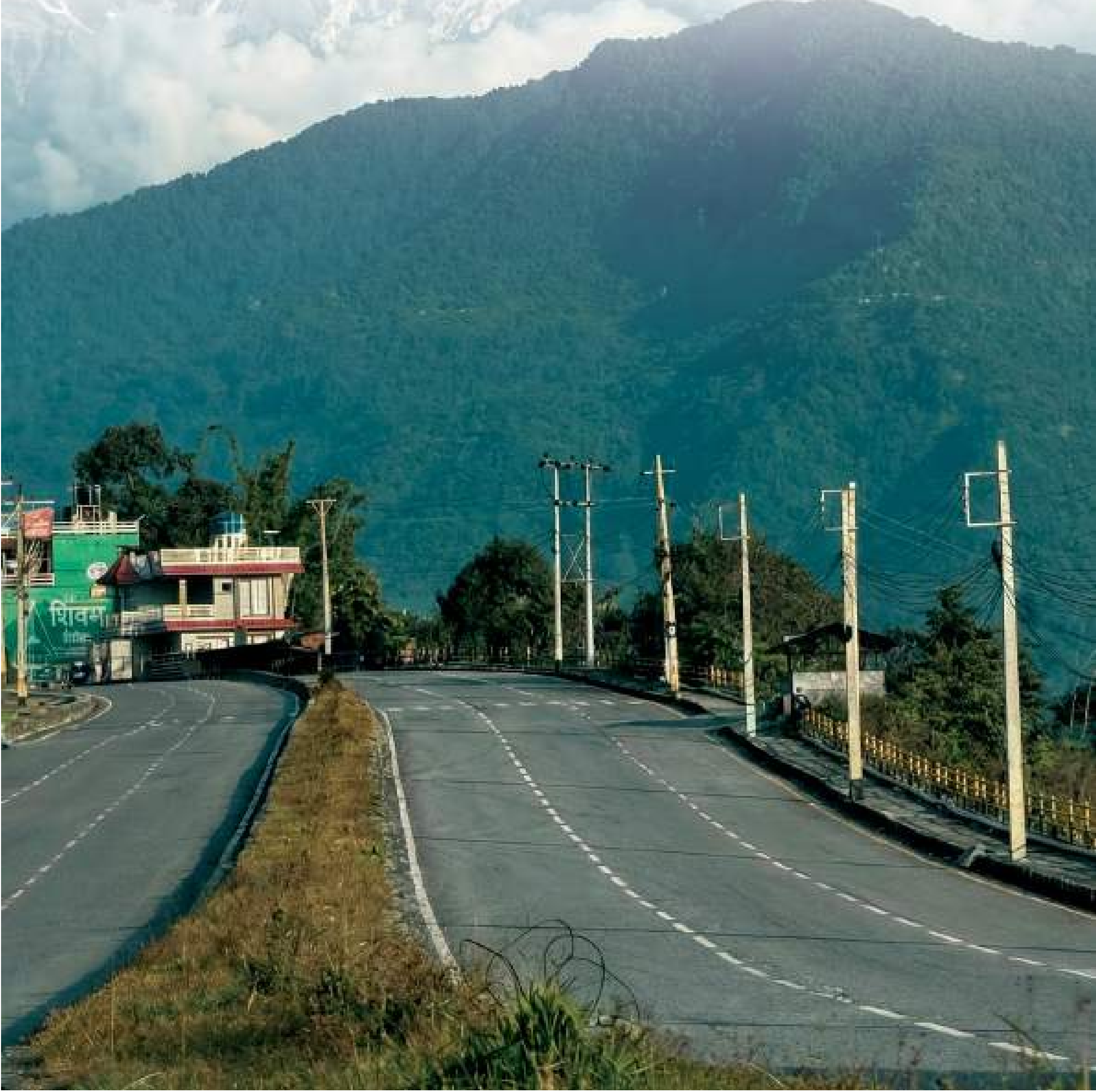
CDRI

Coalition for Disaster Resilient Infrastructure

Towards Resilient Public Finance

National Assessment of Fiscal Risks in Critical Infrastructure Sectors in Nepal



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Foreword

Amit Prothi

Director General
Coalition for Disaster Resilient Infrastructure

Nepal's geography makes it particularly vulnerable to both geological and climate-induced hazards. Earthquakes, floods, and landslides have caused repeated human and economic losses, with single events wiping out years of development progress. As climate change alters monsoon patterns and accelerates glacial melt, the frequency and severity of disasters are projected to increase, compounding the already high risk levels. These shocks reverberate through public finances, straining limited reserves, slowing recovery, and constraining the resources available for long-term development. Strengthening financial preparedness against such recurrent shocks is therefore a critical priority, not only to protect infrastructure and livelihoods, but to ensure that Nepal's pathway to growth and resilience remains on course.

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 Nepal is among the first in the region to systematically link disaster-related impacts on infrastructure to fiscal outcomes. Key recommendations to enhance disaster risk financing strategies and strengthen institutional capacities to manage contingent liabilities in infrastructure are also suggested.

The study aims to serve as 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 valuable tool for policymakers, financial planners, and development partners working to build fiscal resilience in Nepal and other similarly vulnerable economies.

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

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Executive Summary

Nepal, situated in the seismically active Himalayas and exposed to South Asia's intense monsoon system, faces high and recurrent disaster risks. Earthquakes, floods, and landslides are the most frequent and destructive hazards, generating repeated economic shocks that erode development progress and place severe strain on public finances. These disasters inflict both human costs and fiscal pressures, destroying infrastructure, displacing communities, and compelling the government to redirect scarce resources from planned development to emergency response and reconstruction. Climate change is expected to intensify these pressures by amplifying flood and landslide risks, compounding Nepal's already fragile fiscal resilience.

Major disaster events in recent years underscore the magnitude of this challenge. The 2015 Gorkha earthquake and aftershocks killed nearly 9,000 people and caused losses of $7[1] billion, equivalent to one-third of Nepal's gross domestic product (GDP) at the time. More recently, the Doti-Bajhang-Jajarkot earthquakes of 2022–2023 incurred a reconstruction bill exceeding $481 million, while the September 2024 monsoon floods caused $295 million in damage, primarily to transport and energy systems. The August 2017 floods displaced 1.7 million people and caused $585 million in losses, equivalent to 3 percent of GDP. On average, Nepal incurs annual losses of $325 million from earthquakes and $220 million from floods, highlighting a persistent fiscal vulnerability.

This report, prepared under the Coalition for Disaster Resilient Infrastructure's Finance for Resilient Infrastructure Programme (FRIP), evaluates Nepal's fiscal risks from disasters through a combination of econometric modelling and probabilistic catastrophe analysis. It assesses how disasters translate into fiscal liabilities, quantifies sector-specific exposures, and estimates future post-disaster funding gaps under different financing scenarios. The aim is to provide a robust evidence base to strengthen Nepal's financial preparedness, ensuring the government can respond to disasters rapidly while maintaining fiscal stability and protecting development gains.

Econometric panel modelling of Nepal's fiscal performance revealed that government expenditure increases significantly in disaster years. In contrast, effects on central government debt and revenues were not statistically significant at the national level. This finding suggests that disasters impose immediate and measurable fiscal costs, primarily through increased emergency and reconstruction spending, but these impacts do not persist in subsequent years. The lack of observable long-term fiscal impacts does not imply that disasters leave no economic scars. Instead, it reflects the limitations of aggregated national data, which may obscure localized, sectoral, and distributional consequences. Strengthening sub-national data collection will be critical for capturing these nuances in future assessments.

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

Catastrophe modelling indicates that Nepal's critical infrastructure sectors, particularly energy and transport—face disproportionate risks. In the energy sector, floods are the most damaging hazard, with average annual losses (AAL) of $32.4 million and a 10-year probable maximum loss (PML) of $69.5 million. Under climate change scenarios (RCP8.5), these losses are projected to increase further, with PMLs exceeding $94 million for 10-year events. The roads and bridges sector is even more exposed. Rain-induced landslides account for the highest AAL, estimated at over $101 million annually, while a 10-year PML could reach $210.5 million. These figures point to recurring fiscal liabilities, as monsoon-triggered landslides repeatedly disrupt transport networks. As with the energy sector, climate change significantly heightens future risks, raising both AAL and PML values under higher-emission scenarios.

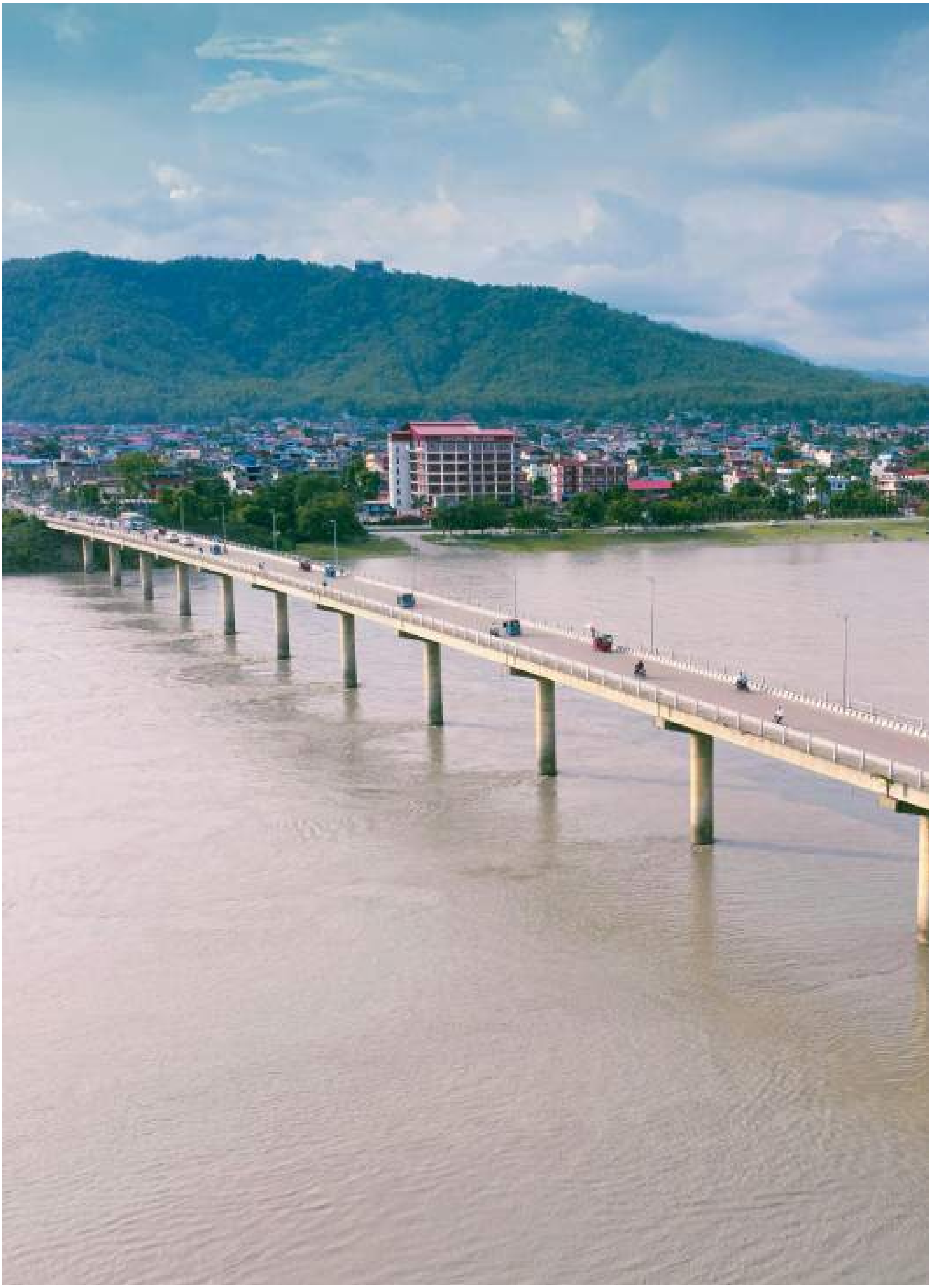
Nepal's primary disaster financing sources are modest relative to the scale of these risks. As of 2024, the government holds NPR 4.65 billion ($35.2 million) in the national Disaster Management Fund. Additional reserves exist in the Prime Minister's Disaster Relief Fund (NPR 1.89 billion), the Central Disaster Management Fund (NPR 1.27 billion), provincial funds (NPR 794 million in total), and 77 district-level funds (NPR 690 million combined). Together, these resources remain far below the requirements of a major disaster. To supplement these reserves, Nepal secured a $150 million Catastrophe Deferred Drawdown Option (Cat DDO) from the World Bank in October 2024, providing contingent liquidity in the event of disaster.

Despite these mechanisms, the analysis reveals persistent funding gaps. If floods and landslides with 10-year return periods were to occur simultaneously in 2026, the combined fiscal need for the energy and transport sectors would exceed available government funds by nearly $100 million, even after drawing down the national disaster fund. With the Cat DDO in place, this shortfall is reduced but not eliminated, especially given that contingent funds are designed to support multiple sectors beyond energy and transport. For higher-return-period events (25–100 years), the funding gap widens dramatically, underscoring the insufficiency of current financing arrangements.

Scenario modelling further illustrates that incremental increases in Nepal's disaster fund—even at 5–10 percent annually are unlikely to close the gap for high-severity events until well into the 2030s or 2040s. While forward commitments under the National Strategic Action Plan for DRR 2018–2030 include allocating 5 percent of the development budget to disaster risk reduction, these resources remain insufficient to cover the expected average annual losses from earthquakes and floods.

This report highlights that Nepal's fiscal resilience is constrained by recurring disasters, rising climate risks, and limited financial buffers. To safeguard public finances and development progress, Nepal will need to do the following:

- Adopt a layered risk financing strategy that integrates budgetary reserves, contingent credit, insurance, and risk-transfer mechanisms to address both frequent low-severity and rare high-severity events.
- Increase allocations for post-disaster response at both national and sub-national levels, ensuring that reserve funds are scaled to at least cover average annual expected losses.
- Mainstream disaster-linked fiscal liabilities into debt management frameworks to improve transparency and sustainability.
- Strengthen exposure, vulnerability, and fiscal impact data collection, particularly at the sub-national and sectoral levels, to improve the accuracy of modelling and support evidence-based fiscal planning.
- Invest in resilient infrastructure standards in critical sectors such as energy and transport, reducing recurrent damage and long-term reconstruction costs.
- By shifting from reactive disaster financing to proactive fiscal risk management, Nepal can better absorb shocks, protect fiscal stability, and sustain development progress in the face of increasing disaster risks.



Chapter 1

Introduction

Introduction

Nepal is highly vulnerable to disasters due to its location in the fragile Himalayan arc and its steep, complex terrain. The country faces a wide range of geological and climate-induced hazards, including earthquakes, floods, landslides, glacial lake outburst floods (GLOFs), droughts, avalanches, and storms. These hazards are increasing in frequency and intensity with climate change, posing greater risks to lives, livelihoods, and infrastructure. Disasters repeatedly hamper development by destroying physical assets, displacing communities, and straining government finances.

Nepal's economic and social conditions compound these risks. A large share of the population depends on agriculture for livelihoods, much of it at subsistence levels, which makes the economy highly sensitive to climate shocks. Many rural and mountainous communities remain isolated with

limited access to services, while urban centres such as Kathmandu facing increasing pressures from unplanned expansion and inadequate infrastructure. The interconnected nature of Nepal's critical infrastructure, particularly transport and energy, means that disruptions in one sector quickly cascade across others, destabilizing supply chains and economic activity. These dynamics impose a heavy fiscal burden, as the state must repeatedly divert resources towards disaster response, recovery, and reconstruction efforts. Against this backdrop, strengthening fiscal resilience through a comprehensive disaster risk financing (DRF) strategy is a critical priority for Nepal's long-term stability and growth.

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 initiative. CDRI 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 Nepal's critical infrastructure sectors, with a particular focus on energy and transport. The aim is to support evidence-based policymaking and enhance financial preparedness for future events.

The report aligns with Nepal's ongoing efforts to strengthen DRF under its Disaster Risk Reduction and Management Act 2017 (DRRMA, n.d.) and the 2020 National DRF Strategy (PreventionWeb, 2020). These frameworks establish multi-level funds at federal, provincial, district, and local levels and promote a proactive approach to financing through contingency reserves, insurance mechanisms, and the build-back-better principle. With the National Disaster Risk Reduction and Management Authority (NDRRMA) as the coordinating body, Nepal has built important institutional foundations for fiscal resilience. This report builds on these priorities by offering detailed analysis and options to enhance the government's ability to manage disaster-related fiscal risks, protect development gains, and ensure resilient, sustainable growth amid increasing climate and disaster challenges.

Fiscal Risk Assessment Framework

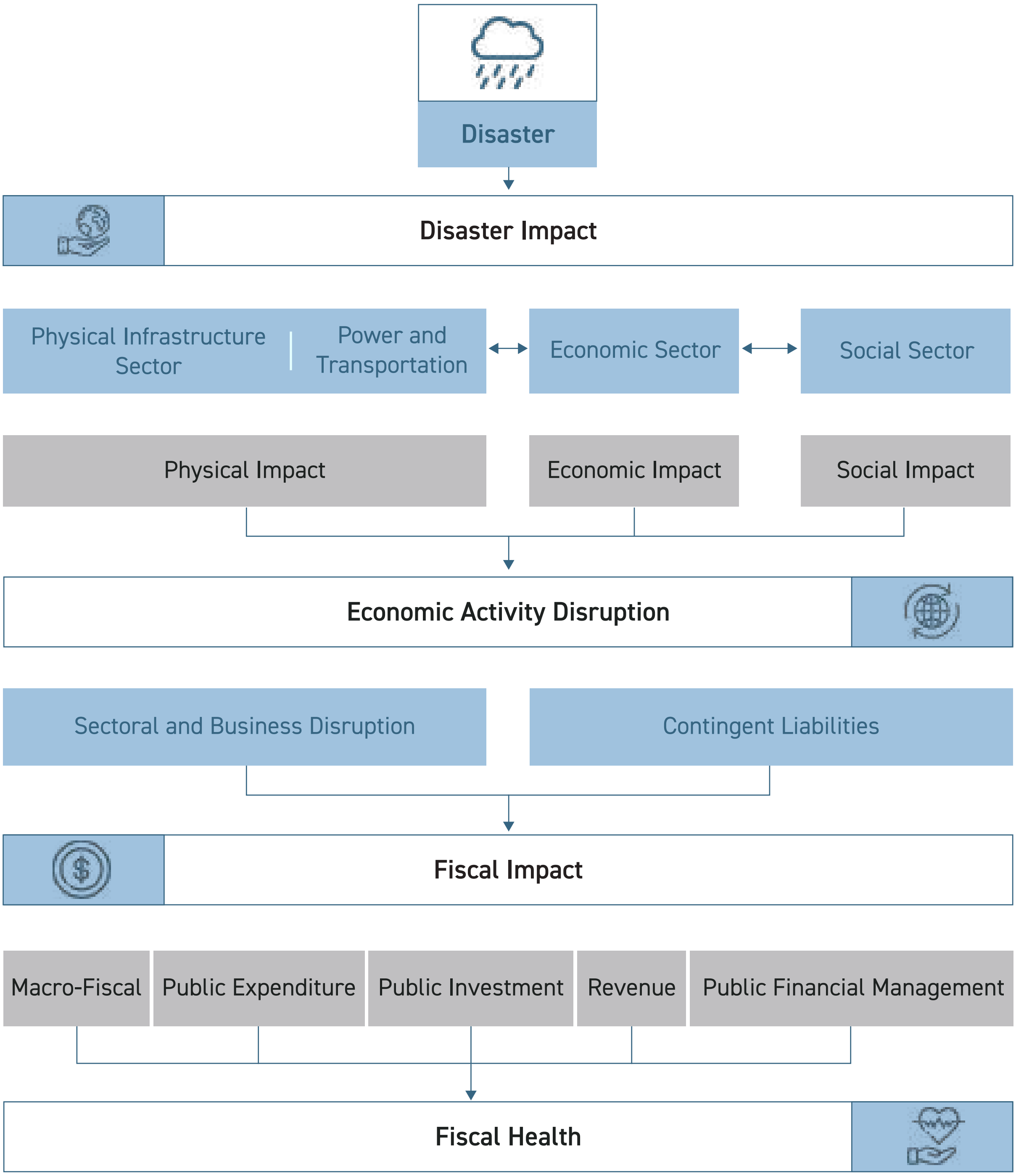
The International Monetary Fund (IMF) defines fiscal risk as the economic factors that may cause actual fiscal outcomes to differ from projected or expected fiscal outcomes (International Monetary Fund, 2016). The Organisation for Economic Co-operation and Development (OECD) describes fiscal risks as changes in the expected fiscal outcomes outlined in an economy's annual budget or forecasting documents (Organisation for Economic Co-operation and Development, 2019). Fiscal risks can arise from macroeconomic shocks or from contingent liabilities triggered by uncertain events. Governments need to understand these risks and prepare for them by conducting financial risk assessments to ensure 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 gross domestic product (GDP) on average to 6 percent in extreme circumstances (Albala-Bertrand, 1993), making them a significant source of fiscal risk. Public-private partnerships (PPPs) and private non-financial company liabilities are additional sources that may require government bailouts. According to a study by Bova et al. (2016), 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 ensuring the government's capacity to respond effectively during a crisis depends on recognizing and controlling these risks.

Disasters have significant 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 effects (Inter-American Development Bank, 2017). Knowing these channels is essential for policymakers to effectively manage the fiscal consequences of disasters.

Figure 1.1 presents a structured framework adopted for this report. The framework demonstrates the cascading effects of disasters on economic and fiscal stability, beginning with their impact on physical infrastructure, economic, and social sectors. These disruptions, interruptions in economic activity, including sectoral and business disruptions, create contingent liabilities for the government. As economic activity decline, 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 1.1: Framework For Assessing Fiscal Risk Arising From Disasters



Source: Asian Disaster Preparedness Center – Author's illustration

Chapter 2

Financial Risk Assessment based on Historical Data

Financial Risk Assessment based on Historical Data

Climate-induced disasters, such as floods, cyclones, and other hazards, can severely affect human lives, economies, and fiscal stability. A disaster can result in loss of life, displacement of people, and damage to infrastructure, leading to lower economic output and higher demand for emergency services, reconstruction, and social welfare and protection programmes. Climate-induced extreme weather events result in an average increase in the fiscal deficit of 0.8 percent and 0.9 percent of GDP in lower-middle-income and low-income countries, respectively (International Monetary Fund, 2023).From a fiscal perspective, the frequency and severity of climate-related disasters can pose a higher risk of negative fiscal shock by straining public fiscal accounts, leading to budget deficits and rising debt accumulation, resulting in a weakened fiscal stance due to the negative impacts of revenue and expenditure channels, increased public debt, postponed investment projects, and a cyclical fiscal policy.

Disasters can significantly impact government revenues, particularly by negatively affecting economic activity. This often results in lower tax and non-tax revenues due to decreased tax incomes, disruptions to international trade, and fewer labour hours. However, there may also be a post-disaster recovery boost that stimulates economic activity, causing a short-term increase in foreign aid or tax revenue. Disasters also affect the government's assets and liabilities, beyond the immediate changes in revenue and spending. For example, damage to public infrastructure raises the cost of repairs or replacements. Yet, many governments lack comprehensive balance sheets that include non-financial assets, making it more challenging to assess the fiscal impact.

Between 1994 and 2013, disasters caused an estimated $2.6 trillion in economic losses, equivalent to 4 percent of the world's GDP in 2015 (Guha-Sapir et al., 2016). On average, across a sample of events between 1990 and 2014, the cost to a country's economy from disasters was 1.6 percent of GDP. In some cases, costs were much higher, with the most significant disasters accounting for up to 6 percent of GDP (Bova et al., 2016). The study by the International Monetary Fund found that the highest fiscal cost recorded was 6 percent of GDP. Multiple studies show that disasters and economic growth are negatively linked, with the majority demonstrating that disasters reduce GDP in both the long and short terms. To prepare governments for the worst and prevent underestimating the financial costs of such events, predicting future damages and studying low-frequency, high-impact disasters are crucial.

Figure 2.1 summarizes how disasters impact government finances through several key fiscal channels. These include macro-fiscal effects such as increased spending and decreased revenues that strain the fiscal balance, often resulting in higher public debt and triggering sovereign guarantees. Revenue is further affected by declines in production, trade disruptions, and loss of labour hours, all of which reduce 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 2.1: Fiscal Impact Channels of Disasters

Source: Asian Disaster Preparedness Center – Author's illustration

As governments borrow money to fund recovery, this could lead to budget deficits and increased public debt. Disasters can cause production losses, disrupt trade, and decrease tax revenues due to lost labour hours and business earnings, significantly affecting revenue. Governments need to allocate funds quickly for emergency response and recovery, often sharing disaster costs with local governments, which necessitates additional assistance. Public financial management faces challenges in guaranteeing the effective use of disaster funds and maintaining transparency. Public investment also suffers, as funds are diverted from future projects to rebuild damaged infrastructure.

Overview of Impact of Disasters in Nepal

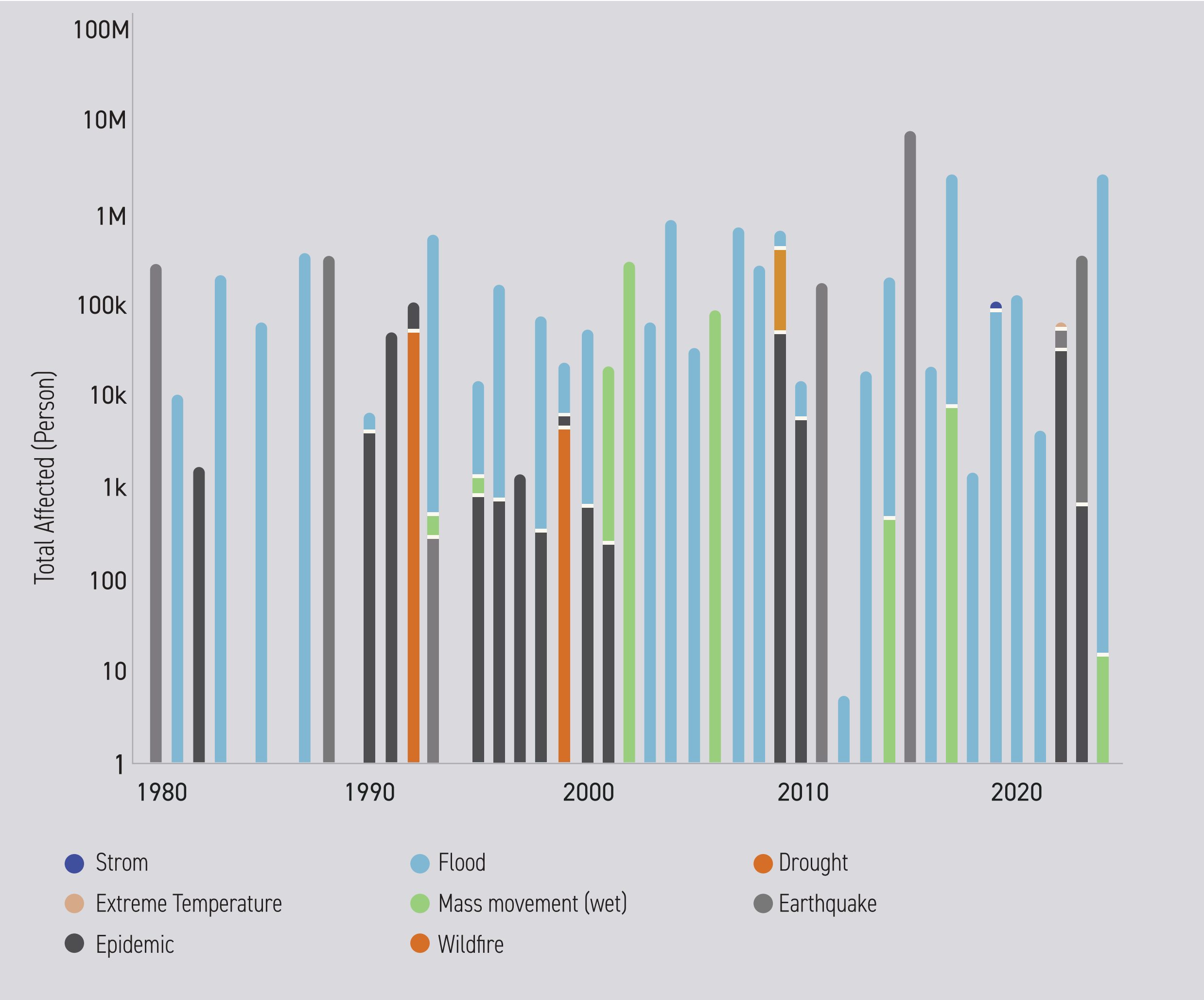
Nepal's history of disasters highlights the destructive force of both geological and climate-induced hazards. Located in the Himalayan arc, the country has experienced some of the world's most severe earthquakes. The 1934 Bihar–Nepal earthquake devastated entire regions, while the 2015 Gorkha earthquake resulted in nearly 9,000 deaths, widespread destruction of homes, infrastructure, and heritage sites, and losses exceeding one-third of the national GDP (UN Nepal Information Platform, 2015). Beyond earthquakes, floods and landslides occur annually during the monsoon season; the 2017 floods inundated large parts of the Terai region, damaging nearly 200,000 houses, and displacing tens of thousands of people (International Recovery Platform, 2017).

Other events have demonstrated Nepal's vulnerability to cascading and compound hazards. The 2008 Koshi River disaster, caused by a glacial lake outburst flood, led to widespread displacement and destruction along riverbanks. The 2014 Jure landslide buried entire settlements and blocked the Araniko Highway, cutting off Nepal's only road connection to China and disrupting cross-border trade. Avalanches in the Everest region, including the deadly 2014 events and those triggered by the 2015 earthquake, highlight the risks faced by mountain communities and tourism-dependent livelihoods.

Between 1980 and 2017, disasters in Nepal killed more than 20,000 people, affected millions of lives, and caused billions of dollars in damage (Government of Nepal, Ministry of Home Affairs, 2019). These impacts demonstrate how primary hazards often trigger secondary disasters—such as earthquakes leading to landslides and avalanches, or heavy rains causing floods and slope failures—which increase social and economic costs. Disasters have repeatedly hindered development, reducing GDP growth, damaging critical infrastructure, and limiting fiscal capacity. Historical patterns confirm that earthquakes, floods, and landslides continue to be the most frequent and devastating hazards, each major event leaving long-lasting recovery challenges. These experiences highlight Nepal's heightened vulnerability and the pressing need for stronger resilience in infrastructure, governance, and fiscal systems.

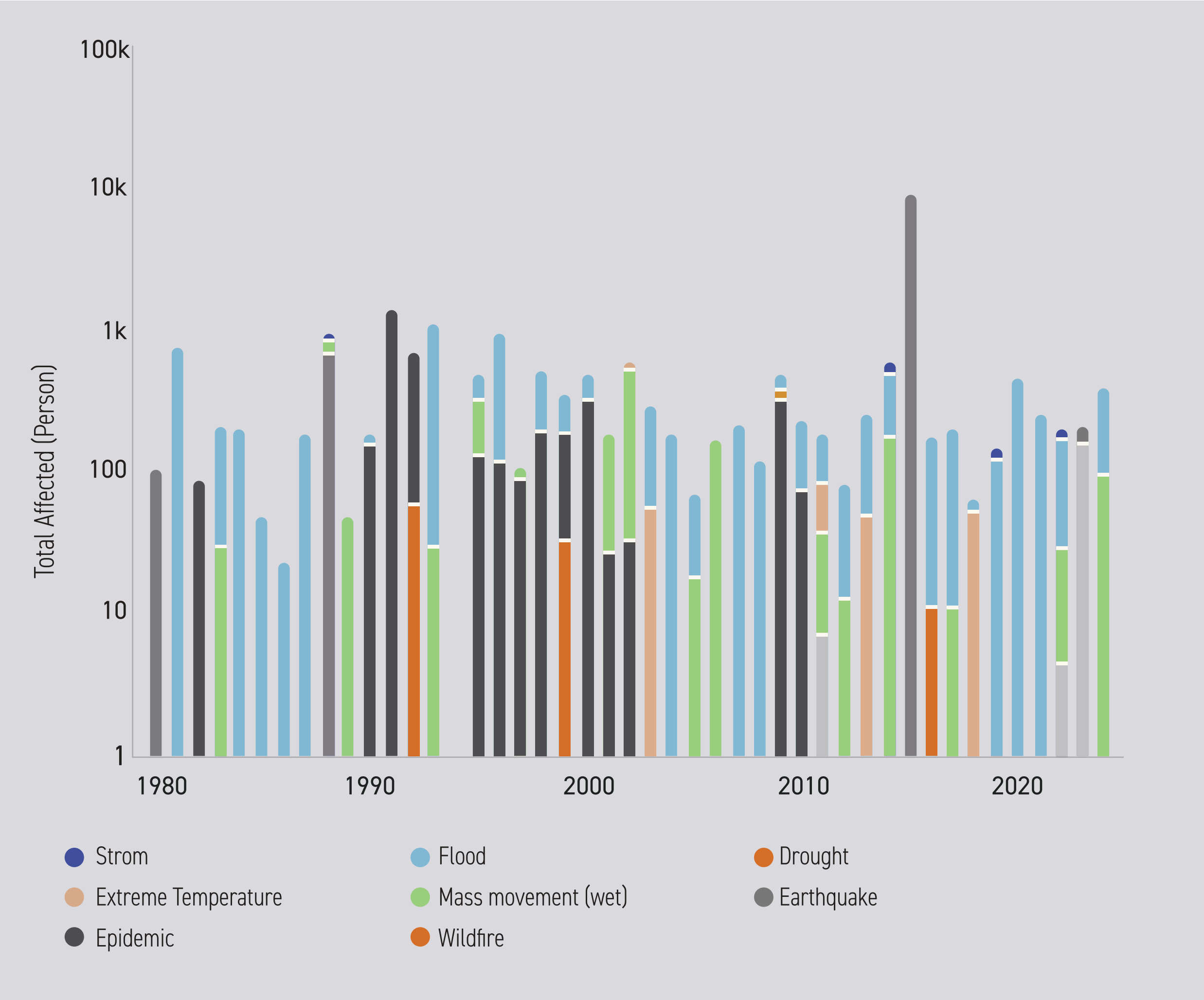
Historical disaster data for Nepal (Figures 2.2 and 2.3), drawn from the World Bank's Climate Knowledge Portal (using EM-DAT, CRED), shows that floods, landslides, and epidemics have consistently affected large populations, while earthquakes remain the deadliest hazard (Centre for Research on the Epidemiology of Disasters, n.d.). Major events such as the 2015 Gorkha earthquake and the 2017 Terai floods highlight how single shocks cascade into widespread human impacts, underscoring Nepal's enduring vulnerability to both geological and climate-induced hazards.

Figure 2.2: Time Series of Disasters Statistics Nepal 1980-2024: Total Affected (Persons) (EM-DA T data)



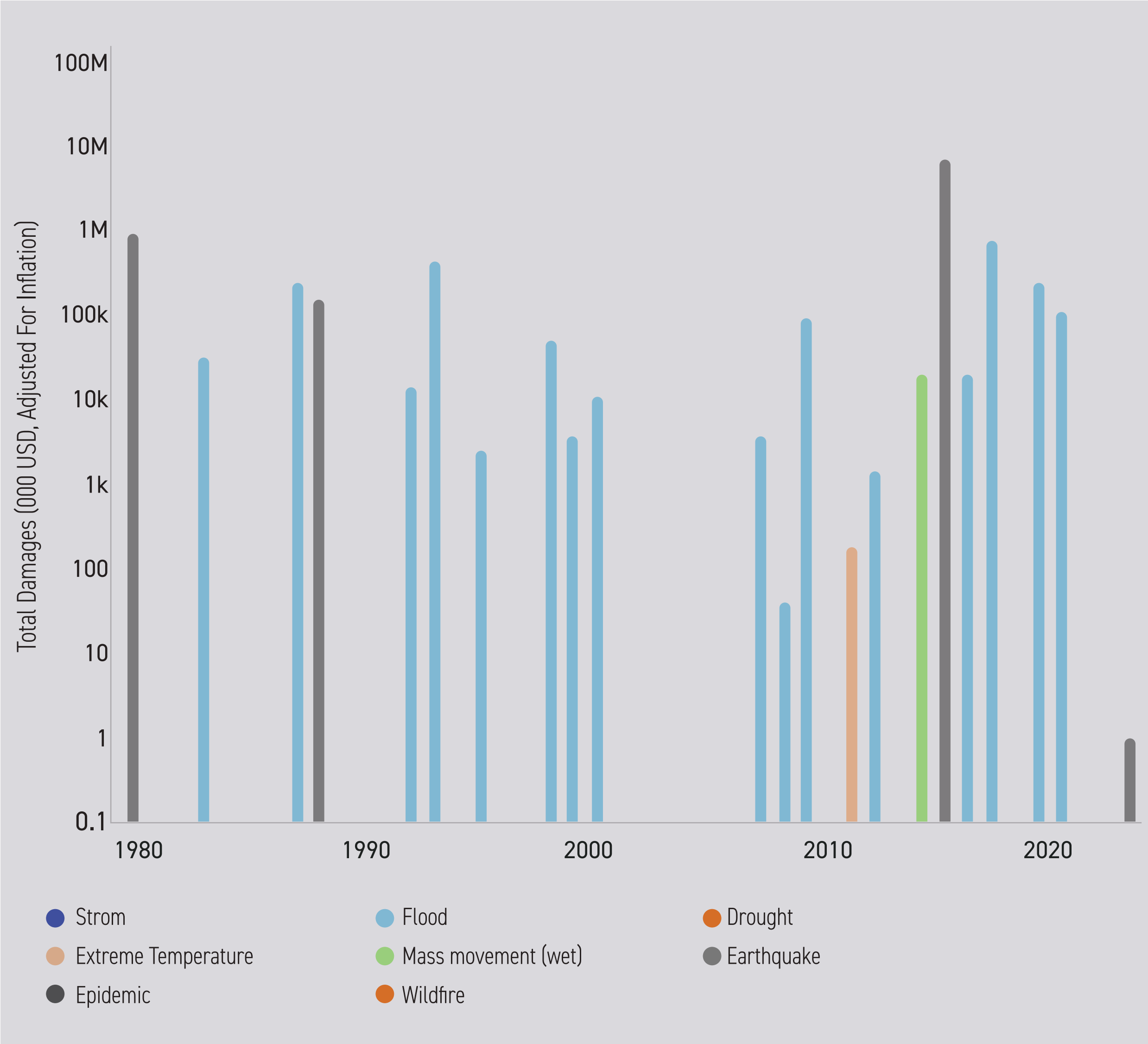
Source: Compiled by ADPC from the Government of Odisha reports

Figure 2.3: Time Series of Disasters Statistics Nepal 1980-2024: Total Deaths (Persons) (EM-DA T data)



Data from the World Bank's Climate Knowledge Portal, based on EM-DAT (CRED), highlights the substantial and recurring fiscal burden of disasters in Nepal. Earthquakes dominate recorded losses, with the 2015 Gorkha earthquake the costliest event, while recurrent floods and landslides also impose heavy cumulative damage. This pattern, as shown in Figure 2.4, demonstrates how disasters not only disrupt development but also create long-term financial pressures on the government.

Figure 2.4: Time Series of Disasters Statistics Nepal 1980-2024: Total Damages (000 $, Adjusted for Inflation) (EM-DA T data)



Damage is the replacement value of physical assets wholly or partially destroyed, built to the same standards that prevailed before the disaster. Losses refer to 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; UNDP, 2013).

Impact of Disasters on Energy Infrastructure

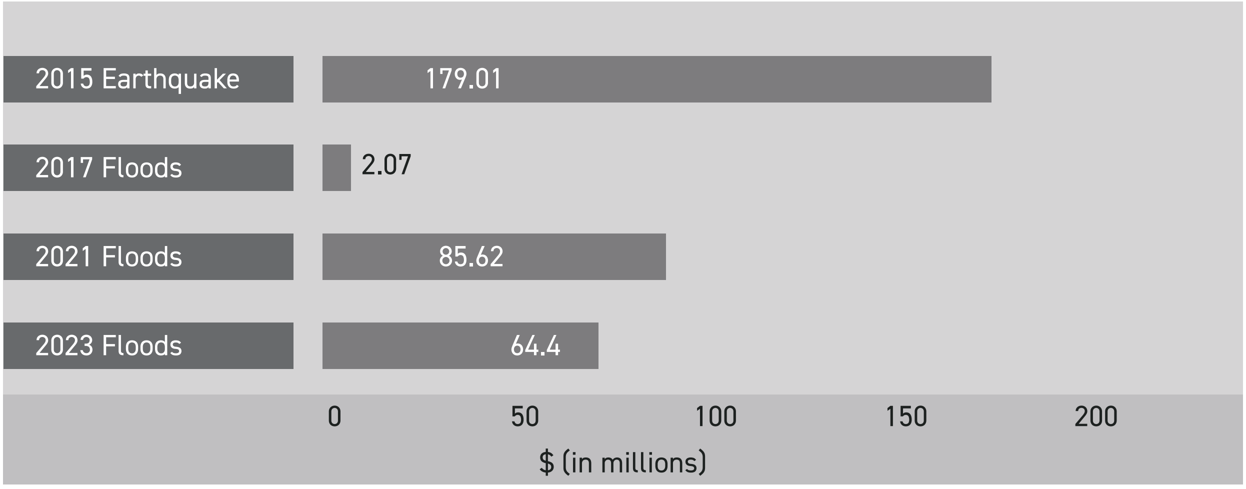
The Department of Electricity Development (DoED) and the Nepal Electricity Authority (NEA) oversee the management and operation of Nepal's energy sector. Electricity is generated primarily through hydropower, with both public and private producers contributing to the national supply, as well as community-based off-grid systems such as micro-hydro plants and solar home systems. Access to reliable electricity is central to livelihoods, especially for households and small enterprises that rely on it for income generation. Disasters consistently undermined this access, disrupting both on-grid and off-grid services and leading to significant repair and reconstruction costs.

The 2015 Gorkha earthquake caused unprecedented destruction to the energy sector. Of the 787 MW total installed hydropower capacity at the time, around 115 MW were severely damaged and 60 MW partially damaged, while nearly 1,000 MW of projects under construction suffered partial losses. The transmission network was also significantly affected, with substations, control rooms, and staff facilities damaged at multiple sites. Distribution infrastructure was also affected, with 800 km of lines and 365 transformers rendered inoperable. Off-grid systems were not spared: over 260 micro-hydro facilities, more than 115,000 solar home systems, and numerous institutional solar plants were damaged. Overall, the sector incurred losses exceeding NPR 17 billion, primarily borne by private developers (UN Nepal Information Platform, 2015).

Floods in subsequent years added to the burden. In 2017, inundation in the eastern Terai submerged substations, forcing prolonged power outages and damaging thousands of poles, transformers, and conductors, with losses estimated at NPR 220 million (International Recovery Platform, 2017). In 2020, severe flooding and landslides led to power cuts and forced hydropower plants to halt generation, although permanent damage was limited (Kathmandu Post, 2020). The 2021 monsoon floods and landslides were more destructive, damaging nearly two dozen hydropower projects under construction and operating, with reported losses of around NPR 10 billion (Kantipur News, 2021). In 2023, floods in Sankhuwasabha and neighbouring districts caused catastrophic damage to 30 hydropower projects, 13 operating and 17 under construction, resulting in losses exceeding NPR 8.5 billion and disrupting nearly 460 MW of capacity (Shrestha, 2023).

These recurring shocks underscore the vulnerability of Nepal's hydropower-dependent energy system to earthquakes, floods, and landslides. Both public infrastructure and private investments face mounting risks, while communities relying on local grids and solar systems remain highly exposed. Figure 2.5 presents available data on recorded damages to the energy sector from recent disasters, highlighting the scale of recurrent losses.

Figure 2.5: Power Sector Estimated Damages from Past Disasters



Source: Data compiled by authors

Impact of Disasters on Roads

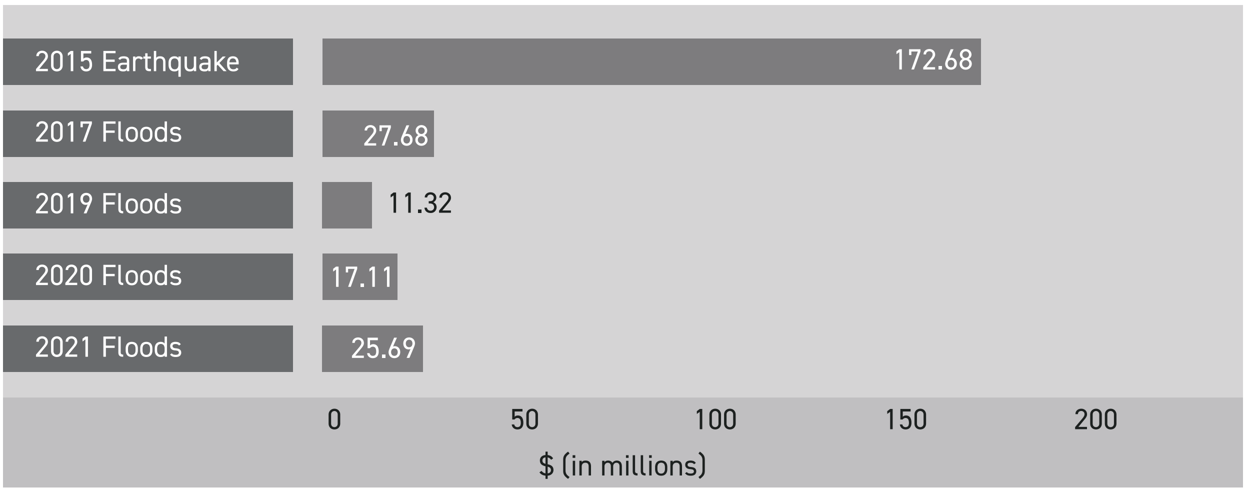
The Department of Roads (DoR) and the Department of Local Infrastructure Development and Agriculture Roads (DoLIDAR) are the two main government agencies responsible for managing Nepal's road sector. Despite being the backbone of national connectivity, Nepal has the lowest road density in South Asia, and about one-fifth of the population still lacks road access. This makes the sector particularly critical, as damage to the already limited networks severely reduces people's access to markets, services, and livelihoods.

The 2015 Gorkha earthquake caused extensive damage to both the strategic road network (SRN) and the local road network (LRN). Although only a small percentage of the SRN was completely destroyed, landslides blocked hill and mountain roads for days, and widespread cracking and washouts required major repair. Distribution losses included the costs of clearing debris, operating equipment, and maintaining temporary access. The post-disaster needs assessment estimated damages and losses of NPR 4.6 billion for the SRN and over NPR 12 billion for LRN, highlighting the greater vulnerability of rural roads to seismic and landslide impacts.

Floods have proven equally disruptive to road infrastructure. The 2017 monsoon floods in the Terai caused widespread submergence of highways and local roads, damaging bridges and culverts across 35 districts. The post-flood recovery and needs assessment estimated road-sector damages of nearly NPR 2.9 billion, with 87 percent of losses attributable to roads themselves. Subsequent floods in 2019, 2020, and 2021 continued to impose high costs. The 2019 floods damaged roads and bridges across the Terai and Kathmandu Valley, with estimated losses of NPR 1.25 billion. In 2020, over 150 landslides and flood incidents along national highways caused damage totalling NPR 2 billion (Shrestha, 2020). The October 2021 floods and landslides incurred an additional NPR 1.5 billion in losses, with total annual road damages estimated at NPR 2.8 billion (The Kathmandu Post, 2021).

These repeated events highlight the acute vulnerability of Nepal's roads to earthquakes, floods, and landslides, particularly in rural and mountainous terrain. Each disaster not only disrupts transportation and trade but also damages public finances and delays recovery. Figure 2.6 shows data on road-sector damage from recent disasters, highlighting the scale and frequency of these losses.

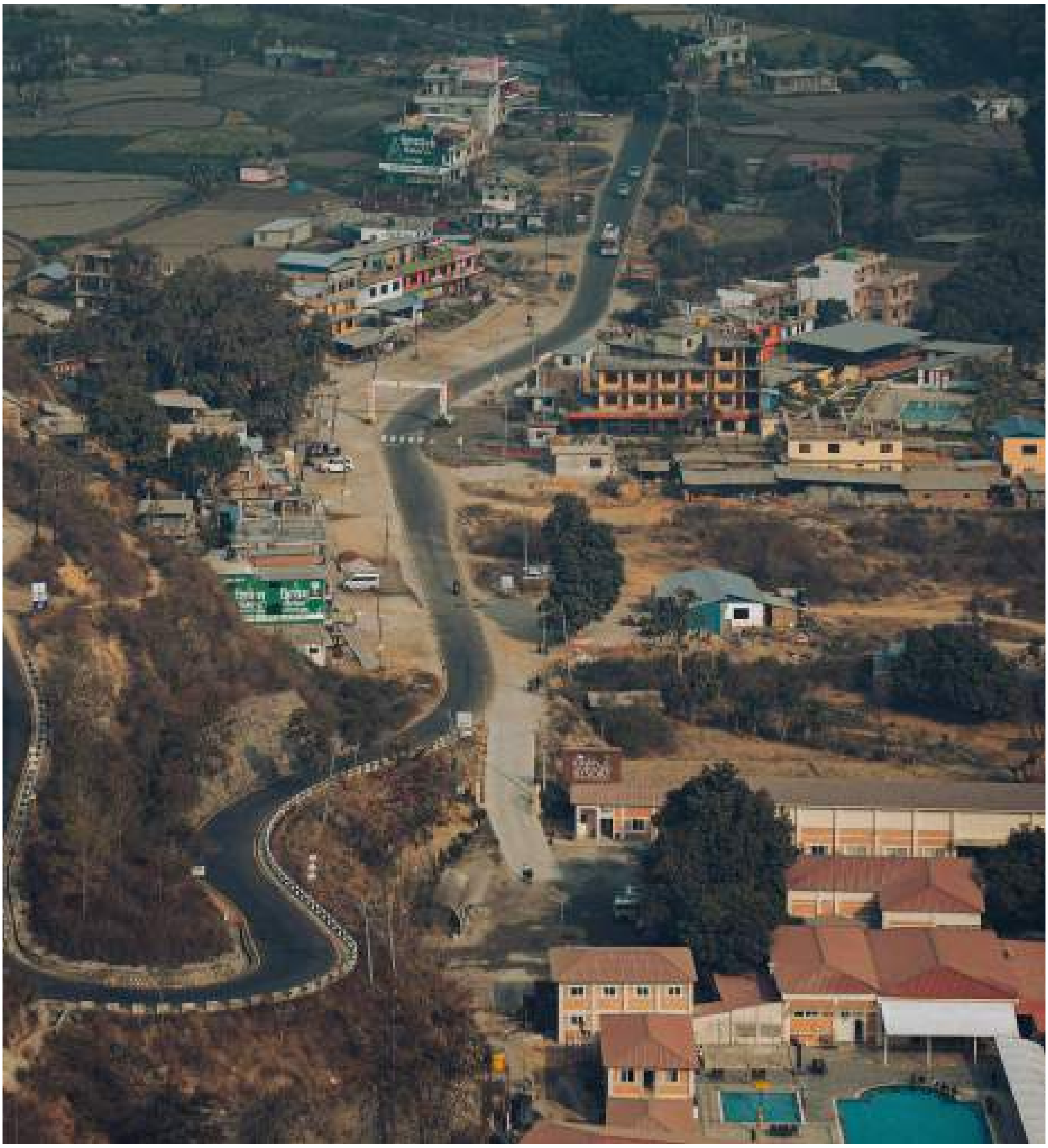
Figure 2.6: Road Sector Estimated Damages from Past Disasters



Source: Data compiled by authors

Fiscal Impact

Recurrent disasters and the COVID-19 pandemic have significantly strained Nepal's public finances. Major shocks - from earthquakes and annual monsoon floods to the pandemic-forced the government to increase emergency response spending and reconstruction outlays, even as economic disruptions undermined revenue collection (World Bank, 2021). For example, the cumulative cost of disasters in 2008–17 (including the 2015 earthquake and 2017 floods) exceeded 37 percent of GDP. These shocks widen the gap between unplanned recovery expenditures and revenue inflows, often leading to the reallocation of funds from development programmes. The resulting heightened fiscal pressure threatens long-term economic stability, similar to the situation in Fiji. Nepal's experience underlines the importance of establishing fiscal buffers and disaster-risk financing measures to handle such recurrent shocks.



Revenue Trends

Nepal's government revenues reflect a pandemic-driven decline followed by a strong rebound and recent volatility. Total revenue (tax and non-tax) slightly declined at the onset of COVID-19, from approximately NPR 829 billion in FY2018/19 to NPR 793 billion in FY2019/20. However, a robust recovery ensued: revenues surged to NPR 935 billion in FY2020/21 and further to NPR 1,066 billion in FY2021/22, surpassing pre-pandemic levels. This was driven by a rise in tax receipts as economic activity (especially imports and consumption) rebounded. A temporary decline occurred in FY2022/23 (down to NPR 957 billion amid import restrictions), but by FY2023/24, revenues increased again to approximately NPR 1,058 billion (Radio Nepal, 2025).

Tax revenue makes up the majority of Nepal's revenue. It rose from around NPR 613.4 billion in FY2019/20 to NPR 985.4 billion by FY2021/22, before moderating to NPR 944.6 billion in FY2023/24. This pattern shows initial pandemic losses followed by a vigorous recovery peaking in FY2021/22, marking a high point and then a slight decline afterward. Non-tax revenue (such as fees, dividends from state enterprises, and other charges) initially dropped during the pandemic, falling from about NPR 92.1 billion in FY2019/20 to NPR 63.9 billion in FY2020/21. In the subsequent years, non-tax inflows recovered and even grew, reaching roughly NPR 115.1 billion by FY2023/24 (Financial Comptroller General Office, 2024). This latter increase likely results from one-time receipts or policy changes (such as larger profit transfers from the central bank or state-owned companies). Meanwhile, foreign grants comprise a small part of the revenue but surged during the crisis period nearly doubling from approximately NPR 7.5 billion in FY2019/20 to about NPR 13.9 billion in FY2020/21 as donors provided COVID-19-related aid (Ministry of Finance, Government of Nepal, 2023). Grant inflows have since returned to more typical levels.

Sources of Revenue

The Government of Nepal's revenue mainly comes from taxes, which in FY2023/24 accounted for approximately 89 percent of total income. Major tax categories include taxes on goods and services (notably value-added tax or VAT and excises) and taxes on income and profits; taxes on international trade (import duties and tariffs) are also significant given Nepal's import-dependent consumption base. Non-tax sources (around 11 percent of FY2023/24 revenue) include dividends, interest, service fees, fines, and other miscellaneous receipts. Nepal's revenue composition shows a strong dependence on import-related taxes this is a structural challenge because external shocks (such as trade disruptions or changes in commodity prices) can directly impact revenue collection.

Public Debt Trajectory

Nepal's public debt has steadily increased over the past five years. Government debt grew from about NPR 1.43 trillion in FY2019/20 to NPR 2.43 trillion in FY2023/24 a roughly 70 percent rise. (In dollar terms, this increased from about $11–12 billion to over $19 billion of debt outstanding.) Each year during this period, the debt stock grew in absolute terms. The most significant increase occurred during the peak of pandemic response: for instance, public debt rose from NPR 1.74 trillion in FY2020/21 to NPR 2.01 trillion in FY2021/22. This trajectory reflects the government's reliance on borrowing to finance larger budget deficits, support economic relief and recovery efforts, and maintain essential public services amid revenue shortfalls. Notably, Nepal has tapped concessional external loans (from development partners like the World Bank's IDA and the Asian Development Bank or ADB) along with increased domestic borrowing to meet its financing needs (Ministry of Finance, Government of Nepal, 2023). While Nepal's debt remains below the levels of some peers, the debt-to-GDP ratio has risen from about 34 percent in 2019 to about 47 percent by 2023 (Country Economy.com, 2023), reversing a long-term trend of prudent debt levels. This upward debt trajectory underscores growing fiscal pressures and the cost of crisis response on the government's balance sheet.

Fiscal Health Context

The widening gap between Nepal's revenues and debt is a central fiscal concern. In FY2023/24, total government revenue stood at roughly NPR 1.06 trillion (approximately $8.3 billion), while public debt exceeded NPR 2.43 trillion (about $19–20 billion), which is more than double the annual revenue. Even though revenue collection has rebounded post-pandemic, high debt levels and continued deficit financing indicate a structural imbalance that could threaten long-term fiscal stability. Nepal's fiscal position thus faces the dual challenge of increasing income while containing debt. Strengthening domestic revenue mobilization (for example, broadening the tax base beyond imports and improving tax compliance) will be crucial. On the expenditure side, improving efficiency and absorption—especially in development projects—can help ensure funds are used effectively without persistent overruns. Importantly, debt sustainability will require prudent management: Nepal must balance concessional external borrowing and domestic debt to keep debt service burdens manageable. As the country progresses into the post-pandemic period, focusing on fiscal consolidation measures, economic diversification (to make revenue less vulnerable to external shocks), and disaster risk reduction financing is essential to restore fiscal health. These steps will help Nepal navigate towards a more resilient and sustainable fiscal path in the coming years.

Table 2.1: Historical data on GDP, total budget, disaster effects, and disaster response budget in Nepal since 2011

Year	GDP (million $, current values)	Total budget (million $, current values)	Budget for disaster response (NDRRMA budget allocation) million $	Major disaster	Total effects (damages and losses, million $, current values)	Damage to roads (public source datasets)	Damage to energy (public source datasets)
2011	21,685	4,675.5		Floods and landslides	13.8	NA	NA
2012	21,703	4,750.7		Floods and landslides	15.9	NA	NA
2013	22,161	4,602.3		Floods and landslides	23.4	NA	NA
2014	22,722	5,264.5		Floods and landslides	171.1	NA	NA
2015	24,361	6,212.7		Earthquake	7,100.8	172.68	179.01
2016	24,524	7,705.4		Floods and landslides	26.4	NA	NA
2017	28,972	9,875.9		Floods and landslides	571.7	27.68	2.07
2018	33,112	11,685.6		Floods and landslides	39.7	NA	NA
2019	34,186	11,905.1		Floods and landslides	42.6	11.32	NA
2020	33,434	13,113.5	2.1	Floods and landslides	32.2	17.11	NA
2021	36,927	12,626.4	17.1	Floods and landslides	569.7	25.69	85.62
2022	40,828	13,270.8	9.3	Floods and landslides	22.6		64.4

Source: Data compiled by authors

The combined impact of disaster-related spending, pandemic-driven revenue volatility, and increasing borrowing needs has widened Nepal's fiscal gap, threatening its long-term economic resilience. Key trends are as follows:

Increase in debt burden

Nepal's debt-to-GDP ratio increased from about 34 percent in 2019 to about 47 percent in 2023, as the government heavily depended on both concessional external borrowing and domestic debt to finance pandemic response and disaster recovery.

Diversion of developmental funds

Resources earmarked for infrastructure and development projects are frequently reallocated to finance post-disaster relief and reconstruction, which slows progress on essential long-term investments.

Dependence on external support

Although tax revenues remain Nepal's dominant source of income, the country relies on foreign grants and concessional loans during crises. These flows, though vital, are often insufficient and unpredictable, leaving fiscal gaps unaddressed and adding to debt accumulation.

Chapter 3

Institutional Frameworks and Provisions for Financing Post-Disaster Losses

Institutional Frameworks and Provisions for Financing Post-Disaster Losses

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

Institutional Framework for Disaster Risk Management

The Disaster Risk Reduction and Management Act 2017 (NDRRMA, n.d.) delineates the roles and responsibilities of the three levels of government in Nepal for disaster risk reduction and management. At the federal level, it established the Disaster Risk Reduction and Management (DRRM) National Council, Executive Committee, and NDRRMA. The first amendment of the DRRM Act in 2019 also includes a provision for a Provincial Disaster Management Council (Chapter 6, Clause 13a in NDRRMA, n.d.). Furthermore, it details the structure and functions of Provincial Disaster Management Executive Committees. The act also stipulates a structure (namely, a Disaster Management Committee) and

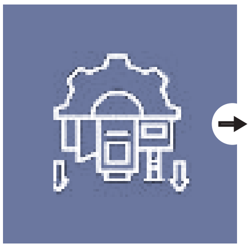
DRRM functions for each local government. Local governments are additionally guided by the Local Government Operationalization (LGO) Act 2017 (Oxford Policy Management, n.d.), which creates disaster management structures and functions for each local government and its ward units. The DRRM Act established the NDRRMA, which oversees and executes DRRM-related functions nationwide. The NDRRMA plays a central role in DRRM in Nepal by steering and coordinating the processes and actions on all aspects of DRRM to achieve disaster resilience. The DRRM Regulations 2017 further elaborate on the functions of different government decision-making mechanisms in accordance with the provisions of the DRRM Act. The Government of Nepal has approved the National DRRM Policy and Disaster Risk Reduction National Strategic Action Plan 2018-2030 (DP Net Nepal, 2017), which provides a comprehensive planning framework for DRRM, covering key priority areas and guiding government agencies and stakeholders in meeting their targets through appropriate processes.

Disaster Risk Financing Mechanisms in Nepal

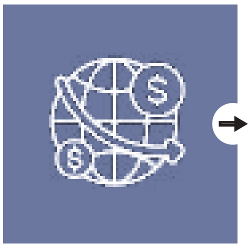
The DRRM Act and Rules make a provision for the determination and implementation of instruments and procedures for disaster risk transfer, including insurance and social security. They also provide for the establishment and operation of disaster management funds at various levels to ensure effective relief and recovery of loss or damage resulting from disasters.

The National Disaster Risk Financing Strategy, 2020, aims to integrate disaster risk management and risk transfer instruments across the public, private, and individual levels in financial risk management (DRR Portal, n.d.). Some key highlights of the scope of the strategy, directly affecting the budgetary provisions for disaster loss and damage, include the following:

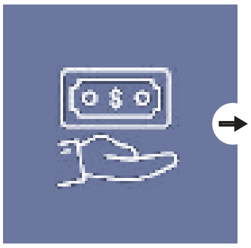
Establish a catastrophe fund to cover catastrophic losses exceeding the initial coverage transferred to insurance for disasters affecting public service infrastructures, especially historical, religious, and cultural heritage sites, as well as sovereign liabilities.



Arrange liquid financial resources, such as reserves, catastrophe bonds, contingent credit, insurance-linked securities, and other available disaster management financing instruments at the onset of a catastrophe.



Ensure the adoption of pre-arranged, well-planned protection measures like insurance and reinsurance to maintain the financial stability of banks, insurance companies, financial service providers, and cooperatives in managing their financial risks during a disaster.



Establish and operate a pre-arranged financing mechanism.

In 2021, the DRF National Strategy Implementation Plan 2078 (2021) was drafted (PreventionWeb, 2020). The plan outlines short-term, medium-term, and long-term activities to achieve the main objectives in disaster risk assessment, disaster risk reduction, financial management, and social security sectors as specified in the strategy.

The implementation plan presents the Government of Nepal's risk layering approach to DRF, considering the frequency, severity, and financial impact of disasters, and matching these events with appropriate DRF instruments. For any risk transfer instruments to be developed such as catastrophe bonds, risk pools, and insurance the implementation plan emphasizes the importance of justification through cost-benefit analyses and available resources. Along with cost-benefit analyses, six additional criteria must be met when developing DRF instruments, including adhering to legal requirements, coordinating responsibilities with all levels of government, conducting feasibility studies with cost estimates, following government procurement processes for service providers, employing a phased approach to implementing market-based financial instruments, and coordinating with relevant government agencies on annual budgets and resource mobilization.

The implementation plan includes many items that require various stakeholders across the public, private, and development sectors to take responsibility. As the leaders and managers of this plan, NDRRMA has encouraged stakeholders, especially development partners, to coordinate and align their activities (United Nations Development Programme, 2024).

Historical Perspective of Disaster Risk Financing

The National Calamity Relief Act (1982) emphasized relief efforts in disaster-affected areas, established the District Disaster Relief Committee and Local Disaster Relief Committee, and created the Natural Calamity Aid Fund.

After a major earthquake in 1988, a shift in disaster paradigm was observed, from response and recovery to disaster risk reduction. The Nepali government, in collaboration with the Japanese government, established the Disaster Prevention Technical Centre (DPTC) at the Ministry of Water Resources (MoWR) in 1991. Japan International Cooperation Agency (JICA) funded this initiative until 1999, aiming to enhance the government's capacity to manage with hazards through technology and training support. Subsequently, the Department of Water Induced Disaster Management was established in 2000, along with the National Disaster Fund for Relief and Rehabilitation established through the 11th FYP.

In 2010, Nepal started the process of developing Nepal prepared the National Adaptation Programme of Action (NAPA), aiming to attract substantial funding from the adaptation fund and other international donor agencies for climate change adaptation and to reduce the impact of climate-induced disasters.

The Government of Nepal initiated the Nepal Climate Change Support Programme (NCCSP), and more than 100 Local Adaptation Plans of Action (LAPA) were implemented in 14 districts. The climate change policy ensured that 80 percent of NCCSP be allocated at the local level for implementation.

After the 2015 earthquake, Nepal's disaster management shifted towards disaster risk reduction and recovery. The official development assistance expenditure increased by 72 percent between 2014 ($884 million) and 2015 ($1225 million), focusing on disaster relief and various other efforts on disaster risk reduction (DRR).

A new Disaster Risk Reduction and Management (DRR&M) Act, which came into force in 2017, aligns with the new constitutional amendments for federalized local-level governance. The DRR&M Act is to be implemented by the independent DRR&M authority that will operate at different levels of governance.

The 2018 National Policy for Disaster Risk Reduction aims to establish a disaster management fund at the federal, provincial, and local levels.

Current Disaster Risk Finance Mechanism

Nepal relies on various types of financing, including central and district-level disaster relief funds, a government allocation fund, and donor funding.

Prior to 2017, the Ministry of Home Affairs (MOHA) administered the Natural Disaster Relief Fund, a federal-level fund. After the enactment of the National Disaster Risk Reduction and Management Act, the MOHA renamed the National Disaster Relief Fund to the Central Disaster Management Fund. It was intended to be transferred to the NDRRMA; however, management of the NDRRMF still remains with MOHA. According to 2022 data, the National Disaster Fund has more than NPR 1 billion (roughly $9 million), accumulated over the years following allocations by the Government of Nepal.

As per the DRRM Act, 2074, Clause 22 provisioned a disaster management fund at the central level managed by NDRRMA. Likewise, Clause 23 also established separate disaster management funds at the provincial, district, and local levels. While provinces have created such funds, not all local levels have done so.

The DRRM Act did not discontinue the Prime Minister's Disaster Relief Fund (PMDRF), which is mandated by another Act and established in 1988. Funds may come from multiple sources, approved by the Ministry of Finance and audited annually by the Auditor General. There are 77 district disaster management funds managed by the district administration office, under MoHA, with expenditures approved by the District Disaster Management Committee (DDMC).

The National Disaster Risk Financing Strategy, 2020, aims to allocate financial resources to minimize disaster damage, improve post-disaster resilience of individuals, society, and the nation, and realize the concept of 'Build Back Better and Stronger'.

Ex Ante Disaster Risk Financing Mechanisms

The Government of Nepal has limited *ex ante* DRF instruments in place. Contingent budget allocations are limited relative to the total public expenditure of NPR 1 billion (approximately $8.4 million) per annum. All district treasuries are allocated about NPR 1 million ($8,400) to respond to disasters such as floods and landslides (Asian Development Bank, 2019). In 2020, the World Bank approved a $50 Catastrophe Deferred Drawdown (Cat DDO) with a soft trigger of a declaration of a State of Disaster ('upon imminent or occurring adverse natural event') by either MoHA or, in the case of a health-related shock, the Ministry of Health and Population (World Bank, n.d.).

Table 3.1: NDRRMA budget allocation since the DRRM Act of 2019

Year	Allocation		Actual Expenditure	
	(million NPR)	(million $)	(million NPR)	(million $)
22-23	1150	9.3	-	-
21-22	2000	17.1	1630	14.0
20-21	250	2.1	400	3.4
19-20	0	0	0	0

Insurance

The Crops and Livestock Insurance programme was introduced in Nepal after the Insurance Board formally issued the Crops and Livestock Directives, 2013, on 14 January 2013. The total sum assured under livestock and fishery insurance policies stands at NPR 12,741,828,831, while crop insurance totals NPR 869,008,340, bringing the total of agriculture insurance programmes to NPR 13,610,837,171 so far (World Bank, n.d.).

Insurance companies have introduced the Integrated Property Insurance Programme and the Micro-insurance Programme in accordance with the legal framework set by the Insurance Board, the regulatory body. The government of Karnali Province has launched the Natural Disaster Risk Group Insurance Programme. The coverage limit of this insurance is NPR 200,000, and approximately 1.7 million people are covered. The Infrastructure Security Insurance Programme has been initiated to insure large physical infrastructures and hydropower projects during their construction phase.

A specialized disaster microinsurance and micro-financing product for women is available through the Centre for Self Help Development at an annual cost of NPR 100. In exchange for the premium payment, the family of a female policyholder receives NPR 5000-6500 if the policyholder dies due to a disaster, NPR 2500- 3250 if her husband dies in a disaster, and up to NPR 6500 for repairing or rebuilding dwellings that collapse during a disaster.

Post-Disaster Financing Sources of the Country

The Prime Minister's Disaster Relief Fund

The Prime Minister's Disaster Relief Fund serves as Nepal's primary source of financial resources for disaster relief efforts. The fund, also known as the Prime Minister's Fund, is used for rescuing, treating, providing relief, and rehabilitating victims, as well as restoring physical infrastructure damaged by natural hazards and calamities. After major disasters, the government appeals internationally for donations to the fund.

Table 3.2: Funds in the PM DRF, and allocation for expenditure in the past few years (DP Net 2019)

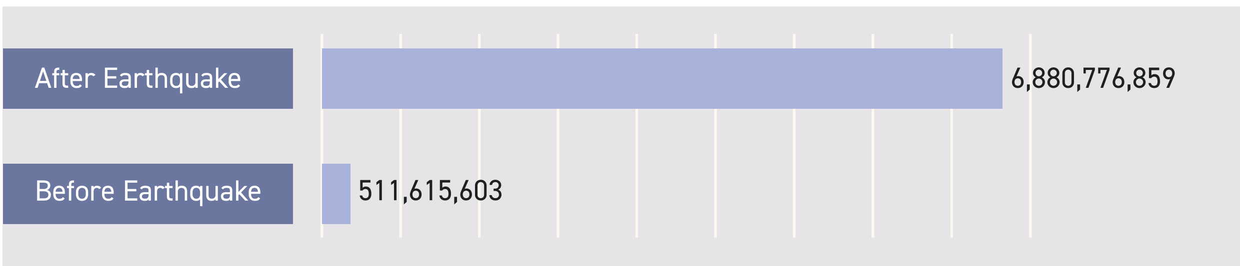
Year	Funds in PM DRF		Fund allocated to NDRRMA for Disbursement	
	(Million NPR)	(Million $)	(Million NPR)	(Million $)
2023	4100	35.1	-	-
2022	4600	37.1	1000	7.5
2021	3100	23.5	0	0

Source: Government of Nepal, Ministry of Home Affairs (2019)

The 2015 earthquake received substantial contributions to the PM DRF from international support.

Prior to the disaster, the fund remained at NPR 6.8 billion ($0.5 billion). Post the earthquake, the fund grew manyfold to over NPR 800 billion ($6.8 billion).

Figure 3.1: Contributions to PM DRF Funds (NPR) Before and After the 2015 Earthquake



Central Disaster Management Fund and District Disaster Management Funds

The funds under the Central Disaster Management Fund (CDMF) are managed by a committee, headed by the Vice Chairperson of the National Planning Commission, and includes the secretaries of eight ministries. This committee must reach a unanimous decision on funding before funds are released to the Office of the Chief District Officer (which coordinates the District Relief Fund) via the MOHA. The Auditor General of Nepal audits expenditures from both the Central Relief Fund and the District Relief Fund to ensure maximum accountability and transparency (United Nations Development Programme, 2017; UNICEF Nepal, n.d.). Refer to Table 3.3.

Table 3.3: Disbursement from CDMF to DDM fund

Year	Disbursement to DDM fund (NPR)	Disbursement to DDM fund ($, million in current values)
2018	167,449,425	1.5
2017	1,099,751,796	10.4
2016	9,157,939,759	86.1
2015	10,837,872,745	108.9

Source: UNDP (2017) and UNICEF Nepal (n.d.)

Disaster Victim Rescue and Relief Standards, 2007

The Disaster Victim Rescue and Relief Standards, 2007 (Sixth Amendment 2017), outline the provision of emergency rescue and relief distribution. According to the standards, the grieving family of each victim killed in the disaster receives NPR 100,000 in relief. If a household cannot sustain its daily livelihood due to damage to housing and food supplies following a disaster, it will receive an immediate relief of NPR 10,000. When a family is displaced due to the complete destruction of their home, they are entitled to NPR 50,000 and must submit an application to the Central Disaster Management Committee for additional relief as required. Similarly, persons injured in disasters will be treated free of charge at government hospitals.

Post-Disaster Budget Reallocations

Post-disaster budget reallocations mainly focus on halting capital works programmes where contracts are not yet active. Funds previously allocated to capital works programmes that have not yet begun active contracting are then re-allocated to post-disaster recovery.

International Assistance

Nepal calls for international assistance in the event of major disasters. Following the 2015 earthquake and its aftershocks, pledges totalling $4.4 billion were made at the International Conference on Nepal's Reconstruction in June 2015 (Ministry of Finance, 2015). Of the total amount, donors pledged $2.2 billion in grants and $2.2 billion in loans. ADB provided $231 million in disaster-response assistance after the 2015 earthquake (Ministry of Finance, Government of Nepal, 2015).

Nepal Central Emergency Response Fund

In an innovative approach to managing the effects of severe monsoon flooding in Nepal, the United Nations is leveraging predictive analytics and meteorological data to forecast upcoming major monsoon floods, assess likely impacts and respond proactively before possible disaster strikes.

Using hydrological forecasts, a two-step trigger system was developed for two river basins in Nepal the Karnali and Koshi basins consisting of a readiness trigger and an action trigger. Once a predetermined waterflow threshold is projected to be breached seven days ahead, the first trigger activates the release of funding to cover critical readiness activities. Upon confirmation of the second trigger, recipient agencies begin delivering the Central Emergency Response Fund (CERF) provided by the UN to communities prior to peak flooding.

The fund is allocated to nongovernmental organization (NGO) partners and Red Cross/Red Crescent Partners, including UNICEF, the World Food Programme (WFP), the United Nations Population Fund (UNFPA), the World Health Organization (WHO), and the United Nations Entity for Gender Equality and the Empowerment of Women (UN Women). Refer to Table 3.4.

Table 3.4: CERF allocations in the past few years

Year	Agency receiving the funds from CERF	Amount ($)
2022	UN Women	127,090
	UNFPA	551,175
	WFP	2,508,426
	Total	**3,186,691**
2021	UN Women	53,582
	UNFPA	353,397
	UNICEF	532,408
	WFP	1,864,626
	WHO	398,288
	Total	**3,202,301**
2017	FAO	400,003
	IOM	450,149
	UNDP	451,124
	UNFPA	244,474
	UNICEF	741,960
	WFP	1,499,849
	Total	**4,787,881**
2016	FAO	159,133
	UNICEF	225,004
	WFP	1,558,862
	Total	**1,942,999**

Trend Analysis of Disaster Risk Financing in Nepal

The available evidence suggests a mixed pattern for Nepal's DRF over the past decade. While overall allocations have increased since the establishment of the NDRRMA, the scale and consistency of funding remain limited compared to the country's recurrent disaster losses.

Allocations to NDRRMA show an upwards but uneven trend. After no budget in FY2019/20, allocations increased to NPR 250 million in FY2020/21 and then jumped to NPR 2 billion in FY2021/22, before moderating to NPR 1.15 billion in FY2022/23. Actual expenditures have not always aligned with allocations, highlighting persistent challenges in absorptive and disbursement capacity. Refer to Table 3.5.

Table 3.5: DRR budget allocation and expenditure vs. estimated damages over the past few years

Year	GDP (Million $)	Total budget (Million $)	Budget for disaster response (NDRRMA budget allocation)	Budget expenditure on disaster response	Major disaster	Total effects (Million $, current values)	Damage to roads	Damage to energy
2011	33,434	13,113.5	2.1	3.4	Floods and landslides	32.2	17.11	NA
2012	36,927	12,626.4	17.1	14	Floods and landslides	569.7	25.69	85.62
2013	40,828	13,270.8	9.3	NA	Floods and landslides	22.6	NA	64.4

The Prime Minister's Disaster Relief Fund, Nepal's main post-disaster financing vehicle, demonstrates volatility. The fund grew significantly after the 2015 earthquake, driven by international contributions, but in more recent years, it has stabilized at around NPR 3–4.5 billion. This stability indicates some degree of continuity in financing, although the scale falls far short of the needs generated by major floods, landslides, and earthquakes.

At the subnational level, resources from the CDMF and DDMF have sharply contracted. Disbursements exceeding NPR 10 billion in 2015 fell to less than NPR 200 million by 2018, reflecting a clear downwards trend in district-level funding flows.

Overall, the trend indicates a financing system that remains highly reactive and dependent on external support. Incremental gains-such as increased NDRRMA funding, insurance initiatives, and contingent credit-lines-signal progress, but these remain modest compared to the scale of recurrent losses. The overarching pattern is one of underfunding and volatility, with international assistance remaining central role to closing financing gaps.

Chapter 4

Economic Modelling

Economic Modelling

To evaluate the economic impact of disasters in Nepal, a country-level panel model approach was adopted. The analysis relied on fiscal data from the World Bank and disaster event data from the EM-DAT International Disaster Database, covering the period from 2000 to 2019 (Centre for Research on the Epidemiology of Disasters, n.d.). The chosen timeframe reflects the availability of consistent data while avoiding distortions caused by the COVID-19 pandemic. To enable cross-country comparison, the model included 69 middle-income countries, based on the assumption that income level affects both disaster impacts and fiscal responses.

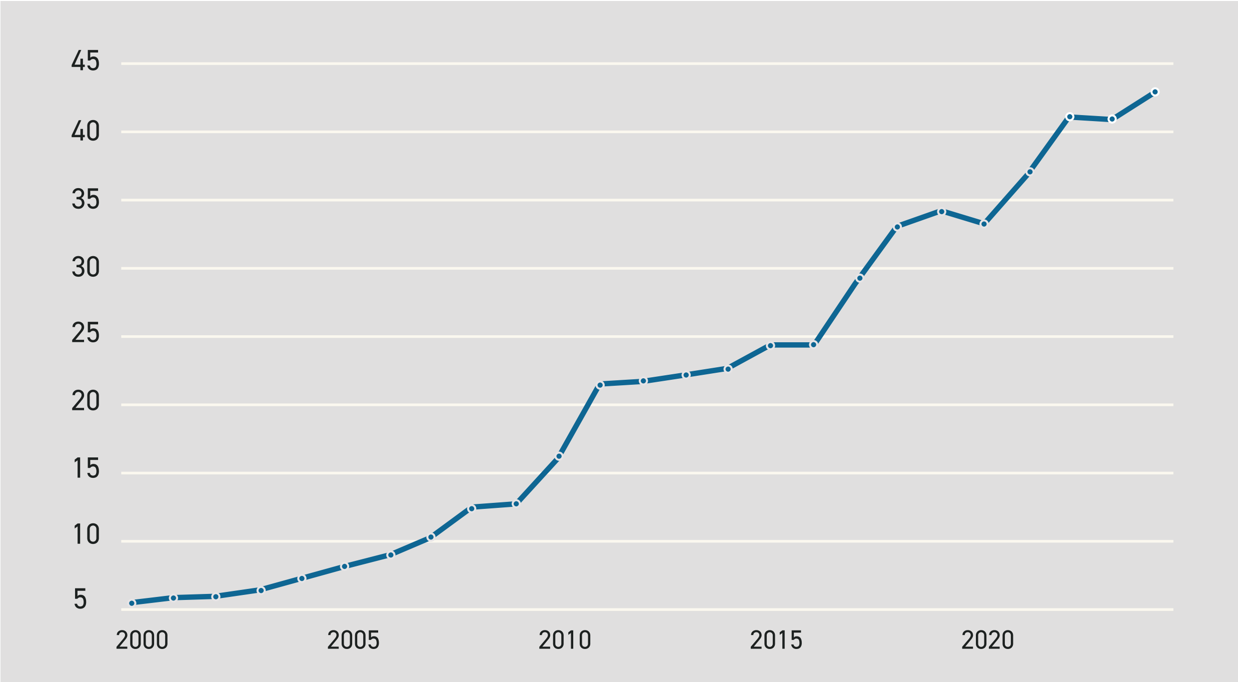
Fiscal variables included government expenditure, central government debt, and revenue (excluding grants), all expressed as a percentage of GDP. As World Bank data are published in ratios, the annual GDP in current $ was used to convert them into absolute values. A first-order differencing method was then applied to remove autocorrelation across years, ensuring a clearer relationship between disaster shocks and fiscal outcomes. By using GDP from the year prior to disaster events, the model avoided distortions caused by sudden output losses during disaster years.

Disaster variables were sourced from EM-DAT and focused on sudden-onset hazards such as floods, flood-induced landslides, and cyclones. Extremely large but infrequent events, such as earthquakes and tsunamis, were excluded from the panel dataset to prevent them from overshadowing the effects of more frequent disasters. Nonetheless, the model's findings remain applicable to large events such as the 2015 Gorkha earthquake. Missing data points in EM-DAT were addressed using quantile imputation, which preserved distributional characteristics and reduced bias in estimating people affected, fatalities, and damages.

To better capture disaster severity, the 'Life Years Lost' (LYL) index was applied. Adapted from the WHO's Disability Adjusted Life Years (DALYs), this metric integrates fatalities, people affected, and financial damages into a single severity score. For Nepal, the average annual LYL during 2000–19 was 154,755, with the 2015 earthquake and the 2004 floods and landslides being the most severe events. In parallel, disaster-related damage was also expressed as a percentage of GDP to provide a more direct measure of economic disruption.

Finally, deviations in GDP from fitted pre-disaster trendlines were examined to identify sector-specific impacts of major events. For Nepal, this approach is applied to the 2015 Gorkha earthquake, during which GDP growth dropped significantly, and to severe flood years such as 2004 and 2017. These deviations help reveal which sectors, such as agriculture, construction, and tourism, were most affected by shocks, providing a clearer view of how disasters disrupt Nepal's growth trajectory (Figure 4.1).

Figure 4.1: Total GDP per year (2000–23)



Source: World Bank Group

Economic Model and Data

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

Countries Included in the Model

The panel model covered 69 middle-income countries (IMF, 2023). Nepal, classified as middle-income, is included so its disaster–fiscal dynamics can be compared with peer economies.

Table 4.1: Summary of panel country sample (Middle-Income; n = 69)

Component	Details
Country Group	69 middle-income countries
Basis of Inclusion	Income classification (IMF, 2023)
Nepal's Status	Middle-income; included in panel

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

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

Fiscal Variables and Sources

Fiscal data was obtained from the World Bank for the period 2000–19. The indicators used were expense (percentage of GDP), revenue excluding grants (percentage of GDP), and central government debt (percentage of GDP). GDP in current $ was also included to convert percentage ratios into absolute values, enabling analysis of year-to-year changes through first-order differencing. These fiscal variables provided the basis for modelling how government finances respond to disaster shocks. Refer to Table 4.3.

Table 4.3: Fiscal variables and sources for Nepal

Component	Details
Source	World Bank
Indicators	Expense (% GDP), Revenue excl. grants (% GDP), Central Government Debt (% GDP), GDP (current $)
Coverage	2000–2019
Processing	Converted to absolute values; first-order differencing applied

Disaster Variables and Sources

Disaster data was obtained from the EM-DAT International Disaster Database for the same period, 2000–2019. The analysis focused on sudden-onset events—floods, flood-induced landslides, and cyclones while excluding rarer catastrophic events like earthquakes and tsunamis to avoid distortion. Three variables were included: fatalities, population affected, and monetary damages. To create a standardized measure of severity, these variables were combined into the LYL index, adapted from the WHO's DALY framework (Noy, 2016). Missing values were addressed using quantile imputation to maintain the statistical distribution of disaster impacts.

Table 4.4: Disaster variables and sources for Nepal

Component	Details
Source	EM-DAT (International Disaster Database)
Variables	Fatalities, Population Affected, Monetary Damages
Hazard Types	Floods, Flood-induced Landslides, Cyclones
Coverage	2000–2019
Derived Measure	Life Years Lost (LYL), adapted from WHO DALY (Noy, 2016)

Economic Modelling Results

The econometric analysis examined the relationship between disaster intensity and fiscal performance using two measures of disaster impact: LYL and total monetary damage (percentage of GDP). The results consistently indicated that government expenditure (percentage of GDP) increases significantly after disasters, while the effect on central government debt (percentage of GDP) was not statistically significant. In both models, the coefficients for debt were positive but not significant (p-values 0.38–0.50), suggesting that although debt levels tend to rise after disasters, the increase could not be confirmed at the 5 percent significance level. Conversely, expenditure was statistically significant (p-values 0.024–0.045), indicating that government spending reliably responds to disaster shocks.

To demonstrate the scale of these effects, Table 4.5 presents the estimated fiscal impacts for three scenarios:

- An average-intensity disaster (mean LYL = 154,755),
- A disaster one standard deviation above average intensity (LYL ≈ 433,269), and
- Two high-severity historical events the 2015 Gorkha earthquake (LYL = 3,213,590) and the 2004 floods and landslides (LYL = 1,219,080).

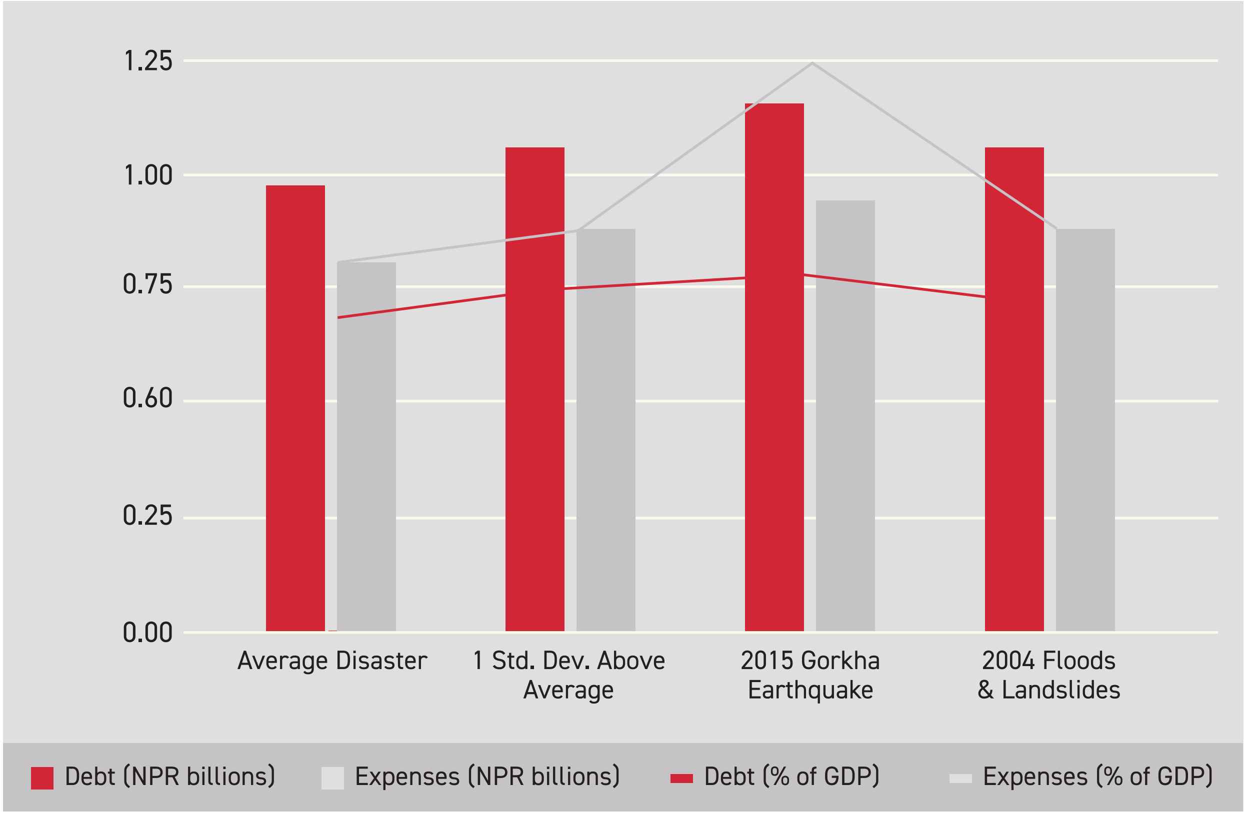
For each case, results are expressed as both a percentage change and the corresponding monetary change in Nepalese Rupees, based on 2019 fiscal values.

Table 4.5: Fiscal impacts of disasters in Nepal (average to high severity)

Event/scenario	Fiscal variable	Change (%)	Change (NPR)
Average Disaster	Debt (% of GDP)	0.11%	976,599,270
	Expense (% of GDP)	0.13%	808,598,800
1 Std. Dev. Above Avg.	Debt (% of GDP)	0.12%	1,060,737,744
	Expense (% of GDP)	0.14%	878,263,269
2015 Gorkha Earthquake	Debt (% of GDP)	0.125%	1,145,283,234
	Expense (% of GDP)	0.20%	948,264,736
2004 Floods & Landslides	Debt (% of GDP)	0.116%	1,063,997,800
	Expense (% of GDP)	0.14%	880,962,510

To visualize these findings, the results for average disasters, higher-than-average events, and two historically severe events (the 2015 Gorkha earthquake and the 2004 floods and landslides) are compared. Figure 4.2 presents the fiscal impacts both as a percentage of GDP (lines) and absolute monetary values (bars), highlighting the scale and variability of government expenditure and debt changes across different disaster severity levels. Bars represent the absolute change in central government debt and expenditure (NPR billions), while lines indicate the percentage change relative to GDP. Results demonstrate that government expenses consistently increase following disasters, with statistical significance ($p < 0.05$), whereas changes in debt were not statistically significant.

Figure 4.2: Modelled fiscal impacts of disasters in Nepal



The results showed that government expenditure (percentage of GDP) increased significantly following a disaster, but this effect did not last in the years immediately after. While there was no significant correlation between disaster intensity and the fiscal variables modelled, this does not necessarily mean that they are unaffected in the event of a disaster. It is possible that there are more localized impacts, but the aggregated data was not able to fully quantify these impacts.

The same applies to the time lag variables. This study found no long-term impact on Nepal's government expenditure. This indicates that the biggest fiscal impact occurs immediately after the disaster. While individual businesses and households may have experienced long-term economic impacts, these were not large enough to be visible at the country level. It is recommended that the Government of Nepal collaborate with the state statistics department and disaster recovery agencies to collect local-level data to quantify these smaller impacts.

Key Findings

Expenditure pressure :

Across all scenarios, expenditure rises more sharply than debt, underscoring the government's immediate fiscal burden for relief and recovery.

Magnitude of losses :

For high-severity events, fiscal expenditure increases by nearly **NPR 950 million** (~0.2 percent of GDP), highlighting the fiscal stress that disasters can impose on public finances.

Debt versus expense :

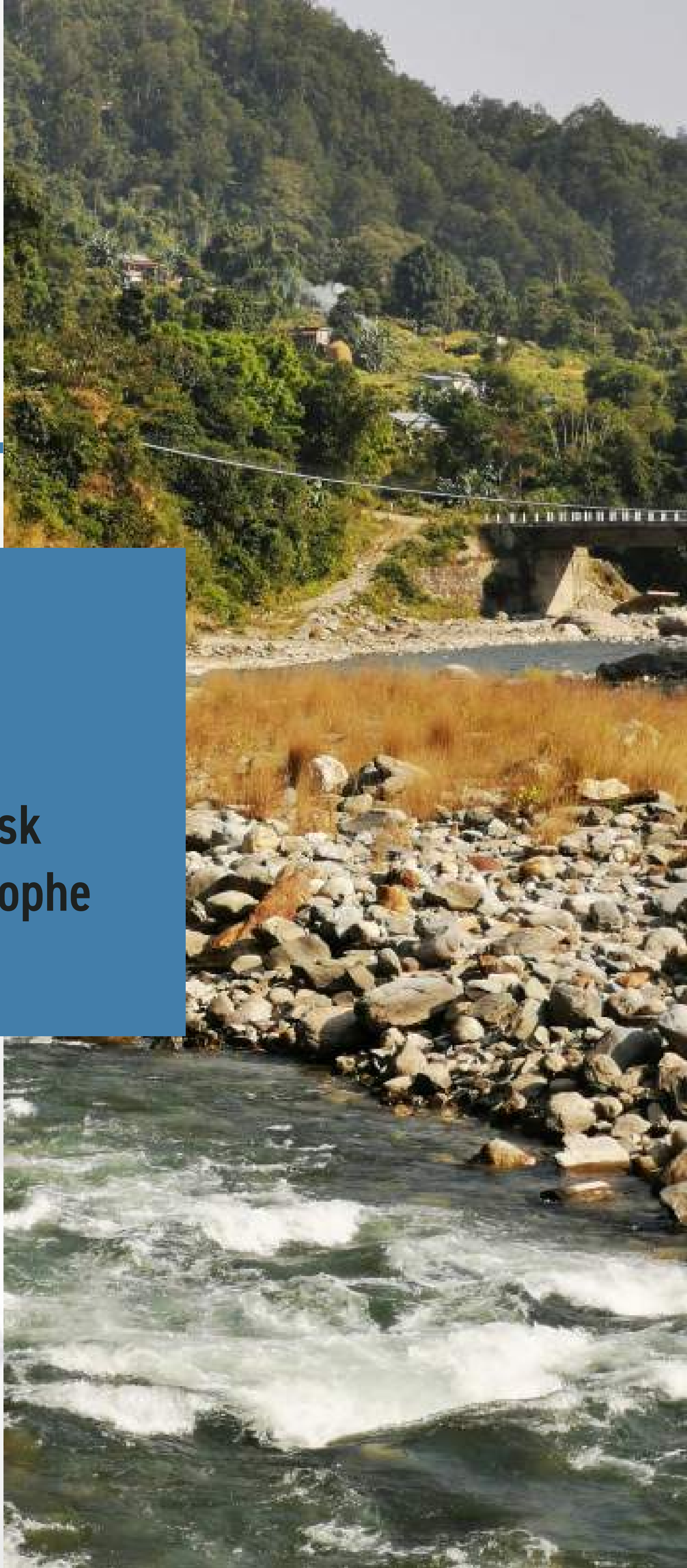
Increases in debt are generally smaller and less statistically significant than increases in expenditure, suggesting that post-disaster financing mainly relies on reallocation and aid rather than direct debt accumulation.

Immediate impact :

A dynamic panel model suggested that most fiscal impacts are realized within the year of the disaster, with limited carry-over effects into subsequent years.

Chapter 5

Probabilistic Assessments of Future Fiscal Risk through Catastrophe Modelling



Probabilistic Assessments 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 potential costs before a major disaster, we can plan and prepare for such events more effectively. This includes analysing the breakdown of losses that contribute to disasters, enabling a more tailored disaster risk finance strategy. This section of the report presents the results of catastrophe modelling used to assess the future impact of disasters on the energy and road sectors and their subsequent effects on the fiscal health of the state.

Hazard Models

For the FRA of Nepal, three hazards are considered: earthquakes, floods, and landslides. These natural hazards are represented as a collection of events. Each event is a single instance of the hazard (for example, a single tropical cyclone), which produces a certain intensity at the location of the infrastructure elements and has a specific probability of occurrence. The entire set of events (all the simulated tropical cyclones) accurately represents how each hazard might occur. In the following sections, we will describe the different hazard models used in this assignment.

Climate Models

To assess future fiscal risks, this study uses a set of hazard models that incorporate both climate-driven and geophysical processes. Projections from CMIP6 global circulation models and downscaled hazard models are employed to estimate the potential impacts of floods, landslides, and tropical cyclones under different emission scenarios, alongside a stationary seismic hazard model. These models provide the probabilistic hazard inputs needed for catastrophe modelling in Nepal, ensuring consistency with approaches applied in recent global and regional risk assessments.

Model for Flood and Landslide Hazards

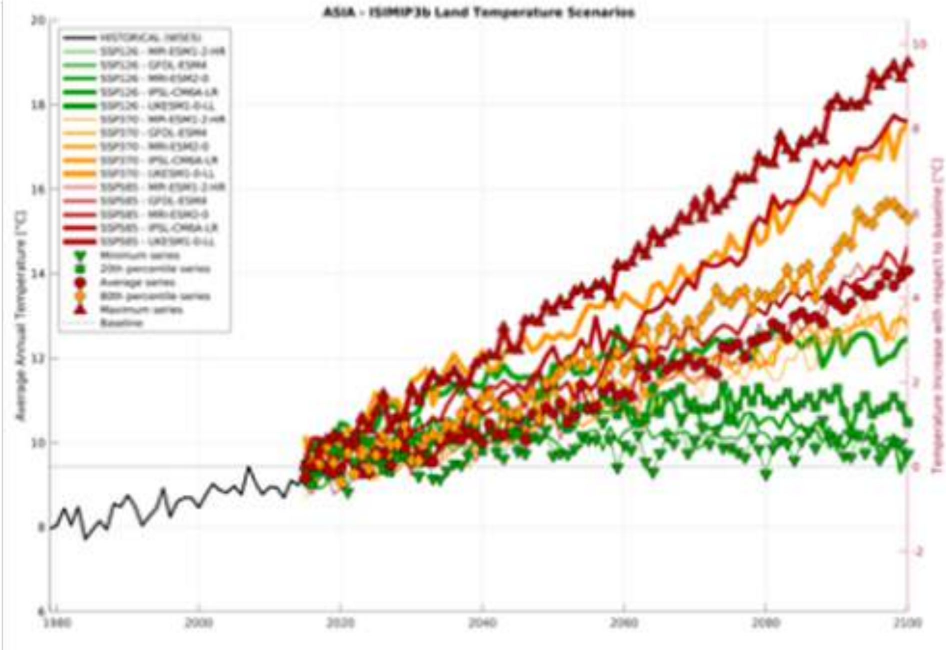
The climate models considered for this assignment are the same as those defined for the development of the GIRI model of CDRI **(Cardona et. al. 2023).** Multiple projections from Global Circulation Models included in CMIP6[2] were verified, including anthropogenic forcings expressed as combined scenarios of SSP (shared socio-economic pathways) and RCP (representative concentration pathways), as outlined by the IPCC (AR6). Figure 5.1 shows the spatial average of several future projections of surface temperature, up to 2100, obtained from the ISIMIP3b[3] database for Asia, compared to the average historical series obtained from the W5E5[4] dataset.

[2]Climate Model Intercomparison Project version 6.

[3]Available at https://www.isimip.org/gettingstarted/isimip3b-bias-adjustment/

[4]Available at https://www.isimip.org/gettingstarted/input-data-bias-adjustment/details/114/

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



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

Hydrometeorological phenomena are modelled using meteorological forcing (precipitation, temperature, etc.) from a historical period called Base climate, which corresponds to 1980–2010, a recent 30-year period as the climate norm. Climate projections are applied to modify the Base climate using the Delta method, which adjusts the meteorological forcing in the base climate to match the 30-year average of a projected future climate. From this modified forcing, hydrometeorological hazards are then recalculated.

Model for Tropical Cyclones Hazard

Cyclogenesis is a mesoscale process that requires high-resolution inputs from climate models. Therefore, not all climate models included in CMIP6 are suitable for cyclone hazard modelling. Only a few of the CMIP6 models have sufficient spatial resolution to project future cyclone tracks. These models are all part of the PRIMAVERA High Resolution Project within CMIP6. For this assignment, we are using four high-resolution[5] models: CMCC-CM2-VHR4[6], CNRM-CM6-1-HR[7], EC-Earth3P-HR[8], and HadGEM3-GC31-HM[9]. The mentioned models only consider an emissions scenario SSP5-RCP8.5; therefore, for tropical cyclones only, the model is built based on a single trajectory rather than two bounds of climate variation as is done for the other hydrometeorological hazards.

[5]In the context of climate modelling, high resolution refers to a spatial grid of 50 km in pixel size.

[6]Centro Euro-Mediterraneo sui Cambiamenti Climatici

[7]Centre National de Recherches Météorologiques. Meteo France.

[8]Earth Consortium

[9]Hadley Centre Global Environment Model

Flood Hazard Model

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

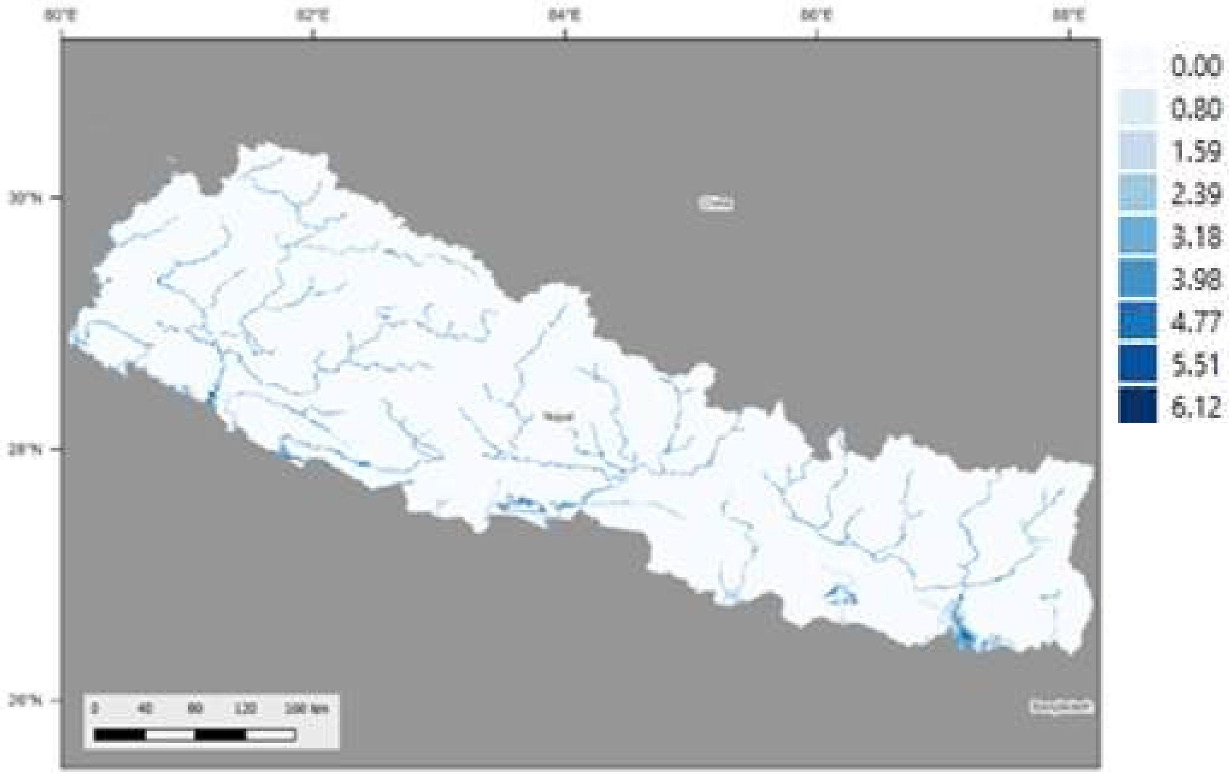
The model is based on defining inflows to different parts of the tributary basin upstream of various points along the main rivers and streams, to hydraulically move the flows within the channels. These inflows vary across the sub-basins that comprise the main channel basin. In this way, at an intermediate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

To develop a global flood model used for hazard assessment in Nepal, a comprehensive worldwide database of flow data was compiled from multiple sources. It includes nearly 8,000 gauging stations worldwide with long enough time series to enable statistical analysis of extreme values. Although data were collected daily, most were on a monthly scale; therefore, stochastic techniques were applied to rescale the time series to a daily scale while preserving their statistical characteristics. This algorithm was calibrated using regions with available daily time series.

Flood discharge magnitude is estimated using statistical methods applied to hydrological data from the region. The method used here is regional frequency analysis. The proposed methodology analyses statistical data from a homogeneous region identified using the index flood method (IFM) to estimate flood frequency at the site with the highest possible confidence, including very low-frequency quantiles. This approach allows the sample size to be increased by combining time series from homogeneous groups into a longer dimensionless time series, thereby reducing uncertainty in estimating outlier quantiles.

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

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

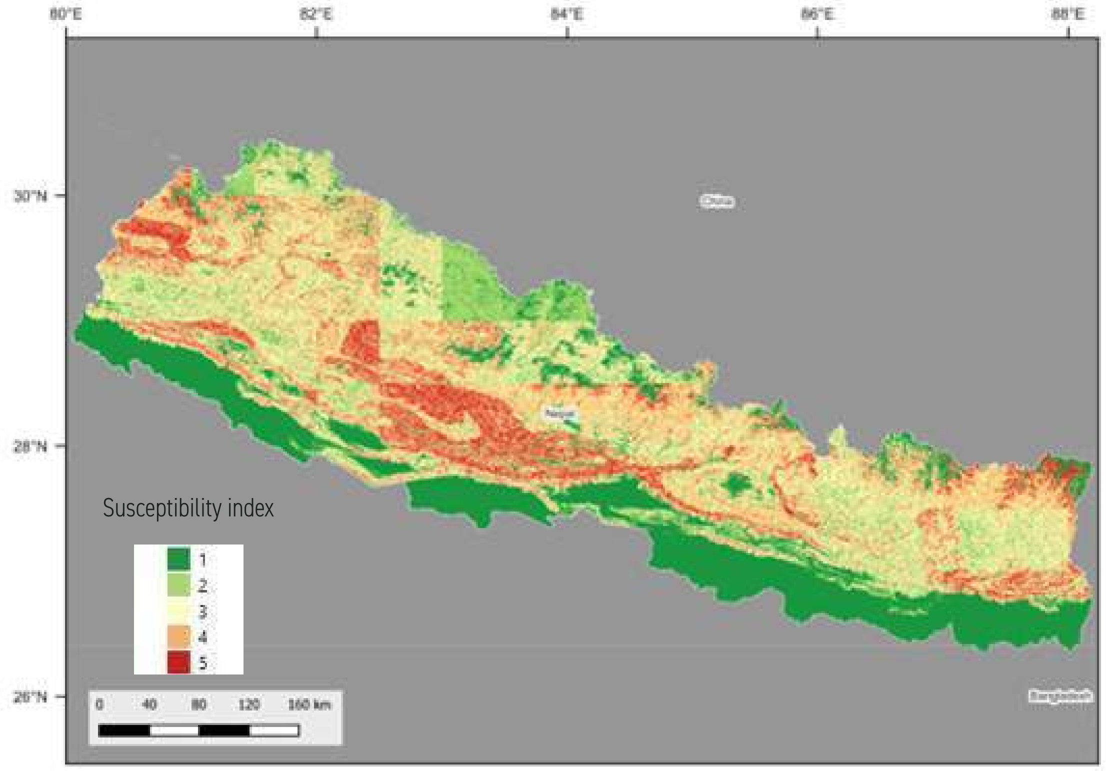


Landslides Hazard Model

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

The global landslide susceptibility was modelled by Nadim et al. (2023). Susceptibility is modelled heuristically based on slope, lithology, vegetation cover, and soil moisture. Each of these factors is assigned a susceptibility score (an integer number between 0 and 5) and weighted according to its expected impact 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 road density, are included to account for human influences on landslides. The susceptibility map has a spatial resolution of 30 m and is expressed as an integer number between 0 and 5. Further details on the model are provided in Nadim et al. (2023). Figure 5.3 shows the landslide susceptibility map for Nepal.

Figure 5.3: Landslide susceptibility of Nepal



Landslide hazard depends not only on susceptibility but also on triggering factors, which are external forces that locally increment instability, leading to a landslide event. In this assignment, such factors include excess rainfall and seismic acceleration. The rainfall trigger is obtained directly from climate modelling (see Section 3.1.1.1), and the earthquake trigger is simulated using the seismic hazard model (see Section 3.1.4). Nonetheless, landslide thresholds are required to define the corresponding triggering intensity. In this assignment, we have used the thresholds proposed by Nadim et al. (2023), presented in Tables 5.1 and 5.2.

Table 5.1: Rainfall threshold for landslide hazard

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

Source: Nadim et al. (2023)

Table 5.2: Seismic acceleration threshold for landslide hazard

Range of PGA	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 predicts the probability of a landslide according to the simulated triggering rainfall or seismic acceleration. It should be noted that landslides are assumed to be highly energetic events, which saturate the vulnerability of any exposed element and result in total loss. Therefore, vulnerability functions are not developed for this phenomenon.

Seismic Hazard Model

Seismic hazard is unrelated to climate and therefore considered stationary. For the FRA of Nepal, the global seismic-hazard model developed by Cardona et al. (2014) was used. This is the same model employed for the GIRI assessment of CDRI (Cardona et. al. 2023) and the GAR15 Global Risk Model. The model's spatial resolution is suitable for this assignment. This section provides a general overview of the model.

The seismic hazard at the bedrock level is calculated based on historical data recorded in seismic catalogues. Using this information, which relates to the magnitude and location of each earthquake's hypocentre, the intensity of events is calculated through a set of stochastic scenarios that are mutually exclusive and collectively exhaustive. Each scenario has a geographical distribution of probability. This process considers the attenuation of seismic energy with distance from the point of impact, in the surroundings where each event strikes. This evaluation thus gives us a curve of the probability of exceeding the acceleration at a point where certain exposed assets may be subjected. Given that the said curve is generated for each point within the calculation grid, it enables the creation of seismic hazard maps for various spectral ordinates and return periods-aligned with the dynamic structural response of the exposed structures. This input is fundamental to the probabilistic risk assessment of the exposed elements in countries with seismic hazards. An in-depth description of the seismic hazard model can be found in Cardona et. al. (2014).

Figure 5.4 displays an example of a seismic hazard map calculated for a 475-year return period of the peak ground acceleration at the bedrock level (i.e., Vs30[10]=1,100 m/s).

Figure 5.4: 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 constitute an infrastructure system, 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. It is common that some, or even all, of the three fundamental characteristics are not available in the information that exists within the country, which is why it is necessary to make estimates that represent or account for said inventory of exposed elements in an approximate way. In this assignment, exposure for Nepal is limited to the energy and roads sectors.

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

Energy Sector

In this assignment, the Energy sector refers to the existing infrastructure for the generation, transmission, and distribution of electricity within the territory. Oil and gas infrastructure, which some authors consider part of the energy sector, is not included.

The energy sector is therefore subdivided into three subsectors: generation, transmission, and distribution. Each subsector requires an independent exposure model that accounts for the unique characteristics of its elements. For example, elements in the generation subsector typically comprise power plants that vary greatly in terms of the type of energy they convert, their capacity, or the components that make up the facility. On the other hand, transmission lines, although diverse as well, are far more constrained in terms of the number of typologies to be considered. This makes the energy sector one of the most complex to engage in a risk assessment model.

Power generation in Nepal is diverse. According to data from WRI[11] and OSM[12] there is more than 2,000 MW of installed capacity, distributed among four main types of energy conversion, as shown in Table 5.3. Regarding transmission, Nepal has nearly 3,000 km of transmission lines. Table 5.4 shows the total length of transmission lines at different operational voltages.

Table 5.3: Installed capacity of the generation sector in Nepal

Source Energy	Capacity [MW]	[-]
Gas	2	0.1%
Hydro	1,669	67.5%
Other	767	31.0%
Solar (photovoltaic)	35	1.4%
Total general	2,472	

Table 5.4: Transmission lines voltages and lengths in Nepal

Voltage (kV)	Length (km)	[-]
<110	195	7.5%
110 - <220	1,870	72.2%
220 o >220	525	20.3%
Total	2,950	

[11] World Resources Institute
[12] Open Street Map

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

Generation

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

First, the raw data is debugged by removing elements that lack information about the energy source or generation capacity. Then, the data on energy sources is reclassified to one of the basic classes presented in Table 5.5. Next, the capacity of each plant is verified within the existing information. If there is no data on plant capacity, it is randomly assigned based on a probability distribution of capacities for the same type of energy source (see Cardona et al. 2023 for further details). Finally, the replacement cost is determined using the cost indicators used by Cardona et al. (2023) and defined by IRENA (2024), multiplied by the plant capacity.

Table 5.5: Basic energy source classes and unitary costs

Energy source	Cost indicator ($/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

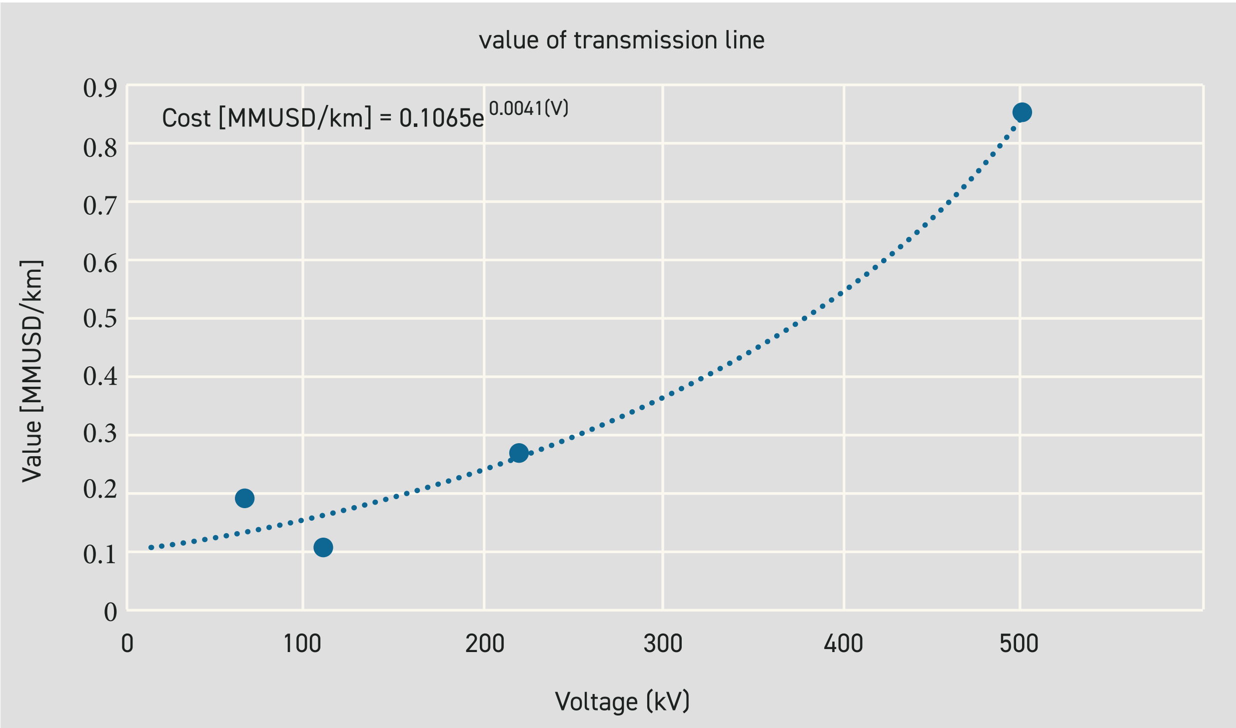
Source: Cardona et al. (2023)

Transmission

For the transmission subsector, raw data are obtained from the power lines database and the power substations database, both managed by OSM. No official information was received during the execution of this assignment. The procedure for estimating the cost of transmission infrastructure is described next.

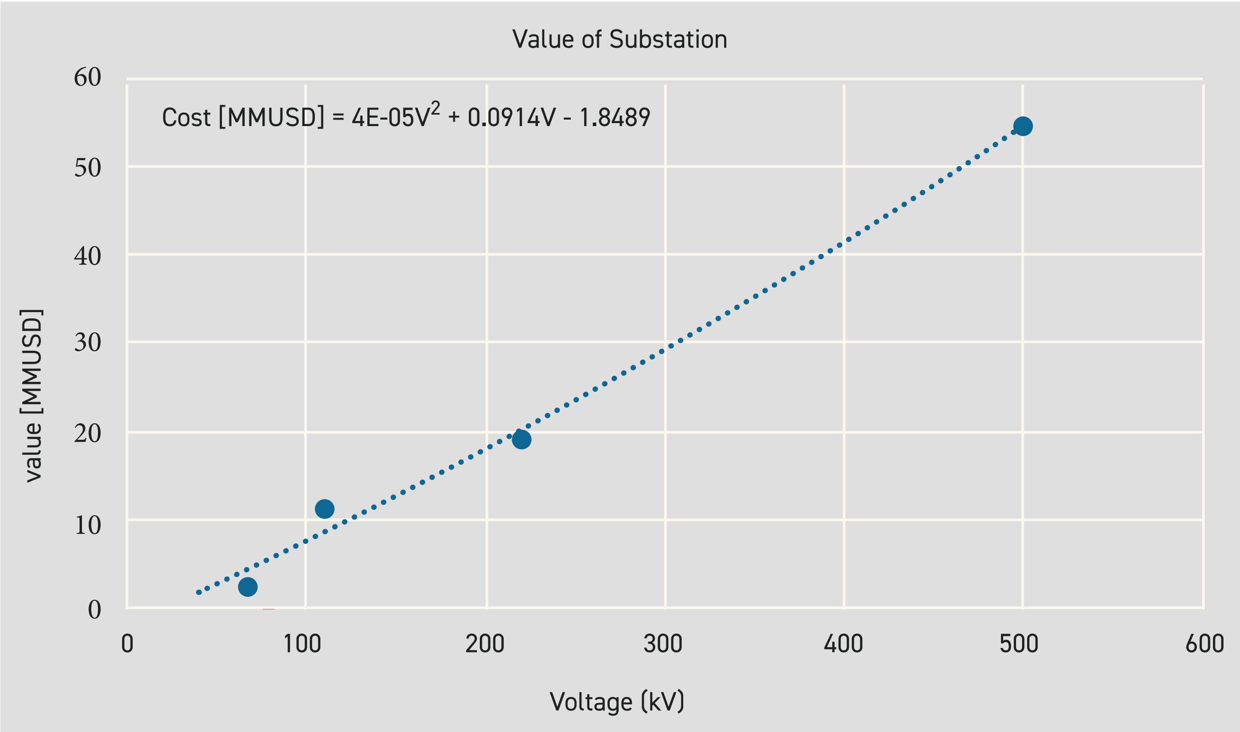
For the transmission lines, first, the length of each element is determined from the raw spatial data. Long segments are cut into parts of 150 m or less. Then, the line voltage is used to determine the cost indicator in accordance with the price function proposed by Cardona et al. (2023), as shown in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

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



For substations, the raw data is first debugged to remove substation elements that do not correspond to transmission or distribution networks. Finally, the cost is evaluated based on the working substation voltage using the pricing function proposed by Cardona et al. (2023), as shown in Figure 5.6.

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



Distribution

Distribution networks are closely related to population density. They tend to be denser where populations are more concentrated, and vice versa. Furthermore, data on the real location and characteristics of the distribution network (such as cable posts, buried lines, and transformers) is either unavailable or non-existent. It is also important to mention that no official information was received during the execution of this assignment. Therefore, we apply the framework developed by Cardona et al. (2023) to construct a population-based exposure proxy for the distribution network.

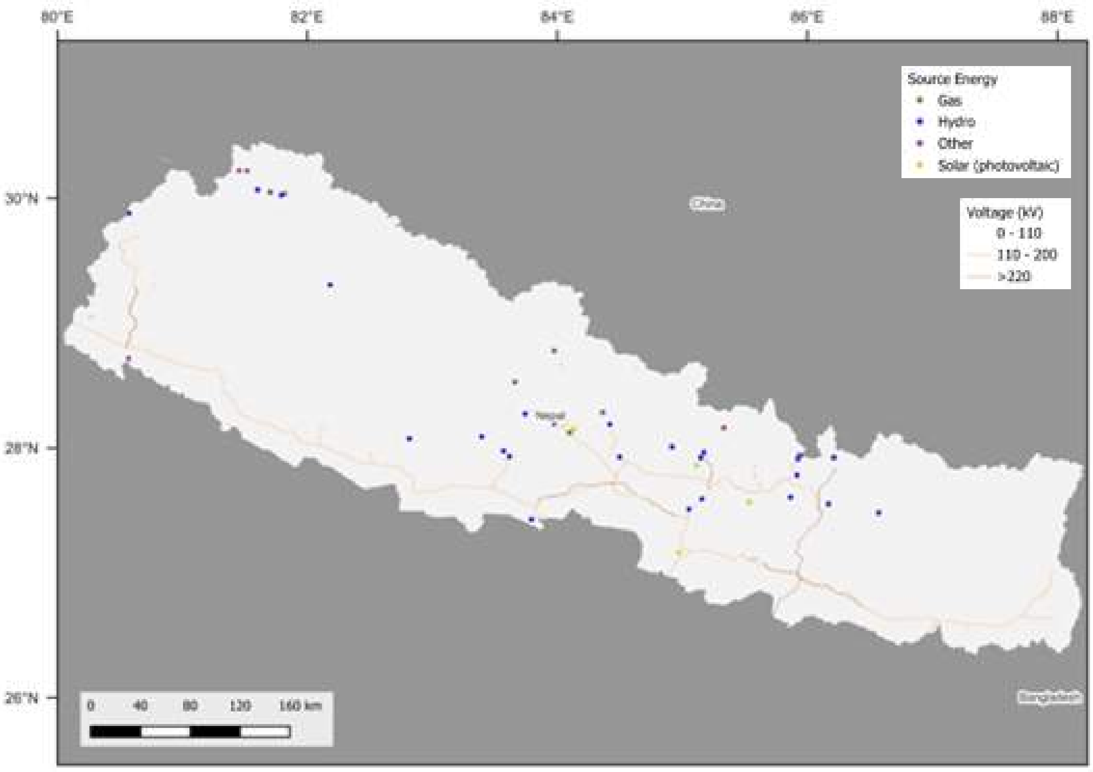
Cardona et al. (2023) propose the valuation of the distribution subsector as a factor of the transmission subsector.[13] This results in a bulk valuation that must be distributed geographically using the raster population grid from GHSL (European Commission, Joint Research Centre, n.d.). This population grid is transformed into a population with access to electricity, which, for Nepal, is 91.3 percent of the total population according to World Bank data (World Bank, n.d.). This procedure yields higher exposure values in denser populations and provides a bulk infrastructure value that is consistent with the observed electricity access.

Exposure Database

The resulting exposure model consists 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 5.7 gives a general overview of the sector for Nepal.

[13] The factor is 2.26. See Cardona et al. (2023) for further details.

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



Road Sector

The roads sector in this assignment refers to highway infrastructure. Road infrastructure varies with design conditions, including topography, weather, and traffic. Furthermore, highway segments comprise multiple elements, such as pavement structure, retaining walls, gutters, and box culverts. A similar situation applies to bridges, where each bridge is completely different from the others. Although they can be classified into archetypes, bridges are among the few infrastructure elements that avoid typification. In addition, the available data has significant 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 OSM dataset, Nepal has around 23,000 km of roads, including national highways, feeder roads, and district roads. In addition, there are 100 km of bridges within these road categories. Minor district or rural roads, as well as private roads and bridges, are not part of this assignment.

Road Segments

The process for determining the replacement cost of road sector components follows the method proposed by Cardona et al. (2023) and is used to value exposed elements in CDRI's GIRI model. This model utilizes the Global Roads Network dataset from OSM, which is processed to remove incorrect or incomplete records. The roads included are segmented into lengths no longer than 300 m to improve the model's granularity. The basic value of each segment is calculated from its length using a nominal cost of $1.09 million/km.

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

Road type refers to the operational level of a road within a country's network. It is an important modifier to consider when adjusting replacement costs based on the overall importance of the road. The corresponding multiplication factor is presented in Table 5.6.

Table 5.6: Road-type multiplier

Road type	Factor
National Highways	1.00
Feeder Roads	0.83
District Roads	0.67

Source: Cardona et al. (2023)

The *number of lanes* indicates the demand supported 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 two-lane road is used as the baseline with a multiplication factor of 1. Roads with more lanes imply a higher exposure value relative to the basic replacement cost.

Pavement type also modifies the cost of the segment. It is evident that replacing a paved road segment 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 5.7.

Table 5.7: Pavement type multiplier

Pavement type	Factor
Paved	1.00
Affirmed	0.34
Loose	0.18

Source: Cardona et al. (2023)

Finally, slope significantly affects the segment value. Replacing a road segment with similar characteristics in steep terrain would be substantially more expensive than replacing it in a plain terrain. Furthermore, some critical elements, such as retaining walls, are far more likely to be present in steep terrain than in flat terrain, where they may be absent. We use the slope factors proposed by Cardona et al. (2023), as presented in Table 5.8.

Table 5.8: 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

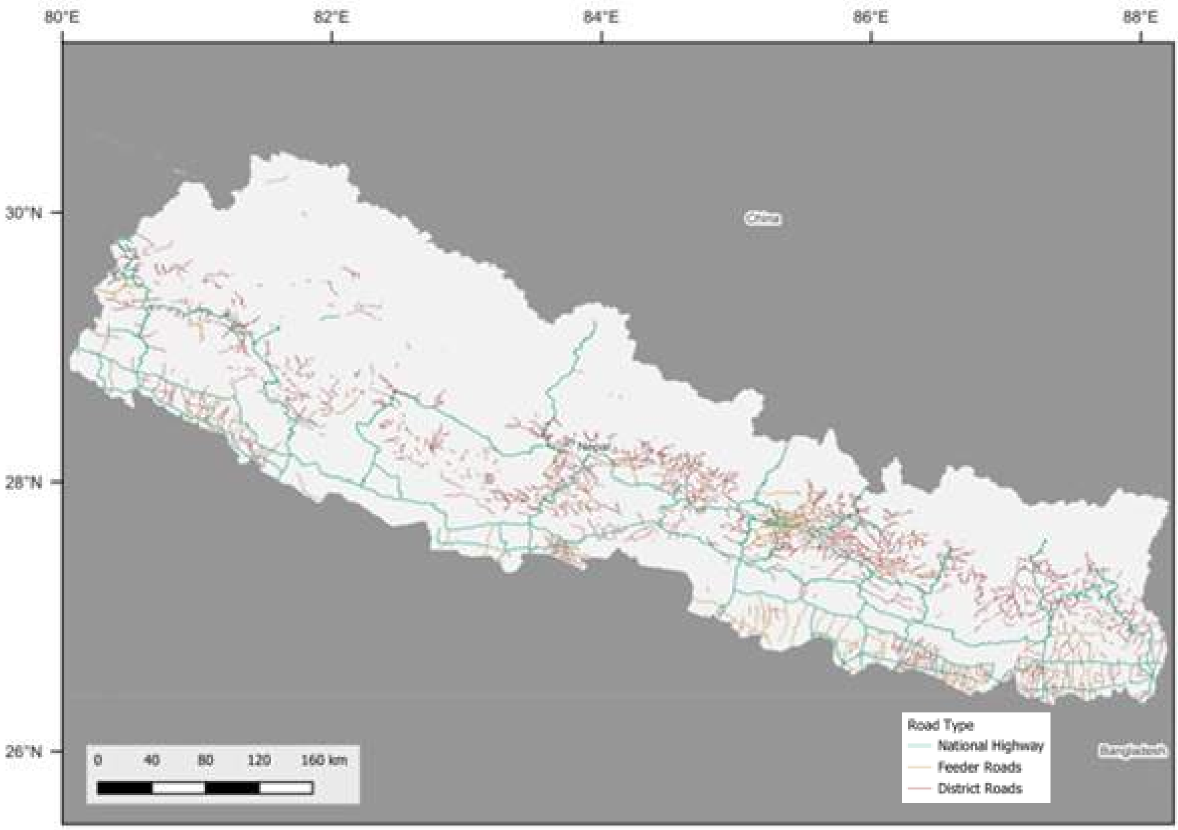
Bridges are infrastructure elements that are particularly difficult to categorize. It can be confidently stated that there are as many bridge types as there are bridges in the world. This, of course, complicates any attempt to classify bridges. However, given the current data available, such classification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

Finally, tunnels are included. They share some of the challenges noted for bridges including the difficulty of making a broad generalization and the lack of detailed information. Nonetheless, based on 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 consists of geolocated vector entities with attributes important for risk estimation. The replacement cost and the archetype of each element are included as key fields to characterize the exposure. Figure 5.8 shows a general overview of the sector for Nepal.

Figure 5.8: Map of the exposure database for road sector in Nepal



Vulnerability Models

The physical vulnerability of exposed elements can be mathematically represented using vulnerability functions, which sufficiently represent the complexity of the loss-generation process when these elements are subjected to the impact of a hazardous event. Additionally, vulnerability functions express potential loss probabilistically, allowing the application of the risk assessment introduced in Product 1.

Probability Model for the Loss

In catastrophic risk modelling, losses are considered as random variables. This approach allows the uncertainty inherent in the amount of loss caused by any hazard to be directly considered in the calculations. Vulnerability is defined for each element within the exposure portfolio, meaning that the loss referred to here pertains to a single exposed element. Generally, loss is defined as a variable in the range 0 to 1, representing 0 to 100 percent of the element's exposed value (e.g., the replacement value of a property or an infrastructure element). Consequently, when discussing vulnerability, the loss always corresponds to a relative loss based on the degree of damage; that is, it is a fraction of the exposed value.

In general, there is insufficient information on damage and losses from historical events to allow a probability model to be adjusted to the loss based on statistical estimates. Therefore, defining 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 is 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),** which aimed to define probability models for earthquake-induced damage in California. Since then, the use of the Beta distribution as a probability model for loss has become widespread worldwide for all hazards and all types of exposed elements, as it is a practical model under the following criteria:

1. It describes a continuous random variable within the real interval [0,1]
2. It is defined with only two parameters (α and β)
3. 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 in turn depends on the estimated probability moments obtained from the vulnerability model. As mentioned, the Beta distribution's ability to alter its shape within its defined interval is one of the criteria by which it is widely used in catastrophe risk modelling. Table 5.9 illustrates the expected shapes of the Beta distribution for different combinations of expected value and variance for the loss. The table includes a general description of the expected outcomes for hazard events at different intensity levels, an illustration of 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 captures the distribution loss across events of different characteristics.

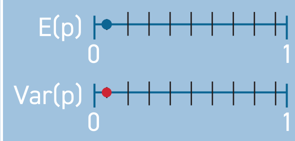
Table 5.9: Variation of the beta distribution in response to events of different intensity levels

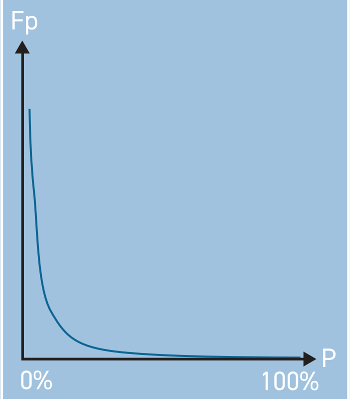
Description | **Probability moments** | **Beta distribution**

Very low intensity event:

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 behaviour, with a rapid decrease. That is, the highest probability density is concentrated near zero loss, as expected for a very low intensity.

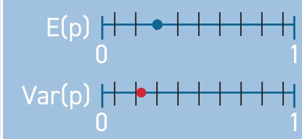


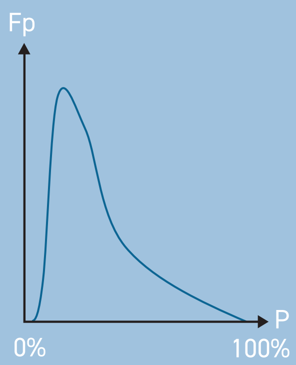


Low intensity event:

The expected value of the loss increases, and its variance also increases (i.e., the loss is more uncertain).

The distribution is wider and centred more to the right, but it is still skewed towards low losses.

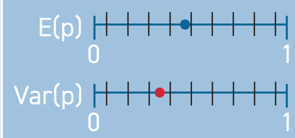


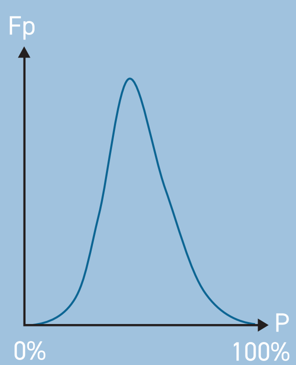


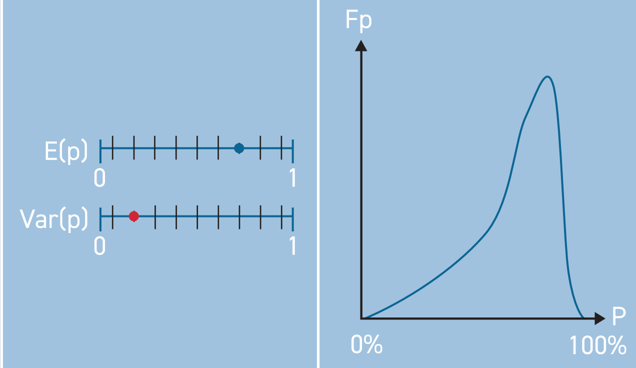
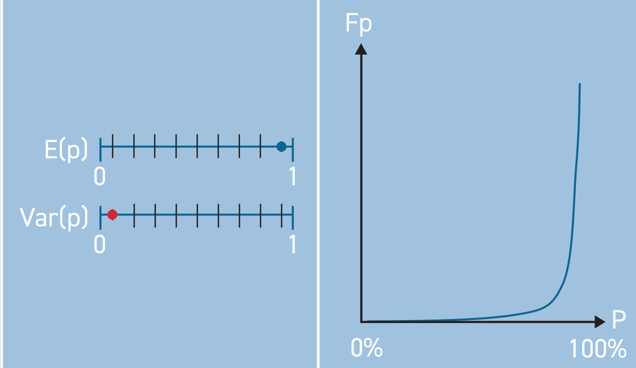
Intermediate intensity event:

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.





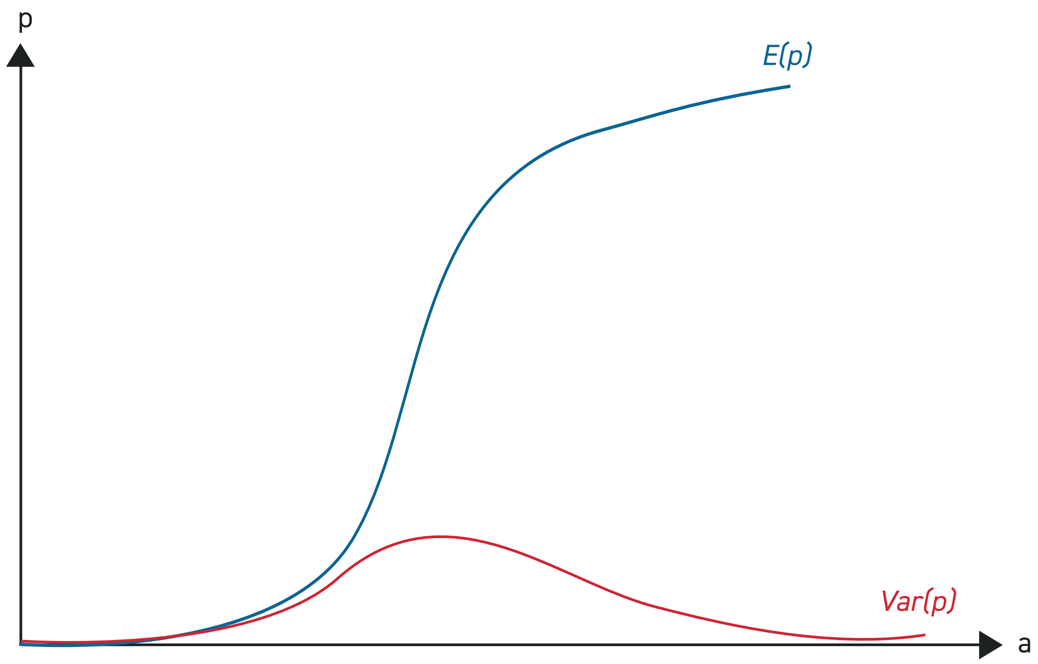
Description	Probability moments	Beta distribution
High intensity event: The expected value of the loss increases, but its variance decreases because at high intensities, the uncertainty of a high level of damage is increasingly low. The distribution begins to skew to the right towards high loss values, with some density at low losses, but very concentrated towards high damages.		
Very high intensity event: The expected value of the loss is very high, and its variance is small because there is little uncertainty about the level of damage for a very high intensity. The distribution is an exponential function, with rapid growth in the density values, indicating that losses are almost certainly very high.		

Vulnerability Functions

Vulnerability functions are mathematical models that represent physical vulnerability, consisting of two main functions: one that describes how the expected loss varies with the intensity of the hazard, and another that details how the variance changes. Vulnerability functions are the preferred vulnerability model for property or infrastructure elements in catastrophe risk assessments because they effectively capture the potential loss.

The form of the expected value and variance functions is not entirely free. In general, as illustrated in Figure 5.9, the expected value function must be increasing, whereas the variance function should initially increase and then decrease to accurately reflect the expected variability of the intensity of the phenomenon. Figure 5.9 illustrates a typical shape of vulnerability functions.

Figure 5.9: Vulnerability function



Vulnerability functions are defined and assigned to types of exposed elements based on specific categories. This means that one function can describe the behaviour of multiple exposed elements within the same category. This approach makes sense considering the probabilistic nature of probability functions, which capture the behaviour of similar exposed elements. The typification or categorization of exposed elements is generally established in the exposure model based, typically, on their construction or functional characteristics.

The vulnerability functions developed by Cardona et al. (2023) for infrastructure archetypes are used in this assignment. These functions are also used in the GIRI model of CDRI. The GIRI library of archetype functions is currently the most comprehensive resource of infrastructure vulnerability models for catastrophe risk assessment available. The vulnerability functions applied for Nepal's risk assessment in this assignment are presented in Figures 5.10 to 5.15. As mentioned earlier, no vulnerability functions are used for landslide hazards, on the assumption that a landslide always results in the destruction of the infrastructure element. This assumption is particularly valid for road infrastructure, which is the only type affected by landslides in this assignment.

Energy Infrastructure

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

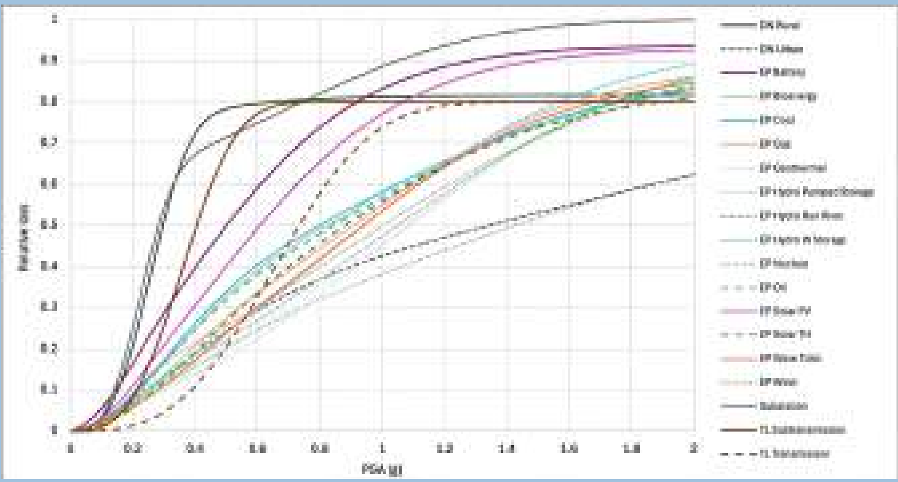


Figure 5.11: Flood vulnerability functions for the infrastructure of the energy sector

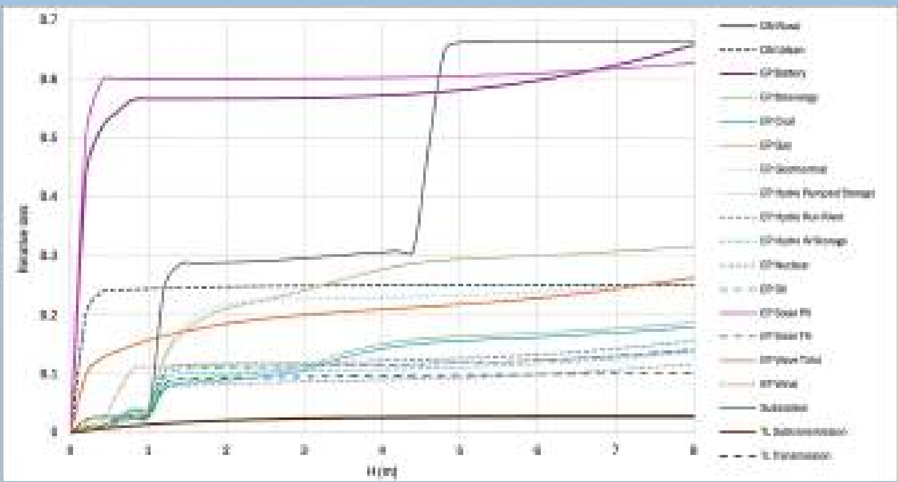
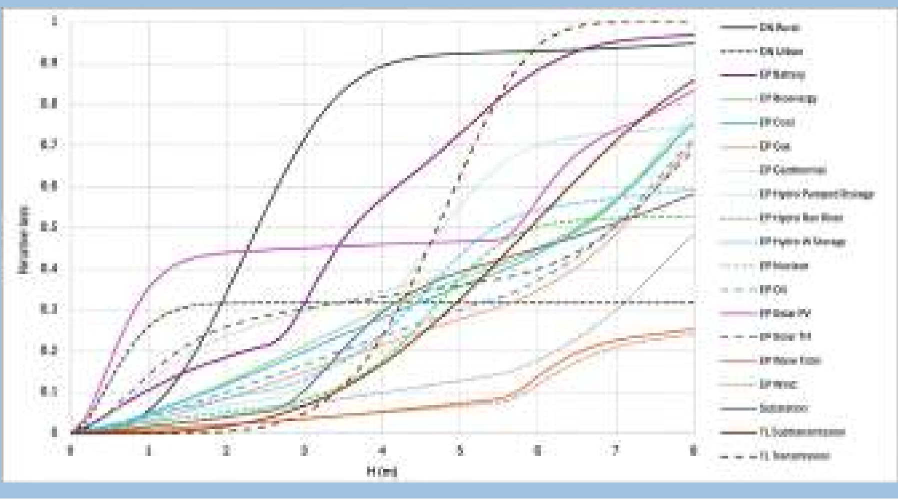
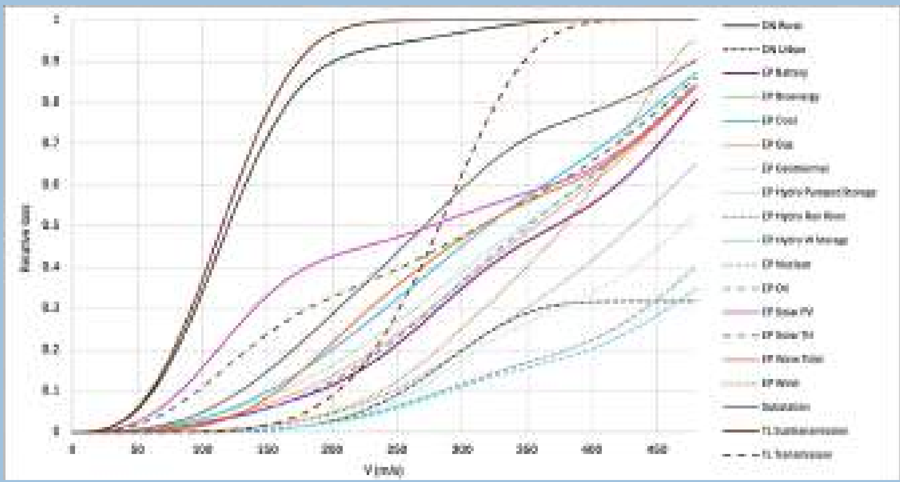


Figure 5.12: Storm surge (cyclone) vulnerability functions for the infrastructure of the energy sector



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

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



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

Road Infrastructure

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

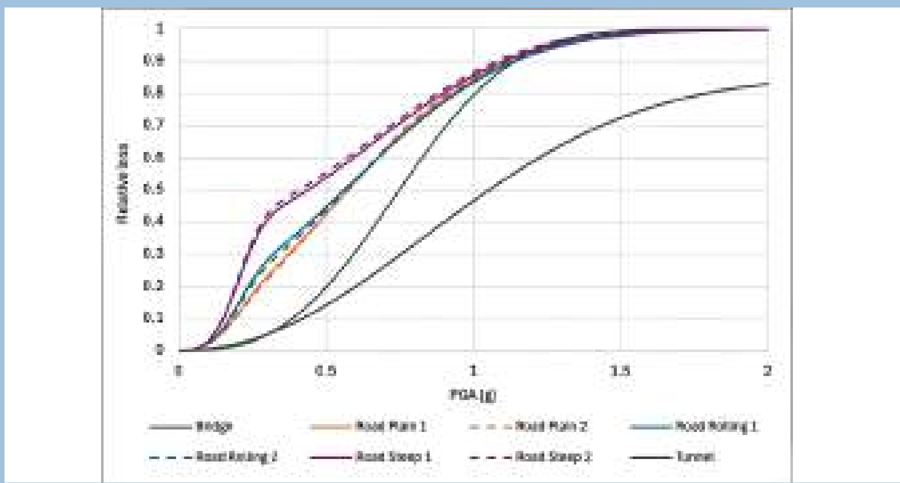
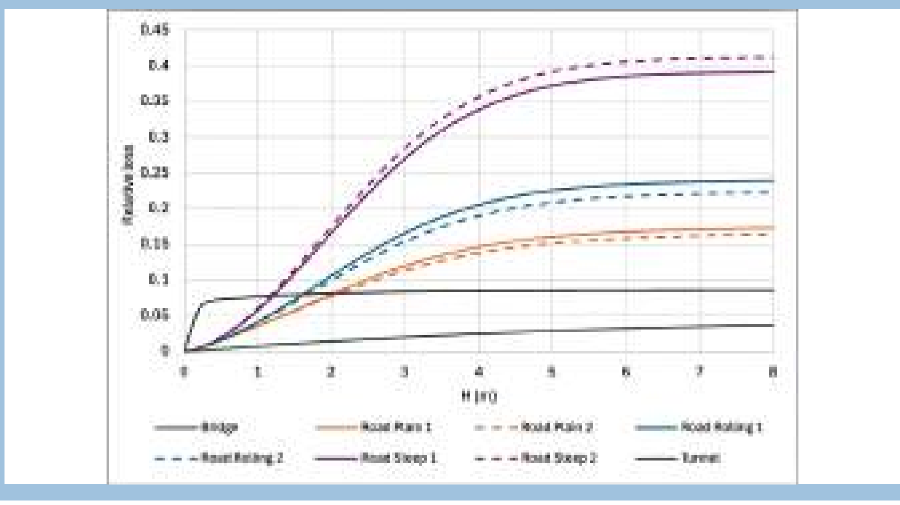


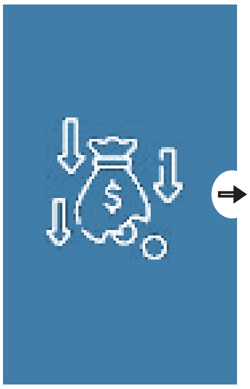
Figure 5.15: Flood vulnerability functions for infrastructure of the road sector



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

Risk Assessment Results

Risk results are expressed in terms of the Average Annual Loss (AAL) and the Probable Maximum Loss (PML), which are standard risk metrics commonly used in catastrophe risk assessments and the insurance industry. Although these metrics are formally described in Product 1 of this consultancy, here we provide their definitions for the reader's convenience.



Average Annual Loss:

The AAL is an important indicator because it integrates, into a single value, the impact in terms of loss from hazard scenarios affecting vulnerable, exposed elements. It is considered as the most reliable risk indicator, not only because it summarizes the loss-time process into a single number but also because it exhibits low sensitivity to uncertainty. The AAL represents the expected value of annual loss and indicates the annual value to be paid each year to cover all future losses over the long term. In a basic insurance scheme, the AAL would be equivalent to the annual pure premium.

Probable Maximum Loss:

This is a loss that does not occur frequently, that is, a loss usually associated with long return periods. Instead of a single PML value, there is a complete curve (showing loss versus return period). However, it is common practice to define a PML value by selecting a return period. There are no universally accepted standards to define what constitutes 'not very frequently'. In the insurance industry, for example, the return periods used to define the PML ranges from 200 to 2,500 years.

The AAL is presented as a total for each combination of hazard and sector, and it is disaggregated by subsector and other important features. Furthermore, the AAL is disaggregated in risk maps that illustrate the geographical variation of expected losses. In all these results, AAL values can be presented as absolute or relative. Absolute AAL refers to the modelled monetary amount. Relative AAL is the same amount but divided by or normalized to the exposure value being considered. For example, if the AAL presented is the total for a specific sector in the territory, then the relative AAL is normalized by the total exposed value for that sector. Conversely, if the AAL reported is of one single exposed element (such as on risk maps), 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 a function of loss versus return period for each hazard and sector. Both absolute and relative PML values are included. Relative PML values help compare hazards. For the AALs, absolute PMLs are the calculated amounts, while relative PMLs are normalized by the exposed sector value. Since PMLs are derived from large quantiles in probability distributions, they cannot be disaggregated to present maps. In this report, relative PMLs are always as per-hundred fractions with the symbol %.

Energy Infrastructure

Table 5.10 shows the AAL for Nepal's energy sector for the hazards considered in this assessment, both in absolute and relative terms. It is noteworthy that the highest losses result from floods, with the climate scenario SSP5-RCP8.5 causing the highest losses, followed closely by floods under climate SSP1-RCP2.6 and in the current climate. The lower AAL is for earthquakes, mainly because these events are less frequent. AAL is a metric strongly influenced by the frequency with which they occur.

Table 5.10: Absolute and relative AAL for the energy sector infrastructure

Hazard	Average annual Loss	
	$	%
Earthquake	2,553,000	0.33
Flood	32,418,000	4.15
Flood (RCP2.6)	33,412,000	4.28
Flood (RCP8.5)	44,219,000	5.66

The relative AAL across subsectors is distributed as shown below. In the case of earthquake hazard (see Figure 5.16), the highest relative AAL is observed in the generation subsector, as components in power plants and facilities are more sensitive to ground shaking than those in other subsectors. For floods (see Figure 5.17), the largest AAL occurs in the generation subsector, followed by the distribution subsector. For transmission, the AAL is low, which makes sense since most of this subsector, namely transmission lines, are elevated. In addition, there is a noticeable increase in AAL due to climate change under scenario SSP5-RCP8.5 across all subsectors.

Figure 5.16: Relative AAL from earthquake for energy infrastructure portfolios

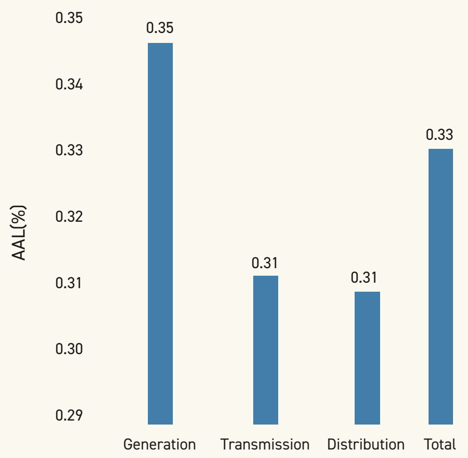
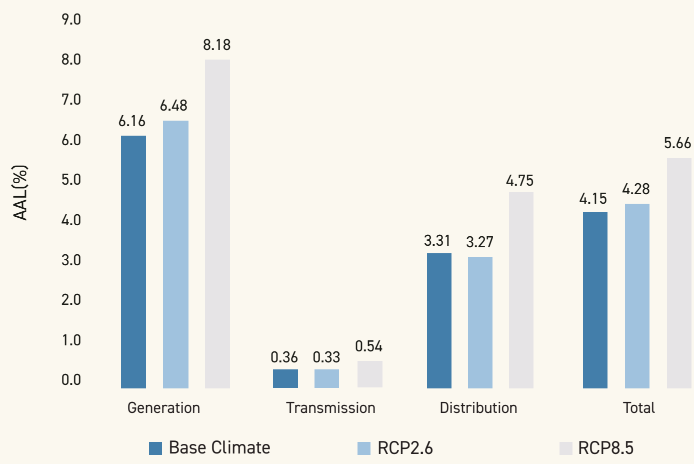


Figure 5.17: Relative AAL from flood for energy infrastructure portfolios



The AAL for each subsector is computed by aggregating the individual losses calculated for each exposed element. Each element in the exposure portfolio has a unique set of location, price, and vulnerability conditions, making its risk evaluation specific to that element. AAL is further disaggregated by element to illustrate these differences and emphasize the uniqueness of each within the risk landscape. Figures 5.18 to 5.21 clearly illustrate the variation in the relative AAL among the exposed elements. They display the relative AALs for the elements in the energy sector across all hazards and climate scenarios considered. It is noteworthy that a complete dataset with geolocated vector information of the exposed elements will be provided to ADPC, enabling further analysis of the extensive results.

Figure 5.18: Relative average annual loss from earthquakes for energy portfolios

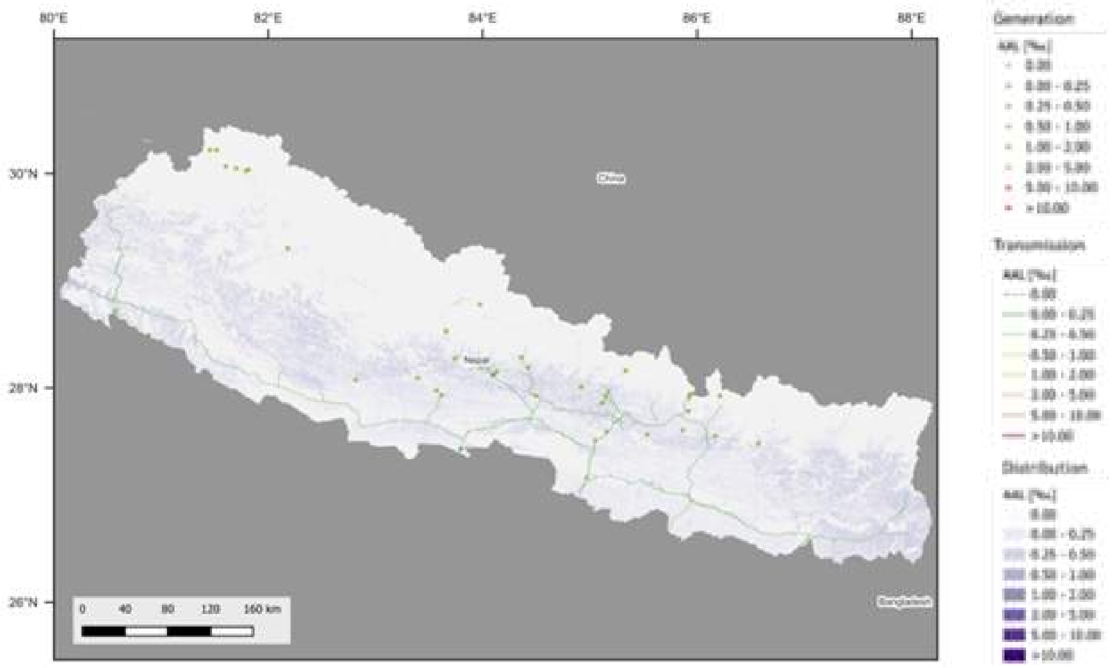


Figure 5.19: Relative average annual loss from floods for energy portfolios

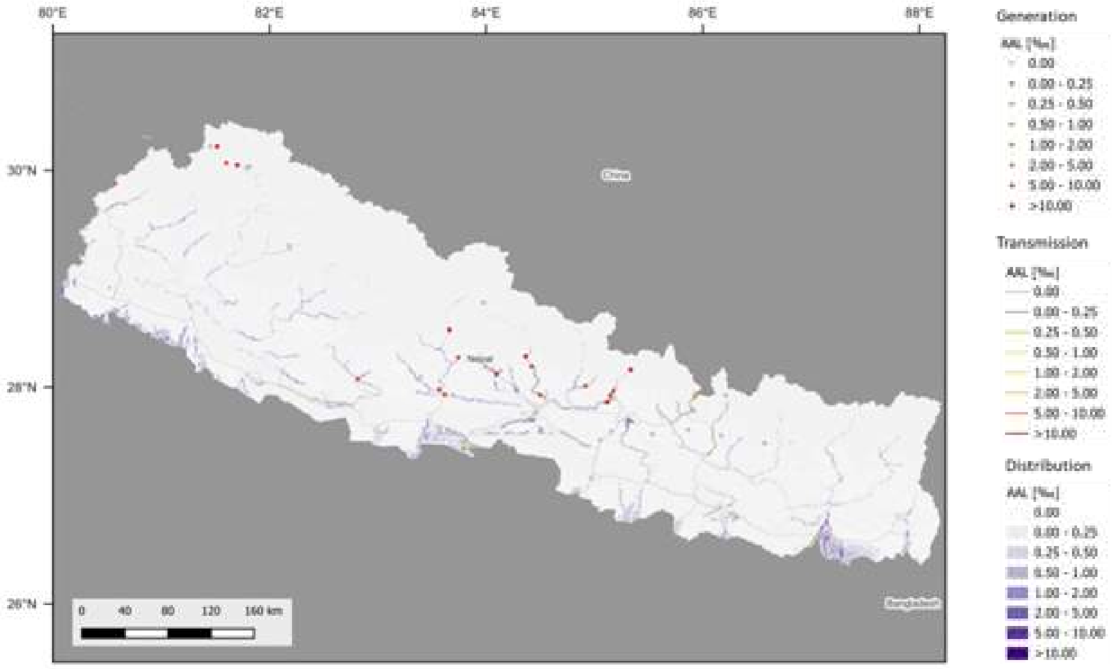


Figure 5.20: Relative average annual loss from floods (SSP1-RCP2.6) for energy portfolios

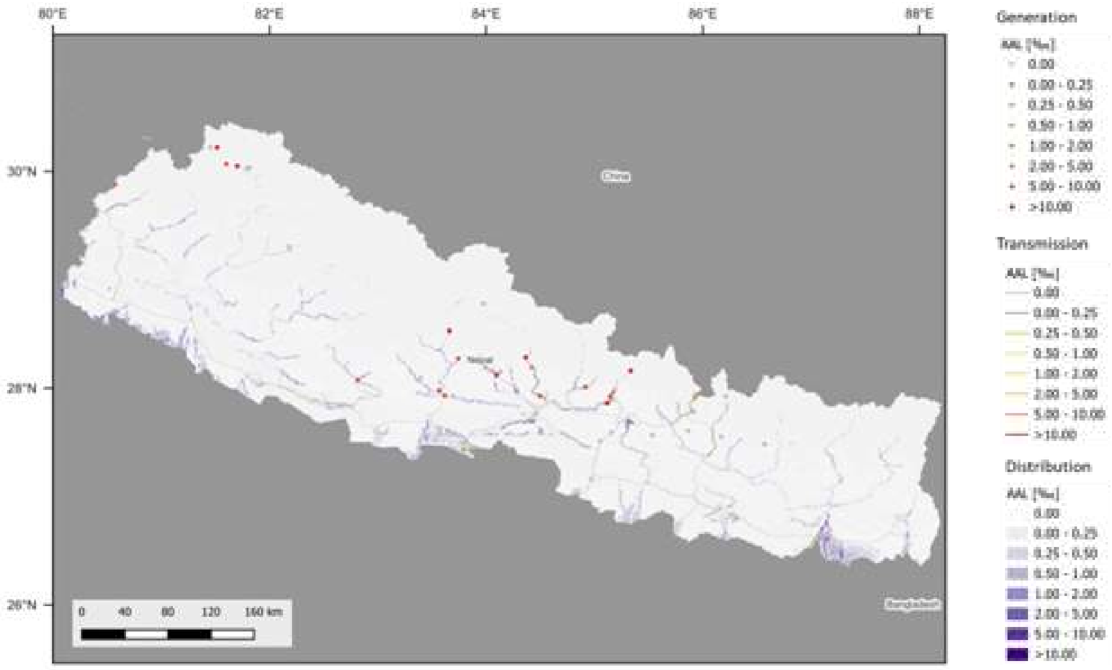


Figure 5.21: Relative average annual loss from floods (SSP5-RCP8.5) for energy portfolios

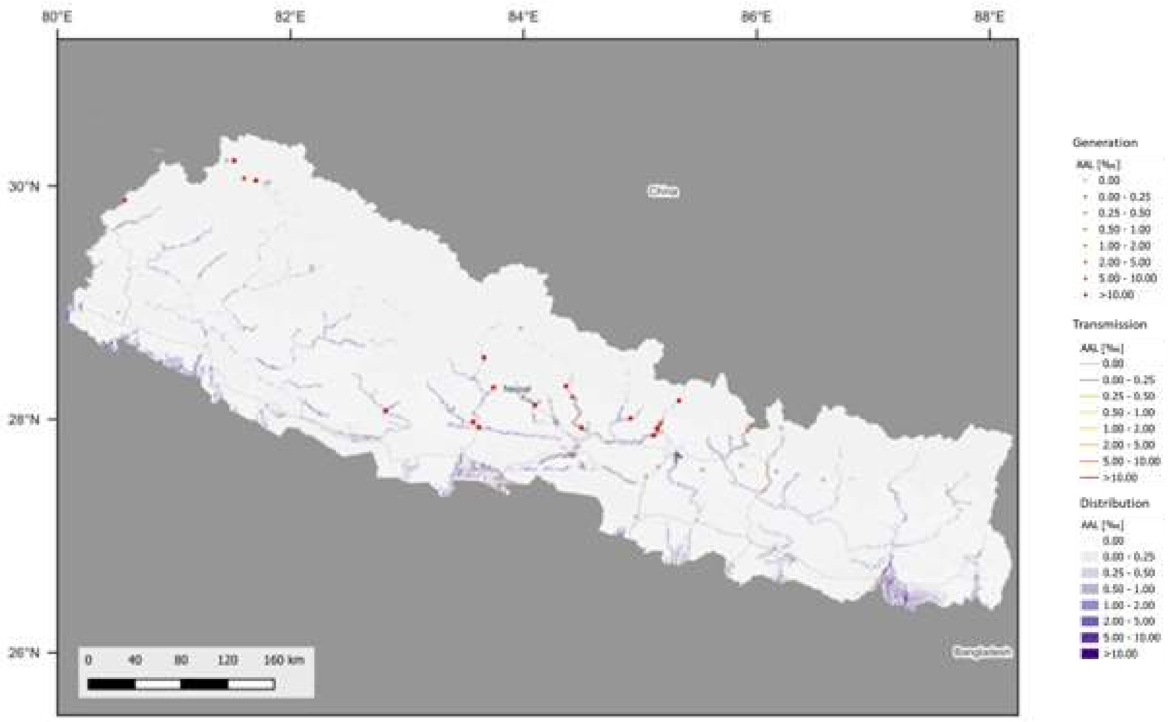
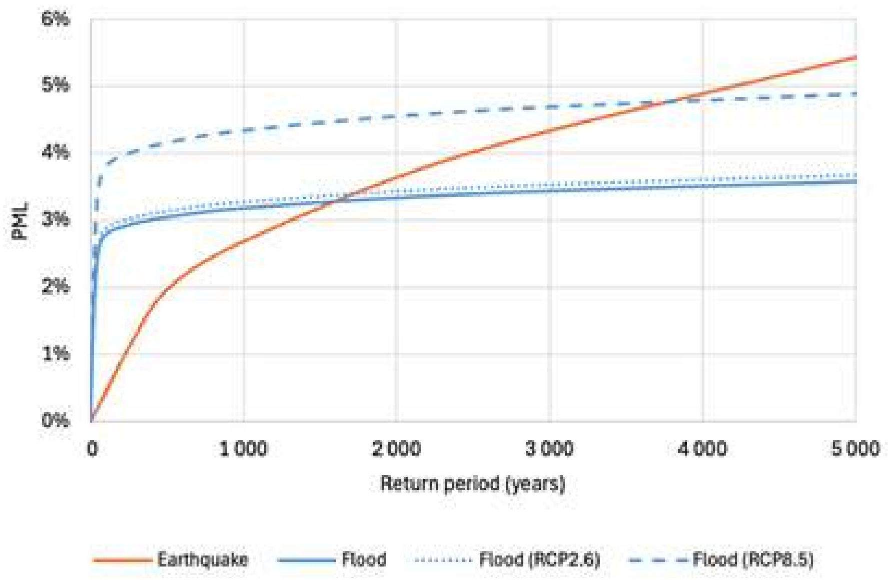


Table 5.11 presents the PML values for Nepal's energy sector, categorized by hazard and selected return periods. PMLs are always higher than AALs due to how they are defined and calculated. These PMLs are presented in relative terms in Figure 5.22 as PML curves, illustrating the full variation of the metric across the return period. For larger return periods, earthquakes primarily drive the risk for this sector. Notice the rapid increment of the earthquake PML function, in comparison to the relatively flat PML curve for floods. This difference is due, again, to the frequency of hazard events.

Table 5.11: PML for energy sector infrastructure (values in $)

Return period (years)	Eartquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)
10	$3,428,000	$69,533,000	$71,665,000	$94,845,000
25	$8,569,000	$141,814,000	$146,159,000	$193,442,000
50	$17,138,000	$196,598,000	$202,606,000	$268,176,000
100	$34,276,000	$217,992,000	$224,611,000	$297,375,000
250	$85,689,000	$228,892,000	$235,748,000	$312,279,000
500	$153,653,000	$238,009,000	$245,044,000	$324,753,000
1,000	$209,707,000	$248,531,000	$255,757,000	$339,155,000
2,500	$313,997,000	$264,953,000	$272,452,000	$361,645,000
5,000	$424,419,000	$279,599,000	$287,318,000	$381,711,000

Figure 5.22: PML Curve for the Energy Sector Infrastructure



Road Infrastructure

Table 5.12 presents the AAL for Nepal's road sector for the hazards considered in this assessment, both in absolute and in relative terms. Note that the highest losses in this case are caused by rain-triggered landslides, with higher values under the scenario SSP5-RCP8.5, followed closely by SSP1-RCP2.6 and the current climate. Next, floods also contribute to the overall AAL, showing the same pattern regarding climate influence. Finally, earthquakes and earthquake-triggered landslides contribute the least to the AAL. As noted, this relates to the frequency of events; it is quite high for hydrometeorological hazards such as floods and rain-triggered landslides, and low for earthquakes and the landslides they induce.

Table 5.12: Absolute and Relative AAL for the Roads and Bridges Infrastructure

Hazard	Average Annual Loss	
	$	%
Earthquake	$ 8,591,000	0.45
Landslide - Earthquake	$ 4,370,000	0.23
Flood	$ 24,853,000	1.31
Flood (RCP2.6)	$ 24,182,000	1.27
Flood (RCP8.5)	$ 39,330,000	2.07
Landslide - Rain	$101,238,000	5.33
Landslide - Rain (RCP2.6)	$105,393,000	5.55
Landslide - Rain (RCP8.5)	$115,736,000	6.10

The relative AAL among subsectors is shown below. In the case of earthquake hazard, the highest AAL is found in the district roads. This seems logical because this subsector has higher exposure across the country, allowing an earthquake event to impact multiple roads across multiple locations. Nonetheless, the AALs for earthquakes and earthquake-triggered landslides are lower than those for floods.

For floods (see Figure 5.23), the highest AAL is on national highways, followed by district roads and feeder roads; the results are similar for the last two. This contrasts with the AALs for rain-triggered landslides, where higher values are on district roads, followed by national highways and feeder roads, but in lower proportions, with very close results for the last two. This is due to the mountainous terrain covering most of Nepal. A similar pattern appears for bridges, with higher AALs for landslides than for floods, because although rivers usually pose obstacles for bridges, in Nepal, these rivers are mostly torrential, making them more prone to landslides in the vicinity.

Figure 5.23. Relative AAL from (A) Earthquake, (B) Flood, and (C) Rain-Triggered Landslides for the Road and Bridge Infrastructure Portfolios

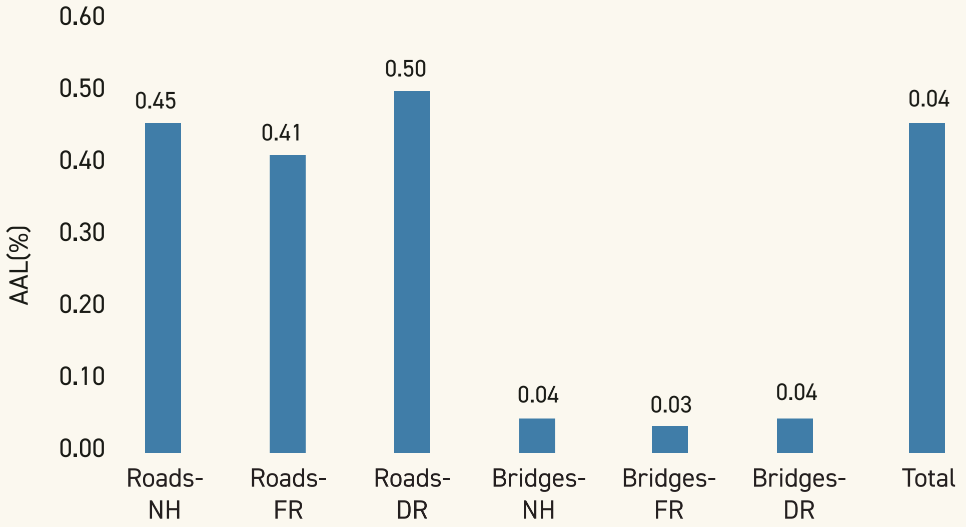


Figure 5.24: Relative AAL from earthquake-triggered landslides for road and bridges infrastructure portfolios

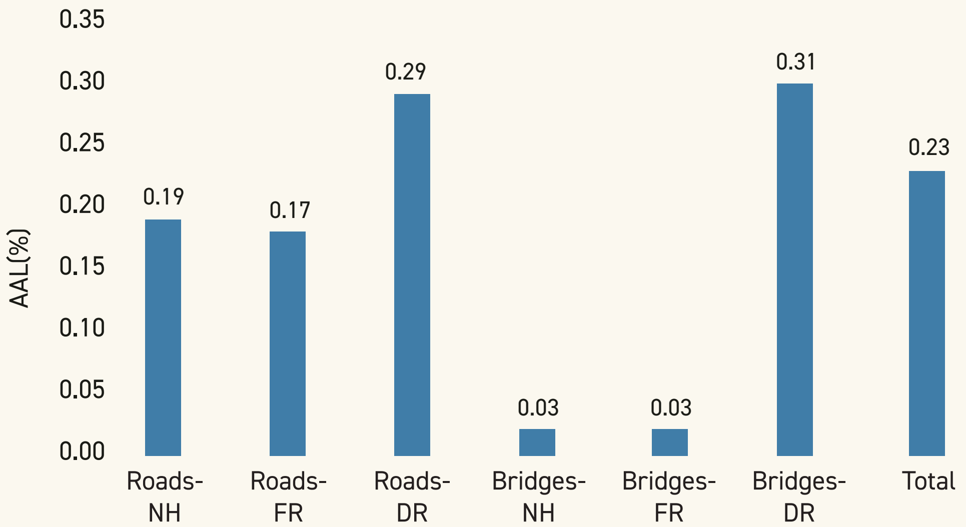


Figure 5.25: Relative AAL from flood for road and bridges infrastructure portfolios

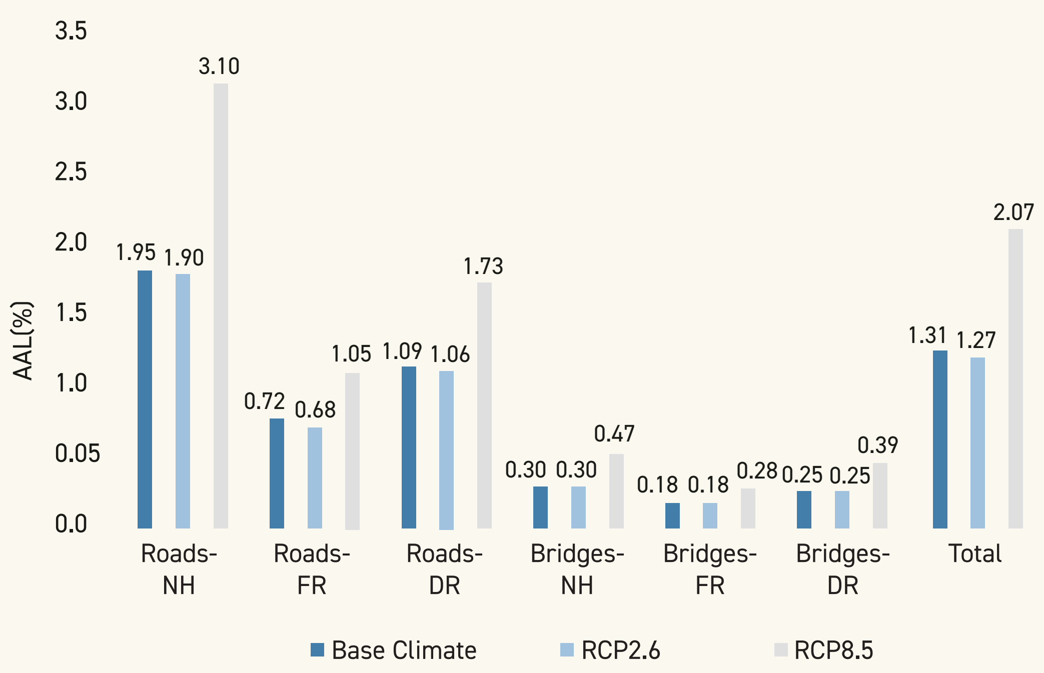
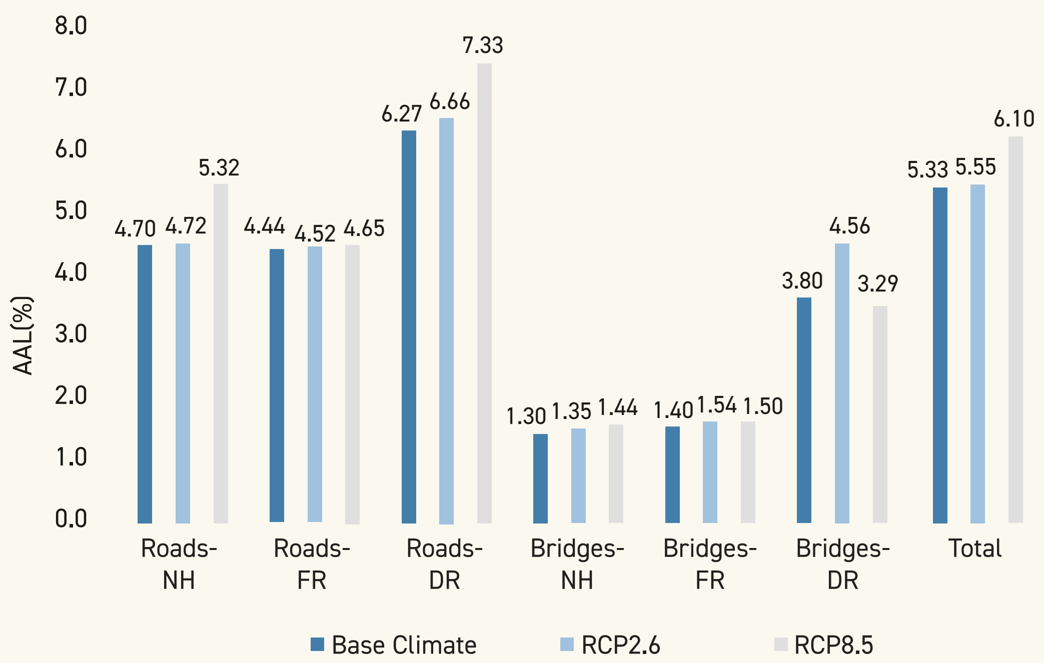


Figure 5.26: Relative AAL from rain-triggered landslides for road and bridges infrastructure portfolios



The AAL of each road segment in the model is presented in Figures 5.27 to 5.34, for each hazard. The maps clearly demonstrate the variation in the relative AAL among the exposed elements of the road network, despite the country's large size. As mentioned earlier, a complete geolocated dataset will be provided to ADPC, enabling more detailed consultation

Figure 5.27: Relative AAL from earthquakes for road portfolios

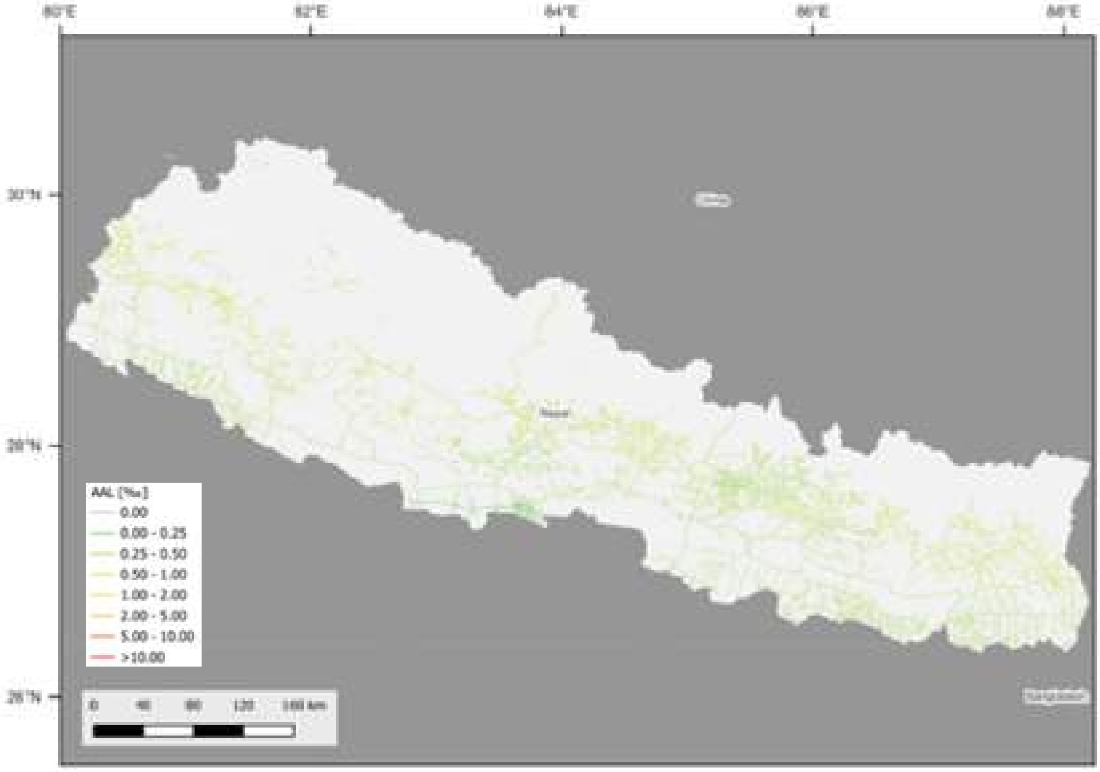


Figure 5.28: Relative AAL from earthquake-triggered landslides for road portfolios

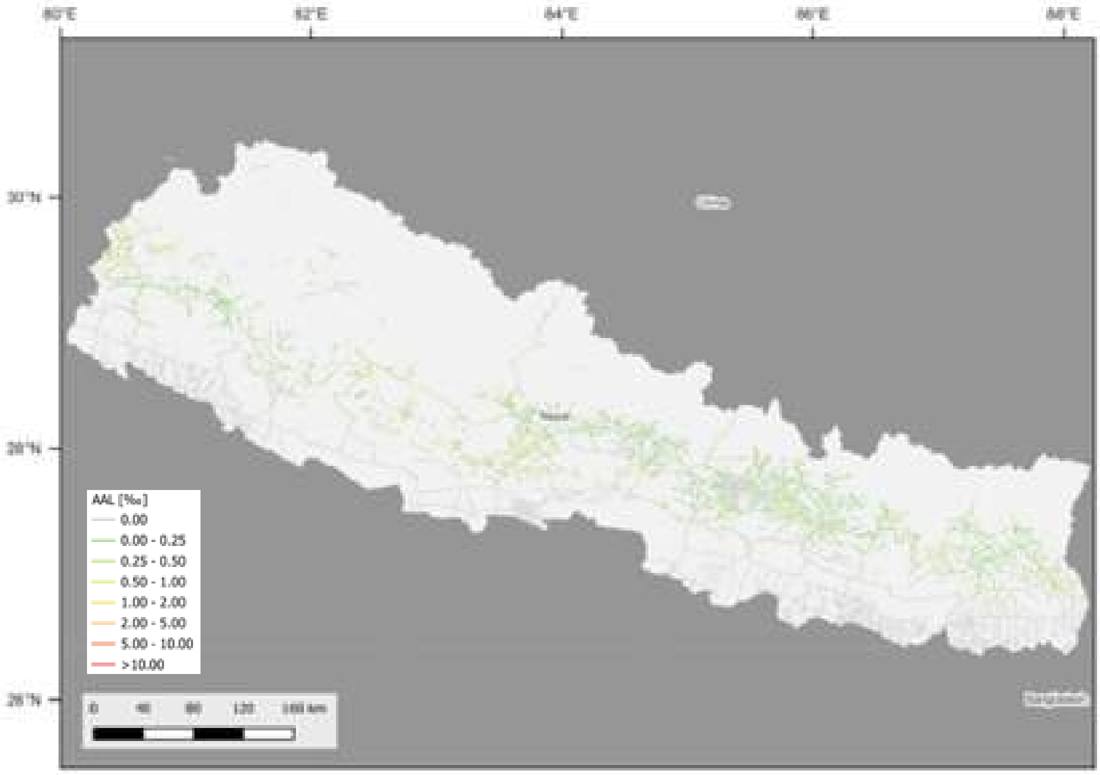


Figure 5.29: Relative AAL from floods for road portfolios

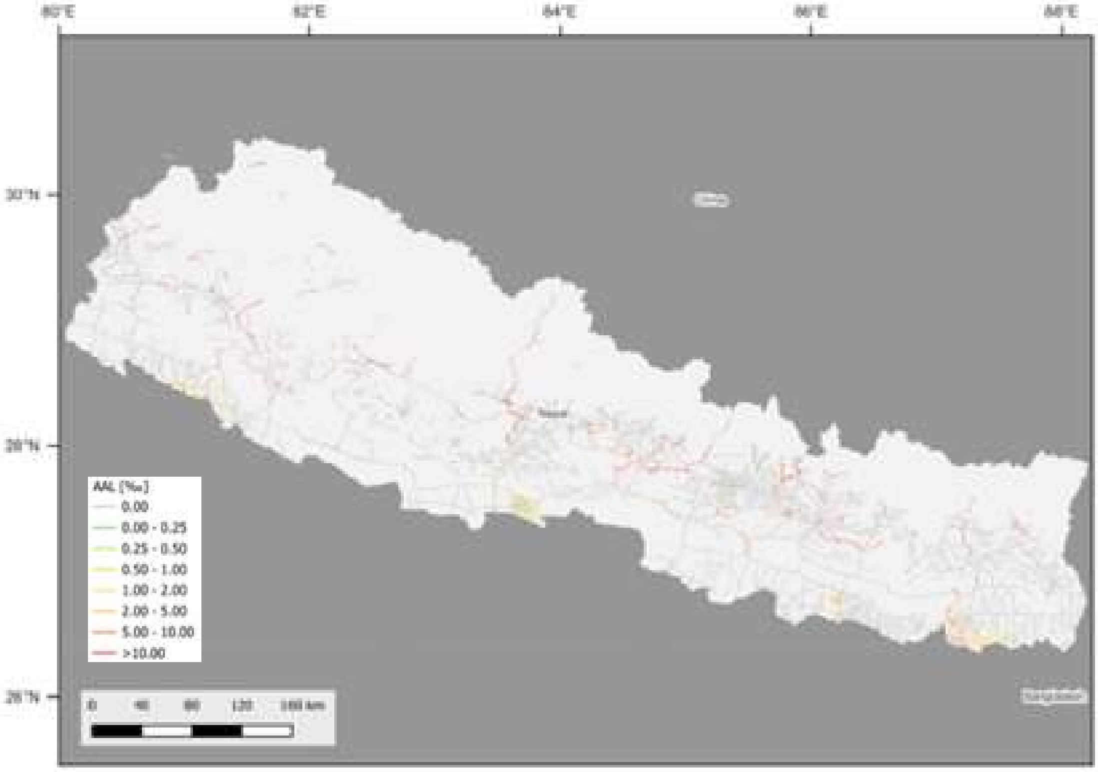


Figure 5.30: Relative AAL from floods (SSP1-RCP2.6) for road portfolios

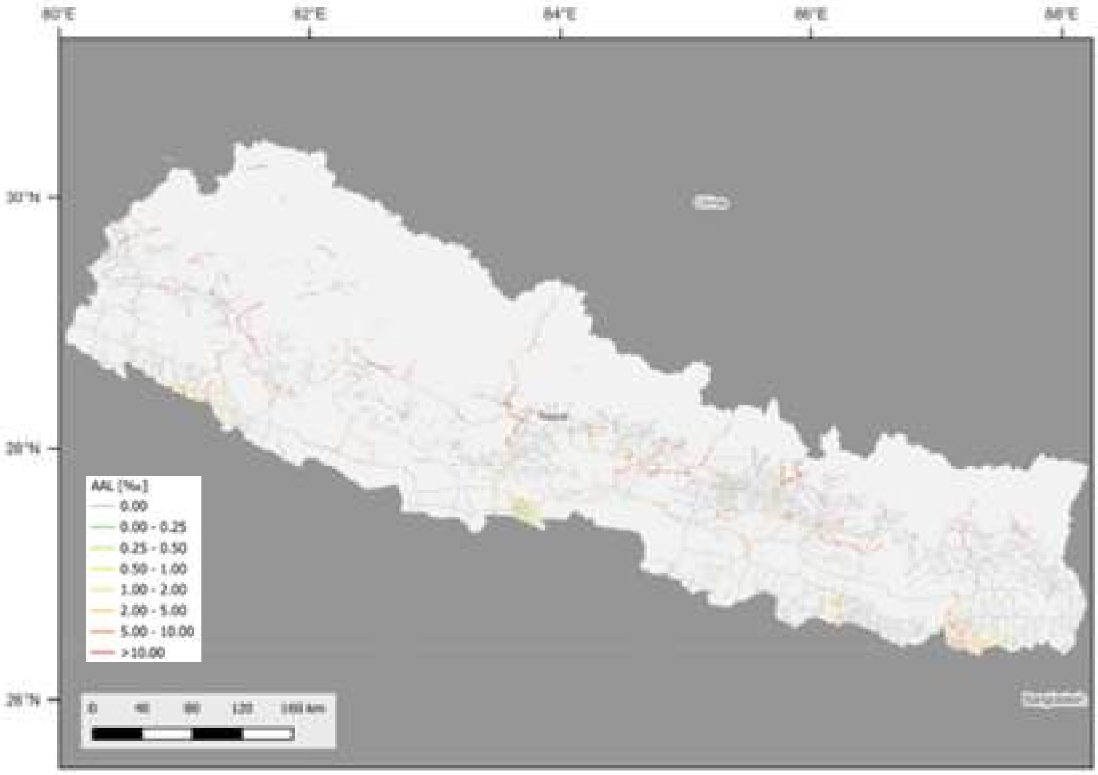


Figure 5.31: Relative AAL from floods (SSP5-RCP8.5) for road portfolios

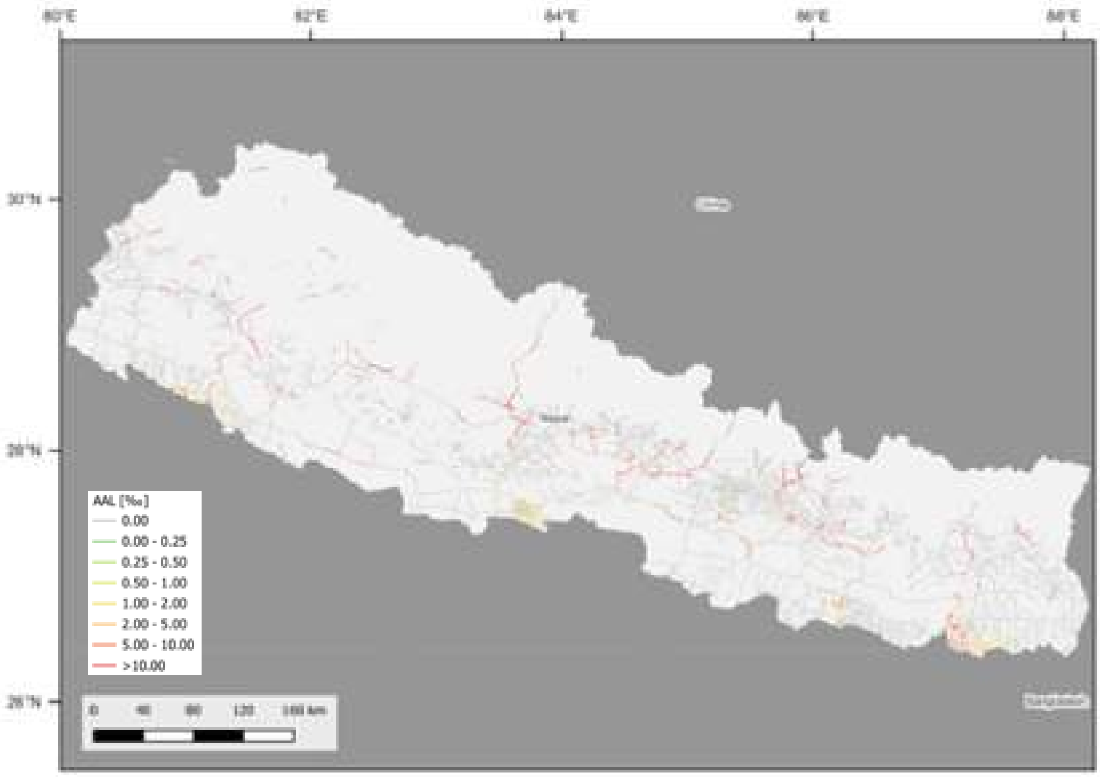


Figure 5.32: Relative AAL from rain-triggered landslides for road portfolios

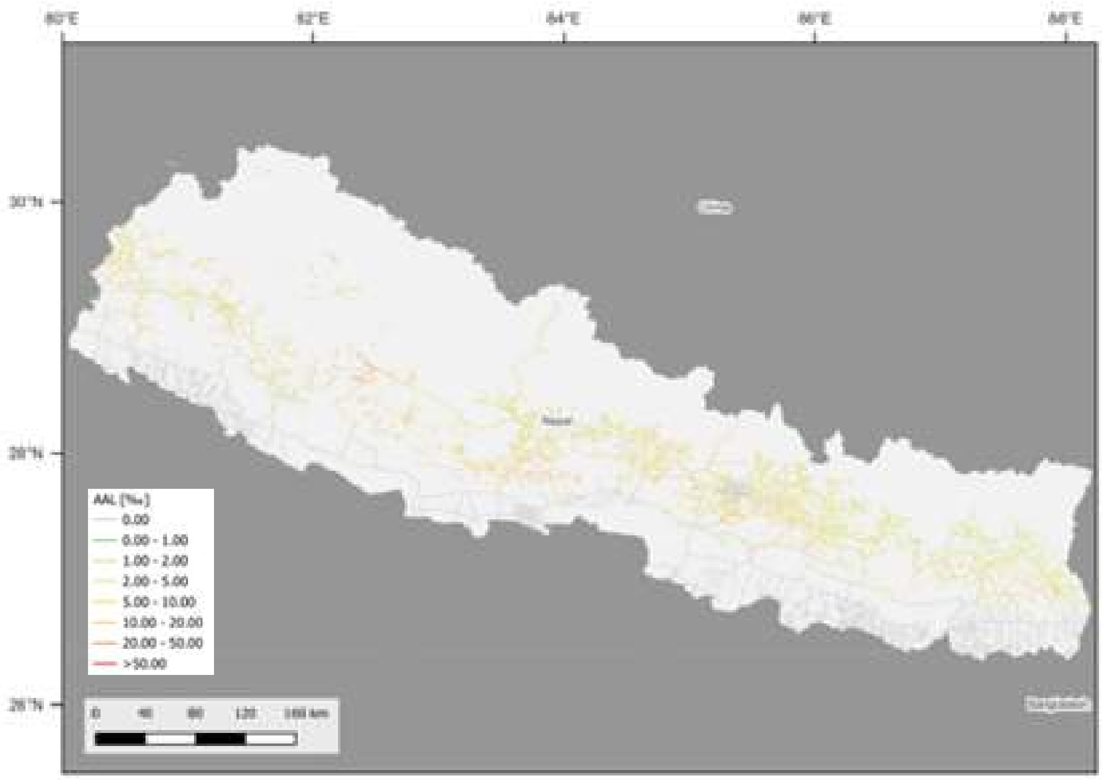


Figure 5.33: Relative AAL from rain-triggered landslides (SSP1-RCP2.6) for road portfolios

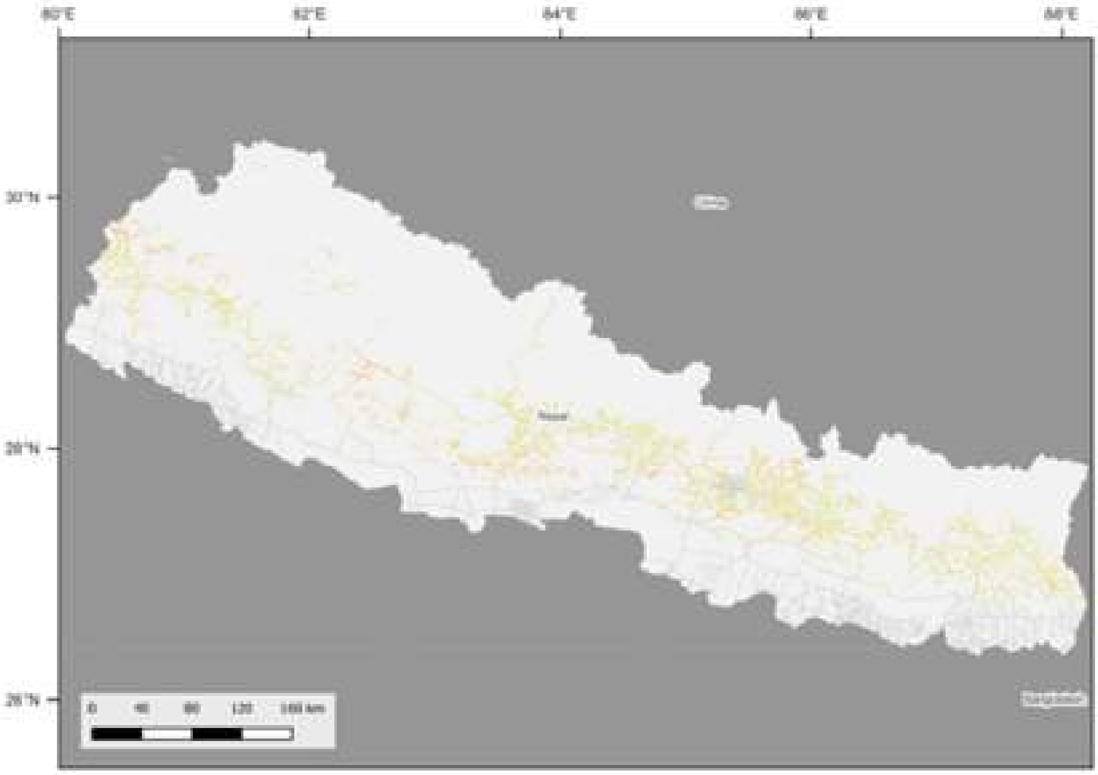


Figure 5.34: Relative AAL from rain-triggered landslides (SSP5-RCP8.5) for road portfolios

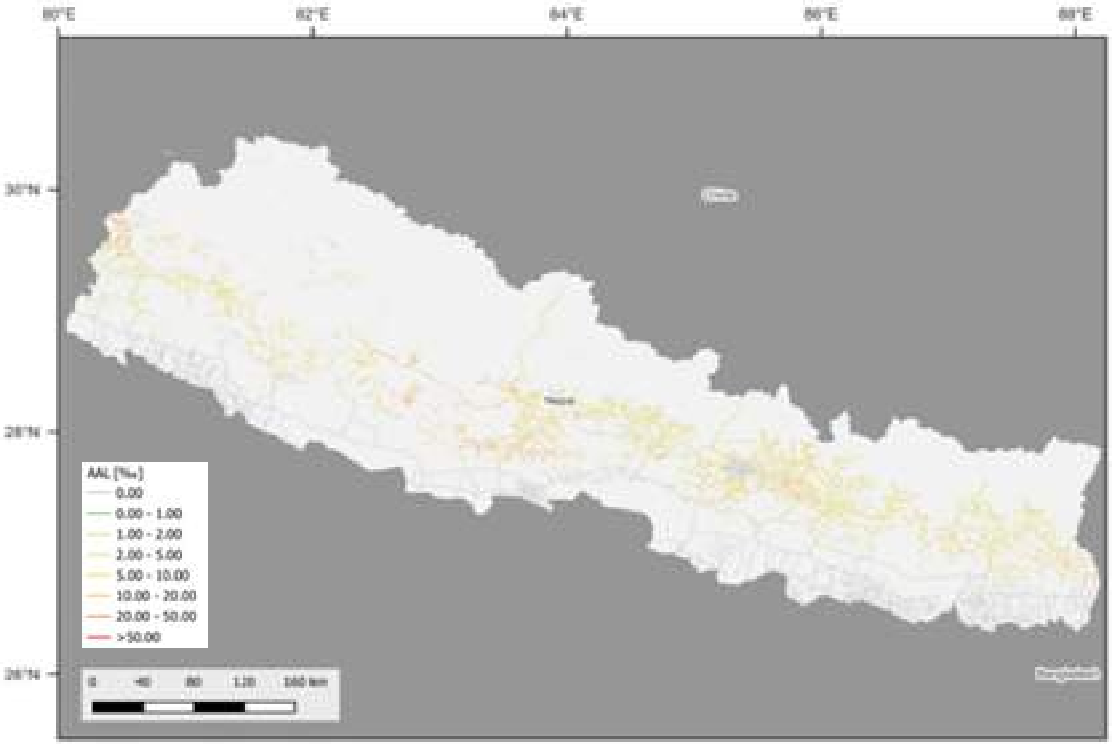


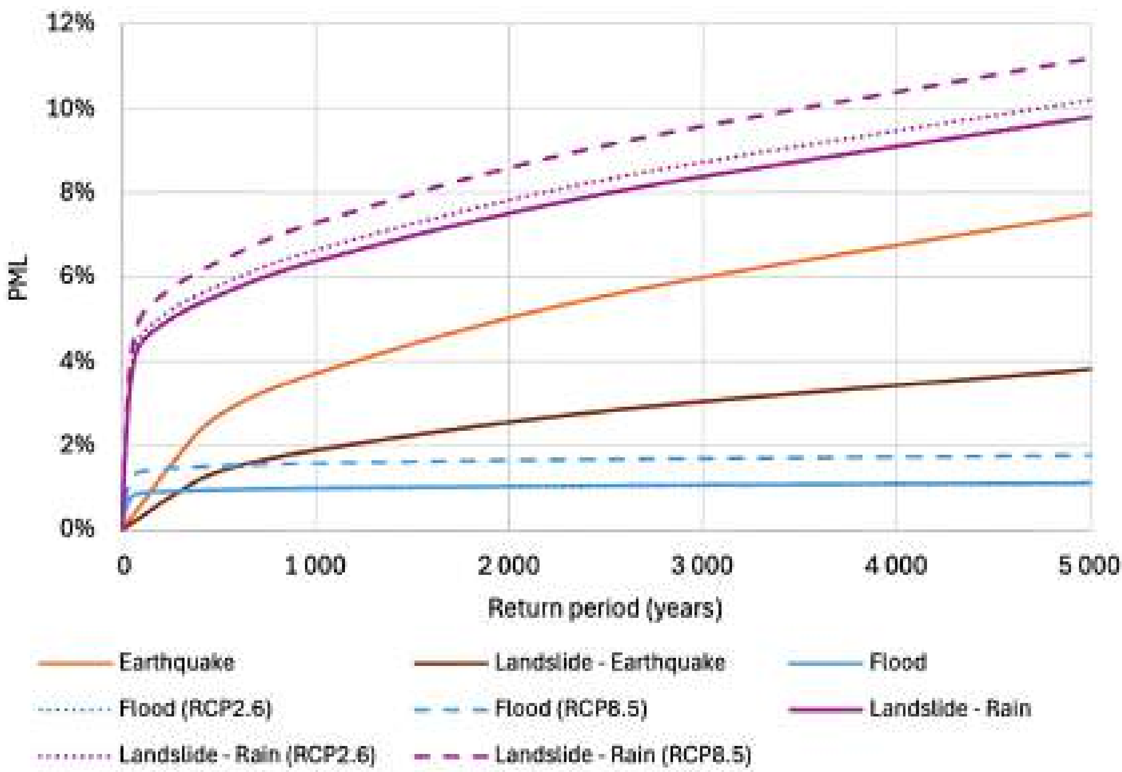
Table 5.13 presents the PML values for Nepal's road sector, categorized by hazard and some selected return periods. As noted, PMLs consistently exceed AALs across all calculated return periods.

Table 5.13: PML for roads and bridges infrastructure (values in 000' $)

Return period (years)	Earthquake	Lanslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide - Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	$11,538	$5,870	$53,307	$51,868	$84,365	$210,513	$219,153	$240,658
25	$28,845	$14,675	$108,715	$105,780	$172,063	$457,649	$476,432	$523,183
50	$57,690	$29,351	$150,690	$146,622	$238,479	$697,865	$726,506	$797,797
100	$115,381	$58,701	$167,022	$162,516	$264,265	$843,330	$877,942	$964,093
250	$288,452	$146,753	$175,229	$170,510	$277,118	$948,918	$987,864	$1,084,802
500	$516,910	$262,842	$182,064	$177,169	$287,795	$1,057,517	$1,100,920	$1,208,951
1000	$705,151	$358,341	$189,929	$184,832	$300,063	$1,211,199	$1,260,910	$1,384,641
2500	$1,055,149	$535,759	$202,165	$196,756	$319,116	$1,516,245	$1,578,475	$1,733,368
5000	$1,425,495	$723,340	$213,043	$207,357	$336,023	$1,860,083	$1,936,425	$2,126,444

Figure 5.35 presents the relative PML curves for all the hazards considered. Although rain-triggered landslides and floods dominate the risk landscape for very short return periods, the earthquake PML becomes significant for intermediate and long return periods, highlighting the greater impact of this hazard on the risk for large or catastrophic events. Nonetheless, rain-triggered landslides continue to dominate the risk for Nepal's roads across all return periods. This is understandable given the mountainous terrain present throughout most of the country. Note the rapid increase in the earthquake- and landslide-related PML functions compared to the relatively flat curve for floods.

Figure 5.35: PML curve for roads and bridges infrastructure



Chapter 6

Post-Disaster Funding Gap Assessment

Post-Disaster Funding Gap Assessment

Post-disaster funding gap assessment is a systematic process for determining the available financial resources for recovery and reconstruction, and estimating the additional funding requirements. Conducting a timely funding gap assessment is critical to ensuring that affected sectors receive the necessary resources to rebuild and recover effectively and efficiently. As it involves multiple processes, it requires inputs from various perspectives to ensure fiscal resilience. There are advantages to conducting a funding gap assessment. Funding gap assessments can do the following:

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

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

3. Can be used to advocate for additional funding from governments, international organizations, donors, and the private sector. Resource mobilization is a pivotal component of ensuring efficient disaster recovery, and funding gap assessments are essential in this process. They also help guide stakeholders in identifying which resources are most critical and how to leverage them strategically to support recovery initiatives.

4. Enhance transparency and accountability in the recovery process. Stakeholders can monitor the allocation and use of funds, reducing the risk of corruption and mismanagement.

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

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

Disasters pose significant fiscal risks to Nepal. Unexpected shocks can cause major challenges that disrupt the government's finances and severely affect the economy's smooth operation.

Fiscal Risks from Disasters in Nepal

Nepal has experienced heavy damage and losses from disasters over the years. For instance, the September 2024 monsoon floods caused damages totalling **NPR 46.68 billion** ($295 million), with **NPR 38.92 billion** (83 percent) in physical infrastructure (such as roads, hydropower, and water systems) (The Kathmandu Post, 2024b). The Doti-Bajhang-Jajarkot earthquakes in 2022-23 required an estimated reconstruction cost of over NPR 63.5 billion ($481 million at $1 = NPR 132) (Nepal Press, 2024). In 2015, the Gorkha earthquake and subsequent aftershocks caused the deaths of approximately 9,000 people, leading to losses and damages estimated at $7 billion, equivalent to one-third of Nepal's GDP. The severe flooding in August 2017 affected 1.7 million people and caused losses and damages of $585 million, about 3 percent of Nepal's GDP (Nepal Institute for Policy Research, n.d.). These recurring disasters divert limited public resources from planned development efforts towards urgent reconstruction needs.

Risk assessments further highlight Nepal's vulnerability. A recent earthquake assessment shows that Nepal could incur an average of $325 million per year in direct damage to private and public assets. Approximately 88 percent of this loss is attributable to damage to residential buildings. For floods, estimates show an AAL of $220 million (Government of Nepal, 2024).

Estimating Future Funding Gaps for Energy, Roads, and Bridges

Government Reserves

The Government of Nepal has **NPR 4.65 billion** ($35.2 million) available in the disaster management fund for emergency response during disasters. The current balances in the key disaster-related funds are as follows (The Himalayan Times, 2025):

1. Prime Minister's Disaster Relief Fund: NPR 1.89 billion
2. Central Disaster Management Fund: NPR 1.27 billion
3. Provincial Disaster Management Fund: NPR 794.1 billion

By province, the fund balances include the following

Koshi	Madhes	Bagmati	Gandaki
NPR 60.9 million	NPR 117.8 million	NPR 75.8 million	NPR 250 million

Lumbini	Karnali	Sudurpaschim
NPR 65 million	NPR 95.2 million	NPR 118.9 million

A total of NPR 690.5 million is also available across the 77 district-level disaster funds.

In October 2024, the World Bank approved $150 million in contingent financing for the Government of Nepal under the Nepal Disaster Resilience Development Policy Credit with Catastrophe Deferred Drawdown Option (Cat DDO) to be used in the event of a natural, climate-induced hazard, or health emergency (World Bank, 2024).

Energy Sector

Based on the catastrophe model in Chapter 5, excluding climate change effects, the highest AAL for the energy sector is attributable to floods, estimated at **$32.4 million**. The highest PML for hazards with a 10-year return period will also be due to floods, estimated at **$69.5 million**. Table 6.1 shows the summary of AALs and PMLs for the energy sector.

Table 6.1: AALs and PML for energy sector infrastructure (values in $)

Average annual loss				
Hazard	Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)
Value ($)	$2,553,000	$32,418,000	$33,412,000	$44,219,000
Probable maximum loss				
Return period (years)	Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)
10	$3,428,000	$69,533,000	$71,665,000	$94,845,000
25	$8,569,000	$141,814,000	$146,159,000	$193,442,000
50	$17,138,000	$196,598,000	$202,606,000	$268,176,000
100	$34,276,000	$217,992,000	$224,611,000	$297,375,000
250	$85,689,000	$228,892,000	$235,748,000	$312,279,000
500	$153,653,000	$238,009,000	$245,044,000	$324,753,000
1000	$209,707,000	$248,531,000	$255,757,000	$339,155,000
2500	$313,997,000	$264,953,000	$272,452,000	$361,645,000
5000	$424,419,000	$279,599,000	$287,318,000	$381,711,000

Figure 6.1: AAL for energy sector by hazard (in $)

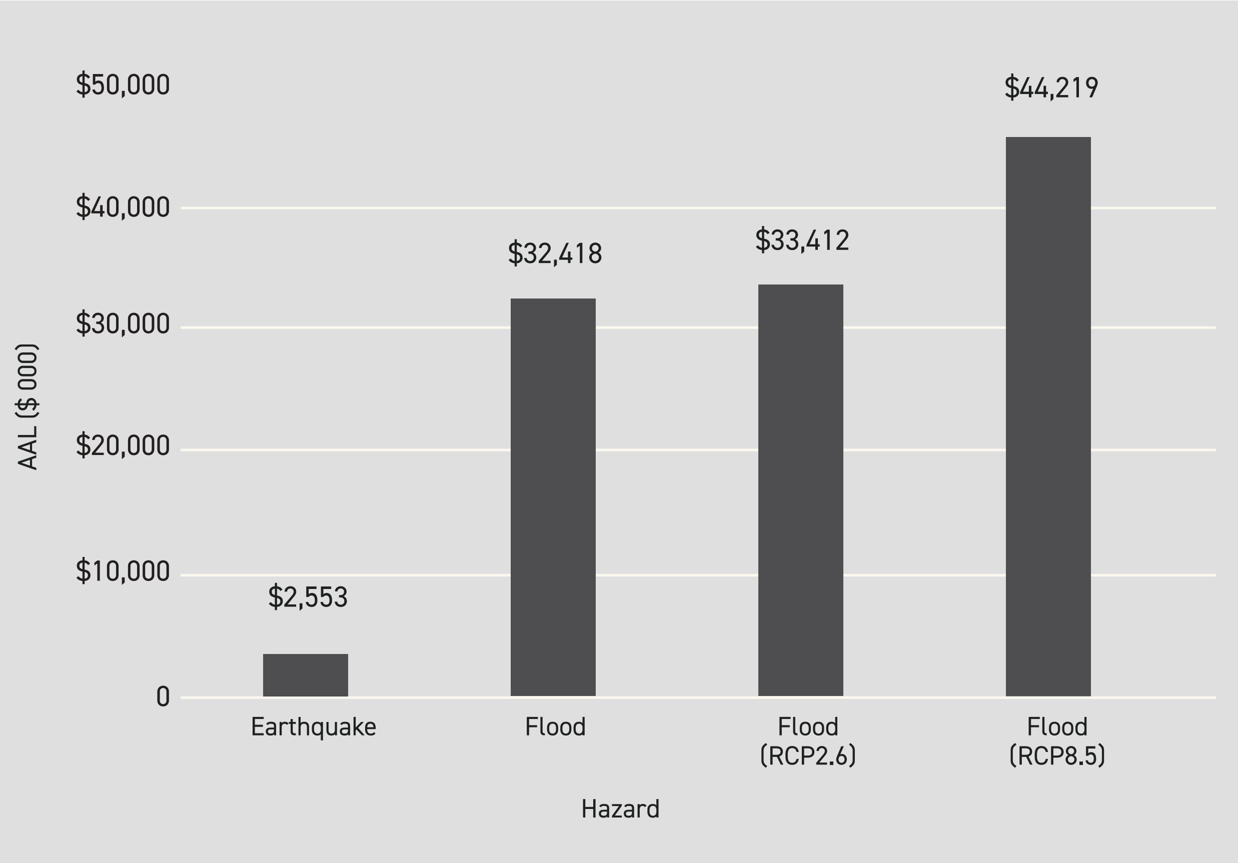
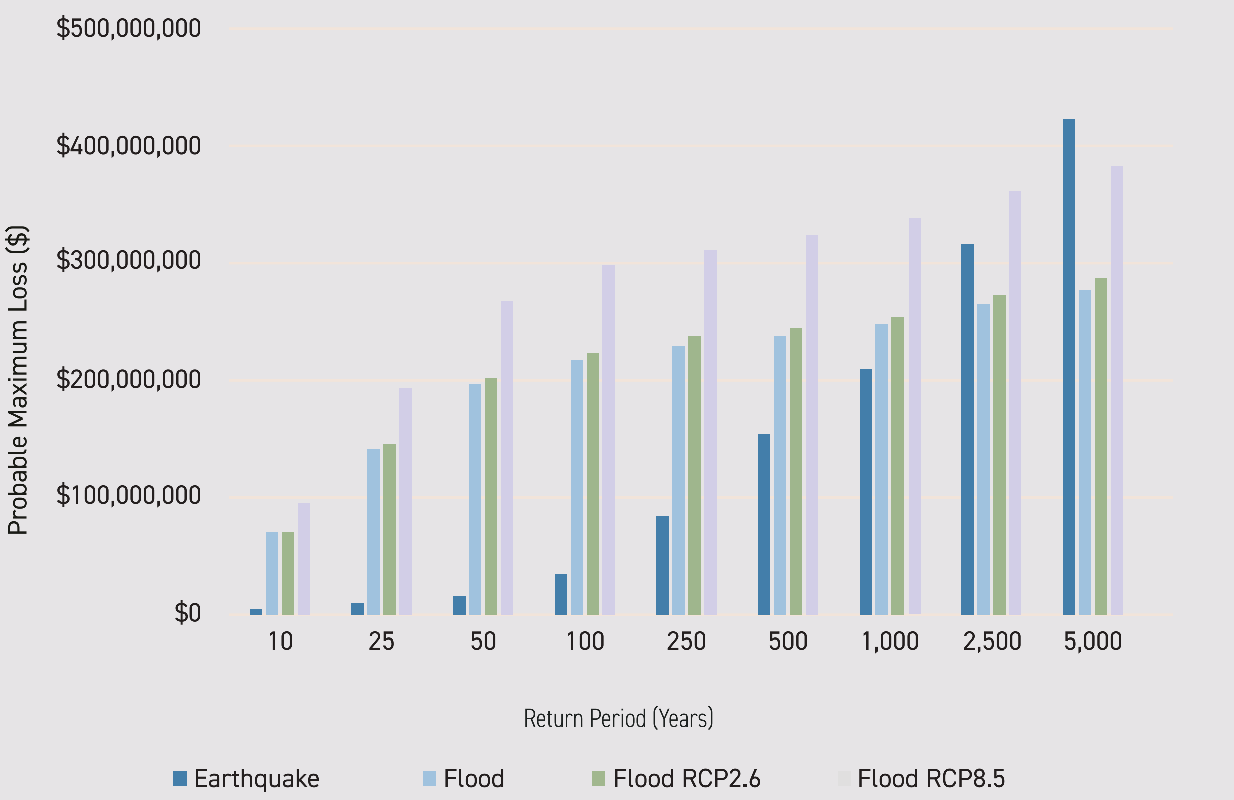


Figure 6.2: PML for energy sector by hazard type (in $)



Roads and Bridges

Without the effects of climate change, the highest AALs for the roads and bridges will be due to rain-induced landslides, estimated at $101.2 million. The highest PML for hazards with a 10-year return period will also come from rain-induced landslides, estimated at $210.5 million. Table 6.2 summarizes the AALs and PMLs for the roads and bridges sector.

Table 6.2: AALs and PMLs for roads and bridges infrastructure

Average annual losses ($ '000)								
Hazard	Earthquake	Lanslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
Value ($)	$8,591	$4,370	$24,853	$24,182	$39,330	$101,238	$105,393	$115,736
Probable maximum losses ($' 000)								
Return period (years)	Earthquake	Lanslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	$11,538	$5,870	$53,307	$51,868	$84,365	$210,513	$219,153	$240,658
25	$28,845	$14,675	$108,715	$105,780	$172,063	$457,649	$476,432	$523,183
50	$57,690	$29,351	$150,690	$146,622	$238,479	$697,865	$726,506	$797,797
100	$115,381	$58,701	$167,022	$162,516	$264,265	$843,330	$877,942	$964,093
250	$288,452	$146,753	$175,229	$170,510	$277,118	$948,918	$987,864	$1,084,802

Average annual losses ($ '000)								
Hazard	Earthquake	Lanslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
Value ($)	$8,591	$4,370	$24,853	$24,182	$39,330	$101,238	$105,393	$115,736
Probable maximum losses ($' 000)								
Return period (years)	Earthquake	Lanslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
500	$516,910	$262,842	$182,064	$177,169	$287,795	$1,057,517	$1,100,920	$1,208,951
1000	$705,151	$358,341	$189,929	$184,832	$300,063	$1,211,199	$1,260,910	$1,384,641
2500	$1,055,149	$535,759	$202,165	$196,756	$319,116	$1,516,245	$1,578,475	$1,733,368
5000	$1,425,495	$723,340	$213,043	$207,357	$336,023	$1,860,083	$1,936,425	$2,126,444

Figure 6.3: AAL for roads and bridges by hazard (in $ 000)

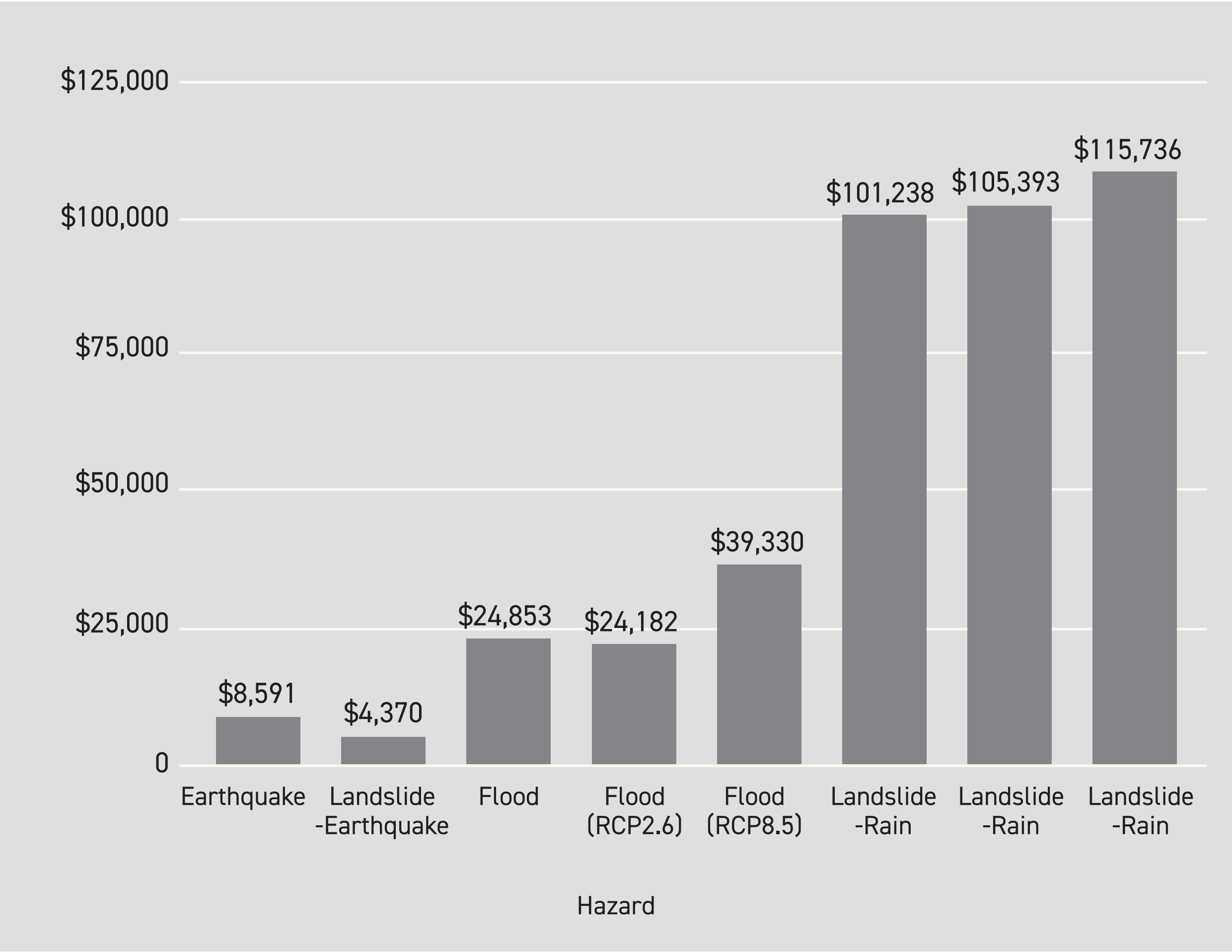
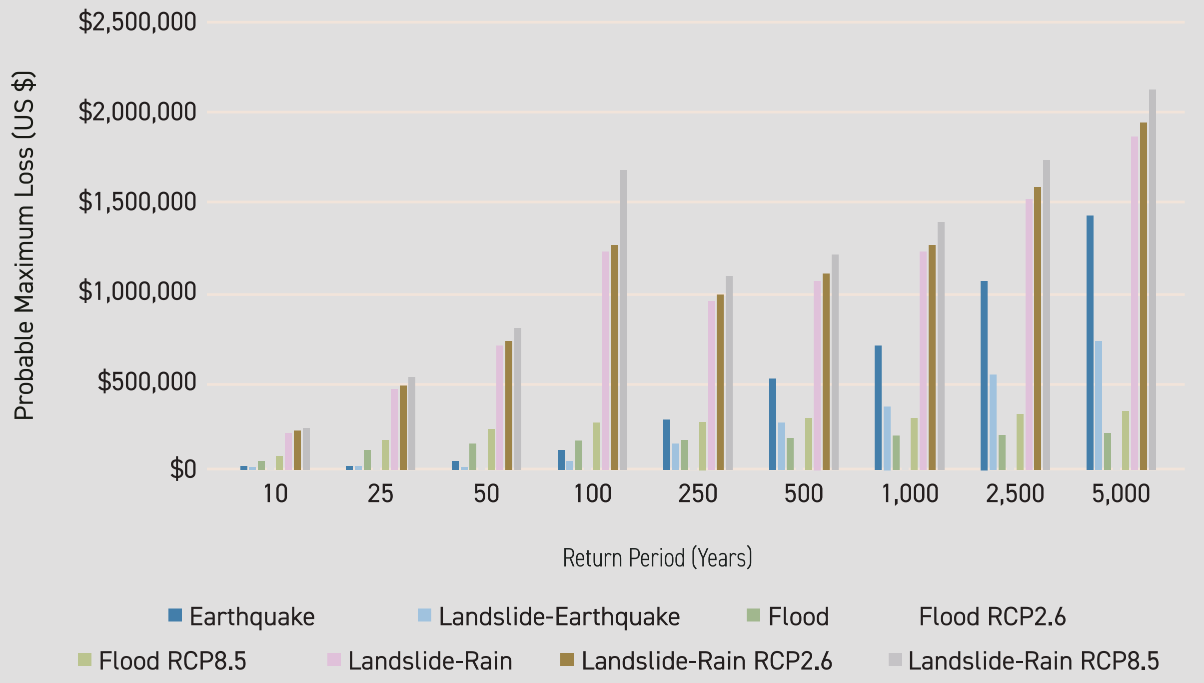


Figure 6.4: PML for roads and bridges by hazard (in $)



It should be noted that hazards with longer return periods have higher AALs and PMLs.

Using the available disaster management fund of NPR 4.65 billion ($35.2 million at $1 = NPR 132), Table 6.5 shows the gap if hazards with the highest AALs with a 10-year return period occur in 2026.

Table 6.5: Funding gap without climate change effects (without CatDDO)

Year Basis	Disaster fund		Energy AAL	R&B AAL	Gap/Surplus	
	NPR (000)	$ (000)	$ (000)	$ (000)	$ (000)	NPR (000)
2026	4,650,000	35,227	32,400	101,200	(98,373)	(12,985,200)

Table 6.5 shows that the government's allocated disaster relief fund will not be sufficient to meet the post-disaster needs of the energy, and roads and bridges sectors if floods and rain-induced landslides (without considering the effects of climate change) occur in 2026.

It should be noted, however, that if only floods occur, the disaster fund can cover the effects of floods on the energy sector. On the other hand the impacts of landslides on roads and bridges are too severe to be covered by the disaster fund.

On the other hand, Table 6.6 shows the difference with the $150 million CatDDO from the World Bank.

Table 6.6: Funding gap without climate change effects (with CatDDO)

Year Basis	Disaster fund		WB CatDDO	Energy AAL	R&B AAL	Gap/Surplus	
	NPR (000)	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	NPR (000)
2026	4,650,000	35,227	150,000	32,400	101,200	51,627	6,814,800

Table 6.6 shows that funds are sufficient to cover the combined AALs of the energy and roads and bridges sectors with the World Bank contingent assistance. However, it should be noted that these funds are meant for all sectors, not just energy and roads and bridges sectors.

Extreme Cases

In analysing extreme cases, the potential post-disaster funding gaps will be estimated using the values in the PML. The following scenarios are considered.

Scenario 1.

Hazards with a 10-year return period that occur without climate change effects in the same year. This assumes the least-cost scenario since hazards with longer return periods have higher PMLs.

1

The higher PML for the energy sector is about $69,533,000 due to floods with a 10-year return period.

2

Rain-induced landslides with a 10-year return period can lead to the highest PML for the roads and bridges sector, estimated at about $210,513,000.

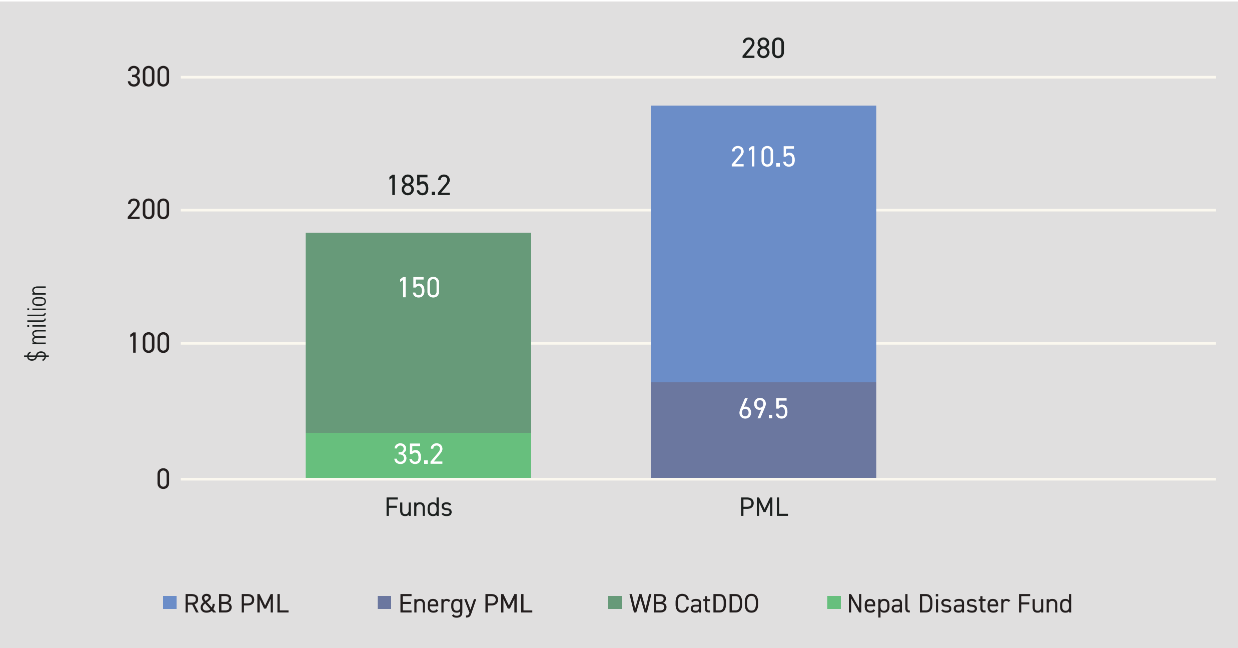
Using the above figures, Table 6.7 shows that if floods and rain-induced landslides with a 10-year return period occur in the same year, there will be a significant funding gap even with the CatDDO from the World Bank.

Table 6.7: Funding gap from PML without climate change effects for hazards with 10-year return period ($ million)

Nepal disaster fund		WB CatDDO	Energy PML	R&B PML	Gap with CatDDO	Gap without CatDDO
NPR billion	$ million	$ million	$ million	$ million	$ million	$ million
4.65	35.2	150	69.5	210.5	-94.8	-244.8

However, as shown in Table 6.7, if the Nepalese government can reduce the vulnerability of roads and bridges from rain-induced landslides, the funding gap can be substantially decreased.

Figure 6.5: PML and available fund for hazards with 10-year return period ($ million)



Scenario 2.

Hazards without climate change projected impacts with the highest PMLs occurring within the same year, such as 2026. This scenario considers floods in the energy sector and rain-induced landslides in roads and bridges across various return periods, with the highest PMLs, along with the available government fund and World Bank CatDDO contingency credit. Table 6.8 shows the funding gap for hazards (excluding climate change impacts) with the highest PMLs by return period if they occur within the same year.

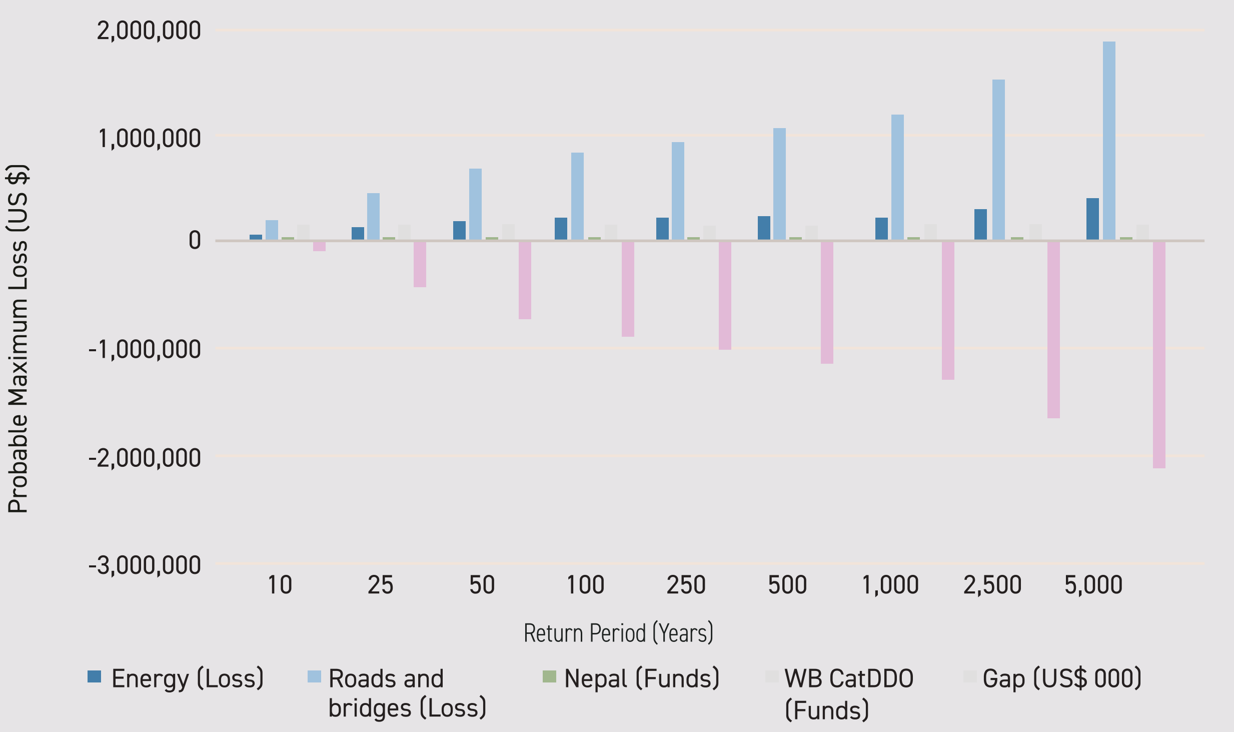
Table 6.8: Funding gap based on highest PMLs by return period (no Climate Change)

Return period (Years)	Probable maximum loss		Source of post-disaster funds		Gap	
	Energy	Roads and bridges	Nepal	WB CatDDO	$	NPR
	$ (000)	$ (000)	$ (000)	$ (000)	$ (000)	NPR (000)
10	69,533	210,513	35,200	150,000	-94,846	-12,519,672
25	141,814	457,649	35,200	150,000	-414,263	-54,682,716
50	196,598	697,865	35,200	150,000	-709,263	-93,622,716
100	217,992	843,330	35,200	150,000	-876,122	-115,648,104
250	228,892	948,918	35,200	150,000	-992,610	-131,024,520
500	238,009	1,057,517	35,200	150,000	-1,110,326	-146,563,032
1,000	248,531	1,211,199	35,200	150,000	-1,274,530	-168,237,960
2,500	313,997	1,516,245	35,200	150,000	-1,645,042	-217,145,544
5,000	424,419	1,860,083	35,200	150,000	-2,099,302	-277,107,864

Note: Earthquakes with return periods of 2,500 and 5,000 years have the highest PMLs for the energy sector.

Table 6.8 indicates that the government funds and the World Bank CatDDO will not be adequate to support the post-disaster recovery needs of the energy and road and bridges sectors if floods and landslides with different return periods occur in the same year.

Figure 6.6: Highest PMLs, available funds, and funding gap by return period (no climate change) (in $ 000)



It should also be noted that the available disaster funds will not cover the probable maximum loss for roads and bridges caused by rain-induced landslides.

Scenario 3.

Nepal will allocate 5% of the development budgets at all levels for DRR, as highlighted in the National Strategic Action Plan for DRR 2018–2030. This scenario assumes the following:

1. For the FY 2025/26, Nepal's total national budget is NPR 1.964 trillion (approximately $14.4 billion). The capital (development) expenditure allocation amounts to NPR 407.9 billion, or about 20.8 percent of the total. This NPR 407.9 billion represents the government's forecasted development budget for FY 2025/26.[14]

2. Nepal will keep its overall budget steady over the years and allocate 5 percent of the development budget (NPR 407.9 billion), which is about NPR 20.4 billion ($154 million) per year for DRR.

3. Nepal will incur, on average, $325 million per year in direct damages to private and public assets from earthquakes, and an average of $220 million due to floods, according to the Official Statement of the Government of Nepal at the 2024 Asia-Pacific Ministerial Conference on Disaster Risk Reduction (APMCDRR).

Based on the above assumptions, Table 6.9 shows the post-disaster funding gap.

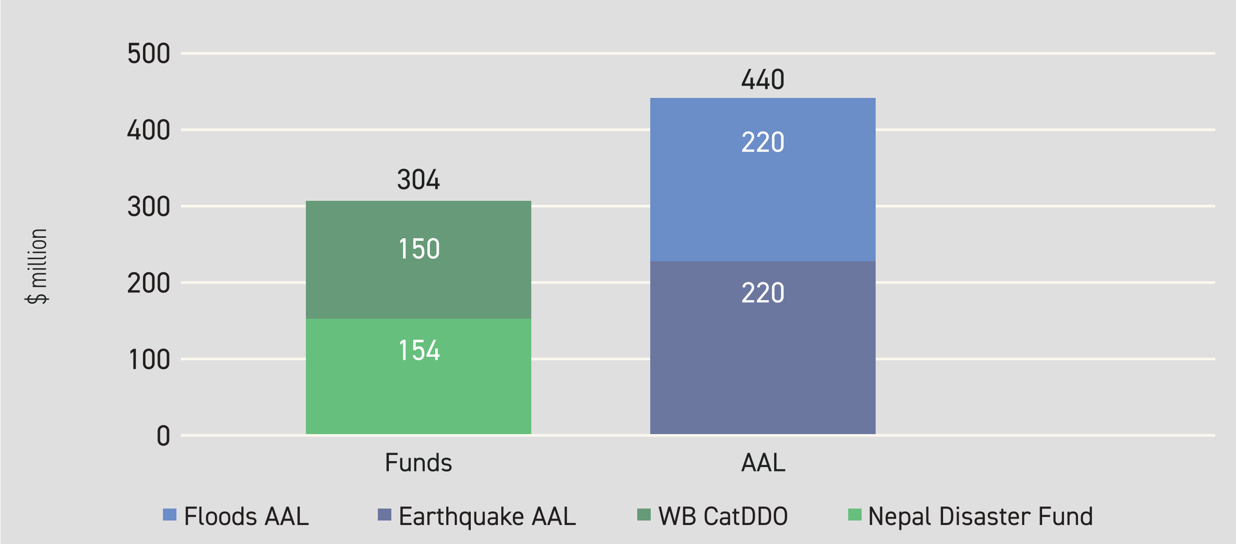
Table 6.9: Funding gap at 5% of development fund budget for DRR ($ million)

Nepal disaster fund		WB CatDDO	Earthquake AAL	Flood AAL	Gap with CatDDO	Gap without CatDDO
NPR billion	$ million	$ million	$ million	$ million	$ million	$ million
20.4	154	150	325	220	-241	-391

Table 6.9 shows that allocating 5 percent of the development budget for post-disaster response still leaves a funding gap for responding to earthquakes and floods in Nepal.

[14] Available at https://risingnepaldaily.com/news/62748?utm

Figure 6.7: AAL and available fund at 5% of development fund budget for DRR ($ million)



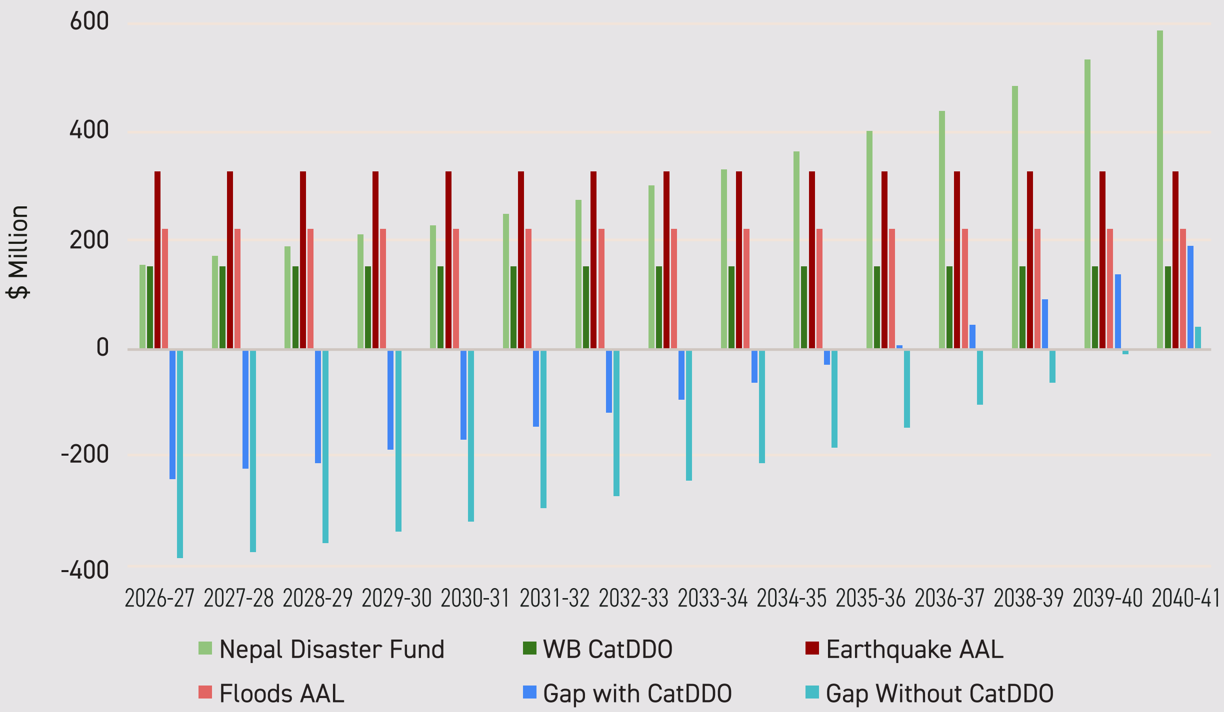
If Nepal's disaster fund increases by 10 percent annually, Table 6.10 shows the funding gap.

Table 6.10: Funding gap with 10% increase in Nepal's disaster fund ($ million)

Year	Nepal disaster fund		WB CatDDO	Earthquake AAL	Flood AAL	Gap with CatDDO	Gap without CatDDO
	NPR billion	$ million	$ million	$ million	$ million	$ million	$ million
2026-27	20.4	154	150	325	220	-241	-391
2027-28	22.4	169	150	325	220	-226	-375
2028-29	24.7	186	150	325	220	-209	-359
2029-30	27.2	205	150	325	220	-190	-340
2030-31	29.9	225	150	325	220	-170	-320
2031-32	32.9	248	150	325	220	-147	-297
2032-33	36.1	273	150	325	220	-122	-272
2033-34	39.8	300	150	325	220	-95	-245
2034-35	43.7	330	150	325	220	-65	-215
2035-36	48.1	363	150	325	220	-32	-182
2036-37	52.9	399	150	325	220	4	-146
2037-38	58.2	439	150	325	220	44	-106
2038-39	64	483	150	325	220	88	-62
2039-40	70.4	532	150	325	220	137	-13
2040-41	77.5	585	150	325	220	190	40

Table 6.10 indicates that the expected AAL from earthquakes and floods in Nepal are much higher than the available disaster funds, even with a 10 percent annual increase. The gap will only be closed in 2040–41 without the World Bank's CatDDO. It should be noted that the estimated AALs cover various sectors, not just the energy and road and bridges sectors.

Figure 6.8: AAL per disaster, available funds, and funding gap with 10% increase in Nepal's disaster fund ($ million)



Scenario 4. Nepal's annual disaster risk reduction allocations will increase by at least 5 percent of development budgets across all levels, as highlighted in the National Strategic Action Plan for DRR 2018–2030. This scenario assumes the following:

1. For the FY 2025/26, Nepal's total national budget is NPR 1.964 trillion (approximately $14.4 billion). The capital (development) expenditure allocation amounts to NPR 407.9 billion, or about 20.8 percent of the total. This NPR 407.9 billion represents the government's forecasted development budget for FY 2025/26.[15]

2. Nepal will keep its total budget steady over the years and allocate 5 percent of the development budget (NPR 407.9 billion), which is about NPR 20.4 billion ($154 million) per year for disaster risk reduction.

3. The AALs and PMLs for the energy and road and bridges sectors are based on the results of the catastrophe model.

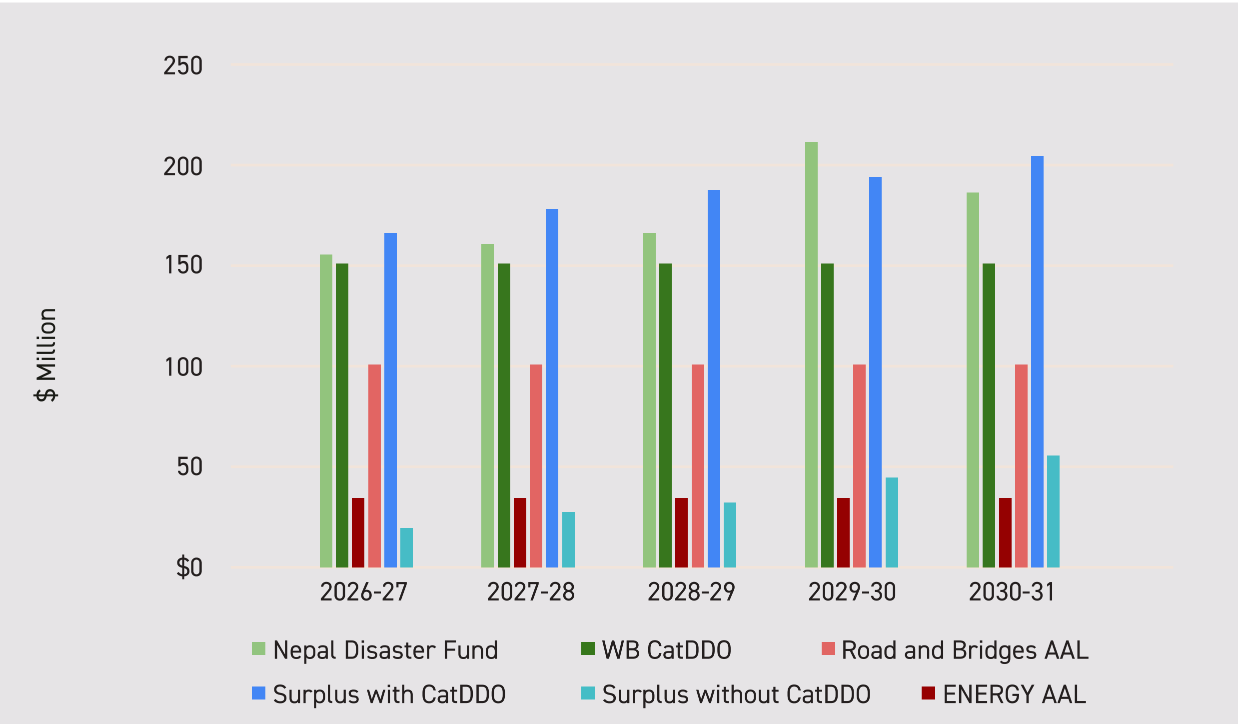
[15] Available at https://risingnepaldaily.com/news/62748?utm

If Nepal's disaster fund increases by 5 percent annually, Table 6.11 shows that the disaster fund will be sufficient to meet the post-disaster needs of the energy and road and bridges sectors.

Table 6.11: Funding difference if there is 5% annual increase in Nepal's disaster fund with the AALs for energy and road and bridges ($ million)

Year	Nepal disaster fund		WB CatDDO	Earthquake AAL	Road and bridges AAL	Surplus with CatDDO	Surplus without CatDDO
	NPR billion	$ million	$ million	$ million	$ million	$ million	$ million
2026-27	20.4	154	150	32.4	101.2	170.4	20.4
2027-28	21.4	162	150	32.4	101.2	178.1	28.1
2028-29	22.5	170	150	32.4	101.2	186.2	36.2
2029-30	23.6	178	150	32.4	101.2	194.7	44.7
2030-31	24.8	187	150	32.4	101.2	203.6	53.6

Figure 6.9: AAL for energy and road sectors, available funds, and funding surplus if there is 5% annual increase in Nepal's disaster fund ($ million)

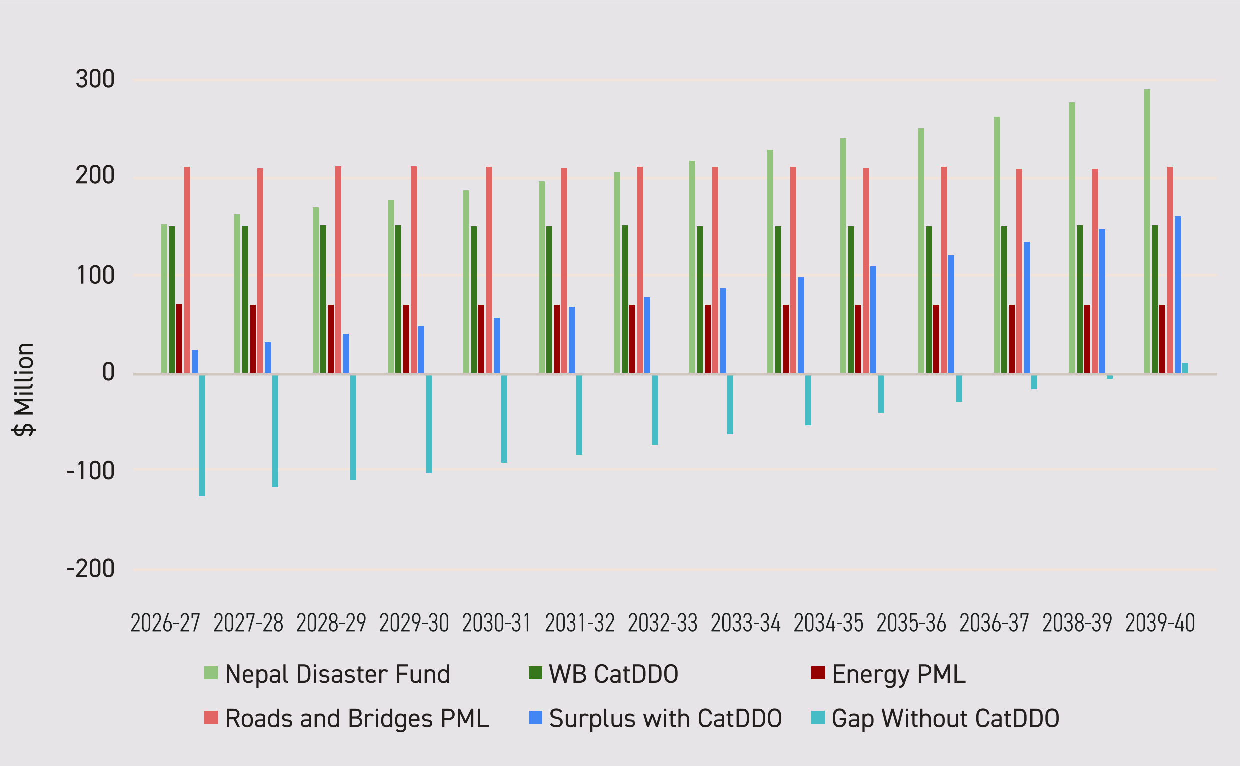


On the other hand, if hazards with a 10-year return period that have the highest PMLs for the energy and roads and bridges sectors are considered, Table 6.12 shows the funding situation.

Table 6.12. Funding difference with a 5% annual increase in Nepal's disaster fund for energy and roads with a 10-year hazard return period ($ million)

Year	Nepal disaster fund		WB CatDDO	Energy PML	Road and bridges PML	Surplus with CatDDO	Gap without CatDDO
	NPR billion	$ million	$ million	$ million	$ million	$ million	$ million
2026-27	20.4	154	150	69.5	210.5	24.0	-126.0
2027-28	21.4	162	150	69.5	210.5	31.7	-118.3
2028-29	22.5	170	150	69.5	210.5	39.8	-110.2
2029-30	23.6	178	150	69.5	210.5	48.3	-101.7
2030-31	24.8	187	150	69.5	210.5	57.2	-92.8
2031-32	26.0	197	150	69.5	210.5	66.5	-83.5
2032-33	27.3	206	150	69.5	210.5	76.4	-73.6
2033-34	28.7	217	150	69.5	210.5	86.7	-63.3
2034-35	30.1	228	150	69.5	210.5	97.5	-52.5
2035-36	31.6	239	150	69.5	210.5	108.9	-41.1
2036-37	33.2	251	150	69.5	210.5	120.8	-29.2
2037-38	34.9	263	150	69.5	210.5	133.4	-16.6
2038-39	36.6	277	150	69.5	210.5	146.6	-3.4
2039-40	38.5	290	150	69.5	210.5	160.4	10.4

Figure 6.10: PML for energy and road sectors, available funds, and funding gap with a 5% annual increase in Nepal's disaster fund over a 10-year period ($ million)



The above data shows that if Nepal's disaster fund increases by 5 percent annually, it can meet the post-disaster requirements of the energy and road and bridges sectors, if there is the CatDDO from the World Bank. Otherwise, a funding gap will only be closed around 2039-2040.

Again, it should be noted that the disaster fund and the CatDDO are intended to cover all sectors, not just energy, and roads and bridges.

Chapter 7

Recommendations

Recommendations

The Government of Nepal recognizes that the constant threat of climate change and natural hazards that lead to disasters is one of the factors that could impact the country's economic outlook (Government of Nepal, 2024). Based on the earlier discussions, the following are some recommendations that the Government of Nepal can consider to reduce the fiscal risks from disasters.

1 Make critical infrastructure resilient.

To mitigate the adverse impacts across sectors, hazards and their risks must be identified, and suitable risk reduction measures must be implemented to ensure critical infrastructure can withstand the severity of future hazards.

a Improve the structural integrity of power grid infrastructure, roads, and bridges.

Building more resilient infrastructure with higher design standards would allow these systems to withstand more hazards. Although this may be costly, it will ultimately reduce repair expenses, service disruptions, and frequent maintenance costs-especially considering the projected effects of climate change, including increased intensity and frequency of natural hazards. Besides improving the structural design of roads and bridges, incorporating landslide-prevention measures during construction is essential. It should be noted that the catastrophe model identifies rain-induced landslides as the leading cause of the highest AALs and PMLs. Regular inspections and maintenance of the power grid, roads, and bridges are also necessary to prevent vulnerabilities from increasing.

b Identify and assess specific critical infrastructure assets and estimate potential damages from disasters, along with their subsequent impacts on other sectors.

The country should identify critical assets, assess their vulnerability to frequent and extreme disasters, and analyse the impacts on other important sectors of the economy to determine appropriate risk management mechanisms. This assessment should lead to further analysis of how to strengthen structures and identify risk-reduction investments that will make critical infrastructure resilient.

c Update and upgrade hazard maps.

Upgraded and updated hazard maps will improve the accuracy of estimating potential damage to critical infrastructure, as mentioned above. These estimates will help the government plan budgets for emergency response. Moreover, hazard maps are essential for encouraging insurance companies to expand their disaster-related insurance coverage, as they play a key role in risk assessment, pricing, and underwriting. Identifying high-risk areas prone to floods, earthquakes, cyclones, and other disasters enables insurers to determine risk levels, evaluate coverage eligibility based on property risk exposure, design customized policies for different risk zones, estimate potential losses, maintain adequate financial reserves or reinsurance, and set appropriate premiums for policyholders.

d Update building codes and regulations to incorporate disaster and climate risks into development planning and investment decisions, reducing adverse disaster effects and impacts.

To institutionalize social and economic resilience, update and integrate building codes, land-use plans, zoning regulations, and similar policies into the design of both public and private investments. Moreover, disaster risk management and potential climate change impacts should be integrated into development plans and investments from both the government and the private sector. This initiative would ensure that every new public infrastructure investment incorporates disaster-proof designs tailored to withstand extreme weather events. For instance, constructing elevated roads, climate-resistant bridges, and improving drainage systems to prevent flooding should be carefully evaluated. Such investments are critical not only for safer transportation but also for reducing the fiscal burdens associated with frequent infrastructural damage. Additionally, older structures may also need to be retrofitted to enhance their durability and resilience, ultimately lowering their vulnerability to future hazards. Moreover, resilient infrastructure can enable the creation of tailored insurance products with better terms, such as higher coverage limits, lower deductibles, or more comprehensive coverage options at reduced costs. Insurers often rely on reinsurance to manage their risks; when a country or sector shows reduced vulnerability through resilient infrastructure, reinsurers may offer better terms, indirectly lowering overall insurance costs (Swiss Re Institute, 2024).

e Strictly implement land use planning to mitigate disaster risks.

The National Land Policy 2019 of the Government of Nepal clearly outlines measures for disaster mitigation to reduce the adverse effects of disasters through land use management in vulnerable areas. Based on this policy, the Government of Nepal enacted the Land Use Act, 2019, and the Land Use Regulation 2022, which must be fully implemented by the relevant local governments. The Land Use Act, 2019, provides a clear framework for land use planning through zoning across the country. The Land Use Regulation 2022 offers additional details to support the implementation of the act. The federal government has prepared and distributed detailed land-use zoning maps for all local levels to support local planning, which is currently being implemented.

f Build a state-wide disaster risk database.

The state should establish a comprehensive digital disaster database that consolidates historical data on disaster impacts, including detailed assessments of expenditures and infrastructure damages. Such a database would be instrumental in macroeconomic analysis of disaster effects across sectors and for developing accurate catastrophe risk models. By mapping essential infrastructure and analysing their exposure to frequent and severe disasters, the government can better evaluate inter-sectoral vulnerabilities and design appropriate risk financing and management strategies. Moreover, a comprehensive disaster database supported by current hazard maps will allow the government to conduct informed risk assessments, develop effective risk financing strategies, enhance budget planning for contingencies, and strengthen national disaster preparedness.

2 Nepal should strengthen enforcement of the national policy

a

Requiring that 5 percent of the development budget be allocated to disaster risk reduction (DRR). Due to the shrinking external funds in recent years, the Government of Nepal needs to allocate/earmark adequate funds for potential disasters across sectors such as roads, bridges, power grids, and humanitarian response. Since development programmes are often severely affected by regular/disasters such as floods and landslides, it is imperative to earmark a budget for these critical sectors. While this allocation may not fully cover post-disaster damages in the short term, consistent investment in hazard-resilient and safe infrastructure will gradually reduce vulnerability and help close the post-disaster financing gap over time. Similarly, it is important to have pre-arranged disbursement rules for allocated funds to avoid delays in post-disaster response. Such rules should improve local-level response capacity and eliminate centralized, reactive financing mechanisms.

3 Enforce structural designs:

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The Government of Nepal needs to prioritize the enforcement of road and bridge designs in Nepal to increase their resilience against disasters like landslides and floods, thereby reducing potential damage.

4 Expand and formalize the implementation of risk layering

With a multi-tiered financing framework: The study reveals a heavy reliance on ex-post budget reallocations and international assistance, with limited pre-arranged financing and growing post-disaster funding gaps, particularly in the energy and transport sectors. The government might 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:

The potential expansion of existing parametric insurance coverage schemes like the Himalayan Everest Insurance initiative, supported by the Rockefeller Foundation and the Nepal Economic Forum, the parametric crop and livestock insurance schemes which target smallholder farmers and aim to improve climate resilience and have been piloted in parts of western Nepal (e.g., Bardiya, Kailali, and Karnali provinces) by insurers such as Shikhar Insurance Co. Ltd., with support from partners including Global Parametrics and Practical Action, and the Parametric Flood Insurance which was supported by InsuResilience Solution Fund (ISF), Swiss Capacity Building Facility (SCBF), and USAID Tayar Nepal, among others.

c High-risk/low-frequency catastrophic events:

Additional contingent credit lines and standby loans from other sources for rapid liquidity. On the other hand, the feasibility of utilizing other insurance and reinsurance schemes for critical infrastructures should assessed since they are essential for recovering rehabilitation costs. This provision would enable the quick restoration of essential transportation services and power supply by reducing delays in such infrastructure repairs and supporting fiscal discipline within the broader budget framework.

Additionally, annual risk-layering reviews should be part of the budget process, integrated into the Ministry of Finance's fiscal strategy.

5 Improve the knowledge and capacity national and local government staff and communities.

a. Improved capacity of relevant line agency staff and local governments will effectively ensure compliance to rules and regulations as well as during monitoring activities.

6 Integrate disaster resilient features in the reconstruction of damaged infrastructure

a. Due to the Gen-Z revolution of September 2025. The reconstruction of damaged buildings and other infrastructure across the country (both public and private), including some heritage buildings caused by the recent Gen-Z revolution (September 9-10, 2025) may be the priority of the government over the next few years. In doing so, the government must consider disaster resilient features in the restoration, repair and reconstruction of the affected infrastructure.

Chapter 8

Annexure

Annexure

Annex A: Disaster-related Insurance Schemes in Selected Countries

Sri Lanka[16]

Recently, the global advisory, broking, and solutions company WTW (NASDAQ: WTW) launched Asia's first 4-peril parametric insurance policy to protect Sri Lanka's shrimp farms against weather risks, marking a significant milestone in Asia's aquaculture development. The unique solution was designed and implemented for Taprobane Seafood Group, Sri Lanka's largest seafood company, helping it meet a critical condition to secure $15 million in project financing from the Dutch entrepreneurial development bank FMO.

Shrimp farming is associated with a diverse range of risks and uncertainties, most prominently 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 for securing $15 million in project financing from the Dutch entrepreneurial development bank, FMO.

The WTW also recently launched Nitrogen Risk Insurance, the world's first parametric insurance solution that allows sugarcane farmers in Queensland, Australia, to cover the risk of yield shortfall from reduced applications of nitrogen fertilizer on ratoon crops.

Thailand[17]

Since 2011, the Thailand Rice Disaster Relief Top-up Crop Insurance Scheme, which uses weather-index insurance for rice, has been available to farmers. The 'Remote-sensing based information and insurance for crops in emerging economies' project is a public-private partnership 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 links remote sensing to advanced crop-yield modelling to build a rice production monitoring system that provides accurate and timely information on rice areas, yield, and disaster-affected rice areas.

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[16] WTW. (2023, July). WTW launches Asia's first 4-peril parametric insurance solution to unlock financing for aquaculture development (Press release). https://www.wtwco.com/en-ph/news/2023/07/wtw-launches-asias-first-4-peril-parametric-insurance-solution-to-unlock-financing-for-aquaculture

[17] United Nations Economic and Social Commission for Asia and the Pacific. (2017). Disaster risk transfer mechanisms: Issues and considerations for the Asia-Pacific region.

India

Modified Area Crop Insurance Scheme of India (2010)

The National Agricultural Insurance Scheme (NAIS), established by the Government of India, is the world's largest crop insurance programme, covering approximately 25 million farmers and managed by the Agriculture Insurance Company of India (AICI), which provides insurance for food crops, oilseeds, and a few commercial crops using an area yield-based approach.[18] By comparing current crop yields with historical data, this indexed strategy provides indemnity payouts to farmers insured in specific locations when actual yields are below 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 made after a disaster and on subsidized premiums. As a result, the government faces unlimited financial risk, and delays in claims settlement could lead to hardship for farmers. To enhance the programme'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.

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 contingent 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 for farmers against adverse weather conditions, such as droughts or excessive rainfall, which can lead to crop losses and financial instability. By utilizing weather indices to trigger payouts, the insurance scheme ensures timely compensation for farmers, thereby mitigating the economic impact of climate-related disasters. Since then, weather-based crop insurance in India has evolved significantly, with various programmes and approaches aimed at supporting farmers during adverse weather events.

[18] World Bank. (2011). Disaster risk financing and insurance case study: National agricultural insurance scheme in India. https://www.farm-d.org/app/uploads/2019/05/DRFI_India_mNAIS_Jan11

For instance, more recent initiatives include heat-linked parametric insurance systems that provide a lifeline to women in the informal sector in India.[19,20] 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'[21] 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, whereas those who have bank loans are required to do so. The Ministry of Agriculture oversees the programme, which has been redesigned to expedite the processing and payment of claims, improve technology interventions, and provide states greater flexibility in selecting risk covers and distributing 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 natural hazards and pests. It also seeks to use smartphones and remote sensing technologies to expedite the estimation of crop losses.[22] In general, PMFBY seeks to uphold contemporary farming methods, stable farmer incomes, encourage sustainable agricultural production, and ensure the flow of financing to the agricultural sector to enhance competitiveness and food security. Through its comprehensive coverage and government support, PMFBY plays a significant role in mitigating the financial impact of agricultural disasters on farmers and promotes sustainable agricultural production in India.

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[19] Clarke, D. J., Mahul, O., Kolli Rao, N., & Verma, N. (2012). Weather-based crop insurance in India (Policy Research Working Paper No. 5985). World Bank. https://documents1.worldbank.org/curated/en/693741468269445619/pdf/WPS5985

[20] ICICI Foundation. (n.d.). Financial inclusion. https://www.icicifoundation.org/financial-inclusion

[21] Government of India. (2020). Pradhan Mantri Fasal Bima Yojana (PMFBY). https://www.mygov.in/campaigns/pmfby/

[22] Kaur, S., Raj, H., Singh, H., & Chattu, V. K. (2021). Crop insurance policies in India: An empirical analysis of Pradhan Mantri Fasal Bima Yojana. Risks, 9, 191. https://doi.org/10.3390/risks9110191

Philippines[23]

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

Contingent credit for disasters is also in place, and insurance for public assets is in use. On 17 November 2021, the World Bank approved the Fourth Disaster Risk Management Development Policy Loan with a Catastrophe-Deferred Drawdown Option (CAT-DDO 4) of $500 million for the Government of the Philippines. Through a Cat DDO, the Philippines can access funds upon the declaration of a national state of calamity due to an imminent or ongoing natural catastrophe or upon the declaration of a state of public health emergency. The loan is available for three years and may be renewed for up to 15 years in total. Past Cat DDOs have been successfully disbursed to support the Philippines towards recovery in the aftermath of disasters such as Tropical Storm Washi (2011) and Tropical Cyclone Mangkut (2018), as well as the COVID-19 pandemic. The latest CAT-DDO 4 has also been disbursed after Typhoon Rai, which battered the country in December 2021. On 16 November 2023, a $500 million development policy loan for the country was approved by the World Bank/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 or public health emergency.

Catastrophe Bond[24]. In November 2019, the World Bank issued two tranches of cat bonds to capital market investors, providing the Philippines with insurance coverage of up to $225 million ($75 million for earthquakes and $150 million for tropical cyclones) for three years. The types of events that will trigger a payout are predefined in accordance with Philippine requirements. 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.

[23] Department of Finance, Philippines, 2023.

[24] World Bank. (n.d.). The Philippines: Transferring the cost of severe natural disasters to capital markets (Case study).

Mongolia

In 2006, the Government of Mongolia, with assistance from the World Bank, implemented a pilot index-based insurance programme in three provinces to address mortality rates among the livestock population. Shocks to the well-being of animals have devastating implications for the rural poor and the overall economy. The scheme combines self-insurance, market-based insurance, and social insurance. Herders pay a premium for a commercial risk product (a base insurance product) with specified trigger percentages for livestock mortality rates, whereas 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 as the government fully covers insured losses beyond the financial capacity of the pool through a reinsurance treaty with the World Bank.

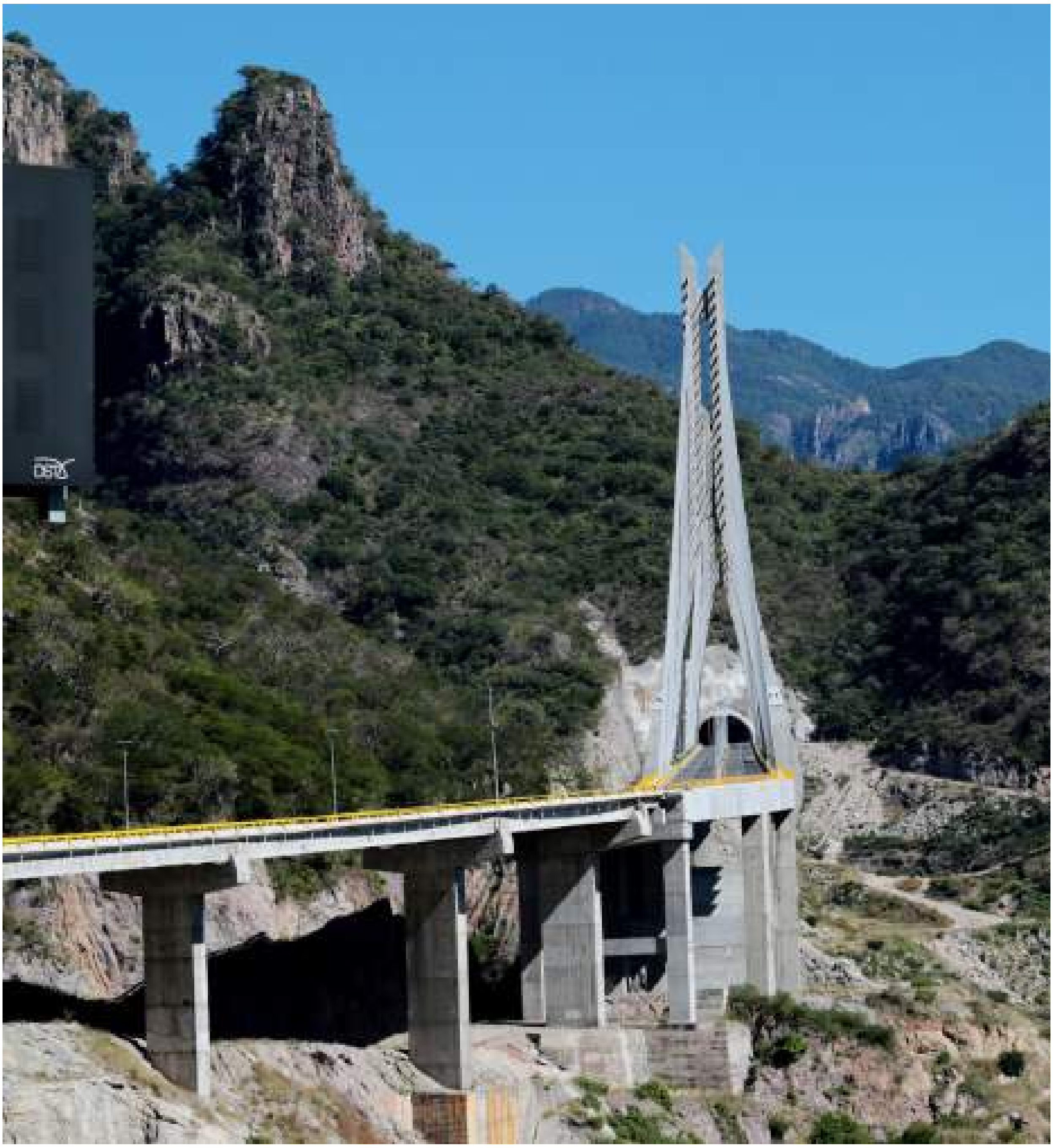
Mexico[25]

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).

Natural Disaster Prevention Fund (Fondo para la Prevención de Desastres Naturales, FOPREDEN) includes the Preventive Trust (Fideicomiso preventivo, FIPREDEN), which promotes and strengthens preventive actions for DRR, mitigates the effects of natural phenomena, and fosters DRR research. FIPREDEN provides resources to the agencies and federal and state units for unscheduled preventive actions.

[25] United Nations Development Programme. (2014, June). Mexico: Country case study report—How law and regulation supports disaster risk reduction; World Bank. (2012). FONDEN: Mexico's natural disaster fund—A review.



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 Agropecuario y Pesquero, CADENA) as one of the components of the Disaster Management Prevention Programme (Programa de Prevención y Manejo de Desastres). This fund aims to assist, through insurance, 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, including, Art. 129.

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

FONDEN resources are leveraged through market-based risk transfer instruments. Despite its stable annual budget appropriation, funding needs arising from one or multiple disasters can cause a shortfall in any given year. To manage the volatility of demand for 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 employs a range of tools to assist local governments and organizations in responding to disasters, such as risk transfer programs and reserve funds. To transfer Mexico's seismic risk to the global capital markets, FONDEN issued a $160 million catastrophe bond (CatMex) in 2006. Mexico decided to further diversify its coverage by pooling multiple risks across multiple regions after CatMex matured in 2009. Using the World Bank's recently established MultiCat Programme, which assists sovereign and sub-sovereign entities in pooling multiple perils across multiple regions and lowering insurance costs, the World Bank issued a multi-peril cat bond in October 2009[26]. 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. It ensures timely access to funds for disaster management, reducing reliance on traditional post-disaster financing mechanisms.[27] 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.

[26] 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

[27] World Bank. (2013). Disaster risk financing and insurance case study: Mexico MultiCat bond. https://openknowledge.worldbank.org/server/api/core/bitstreams/42f4a9ed-6f3d-5bbb-bb5b-e5c2cc6703ae/content

Component for the Attention of Hazards (CADENA) Mexico (2003)

In Mexico, disasters caused by extreme climate and geophysical hazards, particularly 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, in which small-scale farmers constitute 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 programs: commercial farmers who require insurance to finance, farmers able to pool risks and access credit, and small-scale, vulnerable farmers who lack access to credit or insurance. The CADENA Program, 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).[28] 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 reduce financial losses from natural catastrophes to public property. This programme evaluates fiscal risks for the government by quantifying both explicit and implicit contingent liabilities. It does this by fusing historical data with simulated loss data. It has an excess-of-loss insurance component based on indemnity that activates when disaster-related claims reach a defined threshold. To increase resilience to disasters, Mexico's programme works in combination with risk-reduction initiatives, such as bolstering early warning systems, while also protecting the government budget.[29] The indemnity-based coverage kicks in when disaster-related costs exceed a certain threshold, shielding the government from excessive financial burdens. Moreover, the programme's integration with risk-reduction measures, such as early warning systems, enhances resilience to disasters, further emphasizing its role in comprehensive disaster risk management and financial protection.

[28] World Bank. (2013). Mexico agriculture insurance market review.
https://documents1.worldbank.org/curated/pt/124521468287160777/pdf/881000BRI0P1300urance04Pager0Cadena

[29] World Bank. (2013). Quantifying contingent liabilities associated with natural disasters.
https://documents1.worldbank.org/curated/en/672271467997574054/pdf/97977-BRI-Box391499B-PUBLIC-Short-Note-1-Risk-Assessment-04Nov2013

Türkiye

Turkish Catastrophe Insurance Pool (TCIP-2000)

The Turkish Catastrophe Insurance Pool (TCIP) functions as a pivotal mechanism for disaster risk financing and insurance, providing coverage for disasters such as earthquakes, floods, and landslides. In 2000, the Turkish government instituted a mandatory earthquake insurance system for all residential structures on registered urban land. This initiative aimed to shift the financial burden from the government and onto private insurers. To facilitate this transition, the World Bank provided crucial financial and technical support to establish 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 towards bolstering disaster resilience and easing the burden on government resources amid seismic risks. By transferring risk from individuals and businesses to a pooled system, TCIP contributes 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.[30]

Taiwan

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 has offered basic insurance protection against earthquakes since 1 April 2002. The programme 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 to implement TREIP and give homeowners basic earthquake insurance protection.[31] 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.

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[30] World Bank. (n.d.). Disaster risk financing and insurance case study: Turkish catastrophe insurance pool. https://www.gfdrr.org/drfi

Caribbean Catastrophe Risk Insurance Facility (CCRIF-2007)

The Caribbean Catastrophe Risk Insurance Facility, the world's first multi-country risk pool, was established in 2007 and is the first insurance product to successfully develop parametric policies backed by both traditional and capital markets. To enable the introduction of new products and expansion into new geographic areas, the facility underwent a restructuring in 2014. It became a segregated portfolio company (SPC), which is now known as CCRIF SPC. It is registered, owned, and operated in the Caribbean. The CCRIF SPC helps governments in the Caribbean and Central America mitigate the financial impact of natural-hazard catastrophes by promptly supplying short-term liquidity when a policy is triggered. For tropical cyclones, earthquakes, excessive precipitation, the fisheries industry, and public utilities, CCRIF provides parametric insurance coverage. Through its parametric approach, CCRIF triggers payouts based on predetermined parameters such as wind speed or rainfall intensity, enabling 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.[32]

[31] Taiwan Residential Earthquake Insurance Fund. (n.d.). About TREIF. https://www.treif.org.tw/

[32] CCRIF SPC. (2023). Annual report 2022-2023. https://www.ccrif.org/sites/default/files/publications/annualreports/CCRIFSPC-Annual-Report-2022-2023_lowres

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

A regional initiative called the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) Program was launched in 2007 to strengthen the Pacific region's financial resilience to disasters and climate change risks. The PCRAFI facility and the PCRAFI Technical Assistance Program are the two main pillars of Phase II, which was started in April 2016. PCRAFI's holistic approach helps countries better understand and quantify their vulnerability to natural hazards by facilitating the development of risk assessment tools such as the Pacific Risk Information System (PacRIS). The Secretariat of the Pacific Community (SPC) is undertaking a project under the Technical Assistance Program to build capacity for the Hazard and Exposure Database. Through in-country surveys, improved data collection capabilities, and case studies highlighting the value of risk information, this project seeks to update data in the Pacific Risk Information System (PacRIS) and eventually empower nations to independently impact data and improve their future exposure.[33]

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

An IBRD Flexible Loan product called the Drawdown Option (CAT-DDO) is designed to improve countries' crisis preparedness and responsiveness to natural catastrophes and public health emergencies. It offers swift disbursement contingency finance in the case of a disaster, providing liquidity up front while additional funding is raised. Approved prior to a disaster event, the Catastrophe-Deferred Drawdown Option (Cat-DDO) offers immediate liquidity upon activation, 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 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.[34]

[33] World Bank. (2013). PCRAFI catastrophe risk assessment methodology.
https://reliefweb.int/report/world/pacific-catastrophe-risk-assessment-and-financing-initiative-pcrafi-risk-assessment

[34] World Bank. (2018). A product note on IDA catastrophe deferred drawdown option (Cat-DDO).
https://thedocs.worldbank.org/en/doc/563361507314948638-0340022017/original/productnotecatddoidaenglish2018

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

Established in 2009, the Asia Pacific Disaster Response Fund (APDRF) provides developing member countries (DMCs) of the Asian Development Bank (ADB) with loans that can be disbursed promptly for life-saving measures in the immediate aftermath of significant natural catastrophes. This funding helps DMCs augment relief from other donors during emergencies and help restore life-saving services to impacted individuals. This mechanism enhances countries' crisis-response capabilities, particularly when emergencies exceed their capacity to address immediate expenses. Additionally, APDRF supports DMCs in mitigating the financial impacts of disasters by providing essential funding for urgent relief efforts, thereby contributing to the broader objectives of disaster risk management and resilience building in the Asia-Pacific region[35]. Assistance is eligible if specific emergency requirements are met, including a disaster, an official declaration of emergency beyond the nation's capacity 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 capacity, 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.[36]

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

One of the Inter-American Development Bank's (IDB) most important tools for assisting member nations in successfully managing the financial risks associated with natural catastrophes is the Contingent Credit Facility (CCF) for Natural Disaster Emergencies. It functions as a critical mechanism for disaster risk financing and insurance, providing member countries of the Inter-American Development Bank (IDB) with access to contingent loans following verified disasters. It provides contingent loans that are repaid in the event of a catastrophic event, thereby funding essential amenities and humanitarian relief. Countries must have a Comprehensive Natural Disaster Risk Management Program (CDRMP) in place in order to be eligible for the CCF. The CCF, which incorporates parametric triggers based on preset event characteristics, symbolizes the IDB's approach towards proactive disaster risk management. It focuses on giving prompt financial support during the emergency phase of disasters.[37]

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[35] Asian Development Bank. (n.d.). Funds and resources: Asia Pacific disaster response fund. https://www.adb.org/what-we-do/funds/asia-pacific-disaster-response-fund-apdrf

[36] NDC Partnership. (n.d.). Asia Pacific disaster response fund. https://ndcpartnership.org/knowledge-portal/climate-funds-explorer/asia-pacific-disaster-response-fund-apdrf

[37] 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 J. Durante & R. Rosillo (Eds.), Natural disasters and climate change (SpringerBriefs in Economics). Springer. https://doi.org/10.1007/978-3-030-43708-4_1

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

To address the lack of insurance coverage for natural hazards in Southeast Europe (SEE), a region highly vulnerable to disasters, Europa Reinsurance Facility Ltd. collaborated with the World Bank to 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 totalling more than $12 million.[38] 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 comprises two components: participation in the SEEC CRIF, which supports countries in their efforts to join Europa Re, and the provision of technical assistance from donors delivered by Europa Re. This assistance includes risk mapping, product design, weather monitoring, and legislative reforms.[39] 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) launched by the World Bank, International Finance Corporation (IFC), and Private Sector (2009)

The European Union, Japan, and the Netherlands support the Global Index Insurance Facility (GIIF), managed by the World Bank Group, which aims to improve access to financing for microfinance institutions, small-scale farmers, and microentrepreneurs in developing nations. GIIF was established in 2009 with a primary focus on sub-Saharan Africa, the Caribbean, and the Asia-Pacific region. It uses index insurance solutions to manage catastrophic risks in agriculture, food security, and catastrophe risk reduction.[40] Through its initiatives, GIIF has enabled billions of dollars in funding, millions of contracts affecting tens of millions of people globally, and promoted resilience and financial inclusion in disadvantaged communities.[41] A crucial component of GIIF is index-based insurance, which eliminates the need to estimate individual losses by relying on predetermined indices to initiate payouts and ensures faster claims processing. Index-based insurance can help mitigate catastrophic risks associated with agriculture, food security, and disaster risk reduction. This approach enables faster claims processing and ensures timely financial assistance to those affected by disasters, thereby promoting resilience and financial inclusion in vulnerable communities worldwide.

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[38] Global Environment Facility. (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

[39] World Bank. (2024). Southeast Europe and Caucasus catastrophe risk insurance facility (Serbia and North Macedonia). https://projects.worldbank.org/en/projects-operations/project-detail/P110910

[40] World Bank. (2024). Global index insurance facility: Overview. https://www.indexinsuranceforum.org/overview

[41] InsuResilience Global Partnership. (2017). The global index insurance facility (GIIF).

African Risk Capacity Agency (ARC) (2012)

The African Risk Capacity (ARC) Group comprises 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 group's commercial affiliate, founded in 2014. The ARC Group, comprising ARC Agency and ARC Ltd, was founded to improve African governments' capacity to plan, prepare, and respond to epidemics and natural disasters caused by extreme weather events. With an emphasis on inclusivity and gender equality, ARC offers member states facilities for risk pooling and transfer, early warning systems, 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 shift the cost of climate risks from governments to ARC, guaranteeing timely and equitable disaster aid through contemporary financing methods such as risk pooling and transfer. [42] Through ARC, member states can access readily available response funds, reducing reliance on external aid and ensuring timelier and more equitable disaster relief. By merging traditional disaster relief approaches with modern financial mechanisms such as risk pooling and transfer, ARC offers a sustainable African-led strategy for managing extreme climate risks and disease outbreaks, thereby promoting resilience and reducing the financial burden on governments and vulnerable populations.

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

Through SEADRIF, ASEAN nations can improve their financial resilience to climate and catastrophe risks and access financing options for disaster risk. SEADRIF was founded in Singapore as a trust to own a general insurance business. It offers financial and consulting services for rapid post-disaster funding, with an emphasis on flood risk 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.[43] 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 across 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.[44]

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[42] African Risk Capacity. (n.d.). About African Risk Capacity. https://www.arc.int/about

[43] 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

[44] 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

Pandemic Emergency Financing Facility of the World Bank (2016)

The Pandemic Emergency Financing Facility (PEF) - a financing mechanism that had now officially closed, 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 as UNICEF and WHO.[45]

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.[46] It serves as a crucial mechanism for disaster risk financing and insurance by providing rapid, 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.[47] Through its proactive financing of emergency response, CERF plays a vital role in strengthening global disaster preparedness and resilience, ultimately contributing to more effective disaster risk management worldwide.

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[45] World Bank, & World Health Organization. (2022). Report on the pandemic emergency financing facility (PEF) framework. https://thedocs.worldbank.org/en/doc/24dce6fdf04a1313a07f7c24f539f4c7-0240012017/pandemic-emergency-financing-facility-pef-framework

[46] United Nations Central Emergency Response Fund. (n.d.). Central emergency response fund. https://cerf.un.org/

[47] United Nations. (2022). Annual report of the Central Emergency Response Fund (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 their natural hazard risk in exchange for a payment (insurance premium). Providers of insurance include licensed and supervised insurance companies, captive insurers, and insurance pools, all of which are entities exclusively dedicated to insurance. In some jurisdictions, non-licensed insurance activity exists. Depending on how this activity is controlled, it could prevent the entity from fulfilling a claim payment after a disaster due to insufficient funds if it is acting as an unlicensed insurer.

Main usage

Major disaster risk refers to a low-frequency, high-severity event (e.g. earthquake, flood, cyclone, tsunami, and drought). Although exposure and vulnerability to these events can be reduced, significant residual risk may remain, making insurance a visible risk management strategy.

Advantages

- Agreed well-defined benefit in the 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 in 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 the regulatory environment, the solvency and reputation of the insurance markets, and the availability of support from professionals such as actuaries, risk assessors, auditors, brokers, and loss adjusters.
- Complementary social protection solutions, allowing low-income populations to enjoy social protection or support in the acquisition of insurance, while avoiding the crowding out of insurance solutions for people who can afford premiums.
- No unlicensed competition. Insurance credibility and resilience depend on all insurance providers being licensed and supervised by the insurance regulator.

2 Disaster Reinsurance

Definition

Reinsurance is a financial transaction by which disaster risk and other insured risks assumed by an insurer in the original insurance policy are transferred (ceded) from the insurance company (cedent) to a reinsurance company (reinsurer) in exchange for a payment (reinsurance premium). Providers of reinsurance are professional reinsurers, which are entities exclusively dedicated to the activity of reinsurance. In most jurisdictions, however, insurance companies are allowed to participate in reinsurance (Wehrhahn 2009). Reinsurers can effectively assume large 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 (e.g., earthquakes, floods, cyclones, tsunamis, and droughts). This risk is difficult to diversify at the primary insurer level. Hence, without additional risk-transfer mechanisms, insurers would not be able to accept this type of risk economically. Insurers that assume disaster risk protect their balance sheets 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 an insurance company's exposure can be substantial.
- 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.
- The reinsurer dictates terms on the risks reinsured 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, tradable capital market products. Investors assume insurance risk in exchange for a higher rate of return than that available from securities free of that risk. The insurance risk materializes when a predefined disaster 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 occur. 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 a huge 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 a 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 triggers related to underwriting risks further complicates the instrument's structure.
- Costs may be relatively high if the volume of issuance is small. Transaction sizes range from approximately $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 challenging to assess.

Preconditions

- Sophisticated securities markets that can issue ILS.
- Sophisticated investors looking to diversify their investments away from traditional forms of market risk.
- Transparent product structures.
- Transparent and robust disaster risk models.
- Clearly defined triggers.
- An enabling government policy including tax benefits for ILS investors, regulations that allow insurers and reinsurers to use ILS for capital relief, etc.
- Attractive returns for investors in the ILS markets.
- Credibility of the securities sector, including 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 indemnifies the insured against pure agricultural loss (i.e., crop or livestock). A loss assessment process verifies the loss. The insured person could be the farmer, a farmer group, or an agricultural lender whose delinquency risk depends on agricultural output.

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

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

Main usage

Agricultural indemnity insurance provides coverage to farmers and agricultural lenders against losses of crops or livestock. When purchased by agricultural lenders, it can also increase their willingness to lend to farmers who are not otherwise creditworthy, thereby offering better terms than for 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, affordable technology can reduce the time for loss assessment, keeping costs in check. Technology-based tools can also provide corroborative information to reinforce human loss assessment activities.
- **Costly assessments:** The onerous loss assessment process implies high assessment costs.
- **High risk of adverse selection and moral hazard:** Claim payments often rely on crop-cutting experiments, leaving room for manipulation. Adverse selection (i.e., the purchase of insurance by farmers who are more likely to experience claims) is more likely with indemnity than with index-based insurance. Moral hazard (i.e., farmers acting in a manner that leads to greater chances of the claim becoming payable) is also more likely with indemnity than with index-based insurance.

Preconditions

- **Historical loss, modelled loss, and exposure data:** This information is required for several aspects of the product design, product evaluation, and product pricing processes. Insurance can be used for risks with low frequency and high values. However, the product needs to be designed so that risks with higher frequency and lower values are not transferred to the insurer but are instead retained—and ideally reduced—through farmers' risk-reduction efforts.
- **Subject specialists:** Worthy products are usually developed with assistance from subject specialists. It is therefore important to ensure that the product development team has access to the requisite 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. 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 is often embedded in the main business activities of the insured persons.

- **Availability of reinsurance:** Crop and livestock claims depend upon weather and other natural hazards, which can affect the entire region of coverage in a relatively short time span. This can result in large, often covariate losses for the insurer and increase capital requirements 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 is necessary for agricultural insurance, which inherently faces large, 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 within a predefined area—area yield index insurance or a trigger event based on weather indices, satellite imagery, and similar data. 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 operates 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 based on parameters that typically yield multiple outcomes (e.g., wind velocity and precipitation levels) and can result in a graded payout scale. In such cases, claims are often linked to the trigger in a graded manner (e.g., the farther above the observation the trigger is, the higher the claim payout) until a pre-agreed ceiling is reached. The insured person may be a farmer, a farmer group, or a lender whose delinquency risks depend on agricultural output.

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

1. **Area yield index insurance:** Indemnities are computed from the decrease in the average yield over an area without ascertaining the crop output of individual farmers.
2. **Area revenue index insurance:** Indemnities are 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.
3. **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 for farmers and agricultural lenders by eliminating subjectivity in loss verification and reducing the time required 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 extend better terms to 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 complete 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 the actual loss experienced. The payout may be greater or less than the expected loss. Basis risk can reduce customer satisfaction and affect the continuity of an insurance program.
- **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 modelled weather data:** This information is required for several stages of product design, evaluation, and pricing. If such information is unavailable, designing a robust product will not be feasible.
- **Subject experts:** Valuable products are usually designed with assistance from subject specialists. It is important to 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 modelled loss data:** Especially for area yield index insurance, historical and modelled loss data are essential in pricing the product and determining the trigger.

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

6 Sovereign Parametric Insurance

Definition

Like any parametric insurance, sovereign parametric insurance *ex ante* agrees to make a payment upon the occurrence of a trigger observation or an event linked to the loss, rather than indemnifying the pure loss. The government of a sovereign state may purchase it and work on the usual insurance principles of premium payment to cover risks. Trigger observations can be specified intensities of natural hazards at a specified location (e.g., rainfall level, wind speed, seismic shocks as measured on the Richter scale) as recorded 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 assure a country's fiscal position while reducing subjectivity in loss verification and the time required 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.

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 the actual loss experienced. The payout may be greater or less than the expected 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 costs, index insurance can have high start-up costs, especially in the absence of appropriate weather data and skilled meteorological expertise. A country's readiness to purchase parametric insurance coverage depends in part on its existing infrastructure, including asset inventories, meteorological data,

- **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.

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 modelled 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 precipitation data. If this type of information is unavailable, 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 ensure that the product development team is multiskilled and possesses the requisite experience and expertise. Often, it is necessary to involve reinsurance companies interested in underwriting the cover to provide domain expertise.
- **Historical and modelled loss data:** Historical and modelled loss data are essential in pricing the product as well as in defining the trigger. Insufficient or inappropriate data may lead to gaps in coverage or other serious product-related issues.
- **Real-time hazard data:** In the absence of real-time data, it is difficult to gauge the amount of claim payment on time.
- **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 in which organizations (often primary underwriters) pool their funds 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 unfavourable outcomes, underwriting of large risks by pool members, technical capacity for development of complex insurance products, advice and information gathering for loss assessment, stability of underwriting results, and reduction of the impact of single and large risks.

Advantages

Designing an insurance pool should consider the following factors (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 can undertake more in-depth analysis.
- **Leverage:** A pool can leverage its collective buying power as a block to negotiate premiums 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 concerning efficient and cheap technology for indemnity and area yield index products.

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.

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

Preconditions

- **Reinsurance:** An agriculture or disaster insurance pool will have high covariate risks. It is imperative to maintain appropriate reinsurance arrangements and ensure the pool's solvency.
- **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 term (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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