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Geospatial distribution of landslides in the Lumbini province

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ABSTRACT

Lumbini Province, located in western Nepal, is known for its diverse geography, ranging from the low land Tera to the rugged hills of the Chure and Mahabharat ranges. The Main Boundary Thrust passes through the region, which makes the geology more complicated due to tectonic movements. This study aims to analyze the geospatial distribution of Landslides in Lumbini province as well as the causes and triggering factors in different areas in the province. First, a preliminary literature review is done on Landslides and its possible triggering factors. The data for this project are retrieved from the Bipad Portal (2012-2024), rainfall records from DHM, seismic and geological maps from the Department of Mines and Geology, and road infrastructure details from the Department of Roads. The data is analyzed by statistical methods to understand the triggering factors (rainfall, tectonic activity, toe-cutting, and road construction) and how these factors influence landslides over the years from 2012-2024. The study shows that the area most affected by landslides are Rolpa and Eastern Bulum, which are located in the region influenced by the tectonic activity along the MBT. The meteorological station in Baldyanggadi, Palpa, also showed a significant increase in rainfall from 90.4mm to 252.0mm on September 28, 2024, which resulted in several landslides. The weak Geology of Chure helps in triggering Landslides as major cities are located in and around Chure in this province with a larger population density, rather a small size of the landslide could be huge in terms of inventory value. Important infrastructures and historical and ecological complex ecosystems in this region can be harmed by landslides in the future. Therefore, the findings suggest that small technical and financial steps in the field can reduce the risk of Landslides in the Lumbini province by a high percentage.

Keywords: Landslide; Distribution; Bipad portal; Lumbini province

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INTRODUCTION

Lumbini Province, located in western Nepal, is known for its diverse geography, ranging from the lowland Terai to the rugged hills of the Chure and Mahabharat ranges. Lumbini province has twelve districts: Arghakhanchi, Banke, Bardiya, Dang, Eastern Rukum, Gulmi, Kapilvastu, Parasi, Palpa, Pyuthan, Rolpa, and Rupandehi. (Resource Mapping and Growth Diagnostic Study in Lumbini Province, July, 2024). The Nepal Himalaya has eight well-defined regional geomorphologic zones in a north-south direction: 1) Terai (the northern edge of the Indo-Gangetic plain), 2) Siwalik (Churia) Range, 3) Dun Valleys, 4) Mahabharat Range, 5) Midlands, 6) Fore Himalaya, 7) Higher Himalaya, and 8) Inner and Trans Himalayan Valleys. (Hagen, T. , 1969). Among these twelve districts, Banke, Bardiya, Dang, Kapilvastu, Rupandehi, and Nawalparasi border India while Palpa, Arghakhanchi, Gulmi, Pyuthan, and Rolpa's most portion lies in the Chure Region.

The Main Boundary Thrust passes through the region, which makes the geology more complicated due to tectonic movements. Processes and causes that contribute to landslides in Nepal can be put in four categories: (i) geological causes (weak, weathered, sheared materials, and contrast in permeability of materials); (ii) morphological causes (fluvial, erosion of slope toe, tectonic uplift, erosion of marginal sides; (iii) physical causes (intense rainfall, prolonged or exceptional precipitation, earthquake, ad snowmelt); and (iv) human causes (deforestation, irrigation, mining, road construction, water leakage, land use changes) (Dahal, 2012).

On analyzing the data of Landslides that occurred in the Lumbini province from the *Bipad Portal,* it can be observed that Rolpa and Palpa record the highest number of Landslides, followed by Gulmi and Pyuthan. Arghakhanchi and East Rukum reported moderate cases as shown in Table 1 (Bipad Portal, 2025). The districts in the Terai, on flatlands, are found to have minimal landslides while the hilly districts such as Arghakhanchi, Eastern Rukum, Gulmi, Palpa, Pyuthan, and Rolpa had more landslides.

From the data on Landslides in 2012-2022 from the *Bipad Portal,* a high number of landslides are seen to occur in the Lumbini province (Bipad Portal, 2025). An infamous one is the Landslide in Shree Siddhababa Dham, Butwal along the Jaya Prithvi Highway (Republica, 2023). The Tamghas-Ridi, Ridi-Rudrabeni-Wamitaksar, and Palpa-Butwal road sections also face landslides very often (Ratopati, 2024). A large number of human settlements in the Himalayas are situated either on old landslide masses or in landslide-prone areas. So, a great number of people are affected by large- and small-scale landslides all over the Himalayas, especially during monsoon periods. For example, only in the half monsoon period of 2009 (June 10 to August 15), 50 people were killed by landslides in Nepal (Dahal, 2012). Over the past years, efforts have been taken to study the distribution and causes of landslides in some major sections such as Siddhababa and Tamghas-Ridi but the risk of landslides in this province is higher than these landslides. Thus, there is a dire need to research the distribution and causes of Landslides in this region, the findings of which could be used for a wide range of projects such as road design, river training works, slope protection, Hydropower, and many other civil engineering works. This project aims to fill this research gap by pointing out not only the geospatial distribution of Landslides but also the causes and triggering factors in different parts of the province and suggesting measures to reduce the vulnerability.

After the 2015 Gorkha Earthquake, Marc (2019) Suggested that rainfall-induced landslide rates in three selected catchments covering 7% of the total affected area were ~3–6 times higher for the 2015 monsoon when compared to pre-earthquake levels. The 2008 Wenchuan earthquake (Mw 7.9) triggered nearly 200,000 coseismic landslides over an area of 110,000 km^2, out of which more than 800 dammed rivers, posing severe threats to downstream settlements. (Liu et al. 2022). These landslides resulted in almost one-third of the total fatalities and economic losses during the event. (Liu et al. 2020). As there is seismically Active Main Boundary Thrust (MBT) with fault lines accompanied by movement of the plates at 15±2mm/yr in Western Nepal (Mugnier J. L., 2004)., small to medium-sized earthquakes frequently occur in Western Nepal. Slope angle, aspect, distance from thrust, from epicenter, are the governing factors for co-seismic landslides. (Zou, 2022). These earthquakes play an important role in triggering landslides.

Landslides are usually initiated only after a few days of the first monsoon rainfall and the role of antecedent rainfall for landslides in Nepal is bona fide (Dahal, 2012). According to (Meteorological Forecasting Division, 2024), Lumbini province was the only province to have all twelve districts in the danger zone. The meteorological stations in Sandhikharka (Arghakhanchi) and Baldyanggadi (Palpa) were among the stations that broke their past rainfall record as of 28 September 2024 (8:45 am), with the rainfall increasing drastically from 90.4mm to 252.0mm in Baldyanggadi (Table 1) (Situational Report on Extreme Precipitation and Flooding Event of 27-29 September 2024, 2024).

Another major cause of landslides is toe-cutting. When the toe part of a slope is cut for any reason, it weakens the hill slopes, especially in the dip-slope type. This shifts the failure surface downward and outward and reduces the Factor of Safety of the slope. The weak slope is vulnerable and there is a high probability of failure when triggered by a minute reason too. (Chakraborty and Dey, 2019). According to Stark et al. (2005), an excavation done for widening the major east-west state highway triggered a landslide near San Francisco, California as it exposed the cut slope and unloaded the toe of the slope. Toe cutting does not happen only by excavation, it also has natural causes like river currents (Chakraborty and Dey, 2019). When the water level rises or river courses change causing meandering of channels, a portion of the toe of the river bank slope is cut (Gao, 2024). Toe cut by the river is a critical yet very underrated factor leading to Landslides. Hydraulic conditions, such as channel slope, water level, flow velocity, and soil properties affect the fluvial erosion of the bank toe and the change in bank geometry by controlling the boundary shear stress (Pizzuto, 1989; Partheniades, 1965; Chen, 2017). This increases the pore pressure of the soil at the bottom of the slope and this increases the c-phi value of soil. This weak soil at the bottom makes the slope more vulnerable to failure.

Indian plate subducting over Eurasian plate forming the rise of the formation creating Great Himalayas. Not only Great Himalayas are bored rather the sequence of formation known as depozones is born stretching parallel to plate boundaries. Here subducting rate being higher than the converging rate the compressional type of geological basin is formed. The rather dynamic nature of the plate causes an average of 17 mm/yr subduction causing high storage of strain energy causing frequent earthquakes (as an energy release mechanism). Indian plate having Flexural rigidity extends the basin longer in width up to 400 Km towards the south up to the Indo-Gangetic plane.

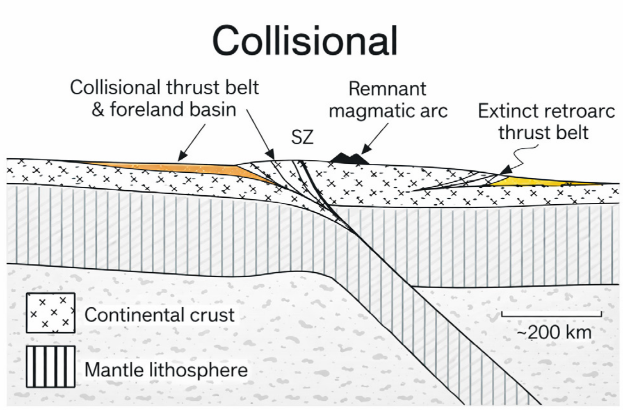

Fig. 1: Tectonic collision (DeCelles, 2011).

METHODOLOGY

The project begins by identifying the landslide risk in Lumbini Province through preliminary data analysis and problem framing, followed by a comprehensive literature review on landslide triggers and regional geology. Multi-source data such as landslide incidents from the Bipad Portal (2012-2024), rainfall records from DHM, seismic and geological maps from the Department of Mines and Geology, and road infrastructure details from the Department of Roads and DOLIDAR are systematically collected and integrated. Spatial analysis using GIS tools correlates landslide distribution with triggering factors (rainfall, tectonic activity, toe-cutting, and road construction), while statistical methods quantify relationships between variables like monsoon variability and landslide frequency. Findings are mapped to highlight high-risk zones, and HYRCAN slope stability modeling assesses anthropogenic impacts. The study concludes with evidence-based recommendations for landslide mitigation, infrastructure planning, and policy interventions in Lumbini's geospatial and socio-economic context.

To complement the geospatial and statistical analysis, a Digital Elevation Model (DEM) of Lumbini Province was processed in QGIS to derive topographic parameters critical for landslide susceptibility. Slope angle, elevation, and aspect maps were generated to assess terrain characteristics. Slope was classified into six categories (e.g., 5-15°, 15-25°), elevation into five tiers (e.g., <1,375 m for Terai, 1,375-2,730 m for mid-hills), and aspect into directional sectors (e.g., North, South, Southeast). These parameters were analyzed to identify correlations between terrain features and landslide distribution in Lumbini Province.

CAUSES AND GEOSPATIAL DISTRIBUTION OF LANDSLIDES

Earthquake induced landslides

From the (Bipad Portal, 2025), it can be observed that the maximum number of Landslides occurred in Rolpa (125) and East Rukum (44). In Rolpa, about half of the landslides (55) occurred after 2023, 31 in 2023, and 22 in 2024. Similarly, in East Rukum, 16 landslides occurred in 2023. Landslides in these two districts are mostly found to occur around the Thrust (MBT) and Fault lines, which can thus be attributed to tectonic movements along the MBT and the faults perpendicular to it (Fig. 3) (DMG, 2020; Bipad Portal, 2025).

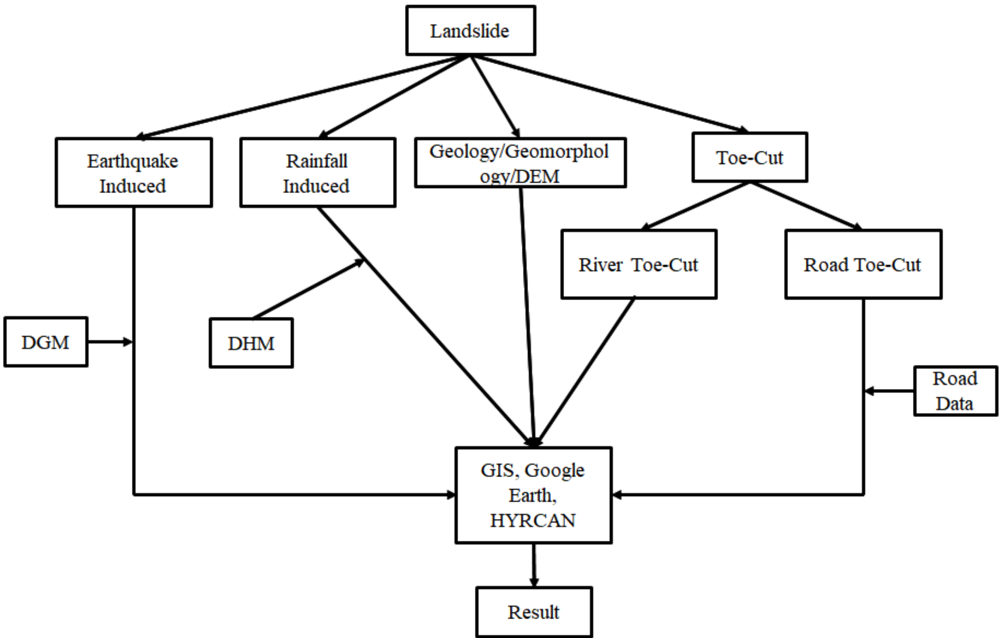

Fig. 2: Adopted methodology for the research.

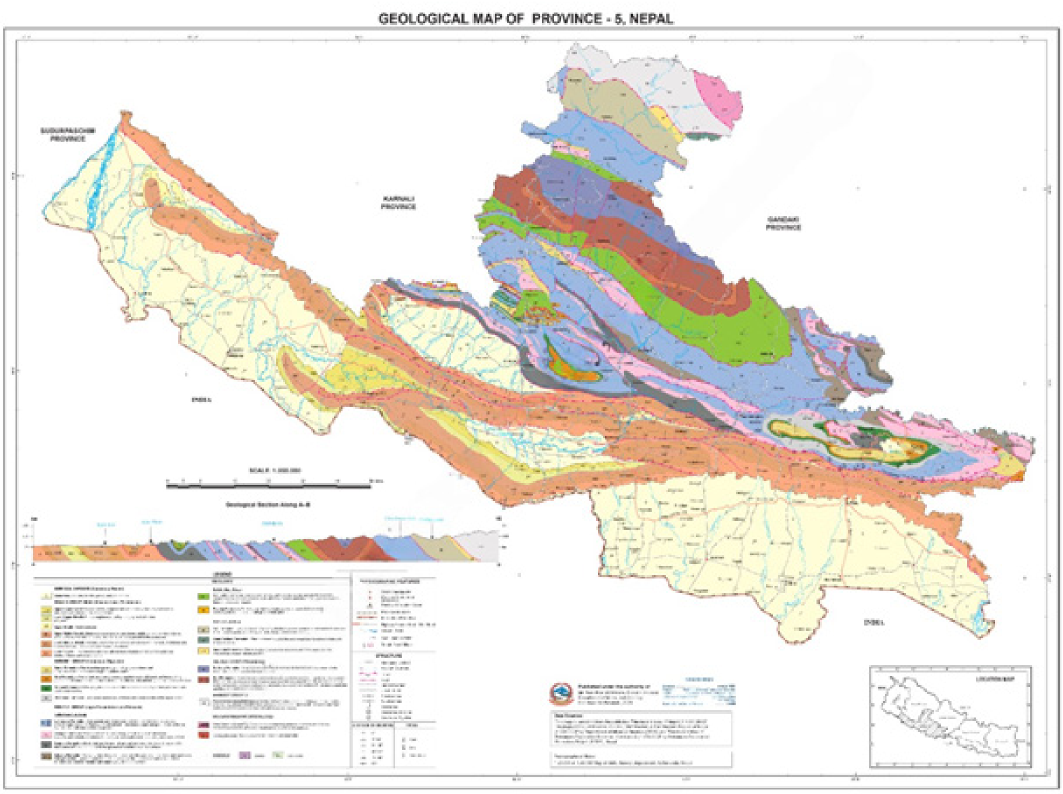

Fig. 3: Geological map of Province-5, Nepal [Source: (DMG, 2020)].

It was found that many earthquakes of small magnitude have occurred in the years 2022 and 2023. Landslides occurred in July, which means that these might be the secondary disasters after the earthquakes suggesting that rainfall was the triggering factor for the landslides on the slopes which were already vulnerable due to earthquakes. Furthermore, according to Subedi, et al., 2024, there is a huge seismic gap for a major earthquake in Western Nepal, which makes it more vulnerable to coseismic landslides.

Rainfall induced landslides

After Rolpa, Palpa is the district with the most number of Landslides (2012-2024) and the number of Landslides is 31 in 2020, 17 in 2021, 5 in 2022, 24 in 2023, and 15 in 2024, with most of the incidents occurring in July-September. [Source: (Bipad Portal, 2025)]. The large number of Landslides in 2020 is because the highest (159.9%) percentage of monthly normal precipitation was recorded at Tansen, Palpa in July 2023 (Preliminary Precipitation and Temperature Summary, July, 2023, 2023). Therefore, Landslides in Palpa can be attributed to rainfall. In Palpa, 80% of the total rainfall occurs from June to September (Dahal, 2012). South-facing slope in Palpa is also the supporting factor for increasing the vulnerability of slopes.

One of the reasons for high rate of landslides may be antecedent rainfall in this case. Antecedent rainfall is rainfall that precedes a few days or weeks before a Landslides event. From the rainfall data obtained from the DHM, it is clear that rainfall in Palpa fluctuated a lot. After rainfall, the pore water pressure of weak and loose soil increases, and later, it reduces in the upper surface and creates suction pressure. When rainfall occurs, the pore water pressure increases in this soil, which reduces the suction pressure. This increase in pore water pressure leads to the sliding of land mass. And to the fluctuating rainfall data in Palpa, Antecedent rainfall can be considered as the triggering factor. For rainfall analysis, we considered two meteorological stations situated in the Lumbini province. For this, we first retrieved the rainfall data of different stations in Palpa between 2014 and 2022 from the Department of Hydrology and Meteorology (DHM), Nepal, and took an average of the rainfall of the selected stations for each year. It was observed that the average rainfall data of Baldyanggadi was close to that of the average precipitation, except for the year 2019 (Fig. 5). So, Baldyanggadi station was selected for rainfall analysis. The second meteorological station chosen was from Ridi Bazar, for verification. Plotting monthly rainfall from 2012-2024 for each station shows that most rainfall occurs between June to September (Fig. 6a and b). Another point evident from the graphs is the increasing amount of rainfall over the years.

When the number of landslides and precipitation over the years recorded in Baldanggadi, Palpa is plotted, it can be observed that the number of landslides increased according to the yearly precipitation. This can be seen clearly in Fig. 7a. For further clarification, the landslides that occurred in 2020 are plotted with the rainfall in Ridi Bazar, which also showed a similar trend (Fig. 7b). The skewed rainfall in September is the unusual one that occurred on September 25-28, 2024, all over Nepal. A meticulous analysis of the data for 2024 shows that almost 90% of rainfall occurred in June and July. Fifteen landslides occurred in Palpa between June- September 2024 out of which, 10 incidents happened in July only. Thus, it is proved that landslides in Lumbini province are mainly influenced by rainfall.

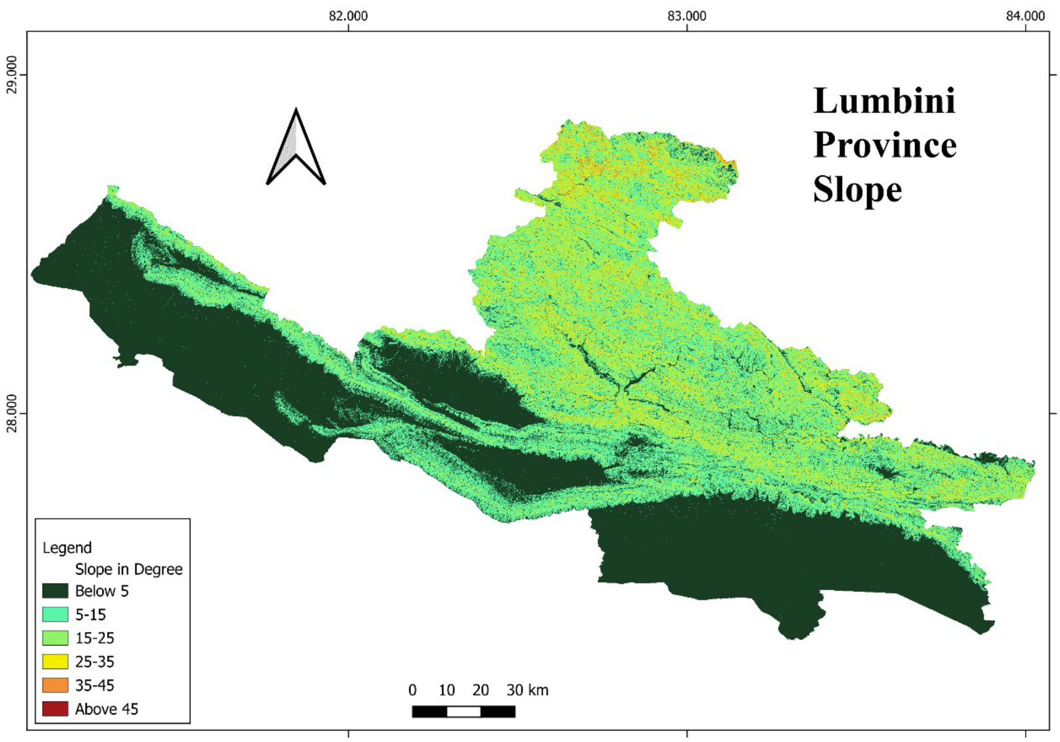

Fig. 4: Slope map of Lumbini Province- (Moderate slopes (15–25°) dominate landslide-prone districts like Rolpa and Palpa, while steeper slopes (>35°) cluster near tectonic zones (MBT) and river valleys, aligning with earthquake-triggered instability.)

Station	District	Elevation (m)	2014	2015	2016	2017	2018	2019	2020	2021	2022
Tansen	Palpa	1185	1431.2	1105.9	1580.9	1683.2	1363.1	1047.9	2265.5	2750.2	1980
Gandakot	Palpa	519	1777.5	1144.2	1605.7	1845.9	1696.8	NA	2366.9	3206	2252.2
Jalpa	Palpa	1512	1846.3	1477.1	1791.6	2105.5	1615.3	1758.4	3075.8	3307.5	2062.8
Archale	Palpa	1005	1511.7	1483.7	1923.4	1810.5	2490.4	1226.5	1869.3	4389.2	2743.5
Hattilung	Palpa	1127	N/A	2058.1	3315.8	2176.9	2644.5	1021.3	3642.7	4323.8	1917.8
Baldyanggadi	Palpa	1640	1309.2	1309.2	2071.9	1819	2041.1	1629	2308.9	1347.4	2043.4
	Average Rainfall		1575.18	1429.7	2048.217	1906.833	1975.2	1336.62	2588.183	3220.688	2166.617
	Landslide		5	0	2	4	7	4	10	31	17

Fig. 5: Rainfall in Palpa (DHM)

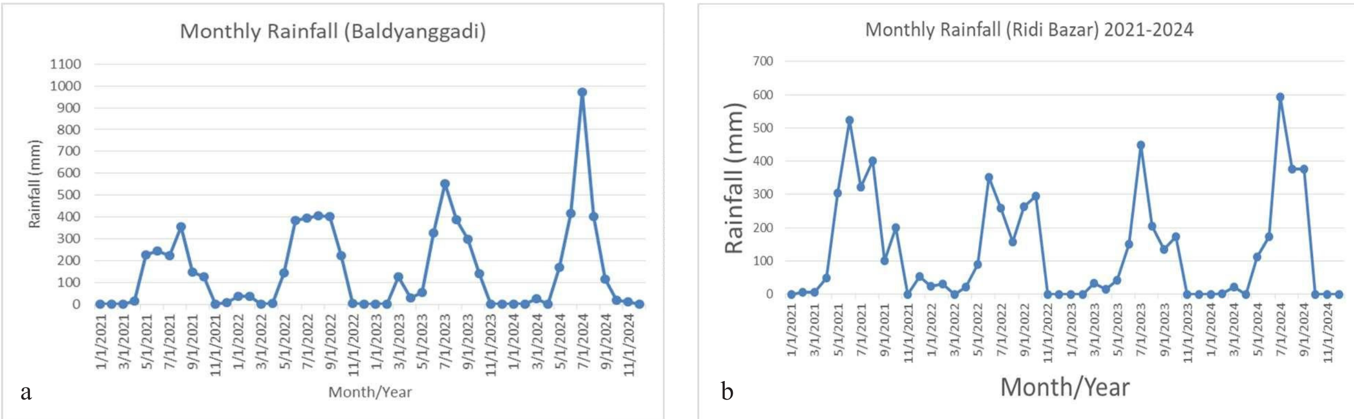

Fig. 6: Rainfall (2012-2024); a) Baldanggadi Station, b) Ridi Station.

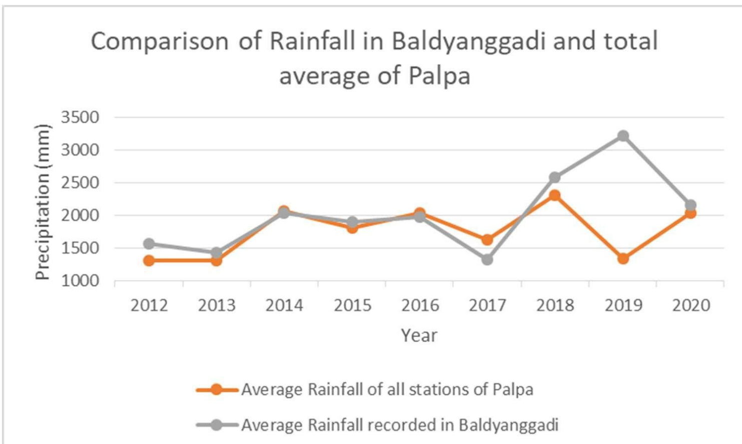

Fig. 7: Average yearly rainfall and landslides in Palpa.

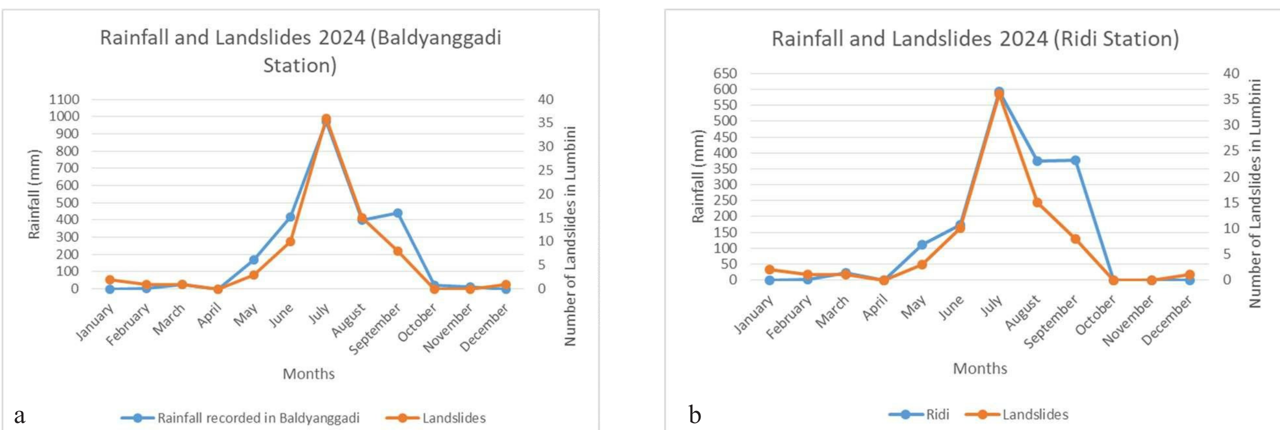

Fig. 8: Rainfall and landslides 2024, a) Baldyanggadi station, b) Ridi station.

Landslides induced by toe cut

Toe cut by excavation

In Arghakhanchi, most of the Landslides are found to be triggered due to road construction. With only nine cases of Landslides from 2012-2024, the number of Landslides in Arghakhanchi from 2020 to 2025 is 37 (Bipad Portal, 2025). This can be attributed to haphazard excavation for road construction. From the data obtained from Department of Roads, it can be seen that 316.76km length of earthen roads were in Arghakhanchi in the year 2019/2020 which had only 62.24km long Bituminous pavement, followed by Gulmi with 200km long earthen roads and 44.97km long Bituminous pavement. These earthen roads are highly vulnerable to failure as they do not have proper drainage, which allows the infiltration of rainwater. This leads to an increase in pore pressure, which increases the c-phi value of soil and causes slope failure. Road Density and Population influenced per km road is very less compared to the length in Arghakhanchi.

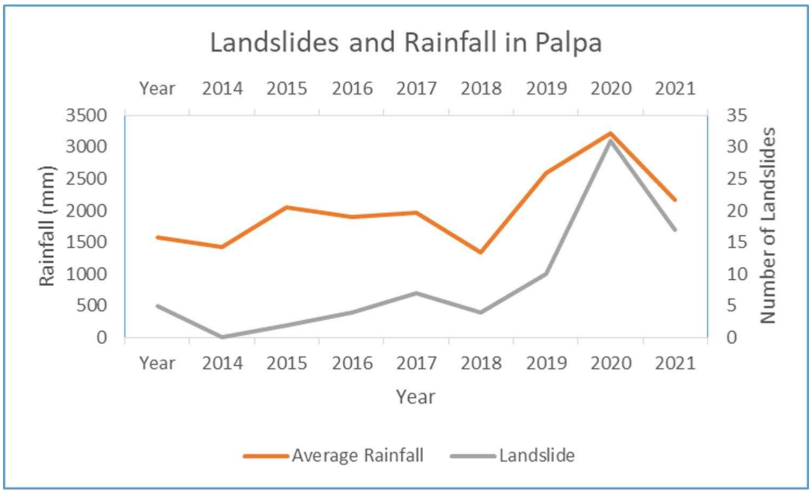

Fig. 9: Avg yearly rainfall and landslides

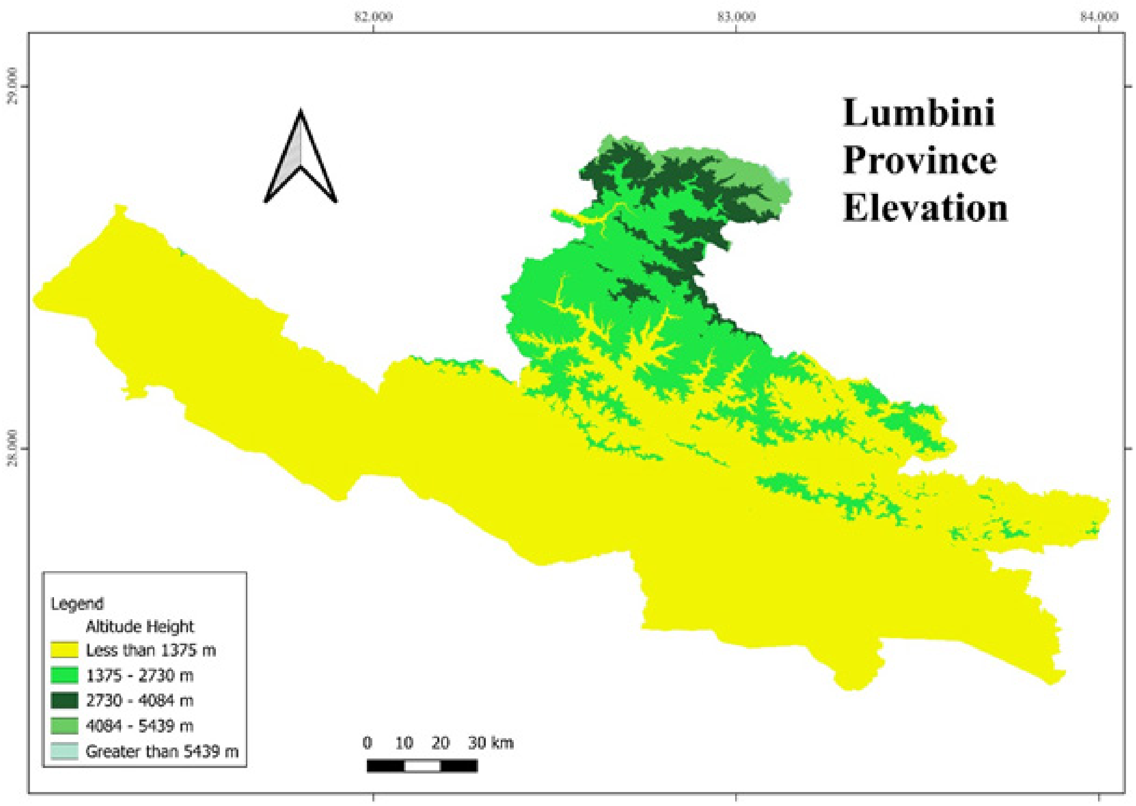

Fig. 10: Elevation map of Lumbini province, (the Terai (<1,375 m) experiences minimal landslides, while mid-hill districts (1,375–4,084 m) such as Palpa and Gulmi correlate with high landslide frequency due to monsoon rainfall and anthropogenic activities.)

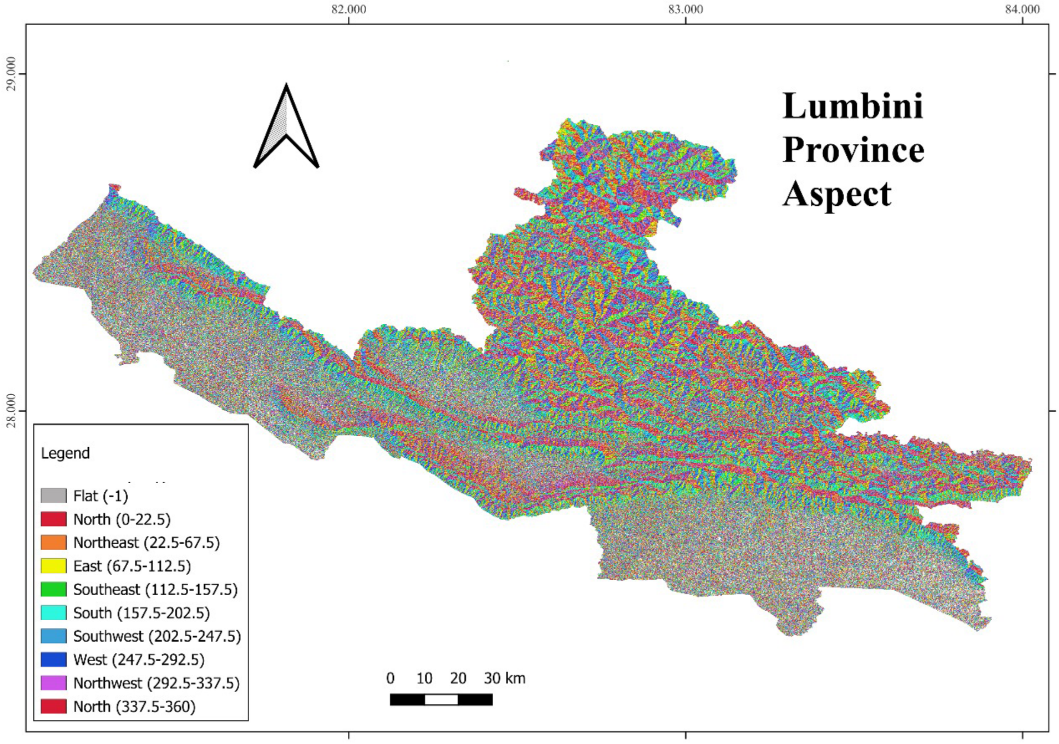

Fig. 11: Aspect map of Lumbini Province, (South-facing slopes (157.5–202.5°) dominate landslide-prone districts like Palpa, where intense rainfall and solar exposure accelerate slope failure.)

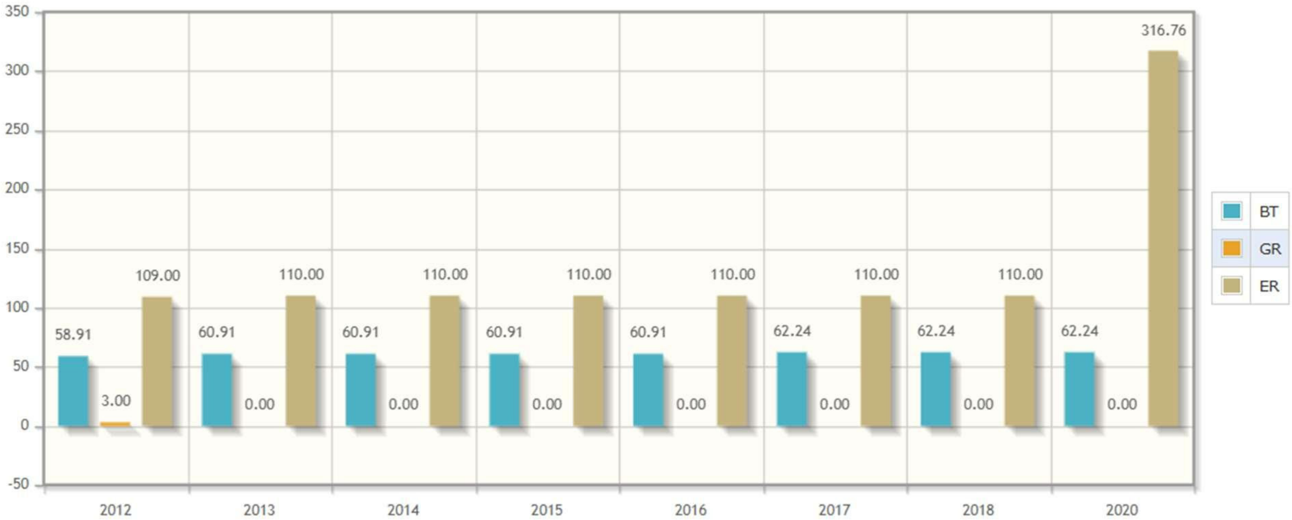

Fig. 12: Roads in Arghakhanchi over the years (Source: DOR).

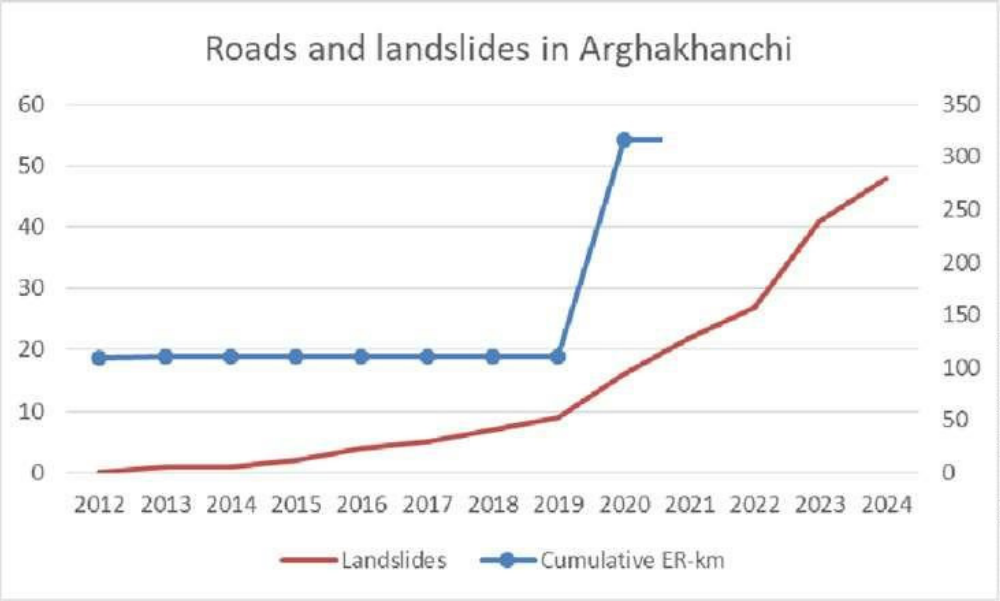

Fig. 13: Landslides vs earthen roads in Arghakhanchi (Note: Road data after 2021 is unavailable.)

Toe-cut by river

Fig. 13: Landslides vs earthen roads in Arghakhanchi (Note: Road data after 2021 is unavailable.)

As Gulmi has big rivers like the Kali Gandaki river at its east, Badighad, and Hudi Khola, and lots of small streams, we considered Gulmi district for research on landslides due to toe-cutting. To assess the effect of toe-cutting on Landslides, we traced landslides along the length of four rivers. Nine landslides were found to have occurred along the bank of the Badighat River of which eight occurred in the convex section of river meandering. There were three landslides along the Kali Gandaki River, three along Ridi, and three along the Hudi River. Removal of the toe due to river meandering in these landslides viewed on Google Earth indicates that these landslides occurred due to toe-cutting by the rivers. Analysis in HYRCAN, by Bishop Method, highlights these effects as it shows a marked reduction in Factor of Safety after toe erosion.

Topographic influence on landslides distribution

The DEM analysis revealed that moderate slopes (15–25°) dominate Lumbini Province, particularly in the Chure and Mahabharat ranges, aligning with landslide-prone areas such as Palpa and Rolpa. Steeper slopes (>35°) were localized along river valleys and tectonic zones, where toe-cutting and seismic activity further destabilize slopes. Elevation data confirmed that the Terai region (<1,375 m) experiences minimal landslides, while mid-hill districts (1,375–4,084 m) correlate with landslide clusters. Aspect mapping highlighted that south-facing slopes (157.5–202.5°), common in Palpa, are disproportionately affected due to higher solar exposure and rainfall infiltration, exacerbating pore pressure and slope failure.

WEAK GEOLOGY (CHURE)

Foreland basins are formed at the southern part (Indo-Gangetic Plain) of the Himalayas whereas retro arc basins are formed towards the northern part (Hoh

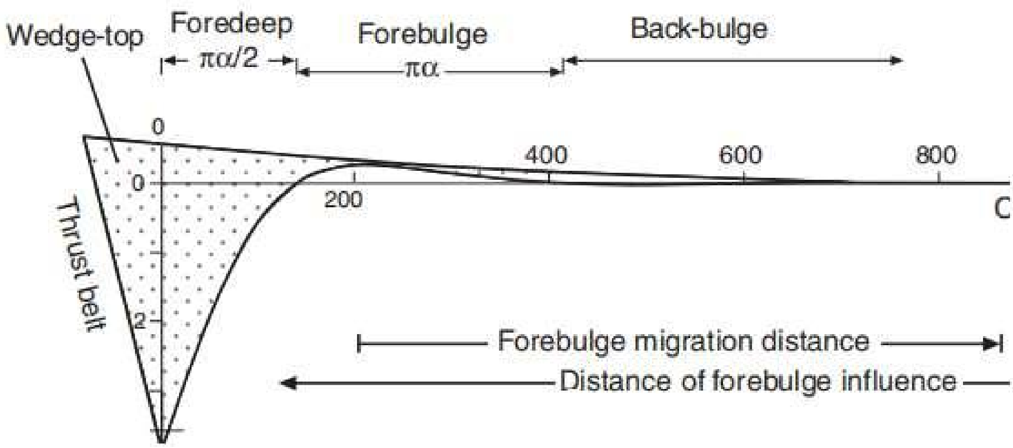

Fig. 15: Foreland basin (DeCelles, 2011).

Fig. 16: Lumbini-Chure by area.

-Xil Basin) ((Haisheng et al. 2008)). During Subduction, shortening of the Eurasian plate occurs which increases the load on the Indian plate causing the effect of the foreland even the greater distance also being the high flexural rigidity of the Indian plate the extent of depozones is clear and higher. (Kapp, 2019). They are raised due to tectonic movement poses high potential energy. Due to small movement or any simple erosional process, a landslide can be triggered. Additionally Duplex causes the fold mountain to gain more energy raising its elevation. Finally, there is a high chance of hazard in that region. (Mitra, 1986).

Knowing the fact that Lumbini province does not cover the high Himalayas in its relatively medium to low slope. Lumbini has a higher percentage, i.e., 27.9% of Chure. (Federation of Nepalese Chambers of Commerce and Industry- Lumbini Province, n.d.), Chure being the youngest formation is relatively highly susceptible to landslide. Long erosional processes and depositional processes from higher gradients to lower gradients cause the accumulation of the sediment forming Chure range at the foothills of the Himalayas below the Mahabharat range. During deposition larger sediment (Conglomerates – Sandy Conglomerates) which are loose and fragile, dissipates its energy quickly followed by its deposition relatively early forming Upper chure. Similarly, Middle chure is accompanied by layers of sandstone and mudstone. Finally, Lower chure contains much finer sediments (Distal silty and sandy*)* (Mugnier, 1999), traveled to a much greater distance. This process of upward coarsening is seen in the chure range of this province as well.

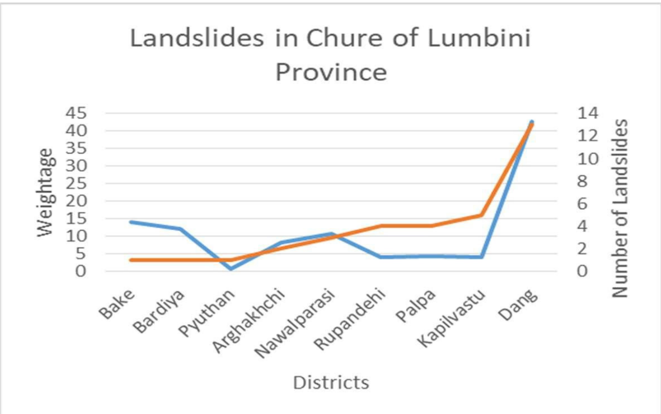

Fig. 17: Number of landslides in Chure (2012-2024)- by weightage (area)

Chure receives around (2500-2000 mm) of rainfall annually accompanied by the gentle northern face and steep southern face along with an alternation bed of mudstone and sandstone. The north face is relatively stable because the saturation and evaporation process is rather slow which makes the fluctuation of -ve pore water pressure slow. A steeper south face with direct sunlight and quick fluctuation of -ve pore water pressure make the south face much more susceptible than the north (Thapa, 2023). Thus the landslide is prominently visible at the south face of the Chure (Mugnier, 2004). Alternation bed of mudstone and sandstone at the south face during rainfall and flooding saturates the lower mudstone layer quickly leaving behind the cantilever portion of sandstone, which is another main cause of landslides in Chure. (Ghimire, 2020). Also, the age of the formation plays a vital role in stability, as the eastern part of Chure is relatively younger than the western part (i.e difference of 50 million years to 2 million years), the western part of the province suffers less landslide in chure compared to eastern part which applies to the whole country as well (Thapa, 2023).

OTHER CAUSES

Global warming

Since the pre-industrial era (i.e., 1850), the temperature of the Earth has increased by an average of 0.11° Fahrenheit (0.06° Celsius) per decade (Lindsey, 2020). January 2025 globally was 0.09 degrees Celsius (0.16° Fahrenheit) warmer than January 2024, the previous hottest January, and was 1.75 C (3.15° F) warmer than it was before industrial times (Rohde, 2025). If the rainfall pattern goes on increasing at the same rate as evidenced in the rainfall data obtained from the Department of Hydrology and Meteorology, there are high chance that the number of Landslides increase exponentially (Maharjan, 2025). This poses a serious issue.

Construction of dams

An increase in the water table reduces the effective stress of the soil, which makes the slope susceptible to Landslides (Hopkins, 1975). This also aids in the destruction of the ecosystem, making overhanging cliffs and thus increasing the susceptibility of landslides. Furthermore, the high sediment flow in the rivers makes the river toe-cutting process more rigorous (Leeder, 2001)

RESULTS AND DISCUSSION

Table 1: Number of landslides (2012-2024)

S.N	District	Number of Landslides
1	Rolpa	125
2	Palpa	124
3	Gulmi	96
4	Pyuthan	72
5	Arghakhanchi	48
6	East Rukum	44
7	Dang	19
8	Kapilvastu	6
9	Rupandehi	5
10	West Nawalparasi	4
11	Banke	2
12	Bardiya	1

Source: Bipad Portal

1. Earthquake rainfall-triggered Landslide cases are seen in the northern part of this province (Rukum and Rolpa). Here the rainfall itself is not the driving factor rather it plays a triggering role in the landmass weakening and ultimately failure of slip surface causing landslide.

2. Monsoon Rainfall can be the best statement to address the problem of landslides in hilly districts (Palpa, Gulmi) where the high volume of rainfall occurs relatively in small time of the year.
3. Toe cut due to river during road construction is also seen as a major problem initiating landslides in the hilly district(mainly Argkanchi, Gulmi) of this province. As haphazard road construction and track openings destabilize the slope due to the weakening of the slope. Also naturally due to the river(volume of water, amount of sediment, Angle of meandering, Slope of terrain, longitudinal slope of river) similar weakening of the slope occurs causing landslides.
4. The topographic analysis reinforces the interplay of natural and anthropogenic landslide triggers. The prevalence of 15–25° slopes in high-risk districts suggests that even moderate gradients become hazardous when combined with rainfall or road construction. South-facing slopes, already vulnerable due to climatic effects, face compounded risks from deforestation or improper excavation. These findings underscore the need for slope-specific mitigation, such as terracing or bioengineering in 15–35° zones and enhanced drainage on south-facing roads.
5. The Weak Geology of chure helps in triggering landslides as most of the economic city are located in and around chure in this province with a larger population density, rather small size of landslide could be huge in terms of monitory value.

CONCLUSIONS

Despite being rather easy terrain, Lumbini province is susceptible and vulnerable in the sense that various natural and anthropogenic causes are present which weaken the slopes and cause landslides. Triggering factors (rainfall being the most) play vital role during the initiation of landslides occurred by various causes.

The project concluded that Lumbini province is susceptible and vulnerable in the sense that various natural and anthropogenic causes are present which weaken the slopes and cause landslides. It is found that earthquake-induced rainfall-triggered Landslide cases are seen in the northern part of this province (Rukum and Rolpa). Monsoon Rainfall can be the best statement to address the problem of landslides in hilly districts (Palpa, Gulmi) where the high volume of rainfall occurs relatively in a small time of the year. The weak Geology of Chure helps in triggering landslides as major cities are located in and around Chure in this province with a larger population density, rather a small size of the landslide could be huge in terms of monetary value. Important infrastructures and historical and ecological complex ecosystems in this region can be harmed by landslides in the future. Therefore, the findings suggest that small technical and financial steps in the field can reduce the risk of Landslides in the Lumbini province by a high percentage.

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REFERENCES

Bipad Portal, 2025, Bipad Portal: https://bipadportal.gov.np/incidents/

Chakraborty, R., and Dey, A., 2019, Effect of toe cutting on hillslope stability. Geotechnical Applications: IGC 2016, pp. 191-198.

Chen, C. H., 2017, Investigating effect of water level variation and surface tension crack on riverbank stability. Journal of hydro-environment research, v. 15, pp. 41-53.

Dahal, R. K., 2012, Rainfall-induced landslides in Nepal. International Journal of Erosion Control Engineering, v. 5(1), pp. 1-8.

DeCelles, P. G., 2011, Foreland basin systems revisited: Variations in response to tectonic settings. Tectonics of sedimentary basins: Recent advances, pp. 405-426.

Gao, P., 2024, Exploring meandering river cutoffs. Geological Society, London, Special Publications.

Ghimire, M., 2020, Landslide distribution and processes in the Hills of Central Nepal: geomorphic and statistical approach to susceptibility assessment. Journal of Geoscience and Environment Protection, v. 8(12), pp. 276.

Hagen, T., 1969, Report on the geological survey of Nepal. Denkschr. Schweiz. Naturf. Ges., , v. 81, pp. 185.

Haisheng, Y., Chengshan, W., Zhiqiang, S., Jinhui, L., & Lidong, Z., 2008, Acta Geologica Sinica-English Edition, v. 82(1), pp. 206-213.

Hopkins, T. C., 1975, Effects of water on slope stability.

Kapp, P., 2019, Mesozoic–Cenozoic geological evolution of the Himalayan-Tibetan orogen and working tectonic hypotheses. American Journal of Science, v. 319(3), pp. 159-254.

Leeder, M. R., 2001, Lateral erosion ('toe-cutting') of alluvial fans by axial rivers: implications for basin analysis and architecture. Journal of the Geological Society, v. 158(6), pp. 885-893.

Lindsey, R., 2020, Climate change: Global temperature. Climate. gov, v. 16.

Liu, X., Chen, Q., Zhao, J., Xu, Q., Luo, R., Zhang, Y., Yang, Y. and Liu, G., 2020, The spatial response pattern of coseismic landslides induced by the 2008 Wenchuan earthquake to the surface deformation and Coulomb stress change revealed from InSAR observations. International Journal of Applied Earth Observation and Geoinformation, v. 87, pp. 102030.

Maharjan, K. R., 2025, Climate change impacts on flood dynamics and seasonal flow variability in central Nepal: the Kaligandaki River Basin case. Theoretical and Applied Climatology, v. 156(3), pp. 149.

Marc, O. B., 2019, Long-term erosion of the Nepal Himalayas by bedrock landsliding: The role of monsoons, earthquakes and giant landslides. Earth Surface Dynamics, v. 7(1), pp. 107–128.

MFD, 2024, Retrieved from Department of Hydrology and Meteorology. Meteorological Forecasting Division

Mitra, S., 1986, Duplex structures and imbricate thrust systems: geometry, structural position, and hydrocarbon potential. AAPG bulletin, v. 70(9), pp. 1087-1112.

Mugnier, J. L., 1999, The Siwaliks of western Nepal: I. Geometry and kinematics. Journal of Asian Earth Sciences, v. 17, pp. 629-642.

Mugnier, J. L., 2004, Episodicity and rates of thrust-sheet motion in the Himalayas (western Nepal).

Partheniades, E., 1965, Erosion and deposition of cohesive soils. Journal of the Hydraulics Division, pp. 105-139.

Pizzuto, J. E., 1989, Evaluation of a linear bank erosion equation. Water Resources Research, v. 25(5), pp. 1005-1013.

Rohde, R. H., 2025, Temperature Update. Berkeley Earth.

Stark, T. D., Arellano, W. D., Hillman, R. P., Hughes, R. M., Joyal, N., and Hillebrandt, D., 2005, Effect of toe excavation on a deep bedrock landslide. Journal of Performance of Constructed Facilities, pp. 244-255.

Subedi, M. K. 2024, Reconnaissance of the Effects of the M W5. 7 (M L6. 4) Jajarkot Nepal Earthquake of 3 November 2023, Post-Earthquake Responses, and Associated Lessons to Be Learned. Geosciences, v. 14(1), pp. 20.

Thapa, P. B., 2023, Landslide Susceptibility Assessment in Nepal's Chure Region: A Geospatial Analysis. Land, v. 12(12), pp. 2186.

Xu, Q., Li, W., Tang, C., Fan, X., Luo, Y., Zhu, J., ... and Towhata, I., 2022, Report on Landslides Triggered by the 2008 Wenchuan Earthquake. Coseismic Landslides: Phenomena, Long-Term Effects and Mitigation, pp. 1-40.

Zou, Y. Q., 2022, Factors controlling the spatial distribution of coseismic landslides triggered by the Mw 6.1 Ludian earthquake in China. Engineering Geology, v. 296, pp. 106477.