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Index of Social Vulnerability to Natural Disasters in Nepal

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Abstract

Social vulnerability to natural hazards is a significant issue in Nepal, a country prone to earthquakes, floods, landslides, and other disasters. Despite existing studies, there remains a gap in comprehensive vulnerability assessments that account for multiple hazards and socio-economic factors. This study aims to develop a modified Social Vulnerability Index (SVI) to assess social vulnerability across Nepal's provinces using updated data and a multi-hazard approach. Using Principal Component Analysis (PCA), the study analyzed 18 socio-economic and demographic variables to derive three principal components explaining 88.55% of the variance in vulnerability. The SVI scores for each district were calculated and aggregated at the provincial level. Data from the 2021 Nepal Census and historical disaster records from 2015 to 2021 were used to quantify vulnerability. The study found significant regional differences in vulnerability. Madhesh (SVI = 21.84) and Karnali (SVI = 4.46) provinces were identified as very high vulnerability regions, while Gandaki province (SVI = -18.75) showed very low vulnerability. Terai regions were generally highly vulnerable, especially in terms of flooding.

The findings emphasize the need for multi-hazard assessments in disaster risk management. The SVI is a practical tool for targeted disaster preparedness, resource allocation, and vulnerability monitoring over time. This study offers a comprehensive vulnerability assessment for Nepal, providing policymakers with essential tools to reduce disaster risks and enhance resilience across provinces.

Keywords Principal component analysis, multi-hazard, vulnerability assessment, disaster risk.

1. Introduction

Research on social vulnerability to natural hazards is crucial for disaster risk management a community resilience by socio-economic, demographic, and geographic factors (Li, 2024; Li & Jiang, 2024). As climate change exacerbates natural hazards, understanding social vulnerability has become increasingly important to inform policies aimed at enhancing resilience, particularly in regions highly susceptible to disasters.

Nepal faces significant vulnerability to natural hazards due to its diverse terrain and socio-economic factors, despite the recognition of social vulnerability as a crucial component in disaster management (Aksha et al., 2019; Gautam, 2017). These studies have not sufficiently explored the intersection of urban-rural disparities, the impact of mountainous terrain, and the availability of resources in shaping vulnerability.

Nepalese literature lacks comprehensive vulnerability indexes that integrate socio-economic and geographic variables, often overlooking the nuanced disparities between

its diverse provinces, unlike models used in China and Bangladesh (Ge et al., 2024; Zhao et al., 2024). Studies in Nepal often use static frameworks, neglecting temporal and spatial variations in vulnerability across regions, necessitating a locally adapted vulnerability assessment framework considering demographic and environmental factors.

Social vulnerability is typically measured through various indices that capture demographic, socio-economic, and infrastructural conditions. Research by Khanal & Shrestha (2007) highlighted the use of vulnerability indices to understand the disparities in disaster impact based on socio-economic status and geographic location. Recent studies have expanded on this framework by integrating new indicators such as healthcare access, disability, and employment status (Mainali & Pricope, 2018). In China, Li (2024) and Li & Jiang (2024) used a modified vulnerability index to assess spatial and temporal variations, which highlighted the critical role of wealth and geographic disparities in shaping vulnerability.

In South Asia, studies like those by Aksha et al. (2019) and Gautam (2017) have focused on vulnerability assessments in Nepal, but these indices have not fully addressed the complex geographic and socio-economic factors that contribute to disaster risk. For instance, the work by Yang et al. (2015) in China emphasizes the need for region-specific data, a critical component that has been overlooked in Nepalese vulnerability studies. Similarly, Zhao et al. (2024) applied machine learning techniques to develop global vulnerability indices but did not address the unique characteristics of South Asian countries, particularly Nepal.

Despite the progress made, a gap remains in the application of vulnerability indices that account for the intersectionality of socio-economic, geographic, and environmental factors in Nepal. Studies in countries like Bangladesh (Tasnuva et al., 2021) and Ecuador (Bucherie et al., 2022) have used principal component analysis (PCA) to assess vulnerability, but these methods have not yet been adapted to the specific context of Nepal, where vulnerability is shaped by factors such as uneven access to resources, lack of infrastructure, and rural-urban divides.

While previous studies provide useful insights into vulnerability measurement, they often fail to incorporate the specific geographical and socio-economic complexities of Nepal. Many studies (Li, 2024; Zhao et al., 2024) focus on wealth and health indicators but neglect the impact of mountain terrain, remote areas, and the unique socio-economic structure of Nepal. Additionally, there is a limited focus on urban-rural disparities in the context of natural hazard exposure in Nepal (Spielman et al., 2020). The absence of a region-specific vulnerability index that considers both the physical landscape and socio-economic factors creates a significant research gap. The objective of this study is to develop a modified Social Vulnerability Index (SVI) tailored to the Nepali context, incorporating socio-economic, demographic, and environmental factors. The study aims to assess the social vulnerability of Nepal's seven provinces, providing insights to inform disaster risk management and policy development.

2. Material and method

This section outlines the methodology used in this study to assess social vulnerability to natural hazards in Nepal, including the data collection process, the development of the Social Vulnerability Index (SVI), and the analytical techniques applied. The study covers all seven provinces of Nepal, with a particular focus on the Terai region and the hill/mountain areas. These areas were selected due to their distinct geographical, socio-economic, and disaster exposure characteristics.

2.1 Data collection

Data for this study were collected from multiple sources to ensure a comprehensive analysis of social vulnerability. The data collection methods include:

2.1.1 Primary data: Household surveys were conducted using structured questionnaires that captured socio-economic factors such as income levels, education, access to healthcare, and infrastructure quality.

2.1.2 Secondary data: Secondary data were obtained from the 2021 Nepal Census, government agencies, disaster management authorities, and relevant NGOs, providing historical disaster data and infrastructure details.

2.2 Social vulnerability index (SVI) development

The Social Vulnerability Index (SVI) was used as the main tool for assessing social vulnerability to natural hazards in the study area. The SVI was constructed using a modified approach based on previous studies (Li, 2024; Zhao et al., 2024), incorporating both traditional and innovative indicators. The key components of the SVI include:

2.2.1 Variable Selection: Eighteen variables were selected from the literature, covering demographic, socio-economic, and infrastructural factors. These variables include age, gender, education, income, access to resources, and housing conditions (Aksha et al., 2019; Moktan et al., 2022).

2.2.2 Index Construction: The Social Vulnerability Index (SVI) was adapted to the Nepali context by modifying existing indices used in other countries, such as those developed by Li (2024) and Zhao et al. (2024), to include relevant local factors.

2.2.3 Factor Reduction (PCA): Principal Component Analysis (PCA) was used to reduce the dimensionality of the 18 variables, identifying three principal components that explain 88.55% of the total variation in the data.

Table 1 presents the 18 variables selected based on the literature review. These variables, which include key socio-economic and demographic factors, are crucial for assessing social vulnerability. The table lists each variable, the rationale for its inclusion, and its source.

Table 1. Components of SVI for Nepal

Concepts	Variables	Descriptions
Age	P65	Population of elderly of 65 years and above
	P5	Population of children under 5 years

Built environment	PNOCH	Households besides cement bonded bricks as the foundation of the housing unit
	PNOP	Households besides piped water connection
	PNOE	Households besides electricity
	PNOF	Households besides flush toilet
	PNOCO	Households besides cement bonded bricks
Education	PNORW	Population aged 5 years and above who cannot read and write
Family structure	PFH	Households headed by female
	PAH	Average household size
Gender	PF	Population of female
Level of employment	PNOEA	Population aged 10 years and above who are not economically active
Occupation	PAFMQ	Population 10 years of age and above who performed economic activity in agriculture, forestry, fishing, mining, and quarrying in the last 12 months
Renters	POR	Households occupying a rented house
Socioeconomic status	PFS4	Households with family size > 4
	PNOA	Households without any amenities/assets
Urban/rural	PHWC	Households with wood/ firewood as cooking
	PPD	Population density

The study uses several variables to assess social vulnerability to natural hazards, organized into key concepts. Age is represented by the population of elderly individuals (P65) and children under 5 years (P5), both of whom are more vulnerable due to health and dependency factors.

To ensure comparability and facilitate further analysis, all selected variables underwent Z-score normalization. This process standardizes the variables by transforming them to have a mean of 0 and a standard deviation of 1, which allows for more accurate comparisons across diverse data distributions. The Z-score formula applied is:

$$Z = \frac{X - M}{SD}$$

Here, Z is new normalized value, X is original value, M is mean of the variable of 77 districts, and SD is standard deviation of all 77 districts.

The data was loaded into the Statistical Package for the Social Sciences (SPSS) version 29.0.2.0 program in order to perform Principal Component Analysis (PCA). Principal component analysis is a factor reduction approach that identifies smaller components to explain the variance seen in a larger dataset (Aksha et al. 2018). Each provinces SVI was determined by adding the following principal component values, also known as factor values:

$$SVI = PC1+PC2+PC3$$

Based on standard deviation from the mean value, the SVI ratings of each district were plotted in ArcMap to show which districts in Nepal were the most and least susceptible.

Table 2. Classification of vulnerability levels using the standard deviation technique

Vulnerability	Calculation
Very High =	Mean + 1.5*Standard Deviation
High =	Mean + 0.5*Standard Deviation
Medium =	Mean
Low =	Mean - 0.5*Standard Deviation
Very Low =	Mean - 1.5*Standard Deviation

Table 2 uses the standard deviation technique to classify social vulnerability levels in Nepal into five levels: Very High, High, Medium, Low, and Very Low. This classification helps identify regions needing urgent disaster preparedness and response, aligning with the study's objective of understanding varying vulnerability levels across Nepal's provinces.

3. Analysis of data and results

This study used Principal Component Analysis to analyze social vulnerability in Nepal, identifying three principal components that account for 88.55% of data variation. The Social Vulnerability Index (SVI) was computed for each district, categorizing them into four levels: Very High, High, Medium, and Low.

The Terai belt in Nepal is the most vulnerable, with districts in Sudurpaschim, Karnali, Lumbini, and Koshi provinces showing the highest vulnerability. This is due to exposure to natural hazards and socio-economic challenges.

3.1 Causes of social vulnerability in Nepal: Several key factors contribute to Nepal's social vulnerability, each interacting in complex ways to amplify disaster risk across the country:

3.2 Geographical location: Nepal's rugged terrain, including mountainous areas prone to landslides and earthquakes, and low-lying floodplains like Terai, exacerbates vulnerability to natural hazards in certain districts.

3.3 Poverty and marginalization: A substantial portion of Nepal's population lives below the poverty line, with impoverished communities often located in high-risk areas due to the lower cost of land. These communities typically lack the resources to prepare for or recover from disasters, thus increasing their vulnerability (Adhikari et al., 2020).

3.4 Urbanization and migration: Rapid and unplanned urban growth, particularly in cities like Kathmandu, has led to increased population density in seismic risk zones. Additionally, migrant populations, often displaced by poverty and rural underdevelopment, settle in areas with inadequate infrastructure and limited disaster preparedness, further heightening their vulnerability.

3.5 Political and institutional challenges: Nepal's vulnerability is exacerbated by weak governance structures and insufficient disaster management systems, hindering effective risk mitigation and response by local governments.

3.6 Natural disasters and social vulnerability in Nepal: Nepal faces significant social vulnerability due to natural disasters such as earthquakes, floods, landslides, and glacial lake outburst floods. These disasters affect infrastructure, housing, and emergency preparedness, disproportionately affecting the poorest communities and exacerbated by deforestation.

Table 3 highlights the frequency of different types of natural hazards, with fire, landslides, and thunderstorms being the most common. These hazards, particularly in provinces like Sudurpaschim and Lumbini, correlate with the regions' high vulnerability scores, as identified in the SVI analysis.

Table 3. Number of hazards in the seven provinces of Nepal from 2012-2021

Animal Incidents	160	72	23	249	138	177	104	923
Avalanche	1	8	6	3	1		3	22
Boat	1	10	2	4	4	3	8	32
Cold Wave	0	1		2		72	0	75
Drowning	80	57	24	94	104	123	33	515
Earthquake	15	18	10	18	12	8	10	91
Epidemic	2	1	21	14	14	2	18	72
Fire	3097	1088	526	4524	2740	4018	908	16901
Flood	229	172	95	377	230	252	141	1496
Fire	10	15	5	19	7	3	12	71
Rain	177	154	203	177	284	264	245	1504
Altitude	6	21	17	44				88
Landslide	547	468	228	538	320	2	228	2331
Non-Natural	54	33	16	67	42	47	23	282
Snake Bite	5		2	28	48	46	10	139
Snow Storm	0	3	2	3	0	0	0	8
Storm	4	6	10	17	2	4	7	50
Thunderbolt	446	239	189	647	314	204	240	2279
Wind Storm	57	54	24	128	113	158	98	632
Total	4891	2420	1403	6953	4373	5383	2088	27511

Table 3 presents the number of various types of natural hazards and incidents across the seven provinces of Nepal from 2012 to 2021. The data indicates that fire is the most frequently occurring hazard, with a total of 16,901 incidents reported, disproportionately affecting regions like Karnali (4,524 incidents) and Bagmati (3,097

incidents). Landslides, another significant hazard, have a high frequency, especially in Sudurpaschim (547 incidents) and Karnali (468 incidents). Floods and drowning also appear frequently, particularly in the Terai region, with Lumbini (377 flood incidents) and Karnali (104 drowning incidents) showing high vulnerability.

Nepal is highly vulnerable to a range of natural disasters, which have significant social and economic impacts, particularly on marginalized communities.

3.6.1 Earthquakes: Nepal's seismically active zone is at high risk, as demonstrated by the 2015 Gorkha earthquake, highlighting gaps in preparedness and the need for resilient building practices.

3.6.2 Floods: Terai region experiences frequent flooding, disproportionately affecting vulnerable populations, exacerbates socio-economic inequalities, and leads to livelihood loss, home damage, and crop destruction.

3.6.3 Landslides: Landslides in Nepal's hilly regions, exacerbated by poor road construction, deforestation, and unsustainable land use, cause infrastructure destruction, displacement, and loss of life for disadvantaged groups.

3.6.4 Glacial Lake Outburst Floods: Nepal's Himalayan glacial lakes are becoming increasingly vulnerable to glacial lake outburst floods due to climate change, posing a significant threat to infrastructure, agriculture, and livelihoods in remote mountain region (Pathak et al., 2020).

Nepal's social vulnerability is exacerbated by natural disasters, disproportionately affecting poorer, rural, and marginalized communities. Addressing these risks requires comprehensive preparedness, early warning systems, and targeted resilience-building efforts.

Table 4. Disaster occurrences and impact (2015-2021) (USD1@NPR 120)

Year	No. of incidents	Dead	Injured	Affected Family	Pvt house Damage partially	Pvt.house damaged fully	Estimated Loss
2015	978	9304	22,661	828*	299,378	773,936	781,579**
2016	2370	486	764	13,241	1,222	3,428	23,436,490
2017	2460	490	737	19,073	14,427	1,927	20,806,545
2018	3919	478	2,902	8,180	1,880	2,505	36,182,433
2019	4538	489	2452	25,264	6,873	4,939	39,245,919
2020	3770	559	1145	11,314	3,330	1,959	14,190,103
2021	4215	509	1773	6,583	1,580	2,044	21,190,103
Total	**22,250**	**12,315**	**32464**	**84,483**	**328,690**	**790,738**	**163,409,909**

https://drrportal.gov.np/ 2022

Table 4 presents a comprehensive overview of the frequency and consequences of natural disasters in Nepal over a seven-year period, linking directly to the study's objective of assessing the social vulnerability of the country. The table highlights the total number of incidents, casualties, and the damage to infrastructure, including partially and fully damaged private homes and the estimated economic losses.

The National Disaster Database maintained by the Disaster Risk Reduction (DRR) Portal indicates that, between 2015 and 2021, fire was the most frequent hazard, occurring 13,811 times, followed by landslides (2,058 incidents), thunderstorms (1,682), severe rains (1,292), floods (1,122), and windstorms (607). Other recurring hazards include traffic accidents, snake bites, and heat and cold waves.

The 2015 earthquake caused Nepal's GDP growth rate to fall sharply from 6% in 2014 to 2% in 2015, and further to 0.4% in 2016. Similarly, the COVID-19 pandemic caused a historic decline in GDP, with a growth rate of -2.12% in the 2019–2020 fiscal year, which was even lower than the post-earthquake period. Prior to the pandemic, the economy had shown recovery, with GDP growth reaching 7.6% in 2018 and 9% in 2017 (NDRRMA, 2023).

The COVID-19 pandemic also had a far-reaching impact on public health and socio-economic development. By May 6, 2022, the pandemic had caused 11,952 deaths, with the highest number of fatalities in the 60-69 age group. The total number of confirmed cases reached 978,897, with 41.2% of the cases affecting females and 58.8% males.

Table 5. Factor scoring of province with their social vulnerability ranking

Province	SVI	Ranking (Risk)
Koshi Province	-7.634827	Low
Madhesh Province	21.840516	Very High
Bagmati Province	-3.62941	Low
Gandaki Province	-18.75501	Very Low
Lumbini Province	0.18035	Medium
Karnali Province	4.46415	Very High
Sudurpaschim Province	3.53427	Very High

Source: Author calculation from district-wise SVI

Table 5 presents the Social Vulnerability Index (SVI) scores for each of Nepal's provinces, based on the factor scores (F, F and F) calculated from the district-level data. The SVI provides a comprehensive measure of social vulnerability by aggregating socio-economic, demographic, and infrastructure-related factors, which directly link to the study's objective of assessing social vulnerability across Nepal's regions (NDRRMA, 2023).

The Madhesh, Karnali, and Sudurpaschim provinces have the highest vulnerability scores, with Madhesh Province ranking as the most vulnerable (SVI = 21.840516, Very High). This high vulnerability is largely attributed to the region's exposure to

flooding, high population density, and limited access to infrastructure and resources. Similarly, Karnali (SVI = 4.46415) and Sudurpaschim (SVI = 3.53427) also show very high vulnerability, due to factors like geographical isolation, economic hardship, and inadequate disaster preparedness, particularly in the face of frequent natural disasters such as landslides and flooding.

In contrast, Gandaki Province has the lowest vulnerability score (SVI = -18.75501, Very Low), indicating that it is relatively less exposed to the adverse impacts of natural hazards and has stronger socio-economic conditions and infrastructure resilience. Provinces such as Koshi (SVI = -7.634827) and Bagmati (SVI = -3.62941) show low vulnerability, primarily due to better infrastructure, access to services, and less exposure to high-risk areas. Lumbini Province falls into the medium vulnerability category (SVI = 0.18035), reflecting moderate exposure to risks and more balanced socio-economic conditions compared to the other provinces.

The findings from Table 5 align with the study's objective of identifying regions with varying levels of social vulnerability, offering insights into which provinces require more urgent intervention and targeted disaster risk reduction measures. The SVI ranking provides a valuable tool for policymakers and disaster management agencies to prioritize resources and develop region-specific strategies to reduce vulnerability and enhance resilience.

4. Discussion

The findings of this study are both consistent with and offer new perspectives compared to previous research on social vulnerability to natural disasters in Nepal. The results align with Aksha et al. (2018), who identified the Terai region, especially Madhesh Province, as highly vulnerable due to its exposure to flooding and socio-economic challenges. This study confirms that the Terai belt in Koshi and Madhesh provinces remain highly susceptible to social vulnerability. However, this study diverges from the findings of Moktan et al. (2022), who identified the western regions of Nepal, particularly Provinces 4, 5, 6, and 7, as having relatively low vulnerability. The discrepancy arises from the updated data used in this study, which incorporates the 2021 census and additional socio-economic variables that offer a more comprehensive understanding of vulnerability. While the western regions show lower vulnerability, Gandaki Province in particular, the Terai region presents a complex scenario where vulnerability is still high, particularly in Madhesh Province.

These differences underscore the importance of a multi-hazard approach, as emphasized by Aksha et al. (2018), which accounts for various disaster risks, including floods, landslides, and earthquakes. This study supports their argument that focusing on a single hazard category does not fully capture the dynamic and interconnected nature of vulnerability in Nepal. By including multiple hazards, this study offers a more accurate representation of social vulnerability across the country.

The Social Vulnerability Index (SVI), developed in this study, proves to be an invaluable tool for disaster management and preparedness. By identifying high-risk

areas, the SVI helps policymakers prioritize resource allocation to regions that are most vulnerable. It also facilitates the development of tailored disaster response plans, as different regions exhibit unique vulnerabilities that require specific strategies. For example, Madhesh and Karnali provinces, identified as highly vulnerable, need targeted interventions to address flooding and infrastructure challenges, while Gandaki Province requires measures to mitigate landslides and improve rural access. Additionally, the SVI provides a framework for monitoring vulnerability over time, which is critical for assessing the impact of government policies, climate change, and development projects on disaster risk. Regular updates to the index will allow for dynamic disaster management strategies that can adapt to evolving socio-economic and environmental conditions (Kumar, 2024).

The study reveals regional disparities in social vulnerability, with Terai and hill regions being more susceptible to natural hazards. It emphasizes the need for region-specific interventions and integrating multiple hazards into vulnerability assessments (Kumar, 2024).

5. Conclusion

This study provides a comprehensive assessment of social vulnerability to natural hazards in Nepal, utilizing the Social Vulnerability Index (SVI) to evaluate vulnerability across the country's provinces. The findings indicate significant regional disparities in vulnerability, with provinces like Madhesh, Karnali, and Sudurpaschim showing very high levels of vulnerability due to their exposure to frequent natural hazards, such as floods, landslides, and earthquakes. Conversely, provinces like Gandaki demonstrate relatively low vulnerability, reflecting better infrastructure and socio-economic conditions. By incorporating multiple hazard types and using updated socio-economic data, this study presents a more nuanced understanding of vulnerability, particularly in the Terai and hill regions. The SVI serves as a valuable tool for policymakers to identify high-risk areas, allocate resources efficiently, and develop targeted disaster preparedness and response strategies.

The findings of this study have significant implications for disaster risk reduction and management in Nepal. First, they underscore the need for region-specific interventions to address the unique vulnerabilities of different provinces. For instance, the Terai region, which faces recurrent flooding and socio-economic challenges, requires focused efforts in flood mitigation and infrastructure improvement. Similarly, Karnali and Sudurpaschim provinces, which are highly vulnerable to landslides, demand targeted measures to improve road networks and disaster preparedness. Second, the study emphasizes the importance of a multi-hazard approach to vulnerability assessment, which can provide a more comprehensive picture of risk and help prioritize interventions. Finally, the SVI offers a dynamic tool that can be regularly updated to track changes in vulnerability over time, making it a valuable resource for monitoring the effectiveness of disaster management policies and adapting strategies in response to evolving environmental and socio-economic conditions.

This study's novelty lies in its use of an updated and comprehensive Social Vulnerability Index (SVI) that incorporates a broader range of variables and multiple hazard types, including floods, landslides, earthquakes, and other socio-economic factors. Unlike previous studies that focused on single hazards or outdated datasets, this research uses the most recent census data (2021) and considers both geographical and socio-economic factors in determining vulnerability.

References

Adhikari, N., Shahi, P. R. & GC, S. (2020). Estimating Households' Vulnerability to Poverty from an Idiosyncratice Shock: Evidence from Nepal. *The Economic Journal of Nepal, 43(3).* https://doi.org/10.3126/ejon.v43i3-4.48035

Aksha, S. K., Resler, L. M., Juran, L., & Carstensen, L. W. (2020). A geospatial analysis of multi-hazard risk in Dharan, Nepal. *Geomatics, Natural Hazards and Risk*, *11*(1), 88–111. https://doi.org/10.1080/19475705.2019.1710580

Aksha.S.K, Juran.L, Resler.L.M & Zhang.Y. (2018). An Analysis of Social Vulnerability to Natural Hazards in Nepal Using a Modified Social Vulnerability Index. *International Journal of Disaster Risk Science, 10,* 103-116. https://doi.org/10.1007/s13753-018-0192-7

Bucherie, A., Hultquist, C., Adamo, S., Neely, C., Ayala, F., Bazo, J., & Kruczkiewicz, A. (2022). A comparison of social vulnerability indices specific to flooding in Ecuador: Principal component analysis (PCA) and expert knowledge. *International journal of disaster risk reduction*, *73*, 102897. https://doi.org/10.1016/j.ijdrr.2022.102897

Gautam. D. (2017). Assessment of social vulnerability to natural hazards in Nepal. *Natural Hazards and Earth System Sciences*, *17,* 2313-2320. https://doi.org/10.5194/nhess- 17-2313-2017.

Ge, Y., Dou, W., Tao, Z., Yang, Y., Mi, Y., & Zhou, D. (2024). Characterizing the Nature of Social Vulnerability to Disasters in Inner-City Households: Case of Jiaxing, China. *Natural Hazards Review*, *25*(1), 05023017. https://doi.org/10.1061/NHREFO.NHENG-1870 https://doi.org/10.1016/j.ijdrr.2020.101970

Khanal, N. R., Shrestha, M., & Ghimire, M. (2007). *Preparing for flood disaster: mapping and assessing hazard in the Ratu Watershed, Nepal.* International Centre for Integrated Mountain Development (ICIMOD).

Kumar, N.K. (2024). An in-depth analysis of macroeconomic factors influencing Nepal's economic growth. *NPRC Journal of Multidisciplinary Research*, 1(6), 13-22. https://doi.org/10.3126/nprcjmr.v1i6.71739

Kumar, N. K. (2024). Effects of unemployment and inflation on the economy of Nepal. *Rajarshi Janak University Research Journal*, *2*(1-2), 42–49. https://doi.org/10.3126/rjurj.v2i1-2.72303

Li, X. (2024). Measuring social vulnerability to natural hazards in China: a modified index approach. *Population and Environment*, *46*(2), 14. https://doi.org/10.1007/s11111-024-00455-6

Li, X., & Jiang, L. (2024). Spatial and temporal changes in social vulnerability to natural hazards: a case study for China counties. *Natural Hazards*, 1-19. https://doi.org/10.1007/s11069-024-06653-7

Mainali, J. and Pricope, N. G. (2018). Mapping the need for adaptation: assessing drought vulnerability using the livelihood vulnerability index approach in a mid-hill region of Nepal. *Climate and Development.* https://doi.org/10.1080/17565529.2018.1521329

Moktan, S., Kafle, K. R. & Chapagain, S. (2022). Social vulnerability assessment to natural hazards in western Nepal. *Sustainable Cities and Resilience: Select Proceedings of VCDRR 2021, Springer,* 103-114.

National Disaster Risk Reduction and Management Authority. (2023). *Bipad Portal.* Government of Nepal. Retrieved from https://www.bipad.gov.np

National Statistical Office. (2021). *National population and housing census 2021.* Government of Nepal. Retrieved from https://censusnepal.cbs.gov.np.

Pathak.S., Panta.H.K., Bhandari.T., Paudel.K.P. (2020). Flood vulnerability and its influencing factors. *Natural Hazards*, 104, 2175-2196. https://doi.org/10.1007/s11069-020-04267-3

Spielman, S. E., Tuccillo, J., Folch, D. C., Schweikert, A., Davies, R., Wood, N., & Tate, E. (2020). Evaluating social vulnerability indicators: criteria and their application to the Social Vulnerability Index. *Natural hazards*, *100*, 417-436. https://doi.org/10.1007/s11069-019-03820-z

Tasnuva, A., Hossain, M. R., Salam, R., Islam, A. R. M. T., Patwary, M. M., & Ibrahim, S. M. (2021). Employing social vulnerability index to assess household social vulnerability of natural hazards: An evidence from southwest coastal Bangladesh. *Environment, Development and Sustainability*, *23*, 10223-10245. https://doi.org/10.1007/s10668-020-01054-9

United Nations International Strategy for Disaster Reduction. (2005). *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters.* https://www.unisdr.org/wcdr

Yang, S., He, S., Du, J., & Sun, X. (2015). Screening of social vulnerability to natural hazards in China. *Natural Hazards*, *76*, 1-18. https://doi.org/10.1007/s11069-014-1225-1

Zhao, Y., Paul, R., Reid, S., Coimbra Vieira, C., Wolfe, C., Zhang, Y., & Chunara, R. (2024). Constructing social vulnerability indexes with increased data and machine learning highlight the importance of wealth across global contexts. *Social Indicators Research*, 1-19. https://doi.org/10.1007/s11205-024-03386-9