Status of Economic Loss and Damage Caused by Climate Change in Nepal: Patterns, Impacts, and Policy Imperatives

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Abstract

Nepal, the fourth most climate-vulnerable country in the world, is experiencing increasing economic and non-economic losses from climate-induced disasters. This in-depth analysis of available data on climate change impacts in Nepal during the period 1971-2025 shows increasing trends in economic costs as well as non-economic impacts. Recent average annual economic losses stand at 0.08% of GDP (NPR 2.78 billion) with extreme years touching 2.08% of GDP. Physical property accounts for 75% of economic loss, followed by agriculture (18%), livestock (4%), and food storage (3%). Non-economic losses comprise an average of 647 deaths every year due to climate disasters, large-scale displacement, loss of cultural heritage, and ecosystem degradation. Future scenarios project economic losses to reach 2.2% of GDP by 2050 and 9.9% by 2100 in the absence of proper mitigation. The study identifies major gaps in loss and damage assessment capacity, weak financial mechanisms, and low recovery capacity of vulnerable communities.

Keywords

Climate change, loss and damage, economic loss, Nepal, adaptation, disaster risk, climate finance

Background

Nepal, a small landlocked country in the Himalayas, provides a stark example of the global injustices from climate change impacts. Although it has contributed a negligible fraction (<0.03%) to global greenhouse gas emissions, Nepal is laready suffering extreme impacts due to its fragile topography, dependency on monsoonal rainfall, and weak adaptive capacity (Government of Nepal, 2021). The country's vulnerability is compounded by its remoteness, widespread poverty, poor infrastructure, and heavy reliance on climate-sensitive economy, most prominently agriculture, hydropower, and other ecosystem services (Kafle & Khanal, 2020; World Bank, 2021).

Climate-related disasters in Nepal are neither unusual nor small in scale. Nepal regularly experiences monsoon floods, landslides, droughts, glacial lake outburst floods (GLOFs), and heatwaves causing heavy losses and damages (L&D) to the economy and infrastructure.

More than 80% of Nepal's population are exposed to multiple hazards, and over two-thirds of lands are under climate-vulnerable (Ministry of Forests and Environment [MoFE], 2019). As scientific research has linked heightened intensity and uncertainty of rainfall, longer dry spells, rising temperatures, and more extreme events to climate change impacts, recent events (e.g., the catastrophic September 2024 floods and landslides) demonstrate how quickly local economies, and human security can collapse (Nepal Disaster Risk Reduction Portal, 2024).

Economic loss from these occurrences is considerable and growing. Direct climate disaster losses have averaged USD 221.3 million (NPR 27.78 billion) each year over the past decade, that leaps dramatically during calamitous occurrences like the 2017 Terai floods, which inflicted close to USD 585 million worth of damage (nearly 3% of National GDP) (Asian Development Bank [ADB], 2019). Indirect effects, like loss of livelihoods, forced migration, psychological impact, and disruption of trade, add to the overall bill. Disasters progressively paralyze key sectors: agriculture (the lifeline of more than 60% of total population), experiences 90% of its crop loss due to climate hazards; hydropower plants are increasingly disrupted by floods, landslides, and sedimentation, jeopardizing Nepal's aspirations as a regional energy exporter; and infrastructure, from bridges and roads to water supply systems, experiences both severe and cumulative damage (ICIMOD, 2023).

Nepal's vulnerability is compounded by intense urbanization, marginalization and resource limitations hindering action in time to adapt and recover. With increasing climate effects, Non-Economic Losses (NELs) like cultural loss, psychological trauma, and ecosystem disruption further complicate the recovery process, frequently evading monetary calculation but of great national importance (MoFE, 2021).

For all its front-line exposure, Nepal's capacity for preparation for, absorption of, and recovery from climate shocks is seriously constrained by low disaster risk reduction capacity, chronic adaptation finance gaps, and delays in accessing global support mechanisms like the Fund for Responding Loss and Damage created at COP 28 (UNFCCC, 2023). This study responds to the pressing need for clarity on the actual and anticipated economic costs Nepal is incurring from climate change impacts, the most vulnerable sectors and communities, and policy measures required for immediate resilience as well as longer-term adaptation.

Research Problem

Nepal is suffering from mounting and disproportionate economic and non-economic losses with recurrent disasters having profound effects on livelihoods, infrastructure, and development gains, especially for the most vulnerable. However, a systematic framework to estimate these losses, detects sectoral and geO{graphical disparities, and evaluates adaptive capacities is quite lacking. Furthermore, the gap in robust data and comprehensive

policy efforts continues to undermine Nepal's ability to develop sound risk management strategies and access adequate finance for responding to loss and damage, thus imperilling its sustainable development trajectory.

Research Objective

This research aims to examine the trends, sectoral impacts, and policy responses based on available data on economic and non-economic losses and damages

Literature Review

Climate change is weakening Nepal's economy and disproportionately affecting vulnerable groups by reducing agricultural productivity, increasing disaster losses, and eroding livelihoods and food security. Nepal's yearly exposure to extreme events and slow-onset processes, like floods, landslides, droughts, and glacial lake outburst floods (GLOFs), are well documented (MoFE, 2019; Wang et al., 2021). Research on Loss and Damage and disaster showed that, climate-related disasters have imposed an average yearly loss of USD 221 million since last 25 years, doubling the loss for some extreme disaster years such as 2017 (Terai floods) incurring more than USD 584 million (ADB, 2019; Government of Nepal, 2019). In the past decade, overall losses stood at USD 5.34 billion (World Bank, 2022).

Sectoral Literature:

The agriculture sector seemed to expose and impact higher with climate hazards resulting about 90% of crop loss (Khanal & Koirala, 2019), and under the present emission trend agricultural GDP is expected to shrink by 5% up to 2030 (ADB, 2019). Livestock and rural infrastructure (irrigation canals, storage) also experience frequent loss, accelerating to rural poverty and migration (Bhandari & Aryal, 2022). Similarly, hydropower, a national development priority, is severely affected by GLOFs, sedimentation, and unstable flows causing frequent shutdowns and expensive repairs (ICIMOD, 2023; Shrestha et al., 2020). The September 2024 Bagmati floods alone was responsible for shooting down 26 hydropower projects, resulting in direct damage and lost production of NPR 3 billion.

New evidence underscores that as much as 75% of household-level economic losses to climate disasters is in physical property (land, houses), with rural and marginalized communities experiencing greater per-household losses (MoFE, 2021). The big disasters have forced poor families to borrow, sell assets, or migrate, resulting in increased long-term vulnerability (UNDP, 2023).

Non-economic Loss and Damage (NELD):

Even though Literature is increasingly acknowledging impacts of climate change on non-economic loss and Damage, focusing on loss of culture, traditional knowledge, health effects, psychological trauma, yet these are still poorly quantified (MoFE, 2021; Kafle

& Khanal, 2020) as they are inter-linked and complex. For example, loss of traditional irrigation systems and sacred places in hills and mountains also contribute towards sociocultural erosion.

Adaptation and Recovery:

A variety of adaptation interventions are being piloted in Nepal: early warning systems, climate-resilient agriculture, ecosystem-based adaptation, and community DRR interventions (World Bank, 2021; ADB, 2019). Implementation is, however, spotty, particularly for remote and resource-poor locations. Finance continues to be a top constraint: Nepal's National Adaptation Plan pegs adaptation costs through 2050 at USD 47.4 billion, for which only USD 1.5 billion is available domestically, with more than USD 45 billion as an international funding gap (MoFE, 2021; UNFCCC, 2023).

Regional and Global Comparisons:

Comparative analyses have shown that Nepal's experience is consistent and is similar with trends followed by other South Asia and least developed countries: mounting economic losses, widening adaptation gaps, extremely exposed mountain and deltaic ecosystems, and high vulnerability to non-insurable losses (World Bank, 2022; ESCAP, 2021). As South Asia's overall climate-related losses are estimated to reach USD 518 billion by 2050, Nepal stands to lose 2-2.5% of its GDP annually by mid-century even under moderate warming scenarios (ADB, 2019).

Global evaluations further suggest that disaster risk is compounded by development shortcomings and social marginalization (Dazé & Dekens, 2017). While Nepal's climate policy structures have increasingly recognized Loss and Damage (L&D), the overall operationalization of the fund for Loss and Damage and L&D mainstreaming into national planning is still in its initial stage (UNFCCC, 2023; MoFE, 2021).

Research Gaps:

Even though some researches have been conducted on loss and damage, there is a lack of longitudinal, sectoral, and micro-level research on actual vs. reported economic loss, effects of slow-onset events like glacier retreat, and effectiveness of adaptation finance and insurance mechanisms are sparse and uneven. (ICIMOD, 2023; Kafle & Khanal, 2020). Challenges still remain in attributing losses to climate change vs other drivers, and in valuing irreversible or non-market losses and evidence are patchy and limited to mainstream L&D considerations into planning, investment and emergency systems (MoFE 2021).

Research Methodology

This study employs a systematic review approach, synthesizing evidence from government reports, international assessments, research studies, and empirical investigations conducted between 2010 and 2025. Major sources of data include the National Framework on Climate

Change Induced Loss and Damage (2021) of the Ministry of Forests and Environment (Ministry of Forests and Environment, 2021), vulnerability and risk assessment reports (World Bank, 2023; Ministry of Forests and Environment, 2021), and field studies conducted in affected communities (ACT Alliance, 2021; Disaster Preparedness Network Nepal, 2023). Additionally, data and infO{rmation available in Bipod Portal of NDRRMA are also used as the reference materials.

The evaluation system follows the updated approach suggested by Kees Van Der Geest and Koko Warner for assessing loss and damage at the household level, incorporating both quantitative economic indicators and qualitative measures of non-economic effects (ACT Alliance, 2021). Climate trend analysis uses the Mann-Kendall test to establish the statistical significance of hazard trends from 1971 to 2019 (Ministry of Forests and Environment, 2021).

Quantitative Analysis

Quantitative infO{rmation was obtained from national and international databases, such as the Ministry of Home Affairs (MoHA), Ministry of Forests and Environment (MoFE), United Nations Office for Disaster Risk Reduction (UNDRR), and Asian Disaster Reduction Center (ADRC). The dataset covers the period 2010–2024 and contains records of climate-related disasters like floods, landslides, droughts, and glacial lake outburst floods (GLOFs). The main indicators examined are direct economic loss (e.g., damage to infrastructure, loss of crops), indirect loss (e.g., productivity loss, disruption of trade), and sectoral effects (agriculture, hydropower, infrastructure). Economic loss estimates were normalized to 2024 USD using inflationary adjustments from the World Bank and Nepal Rastra Bank. Time-series analysis and descriptive statistics were used to determine trends, while regression models were used to associate climate variables (e.g., rainfall anomalies, temperature trends) with economic losses. Gaps in data were filled through triangulation with secondary sources, such as Asian Development Bank (ADB) and International Centre for Integrated Mountain Development (ICIMOD) reports.

Qualitative Analysis

Qualitative data were obtained from synthesizing published case studies and field reports from climate-sensitive districts, such as Bagmati, Koshi, and Madhesh Provinces. These studies, based on peer-reviewed literature and MoFE, UNDP, and ICIMOD reports, emphasize livelihood effects, rehabilitation constraints, and adaptation at the community level. Semi-structured interviews and focus group discussions from secondary data revealed non-economic losses, including cultural degradation and psychological trauma, in addition to barriers to recovery funding. Thematic analysis was used to determine repeated patterns, for example, disproportionate effects on vulnerable populations and disaster response gaps.

Policy and Financing Analysis.

A documentary review of Nepal's climate and disaster risk reduction (DRR) policies, including the National Adaptation Plan (NAP) together with the Environment and Disaster Risk Management Acts, was undertaken to assess the alignment of L&D systems. Global obligations, for example, the UNFCCC, Fund for Responding Loss and Damage Fund was explored to assess Nepal's qualification for international support. climate finance. Data were cross-checked with UNFCCC, ADB, and World Bank reports to identify funding gaps and policy implementation challenges. The mixed-methods design provided strength by triangulating quantitative disaster data, qualitative case studies, and policy documents. Constraints, including incomplete loss reporting and dependence on secondary qualitative data, were alleviated by cross-validating findings across multiple sources. The methodology enables a holistic understanding of L&D patterns, sectoral vulnerabilities, and policy requirements in Nepal's climate context.

Research Limitations

The study is constrained by several limitations. Economic loss data frequently underrepresents true losses because of reporting deficiencies, unrecognized indirect and non-economic damages, and varying valuation methods. Furthermore, detailed data at the district and sector levels are limited, particularly concerning gradual and cumulative effects such as glacier retreat or migration prompted by drought. The qualitative aspect of the research depends on syntheses derived from existing case studies rather than extensive new field investigations. The anticipated losses are inherently uncertain as climate-related risks and economic frameworks undergo transformation. Despite thorough triangulation efforts, the conclusions are restricted by the accessibility and dependability of both national and international statistical data.

Results and Discussion

3. Economic Damages and Losses

3.1 Overall Patterns in Economic Influence

Nepal's average annual economic loss from climate-induced disasters is approximately 0.08% of GDP (USD ~27.78 million), with floods and landslides contributing significantly (NDRRMA, 2024). Over the 2018–2024 period, disasters caused NPR 23.60 billion (USD ~176 million) in economic losses, with floods (260 incidents, 346 deaths) and landslides (2,881 incidents, 878 deaths) ranking among the top contributors (NDRRMA, 2024). Non-economic impacts include over 3,000 deaths and 11,000 injuries from all disasters in this period, with climate-related events amplifying vulnerability in rural and mountainous areas (NDRRMA, 2024). Climate change intensifies these through increased extreme rainfall, heat, and drought, potentially tripling flood impacts by mid-century (MoFE, 2021). The following table lists the key events of loss and damage between 2020 to 2025.

Table 1 ***Key economic and non-economic loss and damage between 2020 to 2025***

Year	Event/Description	Economic Losses	Non-Economic Losses	Source
2020	Monsoon floods and landslides, mainly in western Nepal (Karnali and Sudurpaschim Provinces), triggered by heavy rainfall linked to shifting monsoon patterns.	Over USD 393,000 in direct damage, part of annual losses averaging 0.08% of GDP.	300 deaths, 223 injuries; widespread displacement and livelihood disruptions in rural communities.	World Bank, 2023; NDRRM, 2024; MoFE, 2021
2021	Melamchi Flood (June 15–16) in Sindhupalchowk District from heavy rainfall and glacial melt, plus additional monsoon/unseasonal floods and landslides in October across multiple provinces.	USD 640.56 million (USD 436 million Melamchi, USD 204.56 million Helambu) covering bridges, agriculture, livestock, irrigation, houses; extreme water-induced disasters may contribute ~1.5% of GDP annually.	1 death, 23 missing; 85% reported mental health impacts, 73% education disruption, 58% cultural losses, 51% social interaction issues, 41% gender-specific burdens, 40% mobility restrictions; dozens of additional deaths from broader floods/landslides.	Parajuli et al., 2023; World Bank, 2022; UNDRR, 2022
2022	Multiple floods, landslides, storms, and erosion across provinces due to intensified monsoons; no single dominant event but rising trend noted.	Estimated USD 29.4 million (derived from NPR 23.6 billion over 2018–2024, adjusted for flood/landslide share). Agriculture and infrastructure impacted; frequency of flood events doubled compared to previous years.	Minimal reported fatalities: part of broader 346 flood-related and 878 landslide-related deaths (2018–2024). Health and livelihood disruptions in vulnerable areas.	World Bank, 2022; Eckstein et al., 2024; NDRRMA, 2024

2023	Monsoon floods and landslides in eastern Nepal (Koshi Province), affecting hydropower and communities; part of ~5,700 disaster incidents nationwide.	Damages to small hydropower plants and infrastructure, contributing to cumulative flood impacts.	~50–100 deaths; injuries and displacement in Sankhuwasabha and Taplejung; health risks from waterborne diseases.	World Bank, 2023; UN Sustainable Development Group, 2023; NDRRMA, 2024
2024	Thame GLOF (August 16) in Solukhumbu District from glacial melt and rainfall; floods/landslides (September 26–28) across provinces, worst in Kathmandu Valley and eastern/western regions.	Thame: damage to 25 houses, 1 hydropower project, 1 health post, 1 school, 1 bridge. September: USD 346 million (USD 288 million infrastructure, USD 53 million productive sectors, USD 0.68 million social); alternative estimate USD 1.3 billion (~0.8–1% GDP). 65,380 agricultural lands affected, 26,698 livestock lost.	Thame: 135 displaced. September floods: 249–268 deaths, 18 missing, 177 injured; 5,996 houses destroyed, 807 families displaced; disruptions in connectivity, trade, and mental health in Koshi, Bagmati, Karnali Provinces.	Lord, 2024; World Bank, 2025; OECD, 2025; NDRRMA, 2024
2025 (up to Aug 12)	No major flood/landslide events yet; ongoing monsoon risks with projections of intensified hazards; minor localized events in Mahottari and Dhanusha.	Minor property/infrastructure damages; projected climate-related losses could reach 2.2% of GDP by 2050.	Minor injuries/displacement; broader risks include heat/drought impacts. No major fatalities reported.	NDRRMA, 2025; UNDRR, 2025

Economic damages exhibit statistically significant rising trends, with a Sen's Slope of 41,854,210 for the 1971-2019 period (Ministry of Forests and Environment, 2021). This increase is due to greater exposure and vulnerability than just climate change intensification. The trend analysis through Mann-Kendall statistics illustrates that 10 of 14 climatic hazards display statistically significant rising trends (Ministry of Forests and Environment, 2021).

Table 1 shows that in 2020, deaths peaked at around 700 with minimal economic losses indicating sudden-onset hazards in rural or underdeveloped regions causing high casualty with limited monetary damage. The opposite pattern was observed in 2021, when economic losses surged to about USD 650 million while deaths dropped sharply to around 120. This pattern is linked to the Melamchi Flood, which inflicted severe damage on infrastructure and property while causing relatively few deaths.

In 2022 and 2023, both indicators were low, suggesting either a period of fewer extreme events or smaller-scale disasters. 2024 saw a dramatic resurgence in both metrics economic losses reached roughly USD 370 million, and deaths climbed to nearly 650. This alignment suggests a severe, widespread disaster that simultaneously caused large-scale destruction and significant human casualties potentially a combination of extreme weather events and cascading hazards in eastern and central Nepal (e.g., floods triggering landslides).

Overall, the contrasting years highlight that the relationship between economic damage and fatalities depends heavily on the nature, location, and preparedness for the disaster with rural-focused events often causing higher death tolls, and urban-focused events leading to higher financial losses.

3.2 Sectoral Distribution of Economic Losses

Empirical investigations conducted in at-risk municipalities indicate discernible trends in the allocation of economic losses (ACT Alliance, 2021).

a. **Physical Properties:** Houses and land make up the biggest part of economic losses contributing to 75% loss because of their high replacement cost, permanent asset destruction, and their economic and cultural value. It seems that the losses are area specific, indicating that 88% of economic losses in landslide prone areas are due to damage to property, whereas in flood-prone areas, 68% of losses are from physical properties (ACT Alliance, 2021). The household surveys data showed that, 38.09% of the respondents in landslide-prone areas had their houses destroyed, whereas another 38.09% had structural damage (ACT Alliance, 2021)

b. **Agriculture**: Agriculture accounts for the second-largest share of losses, making up about 18% of the total, with climate-induced events responsible for roughly 90% of crop losses (Office of the High Commissioner for Human Rights, 2024). Drought is responsible for 40%, while floods contribute 23% of total loss from climate-induced events (Nepal Economic Forum, 2025). The sector faces vulnerability given that 70% of Nepal's population depends largely on subsistence agriculture (Climate Centre, 2021).

c. Livestock: Livestock accounts for the third largest share of losses making up about 4% of the total. Loss of farm animals take place mostly during flood incidents, with 75% of the respondents affected by floods having lost livestock (ACT Alliance, 2021). In landslide prone areas, 11% of the respondents reported the loss of their livestock during landslides (ACT Alliance, 2021) showing that loss of livestock is comparatively very higher in flood prone area compared to landslide prone areas

d. Food Storage: Food storage losses constitute another significant category, contributing about 3% of the total losses. These losses are particularly evident in flood-prone areas, where the destruction of storage facilities undermines indigenous food security initiatives and extends periods of vulnerability well beyond the immediate impacts of a disaster (ACT Alliance, 2021).

3.3 Infrastructure and Sectoral Vulnerabilities

a. **Hydropower Sector**: Nepal's high reliance on hydropower sector (99.8% of electricity production) is at high exposure to climate variability (Nepal Economic Forum, 2025). Existing climate impacts limit not only winter hydropower output to merely 10% of installed capacity (My Republica, 2024) but also are highly vulnerable to GLOFs. The recent flood in September 2024 damaged 26 hydropower plants resulting in a total loss of NPR 3.02 billion (Urja Khabar, 2025). Additionally, it is predicted that the hydro-power potential of Nepal may decrease by 25% by the end of the century because of less snow and low glacial melt (Nepal Economic Forum, 2025).

b. Transportation Infrastructure: Climate-resilience in transportation infrastructure is challenged by rising precipitation extremes, temperature fluctuations, and accelerated erosion and landslide hazards (Asian Development Bank, 2020). The September 2024 disaster alone impacted 41 sections of roads with the total cost of NPR 27.98 billion needed for repairs and maintenance (NDRRMA, 2024).

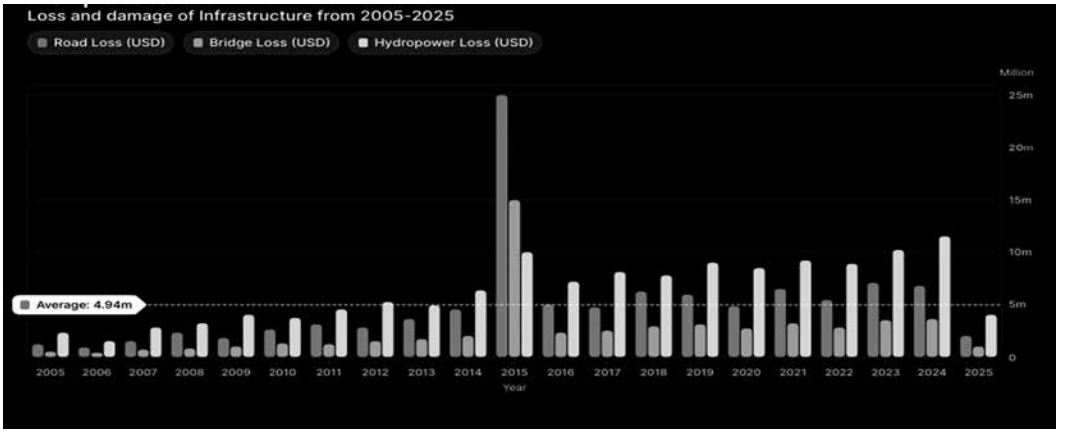

Figure 1: Loss and Damage of Infrastructure from 2005-July 2025

An analysis of data compiled from multiple sources, including PDNA, NDRRMA, World Bank/GFDRR, ReliefWeb, IPPAN press releases, and NEA/MoPIT/DoR bulletins (Fig. 1), reveals that that over the past two decades (2005-July 2025), infrastructure losses in Nepal have shown marked fluctuations, with sharp spikes during years of major disaster events and lower-than-average values during quieter periods. The most notable surge occurred in 2015, when road losses exceeded USD 25 million and bridge losses approached USD 15 million, largely due to the landslides triggered by Gorkha Earthquake, which caused extensive damage to transportation networks in many parts of the country during monsoon. Although losses declined after 2015, they often remained above pre-earthquake levels, with notable bridge losses in 2017 and from 2019 to 2024, likely linked to monsoon-driven floods and landslides that damaged key river crossings. Between 2020 and 2024, losses stayed moderate to high, particularly for bridges, reflecting the impacts of more frequent extreme events and flood disasters such as the 2021 Melamchi floods. Hydropower-related losses appear minimal or less visible in the data, possibly indicating lower reported damages or fewer incidents compared to road and bridge infrastructure. Several factors explain these patterns: natural hazards such as monsoon floods, and landslides; increased exposure from expanded infrastructure in hazard-prone areas; climate variability driving more intense precipitation; and post-disaster recovery efforts that may have reduced losses in certain years.

Disaster incident data from 2019 to 2024 reveals a rising trend in the number of recorded events, from 4,538 in 2019 to 8,472 in 2024. Deaths fluctuated within this period, dipping to a low of 417 in 2022 and peaking at 760 in 2024. Injuries varied as well, starting at 2,452 in 2019, dropping to 1,175 in 2020, and then gradually climbing to 1,637 by 2024. This reflects both the variability of hazard impacts and the influence of extreme events in certain years. Data for 2025 available only up to July, indicate ongoing monsoon risks but no major flood or landslide events comparable to previous peak years.

c. Water and Sanitation: From 2020 to 2025, Nepal experienced substantial climate-induced losses to water and sanitation infrastructure from floods, landslides, and glacial lake outburst floods (GLOFs). The 2021 Melamchi floods inundated the headworks of the $800 million Melamchi Water Supply Project, cutting off water supply to Kathmandu, while out-of-season October 2021 rains damaged water supply systems and sanitation infrastructure in western Nepal (World Bank, 2022). In 2024, heavy rainfall triggered flooding across the country, destroying 1,678 water supply systems and sanitation facilities, with economic losses projected at NPR 5.91 billion (about USD 42 million), indicating critical infrastructure weaknesses (International Water Management Institute, 2024; National Disaster Risk Reduction and Management Authority, 2024). In 2025, GLOFs in Humla ravaged water and sanitation infrastructure, displacing 18 households (United Nations Development Programme, 2025). Repeated hazards, such as melting glaciers and changed monsoon patterns, further dwindled springs and groundwater levels, with Tanahu

district recording 34% and 50% declines in spring and point-source water from 2004 to 2014, a continuing trend throughout the 2020s (Sharma et al., 2021). These disasters inflicted average yearly economic losses of 0.08% of Nepal's GDP, with outlier years like 2017 hitting 2.08% (UN Women, 2021)

3.4 Glacial Lake Outburst Floods (GLOFs)

Historical GLOF events have shown catastrophic economic potential. The 1985 Dig Tsho GLOF resulted the economic damages of approximately USD 3 million, wiping out hydropower infrastructure, bridges, and agricultural fields (ACT Alliance, 2021; Global Facility for Disaster Risk Reduction, 2011). Recent inventories point out 47 potentially hazardous glacial lakes, of which 25 are located in Tibet (Stockholm Environment Institute, 2023).

Economic modelling predicts that potential Thulagi lake outburst would bring damages of USD 400 million, and combined potential damages from all 21 high-risk lakes would bring the loss of USD 8.4 billion (Ministry of Forests and Environment, 2021). Three-dimensional modelling from recent studies predicts future GLOFs will submerge 183-1,699 structures in 1.2-4.9 meters of water, impact 30-88 kilometres of roads, and 0.35-2.23 km^2 of cropland (Sattar et al., 2025).

3.5 Future Economic Projections

Several studies converge on mounting economic consequences under climate change projections. The Asian Development Bank estimates 2.2% of economic losses in terms of yearly GDP by 2050, which could reach up to 9.9% by 2100 under the business-as-usual scenario (Asian Development Bank, 2023). Research on Economic Impact Assessment showed that the current climate variability to cost Nepal cost approximately 1.5-2% of national GDP each year, which is expected to rise to 2-3% by the mid-century period (Climate and Development Knowledge Network, 2014; Asian Development and Policy Consultants, 2023)

For three key sectors, i.e., agriculture, hydroelectricity, and water-induced disasters, it is estimated that an investment of USD 2.4 billion will be required until 2030, to build resilience (Climate and Development Knowledge Network, 2014; Prakriti Resources Centre, 2024). Nepal's National Adaptation Plan foresees a total funding requirement of USD 47.4 billion until 2050 for comprehensive adaptation measures (Ministry of Forests and Environment, 2021).

4. Non-Economic Losses and Damage

4.1 Human Casualties and Health Consequences

Climate disasters account for an estimated 65% of the total deaths occurring from overall disasters in Nepal, with an average of 647 deaths per year (Disaster Preparedness Network

Nepal, 2023; Ministry of Forests and Environment, 2021). Although mortality rates present a statistically non-significant declining trend, absolute numbers continue to be high. The epidemic year of 2001 had 1,866 climate-related deaths, the largest single-year effect (Ministry of Forests and Environment, 2021).

Health consequences reach beyond direct casualties. Climate change enables the spread of vector-borne diseases to highland regions that were previously immune (World Health Organization, 2017; Climate Centre, 2021). A 1°C rise in temperature is associated with five times higher morbidity and mortality due to water and vector-borne diseases (Herd International, 2024). The dengue outbreaks in 2019 and 2022 illustrate new disease threats (Herd International, 2024).

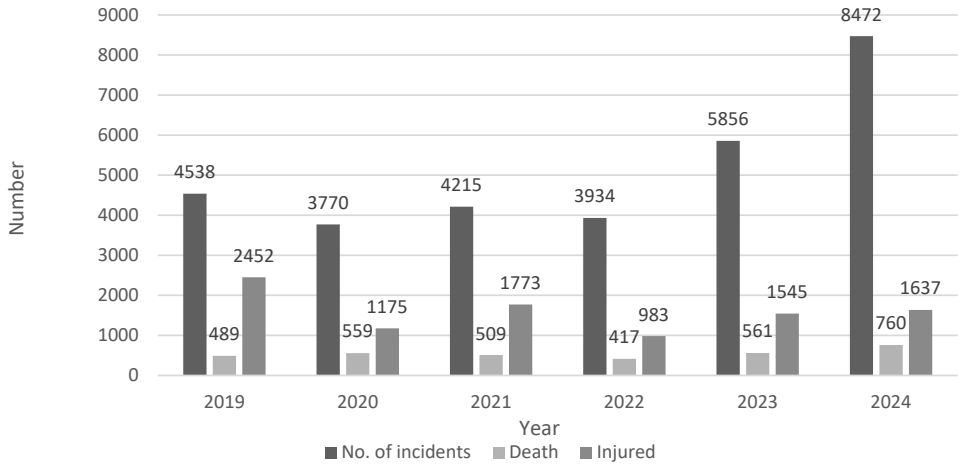

Figure 2: disaster-related incidents, deaths, and injuries

Figure 2 reveals a generally upward trend in disaster frequency, with notable year-to-year fluctuations in human impacts. Incidents increased from 2019 to a peak in 2024. Deaths varied more moderately, ranging from a low in 2022 to a high in 2024, while injuries ranged from 983 in 2022 to 2,452 in 2019.

The year 2019 had high number of incidents and injuries with comparatively lower deaths suggesting many minor or moderate disasters causing more injuries than fatalities. The following year, 2020, saw a drop in incidents and a sharp reduction in injuries, though deaths slightly increased, possibly reflecting fewer large-scale events but with more severe outcomes in some cases. In 2021, incidents and injuries rose again, while deaths dipped slightly, indicating a higher frequency of moderate disasters with relatively lower mortality. The year 2022 marked the lowest point for deaths and injuries alongside a reduced number of

incidents, hinting at a comparatively calmer disaster year or improved preparedness. From 2023 onward, disaster activity intensified. Incidents surged in 2023, with corresponding increases in deaths and injuries, likely tied to extreme weather events such as floods or landslides. The escalation continued into 2024, which recorded the highest incidents, deaths, and injuries in the period.

These patterns are shaped by multiple factors: recurring climate-related hazards like monsoon floods and landslides, increasing population and infrastructure in high-risk zones, variations in preparedness and early warning systems. Overall, the chart reflects an upward trajectory in disaster frequency, with 2024 standing out as the most critical year in both occurrence and human impact.

4.2 Displacement and Human Mobility

Climate displacement impacts thousands of individuals every year, and in 2020 alone, 13,352 individuals were displaced because of extreme weather conditions (Gaurav Migration Concern, 2025). The Internal Displacement Monitoring Centre reported 121,000 new displacements in 2019, along with 29,000 individuals who remained displaced (Climate Action Network South Asia, 2021)

Patterns of displacement show both permanent and temporary. Field observations report showed 9% of households surveyed faced permanent displacement as a result of climate disasters (ACT Alliance, 2021). Migration can be both an adaptation measure and result of climate impacts, with about 58% of Jure landslide-affected families using migration as an adaptive mechanism (ACT Alliance, 2021).

4.3 Loss of Indigenous Knowledge and Cultural Heritage

The non-economic losses encompass priceless cultural assets that are increasingly threatened by the impacts of climate change (United Nations Framework Convention on Climate Change, 2024; Bhattarai, 2024). Traditional practices of weather prediction, native agricultural knowledge, and culturally relevant locations face the threat of deterioration or destruction from extreme weather events. The loss of ancestral lands carries profound psychological and cultural connotations that defy monetary quantification (ACT Alliance, 2021).

Climate effects endanger age-old practices like seasonal food storage systems, disturbing the indigenous food security mechanisms evolved over centuries (ACT Alliance, 2021). For instance, the relocation of Samjung village in Upper Mustang disrupted centuries-old pastoral routes, cultural heritages and sites, seasonal migration knowledge, and local dialect use (NPRC Journal, 2025).

4.4 Ecosystem Services and Biodiversity Losses

Climate change fuels ecosystem degradation impacting biodiversity and dependent

communities. Glacial melting endangers alpine ecosystems and species like snow leopards (Asian Development Bank, 2023). Forest degradation decreases habitat availability and impairs ecotourism potential (Asian Development Bank, 2023). Rising temperatures, erratic precipitation patterns, glacial retreat, shifting species distributions, and an increase in extreme weather events are driving significant biodiversity loss in Nepal, eroding critical ecosystem services that sustain community livelihoods, cultural traditions, and resilience.

Field research reports biodiversity effects such as gradual species extinction of birds, beneficial insects, and invasion by alien species (ACT Alliance, 2021). Agricultural biodiversity is especially vulnerable to shifting precipitation patterns and extreme events, impacting traditional varieties of crops and farming systems (Subedi, 2023).

Location / Ecosystem	Climate Impact	Ecosystem Services & Biodiversity Loss	References
Dolpa & Mustang (High Himalaya)	Warming temperatures, reduced snowfall, changing precipitation	Decline in *Nardostachys jatamansi* (spikenard) and *Cordyceps sinensis* (Yarsagumba), impacting livelihoods, traditional medicine (Amchi), and cultural practices	Kunwar et al., 2020; Shrestha et al., 2012
Langtang & Everest Regions (Glacial areas)	Glacier retreat and glacial lake outburst floods (GLOFs)	Loss of water regulation services, sacred landscapes, and alpine habitats for snow leopard and blue sheep	ICIMOD, 2019; WWF Nepal, 2022
Koshi Tappu Wetland (Terai)	Erratic floods, invasive species (*Eichhornia crassipes*)	Decline in migratory bird populations and fish species, affecting biodiversity, ecotourism, and cultural fishing practices of Majhi and Tharu communities	IUCN Nepal, 2020
Chitwan National Park (Terai)	Flooding and extreme rainfall	Habitat loss for one-horned rhinoceros and gharial; changes in riverine vegetation, affecting tourism and cultural symbolism	DNPWC, 2021
Mid-hill community forests (Gorkha, Kavre)	Drought and increased forest fires	Decline in native tree species and non-timber forest products; reduced carbon sequestration; breakdown of communal forest management traditions	Paudel et al., 2019; MoFE, 2021

4.5 Psychological and Societal Impacts

Psychological distress after a disaster is a considerable yet inadequately measured non-economic loss. On-the-ground research indicates extensive trauma, fear of disaster

recurrence, and interrupted sleep patterns amidst rain occurrences (ACT Alliance, 2021). Children in the affected regions show specific vulnerability, with interrupted schooling and heightened anxiety levels (ACT Alliance, 2021).

Social structures within the community are stressed by successive disasters, as conventional support systems are inundated by repeated events. “Feminization of agriculture” is seen as male migration rises, imposing further pressures on women remaining in rural communities (Climate Action Network South Asia, 2021).

5. Recovery Capacity and Residual Gaps

5.1 Financial Recovery Challenges

Earlier incidences have shown that the path to financial recovery in Nepal is found slow and fraught with systemic obstacles. While economic losses can sometimes be quantified and compensated, non-economic losses rarely receive financial consideration and priorities. Inadequate fund provided at local level and heavily reliance on donor agencies, low penetration of climate/disaster insurance, no budget line allocated for NELD are some of the challenges observed. The difficulties in recovery result from low government compensation and low insurance coverage.

The “residual gap” -losses outstanding after government and non-governmental assistance -is between USD 1,000-2,300 for households hit by landslides and USD 70-13,580 for communities hit by floods (ACT Alliance, 2021). Around 82% of affected households take loans to recover, and many face long-term repayment difficulties (ACT Alliance, 2021).

5.2 Insurance and Risk Transfer Mechanisms

Insurance penetration is low, at just 33% of landslide-affected and 13% of flood-affected households having access to life insurance (ACT Alliance, 2021). Agricultural insurance is available but has issues with coverage adequacy and claim settlement. Asset pooling insurance schemes have been initiated by the government, but geO{graphic coverage is low (Ministry of Forests and Environment, 2021).

Effectiveness of early warning systems differs considerably. Whereas 51% of flood-affected residents surveyed indicated untimely communication, merely 18% deemed warnings effective (ACT Alliance, 2021). Investment in the infrastructure of early warnings has been shown to be advantageO{us in saving lives but needs to be supported through technological and human resource improvements (Ministry of Forests and Environment, 2021).

6. Policy Framework and Institutional Response

6.1 National Framework Development

Nepal has come up with extensive policy frameworks on loss and damage. The National Framework on Climate Change Induced Loss and Damage (2021) offers methodological

guidelines for assessment and response (Ministry of Forests and Environment, 2021). The National Adaptation Plan (2021-2050) identifies 64 priority programs with USD 47.4 billion implementation costs (Ministry of Forests and Environment, 2021).

The National Climate Change Policy 2019 focuses on loss and damage research and vulnerability reduction measures implementation (Ministry of Forests and Environment, 2021). The Nationally Determined Contribution of Nepal pledges to formulate national loss and damage strategies by 2025 (Disaster Preparedness Network Nepal, 2023).

6.2 Organizational Structures

The National Disaster Risk Reduction and Management Authority (NDRRMA) manages disaster response by using the BIPAD portal to consolidate hazard, exposure, and vulnerability infO{rmation (Ministry of Forests and Environment, 2021). Provincial focal point institutions enable UN system coordination with government institutions at the federal levels (United Nations Office for Disaster Risk Reduction, 2025).

The Ministry of Forests and Environment leads climate change coordination through the Climate Change Management Division, while sector ministries maintain specific responsibilities for hazard assessment and response (Ministry of Forests and Environment, 2021).

6.3 Financial Mechanisms and International Support

According to a 2014 Oxfam study on climate change adaptation finance, Nepal received a total commitment of US$ 538.24 million for climate change adaptation from international public finance sources from 2009 to 2012." (Sci.Dev.net, 2015). New commitments cover USD 150 million World Bank contingent financing for disaster response (World Bank, 2024) and USD 36 million Green Climate Fund assistance for GLOF risk reduction (United Nations Development Programme, 2024). In spite of global backing, there are huge financing gaps. The National Adaptation Plan demands USD 2.1 billion per year for medium-term execution, of which Nepal can only provide USD 1.5 billion, needing USD 45.9 billion in external assistance by 2050 (Ministry of Forests and Environment, 2021).

7. Discussion

7.1 Growing Effects and Patterns within Vulnerability

The assessment shows intensifying climate effects on various fronts. Economic losses exhibit statistically significant rising trends that outpace population or economic growth rates, pointing to real intensification of climate vulnerability (Ministry of Forests and Environment, 2021). The trajectory from current 0.08% GDP losses to future 9.9% by 2100 constitutes a fundamental risk to Nepal's development path (Asian Development Bank, 2023).

Physical infrastructure vulnerability is a key issue, with 75% of the economic losses

resulting from damage to property (ACT Alliance, 2021). This focus indicates that climate-proofing building codes and land use planning would greatly minimize losses in the future.

7.2 Sectoral Interdependencies and Cascading Risks

The economic structure of Nepal generates vulnerability hotspots in climate-sensitive sectors. Dependence on hydropower (99.8% of power) coupled with glacier loss and changed precipitation patterns endangers energy security (Nepal Economic Forum, 2025; My Republica, 2024). Agricultural dependence (70% of population) increases food security vulnerability under a changing climate (Climate Centre, 2021).

The study identifies cascading risk patterns in which single events cause several sectoral effects. The September 2024 floods impacted hydropower (NPR 3.02 billion), transport (NPR 27.98 billion), and water systems (NPR 5.91 billion) at the same time, illustrating systemic vulnerability (National Disaster Risk Reduction and Management Authority, 2024; Urja Khabar, 2025).

7.3 Non-Economic Loss Quantification Challenges

Non-economic losses pose huge evaluation challenges even though they have immense effects. Economic losses are given monetary values, but loss of cultural heritage, erosion of traditional knowledge, and psychological trauma do not have standard measurement protocols (United Nations Framework Convention on Climate Change, 2024; Bhattarai, 2024).

The movement of 13,352 people in 2020 constitutes measurable human mobility yet related cultural and psychological effects are still hard to quantify (Gaurav Migration Concern, 2025). Such a measurement gap probably contributes to the underestimation of overall climate change costs and the insufficient policy prioritization of non-economic factors.

7.4 Limits to Adaptation and Transformation Requirements

Field observations show that adaptation interventions currently in place are not adequate to safeguard vulnerable populations. Rates of recovery of less than 10% reveal that adaptation limits are being surpassed (ACT Alliance, 2021). Traditional coping mechanisms, including migration and borrowing, engender new vulnerabilities instead of fostering resilience.

The scale of projected future impacts (9.9% GDP by 2100) suggests that incremental adaptation measures may be inadequate (Asian Development Bank, 2023). To safeguard development gains amidst rising climate change, profound changes in development paradigms, infrastructure planning, and economic systems may be necessary.

8. Conclusions

Nepal is experiencing increasing loss and damage from climate change in both economic and non-economic areas. The current estimated annual economic loss of 0.08% of GDP hides a high variability and rising trends, with extreme years above 2% of GDP. Economic losses are predominantly due to physical property damage (75%) and agriculture (18%), indicating areas where climate-proofing of investments should be a priority.

Non-economic losses, while harder to quantify, affect many people through displacement, health impacts, loss of cultural heritage, and ecosystem degradation. The potential for recovery is much limited, with less than 10% of affected households facing rapid recovery and significant financing gaps persisting after government support.

Future estimates project economic losses at 2.2% of GDP by 2050 and 9.9% by 2100 in the absence of sufficient mitigation and adaptation efforts. Nepal's National Adaptation Plan outlines USD 47.4 billion in needs until 2050, with considerable international financing gaps.

The assessment finds that limits to adaptation are laready being faced by vulnerable populations in Nepal, with implications for transformational change in approaches to development and climate resilience. Existing loss and damage assessment capacities need to be enhanced to infO{rm evidence-based policy formulation and access to international climate finance.

Recommendation:

1. Enhancing loss and damage assessment systems by advancing data collection and methodological frameworks.
2. Augmenting climate-proofing of key infrastructure, especially hydropower and transport sectors.
3. Formulating overarching risk transfer mechanisms including the extension of insurance coverage.
4. Augmenting investment in early warning systems and disaster preparedness
5. Obtaining international climate finance commitments proportionate to adaptation and loss and damage needs identified.
6. Operationalize the FRLD fund by identifying focal points equipped with adequate resources and supported by enabling policies to ensure effective implementation and management
7. Strengthen the preparedness system along with rescue and recovery mechanisms to ensure proactive risk reduction and effective disaster response
8. Develop risk-sensitive land use planning and strengthening early warning systems to reduce disaster vulnerability and improve community resilience

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