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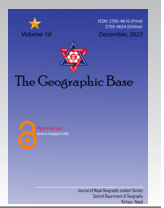

Earthquake Scenario in Sudur Pashchim and Karnali Provinces and its Socio-economic Impacts

Suresh Balayar* and Bishnu Prasad Pangali Sharma

Central Department of Geography, Tribhuvan University, Kirtipur, Kathmandu, Nepal

***Corresponding author:** sureshblyr599@gmail.com

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Abstract

Nepal is located in a seismically active region with a long history of devastating earthquakes. Likewise, several earthquake incidents have been recorded in the Western Nepal The study aims to illustrate the earthquake scenario and analyze the socio-economic impacts in the Sudur Pashchim and Karnali Provinces. A mixed-method research approach was used to meet the objectives of the study. Two hundred households were surveyed and field observations were accomplished for primary data in the most affected areas. Moreover, secondary data were collected from official reports, online portals, news articles, and literature reviews. ArcGIS 10.8.2, GPS, and Excel sheets were used to analyze the data. The study found that about 293 earthquakes incidents with 4 to 6.6 magnitudes hit the region from 1994-2023. Bajhang, Bajura, Humla, and Darchula districts experienced more strokes than others. However, Dadeldhura, Kanchanpur, Surkhet, Dolpa, Kailali, Salyan, and Baitadi districts experienced minimal strokes. The earthquakes affected 292 casualties, 332 injuries, and 3880 families. Besides, private houses were partially and fully damaged more

than government houses in the study area. Also, earthquakes impact socially and psychologically which could cause short or long-term trauma. During the disaster, Earthquake survivors need proper healthcare, shelter, food, clothes, security, and other basic needs. So, they hope with the government and other helping hands. Thus, stakeholders related to disasters, should have enough preparedness and organize awareness programs in the school to community level which can help to mitigate the problems after the disaster.

Introduction

Nepal is positioned in the highly seismically active Himalayan belt, bordered to the south, east, and west by India, and north by China. Nepal faces a high risk of seismic activity, with the potential for significant earthquakes measuring up to Mw 9.2 (Stevens & Avouac, 2016; Stevens & Maharjan, 2018). This hazard has resulted from the ongoing collision between the Indo-Australian and Eurasian plates over the past 50 million years. The collision process has led to the formation of Nepal and the entire Himalayan range. Southward to Northward thrusting of the Indo-Australian plate beneath the Eurasian plate has resulted in numerous earthquakes, making the region one of the most seismically hazardous areas on the planet (Hossain et al., 2015).

Geographically, Nepal can be divided into three ecological belts running east-west: the arid and cold Tibeto-marginal belt in the north, the mountainous region in the middle, and the flat and fertile lowland known as the Tarai along the border with India (Poudel & Silwal, 2020). The rivers flowing from the high Himalayan have a significant role in creating the geographical landforms of the country.

Nepal frequently experiences natural calamities. The country is still in its early geological stages and continues to develop. As a result, landslides and earthquakes occur frequently (Hossain et al., 2015). Additionally, due to its mountainous terrain and the annual monsoon season, Nepal faces flash floods, floods, and landslides triggered by earthquakes. The primary cause of the earthquakes in Nepal is the subduction of the Indian plate beneath the Eurasian plate (Khattrai 1987; Chaulagain et al., 2015). Throughout the history, Nepal has experienced significant destructive earthquakes in the years 1255, 1408, 1681, 1803, 1810, 1833, 1934, 1988, and 2015, leading to numerous casualties and causing extensive damage to structures (Chitrakar & Pandey, 1986; Bilham et al., 1995; Pandey et al., 1995; Chamlagain et al., 2009).

The study area's topography encompasses Tarai (plains), Hills, Middle Mountains, and High Mountains, boasting Churen Himal as its highest peak at 7,348 meters and lowest altitude of 109 meters in the Kailali district (Federation of Nepalese Chambers of Commerce & Industry,

Sudur Pashchim Province, 2024). While most villages are remote and inaccessible, all district headquarters are connected to the national road network. The region is susceptible to natural disasters like floods, landslides, and forest fires, with floods during the monsoon season affecting thousands of people in the Tarai annually, while landslides caused by heavy rains significantly damage the Hill and Mountain areas.

Methods and Materials

Study Area

The study area is situated in the western part of Nepal, specifically in Sudur Pashchim Province and Karnali Province (Figure 1). Sudur Pashchim Province is located at $28^0$42'12" N $80^0$34'01" E and Karnali Province is 29.27^0N 82.18^0E with an area of 19,999.28 km^2 and 27,984 km^2 respectively. There are nine districts in Sudur Pashchim Province: Kailali, Kanchanpur, Doti, Dadeldhura, Baitadi, Achham, Bajhang, Bajura, and Darchula. Whereas, Karnali Province has ten districts: Surkhet, Dailekh, Kalikot, Jumla, Mugu, Humla, Salyan, Jajarkot, Rukum West, and Dolpa.

According to CBS (2021), Karnali Province covers 19.01% and Sudur Paschim Province covers 13.28% of Nepal's total area. The total population in the study area is 28,636,245, with a population density of 60 in Karnali and 138 in Sudur Paschim. The sex ratio is 95.27 in Karnali and 89.51 in Sudur Paschim, while the literacy rate is 76% in both provinces. Approximately 83% of houses are built with brick and mud in Karnali, compared to 49% in Sudur Paschim. In terms of occupation, 74% of people are involved in agriculture, forest, and fish farming in Karnali, while 70% are involved in Sudur Paschim.

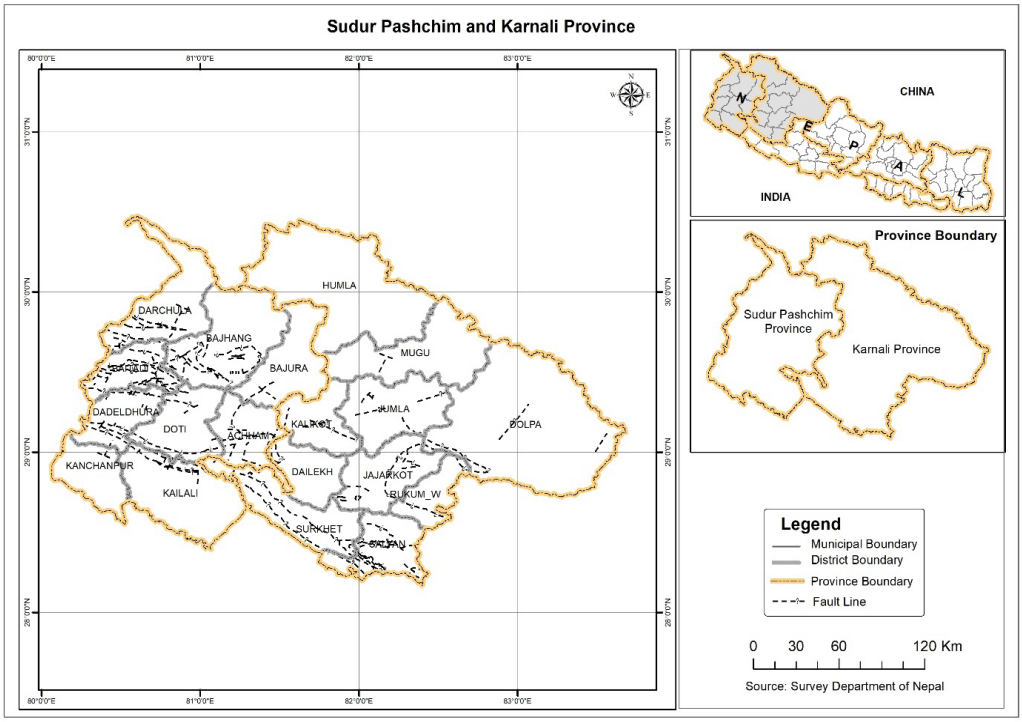

Figure 1: Location Map of the Study Area

To achieve the goal of the study in a standardized and replicable framework, ArcGIS 10.8.2 and Microsoft Excel software were used for mapping, data analysis, and some statistical calculations. All the methods used by the researcher to study the research problem are termed research methods (Kothari, 2004). Thus, the study contains both quantitative and qualitative methods. In quantitative data, the research includes the frequency of earthquakes, human loss, and property loss. Whereas, qualitative data contains the impact of earthquakes on human psychology and society.

It has used both primary and secondary data. Secondary data were collected from the literature review, reports, books, government websites, social media, and news articles. The total frequency, date of incidents and size of earthquakes, their locations, estimated losses, and social impacts were analyzed from the different sources of secondary data.

In primary data, field observation and household surveys were conducted. A purposive sampling method was used, and the most affected areas from earthquakes were selected for primary data collection. Before the field research, a checklist containing general information about the

respondents, earthquakes, and the location was prepared. Moreover, it consisted of questions about the loss of human lives and other assets; past and present (before and after the earthquake) types of houses, and income sources. Furthermore, it was asked about the economic and health conditions with social, and psychological effects of the earthquake.

Two hundred households (HH) were purposively selected from the highly affected areas of the study area for the household survey. Most of the surveys were conducted with the HH head. A checklist was developed before the surveys which contained 30 close and open-ended questions. Respondent profile, year of the earthquake, loss of human life, and property, its impact on society and psychology, policy for infrastructures developed before and after the shocks, and other related questions were organized to meet the objectives of the study. In addition, field observation was done to know the ground reality for disaster-related research. Field visit locations were previously selected with the help of secondary data. The researcher visited most of the earthquake-affected locations with the Global Positioning System (GPS) to know the field reality and analyze the social and economic impacts on the local level.

Results and Discussion

Earthquake Frequencies in Sudur Paschim and Karnali Province

An earthquake in Nepal occurred on June 7th, 1255 AD, resulting in a 7.7 magnitude on the Richter scale and causing the death of one-third of the population in the Kathmandu Valley (Hossain et al., 2015). Historically, Nepal has experienced several strong earthquakes, (i.e., 1934 Bihar-Nepal earthquake (8.0 Mw), 1966 Doti earthquake (6.3 Ms), 1980 Pithoragarh earthquake (6.5 Ms), 1988 Kathmandu earthquake (6.9 Mw), 2011 Sikkim earthquake (6.9 Mw), 2015 Gorkha Earthquake (7.8 Mw), and 2023 Jajarkot Earthquake (5.7 Mw) in the last century (Chaulagain et al., 2017; Chen & Zhang, 2021). The data shows that greater earthquakes caused a huge number of life and property loss.

The people of Nepal are at risk of earthquakes, landslides, and floods altogether. It is a harsh reality that a large number of people in growing urban areas reside near active fault lines, like those found near the Himalayan foothills and the nearby Indo-Gangetic Plains (Bilham, 1995, 2004, 2019; Bilham et al., 2001; Pasari et al., 2021). Such settlements promptly boost disasters that cause human, livestock, and property loss.

National Earthquake Monitoring and Research Center, Department of Mines and Geology (NEMRC/DMG, 2024), recorded two hundred and ninety-three earthquakes from 1994 to 2023 in the

different parts of Sudur Pashchim and Karnali Provinces. The earthquakes have affected people economically, socially, and psychologically in every incident. The frequency of earthquakes according to magnitude is summarized in Table 1, Figure 2. Greater than 4 magnitude earthquake frequencies were recorded. Among them, 6.6 magnitude was the greatest stroke in the study area. The highest number of strokes ranges from 4 to 4.9 magnitude which were 244 in total. After that, 45 frequencies were about 5 to 5.9 magnitude and 4 were above 6 magnitudes.

Table 1: Earthquake Frequencies According to Magnitudes

Magnitude	**Frequency of earthquake**
4-4.9	244
5-5.9	45
6-6.6	4
Total	**293**

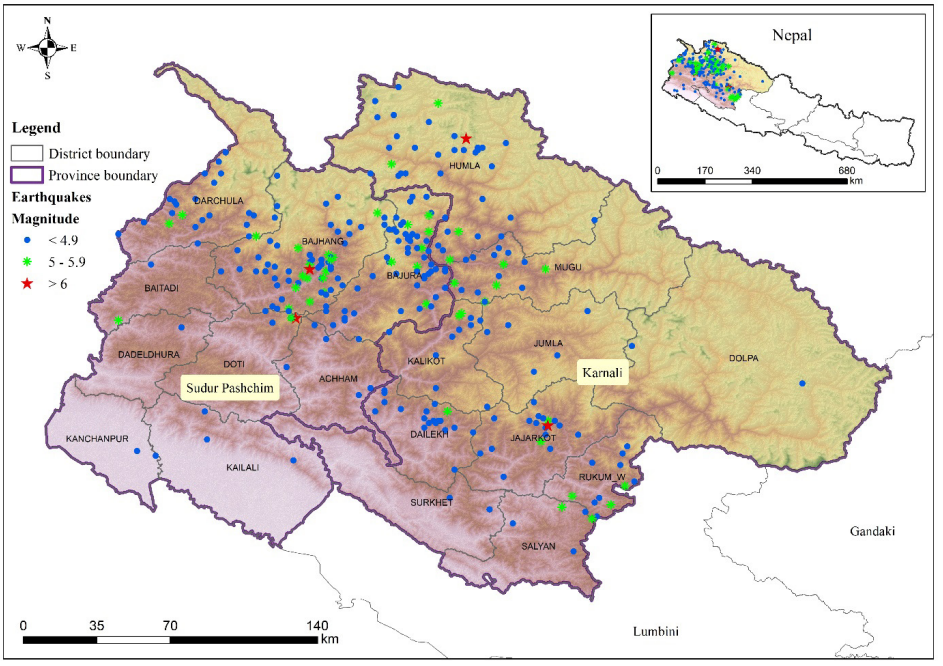

Figure 2: Map of Earthquake Frequencies According to Magnitudes

Source: NEMRC/DMG, 2024 and Survey Department of Nepal, 2022

Year-wise Earthquake Scenario

The highest number of earthquake shocks (52) hit the study area in 2023. It was a disastrous year for the people. On November 3, 2023, a 5.6 magnitude earthquake, according to the United States Geological Survey (USGS), struck about 42 kilometers from Jajarkot, Nepal, in Karnali province. One hundred and fifty-seven people died and more than 170 were injured by the stroke (CNN, 2023). Similarly, the quake hit the study area in 1996 with 22 strokes, 18 strokes in 2012, and 15 in 1995. The data shows that earthquakes strike every year in the study area but the number of strokes fluctuated (Table 2, Figure 3).

Table 2: Year-wise Earthquake Scenario

Year	Earthquake frequency	Year	Earthquake frequency
1994	7	2009	6
1995	15	2010	7
1996	22	2011	10
1997	9	2012	18
1998	3	2013	15
1999	3	2014	3
2000	2	2015	13
2001	9	2016	9
2002	5	2017	11
2003	3	2018	7
2004	4	2019	12
2005	6	2020	8
2006	3	2021	5
2007	4	2022	15
2008	7	2023	52
Total			**293**

Source: NEMRC/DMG, 2024

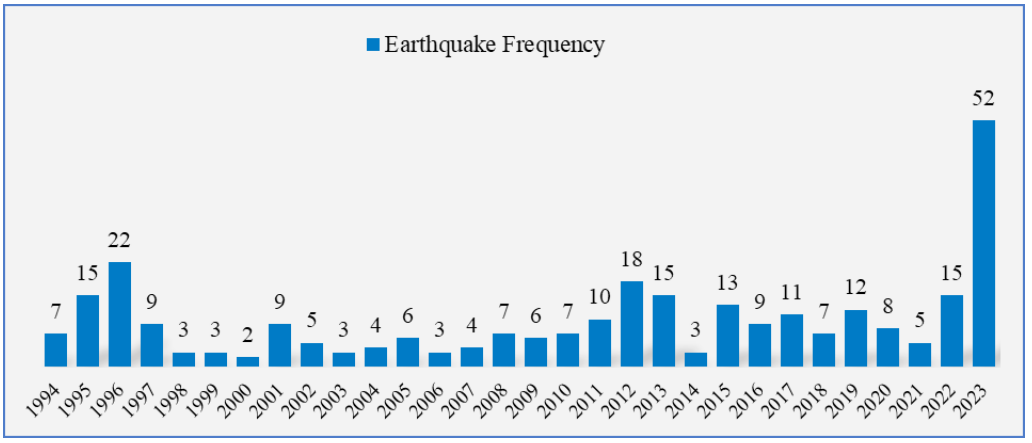

Figure 3: Year-wise Earthquake Scenario
Source: NEMRC/DMG, 2024

Earthquake Scenario According to Year Range

The earthquake scenario according to the year range is illustrated in Table 3. If we look at the history of earthquakes in Sudur Pashchim and Karnali province 2018-2023 was the most disastrous period. In these five years, 99 strokes hit the study area. Then, from 2012-2017 about 69 strokes were released. Similarly, the era of 1994-1999, 2000-2005, and 2006-2011 has 59, 29, and 37 strokes individually.

Table 3: Earthquake Scenario According to Year Range

Year Range	Total earthquake
1994-1999	59
2000-2005	29
2006-2011	37
2012-2017	69
2018-2023	99
Total	**293**

Source: NEMRC/DMG, 2024

District-wise earthquake frequencies

District-wise earthquake frequencies are presented in Table 4. There are nine districts in Sudur Pashchim and ten districts in Karnali province. Among them, Bajhang is the most, and Dadeldhura is rarely affected district by the earthquake. The data shows that Bajhang, Bajura, Humla, Darchula, Jajarkot, and Mugu were the highest-hit districts by earthquakes which were 74, 51, 34, 22, 20, and 20 respectively. However, the lowest affected districts are Dadeldhura (1), Kanchanpur (2), Dolpa (2), and Surkhet (2) times whereas Baitadi, Kailali, and Salyan has 3 times hit by the stroke. All the districts have been affected by stroke since 1994 but North-Western districts were more affected by the earthquake disaster (Figure 4).

Table 4: District-wise Earthquake Frequencies

District	Earthquake frequency	District	Earthquake frequency
Achham	6	Dolpa	2
Baitadi	3	Humla	34
Bajhang	74	Jajarkot	20
Bajura	51	Jumla	5
Dadeldhura	1	Kalikot	9
Darchula	22	Mugu	20
Doti	4	Rukum West	13
Kailali	3	Salyan	3
Kanchanpur	2	Surkhet	2
Dailekh	19		

Source: NEMRC/DMG, 2024

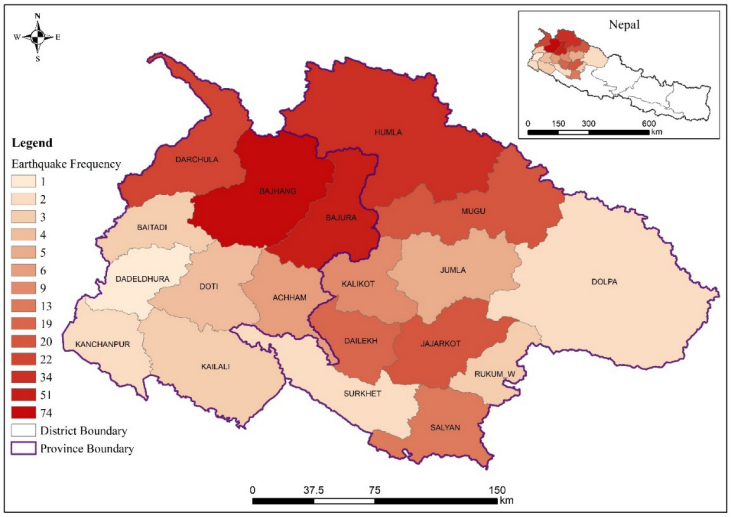

Figure 4: District-wise earthquake frequencies.

Source: NEMRC/DMG, 2024

Earthquake Density

Figure 5 presents earthquake density. According to the figure, Bajhang and Bajura of Sudur Pashchim province have high earthquake density out of nine districts. In Karnali Province, Jajarkot and Dailekh districts have a higher frequency of earthquakes. Other districts have low earthquake densities in both provinces.

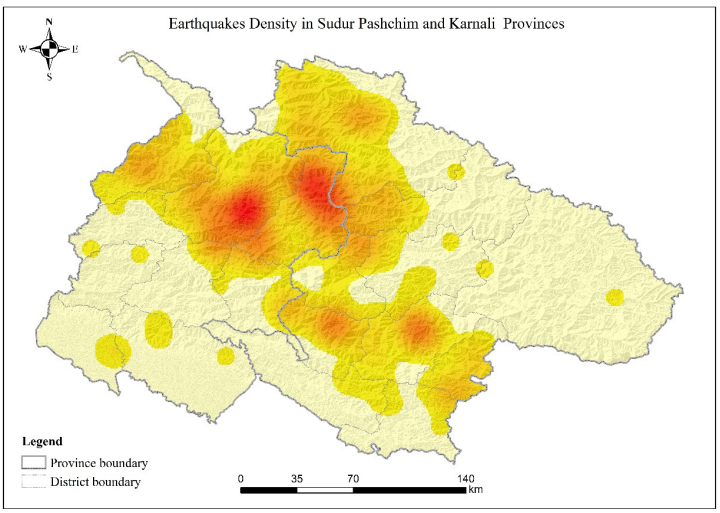

Figure 5: Earthquake density map

Source: NEMRC/DMG, 2024

Socio-economic Impacts of Earthquake

The socio-economic impacts of earthquakes in the Sudur Pashchim and Karnali provinces of Nepal are profound and multifaceted. Socially, earthquakes in the study area have devastating effects on communities and individuals. The research found that the immediate aftermath often results in loss of lives and injuries, leading to widespread grief and psychological trauma. About 135 casualties in Sudur Pashchim and 157 in Karnali province where 286 and 46 were injured respectively (MoHA). Moreover, 3880 families were affected in the study area. The study found that displacement from damaged or destroyed homes forces families into temporary shelters or relocation, disrupting social networks and community cohesion in the study area. The breakdown of social services and infrastructure compounds these issues, making access to healthcare, education, and social support challenging. Also, long-term social impacts include the potential for increased poverty and inequality, as marginalized groups face greater difficulties in accessing aid and recovery resources. Additionally, the loss of cultural heritage sites and historical landmarks can undermine community identity and cultural continuity, further affecting the social fabric of the region.

Economically, these seismic events often lead to substantial destruction of infrastructure, including homes, schools, roads, bridges, and cultural heritages. According to respondents, the disruption of critical facilities impairs daily economic activities and leads to significant financial losses for the people. Whereas, five government houses were fully damaged and 93 were partially damaged in the study area. Similarly, 11,918 private houses were completely damaged and 16,919 houses were partially damaged (MoHA). Also, the damage to agricultural land, roads, bridges, and electrical lines was a huge economic loss for the study area. The cost of rebuilding and recovery places a heavy burden on local governments and international aid organizations, straining limited resources and potentially diverting funds from other development projects. Additionally, the collapse of essential services such as healthcare and education systems impede long-term economic growth and development, leaving communities vulnerable to prolonged economic hardship.

Impact of Earthquakes in Sudur Pashchim Province

The impact of earthquakes in Sudur Pashchim Province is presented in Table 5. Incident frequency, casualties, affected families, injuries, and damage to government, and private houses are exposed in the table. Ministry of Home Affairs (MoHA, 2024) recorded 124 quake shocks in Sudur Pashchim from 1980 to 2023. Whereas 135 people died, more than 286 were injured, and 724 families were affected. Further, one government house was fully damaged, and fifteen were partially damaged.

Besides, 11712 private houses were fully damaged, and 13722 were partially damaged. About 124 lives were lost on July 29, 1980, in Bajhang, Darchula, and Baitadi which was 6.5 magnitude (Singh, 1985). In totality, Bajhang district experienced the highest number of life loss, injuries, family affected, and full and partial damage to private houses. Besides, Kailali and Kanchanpur had the minimal impacts of the earthquake.

Table 5: Impact of Earthquakes in Sudur Pashchim Province

District	Incident frequency	Total Death	Affected Family	Injured	Govt. Houses Fully Damaged	Govt. Houses Partially Damaged	Private House Fully Damaged	Private House Partially Damaged
Achham	13	0	43	5	0	1	0	93
Baitadi	9	22	171	239	0	0	1269	1968
Bajhang	51	78	301	18	1	6	6219	8753
Bajura	20	3	25	11	0	1	9	14
Dadeldhura	4	0	4	0	0	0	2	123
Darchula	16	26	168	0	0	0	4169	2763
Doti	8	6	11	11	0	1	44	3
Kailali	1	0	0	1	0	5	0	4
Kanchanpur	2	0	1	1	0	1	0	1
Total	**124**	**135**	**724**	**286**	**1**	**15**	**11712**	**13722**

Source: MoHA, 2024

Impact of Earthquakes in Karnali Province

The impact of earthquakes across various districts in the Karnali Province is summarized in Table 6. Also, the data reflects the incident frequency, human life loss, injuries, and the number of families affected by the quake. It also exhibits the record of full and partially damaged government and private houses.

Overall, the Karnali Province experienced 42 earthquakes. The total impact included 157 deaths (on Sept. 03, 2023), 3,156 affected families, and 46 injuries. Government buildings suffered limited damage, with 4 fully and 78 partially damaged. Private properties faced significant damage: 206 were fully damaged and 3,197 were partially damaged houses. Jajarkot and Rukum East were the most severely affected in terms of both casualties and property damage. In comparison, Humla, Dolpa, and Jumla experienced minimum impacts of the earthquake.

Table 6: Impact of Earthquakes in Karnali Province

District	Incident frequency	Total Death	Affected Family	Injured	Govt. Houses Fully Damaged	Govt. Houses Partially Damaged	Private House Fully Damaged	Private House Partially Damaged
Dailekh	4	0	25	1	0	25	5	222
Dolpa	1	0	0	0	0	0	1	5
Humla	5	0	0	0	0	0	4	0
Jajarkot	11	157	623	15	0	8	138	2166
Jumla	2	0	1	2	0	0	2	3
Kalikot	4	0	0	3	3	17	10	21
Mugu	6	0	12	0	0	0	4	14
Rukum West	6	0	2495	20	0		17	445
Salyan	1	0	0	2	1	17	24	282
Surkhet	2	0	0	3	0	11	1	39
Total	**42**	**157**	**3156**	**46**	**4**	**78**	**206**	**3197**

Source: MoHA, 2024

Comparatively, Sudur Pashchim Province experienced more incidents and a total number of fully or partially damaged houses but Karnali Province lost more human lives and got injuries. Also, a higher number of families were affected in the Karnali. In total, 166 incidents were filed by the MoHA, which caused 292 casualties and 332 injuries. Likewise, 3,880 families were affected where 16,919 private houses were partially and 11,918 were fully damaged.

Impact of Major Earthquakes in Nepal

Nepal experiences frequent and powerful earthquakes due to its location in a highly seismically active region (Chaulagain et al., 2015; Bhochhibhoya & Maharjan, 2022). On August 26, 1833, a powerful earthquake hit Nepal and the northern part of India with a magnitude estimated between 7.5 to 7.9 MW (Bilham, 1995). The Building Code Development Project (1994), reported 414 casualties, and almost 18,000 buildings and heritage sites were damaged.

Similarly, on January 15, 1934, the most powerful earthquake (8.4 MW) of modern times struck the eastern mountains of Nepal. Nepal reported 8,519 fatalities, while the Indian side recorded 7,188 fatalities (Rana, 1935). Altogether, 207,248 cases of infra-structural damage were reported throughout Nepal, with 134,932 occurring in the eastern mountains alone.

Likewise, the Udayapur earthquake, with a magnitude of 6.8, struck the eastern and central parts of Nepal, including the Kathmandu Valley, on August 21, 1988. It resulted in 721 fatalities and 12,244 injuries, and caused damage to nearly 66,000 buildings, primarily in the eastern

plains, mountains, and central mountains of Nepal (BCDP, 1994). Gupta (1988), said that it also damaged 1202 school buildings, 1159 public buildings, and hundreds of kilometers of road, irrigation canals, and highway bridges.

Additionally, on September 18, 2011, a strong earthquake with a magnitude of 6.9 hit eastern Nepal at 6:25 pm local time near the Sikkim-Nepal Border. The epicenter was on the border side of both countries which caused six casualties and 30 injuries in Nepal (MoHA, 2011).

Further, The Gorkha Earthquake took place on April 25, 2015, about 80 km N-NE of Kathmandu. The epicenter was in the Barpak village of Gorkha district, and the damage was mainly concentrated to the east of the epicenter. It resulted in 8,790 casualties, and 22,300 injuries, and affected 8 million people from 31 out of 75 districts in the country (NPC, 2015). The Gorkha earthquake caused damage to buildings and infrastructure such as road networks, hydropower projects, and water supply systems, amounting to approximately $7 billion (USD; NPC, 2015; Chaulagain et. al., 2017).

Therefore, Nepal should be well prepared for disasters like earthquakes. To mitigate the risk of earthquakes, enhancing building infrastructure is crucial, ensuring all constructions follow seismic-resistant designs and building codes. Public awareness programs should be conducted at schools and community levels. Establishing early warning systems can help to provide crucial seconds or minutes to take protective actions. Strengthening disaster response teams with proper training and equipment will ensure efficient rescue operations post-earthquake. Schools, hospitals, and other critical facilities should be prioritized for retrofitting and structural upgrades. Community-based disaster risk reduction initiatives can foster local participation and resilience. Also, collaboration with international organizations can bring technical expertise and financial support for long-term risk reduction efforts.

Conclusion

The study examined the scenario of the earthquake and its socio-economic impacts in Sudur Pashchim and Karnali Provinces in particular, and the socio-economic impacts of the earthquake in Nepal in general. Using a mixed-method research design, the study concludes that the earthquake is the most disastrous incident in the study area. It hits every year and people have been experiencing huge losses. Bajhang, Bajura, Darchula, Baitadi, and Achham are the most affected districts in Sudur Pashchim, and Jajarkot, Rukum West, and Dailekh are the most in Karnali Province. Regardless, people experienced many casualties, livestock, and property loss in Jajarkot, Bajhang, Darchula, and Baitadi are very remarkable.

Earthquakes cause not only economic loss but also great psychological, and social disturbance. During strokes,

people were terrified and lost. They faced challenges for food, shelter, medicines, and education for their children. Thus, stakeholders who have been working for disaster risk reduction programs should be well prepared for disasters. People need awareness programs and skill-based training at school and community levels.

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