full information.
- Easier loss assessment: Since the claim payment is dependent on a trigger, efforts in assessing losses (e.g., deploying loss assessors on-site and seeking inputs) are substantially minimized.
- Prompt claim settlement: As actual loss assessment is not needed, claim settlement can be prompt after reading off the index.

Disadvantages

- Basis risk: Index-based insurance, unlike indemnity insurance, carries "basis risk." This is the risk that the index measurements that trigger the insurance payout will not match actual loss experienced. The payout could be less or more than the experienced loss. Basis risk can reduce customer satisfaction and affect continuity of an insurance programme.
- Model risk: If robust modelling tools and techniques are not used, the loss frequency results may be incorrect, leading to inappropriate pricing and, in turn, directly affecting client satisfaction and the uptake of insurance.
- Substantial data requirements: Rate making, and trigger definition require a large amount of weather and crop yield data. Insufficient data can lead to incorrect decisions on rate making and product design.
- Complexity: Farmers may face difficulties in comprehending the linkage between triggers and losses and the overall benefits of index-based insurance.
- High product development costs: Subject experts and data infrastructure are required for the design of parametric insurance, increasing product development costs.

Preconditions

- Historical and modeled weather data: This information is required for several stages of product design, evaluation, and pricing. If such information is not available, designing a robust product will not be feasible.

- Subject experts: Valuable products are usually designed with assistance from subject specialists. It is important to make sure 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 modeled loss data: Especially for area yield index insurance, historical and modeled 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; or
  - by setting up a supervisory mechanism that emphasizes 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 normally used 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 are required to capture data regularly and accurately.
- Animal mortality rates: In 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 upon the occurrence of a trigger observation or an event linked to the loss, 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 specified location (e.g., rainfall level, wind speed, seismic shocks as measured on a Richter scale) as measured 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 may be used to provide security to a country's fiscal position while reducing the element of 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 suitable for low frequency, high severity events.

Advantages

- Fiscal support: Sovereign insurance reduces potential post-disaster budget reallocations, which in turn may derail achievement of a government's development goals.

- Easier loss assessment: Since the claim payment is dependent on a trigger, efforts in assessing losses are substantially minimized and objectivity is increased.
- Prompt claim settlement: As actual loss assessment is not needed, claim settlement can be very prompt, occurring within just 2–3 weeks following an event.
- Low operating cost: Operating costs are low relative to traditional insurance products due to the simplicity of sales and loss adjustment, the lack of need to classify policyholders according to their risk exposure, and the lack of asymmetric information.
- Low moral hazard: As the amount for payouts is unaffected by the loss experienced, governments have an incentive to act in a manner that minimizes losses, reducing issues of moral hazard.

Disadvantages

- Basis risk: Index-based insurance, unlike indemnity insurance, carries "basis risk." This is the risk that the index measurements that trigger the insurance payout will not match actual loss experienced. The payout could be less or more than the experienced loss.
- Model risk: If robust modelling tools and techniques are not used, the frequency results can be incorrect, leading to inappropriate pricing and, in turn, directly affecting client satisfaction and the uptake of insurance.
- High start-up costs: Despite low operating cost, index insurance can have high start-up cost, especially in the absence of appropriate weather data and skilled meteorological expertise. The readiness of a country to buy the parametric insurance cover depends in part on its existing infrastructure, such as with regard to an asset inventory, meteorological data, hazard maps, exposure data, vulnerability analyses, historical disaster data, and disaster risk models.
- Data requirements: Rate making and trigger definition require a large amount of data, such as on exposed assets (including public assets), past and modeled hazard events, and weather. 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. Information should be capable of independent verification using different tools. For example, satellite images can complement a primary weather station's information regarding precipitation. If this type of information is not available, it may not be possible to design an appropriate product.
- Subject experts: Valuable products are usually designed with assistance from subject specialists. It is important to make sure 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 modeled loss data: Historical and modeled loss data are essential in pricing the product as well as in defining the trigger. Insufficient or inappropriate data could give rise 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 in a timely manner.
- Frequency and accuracy of recording data: Weather stations and satellite imaging infrastructure need to capture data regularly and accurately and be 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 can have 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 unfavorable 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.

Advantages
Designing an insurance pool should consider the following factor (ADB 2019d):

- Product design: Undertaking product design and providing support on an ongoing basis is more efficient when a centralized pool gathers information.
- Information gathering: Being a repository of losses, the pool is able to undertake more in-depth analysis.
- Leverage: A pool can leverage its collective buying power as a block to negotiate premium and deductibles to the comparative advantage of its members.
- Customization: The scale of provision of member services, including risk control, claims management, and training, is sufficient to support customization.
- Innovation: A pool is better able to support the insurance industry's development of innovative products and offer unique forms of coverage, particularly with regard to efficient and cheap technology for indemnity and area yield index products.
- 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 use of reinsurance and resulting in greater price stability.
- Reinsurance: Economies of scale facilitate the purchase of reinsurance at a more competitive price.

Disadvantages

- Lower diversification: Disaster and/or agriculture insurance pools face high covariate risk from lower diversification, which can be detrimental to their solvency.
- Cost: The management of an insurance pool involves direct costs (e.g., secretariat overhead, salary, system cost) and indirect costs (e.g., time of regulators and other government officials).
- Speed of decision-making: As a pool involves policy decisions that can simultaneously affect all members, decisions are based on deliberations among pool members. Individual underwriters, on the other hand, can make prompt business decisions.

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. In order 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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