



Comprehensive analysis of disaster events and their impacts with emphasis on water-induced disasters in Nepal

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Abstract

Previous studies on disaster events and their impacts in Nepal were focused on event-based impacts rather than a comprehensive analysis covering all the hazards across the provinces for a long period. This study addresses the limitations of previous studies and aims to (i) summarize the disaster events and the losses due to disasters in the last 15 years across the seven provinces in Nepal, and (ii) suggest measures to reduce the impacts of disasters in Nepal. A framework was developed to analyze the impacts of disasters, which can be adopted in parts of the world. All the data available in the Building Information Platform Against Disaster (BIPAD) portal, managed by the Government of Nepal, has been used. During 2011–2025, recorded disaster events were 55,285, subsequently resulting in 16,770 fatalities, 1,509 missing people, and economic loss of 54,616 million Nepalese Rupees (USD 364 million). The frequency of disaster incidents per year has increased noticeably, with averages nearly doubling across successive five-year periods. Although Koshi province records the highest number of disaster incidents, Bagmati province records the maximum number of combined fatalities and missing persons, and Karnali province records the peak economic loss. Water-induced disaster events account for around 20 percent of total disaster events; however, they contribute to about 40 percent of total economic loss. Despite the increasing trend in the number of water-induced incidents, there is a progressive downward trend in the casualties and economic losses, especially in flood events; however, the casualty rate is markedly increasing for landslides, demanding planned landslide management in Nepal.

Keywords: Natural calamity, water-induced disaster, extreme events, impacts of hazards, Disaster losses

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1 Introduction

From 1970 to 2012, weather-, climate-, and water-related disaster events accounted for 8,835 recorded events, causing 1.94 million fatalities and economic losses of USD 2.4 trillion (World Meteorological Organization, 2014). According to the World Meteorological Organization (2021), about 11,000 disasters attributed to over 2 million fatalities and economic losses of over USD 3.64 trillion occurred around the world from 1970 to 2019. The disaster events and economic losses due to extreme events, climate, and water-related events increased to 12,000 and USD 4.3 trillion, respectively, in the 1970–2021 period, with a death toll of 2 million (World Meteorological Organization, 2023). Likewise, over 0.7 million people died, and direct losses of over USD 4 trillion resulted worldwide from around 9,400 ex-

treme events from 1993 to 2022 (Adil et al., 2025). This demonstrates that disaster-related losses have escalated markedly in recent years compared with those recorded a few decades ago. In the 1970–2021 period, around 90% of the global mortality due to disaster events from extreme events, climate, and water-related events was in developing countries (World Meteorological Organization, 2023). Developing countries are more vulnerable to disaster-related losses. In 2024, Asia experienced the highest number of disaster events and disaster-related fatalities worldwide, while ranking second globally in terms of economic losses caused by these events (ADREM et al., 2025).

Between 1970 and 2019, globally, 44% of all disasters were related to floods and accounted for around 31% of all economic losses (World Meteorological Organization, 2021). Similarly, among all types of disasters in 2024, floods were

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responsible for the highest proportion of fatalities, accounting for around 35% of the total and impacting the largest share of the population globally (ADREM et al., 2025). The number of populations vulnerable to global warming-triggered water-induced disasters is projected to escalate progressively globally, with around 50% of those inhabiting South Asia, followed by Central Asia, West Africa and East Asia (Caretta et al., 2022).

Climate change has exerted a direct and significant influence on the occurrence and magnitude of disaster events. The severity and frequency of floods and droughts have escalated globally as a result of increasingly extreme climatic events compounded by deep-rooted societal vulnerabilities (Pörtner et al., 2022). South Asia contributes around 9.3% to global greenhouse gas emissions (Jain et al., 2025), while the contribution of Nepal to global greenhouse gas emissions is only 0.027% (Government of Nepal, 2016). Despite its negligible contribution to global greenhouse gas emissions, Nepal is among the most affected countries in the world. Snow cover area in Nepalese mountains has significantly decreased over the last decade (Ghimire et al., 2026; Desinayak et al., 2022; Bhattacharya et al., 2021; Gurung et al., 2017; Bajracharya et al., 2014) due to an increase in temperature in the mountain region. An increase in temperature is expected in the coming decades in this region (Dhital et al., 2023; Kaini et al., 2020b; Agarwal et al., 2016), contributing to increased river flows (Kaini et al., 2021), which might result in water-induced disasters. The key hazards related to water-induced disasters include rainfall, flood, landslide, inundation, Glacier Lake Outburst Flood, and avalanche. Climate-induced disasters account for approximately 65% of the total annual casualties in Nepal (MoFE, 2021).

Nepal is highly vulnerable to disasters due to its young and fragile geology, diverse geography, monsoon climate, exacerbated by frequent occurrences of earthquakes, landslides, floods, and forest fires. Every year in Nepal, disasters result in substantial losses of life, livelihoods, and critical infrastructure. Nepal, based on the Climate Risk Index, was in 9th place among the 10 most affected countries across the globe in 2009 (Harmeling, 2011). The Climate Risk Index represents the extent to what extent countries have been affected by the impacts of weather-related loss events like storms, floods, heat waves etc. Nepal's position worsened and reached 7th place with the countries most affected in 2014 (Kreft et al., 2016). It further aggravated and reached 4th place in 2017 among the 183 countries around the globe (Eckstein et al., 2019). This indicates that Nepal's position is worsening in terms of climate risk. Looking at the long-term climate risk index (2000–2019), Nepal holds 10th position in the most affected countries by the impacts of weather-related loss events (Eckstein et al., 2021). However, this global rank is changing, and the long-term Climate Risk Index (1993–2022) places Nepal as the 69th most affected country among the 174 countries worldwide by weather-related loss events (Adil et al., 2025).

The Jure landslide occurred on 2 August 2014 in Sindhupalchowk District, stands as one of the deadliest landslides in Nepal's history, claiming 156 lives (van der Geest, 2018). The event caused extensive geomorphological disruption, including the blockage of the Sunkoshi River and

the formation of a temporary landslide dam, which posed significant downstream flood risks. The complex interplay between natural processes such as extreme precipitation, earthquakes, and landslides often triggers cascading or compounding events that amplify overall risk and impact. Cascading hazards are increasingly prevalent in Nepal, necessitating a more integrated and comprehensive framework for hazard assessment and risk management (Maharjan et al., 2021). The principal geohazards triggered by the 2015 Gorkha earthquake (M7.8) comprised widespread landslides, river channel constriction and damming, as well as avalanches accompanied by debris flows and airburst phenomena (Shrestha et al., 2016).

The Melamchi flood of 15 June 2021 was inherently cascading in nature, resulting from the interplay of multiple driving mechanisms (Adhikari et al., 2023). The total economic loss from the Melamchi flood was around 66 billion Nepalese rupees (Parajuli et al., 2023). Likewise, the anomalous hyper-concentrated flood that occurred on 13 August 2023 in Kagbeni, situated in the Himalayan district Mustang, Nepal, resulted in extensive damage to property and infrastructure, with estimated economic losses of approximately 1 billion Nepalese rupees (Fort et al., 2025). Similarly, the flood event in Thame, Solukhumbu, on 16 August 2024, triggered by a glacial lake outburst, swept away around 20 houses and caused widespread destruction to houses, schools, bridges, and agricultural land, resulting in economic loss of approximately 800 million Nepalese rupees (Parajuli et al., 2024). The extreme rainfall events of September 2024 in Kathmandu Valley and resulting floods underscored the vulnerability of the capital city, as floodwater expanded to more than 2.5 times the bank-full water extent, leading to dozens of fatalities and millions of dollars in economic losses, and extensive damage to housing, critical infrastructure, and substantial disruption to essential urban services (Lamichhane et al., 2025; Talchabhadel et al., 2025).

Previous studies on disaster events and their impacts in Nepal were focused on event-based impacts rather than comprehensive analysis covering all the hazards across the provinces for long period. In particular, the impacts associated with total disasters and water-induced disaster have not been sufficiently addressed in current literature. This study addresses the limitations of previous studies and provides a comprehensive analysis of disaster events and their impacts in terms of casualty and economic losses based on temporal hazard-based data across the seven provinces of Nepal for the period 2011–2025. In this regard, this study aims to (i) summarize the disaster events and the losses due to disasters in the last 15 years in Nepal, and (ii) suggest measures to reduce the impacts of disasters in Nepal.

2 Methods

The overall methodology to analyze the disaster events and their impacts with a comprehensive analysis based on locations and hazards is shown in Fig. 1. Firstly, disaster data are collected for different hazards at the national level. The data are divided based on specific locations, like provinces. For each location (province), the data are further

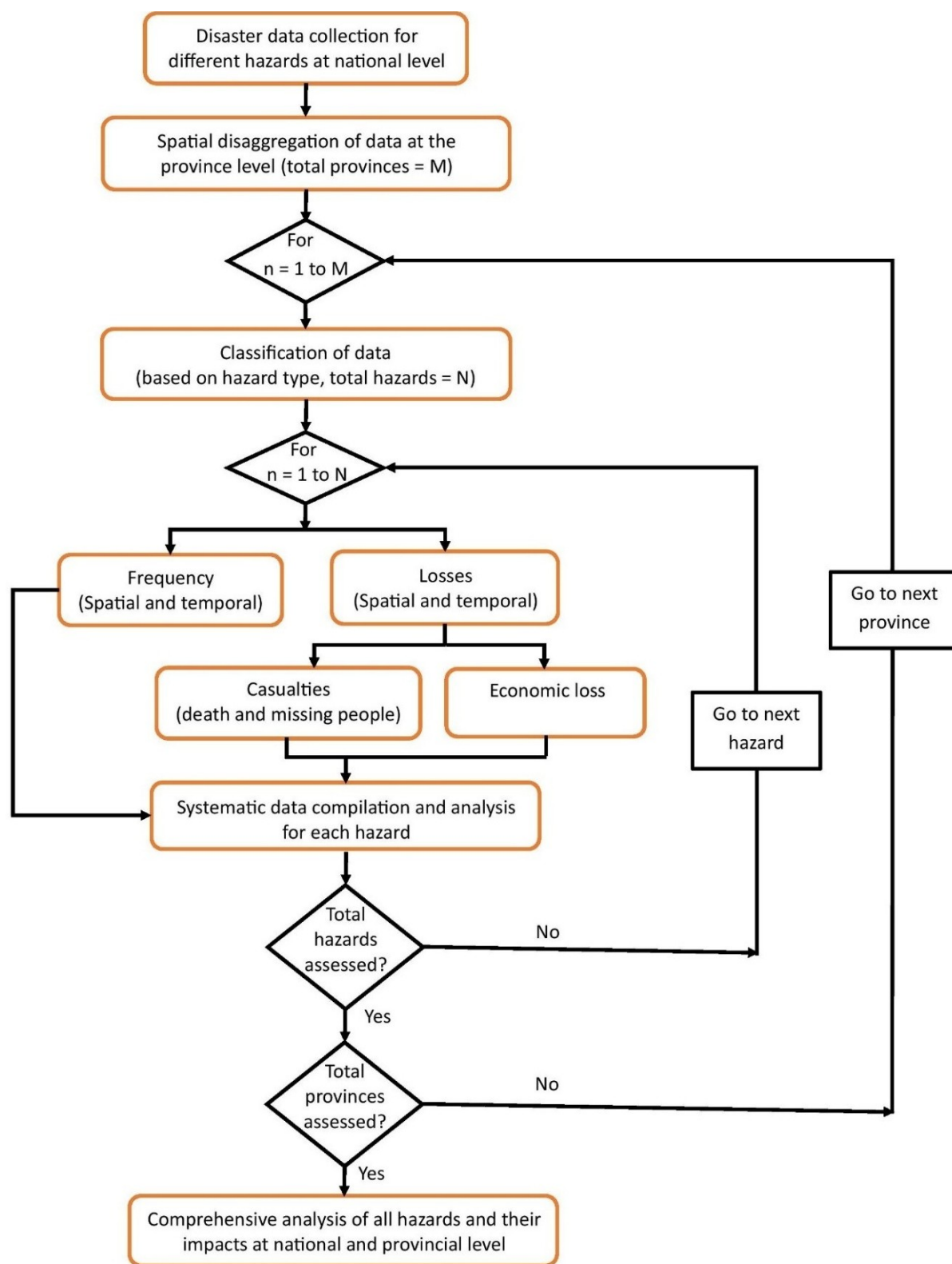


Fig. 1. Flowchart for comprehensive analysis of disaster events and their impacts.

classified based on hazard. Comprehensive data collection and analysis on the total number of disasters and their impacts (casualty and economic losses) for each hazard are carried out. When data collection and analysis for one hazard for a specific location (province) is completed, the same process is repeated for the next hazard for the same location

until all the hazards are completed. After data collection and analysis for all hazards for a specific location (province) is completed, the same process is repeated for the next location (province) until all the locations (provinces) are completed. Finally, a comprehensive analysis is conducted at the national and province level for different hazards.

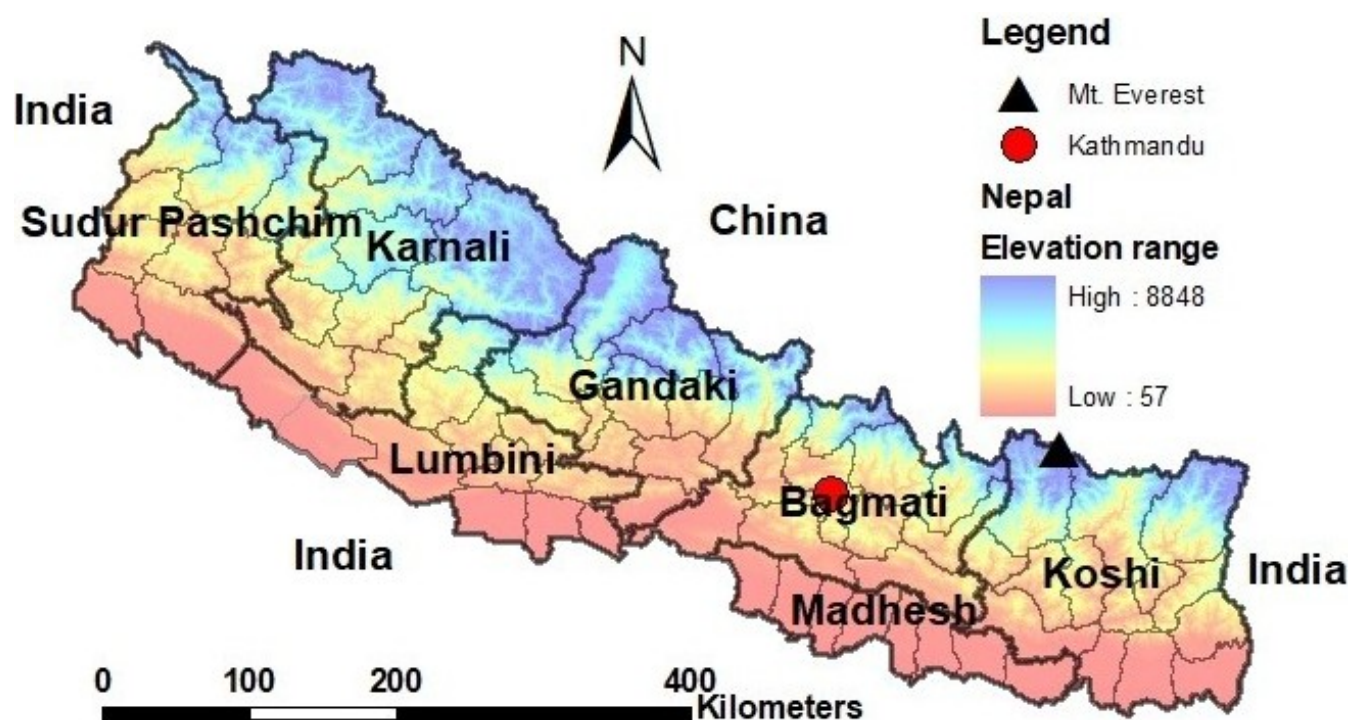


Fig. 2. Study area, Nepal, showing the provincial boundaries.

3 Study area and data

3.1 Study area

Nepal, situated in the northern region of South Asia, exhibits remarkable topographic heterogeneity, with elevation ranging from approximately 57 m (60 m) above mean sea level in the southern lowlands to 8,848 m (8848.86 m) at its highest point, all within a north-south span of around 150 km (Fig. 2). Nepal is administratively divided into seven provinces - Koshi, Madhesh, Bagmati, Gandaki, Lumbini, Karnali, and Sudur Pashchim – distributed longitudinally from east to west. From a disaster risk perspective, Madhesh Province, situated in the low-lying southern plains, is particularly susceptible to recurrent flooding and associated hazards. In contrast, Karnali Province, characterized by rugged hills and high mountain terrain, is more prone to landslides, seismic impacts, and issues related to remoteness and accessibility. The remaining provinces encompass a combination of high-himalayan, middle-hill, and lowland environments, resulting in multi-hazard exposure, including floods, landslides, earthquakes, and extreme weather events.

3.2 Data

The Government of Nepal, Ministry of Home Affairs, National Disaster Risk Reduction and Management Authority, Kathmandu, Nepal, has developed and managed the Building Information Platform Against Disaster (BIPAD) portal (<https://bipadportal.gov.np/>), an integrated and comprehensive disaster information management system. The BIPAD is founded on the principle of establishing a centralized national portal, integrated with autonomous platforms for national, provincial, and munic-

ipal governments, and driven by a bottom-up approach to disaster data collection (NDRRMA, 2020). The information hosted within this portal possesses significant potential to strengthen preparedness, enhance disaster communication, improve response mechanisms, and facilitate effective post-incident coordination. Within the BIPAD portal, data on diverse disaster events are available from 2011 to the present. Accordingly, this study utilizes records spanning 2011–2025 (last accessed in February 2026). Disaster events encompassing all hazard categories have been systematically analyzed in this research.

The BIPAD portal has identified 47 different hazards that could result in disasters in Nepal. The natural hazards are classified into 24 categories: landslide, flood, thunderbolt, fire, heavy rainfall, wind storm, cold wave, earthquake, animal accidents, avalanche, epidemic, forest fire, hailstorm, rainfall, snow storm, storm, drought, glacial lake outburst, heat wave, inundation, soil erosion, volcanic eruption, famine, and other (natural). Similarly, non-natural hazards are systematically classified into 23 distinct categories: high altitude, boat capsize, snake bite, drowning, aircraft accident, bridge collapse, helicopter crash, industrial disaster, mine disaster, pandemics, road accident, animal flu, deforestation, environmental pollution, food poisoning, gas explosion, leakage (chemical), leakage (radiation), leakage (toxic gas), microorganism attack, water accident, response accident, and other non-natural hazards. The disaster-related incidents resulting from these hazards since 2011 are available in the Government of Nepal's official disaster portal (<https://bipadportal.gov.np/>). Among the 47 different hazards, 20 hazardous incidents have contributed to disasters in the last 15 years.

Table 1. Hazard type, number of incidents and affected people from 2011 to 2025 in Nepal (Source: <https://bipadportal.gov.np/>).

S.N.	Hazard Type	Number of incidents	People dead	People missing	People injured
1	Fire	32004	1163	0	4237
2	Landslide	4876	1940	409	1640
3	Thunderbolt	3752	1305	1	3870
4	Heavy Rainfall	2945	141	2	405
5	Flood	2702	1028	629	279
6	Animal Incidents	2522	322	2	1581
7	Forest Fire	2149	31	0	55
8	Wind Storm	1569	116	1	1591
9	Snake Bite	860	240	0	630
10	Drowning	515	418	126	19
11	High Altitude	380	164	0	249
12	Earthquake	329	9131	195	22743
13	Others (Non-natural)	320	353	50	275
14	Cold Wave	117	116	0	0
15	Epidemic	78	99	0	2690
16	Storm	67	63	7	46
17	Boat Capsize	46	60	55	50
18	Avalanche	43	61	31	63
19	Snow Storm	10	17	0	1
20	Bridge Collapse	1	2	1	12
Total		55285	16770	1509	40436

4 Disaster events and their impacts in Nepal

4.1 Disaster events

Based on the data from 2011 to 2025, a total of 55,285 different incidents have been recorded in the BIPAD portal (<https://bipadportal.gov.np/>), and the details of the incidents with respect to hazard are shown in Table 1. It demonstrates that the major hazards contributing to the increasing number of disaster incidents in Nepal include fire, landslide, thunderbolt, heavy rain, flood, animal incidents, forest fire, wind storm, snake bite, drowning, high altitude and earthquake. Among the recorded incidents, fire emerges as the most prevalent, occurring 32,004 times, followed in descending order by landslides (4,876 times), thunderbolt events (3,752 times), heavy rainfall (2,945 times), and floods (2,702 times) during the 2011–2025 period.

The provincial distribution of the total number of disaster incidents, and their impacts considering the casualty (people death plus missing), and economic loss from 2011 to 2025 is shown in Fig. 3. During the period 2011–2025, the total number of incidents is highest in the Koshi province (14,525), followed by the Madhesh (10,136), Lumbini (8,938), Bagmati (8,821), Gandaki (4,882), Sudur Pashchim (4,688), and Karnali (3,295).

The chronological distribution of disaster events across provinces is illustrated in Fig. 4. The disaster events have significantly increased from 1,172 in 2011 to 8,353 in 2025. The disaster events have increased sevenfold in the last 15 years and have escalated markedly over the past decade. The rate of increase in disaster events is substantially higher in Koshi province compared to the other provinces. In 2015, the number of incidents remained relatively low across all the provinces, ranging from 53 to 249. By contrast, in 2025, the recorded incidents rose sharply to 2,161 in Koshi, 1,334

in Lumbini, 1,257 in Madhesh, and 1,240 in Bagmati. This pronounced escalation indicates a disproportionately rapid increase in disaster occurrence in Koshi province, suggesting heightened vulnerability or increased reporting mechanisms relative to other regions.

4.2 Losses due to disaster in Nepal

4.2.1 Casualty

Table 1 shows that the cumulative number of fatalities attributable to disaster events from 2011 to 2025 is 16,770, accompanied by 1,509 individuals as missing. The major hazards considering people's deaths during the disaster from 2011 to 2025 include earthquake (9131 people), landslide (1940 people), thunderbolt (1305 people), fire (1163 people), and flood (1028 people). As illustrated in Fig. 3, Bagmati province records the highest number of casualties (combined fatalities and missing persons), totalling 10,508. This is followed by Gandaki (1,776), Koshi (1,659), Lumbini (1,420), Madhesh (1,079), Karnali (1,050), and Sudur Pashchim (786), indicating a markedly higher burden in Bagmati relative to the other provinces. The total number of incidents, casualty (dead plus missing people), and the total economic losses is shown in chronological order in Fig. 5.

Fig. 5 shows that the number of casualties (dead plus missing people) was 553 in 2011, which reached a peak with a value of 9,532 in 2015. The highest number of casualties in 2015 was due to the Gorkha earthquake in April 2015, a 7.8 magnitude earthquake, with more than 8800 people's deaths (Liang and Zhou, 2016) and aftershocks thereafter. Except for this unexpected casualty due to an earthquake, the total number of casualties has remained almost stable in the last 15 years despite an increased number of disaster incidents.

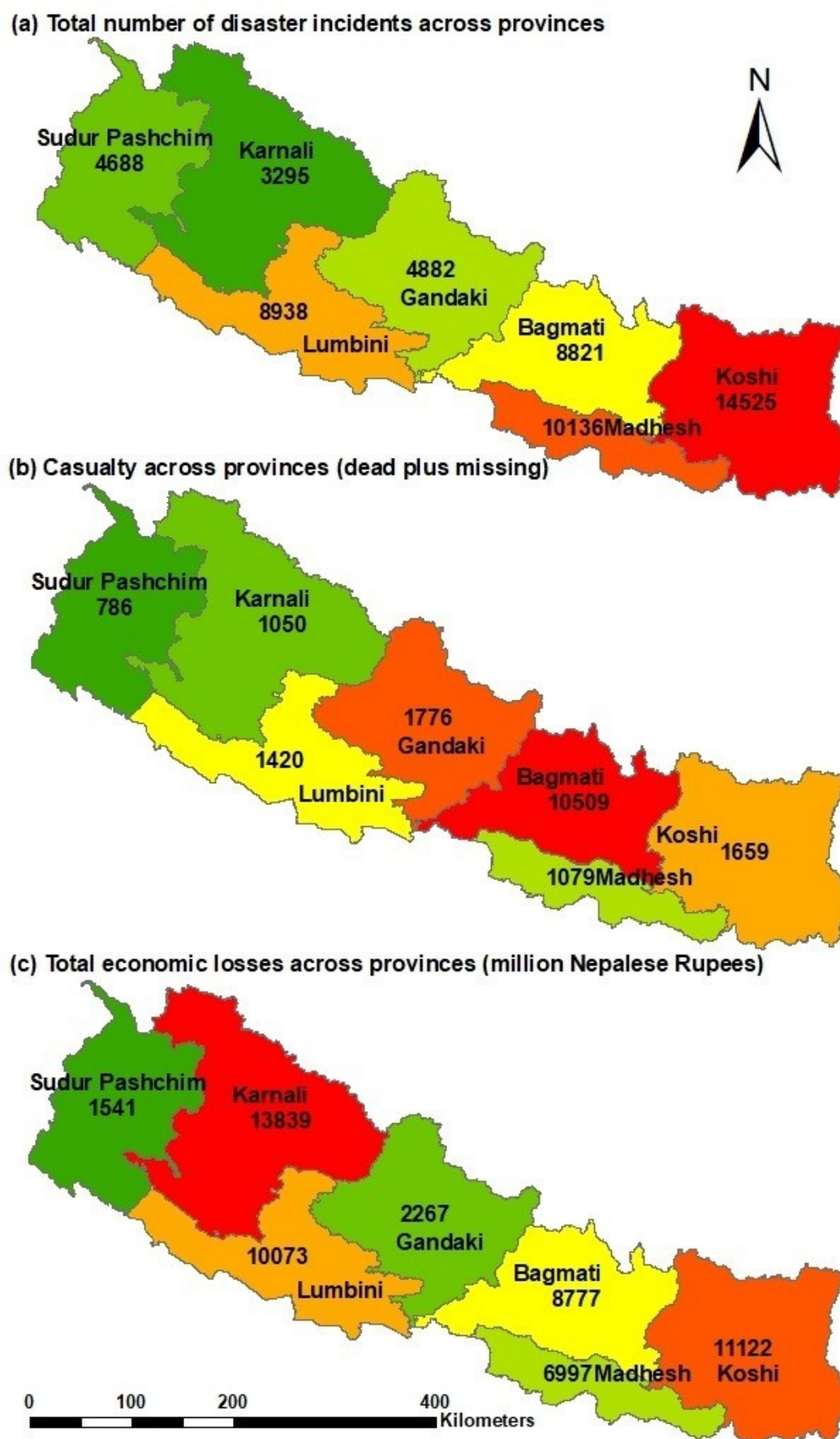


Fig. 3. Provincial distribution of (a) total number of incidents, (b) casualties, and (c) economic loss for the 2011–2025 period (Currently, 1 USD = 150 Nepalese Rupees).

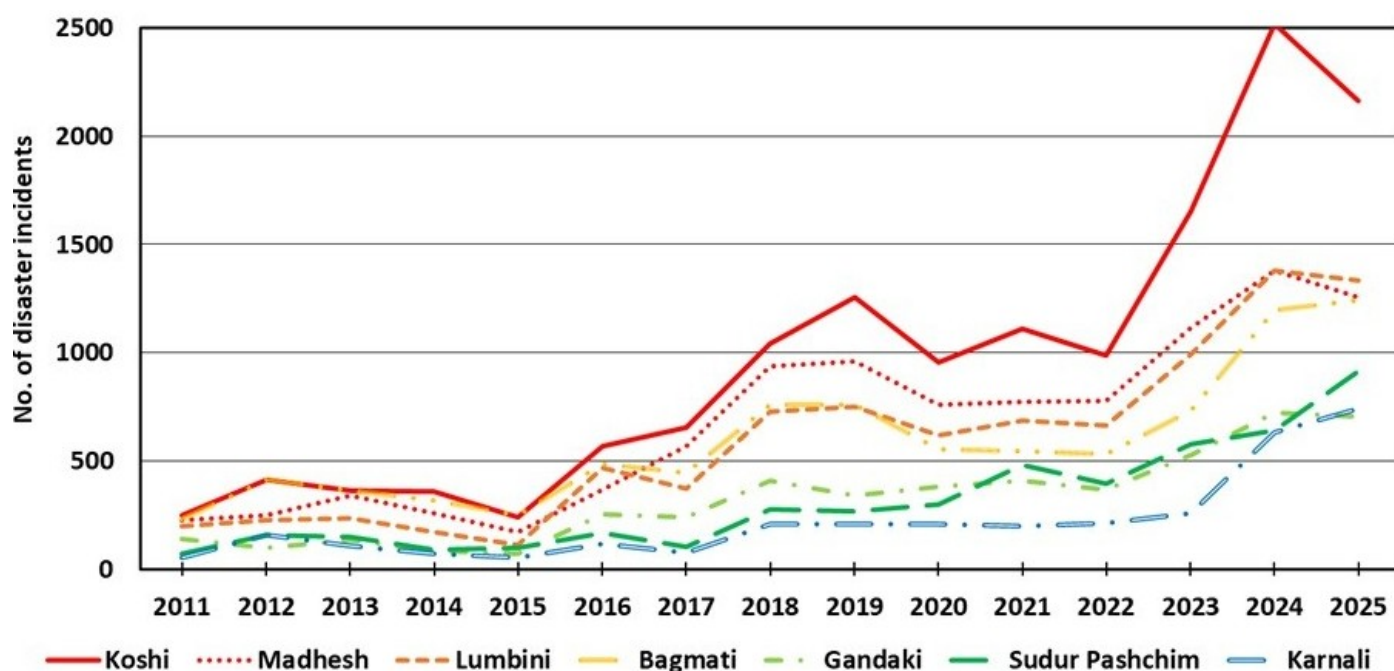


Fig. 4. Chronological distribution of disaster events across provinces.

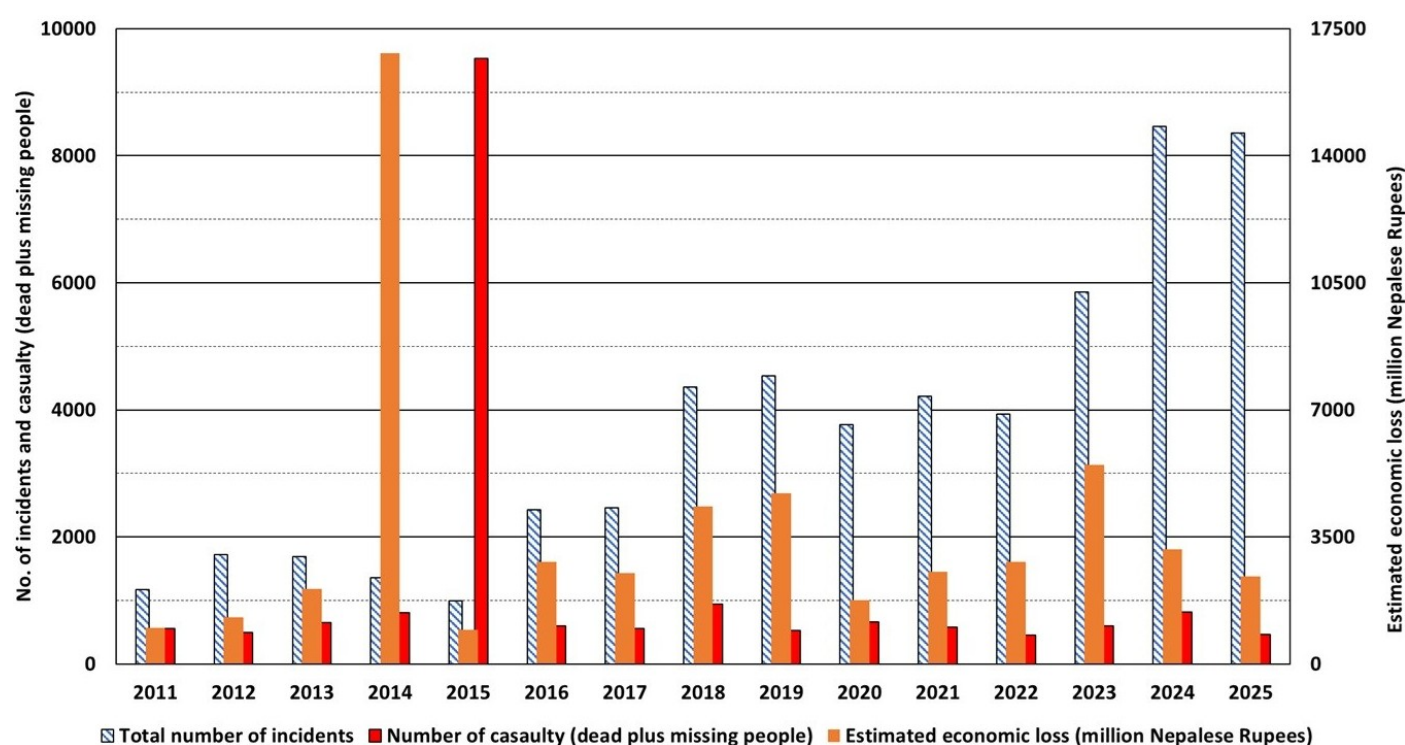


Fig. 5. Total number of incidents, casualties (dead plus missing people), and economic losses from 2011–2025 in chronological order (1 USD = 150 Nepalese Rupees).

4.2.2 Economic loss

The total economic loss due to disaster events from 2011 to 2025 is 54,616 million Nepalese Rupees. As depicted in Fig. 3, Karnali province records the greatest economic loss of 13,839 million Nepalese Rupees in the period 2011–2025. This is followed by Koshi (11,122 million), Lumbini (10,073 million), Bagmati (8,777 million), Mad-

hesh (6,997 million), Gandaki (2,267 million), and Sudur Pashchim (1,541 million), underscoring the disproportionately higher economic burden borne by the Karnali province relative to other provinces. The total economic loss in 2011 was 994 million Nepalese Rupees, and it reached up to 16,815 million Nepalese Rupees in 2014. The huge economic loss in 2014 was mainly due to the flood in Karnali

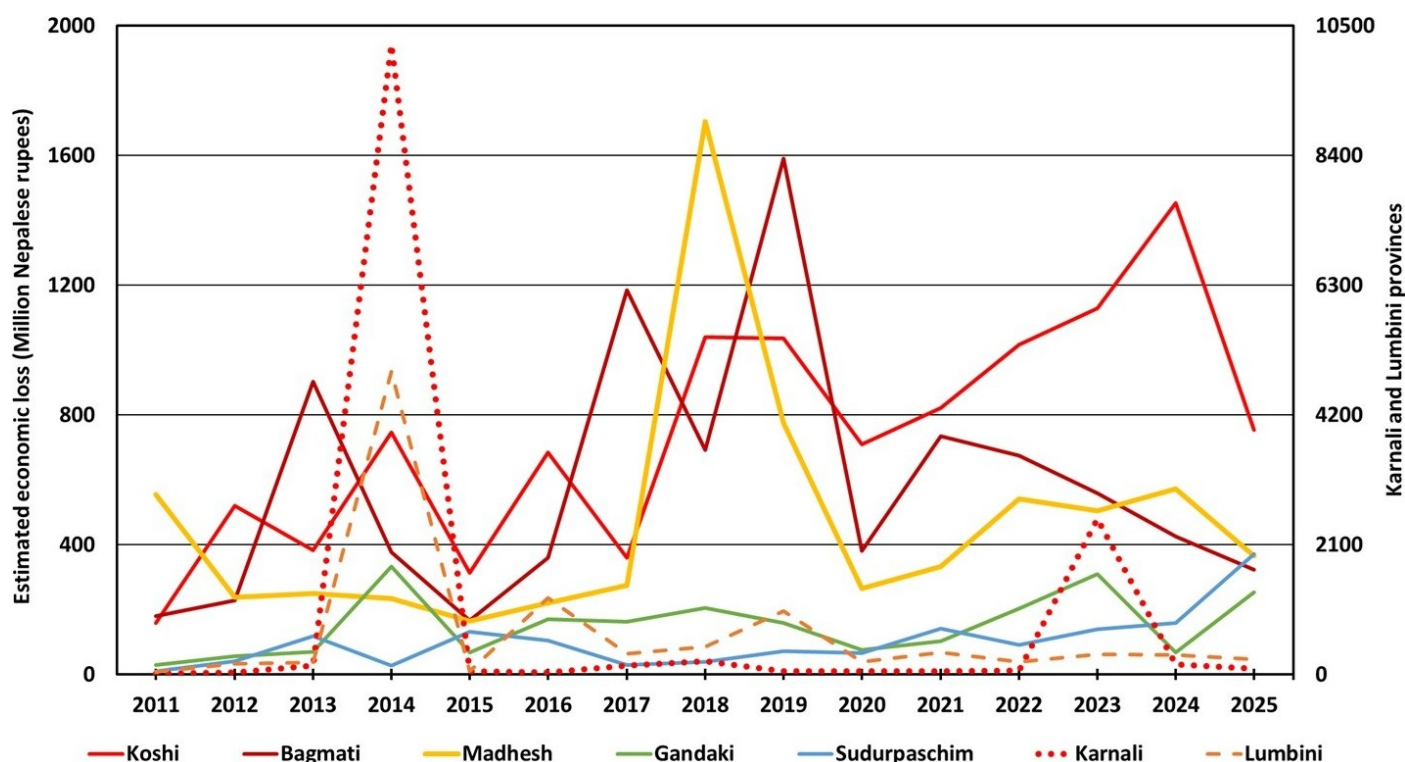


Fig. 6. Chronological distribution of estimated economic loss across the provinces (1 USD = 150 Nepalese Rupees).

and Lumbini provinces in August 2014, especially in Surkhet district, which accounted for a loss of 10,052 million Nepalese Rupees. Fig. 6 shows the chronological distribution of estimated economic loss across the provinces. The economic loss due to disaster events is markedly increasing in Koshi province, followed by Bagmati province and Madhesh province. The economic loss is almost stable in Gandaki and Sudur Pashchim provinces, as these provinces have not recorded any huge loss of more than 400 million Nepalese Rupees.

5 Water-induced disaster events and losses in Nepal

5.1 Water-induced disaster events

Water-induced disasters in Nepal rank among the most catastrophic hazards, resulting in substantial loss of life, widespread infrastructure damage, and significant economic disruption. The key hazards in water-induced disasters include rainfall, flood, landslide, inundation, Glacier Lake Outburst Flood, and avalanche. Nepal experiences an average annual rainfall of about 1,530 mm, characterized by significant spatial and temporal variability, with around 80% of the total precipitation occurring during the monsoon period from June to September (Water and Energy Commission Secretariat, 2005). Intense monsoonal rainfall routinely triggers floods and landslides annually, leading to fatalities, widespread damage to housing, loss of arable land, and significant impairment of essential infrastructure. Chronological distribution of water-induced disaster incidents for 2011–2025 is shown in Fig. 7.

The total number of water-induced disasters in the 2011–2025 period is 10,566. The major hazard contributing

to water-induced disaster incidents in this period is landslide (4876), followed by rainfall (2945), flood (2702), and avalanche (43). This value in 2011 was 481, which increased to 1975 in 2024, illustrating a marked increase in the last decade. The provincial distribution of total water-induced disaster incidents, casualties (dead plus missing people), and estimated economic losses due to water-induced disasters across the provinces from 2011 to 2025 is shown in Fig. 8 which shows that Koshi province recorded the highest number of water-induced disasters (2425), followed by Bagmati (1943), Lumbini (1629), Gandaki (1496), Karnali (1134), Sudur Pashchim (1131), and Madhesh (808).

5.2 Loss due to water-induced disaster events

5.2.1 Casualty

The total number of casualties (dead plus missing people) due to water-induced disasters in the 2011–2025 period is 4271. Fig. 8 shows that Bagmati province (1111) recorded the highest number of casualties (dead plus missing people) due to water-induced disasters, followed by Koshi (658), Lumbini (653), Gandaki (622), Karnali (577), Sudur Pashchim (395), and Madhesh (225). Such casualties are highest for landslide incidents (2349), followed by flood (1687), rainfall (143) and avalanche (92). The chronological distribution of casualties (dead plus missing people) is shown in Fig. 9, which shows that the total number of such casualties is slightly decreasing. However, the casualty rate due to water-induced disasters is markedly increasing for landslide incidents. In contrast, the casualty rate is significantly decreased for flood incidents, which could be due to the river management works, including embankment construction in major rivers in Nepal.

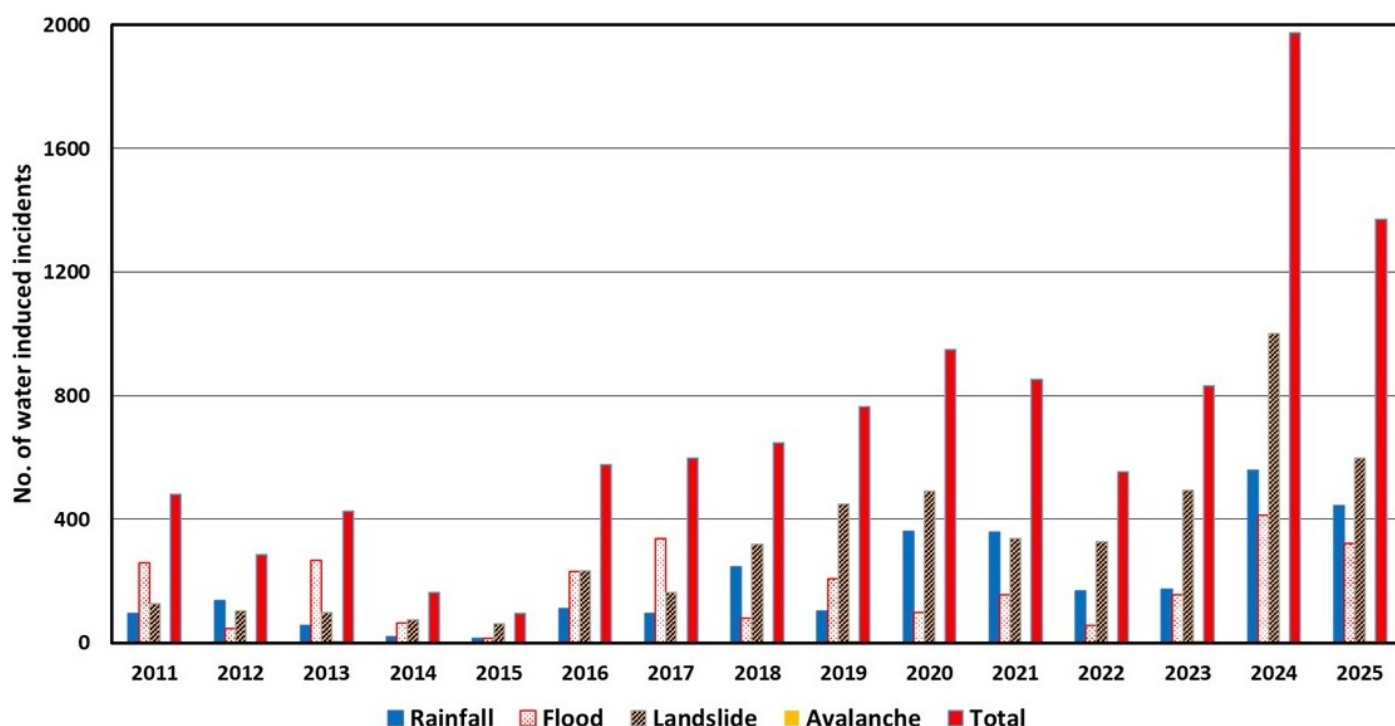


Fig. 7. Chronological distribution of water-induced disaster incidents for the 2011–2025 period.

5.2.2 Economic loss

The total economic losses due to water-induced disasters in the 2011–2025 period are 20,449 million Nepalese Rupees. Water-induced disaster events include around 20 percent of total disaster events; however, they contribute to about 40 percent of total economic losses. Fig. 8 demonstrates that Karnali province recorded the highest economic loss due to water-induced disaster, amounting to 10,420 million Nepalese Rupees, followed by Lumbini (5763 million), Koshi (1507 million), Gandaki (1445 million), Madhesh (626 million), Bagmati (567 million), and Sudur Pashchim (121 million) in this period. The chronological distribution of economic losses due to water-induced disasters for the 2011–2025 period is shown in Fig. 10, which shows a significant decrease in economic losses due to flood incidents; however, it is almost the same for the landslide events.

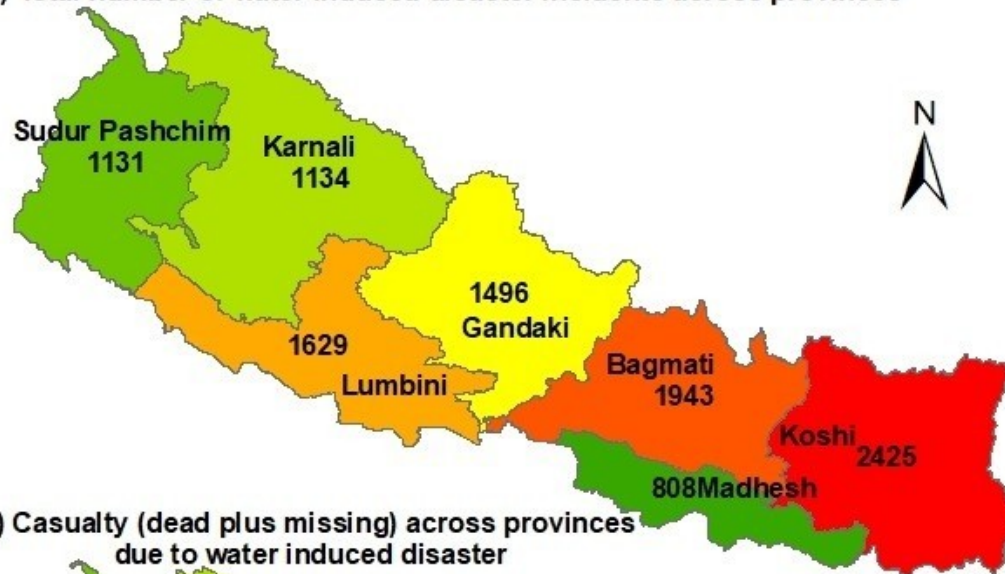
6 Discussion

In Nepal, the frequency of disaster incidents per year has increased noticeably over recent decades. The improved disaster reporting system, enhanced institutional documentation system, digital reporting system, and expansion of BIPAD coverage in recent years could have contributed to the increase in disaster events recorded in the BIPAD portal. The rapidly increasing disaster incidents in the Koshi province could be due to diverse topography, with elevations ranging from 57 m (60 m) to 8,848 m (8848.86 m) above mean sea level, glacial and mountain-related hazards, large river systems with transboundary connections in the region, rapid unplanned infrastructure development, and improved disaster reporting. The average number of disaster incidents in Nepal for the periods 2011–2015, 2016–2020, and 2021–2025 was 6926, 17548, and 30811, respectively. The marked

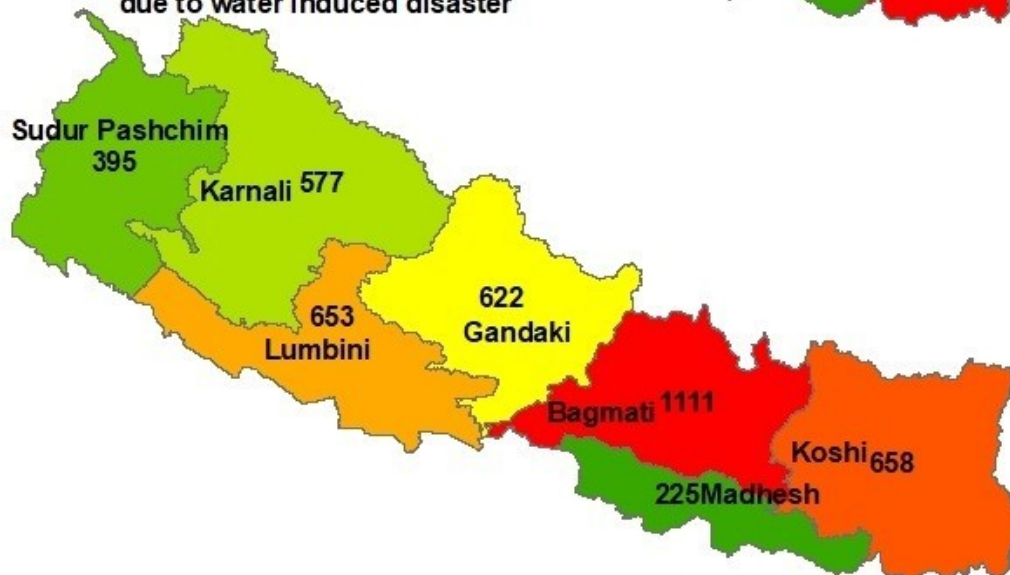
increase in disaster incidents, with averages nearly doubling across successive five-year periods, highlights growing social vulnerability to natural and water-related hazards. This trend aligns with global evidence of escalating frequency and intensity of extreme weather events. According to the [World Meteorological Organization \(2021\)](#), the frequency of disasters has increased fivefold over the past 50 years. Climate change has been identified as a significant driver of increased frequency and intensity of weather and climate-related disasters ([Seneviratne et al., 2021](#)). The temporal distribution of disaster-related casualties (dead and missing persons) in Nepal reveals a notable decline over the three assessed periods, aligned with the global scenario. Global death counts decreased around threefold from 1970 to 2019 ([World Meteorological Organization, 2021](#)). In Nepal, during the 2011–2015 period, the highest total of 11,156 casualties (death and missing people), the succeeding periods, 2016–2020 and 2021–2025, show a significant reduction to 2905 and 2709 respectively. This downward trend may reflect improvements in disaster preparedness, advanced climate forecasting systems, early warning systems, and post-disaster response mechanisms implemented at the national, provincial, and local levels. These findings highlight the importance of continuing investment in disaster risk reduction, community resilience, and disaster-resilient infrastructure to sustain the observed decline in casualty rates, even as the frequency of disaster events escalates.

The temporal pattern of disaster-induced economic losses in Nepal indicates a substantial reduction, with a total loss declining from 22,103 million Nepalese Rupees during the 2011–2015 period to 16,119 million Nepalese Rupees in the 2016–2020 period, and remaining relatively constant at 16,394 million Nepalese Rupees in the 2021–2025 period. This reduction in economic loss may be a result of

(a) Total number of water induced disaster incidents across provinces



(b) Casualty (dead plus missing) across provinces due to water induced disaster



(c) Total economic losses due to water induced disaster across provinces (million Nepalese Rupees)

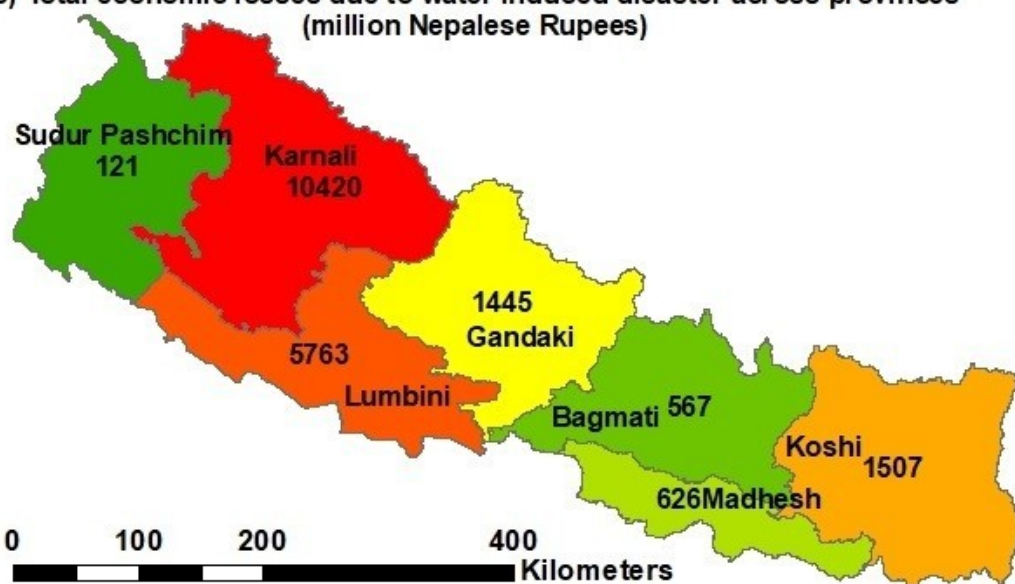


Fig. 8. Provincial distribution of (a) total number of incidents, (b) casualties, and (c) economic loss due to water-induced disaster for the 2011–2025 period (1 USD = 150 Nepalese Rupees).

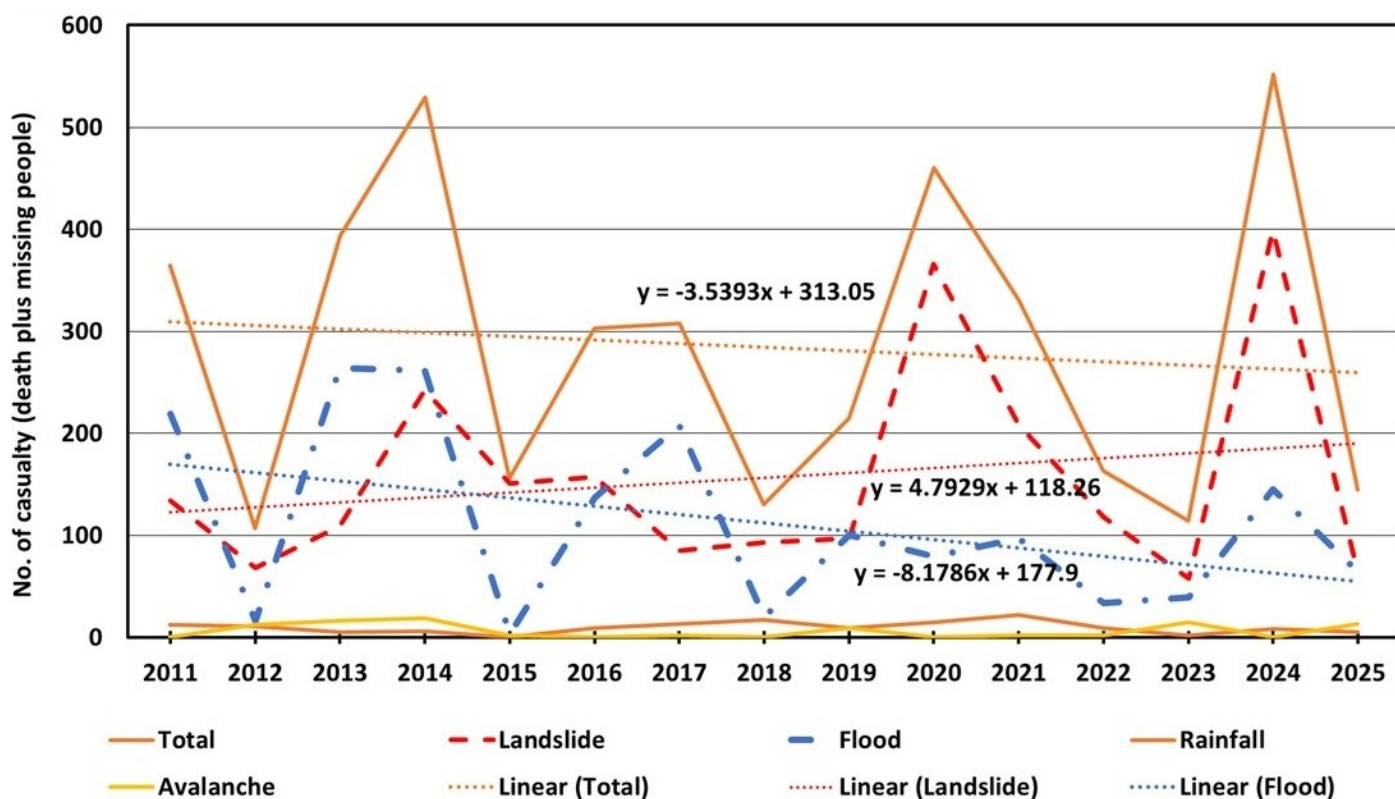


Fig. 9. Chronological distribution of casualties due to water-induced disasters for the 2011–2025 period.

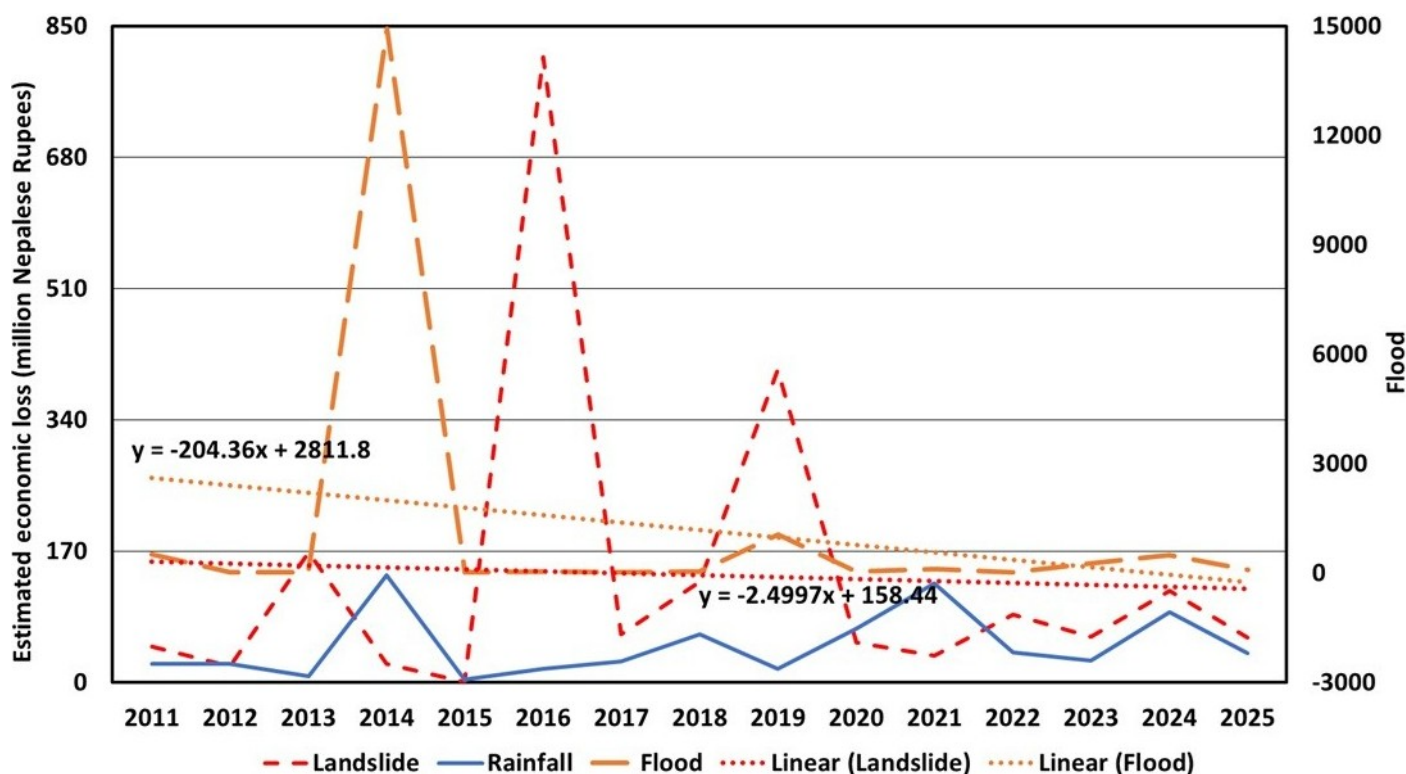


Fig. 10. Chronological distribution of economic losses due to water-induced disaster for the 2011–2025 period (1 USD = 150 Nepalese Rupees).

enhanced disaster risk management practices, more effective preparedness and post-disaster response strategies, and better infrastructure resilience implemented in recent years.

The more constant economic losses in the 2016–2020 and 2021–2025 periods highlight the effectiveness of current mitigation measures against disasters, despite the continuously

increasing frequency of disaster events. This trend in economic loss underscores the necessity for continued investment in disaster-resilient infrastructure and climate adaptation strategies, and to further decrease economic vulnerability.

The average number of water-induced incidents from 2011–2015, 2016–2020, and 2021–2025 is 299, 706, and 1117, respectively. This shows an increasing trend in the number of water-induced incidents. The average number of casualties (people deaths plus missing) due to water-induced incidents from 2011–2015, 2016–2020, and 2021–2025 is 310, 283, and 260, respectively. This reflects a progressive downward trend in the casualties. Likewise, the average estimated loss due to water-induced incidents from 2011–2015, 2016–2020, and 2021–2025 is 3334, 559, and 320 million Nepalese rupees, respectively. This shows a decreasing trend in the number of casualties as well as losses despite the increasing number of disaster events.

The disproportionately water-induced disaster losses in Karnali Province could be due to the interaction of geographical and socio-economic vulnerability and other various reasons, including a mountainous and sparsely populated region, limited and less resilient infrastructures, remoteness from major transportation networks and public services, constrained institutional capacity, limited accessibility and delayed emergency response, and exposure to multiple water-induced hazards. The decreasing trend in the number of casualties as well as economic losses due to water-induced disasters in Nepal, despite the increasing number of water-induced disaster events, could be due to the different river management interventions and watershed management efforts from government and non-government sectors. The federal Government of Nepal has constructed about 1480 km of river embankments and 635 check dams at the catchment level ([Department of Water Resources and Irrigation, 2026](#)). Construction of river embankments in the southern plain region of Nepal has drastically contributed to reduced casualties and economic losses by controlling the river overflows and protecting the agricultural lands and settlements. In particular, the construction of river embankments in the southern plains (Terai region) appears to have played a decisive role in minimizing flood exposure and vulnerability. Effective water-induced disaster risk mitigation in Nepal requires both channelling floodwaters away from inhabited areas through structural measures and the strategic planning and relocation of settlements beyond high-risk zones, guided by rigorous, research-based, and dynamically updated hazard and risk assessment ([Kaini, 2025](#)).

Despite noticeable progress in flood management infrastructures, including embankment construction, landslide management in fragile hill slopes has become a critical issue in Nepal. In recent years, unplanned local road network expansion by provincial and local governments has substantially accelerated landslide incidents in the fragile hill slopes during the monsoon, resulting in the loss of lives and infrastructure. Landslide-triggered sediment loads in rivers have altered the river morphology, reduced the conveyance capacity, and increased the likelihood of aggradation and overbank flooding. Climate change-induced extreme climatic events have also exacerbated landslide events. In this

context, a comprehensive and integrated landslide management strategy is urgently required in the fragile hilly area of Nepal. Identification of potential groundwater zones in the hills of Nepal ([Upadhyaya et al., 2024](#); [Pradhan et al., 2025](#)) and their effective management could also reduce landslides in the fragile hilly region of Nepal. A comprehensive evaluation of climate change impacts on water resources projects is imperative to mitigate anticipated adverse effects through the adoption of appropriate adaptive measures ([Kaini et al., 2024](#)). The Government of Nepal must prepare and enforce a landslide management plan and policy in close coordination with provincial and local governments, as well as research institutions, for scientific research-based solutions to achieve long-term sustainability.

The predominant approach to disaster management in Nepal is largely reactive, and most of the time interventions are undertaken after the disaster events rather than focusing on comprehensive pre-disaster planning. Proactive disaster risk reduction measures, including dynamic hazard assessment, enhanced community preparedness, and land-use planning, are not focused on the national budgetary system, although it is highlighted in the policies. The implementation of post-disaster recovery plans is also generally hindered by financial constraints and procedural delays associated with public procurement rules and regulations, which are mainly formulated for the routine development works rather than emergency disaster prevention and recovery works. In this regard, it is imperative to introduce adaptive procurement mechanisms that help to expedite the decision process and execute the works under emergency conditions. It will contribute to the overall effectiveness of the disaster preparedness and recovery process.

In this context, the United Nations 2030 Agenda for Sustainable Development ([United Nations, 2015](#)) and the Sendai Framework ([UNISDR, 2015](#)) emphasize the importance of strengthening national resilience through systematic enhancement of disaster risk reduction strategies. By prioritizing proactive disaster risk management, early warning systems, and capacity-building measures, countries can mitigate impacts, reduce vulnerability, and enhance long-term adaptive capacity in the face of evolving disaster risks. Disaster risk reduction is fundamental for achieving Sustainable Development Goals. The Paris Agreement ([UNFCCC, 2015](#)) and Sendai Framework ([UNISDR, 2015](#)) have also highlighted the disaster risk reduction and climate change mitigation and adaptation as intertwined elements. Climate change adaptation options must be internalized while designing the new project or rehabilitating the existing projects ([Kaini et al., 2011](#); [Kaini et al., 2022](#)), considering the sustainability aspect ([Kaini, 2016](#)).

Adaptation options, including early warning systems, disaster risk management, climate services, risk spreading and sharing, and social safety nets, have wide applicability across multiple domains ([Lee et al., 2023](#)). Climate change adaptation and mitigation measures should focus on disaster risk reduction to achieve the Sustainable Development Goals and climate resilient development ([UNISDR, 2015](#)), considering the local socio-economic settings ([Kaini et al., 2020a](#)). The national river and water-induced disaster policy has focused on an effective sediment management plan of

river systems, fixation of river waterway and right of way, an enhanced multi-hazard information management system including an early warning system, and cutting-edge research and development in collaboration with research institutions, following the integrated water resources management principle (Government of Nepal, 2023).

7 Conclusions

This study provides a comprehensive analysis of the spatiotemporal dynamics of disaster events, with a focus on water-induced disasters and their associated human, economic and infrastructural impacts across Nepal for the period 2011–2025, highlighting provincial disparities in hazard occurrence and vulnerability. The disaster data were taken from the Government of Nepal's BIPAD portal, which provides data for the 2011–2025 period.

The frequency of disaster incidents per year has increased noticeably, with averages nearly doubling across successive five-year periods. The rate of increase in disaster events is substantially higher in Koshi province compared to the other provinces. The rapidly increasing disaster incidents in the Koshi province could be due to diverse topography, glacial and mountain-related hazards, large river systems with transboundary connections in the region, rapid unplanned infrastructure development, and improved disaster reporting. The major hazards considering people's deaths during disasters from 2011 to 2025 include earthquakes, landslides, thunderbolts, fire, and floods. Bagmati province records the highest number of casualties (combined fatalities and missing persons) due to major earthquakes in 2015.

The total economic loss due to disaster events from 2011 to 2025 is 54,616 million Nepalese Rupees (USD 364 million). Karnali Province records the greatest economic loss in this period. The disproportionately water-induced disaster losses in Karnali Province could be due to the interaction of geographical and socio-economic vulnerability, including a mountainous and sparsely populated region, limited and less resilient infrastructure, remoteness from major transportation networks and public services, constrained institutional capacity, limited accessibility and delayed emergency response, and exposure to multiple water-induced hazards. This is followed by Koshi, Lumbini, Bagmati, Madhesh, Gandaki, and Sudur Pashchim. The economic losses due to disaster events are increasing in the Koshi, Bagmati, and Madhesh provinces. Water-induced disaster events include around 20 percent of total disaster events; however, they contribute to about 40 percent of total economic losses.

The major hazard contributing to water-induced disaster incidents is landslides, followed by rainfall, floods, and avalanches. Koshi province recorded the highest number of water-induced disasters during 2011–2025. However, Bagmati province recorded the highest number of casualties (dead plus missing people), and Karnali province recorded the highest economic loss due to water-induced disaster. There is an increasing trend in the number of water-induced incidents, though, a progressive downward trend in the casualties and economic losses, especially in flood events, which could be due to the different river management in-

terventions, including embankment construction in major rivers. However, the casualty rate is markedly increasing for landslides, demanding planned landslide management in Nepal. The findings highlight the immediate need for the Government of Nepal to prioritize landslide risk management as a high national policy agenda through enhanced hazard mapping, climate adaptation strategies, resilient infrastructure development, early warning systems, and risk-informed land-use planning.

Traditional single-hazard approaches are insufficient to capture cascading and compounding disasters. A shift toward multi-hazard and systems-based scientific methodologies is essential to better understand interdependencies, improve predictive capabilities, and enhance resilience. Proactive disaster risk reduction measures, including dynamic hazard assessment, enhanced community preparedness, and scientific research-based land-use planning, supported by an advanced early warning system enforced by both policy and implementation mechanisms, are essential to reduce the impacts of disasters. Effective water-induced disaster risk mitigation in Nepal requires both channelling floodwaters away from inhabited areas through structural measures and the strategic planning and relocation of settlements beyond high-risk zones, guided by rigorous, research-based, and dynamically updated hazard and risk assessment. It requires collaborative efforts among the stakeholders, including three tiers of government, non-government organizations, research institutions, community-based organizations, and the private sector.

The present study is constrained by the recent 15 years of the dataset as available in the government BIPAD portal; therefore, future research should incorporate longer temporal coverage over multiple decades and employ robust statistical approaches to enhance the robustness, reliability, interpretability, and generalizability of the findings.

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Conflict of interest

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Author Contributions

Research concept, methodology, data analysis, manuscript writing, and finalization were done by the author.

Data availability

Data will be shared upon reasonable request.

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