“Assessment of Climate Induced Disaster in Kathmandu Valley”

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Abstract

Kathmandu Valley faces escalating vulnerability to climate induced hazards, notably flood and urban flash floods, driven by rapid urban expansion, topographic complexity, and shifting climatic trends. This study employs a GIS-based Multi-Criteria Decision Analysis (MCDA) integrated with the Analytic Hierarchy Process (AHP) to spatially assess flood vulnerability across the valley. Key biophysical and socio-environmental indicators including precipitation, proximity to watercourses, topographic wetness, elevation, land use/land cover (LULC), and population density were weighted and analyzed to generate a comprehensive flood risk map.

Results reveal precipitation as the dominant driver of flood risk, followed by river proximity and built-up land concentration. The LULC map underscores the surge in impervious surfaces in core urban zones, amplifying surface runoff and flood susceptibility. Conversely, forested and elevated peripheral areas exhibit natural resilience.

The findings provide critical spatial intelligence for urban planners, disaster risk managers, and policymakers, offering a robust framework for fostering climate-resilient urban development and targeted flood mitigation strategies.

***Keywords**: Climate induced Disaster, Flood vulnerability, Kathmandu Valley, Climate change, Land Use Land Cover (LULC), GIS, Analytic Hierarchy Process (AHP), Disaster risk reduction, Spatial analysis*

Acronyms

AHP: Analytic Hierarchy Process

CAPA: Community Adaptation Plan of Action

CBA: Community-Based Adaptation

CR: Consistency Ratio

CI: Consistency Index

DEM: Digital Elevation Model

DHM: Department of Hydrology and Meteorology

DRR: Disaster Risk Reduction

FGD: Focus Group Discussion

GIS: Geographic Information System

GLOF: Glacial Lake Outburst Flood

ICIMOD: International Centre for Integrated Mountain Development

KIIs: Key Informant Interviews

LULC: Land Use Land Cover

MCDA: Multi-Criteria Decision Analysis

MOFE: Ministry of Forests and Environment

NPC: National Planning Commission

OWL: Open Woodland and Grassland Land Use

RI: Random Index

TWI: Topographic Wetness Index

UNFCCC: United Nations Framework Convention on Climate Change

WRF: Weighted Risk Factor

1. INTRODUCTION

Climate Change and Environmental Challenges

Climate change is a global phenomenon with profound environmental, social, and economic consequences. Rising global temperatures, unpredictable weather patterns, and increasing frequency of extreme climate events have significantly impacted ecosystems and human settlements (Reichle, 2020). Developing nations, including Nepal, face heightened vulnerability due to limited adaptive capacity and dependence on climate sensitive sectors such as agriculture, forestry, and tourism (Ayers & Dodman, 2010).

Nepal ranks among the most climate affected countries, placed fourth on the Global Climate Risk Index in 2017 (Eckstein et al., 2021). Its diverse topography, ranging from the high Himalayas to the lowland Terai, increases susceptibility to various climate induced disasters such as floods, landslides, droughts, and glacial lake outburst floods (GLOFs) (Parry, 2007). Between 1972 and 2016, Nepal recorded over 16 major climate-related disasters, significantly affecting agriculture, infrastructure, and livelihoods (Adhikari, 2018). The rise in temperature, erratic precipitation, and glacier melt have exacerbated Nepal's vulnerability, leading to water scarcity, loss of biodiversity, and soil erosion (Nepal & Kadayat, 2024).

Research conducted by Hejoyoo et al. (2023) in the study "Assessments of Climate Change Indicators, Climate Induced Disasters, and Community Adaptation Strategies: A Case from High Mountain of Nepal" highlights how climate indicators, such as rising temperatures and shifting precipitation patterns, directly contribute to an increase in climate induced disasters. The study emphasizes the need for integrating community-based adaptation strategies, as these approaches have proven effective in minimizing the risks of disasters in high-mountain regions.

Climate induced Disasters in Kathmandu Valley

Kathmandu Valley, the political and economic hub of Nepal, faces unique climate-related challenges due to rapid urbanization, environmental degradation, and weak disaster preparedness mechanisms (Thapa, 2009). The valley is increasingly susceptible to floods, heat waves, and landslides due to unregulated land use, deforestation, and inadequate drainage systems (Shrestha et al., 2021). 25 meteorological stations around the country recorded record-high 24-hour rainfall totals as a result of the unprecedented rainfall that fell on central

Nepal from September 26 to 28, 2024. More than 60 hours of continuous rain triggered landslides and debris flows, severely affecting the Kathmandu Valley and the outskirts (DHM,2024). The urban heat island effect, a result of reduced green spaces and increased concrete infrastructure, has intensified temperature fluctuations, making Kathmandu more prone to extreme heat events (Chidi, 2025).

Findings from the study by Shrestha et al. (2013) suggest that adaptation measures applied in the high-mountain regions, such as reforestation and improved irrigation techniques, could also be effective in Kathmandu Valley. These measures could mitigate urban heat, reduce flood risks, and improve water retention capacity in the valley's rapidly expanding urban landscape.

Despite growing awareness, the specific vulnerabilities of Kathmandu Valley to climate induced disasters remain under-researched. While various community-based adaptation strategies have been implemented, empirical evidence on their effectiveness and sustainability is limited (Khadka et al., 2018). The Analytical Hierarchical Process (AHP) provides a structured framework for assessing disaster risk by integrating multiple criteria such as environmental, socio-economic, and infrastructural factors (Saaty, 2001). By applying AHP methodologies, this study aims to assess the impacts of climate induced disaster identify high-risk zones Kathmandu Valley.

1.2 Research Objectives

General Objective is to

- Assess and map major climate induced disaster

Specific Objectives are to

- Assess the socio-economic impacts of climate induced disaster
- Derive disaster risk Map

2. Literature Review

2.1 Global and National Perspectives on Climate induced Disasters

Globally, climate induced disasters have grown in intensity and frequency due to accelerated global warming. Developing nations, especially in South Asia, are disproportionately affected, with economic and human losses exacerbated by weak governance and inadequate infrastructure (DPNet, 2008). Nepal's case is particularly severe due to its fragile mountain ecosystems, erratic monsoon patterns, and heavy dependence on natural resources.

In Nepal, the recorded rise in temperature is nearly twice the global average, and changes in precipitation patterns have increased the likelihood of both droughts and flash floods (Chaudhary & Bawa, 2011). The vulnerability is further magnified by poverty, limited institutional capacity, and insufficient implementation of environmental policies (Parry, 2007).

Research by Heyojoo et al. (2022) conducted in the high mountain regions of Nepal reported increasing instances of glacial melting, drying water sources, and loss of alpine biodiversity. Their study emphasized how traditional farming systems and livelihood practices are being disrupted, prompting the need for adaptive strategies. These findings provide a relevant lens through which to examine similar vulnerabilities in the urban context of Kathmandu.

2.2 Urbanization and Climate Resilience in Kathmandu Valley

Urban expansion in Kathmandu valley has significantly increased susceptibility to flooding and landslides (PreventionWeb, 2024). Unregulated construction and deforestation have intensified soil erosion and surface runoff, making the valley more prone to disaster impacts (Chidi, 2025). In response, various initiatives have been introduced, such as watershed conservation projects and afforestation programs. However, these efforts have faced challenges due to a lack of coordination between government agencies and local communities (Shrestha et al., 2023).

One effective tool for prioritizing disaster risk reduction strategies is the Analytic Hierarchy Process (AHP), a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology (Saaty, 1980). AHP has been employed in environmental management, including flood risk mapping, urban land-use planning, and prioritizing mitigation efforts.

For instance, studies by Chaulagain et al. (2023) used AHP to identify high-risk zones in Kathmandu Valley based on factors such as elevation, slope, land use, population density, and proximity to rivers. The method enables decision-makers to quantify subjective preferences and compare various risk attributes in a hierarchical model.

By incorporating AHP into local disaster management frameworks, stakeholders can develop more nuanced and context-specific strategies. It supports transparent, inclusive decision-making that aligns with both scientific evidence and community priorities.

2.3 Community Perception and Adaptation Strategies

Community-based adaptation (CBA) has been recognized as a practical and inclusive method for reducing climate vulnerability. According to Khadka et al. (2018), the Community Adaptation Plan of Action (CAPA) incorporates participatory tools and local knowledge to enhance adaptive capacity through a bottom-up planning approach.

In peri-urban Kathmandu, communities have adapted traditional practices such as indigenous irrigation systems and water conservation methods to cope with erratic rainfall and water shortages (Shrestha et al., 2013). Chaudhary and Bawa (2011) also observed that increased local awareness of climate change is linked to improved preparedness and proactive adaptation behaviors.

Nevertheless, the long-term effectiveness and scalability of these community-driven strategies remain underexplored, especially amid rapid urbanization and socio-economic changes.

2.4 Policies Addressing Climate Change and Climate-Related Disasters

Nepal has developed a robust framework of policies to address climate change and its associated disasters, driven by its high vulnerability to climate impacts and international commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The National Climate Change Policy (2019), issued by the Ministry of Forests and Environment (MOFE), serves as a cornerstone, aiming to enhance climate resilience, promote low-carbon development, and integrate climate adaptation into sectoral planning (MOFE, 2019). The policy emphasizes mainstreaming climate change adaptation (CCA) and disaster risk reduction (DRR) into national and local development plans, with specific provisions for vulnerable regions like Kathmandu Valley.

The National Adaptation Programme of Action (NAPA, 2010) and the subsequent National Adaptation Plan (NAP, 2021) outline strategies to address climate-induced hazards, including floods, landslides, and urban heatwaves, which are prevalent in Kathmandu Valley. NAPA prioritizes community-based adaptation (CBA) and identifies Kathmandu as a critical area due to its rapid urbanization and flood susceptibility (MOFE, 2019). The NAP builds on this by integrating climate risk assessments into urban planning, emphasizing infrastructure resilience and early warning systems (MOFE, 2021). These policies align with the Sendai Framework for Disaster Risk Reduction (2015–2030), which Nepal has adopted to strengthen disaster preparedness and response.

At the local level, the Kathmandu Valley Development Authority Act (1988) and subsequent urban planning regulations have been updated to incorporate climate-resilient measures, such as improved drainage systems and green infrastructure. However, implementation challenges persist due to weak coordination among government agencies, limited funding, and inadequate enforcement of land-use regulations. For instance, the Nepal Urban Resiliency Report (2023) highlights that unregulated urban expansion in Kathmandu Valley has exacerbated flood risks, underscoring the need for stricter zoning laws and watershed management (Climate Action Network South Asia, 2023).

Community-based policies, such as the Community Adaptation Plan of Action (CAPA), have gained traction in peri-urban areas of Kathmandu. These plans empower local communities to implement adaptation measures, such as rainwater harvesting and flood-resistant agricultural practices, as noted by Khadka et al. (2018). The Local Adaptation Plans for Action (LAPA) framework further supports Aesthetics the integration of local knowledge with scientific evidence, ensuring context-specific resilience strategies (MOFE, 2021).

Despite these efforts, policy gaps remain. Chaudhary et al. (2024) argue that Nepal's climate policies often lack sufficient focus on urban-specific challenges, such as the urban heat island effect and inadequate drainage systems in Kathmandu. Strengthening inter-agency coordination, increasing investment in climate-resilient infrastructure, and enhancing community participation are critical to bridging these gaps and ensuring effective disaster risk reduction in Kathmandu Valley.

2.5 Analytic Hierarchy Process (AHP) in Disaster Risk Assessment

The Analytic Hierarchy Process (AHP), introduced by Saaty (1980), is a powerful decision-support tool that structures complex problems through pairwise comparisons and priority setting. In recent years, AHP has been widely applied in the field of environmental and disaster management. It allows the integration of both quantitative and qualitative data, which is particularly useful in regions like Nepal where data availability may be limited.

Studies such as Chaulagain et al (2023) have demonstrated the effectiveness of AHP in flood risk mapping in Kathmandu Valley, incorporating variables such as elevation, slope, land use, and proximity to water bodies.

More recently, Subedi et al. (2023) applied AHP to evaluate landslide susceptibility in hilly regions Nepal. Their findings emphasized the importance of slope aspect, land cover, and rainfall intensity as critical parameters. These AHP applications are now guiding policy decisions for urban development and disaster preparedness in Nepal.

As climate change continues to amplify risks in the Kathmandu Valley, integrating AHP into existing planning frameworks can enhance evidence-based, participatory decision-making. The flexibility of AHP to accommodate expert judgment and local knowledge makes it particularly valuable in contexts like Nepal, where topographical and socioeconomic diversity complicate standard planning models.

3. MATERIALS AND METHODS

3.1. Study Area

Kathmandu Valley, located in central Nepal, encompasses an area of 613 to 665 km² with elevations ranging from 1200 to 2722 meters above sea level. Characterized by a bowl-shaped topography, the valley comprises three administrative district Kathmandu, Lalitpur, and Bhaktapur, which include major urban centers as well as multiple municipalities (Dangi et al., 2023; Paudel et al., 2023). The valley is intersected by nine rivers, contributing to frequent flooding, especially in Kathmandu and Bhaktapur districts, which have experienced multiple flood events annually since 2016 (Dangi et al., 2023).

The region's subtropical monsoon climate brings heavy seasonal rainfall, exceeding the national average, with 1627 mm recorded in 2021. Additionally, Kathmandu Valley lies near active tectonic faults and consists of soft sediments, making it highly susceptible to earthquake damage (Paudel et al., 2023).

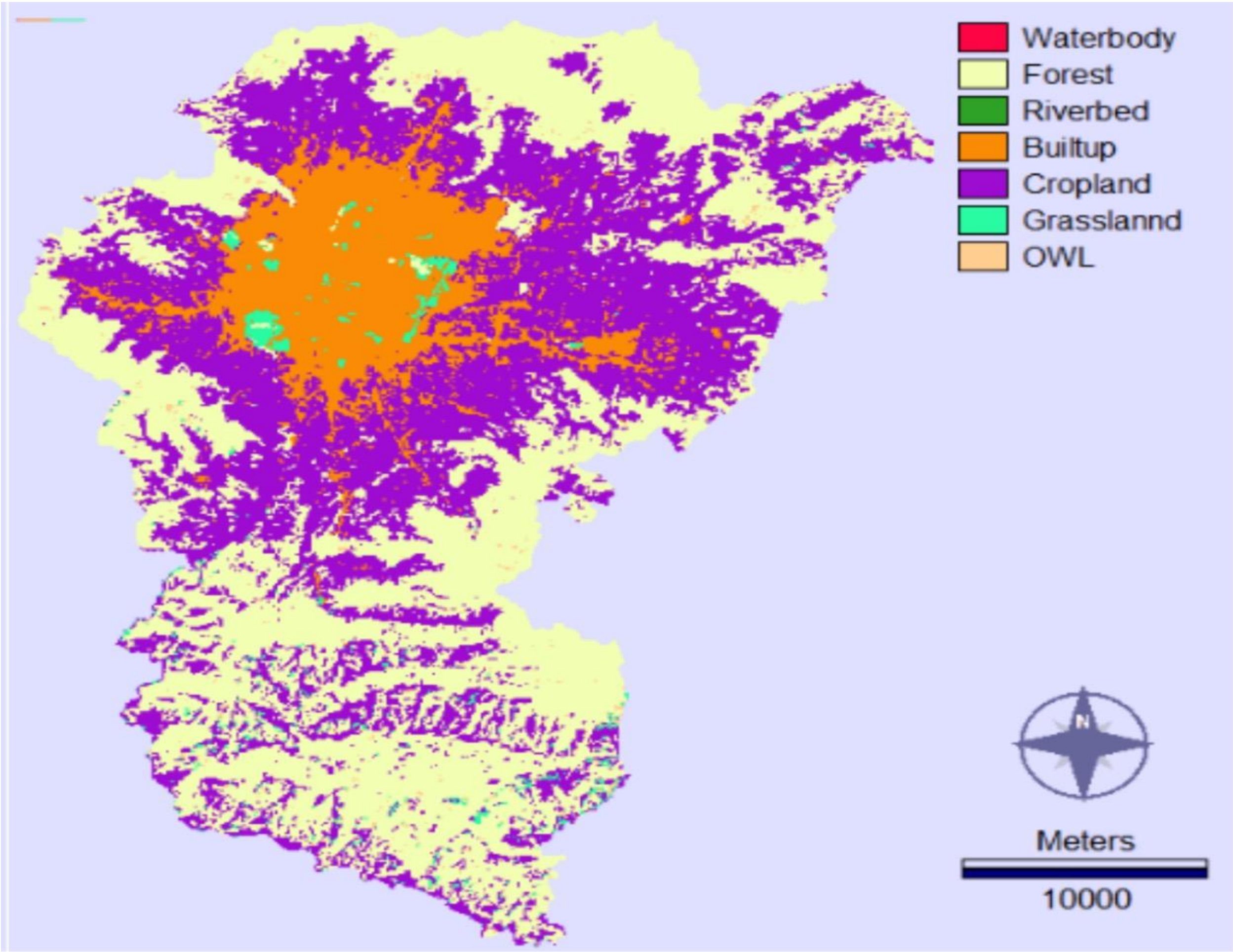

Figure 1: Map of Kathmandu Valley showing LULC

3.2. Methodology

With reference to past literature and expert's opinion, and Key Informant Interviews (kII) out of 4 major climate induced hazard in term of economic loss Flood and forest fire were the major hazard causing maximum economic loss this study considered to map flood risk. Factors were prioritized using a weighted mean by the respondents based on the nature and extent of the problem faced. Out of all the factors, 4 of the major factors are selected and a risk map was created from the weighted overlay method where the weight for the factors is obtained from literature reviews and expert advice.

3.2.1. Flood Vulnerability Factors

Community and infrastructural vulnerability to flooding can be assessed using various indicators depending on the scale of analysis and data availability. Recent flood risk and vulnerability studies have emphasized a combination of demographic, physical, institutional, and adaptive capacity indicators to comprehensively evaluate vulnerability (Dewan, 2013; Kienberger et al., 2014; Singh et al., 2018). However, in data-scarce environments, such as many parts of Nepal, vulnerability assessments often rely on basic indicator most commonly demographic data due to their availability at fine spatial scales, such as census tract levels (Cutter et al., 2003; Tate, 2012).

Specifically, this study selected four key indicators for determining the Flood Vulnerability Index using the Analytic Hierarchy Process (AHP): Distance from river/stream, Topographic Wetness Index, Land Use Land Cover and Precipitation levels. The first indicator reflect the exposure of communities to flooding hazard, for instance, proximity to rivers directly influences the risk and severity of flood impacts while precipitation data, captured as variations in rainfall intensity and frequency, serve as both a hazard trigger and an indirect measure of flood recurrence.

The selection of these indicators aims to support high-resolution flood vulnerability mapping across the Kathmandu Valley through the Analytical Hierarchy Process (AHP) framework. Data for these indicators were gathered from several open data platforms and hydro meteorological datasets.

3.2.1.1 GIS data acquisition and layer preparation

Data from various sources for the different variables were collected and a layer was prepared.

Table 1: Geo-spatial indicators

S.N.	Component	Data source
1	Distance from river/stream	Humanitarian Data
2	Topographic Wetness Index	DEM
4	Precipitation	CHRS Data Portal
5	Land Use Land Cover	ICIMOD

3.2.1.2 Factors, their classes, and rankings Table

Table 2: Factors their Classes and Ranking

S.N.	**Factors**	**Classes**	**Ranking**
1	Distance from river/stream	<200	4
		200-400	3
		400-600	2
		600-800	1
		>800	0
2	Annual Precipitation	<1350	0
		1350-1450	1
		1450-1550	2
		1550-1650	3
		>1650S	4
3	Land Use Land Cover	Forest	4
		cropland	3
		Built-up area	2
		Water bodies	1
		Bare lands	0
4	Topographic Wetness Index	<4	0
		4-8	1
		8-12	2
		12-16	3
		>16	4

3.2.1.3 Re-class variables

The variable thus selected and prepared data in GIS were classified using Euclidian distance under the distance of spatial analyst tools. The result so obtained was reclassified into equal intervals except for distance from the water area as per the opinion of respondents from the affected household survey.

Weighting the criteria using Analytical Hierarchical Process

After the indicators were set the weightage to be assigned were determined by the help of AHP. For estimating the weightage the pairwise comparison matrices were prepared. We need a scale of numbers to do pair wise comparisons matrices because it tells us how much more significant or dominant one element is than another one in relation to the criterion or feature being compared (Saaty, 2008). With the help of nine-point scale of relative importance Saaty scale which is shown in *Table 3*, the weightage of different criteria and indicators were obtained (MOFE, 2021a). The pair wise matrices for all criteria and indicators can be seen in the Annex 3.

Table 3: Showing the intensity and scale of importance

Intensity of Importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

Measuring the consistency

Because the AHP method relies on individual judgment, the expert's and users' assessments are vulnerable to personal preferences and subjectivity, increasing the risk of inaccuracy in their conclusions (Emmanuel et al., 2018). So, it is very necessary to do the consistency test to evaluate the consistency of the comparative judgments.

The consistency ratio is calculated during pair wise correlation matrix by calculating the consistency index which can be determined by the below given formula:

Consistency Index (CI) = $\frac{\lambda max - n}{n-1}$

After consistency index is determined, consistency ratio is calculated by dividing consistency index by Random Consistency Index (RI). Consistency ratio is given by the equation where RI is the standard value based on the number of criteria employed in various study performances (R. W. Saaty, 1987).

Consistency Ratio= $\frac{Consistency\ Index(CI)}{Random\ Consistency\ Index\ (RI)}$

The consistency ratio for the indicators of the components i.e. exposure, sensitivity and adaptive capacity was **0.09** which is accepted since the observed incontinency has a tolerability limit of 0.1 (Saaty, 1987).

4. RESULT AND DISCUSSIONS

Frequency of Hazard

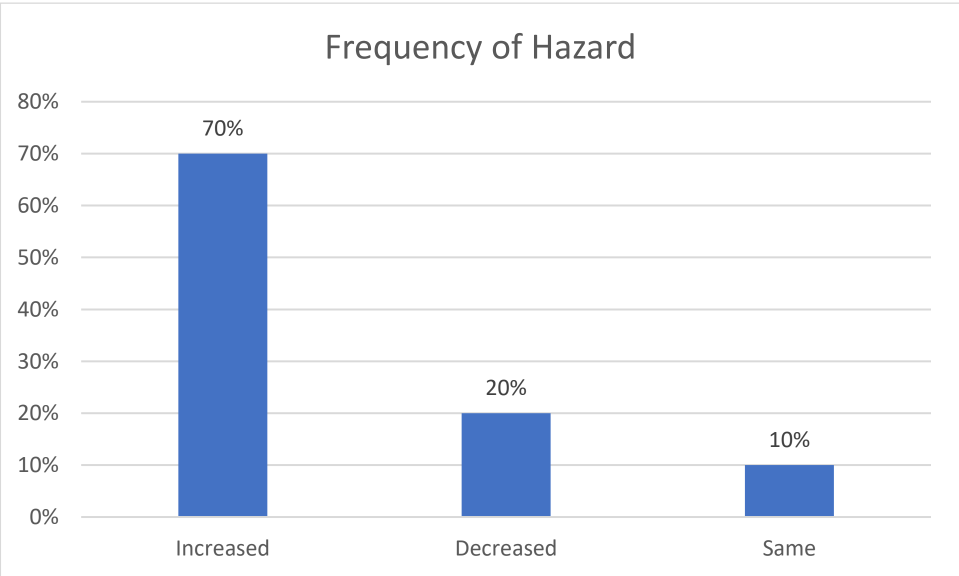

Figure 2: Frequency of Hazard

Figure 3: Frequency of Hazard

The survey results indicate that the majority of respondents report an increasing impact of the hazard over time, reflecting growing concerns about the severity and frequency of the disaster. This suggests that many individuals feel that the hazard has become a more pressing issue in recent years, potentially due to climate change, urbanization, or inadequate mitigation efforts. In contrast, 20% of respondents perceive a decreasing trend in the hazard's impact, which could indicate improvements in local resilience, better disaster management, or reduced vulnerability in certain areas. However, 10% of respondents feel no significant change, suggesting either limited exposure to the hazard or a lack of awareness of the evolving risk. These findings highlight the need for tailored disaster risk reduction strategies that address the varying perceptions and experiences of hazard impacts within the community.

Coping Strategies

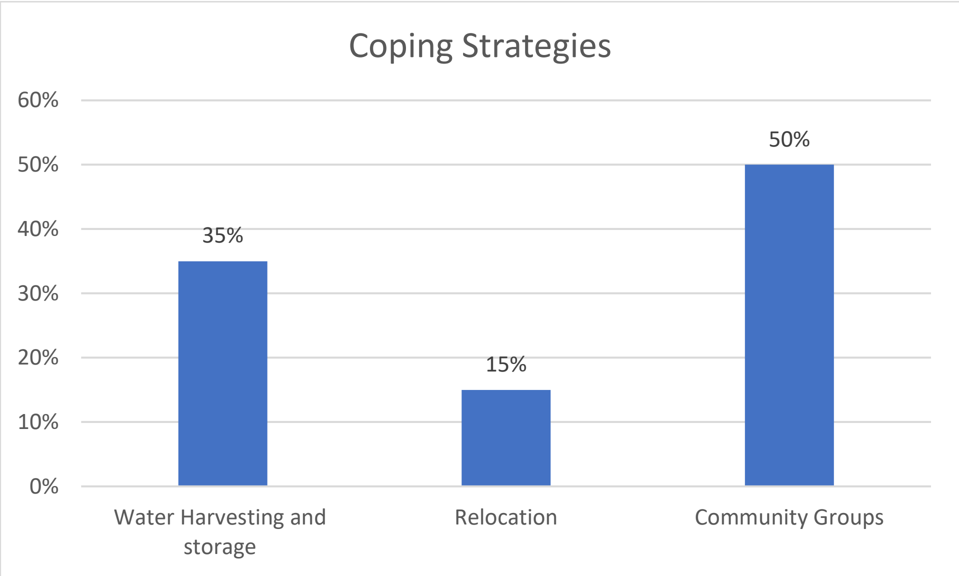

Figure 4:Coping Strategies

The survey results indicate that communities in Kathmandu Valley adopt a range of strategies to cope with hazard risks, with a strong emphasis on collective and adaptive responses. Notably 50% of the respondents identified community groups as their primary flood coping strategy, reflecting strong reliance on social networks and collective action. Water harvesting and storage systems were chosen by 35%, indicating a growing focus on sustainable, infrastructure-based solutions. A smaller proportion (15%) preferred relocation, suggesting it is considered a last resort due to associated social and economic challenges. Overall, the data highlight a preference for local, adaptive strategies that strengthen in-place resilience over displacement.

Perceptions on Government Response to Disaster

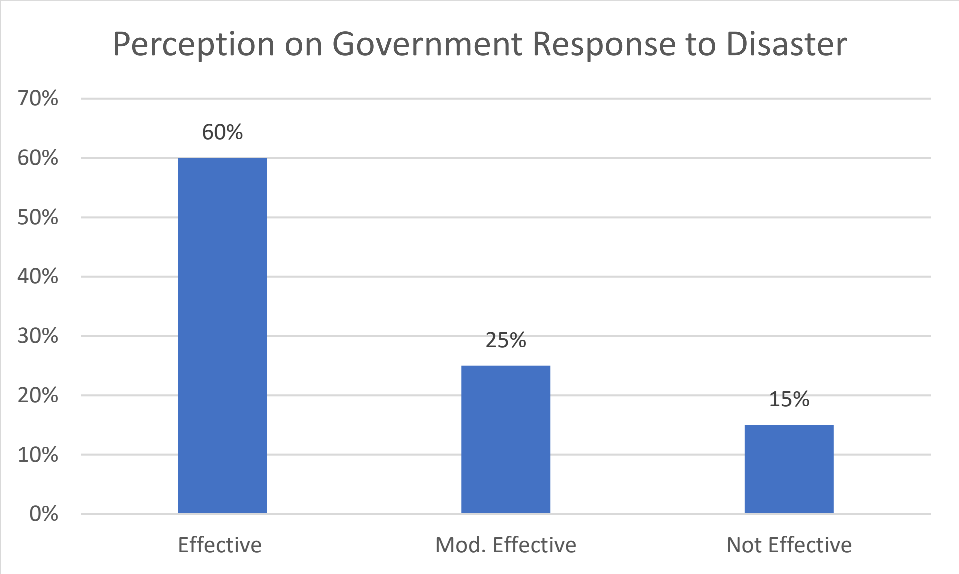

Figure 5:Perceptions on Government Response to Disaster

The survey results indicate that 60% of respondents in the Kathmandu Valley perceive the government's disaster response as effective, suggesting a generally positive evaluation of relief efforts, timely assistance, and coordination. However, 25% of respondents feel the response was moderately effective, pointing to potential gaps in service delivery, accessibility to remote areas, and coordination among agencies. A smaller portion (15%) views the response as ineffective, reflecting concerns over inadequate preparedness, slow aid distribution, and possible mismanagement of resources. These findings highlight the need for improved infrastructure, better coordination, and enhanced disaster preparedness to address the specific challenges of the Kathmandu Valley, ensuring a more efficient and equitable response in future disasters.

Impact of Climate Induced Disaster

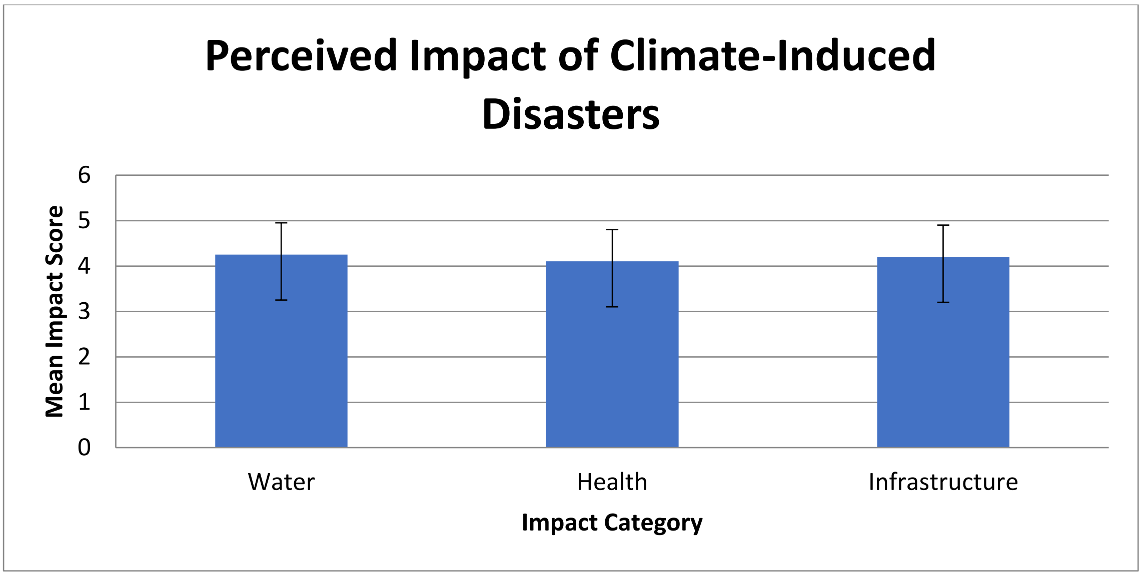

Figure 6: Perceived Impact of Disaster

The bar chart, which illustrates the mean perceived impacts of climate induced disasters on key sectors in the Kathmandu Valley, reveals critical insights into local vulnerability patterns. Among the sectors evaluated, water resources exhibit the highest mean impact score (4.25), indicating a widespread recognition of the sector's sensitivity to climate variability and extremes such as erratic rainfall, prolonged droughts, and flooding events. This is consistent with the region's persistent challenges in water availability, quality, and distribution. Infrastructure follows closely with a mean score of 4.20, highlighting significant concerns over the susceptibility of roads, drainage systems, and urban structures to climate induced hazards, particularly in the context of unplanned urban expansion and fragile topography. Health is also perceived to be significantly affected, with a mean score of 4.10, reflecting concerns related to heat stress, vector-borne diseases, and mental health implications arising from climate shocks. The inclusion of standard deviation as error bars further strengthens the analysis; all three sectors show relatively low variability (ranging from 0.62 to 0.70), indicating a strong consensus among respondents regarding the severity of these impacts. Overall, the chart underscores a high level of perceived vulnerability across all sectors, reinforcing the urgency of integrated adaptation planning and resilience-building strategies in the Kathmandu Valley.

Climate Analysis

The temperature and rainfall data were downloaded from Worldclim for the study areas. Climatic analysis was done from the data obtained from nearest meteorological stations for study area to verify it with the data obtained from Worldclim.

Temperature

As per the data from Department of Hydrology and meteorology average normal maximum and minimum annual temperature of past 30 years (1991-2020) is 26 degree Celsius and 12.5 degree Celsius respectively

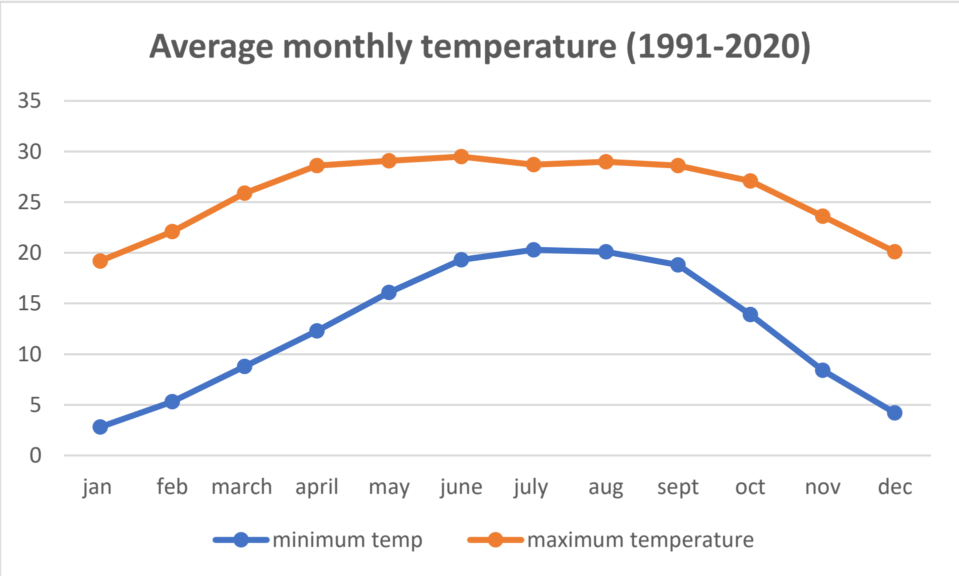

Figure 7: Average monthly temperature (1991-2020)

The average monthly temperature data from DHM (1991–2020) shows a clear seasonal pattern, with temperatures gradually rising from January and peaking during the summer months (June to August), followed by a decline toward December. Maximum temperatures reach around 30°C in the summer, while minimum temperatures rise to about 20°C. These warm months align with Nepal's pre-monsoon and monsoon periods, during which temperature-driven processes play a significant role in influencing flood risks.

High temperatures during the spring and summer months accelerate snow and glacier melt in the Himalayas, increasing river discharge just before and during the monsoon season. When combined with intense monsoon rainfall, this can lead to severe flooding, particularly in downstream areas. Additionally, warmer temperatures can lead to dry spells that harden the soil, reducing infiltration and increasing surface runoff during heavy rains—contributing to flash floods and urban flooding. Therefore, temperature trends, alongside precipitation and land conditions, are important factors in understanding and managing flood hazards in Nepal.

Rainfall

As per the data from Department of Hydrology and meteorology average normal annual precipitation of past 30 years (1991-2020) is 1502.5mm. Similarly the annual precipitation of 2023 and 2024 was observed to be 1623.61and 1964.73 respectively. This shows the valley receives more than the average annual rainfall of Nepal making the watershed largely prone to water induced disaster.

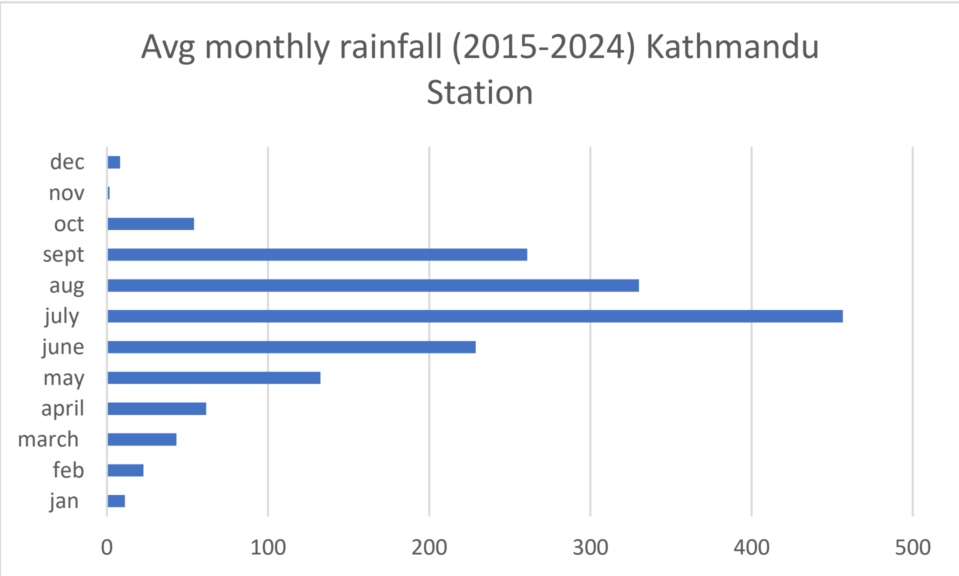

Figure 8: Avg monthly rainfall (2015-2024) Kathmandu Station

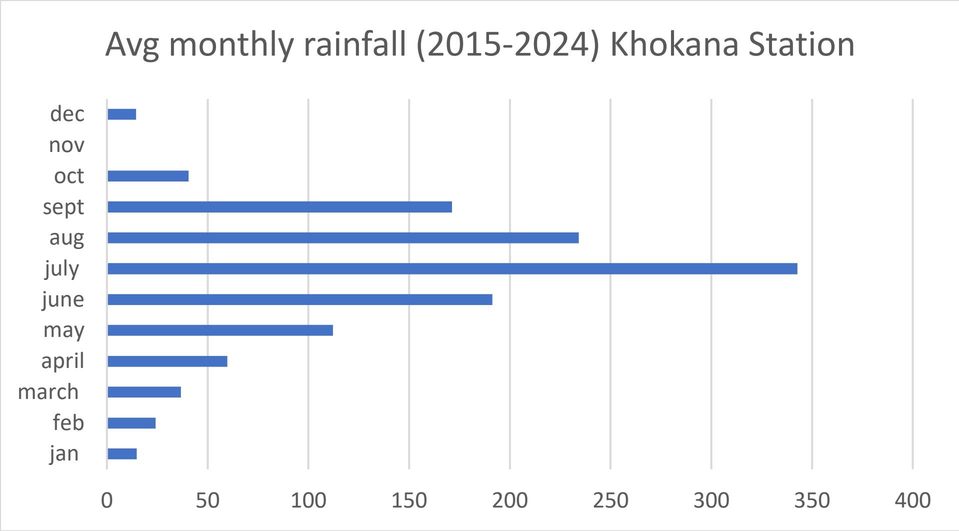

Figure 9: Avg monthly rainfall (2015-2024) Khokana Station

The trend in both the stations show the rainfall intensity during July is the highest with June, July, August and September as a month with high rainfalls.

Trend of rainfall

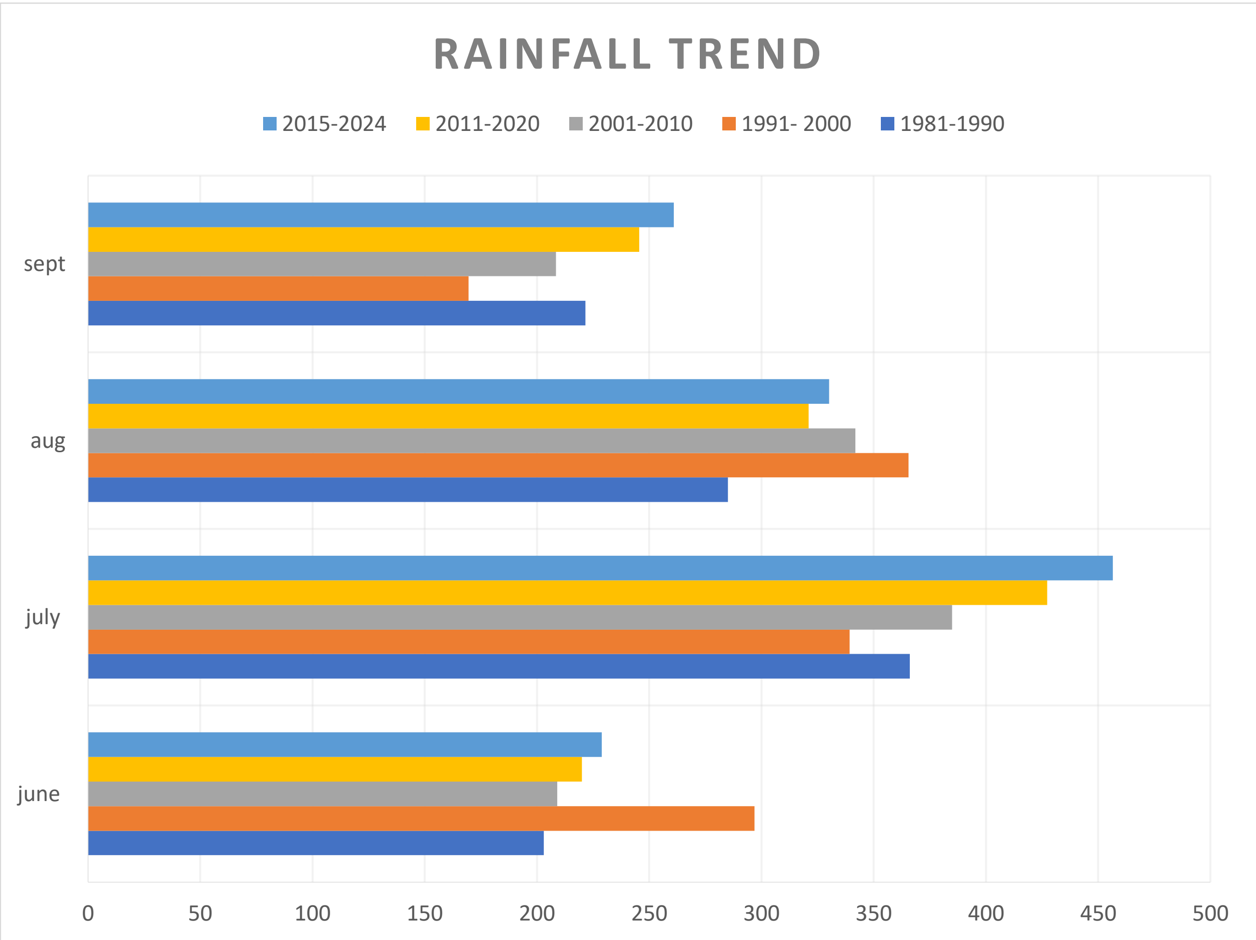

Figure 10: Rainfall Trend of Kathmandu Valley

The rainfall trend data from 1981 to 2024 during the months of June, July, August and September indicates a significant shift in both the intensity and distribution of monsoon precipitation, which has direct implications for flood risk in Nepal. Notably, July has consistently received the highest rainfall, increasing from 366.1 mm in the 1980s to 456.5 mm in recent years (2015–2024). This sharp rise suggests a growing intensity of mid-monsoon storms, which can aggravate natural drainage systems and riverbanks, especially in densely populated and low-lying areas. September rainfall has also increased, from 221.6 mm to over 260 mm, signaling a prolongation of the monsoon season and enhancing the risk of late-season flooding when soils are already saturated and river levels are high.

While rainfall in June and August has fluctuated, the overall pattern reveals that heavy and concentrated rainfall is becoming more common, particularly in the mid to late monsoon months. This trend, combined with rising temperatures that accelerate snowmelt, amplifies flood hazards, especially in river basins and urban centers like the Kathmandu Valley. The variability and increasing unpredictability of rainfall not only raise the risk of flash floods and riverine floods but also complicate flood preparedness and disaster response. These trends underscore the urgent need for climate-resilient urban planning, improved drainage infrastructure, and integrated flood management strategies in Kathmandu Valley.

Risk Mapping

For vulnerability mapping first of all the criteria weights for all components and their indicators were estimated using pair wise matrix as shown in the Annex 3.

Weightage estimation

The criteria weights which of the different criteria and indicators are presented below.

Factors	Criteria weight	Priority percentage
Distance from river/stream	0.26	26%
Urbanization	0.07	7%
Precipitation	0.53	53%
Land Use Land Cover	0.14	14%

Figure 11: Factors and their weight

Precipitation Map

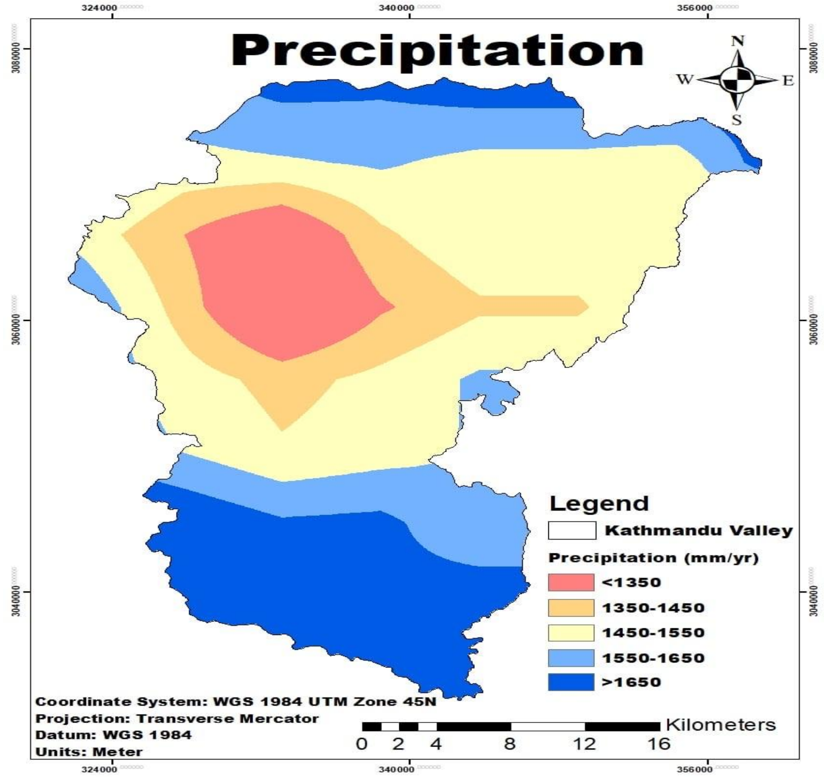

Figure 12: Precipitation Map

The map shows a higher concentration of precipitation in central and southeastern areas of the Valley, particularly around the Bagmati and Hanumante river basins. These zones experience the most intense monsoon rainfall, making them highly susceptible to flash floods and seasonal waterlogging. The pattern also correlates with temperature-induced snowmelt from nearby upland regions, which contributes to increased runoff during the pre-monsoon and monsoon seasons. The spatial variation in precipitation, captured through data from CHRS and other meteorological sources, clearly indicates the hydrological stress imposed on low-lying and densely populated settlements. The high rainfall zones overlap with urban sprawl areas, compounding flood risks due to impermeable surfaces and inadequate drainage. This map, therefore, not only reflects climatic trends but also highlights zones where rainfall intensity and lack of absorption capacity increase the frequency and severity of floods. The precipitation pattern justifies its highest weightage (53%) in the AHP model, emphasizing its role as the most critical factor in flood vulnerability across Kathmandu Valley.

Topographic Wetness Index Map

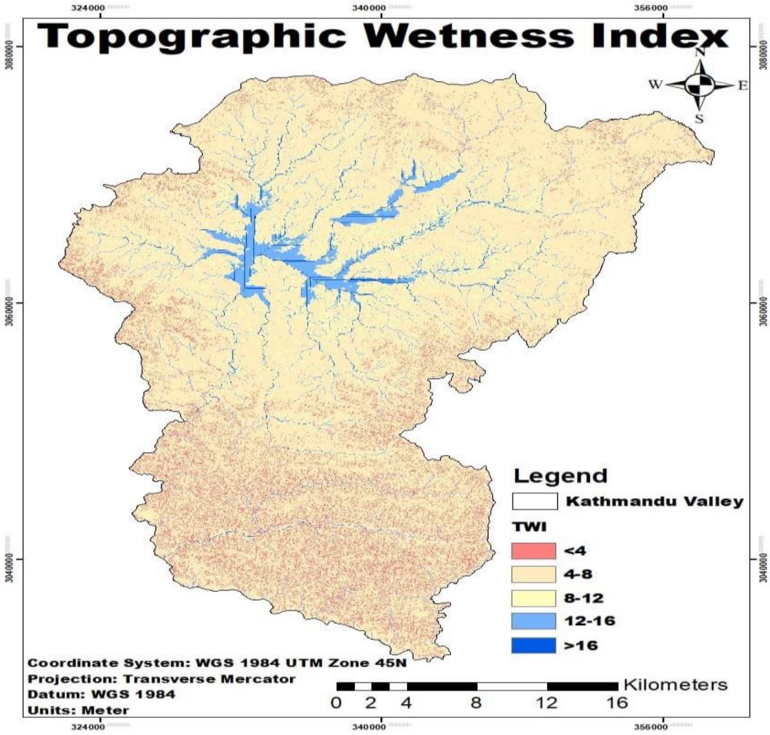

Figure 13: Topographic Wetness Index Map

The Topographic Wetness Index (TWI) Map illustrates areas in the Kathmandu Valley where terrain characteristics favor the accumulation of surface water. Derived from digital elevation models (DEMs), TWI represents the influence of slope and upstream contributing area, indicating the potential for water saturation in the soil. In this map, regions with high TWI values mainly flat, low-lying areas correlate with zones prone to waterlogging and persistent soil moisture. Such areas include parts of Bhaktapur, the floodplains of the Bagmati River, and southern stretches of the Valley. These zones are particularly susceptible to flash flooding during periods of intense rainfall due to limited natural drainage. Conversely, high-elevation zones like Budhanilkantha and Kirtipur exhibit low TWI values, suggesting better runoff dispersion and reduced flood vulnerability. The TWI map serves as a crucial tool for understanding surface hydrology and identifying areas where water stagnation could exacerbate flood risks. When integrated with land use and rainfall data, TWI offers deeper insights into the valley's flood dynamics, supporting targeted interventions such as green infrastructure, wetland conservation, and improved stormwater management in critical areas. It also reinforces the importance of topographical planning in climate-resilient urban development.

Distance From Watercourses Map

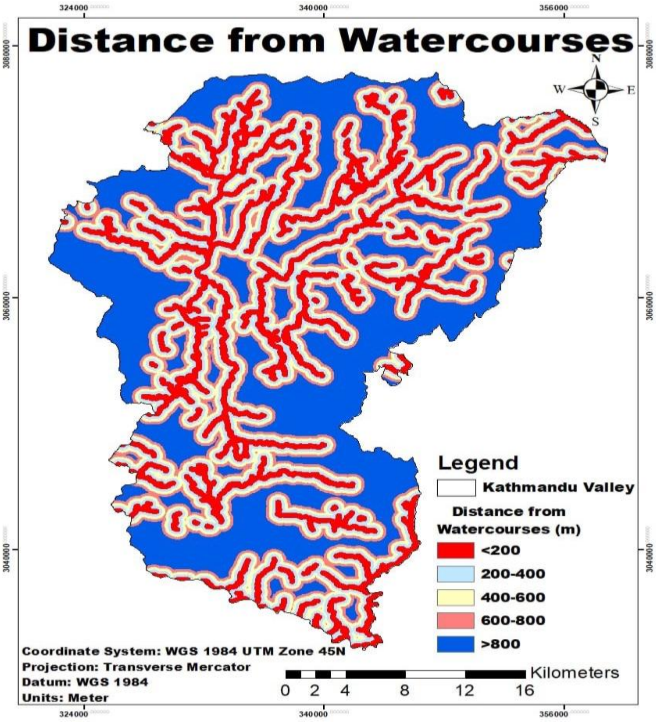

Figure 14: Distance From Watercourses

The Distance from Watercourses Map visualizes the spatial proximity of different areas within Kathmandu Valley to rivers and streams, a key determinant in assessing flood risk. This map was developed using Euclidean distance analysis in GIS, categorizing zones based on their linear distance from major water bodies, including the Bagmati, Bishnumati, Manohara, and Hanumante rivers. Areas located within 200 meters of these watercourses such as Teku, Balkhu, Thapathali, and Bhaktapur fall into the highest risk category due to direct exposure to riverine overflow and embankment breaches during peak monsoon periods. These regions also often coincide with dense urban settlements and poorly managed drainage systems, further amplifying flood vulnerability. In contrast, peripheral zones such as Tokha, Gokarna, and Lubhu, situated over 800 meters from watercourses and at relatively higher elevations, show significantly lower flood susceptibility. The map confirms that river proximity not only influences exposure but also intensifies impact severity during flood events. It validates the second-highest priority weight (26%) in the AHP model and serves as a critical input for land-use regulation, zoning, and infrastructure planning. This map is instrumental for disaster risk reduction planning, enabling the identification of buffer zones, early warning zones, and priority areas for embankment reinforcement.

Land Use Land Cover Map

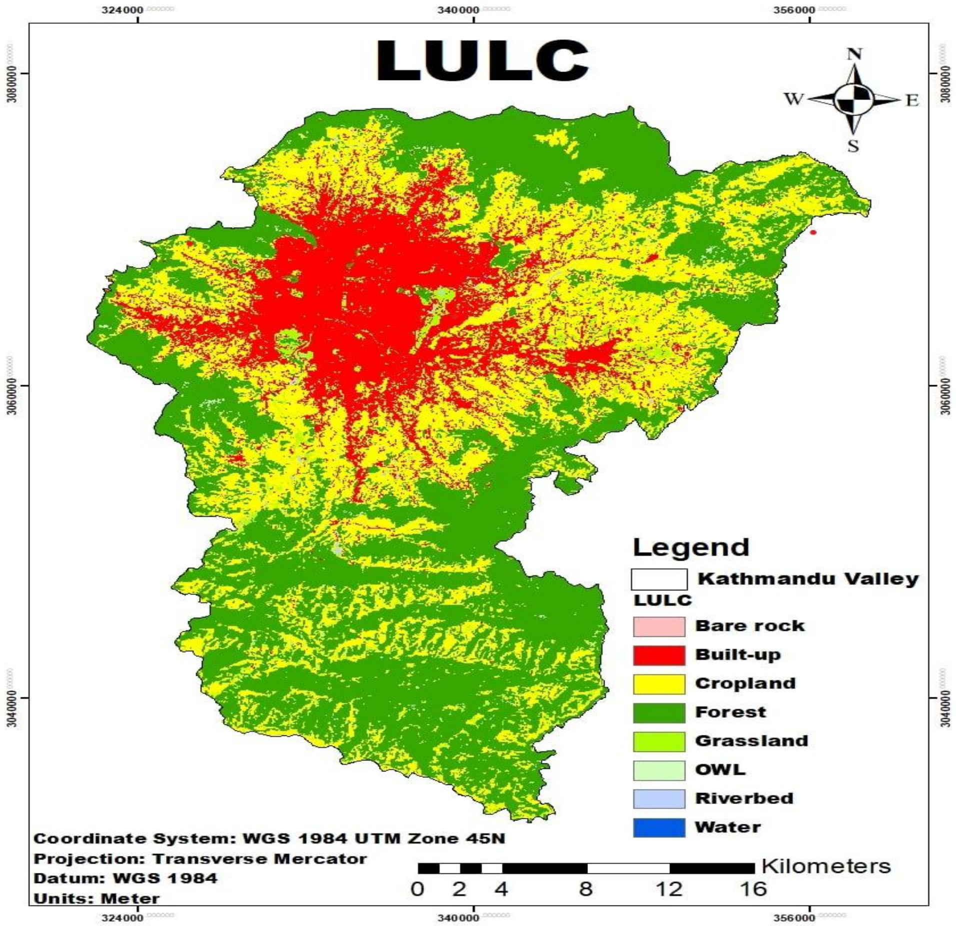

Figure 15: LULC Map

The Land Use Land Cover (LULC) map of Kathmandu Valley illustrates the spatial distribution of various land categories, emphasizing the relationship between land use patterns and flood vulnerability. The central region is heavily dominated by built-up areas (in red), reflecting dense urbanization, especially in Kathmandu, Lalitpur, and Bhaktapur. These areas are highly flood-prone due to reduced infiltration and increased surface runoff. Croplands (yellow) are prevalent around the urban core, contributing moderately to runoff during heavy rainfall events. In contrast, forests (green) and grasslands on the valley's periphery play a crucial role in water retention and flood mitigation. The distribution of riverbeds and water bodies aligns with lower-lying flood-prone zones, reinforcing their importance in risk assessment. Overall, the LULC map highlights the imbalance between ecological land covers and expanding urban areas, underlining the urgency for integrated land use planning to minimize climate induced disaster risks.

Flood Risk Map

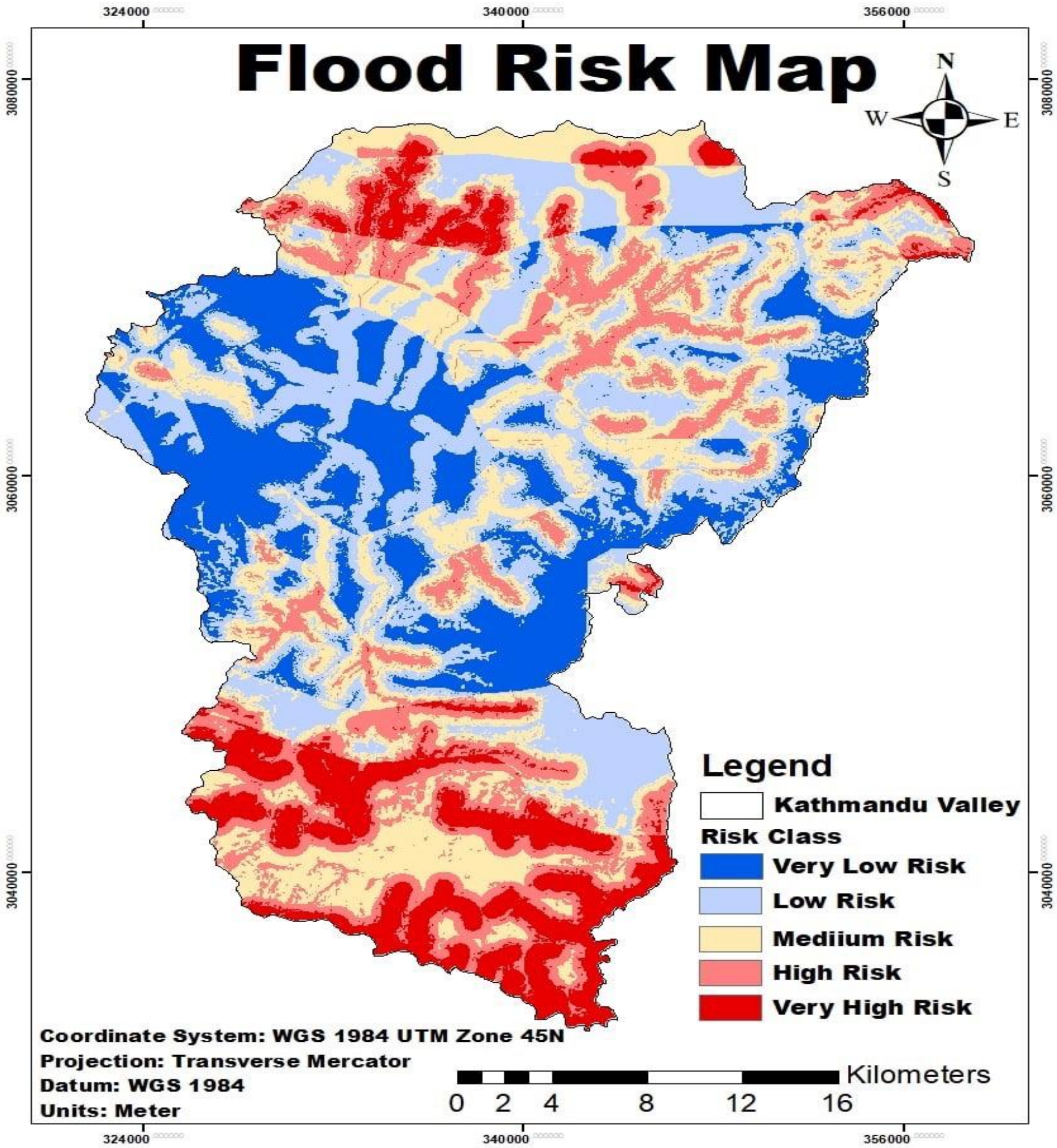

Figure 16: Flood Risk Map

SN	Risk	Area (Sq. KM)
1.	Very Low	180.34
2.	Low	247.22
3.	Medium	231.17
4.	High	167.97
5.	Very High	100.49

The flood risk map of Kathmandu Valley illustrates spatial variations in flood vulnerability based on proximity to major rivers and terrain features. High-risk zones are primarily concentrated along the Bagmati, Bishnumati, Manohara, and Hanumante rivers, affecting densely populated areas such as Teku, Thapathali, Balkhu, and Bhaktapur. These zones are characterized by low elevation and poor drainage, making them highly susceptible to seasonal flooding. Moderate-risk areas, including Patan, Chabahil, and Koteswor, lie adjacent to riverbanks and experience frequent waterlogging during monsoons. In contrast, low-risk zones like Tokha, Gokarna, and Lubhu are located in slightly elevated regions with better runoff dispersion. Elevated outskirts such as Kirtipur and Budhanilkantha are largely free from flood risk. The integration of river networks into the map underscores the critical role of hydrological systems in flood dynamics. This spatial analysis supports informed urban planning, flood-resilient infrastructure development, and targeted disaster preparedness in Kathmandu Valley.

DISCUSSION

Nepal is one of the countries extremely vulnerable to climate change as a result of its physiographic extremes which expose the country to landslides, flash floods GLOFs (Shrestha and Aryal, 2011).The research investigated the impact as well as the risk of flood of the kathmandu valley through multi criteria decision analysis. The study area is remarkably affected by numerous climate induced disaster among which flood and urban flash flood stands first. The result shows the increasing frequency of disaster yet with effective government's response. The result also highlights the perceived impacts of climate induced disasters on key sectors in the Kathmandu Valley, with water resources showing the highest vulnerability (mean score of 4.25) folowed by followed by infrastructure (4.20) and health (4.10). The low variability in responses suggests strong consensus on the severity of impacts across these sectors. Likewise Gautam et al. (2019) in their study also revealed the similar pattern.

Similar to the study conducted by Chaudhary et al. (2024) in Kathmandu valley itself, the annual precipitation of 2023 and 2024 was observed to be 1623.61and 1964.73 respectively. This shows the valley receives more than the average annual rainfall of Nepal making the watershed largely prone to water induced disaster. Along with this the variability and increasing unpredictability of rainfall not only raise the risk of flash floods and riverine floods but also complicate flood preparedness and disaster response. These trends underscore the urgent need for climate-resilient urban planning, improved drainage infrastructure, and integrated flood management strategies in Kathmandu Valley.

Among all the factors Precipitation tends to be the dominant factor causing flood risk in the region, increasing rainfall pattern with the increasing trend of flood event readily supports the fact. This also aligns with Chaudhary et al. (2024) while in the research conducted by khatakho et al. (2021) shows human incursion and lack of effective drainage system, as prime indicators in their flood susceptibility studies in the Valley.

CONCLUSIONS

This study applied a GIS-based Multi-Criteria Decision Analysis (MCDA) integrated with the Analytic Hierarchy Process (AHP) to assess flood vulnerability in Kathmandu Valley. Key indicators precipitation, proximity to rivers, land use/land cover, and topographic wetness were weighted and mapped to identify high-risk areas. Precipitation, with the highest weight (53%), was confirmed as the dominant driver of flood risk.

Spatial analyses revealed that low-lying, densely populated zones near major rivers such as Teku, Thapathali, Balkhu, and Bhaktapur face the greatest flood exposure due to high rainfall, poor drainage, and river proximity. Conversely, elevated areas like Budhanilkantha and Tokha show significantly lower vulnerability. The risk map aligns with community perceptions, which identified water resources, infrastructure, and health as the most impacted sectors.

Overall, the study emphasizes the urgent need for climate-resilient urban planning, improved drainage systems, and targeted flood mitigation efforts, particularly in densely populated flood-prone areas.

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ANNEXES

Annex 1: Key Informant Survey Questionaire

Assessment of Socioeconomic Impacts of Climate induced Hazards in Kathmandu Valley

Respondents Profile

1. Name of Respondent: ______________________________

2. Organization/Institution: __________________________

3. Location (Municipality/Ward): _____________________

Perception on Climate Induced Hazards

4. What major climate induced hazards have affected Kathmandu Valley in recent years?

☐ Floods ☐ Landslides ☐ Heatwaves ☐ Drought ☐ Others (specify): ___________

5. In your opinion, how has the frequency of these hazards changed over the past 10 years?

☐ Increased ☐ Decreased ☐ Remained the same ☐ Don't know

6. How has the severity or impact level of these hazards changed?

☐ Increased ☐ Decreased ☐ No Change ☐ Don't know

Please elaborate: ____

7. Which areas or communities in the valley are most vulnerable to these hazards? Why?

Socioeconomic Impacts

8. What are the major economic impacts of these hazards in your area?

☐ Property loss ☐ Business disruption ☐ Livelihood damage ☐ Infrastructure damage ☐ Other: ____________

9. What are the main social impacts you've observed?

☐ Displacement ☐ School closure ☐ Health problems ☐ Social conflict ☐ Mental stress ☐ Other: ____________

10. Who are the most affected population groups?

☐ Urban poor ☐ Informal settlers ☐ Elderly ☐ Children ☐ Women-headed households ☐ Others: ___________

11. How do these hazards impact access to services? (Rate on a scale of 1 = No impact to 5 = Severe impact)

- Water supply: ___
- Health services: ___
- Transportation: ___
- Education: ___
- Electricity: ___

Community Response and Institutional Support

12. What coping strategies are commonly used by communities during floods or heatwaves?

☐ Temporary relocation ☐ Use of sandbags ☐ Shifting work/school hours ☐ Community support groups ☐ Other: _____________

13. How would you rate the effectiveness of local government in responding to climate hazards?

☐ Very effective ☐ Somewhat effective ☐ Not effective ☐ Don't know

Please explain: ____

14. Are there any existing early warning systems or emergency preparedness plans in your area?

☐ Yes ☐ No ☐ Not sure

If yes, how effective are they? _____________________________

15. What additional resources, interventions, or support are needed to reduce impacts from climate hazards?

Future Risks and Recomendations

16. What future risks do you foresee in relation to climate change in Kathmandu Valley?

17. What recommendations do you have for improving community resilience and reducing socioeconomic impacts?

Annex 2: FGD Questionaire

1. What are the major climate induced hazards your community has faced in recent years?

2. How frequently do these hazards occur and how have they changed over time?

3. What economic activities are most affected by these hazards?

4. How do these hazards impact vulnerable groups (e.g., women, elderly, low-income households)?

5. What coping strategies do households and the community use during these hazards?

6. How effective have local and government interventions been in managing these disasters?

7. What support or resources do you think are most needed to build resilience against these hazards?

8. How does the community participate in disaster preparedness or response planning?

9. Are there any traditional or indigenous practices used to deal with these hazards?

Likert Scale

Respondent_ID	**Flood/Urban Flash Flood**	**Forest Fire**	**Pollution**	**Drought**	**Heatwaves**
Mean	4.6	3.9	2.9	2.65	1.75

Annex 3: Criteria and Indicators

Pair-wise Comparision Matrix						
Factors	Distance from river/stream	urbanization	Precipitation	Landuse land cover	Average (criteria weight)	**λmax**
Distance from river/stream	0.218182	0.285714	0.190476	0.36	0.26	
Urbanization	0.054545	0.071429	0.095238	0.04	0.07	

Precipitation	0.654546	0.428571	0.571429	0.48	0.53	
Landuse land cover	0.072727	0.214286	0.142857	0.12	0.14	
CR: 0.09						4.25

Random Consistency Index

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RCI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59
Source: Adapted from Saaty (1980), pp. 21.													

Nepal Administrative Staff College

Research and Consulting Services Department
Centre for Research and Development

Comment-Address Sheet for Internal Research Report, FY 2081/82

Research Title:	**"Assessment of Climate Induced Disaster in Kathmandu Valley"**
Research Team Member(s):	Sahara Aryal
Date of Evaluation:	2082-02-29

Evaluator's name: Shree Krishna Shrestha		
SN	**Comments**	**Actions taken**
1.	To adress policies	In corporated as suggested
2.		
3.		
4.		
5.		
6.		
7.		

Evaluator's name: Hari Prasad Dhungana		
SN	**Comments**	**Actions taken**
1.	About the elaboration of map	Adressed as suggested
2.		
3.		
4.		
5.		
6.		
7.		

Evaluator's name: Prakash C. Bhattarai		
SN	**Comments**	**Actions taken**
1.		
2.		
3.		
4.		
5.		
6.		
7.		

Evaluator's name: Dr. Rajan Khanal		
SN	**Comments**	**Actions taken**
1.	None	
2.		