FLOOD HAZARD IN BARDIYA, NEPAL: CAUSES, CONSEQUENCES AND EFFECTIVES MITIGATION STRATEGIES

A Thesis

Submitted to the

APF Command and Staff College

Faculty of Humanities and Social Science,

Tribhuvan University

In Partial Fulfilment

For Master's Degree in

Security, Development and Peace Studies

Submitted by

Hari Bahadur Gurung

Eighth Batch (2079-2081)

Roll No. 28MSDPS40050

TU Registration No. 5-1-48-237-96

APF Command and Staff College

Sanogaucharan, Kathmandu, Nepal

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DECLARATION

I hereby declare that this research paper entitled “FLOOD HAZARD IN BARDIYA, NEPAL: CAUSES, CONSEQUENCES AND EFFECTIVE MITIGATION STRATEGIES” submitted to APF Command and Staff College, is entirely my original work prepared under the guidance and supervision of Prof. Dr. Danda Pani Adhikari.

I have made due acknowledgments to all ideas and information cited and extracted from different sources in course of preparing this research. The result of this research paper has not been presented or submitted anywhere else for the award of any degree or any other purpose. I assure that no part of the content of this research paper has been published in any from before. I shall be solely responsible if any evidences found against my research paper.

This thesis is being submitted to APF Command and Staff College, Faculty of Humanities and Social Sciences, Tribhuvan University in Partial Fulfillment of Master Degree in Security, Development and Peace Studies.

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LETTER OF RECOMMENDATION

I certify that this thesis entitled “FLOOD HAZARD IN BARDIYA, NEPAL: CAUSES, CONSEQUENCES AND EFFECTIVE MITIGATION STRATEGIES” was prepared by Mr. HARI BAHADUR GURUNG under my supervision. The researcher has fulfilled the criteria prescribed by Faculty of Humanities and Social Sciences, Tribhuvan University. I hereby recommend the thesis for the final evaluation and approval.

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LETTER OF APPROVAL

This thesis entitled "FLOOD HAZARD IN BARDIYA, NEPAL: CAUSES, CONSEQUENCES AND EFFECTIVE MITIGATION STRATEGIES" submitted by HARI BAHADUR GURUNG to APF Command and Staff College, Faculty of Humanities and Social Sciences, Tribhuvan University in Partial Fulfillment of MASTER DEGREE IN SECURITY, DEVELOPMENT AND PEACE STUDIES approved by the undersigned members of the Evaluation Committee.

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ABSTRACT

The recurrent flooding in Bardiya, Nepal, poses significant risks to local agriculture, infrastructure, and livelihoods, necessitating comprehensive research into its causes, consequences, and mitigation strategies. This study employs a multi-faceted approach, combining field observations, interviews with local stakeholders, and secondary data analysis to thoroughly investigate the underlying causes of flooding in the region. Key contributing factors identified include intense monsoon rains, river overflow, and inadequate drainage infrastructure. The research highlights that the interplay between hydrological factors, such as river discharge and sediment transport, and climatic factors, including changing rainfall patterns and glacier melt, significantly exacerbates the flood risk in Bardiya. In critically examining existing flood management practices, the study assesses the effectiveness of infrastructural developments like embankments and irrigation systems, as well as community-based disaster preparedness and response initiatives. The findings underscore the urgent need for enhanced flood forecasting systems that can provide timely warnings, thereby reducing the impacts of floods. Additionally, the research emphasizes the importance of integrating traditional knowledge with modern technological advancements to develop a more robust and adaptive flood management strategy. The proposed hybrid approach, which leverages both local knowledge and scientific techniques, is shown to have significant potential in mitigating the impacts of floods in the region. The implications of this research are extensive: for government agencies, the study provides a clear directive to revise and strengthen policies and infrastructure related to flood risk management; for local communities, it encourages greater participation in planning and implementing flood preparedness measures; and for security forces, it recommends enhanced training and better coordination with emergency services to improve response efforts during flood events. Furthermore, the research underscores the necessity for ongoing studies to refine data collection and modeling techniques, which are essential for predicting and managing future flooding scenarios more effectively. The study's recommendations aim to foster a collaborative and resilient approach to flood risk management, ensuring the safety and sustainability of Bardiya's communities. The integration of traditional knowledge with modern science, improved forecasting, and a collaborative approach to disaster preparedness and response form the cornerstone of a strategy to mitigate flood risks in Bardiya effectively.

Keywords: Climate change, inundation, infrastructure, community, early warning system

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LIST OF ABBREVIATIONS AND ACRONYMS

APA	American Phycological Association
ANN	Artificial Neural Networks
AUROC	Area Under the Curve of Receiver Operating Characteristics
CBFRM	Community-Base Flood Risk Management
CDMC	Community Disaster Management Committee
CDO	Chief District Officer
DAO	District Administrative Office
DEOC	District Emergency Operations Center
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DRRM	Disaster Risk Reduction and Management
DTR	Distance to a River
EOC	Early Warning System
FDG	Focused Group Discussion
FP	Focal Person
GLOF	Glacial Lake Outburst Flooding
GloFAS	Global Flood Awareness System
ICRC	International Committee of the Red Cross
IK	Indigenous Knowledge
IP	Indigenous Peoples
IWRM	Integrated Water Resources Management
KRB	Karnali River Basin

LK	Local Knowledge
MOEWR	Ministry of Energy, Water Resources
MOEWRI-DHM	Ministry of Energy, Water Resources, and Irrigation - Department of Hydrology and Meteorology
MOF	Ministry of Finance
MOFAGA	Ministry of Federal Affairs and General Administration
MOHA-NEOC	Ministry of Home Affairs - National Emergency Operations Center
MOUD	Ministry of Urban Development
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NASA	National Aeronautics and Space Administration
NC	National Committee
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NPC	National Planning Commission
NRA	National Reconstruction Authority
RF	Random Forest
SPI	Stream Power Index
SVM	Support Vector Machine
TWI	Topographical Wetness Index
US	United States

CHAPTER I

INTRODUCTION

1.1 Background of the Study

A hazard is defined as a potentially damaging physical event, phenomenon, or human activity that may cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation (UNDRR, 2023). Natural hazards, specifically, encompass a diverse range of threats arising from the Earth's dynamic processes. These hazards can significantly impact human livelihoods, infrastructure, and economies, posing substantial risks to communities worldwide (Birkmann et al., 2013). Understanding and addressing these hazards is essential for implementing effective disaster preparedness, response, and resilience strategies to mitigate their potential impacts.

The global increase in the occurrence and intensity of natural hazards poses a significant threat to political, social, and economic environments, impacting human livelihoods and economies. Approximately 65 disasters worldwide are attributed to natural causes, with floods, tropical cyclones, earthquakes, and droughts accounting for over 90% of these events (Ritchie et al., 2024). Floods, in particular, are the most frequent hazard, affecting over 1.4 million people annually with estimated losses reaching five billion US dollars in damages (Devitt et al., 2023). Projections indicate that by 2030, nearly 325 million extremely poor people will reside in areas highly vulnerable to natural hazards (Sharma, 2021).

Natural hazards encompass a diverse range of threats arising from the Earth's dynamic processes, with three primary types being hydro-meteorological, geological, and biological. Hydro-meteorological hazards involve atmospheric and water-related phenomena, leading to events like floods, storms, and hurricanes (Déguénon et al., 2024). Geological hazards are associated with the Earth's crust, resulting in earthquakes, volcanic eruptions, and landslides. Biological hazards arise from living organisms and ecological systems, encompassing pandemics, epidemics, and vector-borne diseases. Recognizing and addressing these hazards is essential for implementing effective disaster preparedness, response, and resilience strategies to mitigate the potential impact on human lives, infrastructure, and ecosystems (Ritchie et al., 2024).

Floods are the mostly occurring natural hazards around the globe. Many lives and property are in a serious threat every year due to this hazard. Nepal has also always been a part of it due to flash floods and fast flowing larger rivers. Terai mainly becomes the main victim yearly and bring about loss of lives and property (Dahal et al., 2015).

Floods are a recurrent and widespread phenomenon in Nepal, owing to the presence of over 6,000 rivers and rivulets nationwide, with key rivers like Koshi, Narayani, Karnali, and Mahalaki originating from the High Himalayas. The summer monsoon season, spanning from June to September, triggers a surge in these rivers, causing substantial damage to flood-prone areas, particularly districts like Baglung, Banke, Rautahat, Bardiya, and Sindhuli (Yogacharya & Gautam, 2008).

Nepal experiences intense rainfall during the summer monsson period, constituting 80% of the annual precipitation, resulting in riverine and flash floods. Flash floods, characterized by their sudden onset and high speed, pose a significant threat. The devastating flood of 1993, along with other major floods in 1978, 1980, and 1987, underscores the destructive impact on life, property, and agriculture (Gauchan, 2023). Human-made interventions, such as barrages and embankments in India affecting natural drainage, exacerbate flooding in Terai region. The socio-economic repercussions of disasters disproportionately affect the poor and vulnerable communities, necessitating the integration of Disaster Risk Reduction (DRR) into broader development efforts. The concept of DRR involves mitigating hazards, enhancing preparedness, and advocating for social, political, and economic changes. In Nepal, DRR measures are integral to building local resilience and are part of the National Strategy for Disaster Risk Management (Mandal, 2019). However, insufficient implementation of building codes, unclear land-use planning, and the lack of an effective early warning system, highlight the need for further improvements in disaster preparedness and response (Dhungel, 2011).

The study investigates the flood hazard in Bardiya Nepal with emphasis on the causes, consequences and effective mitigation strategies of the hazard. The Bardiya district is geographically located between 28.3984° N latitude and 81.6180° E longitude. It lies in Lumbini Province in midwestern Nepal. It covers 2025 km^2 and lies west of Banke District, south of Surkhet District of Karnali Province, east of Kailali District of Sudurpashchim Province as shown in the figure 1. To the south lies Uttar Pradesh, India. Bardiya district is familiar for its diverse wildlife, particularly within the confines of the Bardiya National Park.

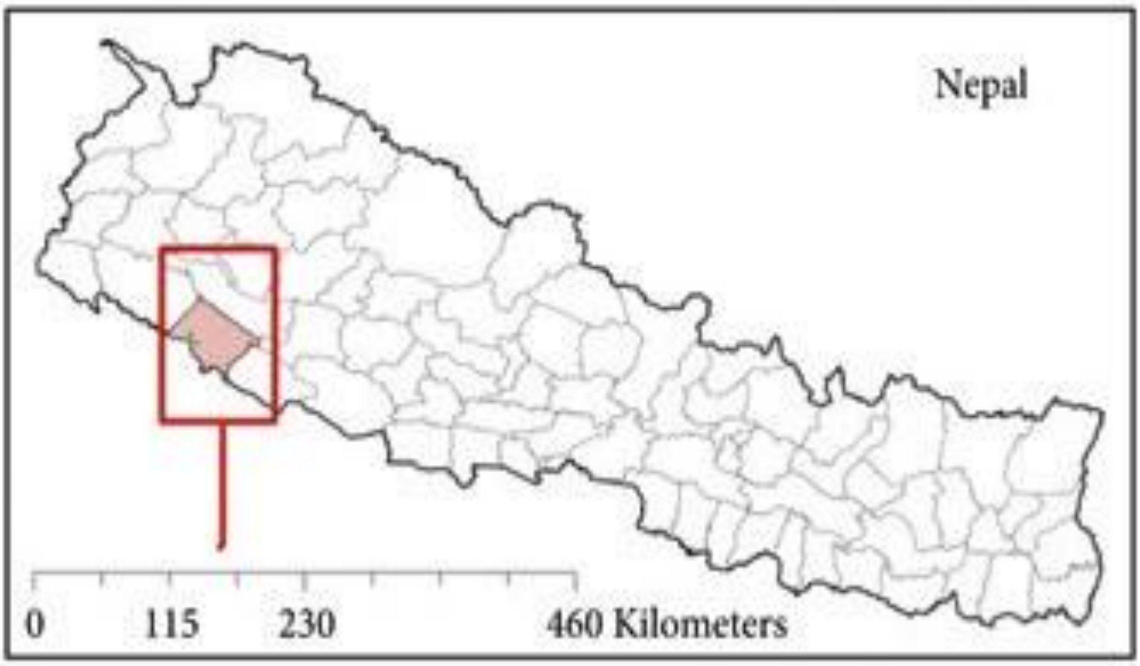
Bardiya National Park covers 968 km^2 occupies most of the northern half of the district (Dhakal, 2013).

In terms of transportation, the district is approximately 569.2 km (14 hrs.58 min.) away from the capital, Kathmandu, when traversing by road. Nestled in the scenic lowlands of western Nepal, Bardiya district emerges as a captivating mosaic of natural beauty, cultural diversity, and historical significance. This district is characterized by a rich tapestry of landscapes ranging from the expansive Terai plains to the lush forests of the Bardia National Park, making it a haven for biodiversity and an enticing destination for those seeking an immersive experience in Nepal's natural wonders.

The district consists of eight municipalities, out of which six are urban municipalities and two are rural municipalities. These are; Gulariya municipality, Rajapur municipality, Madhuwan municipality, Thakurbaba municipality, Basgadhi municipality, Barbardiya municipality, Badhaiyatal rural municipality and Geruwa rural municipality

Figure 1.1

Location map of the Bardiya district with its political division Municipalities and Rural Municipalities



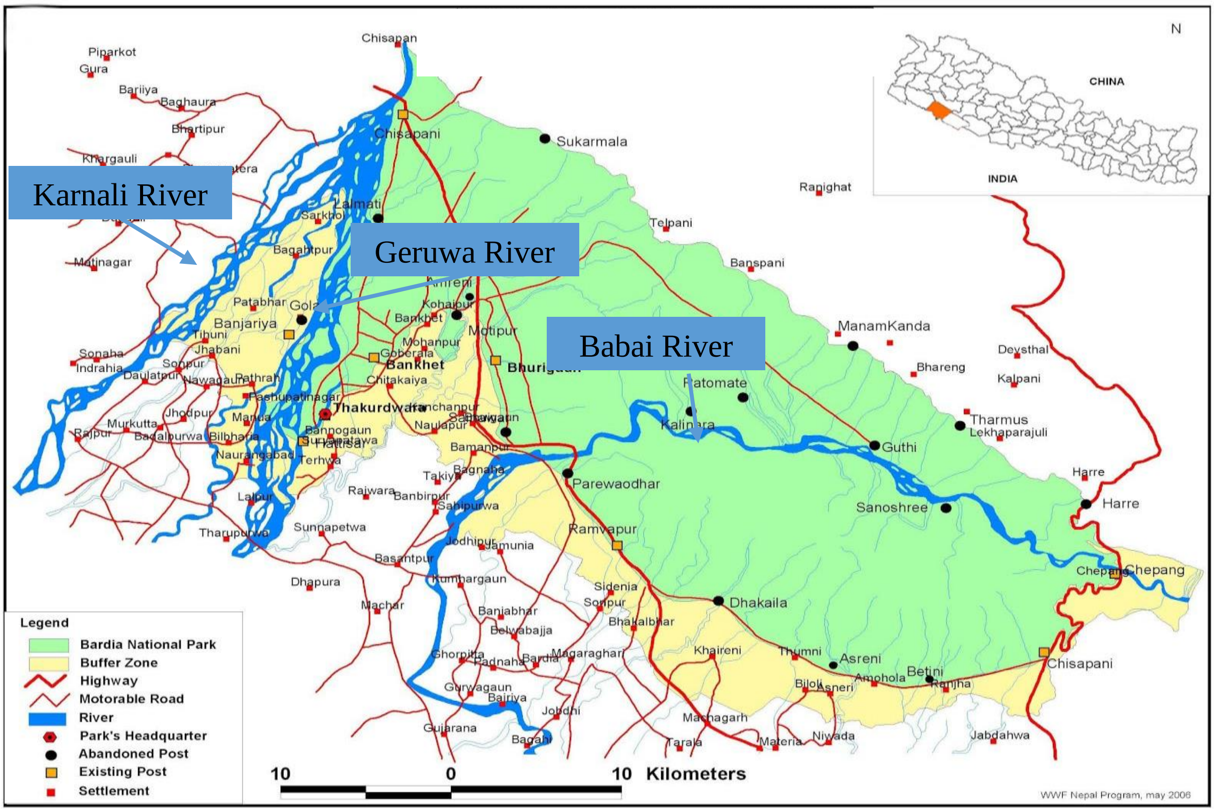
Source: Adapted from Nepal Archives (2020) and Modified by Researcher (2004)

The district's administrative center, Gulariya, serves as a hub for governance and commerce, fostering a unique blend of tradition and modernity. Home to a diverse array of ethnic communities, including Tharus, Brahmins, Chhetri's, and indigenous groups, Bardiya epitomizes the cultural tapestry that defines Nepal. The inhabitants engage in a variety of occupations, ranging from agriculture in the fertile plains to the conservation efforts within the Bardia National Park, where the iconic Bengal tiger roams freely amidst pristine wilderness. While Bardiya district thrives on the bounty of nature, it is not untouched by the challenges that accompany such diverse landscapes.

The Karnali, one of the largest rivers in Nepal is divided into multiple branches when it reaches the Terai as shown in the figure 1.2. The westernmost branch forms the boundary between Bardiya and Kailali districts. An eastern branch is called the Geruwa. The endangered Gangetic dolphin was often seen in its waters, but populations have been declining.

Figure 1.2

The Major rivers system Karnali, Geruwa and Babai Rivers in Bardiya district



Source: Adapted from Nepal Archives (2020) and Modified by Researcher (2024)

Bardiya district, nestled in the western region of Nepal as shown in figure 1.1, has been a witness to the harmonious confluence of diverse ecosystems and communities. However, this picturesque landscape has not been impervious to the capricious forces of nature, and the region has faced its share of challenges, with natural disasters leaving an indelible mark on the lives of its inhabitants. Among these calamities, the recurrent floods caused by the Karnali River and Geruwa River stand out as potent forces that have shaped the district's vulnerability and resilience (Dhungel, 2011).

The Karnali River, originating from the Tibetan Plateau, courses its way through the Himalayan terrain, impacting the topography and socio-economic dynamics of Bardiya district. Its turbulent waters, exacerbated by monsoon rains and snowmelt, have periodically unleashed devastating floods, disrupting the lives and livelihoods of the local population. The Geruwa River, a tributary of the Karnali, further compounds the challenge, augmenting the destructive potential of flood events (Panthi, 2023a).

Upadhyay (2019) stated that Bardiya, a district in western Nepal, exemplifies the socio-economic vulnerability to natural hazards. The district's economy largely depends on agriculture, with significant contributions from rice, wheat, and other crops, making it susceptible to climatic variations and natural disasters. Additionally, Bardiya's socio-economic fabric is characterized by a mix of ethnic communities, including Tharus, Brahmins, Chhetri’s, and indigenous groups, who rely on farming and livestock for their livelihoods. The region's natural beauty, bolstered by the Bardiya National Park, supports biodiversity and provides opportunities for eco-tourism, further enhancing its economic profile. However, this dependence on natural resources and agriculture also makes Bardiya particularly vulnerable to the impacts of flooding, which can disrupt agricultural production, damage infrastructure, and threaten the livelihoods of its residents.

In this analysis, we delve into the multifaceted impact of floods in Bardiya district, with a special emphasis on those triggered by the Karnali and Geruwa rivers. Examining the socio-economic, environmental, and infrastructural consequences, we seek to understand the nuances of the challenges faced by the communities in this region. Additionally, we explore the existing mitigation measures, community resilience, and potential avenues for sustainable development that can bolster the district against the recurrent threat of floods. Through this exploration, we aim to contribute to a comprehensive understanding of the disaster landscape in Bardiya district and foster discussions on effective strategies for mitigating the impact of future flood events (Chhetri et al., 2020).

1.1.1 Flooding in Nepal

Despite being a small country, the landscape of Nepal is diverse; it ranges from the humid plains in the south to the lofty Himalayas in the north with varied geographies, climates and flood risks. Thus, Nepal can be divided into three different geographical regions, and each region extends from east to west across the country. The three different regions are: namely the Terai, the Middle Hills, and the Himalayas (Mandal, 2019).

Flood is the most common natural disaster affecting Nepal. The principal and most destructive type of flooding is from rivers (fluvial). Apart from fluvial flooding during the monsoon, other flood risks include flash flooding from heavy rainfall in mountainous areas, Glacial Lake Outburst Flooding (GLOF), landslide induced flooding, and infrastructural flooding, such as embankment failure (Dahal et al., 2015).

Climate change is likely to have a significant impact on the frequency and intensity of extreme flood event. Increases in air temperature will make GLOF flooding more likely as glacier melting increases and large volume pro-glacial lakes form more quickly. Increases in extreme precipitation will make flash flooding more frequent; increase soil erosion potentially leading to more landslide induced flooding; and increase the frequency of events where urban flooding occurs due to infrastructure being overwhelmed compared to its design (Duwal et al., 2023).

1.1.2 Existing Legal Framework

Natural Disaster (Calamity) Relief Act promulgated in 1982 is the first legal instrument in Nepal directed towards the Disaster Risk Management (DRM). This act has envisioned the Ministry of Home Affairs as the focal ministry for DRM. The main focus of the act is on the relief and rescue work during and after a disaster. The Water Resources Act, 1992 focuses on disaster risk reduction through environmental protection. The Local Self Governance Act, 1999 has given authority to the local bodies to take appropriate measures for the DRM. Both the Water Resources Act and Local Self Governance Act do not spell out anything in detail on how DRM is carried out. Disaster Risk Reduction and Management (DRRM) Act, 2017, which focuses on total spectrum of disaster management, was passed by parliament in September 2017. The Natural Disaster Relief Act has been replaced by this act (Khanal, 2020).

The Local Government Operation Act, 2017 provides mandates and functions to local municipal governments to manage disasters, including preparedness, search and rescue, relief and rehabilitation. Prior to 2017, local bodies like Village Development Committee, Municipalities and District Development Committees have been carrying out various activities for DRRM in accordance with the Local Self Governance Act, 1999. Under the provisions, local government are empowered under the heading of additional functions, duties and powers to formulate land use plan and policies, action plan and implementation as per federal and provincial level laws and regulations.

1.1.3 Flood Risk Management

Table 1.1

Flood Risk Management in Nepal

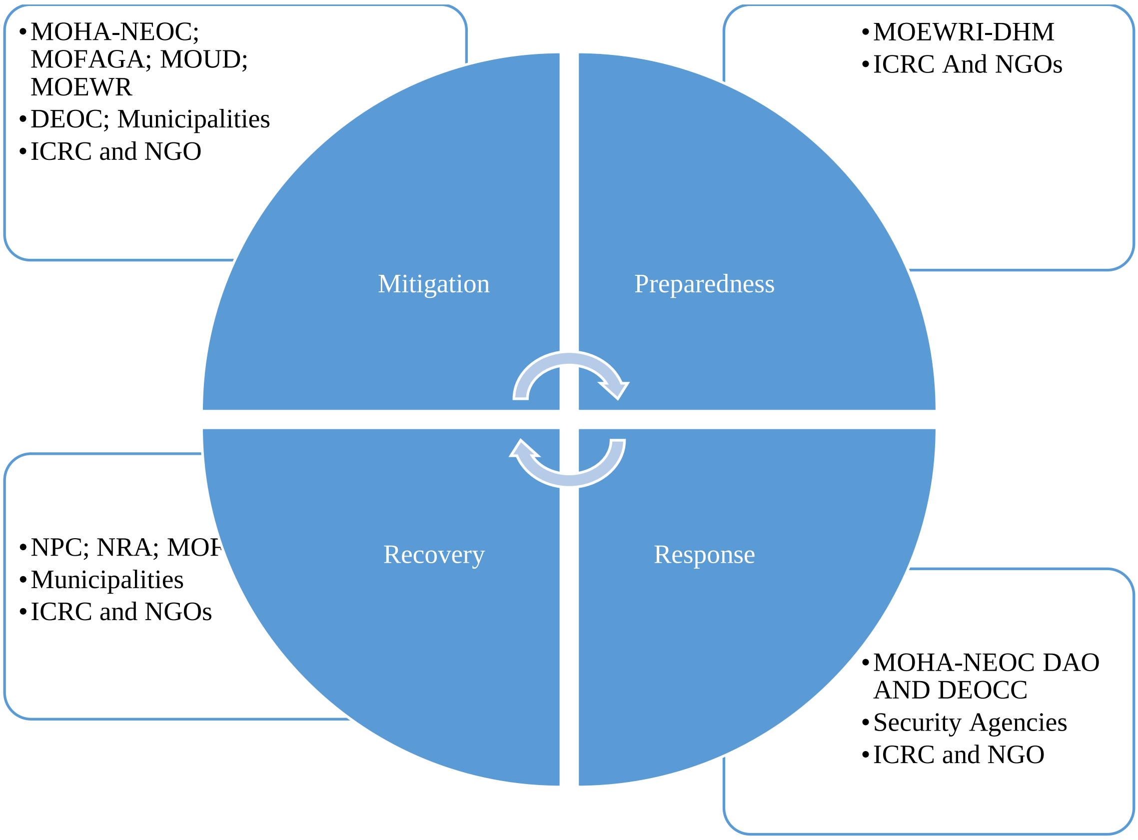
Structural Measures			Catchment-wide interventions (agriculture and forestry actions and water control works
			River training interventions
			Other flood control interventions (passive control, water retention basins and river corridor enhancement, rehabilitation and restoration
Non-Structural Measures	Risk Acceptance	Tolerance strategies	Toleration
			Emergency response system
			Insurance
	Risk Reduction	Prevention Strategies	Watershed management
			Delimitation of flood areas and securing flood plains
			Implementation of flood area regulations
			Application of financial measures
		Mitigation strategies	Reduction of discharge through natural retention
			Forecasting and early warning
			Emergency action based on monitoring, warning, and response systems (MWRS)
			Public information and education

Source: Dangol & Bormudoi (2015)

The roles of the different stakeholder in the flood risk management are given in figure 1.3

Figure 1.3

Stakeholder involved in Disaster Management in Nepal



Source: Dangol & Bormudoi (2015)

Figure 1.3 summarizes the government involved in Flood risk management in Nepal and highlights the "crowded" institutional space and overlapping horizontal (i.e. Ministries) and vertical (National to Local) responsibilities.

In the case of Bardiya a notable DRM practice is of the residents of Nangapur village. The residents of Nangapur village (Fig. 1.2) in Bardiya, formerly bonded laborers known as Kamaiyas, have confronted the dual challenges of poverty and recurrent floods in recent years. Liberated from oppressive practices, they found themselves grappling with the impact of climate change, including unpredictable and intense rainfall that increased the risk of devastating floods. Responding proactively, the village established a Community Disaster Management Committee (CDMC) in 2015, consisting of various task forces with specific responsibilities (Panthi, 2023). The Women's Task Force, Early Warning Task Force, Search and Rescue Task Force, and Primary Treatment Task Force were formed to address different aspects of disaster preparedness. Through the series of an Early Warning System (EWS) Project initiated by an NGO, vulnerable villages receive timely alerts through mass SMS and other mechanisms when rivers reach dangerous levels. Despite the challenges, the CDMC's coordinated efforts were tested and proven effective during the massive floods of August 2017, significantly reducing casualties and damages. However, experts emphasize the need for further risk management and the relocation of vulnerable communities to truly mitigate the yearly devastations caused by floods (Tamang, 2019).

To address these challenges, Nepal has aligned its disaster risk management efforts with the Sendai Framework for Disaster Risk Reduction 2015-2030. The Sendai Framework emphasizes understanding disaster risk, strengthening disaster risk governance, investing in disaster risk reduction for resilience, and enhancing disaster preparedness for effective response and recovery. Nepal's commitment to this framework is evident in its National DRRM Strategic Plan of Action 2018-2030, which aims to build resilience against natural hazards (Khanal, 2020). Despite these efforts, the effectiveness of disaster risk management in Nepal is often hampered by limited resources, insufficient data, and a reactive rather than proactive approach to disaster management. This underscores the need for continued investment in data collection, early warning systems, and community-based disaster risk reduction strategies to better prepare for and mitigate the impacts of natural hazards.

1.2 Statement of the Problem

Bardiya district, despite its natural beauty and cultural richness, faces a myriad of challenges that significantly impact the well-being of its residents and the sustainable development of the region. Among these challenges, the recurring floods caused by the Karnali and Geruwa rivers emerge as a pressing and complex issue, necessitating a thorough examination.

The problem at hand revolves around the destructive consequences of flood events in Bardiya district, particularly those triggered by the unpredictable behavior of the Karnali and Geruwa rivers. The inundation of fertile plains, displacement of communities, destruction of infrastructure, and disruption of livelihoods have become recurrent themes, posing a serious threat to the socio-economic fabric of the district. Additionally, the environmental repercussions of these floods, including soil erosion and habitat degradation, further exacerbate the vulnerability of the region. In August, 2023, continuous rainfall has wreaked havoc in Bardiya, submerging 43 houses in Auri, Bhagatpur, and Dudha of Barbardiya Municipality-8. The affected areas had borne the brunt of heavy rainfall, with Rammapur receiving a staggering 226.4mm of rain in the past 24 hours. Though the water levels in the Babai and Karnali rivers didn't breached the danger mark, the rising flow has led to the embankment slope at the Babai Irrigation Project site slipping (Panthi, 2023a).

The increased frequency and intensity of flood events in recent years underscore the urgency of addressing this problem. Climate change, rapid urbanization, and unsustainable land-use practices contribute to the escalating risks faced by Bardiya district, necessitating a comprehensive understanding of the root causes and effective strategies for mitigation.

This analysis aims to delve into the heart of the flood-related challenges in Bardiya, exploring the socio-economic, environmental, and infrastructural dimensions of the issue. By identifying the key factors contributing to the vulnerability of the district and evaluating existing mitigation measures, this study seeks to provide a foundation for informed decision-making and the development of sustainable strategies to alleviate the impact of floods on the community. Through such efforts, we aspire to contribute to the resilience and well-being of the residents of Bardiya district in the face of this critical challenge.

1.3 Research Questions

This research is guided by the following research questions:

1.3.1 What are the main causes of flooding in the Bardiya district, with a specific focus on the Karnali, Geruwa and Babai rivers?

1.3.2 What are the socio-economic consequences of flooding in terms of community displacement, agricultural land damage, and infrastructure loss in the Bardiya district?

1.3.3 What disaster risk management policies, strategies, and frameworks are currently in place at the local and national levels in the Bardiya district and what needs to put in places to reduce flood hazard?

1.4 Objectives of the Study

The objectives of the study are as follow:

1.4.1 To identify main causes of flooding in the Bardiya district, with a specific focus on the Karnali, Geruwa and Babai rivers.

1.4.2 To analyze the socio-economic consequences of flooding in terms of community displacement, agricultural land damage, and infrastructure loss in the Bardiya district.

1.4.3 To examine disaster risk management policies, strategies, and frameworks are currently in place at the local and national levels in the Bardiya district and examine the measures that needs to be put in places to reduce flood hazard

1.5 Significance of the Study

The significance of the study lies in its potential to illuminate critical aspects of the flooding scenario in Bardiya district, Nepal, providing invaluable insights for policymakers, disaster management authorities, and local communities. By addressing the identified objectives, this study stands to make substantial contributions in various dimensions:

Firstly, understanding the contributing factors for flooding in Bardiya is paramount for proactive and targeted interventions. The identification of hydrological, climatic, and anthropogenic elements influencing flooding will serve as a foundation for informed decision-making. This knowledge can aid authorities in developing and implementing effective land-use policies, climate resilience strategies, and sustainable urban planning, thereby mitigating the risk of future floods.

Secondly, the analysis of the impact of flooding in Bardiya is essential for comprehending the full extent of the challenges faced by the community. By examining socio-economic consequences, environmental impacts, and health-related outcomes, the study can guide the prioritization of resources and efforts in the post-disaster phase. This information is crucial for formulating adaptive strategies, improving emergency response mechanisms, and enhancing community resilience against the multifaceted aftermath of flooding.

Thirdly, the examination of the level of DRM in Bardiya contributes to an evaluation of the region's preparedness and response mechanisms. Identifying the strengths and weaknesses of current policies and frameworks, as well as assessing the effectiveness of EWSs, ensures a more resilient community. Recommendations derived from this analysis can inform policy revisions and the implementation of targeted disaster risk reduction measures, fostering a more robust and adaptive disaster management framework.

1.6 Limitations of the Study

This study has several limitations that must be acknowledged. Firstly, the research focuses on only two municipalities and one rural municipality within Bardiya District, which may not fully capture the variability in flood impacts and mitigation efforts across the entire district. Additionally, the study only considers hydrological and climatic factors influencing flooding, excluding other potential contributing factors such as socio-economic conditions and policy environments. Another significant limitation is the reliance on secondary data without conducting field surveys or household surveys, which may limit the depth and accuracy of the findings. These constraints suggest that further comprehensive studies, including a wider geographic scope and primary data collection, are necessary to develop a more complete understanding of flood dynamics and impacts in Bardiya District.

CHAPTER II

REVIEW OF THE LITERATURE

2.1 Empirical Review

The empirical review is divided into international and national context.

2.1.1 International Context

Wheater (2006) stated that flood hazard in the UK is increasing and considers issues of flood risk management. Urban development is known to increase fluvial flood frequency; hence design measures are routinely implemented to minimize the impact. Studies suggest that historical effects, while potentially large at small scale, are not significant for large river basins. Storm water flooding within the urban environment is an area where flood hazard is inadequately defined; new methods are needed to assess and manage flood risk. Development on flood plains has led to major capital expenditure on flood protection, but government is attempting to strengthen the planning role of the environmental regulator to prevent this. Rural land use management has intensified significantly over the past 30 years, leading to concerns that flood risk has increased, at least at local scale; the implications for catchment-scale flooding are unclear. New research is addressing this issue, and more broadly, the role of land management in reducing flood risk. Climate change impacts on flooding and current guidelines for UK practice are reviewed. Large uncertainties remain, not least for the occurrence of extreme precipitation, but precautionary guidance is in place. Finally, current levels of flood protection are discussed. Reassessment of flood hazard has led to targets for increased flood protection, but despite important developments to communicate flood risk to the public, much remains to be done to increase public awareness of flood hazard.

Sampson et al., (2015) stated that floods are a natural hazard that affect communities worldwide, but to date the vast majority of flood hazard research and mapping has been undertaken by wealthy developed nations. As populations and economies have grown across the developing world, so too has demand from governments, businesses, and NGOs for modeled flood hazard data in these data-scarce regions.

Vojtek and Vojtekova (2015) presented a case study on flood hazard and flood risk assessment at the local spatial scale using geographic information systems, remote sensing, and hydraulic modelling. As for determining flood hazard in the model area, which has 3.23 km2, the estimation of maximum flood discharges and hydraulic modelling were important steps. The results of one-dimensional hydraulic modelling, which are water depth and flow velocity rasters, were the basis for determining flood hazard and flood risk. In order to define flood risk, the following steps were applied: determining flood intensity on the basis of water depth and flow velocity rasters, determining flood hazard using three categories (low, medium, and high) based on flood intensity, defining vulnerability for the classes of functional areas using three categories of acceptable risk (low, medium, and high), and lastly determination of flood risk which represents a synthesis of flood hazard and vulnerability of the model area.

Kundzewicz et al., (2017) observed and projected changes in flood hazard. Spatial and temporal variability of large floods is analyzed, based on a time series of flood information, collected by the Dartmouth Flood Observatory in 1985–2016. Model-based projections of future flood hazard are critically reviewed. It is difficult to disentangle the climatic change component from strong natural variability and direct human impacts. The climate change impact on flood hazard is complex and depends on the river flood generation mechanism. It has not been possible to detect ubiquitous changes in flood characteristics in observation records in Europe, so far. However, we found an increasing tendency in the number of floods with large magnitude and severity, even if year-to-year variability is strong. There is a considerable spread of river flood hazard projections in Europe among studies, carried out under different assumptions. Therefore, caution must be exerted by practitioners in charge of climate change adaptation, flood risk reduction, risk insurance, and water resources management when accommodating information on flood hazard projections, under considerable uncertainty.

Devitt et al. (2023) stated that flooding is one of the most common natural hazards, causing disastrous impacts worldwide. Analyzing 1.2 million river reaches, it highlights that the sensitivity of floodplains to varying flood magnitudes is closely linked to topography and drainage areas, which also correlate with societal behavior. In floodplains sensitive to frequent, low-magnitude events, populations are evenly distributed across hazard zones, indicating adaptation to regular flooding risks. Conversely, in floodplains sensitive to extreme, high-magnitude events, populations tend to settle densely in rarely flooded areas, putting them at considerable risk due to potentially increasing flood magnitudes driven by climate change. This settlement pattern underscores the critical danger posed by infrequent but severe flooding events in the context of a changing climate.

2.1.2 National Context

Yogacharya and Gautam (2008) stated that Nepal is highly susceptible to natural disasters, particularly floods and landslides, due to its fragile geological conditions, extreme topography, climatic variability, and seismic activities, exacerbated by population growth, poverty, deforestation, unscientific agricultural practices, land use changes, and development activities such as road construction, irrigation, hydropower, and urbanization. Notably, heavy rainfall in central and eastern Nepal from July 19-21, 1993, led to catastrophic floods and landslides, resulting in significant loss of life and property, with 1,336 deaths, 163 injuries, and over 500,000 people affected. The disaster destroyed 17,113 houses, caused the loss of 25,425 livestock, and damaged more than 57,584 hectares of arable land and numerous irrigation projects, totaling an estimated property loss of NRs. 4,904 million. Similarly, the breach of the Koshi River embankment on August 18, 2008, displaced over 60,000 people in Nepal and more than 3 million in India, flooding 6,000 hectares of agricultural land and causing damage worth over US $3.7 million. Subsequent heavy rainfall in far-western Nepal in September 2008 led to devastating floods in Kanchanpur, Kailali, and Bardiya districts, underscoring the recurrent nature of these disasters.

Dhungel (2011) explored the use of indigenous knowledge and practices in Tharu Community to reduce the impact of flood disasters. Disasters are more frequent and prominent at present. Nepal is not an exception either. When the disaster strikes, it is poor and marginalized groups that suffer the most. Tharu Community in Nepal is one of the marginalized and vulnerable communities for flood hazards. Hence it is crucial to increase understanding about the ways which impacts of extreme events can be reduced. To carry our Disaster Risk Reduction approaches, it is first required to understand what community needs. Promotion of new risk reduction options needs to consider local tradition and norms to ensure their acceptability by the local people. In spite of huge investments in the area of disaster management, losses continue to mount. The need to bridge the gap between practice and policy with the recognition of indigenous knowledge and local coping strategies is the must.

Hence this paper is an attempt to understand the local practices used by Tharu Community. The research showed that the community people did have knowledge regarding the changing climate and are putting their own efforts in order to cope up. They have their own ways of forecasting and EWSs. They are using the traditional ways of embankment in order to minimize the adverse effects of flood. However, the indigenous practices which proved to be useful in the past years were not enough to cope with the rapid change in climatic patterns. Need to integrating scientific strategies in these indigenous practices is a must.

Dahal et al. (2015) stated that floods are the mostly occurring natural hazards around the globe. Many lives and property are in a serious threat every year due to this hazard. Nepal has also always been a part of it due to fast flowing larger rivers. Terai mainly becomes the main victim yearly and bring about loss of lives and property. Due to these Hazards, flood prediction has always been useful in eradicating the Risks it brings about.

Upadhyay (2019) stated that climate change is perceived to raise temperatures, cause agro-biodiversity extinction, decline agro-production, and lead to the emergence of vector-borne diseases, all negatively impacting agriculture and livelihoods. In response, local farmers, without external support, have developed integrated adaptation strategies based on their collective cultural experiences. These strategies include altering crop cultivation periods, adopting alternative crops, hybrid livestock, dairy cooperatives, and microcredit services. These practices, rooted in indigenous environmental knowledge and cultural values, have enabled farmers to engage with and adapt to natural phenomena. This confirms that agriculture and livelihood adaptation is a socio-cultural-technical process, highlighting the importance of integrating cultural and technical knowledge in climate adaptation efforts.

Chhetri et al., (2020) stated that flooding events are common at the lower region (Terai) of Nepal in the summer monsoon months (June–August). However, large destruction and heavy floods were observed at Banke-Bardiya districts (western Terai) of Nepal on June 16, 2016 and August 13, 2017. NASA cloud images clearly detect the system of cloudburst, cyclone, and smaller tornadoes within a short span of time which caused severe flooding. Uncertainty of weather observations, lack of modern forecasting tool like a Global Flood Awareness System (GloFAS), and trained manpower for the forecasting of extreme events are the existing scenario in the field of hydro-meteorology in Nepal.

Chaudhary et al., (2021) examined the perception of Indigenous People (IP) regarding Climate change. Climate change perceptions of IP are important because of their close connection with nature and the environment. The author found the Tharu have perceived a temperature increase but a rainfall decreases; the former is validated with weather data, but not the rainfall trend due to high annual variation. The high ranking of flooding in both villages and drought in Bikri indicates the importance of the water sector and related hazards. Tharu have used Indigenous as well as scientific knowledge for weather predictions, coping and adaptation to water-related hazards in agriculture-based livelihoods.

R. Sharma, (2021) found that the local communities carry out various local knowledge (LK) experiences to respond during disaster management phases. They own a creative set of approaches based on the LK and that empowers them to live in the flood-prone areas, accepting the paradigm shift from fighting with floods to living with that. The local actor’s involvement is recognized as an essential component for CB-FRM activities. Yet, their program’s implementation is more oriented towards humanitarian assistance in emergency responses. Even, they often overlook the role of LK. Additionally, the results show a high level of presence of local communities during the preparedness and recovery phases, while NGOs and local governments have a medium role in preparedness and low in recovery phase. The lack of local ownership has also emerged as the major challenge. The research provides valuable insights for integrated CB-FRM policies by adopting to LK practices.

Duwal et al., (2023) stated that the Karnali River Basin (KRB) comprises the longest river in Nepal, located south of the Himalayas. Despite its high susceptibility to floods, the basin lacks detailed studies. Proper floodplain management is essential to reduce the impacts due to rising flood frequency, magnitude, and severity aggravated by climate change. This research applies three machine learning techniques, Support Vector Machine (SVM), Random Forest (RF), and Artificial Neural Networks (ANN), to flood event data from the KRB. Ten flood conditioning factors; Aspect, curvature, distance to a river (DTR), normalized difference vegetation index (NDVI), elevation, slope, rainfall, soil, stream power index (SPI), and topographical wetness index (TWI) were selected based on the multicollinearity test. The parameter performance was evaluated using the Cohen Kappa Score, with NDVI having the greatest influence, followed by elevation, DTR, curvature, and TWI. Based on the Area Under the Curve of Receiver Operating Characteristics (AUROC), SVM outperformed RF, ANN, and ANN for FSM. The area of very high flood susceptible areas ranges from 0.8 to

2.5% of the basin area, most of them located in the south with low slopes and elevations. The results of this study suggest the use of SVM for FSM to help with proper floodplain management.

Sharma et al., (2023) examined that the past 50 years (1971–2020) flood loss data; then generated district-wise flood loss spatial maps and explored flood loss mitigation gaps in diverse topography of Nepal Himalaya through literature reviews. Over the past 50 years, on an average, all disasters together caused two deaths per day while more than 300 families got affected daily in Nepal. The proportion of flood disaster alone found 11.43% flood occurrences, 9.33% fatalities, 38.42% missing, 0.75% injury, 61.60% family suffering, and 10.16% property damages. Compared to the 1970s, the number of flood occurrence has increased to more than six folds causing four times human fatalities in the post 2000s. While acknowledging the population growth, the flood loss still shows increasing trend, but the incremental rate is found reduced to almost half. District-wise flood loss spatial maps depict the highest number of flood occurrences in Jhapa while Sarlahi, Surkhet, Chitwan, Mahottari, Sunsari, and Bardiya districts experienced the highest number of peoples' fatalities, missing, injuries, family suffering, fully and partially damages of privately-owned houses, respectively. Although proactive legislations are promulgated, our study found no subsequent reduction in flood loss arguing no progression in holistic flood risk management in Nepal. Our synthesis and identified research gaps highlight the urgent need for adopting evidence-based basin-scale approach to develop effective and sustainable flood mitigation measures.

Gauchan (2023) stated that the monsoon season in Nepal, occurring from June to September, is critical for the country's economic prosperity, delivering 80% of the annual precipitation and significantly supporting the agricultural sector, which contributes 23.5% to the GDP. This season is essential for rice cultivation, contributing over 11% to the GDP, and replenishing water resources crucial for biodiversity and the hydroelectric sector. However, the monsoon also brings severe challenges, including landslides and floods, exacerbated by irregular precipitation patterns and climate change. In 2021, above-average rainfall led to 144 floods, up from 91 in 2020, causing significant damage to crops and affecting livelihoods. The vulnerability to these natural disasters is heightened by Nepal's steep terrain, extensive river systems, and human activities such as deforestation and unregulated construction. Despite decades of disaster occurrences, the government's reactive disaster management approach has been ineffective. A lack of comprehensive data and understanding among local authorities further hinders proactive measures. Recent efforts include the National Adaptation Plan (2021-2050) focusing on policy reforms, EWSs, and climate resilience, alongside initiatives by ICIMOD to develop advanced predictive tools for landslides and floods. Integrating these tools into disaster management strategies is crucial for mitigating the monsoon's destructive impacts and adapting to increasing climate change challenges.

Sah et al. (2024) stated that Kailali holds number of rivers originating from Mahabharat range and Chure range which get flooded every year, causing high losses of agricultural land and the flooding at community level. In order to identify and understand the probable risks in the study area and the methodologies followed to get rid of the flood risk or to protect the land and community from the effect of flood. The study was conducted during the period from March 2022 to May 2023. Field observation, in-depth interview, focus group discussion and questionnaire survey were the major tool applied for the investigation. The study found that flooding is the major hazard, and the earthquake is the minor one. River encroachment is the major one problem of the river training works and inadequate people's awareness is the minor one. The river down to Chure carries lots of sediment and thus increasing the bed loads. Thus, Chure protection programs must be effectively executed so that the lower plain will be sediment less and the inundation of land will be reduced. Originality/Value: The paper contributes on the effective ways to protect community from flood hazards.

2.2 Research Gap

The research gap identified in this study emerges from the comparison between the empirical review and the study's objectives and research methodology. The empirical review highlights significant progress and ongoing challenges in understanding and managing flood risks both internationally and nationally. International studies focus on advanced flood risk assessment techniques, urban development impacts, and the influence of climate change on flood frequency, emphasizing the need for comprehensive flood risk management strategies (Wheater, 2006; Sampson et al., 2015). There is a lack of sufficient studies regarding the statue of hydrological and climate factors influencing the Bardiya district with a specific focus on the Karnali, Geruwa and Babai rivers and social-economic impacts of floods on the local community and their recovery procedures and techniques. Inadequate studies on the perceptions of the local community concerning the flood events, hazards exposure and risk reduction mechanisms.

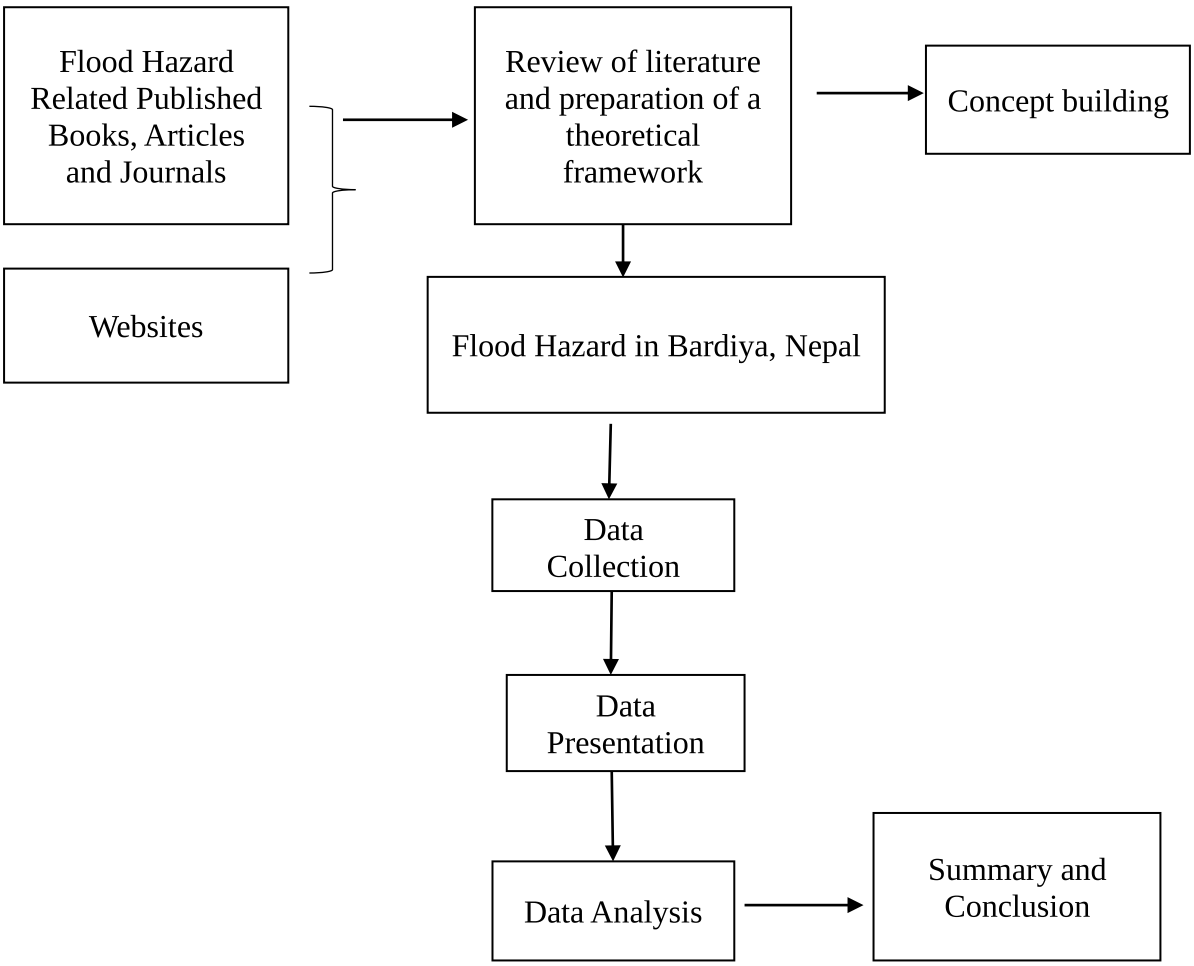
CHAPTER III

RESEARCH METHODOLOGY

For the study of the concerned subject, descriptive method is chosen. The data collection technique for the study is based primary and secondary data. The research is an explanatory and descriptive which has done by employing qualitative research design. Secondary data, documents and records, non-written records are used to develop research. The research paper is more inductive after applying the mentioned methods. The research methodology used in this study is shown in figure 3.1.

Figure 3.1

Flow chart of the research methodology used in this study



Source: The Researcher own work (2024)

3.1 Research Design

The nature of this research is descriptive and analytical. It is descriptive since available information is described. At the same time, it is analytical as the information originate from various sources is synchronized and analyzed properly. The overall research work is conducted through collection of primary as well as secondary data.

3.2 Area of Study

Bardiya district shares its borders with the Indian state of Uttar Pradesh to the south, while the Karnali River delineates its northern boundary. The district's administrative center, Gulariya, serves as a hub for governance and commerce, fostering a unique blend of tradition and modernity. Home to a diverse array of ethnic communities, including Tharus, Brahmins, Chhetris, and indigenous groups, Bardiya epitomizes the cultural tapestry that defines Nepal. The inhabitants engage in a variety of occupations, ranging from agriculture in the fertile plains to the conservation efforts within the Bardia National Park, where the iconic Bengal tiger roams freely amidst pristine wilderness. While Bardiya district thrives on the bounty of nature, it is not untouched by the challenges that accompany such diverse landscapes.

Within the Bardiya district two municipality i.e. Guleria and Rajapur, and one Rural Municipality i.e. Geruwa Rural Municipality are included in this study.

3.3 Nature and Sources of Data

The data for this study are based on the primary and secondary sources of information.

3.4 Techniques and Tools of Data Collection

Primary data through the use of open-ended questionnaire among the different stakeholder of the study area i.e. CDO, Mayor of each municipality, Ward chairperson of the highly affected ward, security personnel and other stakeholder, started from 17th March, 2024 to 24th March, 2024.

Further, the data were also collected from secondary sources. This research paper with available data through report and articles were analytically and critically reviewed to reach a reliable perfect conclusion of this research.

3.5 Method of Data Analysis

Different articles were also taken as reference for the completion of this research paper. Similarly, based on the open-ended questionnaire with the stakeholder (Appendix B). Descriptive method is used where qualitative data were referred to analyze the gathered information during the course of research to address the objectives.

3.6 Ethical Consideration

Ethical considerations can be specified as one of the most important parts of the research. According to Bryman & Bell (2007) the following ten points ethical considerations which were used in this study.

i. Research participants were not be subjected to harm in any ways whatsoever.
ii. Respect for the dignity of research participants was in priority.
iii. Full consent was obtained from the participants prior to the study.
iv. The protection of the privacy of research participants was ensured.
v. Adequate level of confidentiality of the research data was ensured.
vi. Anonymity of individuals and organizations participating in the research was maintained.
vii. Any deception or exaggeration about the aims and objectives of the research were avoided.
viii. Affiliations in any forms, sources of funding, as well as any possible conflicts of interests were declared.
ix. Any type of communication in relation to the research were performed with honesty and transparency.
x. Any type of misleading information, as well as representation of primary data findings in a biased way was avoided.

While collecting the data, each respondent was well explained about the study and was requested to give an informed consent. Even if they agreed to give the answers but during answering, they had the right to stop answering the questions if they felt embarrassed. The responses from the respondents were anonymous. However, identification code was used to identify the data collection form. The respondent had full right either to particular or withdraw the interview at any time of study period. All of the answers were kept confidential.

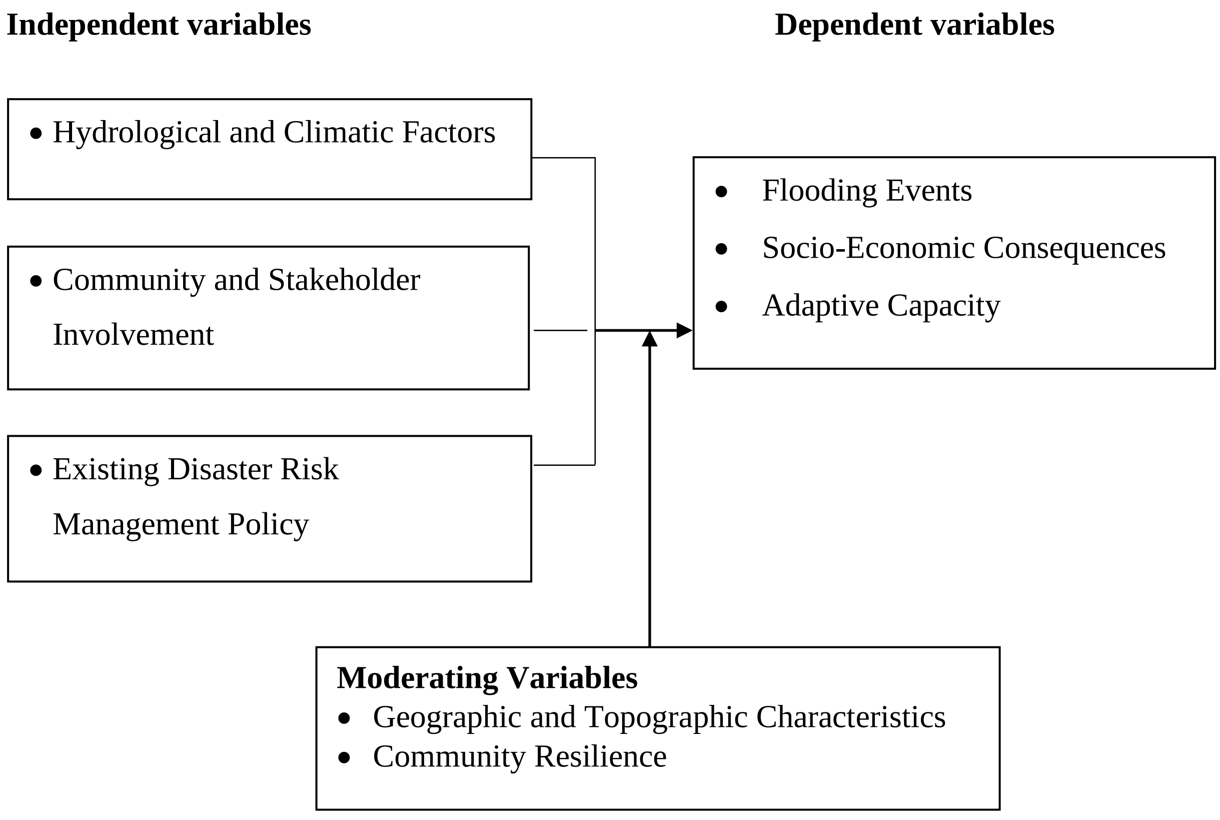
All the questionaries were kept safely so that only the researcher can access to the data. In any sort of report publication, any information with possibility of identification of the respondents was not included. When conducting this research, researcher was mindful of ethical and data protection issues, protection the individuals, communities and environments involved in the studies against any form of harm, manipulation or malpractice.

3.7 Conceptual Framework

A conceptual framework is a visual or written structure that outlines the key concepts, variables, and relationships within a research study. It is a systematic way of organizing ideas, theories, and concepts that guide the research process. The conceptual framework adopted in this study is given in figures 5. It provided a roadmap for the research to follow, ensures coherence across different aspects of the study, and aids in understanding the study's findings.

Figure 3.2

Conceptual Framework of the study



Source: Adapted from Sampson et al. (2015) and Modified by Researcher (2024)

3.7.1 Independent Variables:

a. Hydrological and Climatic Factors

The independent variable of hydrological and climatic factors encompasses a detailed analysis of the natural elements influencing flooding in the Bardiya district. Examining precipitation patterns allows for an understanding of the rainfall distribution, frequency, and intensity, while studying river discharge provides insights into the volume and speed of water flow in the Karnali and Geruwa rivers. Additionally, considering land use changes (e.g., deforestation and urban development), Poor drainage and sewage systems enables an investigation into alterations that may impact water runoff and absorption, while an exploration of climate variability involves studying changes in temperature, humidity, and atmospheric conditions that influence local climate patterns.

b. Community and Stakeholder Involvement

This variable underscores the importance of active community and stakeholder engagement in the water management process. Community awareness, as a sub-variable, measures the extent to which local residents understand water-related issues and risks. Participation in water management decisions assesses the degree of involvement of community members in decision-making processes, ensuring that their perspectives are considered. Stakeholder engagement evaluates the collaboration between various entities, such as government agencies, non-governmental organizations (NGOs), and private entities, in initiatives aimed at managing water resources effectively.

c. Existing DRM Policies and Strategies

This independent variable delves into the efficacy and coordination of existing policies designed to manage and mitigate the impacts of flooding. Evaluating policy effectiveness involves assessing the impact and efficiency of current DRM strategies. Implementation mechanisms explore the methods and processes through which these policies are put into practice, while examining the coordination between local and national levels aims to understand the collaborative efforts between authorities at different administrative levels.

3.7.2 Dependent Variables

a. Flooding Events

The dependent variable of flooding events focuses on the characteristics of such events in the Bardiya district. Frequency, as a sub-variable, gauges how often flooding occurs, providing insights into the recurrence of these events. Intensity measures the severity and magnitude of flooding incidents, while duration examines the length of time that specific areas are affected by flooding, offering valuable information on the temporal aspects of these events.

b. Socio-economic Consequences

This variable captures the broader impacts of flooding on the local community. Community displacement, as a sub-variable, involves quantifying the number of individuals displaced, understanding the duration of displacement, and assessing the strategies employed for relocation. Agricultural land damage evaluates the extent of harm to farming areas, including crop loss and the subsequent impact on livelihoods. Infrastructure loss encompasses the evaluation of damage to physical infrastructure, economic losses incurred, and efforts made for rehabilitation.

c. Adaptive Capacity

Assessing the adaptive capacity of the community involves understanding its ability to respond to changing hydrological and climatic conditions. Sub-variables include evaluating the overall resilience of local communities in the face of flooding events, the effectiveness of adaptive strategies implemented, and the community's capacity to cope with the immediate and long-term impacts of flooding, contributing to a comprehensive analysis of adaptive measures.

3.7.3 Moderating Variables

a. Geographic and Topographic Characteristics

Moderating variables, such as geographic and topographic characteristics, provide context to the study. Physical landscape features, as a sub-variable, identify elements such as elevation, slope, and land cover that influence water flow and distribution. Geographic vulnerability assesses the susceptibility of specific areas to flooding based on their geographical characteristics, contributing to a nuanced understanding of the geographic factors moderating the relationship between independent and dependent variables.

b. Community Resilience

The moderating variable of community resilience explores the community's capacity to withstand and recover from flooding events. Sub-variables include the community's ability to recover, considering factors like resilience and adaptive capacity. Historical experience with floods examines past encounters with flooding events, providing insights into lessons learned and the community's ability to apply these lessons. Social cohesion assesses the strength of social bonds within the community, offering a perspective on how collective resilience is influenced by community dynamics. Local community awareness and education on flood hazards then implementation and effectiveness of preparedness plans, disaster management, and emergency response capacity of the government and local authorities.

CHAPTER IV

FINDINGS AND DISUCSSION

4.1 Causes of Flooding in Bardiya district

The region experiences intense monsoon rainfall and is prone to devastating floods due to the slow and broad flow of rivers like the Karnali and Babai, which deposit sediment and raise their beds, causing communities to be lower in elevation than the rivers themselves. However, socio-political factors exacerbate vulnerability, with insufficient disaster preparedness and management capacity compounded by rapid population growth, poor land use practices, deforestation, and encroachment into floodplains. Climate change further exacerbates these challenges, with increased intensity and magnitude of precipitation events leading to more frequent flooding and landslides. To address these issues, there's an urgent need for improved planning, disaster preparedness, and land use management to mitigate the impacts of climate change and enhance resilience in the Tarai region. There are various hydrological and climatic factors affecting the floods in the Bardiya district. Three major rivers are there within the district and each river has huge impact on the livelihood of the people in the district.

4.1.1 Rivers in the Bardiya district

There are three significant rivers in the Bardiya district: the Karnali River, Geruwa River, and Babai River. These rivers, alongside the Rani Jamara and Babai Irrigation Canals, play a crucial role in the area's hydrology, significantly influencing local agriculture and susceptibility to flooding.

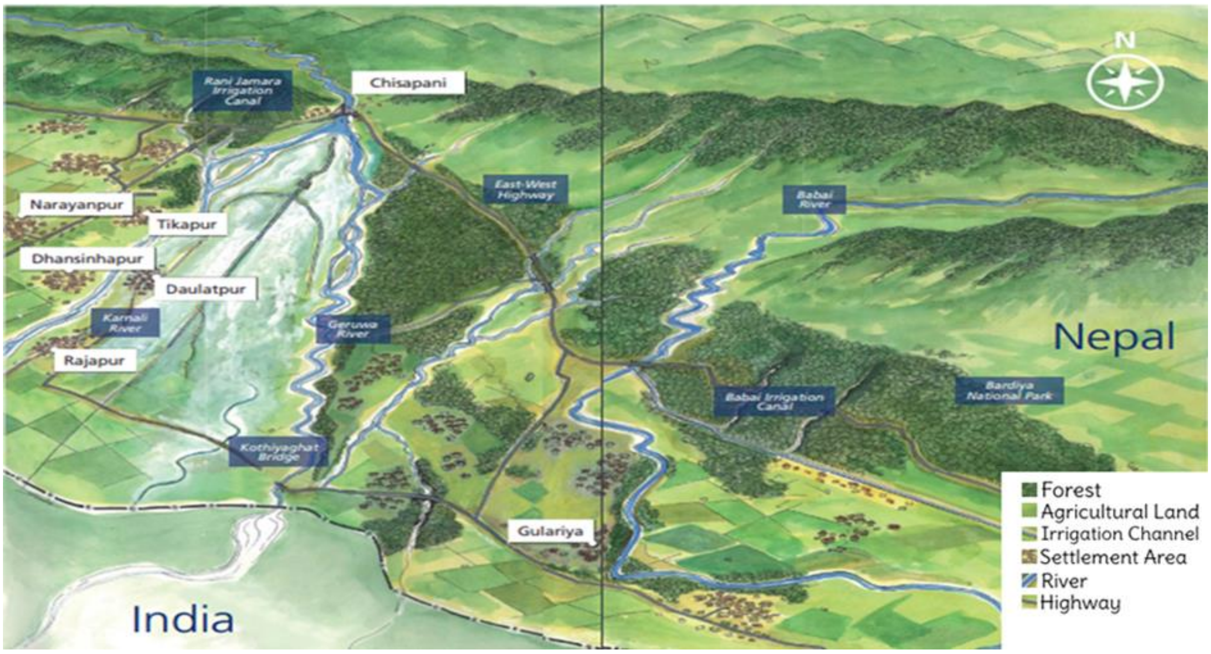
4.1.1.1 Karnali River

The Karnali River is one of the major rivers in Nepal and is also known as the Ghaghara River in India. It originates from the Tibetan Plateau and flows through Nepal before eventually joining the Ganges River in India. The Karnali River is an essential waterway in western Nepal, providing water for irrigation, hydroelectricity generation, and supporting diverse ecosystems along its course. It is a significant watercourse in Nepal, boasts several technical details pertinent to its hydrological characteristics and geomorphological features.

With a catchment area of 43,380 km2 and a total length extending approximately 546 km up to the border, the Karnali River plays a crucial role in the regional water system. Notably, the river experiences bifurcation around 3.7 km downstream from the Chisapani bridge, marking a pivotal point in its course. The average slope of the river, measured from Chisapani, stands at 1:1000, influencing its flow dynamics and sediment transport processes. Designed to withstand varying hydrological conditions, the river's design discharge (Q50) is estimated at 17,180 cubic meters per second, providing insight into its capacity to handle peak flows. Morphologically, the Karnali River exhibits an extremely braided plan form downstream from Chisapani, characterized by multiple interwoven channels (Fig. 1.2 and 4.1). The river's width varies significantly along its course, ranging from 300 to 400 meters at its narrowest points to an impressive 4000 meters at its widest, reflecting its dynamic nature and diverse geomorphic settings. These technical details offer valuable insights into the hydrological and morphological characteristics of the Karnali River, facilitating informed decision-making for water resource management and infrastructure development in the region.

Figure 4.1

Rivers in Bardiya, Nepal



Source: Map Showing the major river in the Bardiya district along with the major road network, Ballouard et al. (2007)

Figure 4.1 and 1.2 presents a detailed view of the Chisapani region, bordered by Nepal to the north and India to the south, illustrating a diverse geographical layout that includes several key water bodies such as the Karnali River, the Geruwa River, and the Babai River. These rivers, alongside the Rani Jamara and Babai Irrigation Canals, play a crucial role in the area's hydrology, significantly influencing local agriculture and susceptibility to flooding. The East-West Highway bisects the region, providing vital connectivity but also posing potential barriers to natural water flow, which might exacerbate flooding risks during heavy rainfall periods. Key localities such as Gulariya and the Bardia National Park are also shown, the latter serving as a critical habitat for wildlife, adding environmental and conservation stakes to the management of water resources and flood control in the region. This intricate network of natural and human-made features underscores the challenges and importance of effective water management in Chisapani, especially in light of the significant rainfall and flood events discussed previously.

4.1.1.2 Geruwa River

The Geruwa River is a tributary of the Karnali River (Fig. 1.2 and 4.1). It is formed by the confluence of the Kuti and Ganga Gad rivers in western Nepal. The Geruwa River flows parallel to the Karnali River for a considerable distance before joining it downstream. The river is significant for its contribution to the overall flow of the Karnali River and its importance for the local communities living along its banks.

4.1.1.3 Babai River

The Babai River is another important tributary of the Karnali River. It originates from the Chure Hills, inner Terai Dang Valley of Mid-western Nepal and flows through the Babai Valley before joining the Karnali River (Fig. 1.2 and 4.1). The Babai River is significant for its role in providing water for irrigation, supporting biodiversity, and facilitating various economic activities in the region.

About 20 kilometers (12 mi.) beyond this confluence, the Babai crosses into Bardiya District and enters Bardiya National Park. The river continues another 30 kilometers (19 mi.) west-northwest until the enclosing Siwalik hills fall away and the Outer Terai begins. At this point the river crosses Nepal's main east–west Mahendra Highway and exits the national park.

On the Outer Terai the Babai is finally free to gradually bend left toward the main inclination of the Indo-Gangetic Plain. The river flows south some 40 kilometers (25 mi.) and enters India's Uttar Pradesh state. The Babai continues about 50 kilometers (31 mi.) (straight line) south from the border before joining the much larger Ghaghara from the left at about 35 kilometers (22 mi.) west-northwest of Bahraich. This confluence is about 10 kilometers (6 mi.) upstream of the Sharda (Mahakali) confluence from the right.

In Nepal the catchment of the Babai is bordered by that of the Rapti on the north, east and south; and by the main Ghaghra catchment on the west until their confluence. In India the Rapti takes a more easterly course, joining the Ghagra some 285 kilometres (177 mi.) southeast of the Babai's confluence.

4.1.2 Climatic Factors

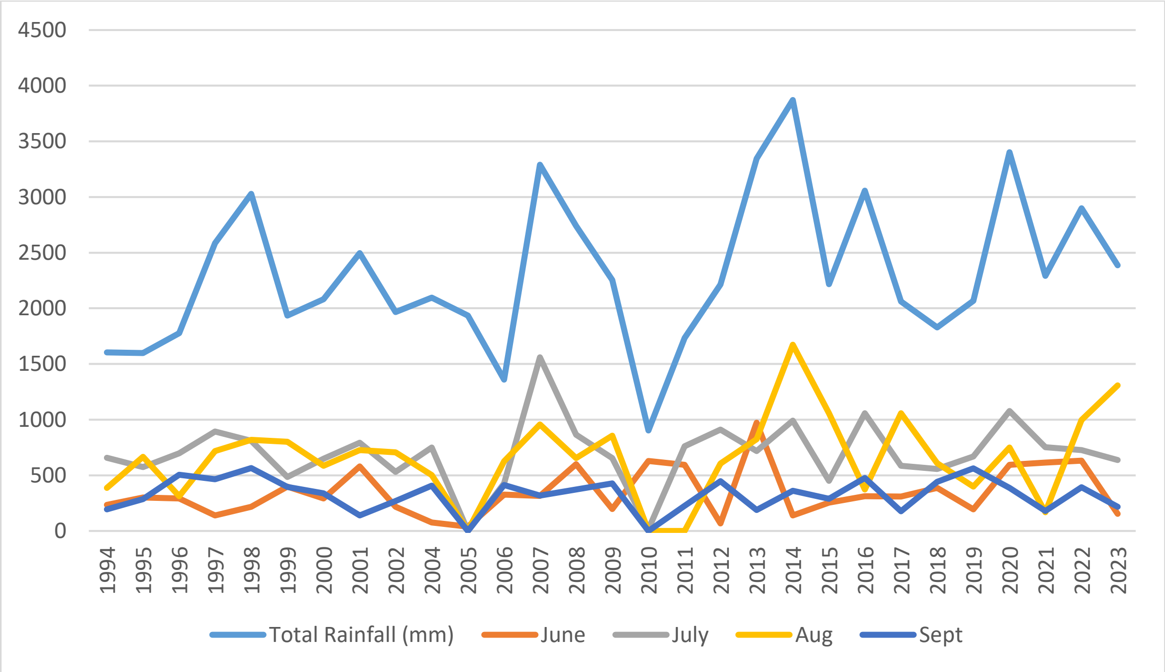
Nepal faces significant challenges from climate change, ranking fourth globally in vulnerability and experiencing severe impacts such as temperature extremes, floods, landslide. Rising temperatures, driven primarily by greenhouse gas emissions from transportation energy, agriculture and forestry sectors, exacerbate these hazards, contributing to property loss and environmental degradation. Despite efforts like the National Adaptation Programme of Action (NAPA) and the National Adaptation Plan (NAP) process, adaptation remains challenging due to financial limitation, dependence on subsistence agriculture, institutional weaknesses, and gender disparities. Bottom-up approaches involving local communities are crucial for effective adaptation, as they possess valuable knowledge and experiences. Women, in particular, bear increased burdens and risks from climate impacts on traditional household tasks. Addressing these challenges requires holistic strategies that integrate climate adaptation into policies and development agendas while prioritizing community engagement and gender-inclusive approaches.

4.1.2.1 Change in the pattern of the rainfall

Respondents have observed a shift in rainfall patterns in Nepal, noting that the predictability and regularity previously associated with rainfall have diminished. Rainfall is now characterized by unpredictable and erratic behavior, often occurring at extreme levels. This change has significant implications, as communities must now be prepared for the possibility of flooding rivers, which can result from sudden and intense rainfall events. Such unpredictability poses challenges for disaster preparedness and underscores the need for adaptive strategies to mitigate the impacts of extreme weather events, emphasizing the importance of community resilience-building efforts and proactive measures to address the increasing vulnerability to flooding in affected areas. The total annual and summer rainfall at Chisapani is shown in the figure below.

Figure 4.2

Charts showing the total rain fall, and monthly rainfall in Summer ie. June, July, August and September



Source: Department of Hydrology and Meteorology (2024)

Figure 4.2 provides a detailed analysis of the total annual rainfall (in millimeters) and the monthly rainfall for June, July, August, and September in Bardiya district from 1994 to 2023. The blue line represents the total annual rainfall, while the orange, gray, yellow, and dark blue lines represent the rainfall for June, July, August, and September, respectively. This data highlights significant variability in rainfall patterns over the years, with clear peaks and troughs that can have substantial implications for the region.

The total annual rainfall shows considerable fluctuation throughout the observed period. Notable peaks occur in the years 2098, 2007, 2013, and 2014, with rainfall exceeding 3000 mm in some instances. The year 2014, in particular, stands out with the highest recorded annual rainfall. Conversely, there are periods of relatively lower rainfall, such as in 2006, 2010 and 2018, indicating significant year-to-year variability. This variability underscores the importance of understanding annual and seasonal rainfall trends to predict and manage water resources and potential flooding events.

When examining the monthly data, June's rainfall shows moderate variability with peaks in 1995, 1997, and 2013. Although June typically has lower rainfall compared to the other monsoon months, its contribution is crucial as it marks the beginning of the monsoon season. July demonstrates considerable fluctuations, with significant peaks in 1997, 2007, 2016, and 2020. July's rainfall substantially influences the total annual rainfall, highlighting its importance in the overall monsoon pattern.

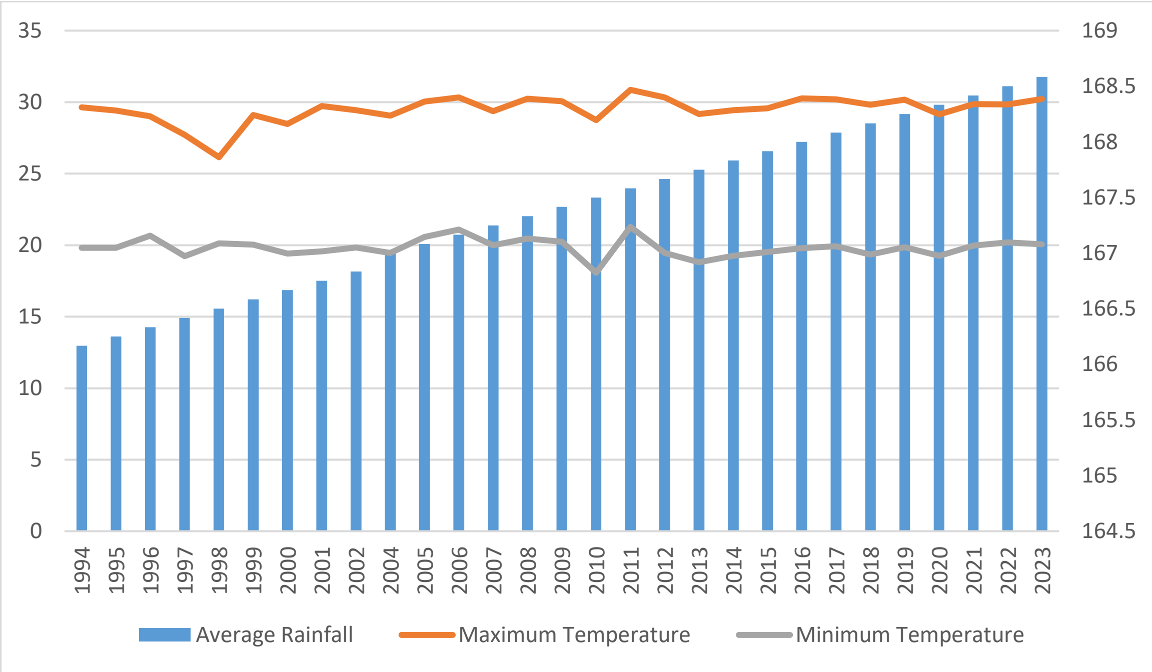
August shows the most variability among the months, with some years experiencing very high rainfall. Notable peaks in August occur in 2007, 2014, and 2023. This month generally has higher rainfall compared to June and September, and in some years, it is the highest among the four months, significantly impacting the total annual rainfall. September (dark blue line) shows relatively consistent rainfall with fewer extreme peaks. Increases are noticeable in 1998 and 2019, but overall, September's rainfall remains moderate compared to July and August.

The data suggests that July and August are the months with the highest rainfall during the monsoon season. The total annual rainfall is significantly influenced by the rainfall in these two months. Years with extreme total annual rainfall, such as 2007 and 2014, coincide with high rainfall in July and August, indicating a pattern where heavy rainfall in these months contributes to overall increases in annual rainfall.

Understanding these patterns is crucial for flood risk management in Bardiya district. High rainfall in July and August could be predictors of potential flooding, necessitating advanced preparation and mitigation strategies. Monitoring these trends helps in better planning for agricultural activities and disaster preparedness, considering the significant role of monsoon rains in the region's economy and ecology. Effective water management and infrastructure development depend on recognizing and adapting to these rainfall patterns to mitigate the impacts of extreme weather events.

Figure 4.3

Max-Temperature, Minium Temperature and Annual rainfall pattern based on Chisapani Station



Source: Department of Hydrology and Meteorology (2024)

Figure 4.3 depicts the average annual rainfall and the maximum and minimum temperatures in Bardiya district from 1994 to 2023. The data is presented in three distinct lines: the blue bars represent the average rainfall (in millimeters), the orange line indicates the maximum temperature, and the gray line shows the minimum temperature over the years.

The average annual rainfall in Bardiya district shows a generally increasing trend over the observed period. Starting from approximately 13 mm in 1994, the average rainfall exhibits a gradual rise, peaking in the later years. Notably, there is a marked increase from 2004 onwards, with the average rainfall reaching higher levels consistently. The period from 2010 to 2023, in particular, sees more pronounced fluctuations with a steady upward trend. This increase in average rainfall highlights the changing precipitation patterns in the region, possibly influenced by broader climatic changes.

The maximum temperature, represented by the orange line, remains relatively stable over the years, with slight fluctuations. Starting at around 30°C in 1994, the maximum temperature experiences minor variations but generally hovers around the same level. A slight downward trend can be observed from 1994 to 2000, followed by a stabilization phase. From 2000 onwards, the maximum temperature shows slight increases and decreases, indicating some variability but no significant long-term trend. The maximum temperature remains consistently above 30°C, reflecting the region's typically warm climate.

The minimum temperature, depicted by the gray line, also shows relative stability throughout the period. Starting at around 20°C in 1994, the minimum temperature exhibits minor variations but maintains a consistent trend over the years. There is a slight increase observed from 2005 onwards, with the minimum temperature slightly rising but staying within a narrow range. This stability in minimum temperature suggests that while there are fluctuations in daily temperatures, the overall minimum temperature has not experienced drastic changes over the years.

The chart highlights several important trends and implications for Bardiya district. The increasing trend in average rainfall suggests that the region is experiencing more significant precipitation over the years, which could have profound effects on agriculture, water resources, and flood risks. The stability in maximum and minimum temperatures indicates that while rainfall patterns are changing, the overall temperature range remains consistent, which can have mixed implications for crop growth and climatic conditions.

Understanding these trends is crucial for planning and managing resources in Bardiya district. The increasing average rainfall necessitates improved flood management and water conservation strategies to mitigate potential adverse impacts. Additionally, stable temperatures provide a consistent climatic baseline, but the increasing rainfall underscores the need for adaptive agricultural practices and infrastructure resilience to cope with changing precipitation patterns.

Table 4.1

Showing the data of rainfall and flood in different time period

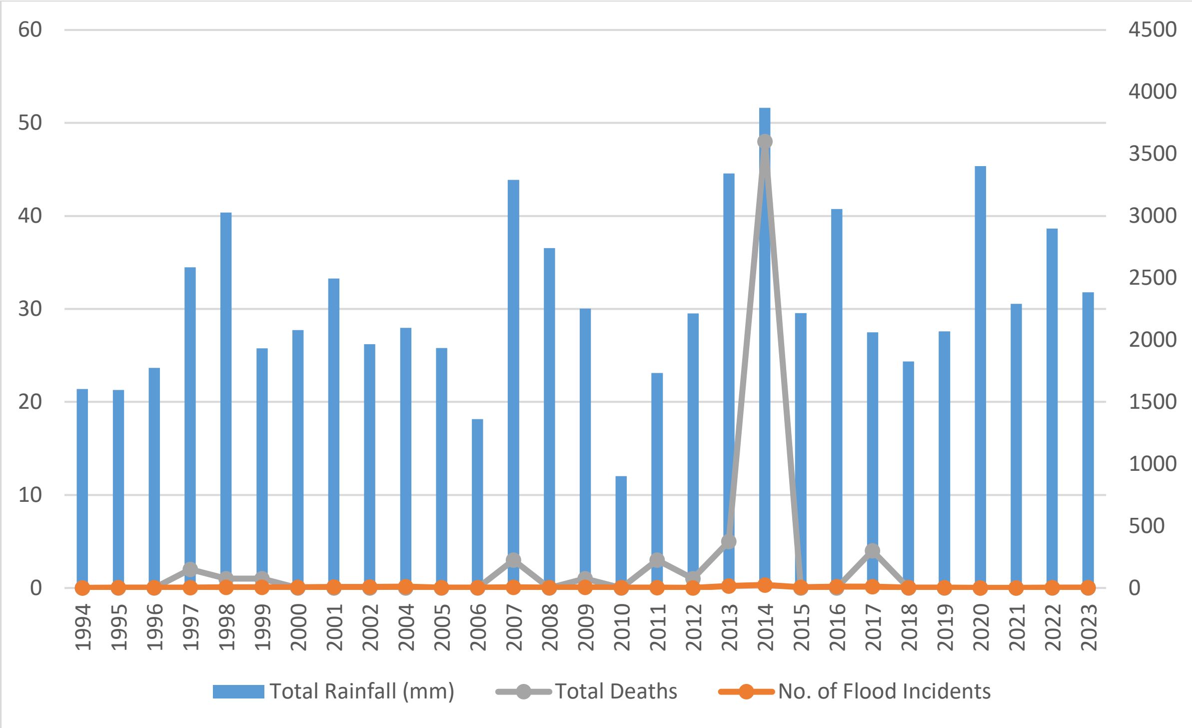
Year	Total Rainfall (mm)	No. of Flood Incidents	Total Deaths
1994	1604.1	1	0

1995	1597.5	2	0
1996	1775.4	3	0
1997	2586.1	4	2
1998	3027.6	5	1
1999	1933.8	6	1
2000	2080.8	7	0
2001	2496.4	8	0
2002	1966.3	9	0
2004	2097.4	10	0
2005	1934.4	4	0
2006	1360.6	3	0
2007	3291.2	5	3
2008	2740.3	4	0
2009	2253.3	6	1
2010	902.7	2	0
2011	1734.3	3	3
2012	2214.3	1	1
2013	3344.0	15	5
2014	3871.5	25	48
2015	2217.1	5	0
2016	3056.6	10	0
2017	2061.0	12	4
2018	1827.8	4	0
2019	2068.7	3	0
2020	3401.25	1	0
2021	2292.53	1	0
2022	2897.76	2	0
2023	2385.41	2	0

Source: Department of Hydrology and Meteorology (2024) and Disaster Risk Reduction Portal (2024)

Figure 4.4

The relationship between rainfall and flood incidents



Source: Department of Hydrology and Meteorology (2024) and Disaster Risk Reduction Portal (2024)

The relationship between rainfall and flood incidents in Bardiya over the years is illustrated through the accompanying data, revealing significant trends and anomalies (table 4.1 and Fig. 4.4). While some years, such as 1994 and 1995, show moderate rainfall with minimal flood incidents and no deaths, other years highlight a more direct correlation between high rainfall totals and increased flood events anomalies (Table 4.1 and Fig. 4.4). Notably, years like 2014, with the highest recorded rainfall of 3871.5 mm, also witnessed the most flood incidents (25) and a significant number of deaths (48), underscoring the potential impact of extreme weather conditions. In contrast, some years like 2020 saw substantial rainfall but fewer flood incidents, suggesting that factors other than just total rainfall may influence the severity and frequency of flooding. Overall, this data provides a clear perspective on how variable the impact of rainfall can be on flooding, potentially influenced by other environmental or human factors.

This significant correlation suggests that increased rainfall can be a contributing factor to more frequent flooding, likely due to the area's capacity to manage or channel the excess water. It's important to note that while rainfall clearly influences flood events, other factors such as land use changes, river management practices, and local topography also play critical roles in flood dynamics. Therefore, the relationship, while significant, does not imply a direct cause and effect but rather highlights rainfall as one important factor among many that can exacerbate flooding.

4.1.2.2 Cloudburst

Key Informant Interviews (KIIs) have highlighted cloudbursts as an additional challenge attributed to climate change in Nepal. Cloudbursts, characterized by sudden and intense rainfall over a short period, pose significant risks such as flash floods, landslides, and damage to infrastructure and livelihoods. This phenomenon exacerbates existing vulnerabilities and underscores the urgency of adapting to changing weather patterns. Cloudbursts can overwhelm drainage systems and lead to rapid water accumulation in rivers and streams, increasing the likelihood of flooding and its associated impacts on communities. Addressing the challenges posed by cloudbursts requires robust adaptation measures, including improved EWSs, resilient infrastructure, and community-based disaster preparedness initiatives. Moreover, integrating local knowledge and experiences into adaptation strategies is essential for effectively managing the risks associated with cloudbursts and building resilience in vulnerable communities.

In the Banke and Bardiya districts of Nepal, flooding exacerbated by cloudbursts and cyclonic activity presents significant challenges. These districts, situated in the low-lying regions of western Nepal, are particularly vulnerable to sudden meteorological events that lead to intense rainfall over short periods. Cloudbursts, characterized by their rapid and extreme nature, release large volumes of water that the local terrain and man-made drainage systems struggle to manage efficiently. This sudden influx of water often results in flash floods, which can rapidly inundate communities, agricultural fields, and critical infrastructure.

Cyclonic activity contributes further to the flooding risk in these areas. As cyclones move inland from the Bay of Bengal, they bring prolonged periods of heavy rainfall and strong winds. These conditions disrupt normal drainage patterns and often lead to rivers and streams overflowing their banks. The Karnali and Babai rivers, significant watercourses in these districts, swell during such events, often breaching levees and inundating adjacent lands and settlements.

Chhetri et al. (2020) highlights the devastating impact of such weather phenomena, The severe flooding in Banke and Bardiya during the monsoon seasons of 2016 and 2017. These events overwhelmed both natural and engineered flood defenses, causing substantial damage to homes, farmland, and infrastructure, and thereby exacerbating the socio-economic challenges in these regions.

4.1.2.3 Melting of the Glacier and possible events of GLOF

The melting of glaciers in the Himalayas, including those that serve as sources for rivers like the Karnali and Geruwa, is a critical consequence of climate change with far-reaching implications. As temperatures rise, glaciers are retreating at accelerated rates, leading to increased meltwater runoff. This meltwater contributes significantly to river flow, particularly during the dry season, sustaining ecosystems, agriculture, and human settlements downstream. However, the accelerated melting also poses risks of Glacial Lake Outburst Floods (GLOFs). These catastrophic events occur when meltwater accumulates behind glacial moraine dams, leading to sudden breaches and massive downstream flooding. GLOFs can devastate communities, infrastructure, and ecosystems in their path. Climate change exacerbates this risk by intensifying glacial melting and altering precipitation patterns, potentially increasing the frequency and magnitude of GLOFs. Addressing the impacts of glacier melt and GLOFs requires comprehensive strategies, including monitoring and EWSs, sustainable water management practices, and adaptation measures to enhance resilience in vulnerable communities. Additionally, mitigating climate change through global efforts to reduce greenhouse gas emissions is crucial to mitigate further glacier loss and associated risks.

4.1.3 Hydrological Factors

4.1.3.1 River Discharge

The discharge characteristics of the Karnali, Geruwa, and Babai rivers are integral to the hydrological dynamics and ecological balance of Nepal's western regions. The Karnali River, originating from the Tibetan Plateau, journeys through the Himalayas, and traverses the Tarai plains before joining the Ganges in India. Its discharge exhibits seasonal fluctuations, with peak flows during the monsoon season, driven by heavy rainfall and melting snow. This surge in water volume sustains agricultural activities, serves as a vital source for irrigation, and fuels hydroelectric power generation. The Geruwa River, a tributary of the Karnali, formed by the merging of the Kuti and Ganga Gad rivers, contributes significant discharge to the Karnali system. While smaller in size compared to the Karnali, its flow patterns closely mirror those of its parent river, reinforcing the hydrological network of the region.

Similarly, the Babai River, originating from the Chure Hills, serves as another critical tributary to the Karnali. Its discharge dynamics, influenced by seasonal variations and monsoonal rainfall, play a pivotal role in sustaining agricultural productivity and supporting local ecosystems. These rivers, with their fluctuating discharges, are essential lifelines for communities residing along their banks, providing water for drinking, irrigation, and other domestic uses. However, the very characteristics that make these rivers lifelines also pose risks, particularly during the monsoon season. Rapid increases in discharge can lead to devastating floods, causing widespread damage to property, infrastructure, and livelihoods, especially in the low-lying plains of the Tarai.

Furthermore, the discharge patterns of these rivers are intricately linked to broader environmental factors, including climate change. With rising global temperatures, glaciers in the Himalayas are melting at accelerated rates, contributing to increased water volumes in rivers like the Karnali, Geruwa, and Babai. While this may initially lead to augmented flows and heightened discharge, it also raises concerns about long-term sustainability and the potential for more frequent and severe flooding events. Thus, managing the discharge of these rivers requires a multifaceted approach that integrates climate adaptation strategies, sustainable water resource management practices, and effective disaster risk reduction measures. By understanding and addressing the complexities of river discharge dynamics, Nepal can better safeguard its communities, ecosystems, and infrastructure from the impacts of climate change and extreme weather events.

4.1.3.2 Sediment Transport

Sediment transport refers to the movement of particles, such as gravel, sand, silt, and clay, by the action of flowing water, wind, or ice. In the context of rivers like the Karnali, Geruwa, and Babai in Nepal, sediment transport plays a significant role in shaping the riverine landscape, influencing river morphology, and affecting ecosystems and human activities downstream.

When asked about the possible factor for flooding, one of the respondent stated that

> *"The Geruwa river was larger in the past and people were more impacted by it, however due to regulation of National Park, the digging and extraction of sediments were not possible. As a result, the land topography also changed resulting high amount of water flow through the Karnali River".*

This was also further evident when the researcher visited the length of the bridge of the both rivers. The Karnali river has a smaller bridge than that of Geruwa. Hence historically proving the statement of the respondent.

In Nepal, where the terrain ranges from the high Himalayas to the low-lying plains of the Tarai, sediment transport is particularly pronounced due to the steep gradients and intense precipitation events. During the monsoon season, heavy rainfall and melting snow and ice lead to increased sediment loads in rivers, as eroded material from the mountains is transported downstream. This sediment can consist of a variety of particles, ranging from fine silt to coarse gravel, depending on factors such as the geology of the region and the intensity of erosion processes.

As these rivers flow from the mountainous regions through the foothills and into the plains, they carry with them varying amounts of sediment. In the mountainous sections, where slopes are steep and erosion rates are high, rivers transport large volumes of sediment, leading to aggradation (build-up of sediment) in river channels and the formation of alluvial fans and deltas in the plains. In the Tarai plains, where the rivers slow down and spread out, sediment deposition occurs, contributing to the fertility of agricultural lands but also posing challenges for infrastructure development and flood management.

Sediment transport also has implications for river ecosystems. The deposition of sediment can create habitats for aquatic organisms and contribute to the nutrient cycling of river ecosystems. However, excessive sedimentation can smother habitats, degrade water quality, and disrupt the natural balance of aquatic ecosystems, impacting biodiversity and the livelihoods of communities dependent on fisheries and other river-based resources.

Moreover, sediment transport interacts closely with other hydrological processes, such as river discharge and flooding. High sediment loads during periods of heavy rainfall can exacerbate flooding by reducing channel capacity and increasing the likelihood of sediment deposition on floodplains and in urban areas, leading to heightened flood risks for communities living along riverbanks.

4.1.3.3 Land Use Changes

Land use changes, particularly the establishment of community forests, has significantly impact in sedimentation patterns within rivers like the Karnali in Nepal. When community forests are established within the sediments or island. However, the placement of community forests within the sediments or islands themselves can also lead to changes in sedimentation patterns. While the vegetation within these forests may help stabilize soil and reduce erosion, it can also trap sediment within the river channel. As sediment-laden water flows through the forested area, vegetation can act as a barrier, causing sediment to settle out and accumulate within the river channel. Over time, this accumulation of sediment can lead to channel aggradation, where the riverbed rises due to sediment deposition.

Figure 4.5

Photograph showing the community forest developed due to the sedimentation within the river.

Source: Sharma, (2022)

4.1.3.4 Infrastructural development

Infrastructural development, particularly the construction of irrigation facilities and embankments, has exerted both positive and negative influences on flooding dynamics in riverine areas such as those along the Karnali, Geruwa, and Babai rivers in Nepal. On the positive side, the establishment of irrigation facilities has provided avenues for managing water resources more efficiently, particularly during periods of drought. These facilities, comprising canals and reservoirs, offer the means to divert water for agricultural use, thereby mitigating water scarcity and minimizing the risk of waterlogging in surrounding areas. Additionally, controlled release mechanisms from reservoirs can help regulate downstream flow, reducing the intensity of flooding during times of heavy rainfall by storing excess water and releasing it gradually. Similarly, the construction of embankments along riverbanks has offered protection against flooding by confining overflowing water within the river channel and preventing its inundation of adjacent settlements and agricultural lands. Embankments also serve to safeguard infrastructure against erosion, effectively stabilizing riverbanks and averting damage.

One of the respondent stated that

> *When the water level rises in the river the irrigation system is also flooded with the water which enters the villages. Similarly smaller tributaries that discharge the water from the village also flooded with the water from Karnali river.*

However, infrastructural developments can also yield adverse consequences for flooding dynamics. Poorly designed or inadequately maintained irrigation facilities may exacerbate flooding incidents. For instance, improper management of canals or reservoirs can lead to waterlogging or the submergence of agricultural lands, particularly during periods of intense rainfall. Moreover, excessive diversion of water for irrigation purposes might diminish downstream flow, thereby heightening flood risks in downstream areas during the monsoon season. Similarly, while embankments provide a protective barrier against floods, they can also induce unintended repercussions. Embankments, if not carefully planned, can impede the natural flow of rivers and disrupt sediment transport processes, resulting in channel aggradation and increased flood susceptibility upstream. Furthermore, embankments may foster a false sense of security, encouraging settlements and agricultural activities in flood-prone areas behind them. This can exacerbate flood damage when embankments are breached or overtopped, as the encroached areas lack natural flood protection.

Criticizing the current state of embankments one of the respondent stated that

> *There has not been proper embankment in the rivers within the district. The embankment project has also been hampered by the lack of budget. The Karnali river management project lacks the funding to pay the contractor and has been barrier to construct further embankments.*

Another respondent supported the view and reinstated that due to this the embankment of the river had been fragile and each year people of Rajapur and Geruwa are suffering from the flood of Karnali river.

The construction and maintenance of embankments face numerous challenges, exacerbating flood management efforts. Firstly, a pervasive lack of resources including funding, skilled manpower, adequate timeframes, and essential materials impede embankment projects, hindering their completion and effectiveness. Additionally, there exists a resistance to embracing new and advanced technologies among stakeholders involved, stemming from inertia and a reluctance to depart from traditional methods. Moreover, there is a prevailing hesitancy to undertake risks associated with embankment construction due to uncertainties in outcomes and potential failures. Political influences wielded by executing agencies often distort decision-making processes, leading to inefficiencies and suboptimal outcomes. Furthermore, inadequate coordination between ministries and local governments results in disjointed efforts, hampering the seamless implementation and management of embankment projects. These challenges collectively undermine the efficacy of embankments as flood control measures, highlighting the need for comprehensive strategies to address these barriers and enhance flood resilience.

In essence, while infrastructural development has introduced mechanisms to manage water resources and mitigate flooding risks along rivers like the Karnali, Geruwa, and Babai in Nepal, it has also introduced complexities and challenges. Effective flood management requires a balanced approach that integrates infrastructural interventions with holistic strategies focused on sustainable water resource management, land use planning, and community engagement. Through careful planning, maintenance, and monitoring, infrastructural projects can contribute positively to flood mitigation efforts while minimizing adverse impacts on riverine ecosystems and communities.

4.2 Impact of the flooding

As floodwaters spread, they can threaten lives, inundate properties and businesses, destroy belongings, damage vital infrastructure and prevent access to essential public services. Often the effects of flood are long term and can be very costly, disruptive and distressing for communities involved. Floods can cause impacts on communities as well as individuals through the temporary, but sometimes prolonged, loss of community services or infrastructure, such as schools, health services, community centers or amenities.
about flood risks.

4.2.1 Community Displacement

Flooding often leads to the displacement of communities living in low-lying areas along riverbanks and floodplains. In Bardiya district, where many communities rely on agriculture for their livelihoods and settlements are often located near rivers, flooding can force residents to evacuate their homes and seek temporary shelter in relief camps or with relatives. Displacement disrupts daily life, causes emotional distress, and poses challenges in accessing basic necessities such as food, clean water, and sanitation facilities. Displaced populations may also face difficulties in returning to their homes and rebuilding their lives, particularly if infrastructure and livelihood opportunities have been severely damaged.

4.2.2 Agricultural Land Damage

Agriculture is the backbone of the economy in Bardiya district, with many households depending on farming for their livelihoods. Flooding can cause extensive damage to agricultural land, destroying crops, eroding topsoil, and contaminating fields with debris and sediment. Submersion of crops can lead to complete loss of yield for the current growing season, resulting in financial hardship for farmers and food insecurity for their families. Additionally, soil erosion and sediment deposition can degrade the fertility of agricultural land over the long term, reducing its productivity and posing challenges for future cultivation. The loss of agricultural income further exacerbates poverty and economic vulnerability among rural communities in the district.

Figure 4.6

Showing the damage of Agricultural land and International Boundary

Source: Field Study (2014)

4.2.3 Infrastructure Loss

Flooding in Bardiya district had cause significant damage to infrastructure, including roads, bridges, schools, healthcare facilities, and water supply systems. Roads and bridges may become impassable or washed away, hindering access to essential services and emergency assistance. Schools and healthcare facilities may be inundated or damaged, disrupting education and healthcare services for the local population. Water supply systems may be contaminated or destroyed, leading to shortages of clean water and increased risk of waterborne diseases. The loss of infrastructure not only disrupts daily life and economic activities but also hampers recovery efforts and long-term development in the affected communities.

During the visit it was seen that due to the flooding the Karnali Bridge connecting Rajapur was impacted and was slightly displaced at one side. Similarly due to the flooding in the Babai River a bridge had collapsed. Most of the bridges and roads that connect rural areas with the cities have been damaged by the floods. The government bodies have been collecting statistics with the help of agricultural, health, educational institutions, security forces, and non-governmental organizations based in the district. Babai River had damaged most of the roads, bridges and public-school buildings in the district.

Figure 4.7

Collapsed bridge of the Babai River and Building due to flood and faulty design

Source: The Himalayan Times (2017)

Similarly, the flooding has also impacted the embankment process within the river figure 4.8 The Babai River had destructed the embankment and entered the Municipality. The location of destruction is shown where new embankments has been constructed.

Figure 4.8

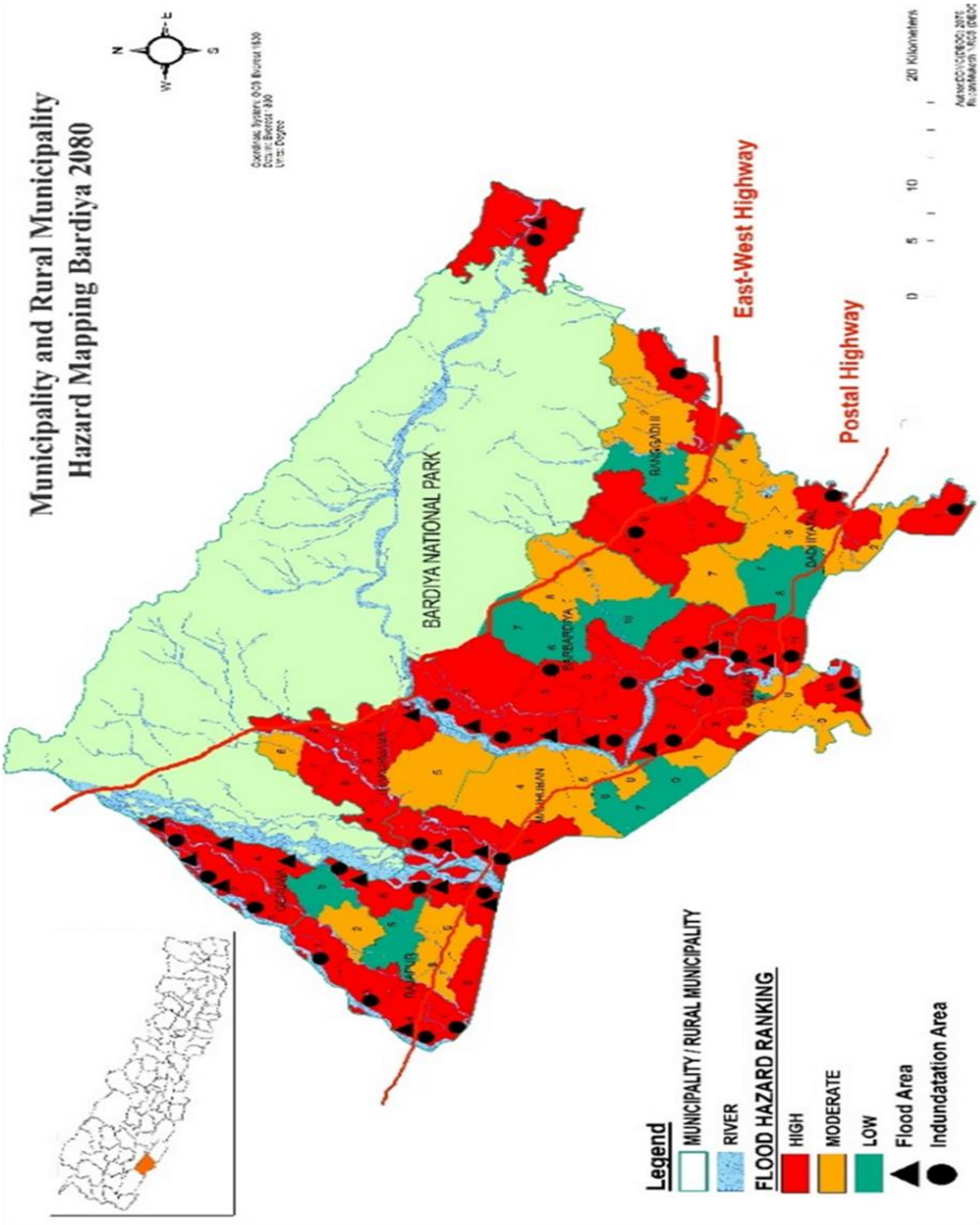
Embankment works on Right & Left banks of Babia River in Gulariya, Bardiya

Source: Field Study (2024)

4.3 Disaster Preparedness

Figure 4.9

Flood hazard assessment and mapping in Bardiya district



Source: Adapted from DDMC (2023) and modified by Researcher (2024)

The figure 4.9 shows that 1,2,3,4 and 6 of Geruwa Rural Municipality, 1,3,4,6,7,9 and 10 of Rajapur, 1,2 and 3 of Madhuban, 1,2,3,7,8 and Thakubaba, 2,3,4, 5 and 10 of Gulariya and 1,2,3,4 and 5 of Barbadiya are highly prone to flood hazard.

It uses a color-coded system to highlight areas with varying degrees of flood hazard—red indicating high risk, orange for moderate risk, and green signifying low risk. The map clearly shows that significant portions of the district, particularly along the river courses and near the southern border adjacent to India, are at high risk of flooding. The East-West Highway, which traverses the district, is also marked, indicating that major transportation routes could be impacted by flood events.

This hazard map is essential for planning and disaster management as it provides a visual tool for identifying areas that require robust flood defenses and preparedness strategies. The presence of Bardiya National Park in the northern part of the map, largely marked in green, suggests that this protected area might face fewer flood hazards, which is crucial for conservation efforts and wildlife protection. However, the communities along the Geruwa and Karnali rivers, shown with extensive red areas, need significant attention to mitigate potential flood damages. This mapping effort aids in prioritizing areas for infrastructure improvements, emergency response planning, and community education about flood risks.

In the Bardiya district of Nepal, DRM policies, strategies, and frameworks are crucially in place at both the local and national levels to mitigate the impact of natural disasters, particularly flooding, which is a significant threat in the region.

At the national level, Nepal has developed comprehensive DRM policies and frameworks to address various hazards, including floods. The National DRRM Policy of Nepal, along with the DRRM Act, provide the legal and institutional framework for DRM in the country. These policies emphasize the importance of proactive measures, including risk assessment, EWSs, preparedness, response, recovery, and resilience-building initiatives.

Furthermore, Nepal's National Adaptation Plan (NAP) process aims to integrate climate change adaptation into development planning and decision-making at all levels, including in flood-prone areas like Bardiya district. The NAP process involves identifying adaptation priorities, mainstreaming climate change considerations into sectoral policies and programs, and enhancing coordination among relevant stakeholders.

At the local level, Bardiya district has established DRM committees and institutions responsible for implementing disaster risk reduction initiatives. These committees work closely with communities, local governments, non-governmental organizations (NGOs), and other stakeholders to develop and implement DRM plans tailored to the specific needs and vulnerabilities of the district.

The Disaster Preparedness and Response Plan (DPRP) developed for the Geruwa Rural Municipality is a strategic document designed to prepare and equip the local community to effectively handle natural disasters. Its primary objective is to minimize human and material losses through improved preparedness and coordinated response efforts. The plan is crafted with a clear understanding of the specific risks and vulnerabilities faced by the community, particularly given Geruwa's geographic and environmental characteristics.

The DPRP assesses the current status of disaster management within the municipality, identifying strengths and areas for improvement. This evaluation includes the effectiveness of existing EWSs, the structural integrity and resilience of critical infrastructure, and the general readiness of the community to respond to disaster scenarios. By understanding these elements, the plan outlines targeted strategies to enhance overall preparedness.

Legally and institutionally, the DPRP is aligned with Nepal's broader legal framework, which empowers local governments to manage disaster risks. This alignment ensures that the preparedness and response activities are supported by necessary legal mandates and are integrated within the local governance structures, enhancing their effectiveness and sustainability.

Key components of the plan focus on preparedness measures that are tailored to meet the specific needs of the Geruwa area. These include conducting regular community training sessions, performing routine infrastructure resilience assessments, and updating and maintaining robust EWSs. These proactive measures are critical in building a community that is well-prepared to face potential disasters.

In terms of response, the DPRP clearly defines the roles and responsibilities of various stakeholders, including local government officials, community leaders, and emergency response teams. This organizational clarity is crucial during disaster events, enabling a swift and coordinated response that can significantly reduce the impact of such incidents. The plan specifies procedures for resource mobilization, emergency medical services, and temporary shelter provisions, ensuring that immediate needs are met efficiently.

Community involvement is another cornerstone of the DPRP. The plan emphasizes the importance of engaging local residents in the preparedness process, educating them about risks, and training them in basic response techniques. This community-centric approach not only enhances local capacity to deal with disasters but also fosters a sense of ownership and responsibility among residents.

Resource allocation is thoroughly addressed within the plan, detailing the financial, human, and material resources required to support disaster management activities. Ensuring that these resources are available and can be deployed quickly is essential for effective disaster response and recovery operations.

Finally, the DPRP includes provisions for its own regular review and updates. This iterative process allows the plan to remain relevant and effective by incorporating new data, adapting to changes in the risk environment, and integrating lessons learned from past disaster events. This dynamic approach ensures that the disaster preparedness and response strategies evolve in line with emerging challenges and opportunities.

4.3.1 Community-based EWSs

Community-based EWSs for floods comprise four inter-related elements: a) assessments and knowledge of flood risks in the area, b) local hazard monitoring (forecasts) and warning service, c) flood risk dissemination and communication service, and d) community response capabilities. In Birdiya district there are a cornerstone of the flood preparedness strategy. These systems leverage local networks and technology to provide timely warnings to residents in flood-prone areas. The effectiveness of these systems hinges on community involvement, ensuring that alerts are not only disseminated rapidly but are also acted upon effectively. Local governance structures, not elected only from selection and respected of the community such as the Badghar (Tharu Community) in Bardiya, play a pivotal role in this process, aiding in the coordination and communication necessary during flood events. This approach not only saves lives by enabling timely evacuations but also helps in safeguarding properties and livestock from impending floods.

Figure 4.10

Early Warning System in the Karnali

Source: Servir, (2020)

The Department of Hydrology and Meteorology (DHM) has set up both automatic and manual rain and river gauges on the bank of the Karnali River at Chisapani.

4.3.2 Infrastructure development

Constructing and maintaining flood protection infrastructure is crucial for mitigating the impact of flooding on communities and critical infrastructure. Embankments, often built along riverbanks, serve as barriers to contain floodwaters within the river channel, preventing inundation of adjacent areas. These structures are designed to withstand the force of floodwaters and minimize the risk of erosion and breaches. Drainage systems, including culverts, stormwater drains, and retention ponds, are essential for managing excess water and preventing urban flooding. Properly designed drainage systems facilitate the efficient removal of rainwater, reducing the risk of waterlogging and damage to roads, buildings, and utilities.

Additionally, flood shelters are strategically located facilities where residents can seek refuge during flooding events. These shelters provide temporary accommodation, food, and basic amenities to displaced individuals, ensuring their safety and well-being until the floodwaters recede (Fig. 4.11).

Figure 4.11

Shelter house build in Bardiya district

Source: Field Visit (2024)

Moreover, heightening water taps and constructing community mess facilities are additional measures that contribute to flood resilience. Elevating water taps above flood levels ensures continued access to clean water for drinking and sanitation purposes during floods, while community mess facilities provide centralized cooking and dining areas for residents affected by flooding, ensuring access to meals and communal support.

4.3.3 Capacity building and awareness-raising

Conducting training programs, workshops, and awareness campaigns plays a crucial role in enhancing the capacity of local communities, government officials, and stakeholders in disaster preparedness, response, and recovery efforts. These initiatives aim to equip individuals and organizations with the necessary knowledge, skills, and resources to effectively mitigate the impact of disasters and manage emergency situations. Organizations such as APF Nepal have taken proactive steps to conduct disaster drills and training exercises, providing hands-on experience and practical training to participants. By simulating various disaster scenarios, these drills enable participants to familiarize themselves with emergency protocols, evacuation procedures, and first-aid techniques, thereby enhancing their readiness to respond to real-life emergencies. Additionally, various non-governmental organizations (NGOs) and international non-governmental organizations (INGOs) collaborate to organize workshops and awareness campaigns focused on disaster risk reduction and resilience-building initiatives. These campaigns raise awareness about the importance of disaster preparedness, EWSs, and community-based disaster management strategies. They also promote the adoption of sustainable practices and innovative solutions to address emerging challenges posed by climate change and environmental degradation. By fostering collaboration and knowledge-sharing among diverse stakeholders, these initiatives contribute to building a more resilient and disaster-ready society capable of effectively responding to and recovering from disasters.

4.3.4 Indigenous method

Indigenous knowledge and practices have played a significant role in flood mitigation in various communities, with examples such as the Tharu community in Bardiya, Nepal, showcasing a blend of tradition and adaptation to environmental challenges. Historically, indigenous communities have developed unique coping mechanisms based on their intimate understanding of the local environment. These methods include the use of traditional forecasting signs from the behavior of animals or the appearance of certain environmental cues, which signal the onset of floods. Moreover, traditional construction practices, such as elevated homes or the strategic use of local flora to stabilize riverbanks and manage water flow, are common indigenous strategies.

In places like Bardiya, the Tharu community utilizes a combination of embankments made from local materials and community-based EWSs. These practices are rooted in generational knowledge passed down through oral traditions and practical application. However, while these indigenous methods provide a crucial foundation for resilience against floods, they often require integration with modern scientific approaches to enhance their effectiveness in the face of increasingly unpredictable weather patterns caused by climate change.

The effectiveness of these traditional methods is increasingly challenged by the scale and unpredictability of modern flood events, underscoring the need for a hybrid approach that respects and incorporates indigenous knowledge while introducing scientific advancements in DRM. This approach not only enriches the overall strategy for disaster preparedness but also ensures community buy-in and the sustainability of flood mitigation efforts.

4.3.5 Other Method

The presence of DRM policies, strategies, and frameworks at both the local and national levels in Bardiya district demonstrates a concerted effort to reduce the impact of floods and enhance the resilience of communities to natural disasters. Continued collaboration, coordination, and investment in disaster risk reduction efforts are essential to effectively address the evolving challenges posed by floods and other hazards in the district.

4.4 Measures to mitigate the flood

4.4.1 Structural Measures

Structural measures in flood management involve physical constructions or alterations designed to prevent or mitigate the impact of floods. These measures are critical components of comprehensive flood risk management strategies, especially in flood-prone areas such as Bardiya, where they can significantly reduce the vulnerability of life and property.

Dams and Reservoirs: One of the most common structural measures is the construction of dams and reservoirs. These structures are designed to control river flow and store excess water during periods of heavy rainfall, which can be gradually released in controlled amounts to prevent downstream flooding. Dams not only help in flood control but also contribute to water supply for irrigation and hydropower generation.

Levees and Floodwalls: Levees and floodwalls are another form of structural intervention used to protect specific areas by containing or diverting floodwaters. These barriers are built along the sides of rivers or around communities to prevent river water from spilling into inhabited areas. Maintaining and reinforcing these structures is crucial to ensure they perform effectively during flood events.

Floodgates and Diversion canals: Floodgates and diversion canals also play a significant role in managing flood risk. Floodgates can be opened or closed to control the flow of water in a waterway, thus preventing floods during rainy seasons and maintaining water flow during dry periods. Diversion canals are used to redirect excess water to less critical areas or towards water bodies that can safely absorb it, thus protecting the main populated or agriculturally important areas from flooding.

River Channel modification: River channel modifications such as dredging and riverbank stabilization are critical in flood management. Dredging involves the removal of silt and debris from the bottom of river channels, which improves water flow and increases the river's capacity to carry water, thereby reducing the likelihood of overflow. Riverbank stabilization involves reinforcing banks with vegetation or other materials to prevent erosion and provide natural barriers to rising waters.

Elevated Structure: Elevated structures are increasingly being used, particularly in highly flood-prone areas. Elevating homes and other buildings above known flood levels can significantly reduce the damage caused by floodwaters. This method is often used in combination with other structural measures to ensure maximum protection for critical infrastructure.

Incorporating these structural measures requires careful planning and significant investment but offers tangible protection against flood risks. However, they must be integrated with non-structural measures such as planning, policies, and community education for a holistic approach to flood risk management. This balanced strategy ensures that while physical barriers can protect against immediate flood threats, the broader societal and environmental factors are also addressed to sustain long-term resilience against flooding.

4.4.2 Non-Structural Measures

Non-structural measures in flood management involve approaches that do not include physical construction but focus on policies, practices, and programs that reduce risks and impacts associated with flooding. These measures are crucial for comprehensive flood risk management, especially in regions prone to frequent and severe flooding like Bardiya. By integrating non-structural strategies, communities can enhance their resilience without altering the landscape through construction projects.

One primary non-structural measure is the development and implementation of effective land-use planning and zoning laws. By restricting construction in flood-prone areas and promoting suitable land use, governments can significantly reduce the vulnerability of properties and infrastructures to flood damages. Such planning involves designating specific areas that are especially vulnerable to flooding as green spaces, recreational parks, or agricultural zones rather than for residential or industrial development.

Another important non-structural approach is the establishment of flood forecasting and warning systems. These systems provide critical information that can be used to alert communities about impending flood events. Effective forecasting and EWSs allow residents sufficient time to evacuate, secure their properties, and take other necessary actions to minimize potential losses. Integrating local knowledge with modern technological tools enhances the accuracy and reliability of these systems.

Public education and awareness programs are also vital non-structural measures. Educating the community about flood risks, preparedness, and response strategies empowers individuals to take proactive steps in protecting themselves and their properties. These programs can include school-based education, community workshops, and public information campaigns that inform residents about how to prepare for and respond to floods.

Flood insurance programs represent another non-structural tool that can mitigate the financial impact of floods on individuals and businesses. By providing financial compensation for losses incurred during flooding, insurance helps communities recover more quickly and reduces the economic impact of disasters on affected populations.

Lastly, environmental management practices such as watershed management, restoring wetlands, and reforestation projects play a significant role in non-structural flood mitigation. These practices help maintain the natural water absorption capacity of the land, reduce runoff, and manage river flows more effectively.

Incorporating these non-structural measures into flood risk management strategies offers a sustainable and often cost-effective way to reduce the impacts of floods. These measures complement structural interventions, providing a balanced approach that enhances flood resilience while preserving the natural environment.

4.4.3 Flood Damage Analysis

Tangible damage analysis involves assessing the physical damage caused by floods to infrastructure, buildings, crops, and other tangible assets. This includes estimating the cost of repairing or replacing damaged structures and infrastructure, as well as the economic losses incurred by affected communities.

Intangible damage analysis focuses on evaluating the non-monetary impacts of floods, such as loss of life, displacement of populations, social disruption, and psychological trauma. This involves assessing the human and social costs of flooding, including the long-term effects on community resilience, livelihoods, and well-being.

4.4.4 Removing Sedimentation to distribute the flow of the river

Addressing sedimentation in the rivers of Bardiya is a critical component of managing flood risks and enhancing the ecological health of river systems. Excessive sedimentation reduces the capacity of river channels to efficiently manage water flows, often resulting in overflow and flooding during periods of heavy rainfall. Strategic dredging is one of the initial steps necessary for mitigating these issues. It involves the careful removal of accumulated sediments to increase the channel's water-carrying capacity and improve flow efficiency. This activity must be regularly monitored and adapted based on ongoing assessments to ensure its effectiveness as river dynamics evolve.

Alongside dredging, comprehensive sediment management plans are vital. These plans would encompass a variety of measures aimed at controlling sediment from upstream sources, including improved land use practices, afforestation projects, and erosion control initiatives. Managing sediment production and accumulation helps in maintaining the natural flow of rivers and reducing the impacts of sedimentation on flood risks.

River training works such as the construction of levees, dykes, and spillways also play a crucial role. These structures are designed to guide and manage the river flow, directing waters away from populated or agriculturally significant areas to prevent flooding. Integrating these structures with the natural processes of the river is essential to maintain ecological balance and effectiveness.

The involvement of local communities in the management of river sedimentation is crucial. Residents who are familiar with the historical changes in river behavior can provide valuable insights that are essential for the success of maintenance and management strategies. Furthermore, community education about the causes and prevention of sedimentation fosters a collective approach to river management, encouraging behaviors that mitigate sediment loads.

Finally, strengthening the policy and regulatory framework governing river management and flood mitigation is indispensable. Effective policies support sustainable practices in river basin management, enforce regulations against activities that increase sedimentation, and allocate funding for research into innovative flood and sediment management techniques.

By taking a comprehensive and integrated approach to manage sedimentation, Bardiya can not only address its immediate flooding issues but also contribute to the long-term sustainability and ecological health of its river systems. This strategy not only protects the community and agricultural lands but also preserves the natural beauty and biodiversity of the region.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

Flooding is a significant natural hazard that poses severe risks to human life, property, and infrastructure. In regions like Bardiya district in Nepal, the impacts of flooding are particularly pronounced due to the area's reliance on agriculture and the presence of major rivers. Natural hazards, defined as potentially damaging physical events, phenomena, or human activities, can cause substantial disruption and degradation. Bardiya's socio-economic fabric is heavily dependent on agricultural activities, with significant contributions from rice, wheat, and other crops. The district is also home to diverse ethnic communities, including Tharus, Brahmins, Chhetri's, and indigenous groups, who depend on farming and livestock for their livelihoods. The region's natural beauty, bolstered by Bardiya National Park, supports biodiversity and offers opportunities for eco-tourism. However, this dependence on natural resources makes Bardiya vulnerable to the impacts of flooding, which can disrupt agricultural production, damage infrastructure, and threaten livelihoods.

The primary objective of this study is to investigate the causes, consequences, and effective mitigation strategies for flood hazards in Bardiya district. The research aims to identify the hydrological and climatic factors influencing flooding, analyze the socio-economic impacts of floods on local communities, and evaluate existing disaster risk management practices. Additionally, the study seeks to recommend integrated flood management strategies that incorporate both traditional knowledge and modern technological advancements.

This research employs a combination of field observations, interviews, and secondary data analysis. The study focuses on three major rivers in Bardiya: the Karnali River, Geruwa River, and Babai River. These rivers significantly influence the area's hydrology and susceptibility to flooding. Field observations were conducted to gather primary data on river dynamics and flood impacts. Interviews with local communities and stakeholders provided insights into the socio-economic consequences of flooding and the effectiveness of current mitigation practices. Secondary data from government reports, scientific studies, and meteorological records were analyzed to understand the historical and climatic trends contributing to flood risks.

The findings reveal that Bardiya's flooding issues are primarily driven by high water discharge during the monsoon season, sediment transport, topographical factors, climate change, and anthropogenic activities. The Karnali River, with its large catchment area and significant discharge capacity, frequently overflows, causing widespread flooding. Sediment transport from the mountainous regions further exacerbates flooding by reducing river channel capacity. Topographical factors, such as the region's flat terrain and extensive river systems, make Bardiya inherently prone to flooding. Climate change has intensified and made rainfall patterns more unpredictable, increasing the frequency and severity of floods. Human activities, including deforestation, unregulated construction, and poor land management practices, contribute to increased runoff and reduced natural absorption of rainfall.

To mitigate the impacts of flooding in Bardiya, several recommendations are proposed. First, enhancing flood forecasting and early warning systems is crucial for providing timely alerts to communities. Integrating traditional knowledge with modern technological advancements can develop robust flood management strategies. Community-based disaster risk reduction approaches should be strengthened, encouraging active participation from local residents in planning and implementing flood preparedness measures. Policies and infrastructure addressing flood risk management must be revised and strengthened, with a focus on sustainable land use and water resource management. Additionally, ongoing research and data collection are essential to refine predictive models and improve understanding of flood dynamics. Investments in resilient infrastructure and coordinated efforts among government agencies, local communities, and international partners are vital for building a comprehensive and effective flood mitigation framework.

In conclusion, Bardiya district faces significant challenges due to recurrent flooding, driven by a combination of natural and anthropogenic factors. Understanding the hydrological, climatic, and socio-economic dimensions of flooding is essential for developing effective mitigation strategies. By enhancing early warning systems, integrating traditional and modern knowledge, and strengthening community-based approaches, Bardiya can better prepare for and respond to flood risks. Sustainable policy reforms, infrastructure improvements, and continued research are critical for building resilience and safeguarding the livelihoods and well-being of Bardiya's residents in the face of increasing flood hazards.

5.2 Conclusion

The Bardiya district in Nepal grapples with a complex array of factors contributing to flooding, as identified through our investigation. Hydrological and climatic factors, particularly the monsoon rainfall patterns and the dynamics of the Karnali, Geruwa, and Babai rivers, play pivotal roles in exacerbating flood risks within the region. The topography, characterized by steep slopes in the Himalayas and expansive alluvial plains in the Tarai, further amplifies these risks by facilitating rapid runoff and sedimentation processes. Consequently, the district is highly susceptible to flooding, with communities facing recurrent inundation events during the monsoon season.

The socio-economic repercussions of flooding in the Bardiya district are profound and multifaceted. Displacement of communities is a significant consequence, as floods force residents to evacuate their homes and seek temporary shelter. Displaced individuals often grapple with challenges related to access to clean water, sanitation facilities, and food security. Moreover, agricultural land, a cornerstone of the local economy, is frequently inundated, leading to crop damage and loss of livelihoods for farmers. Additionally, infrastructure such as roads, bridges, and buildings suffer damage, disrupting essential services and impeding recovery efforts.

Despite the existence of DRM policies and frameworks at both local and national levels, their effectiveness is hindered by various challenges. Resource constraints, including limited funding and manpower, pose significant barriers to the implementation of flood mitigation measures. Furthermore, coordination issues between government agencies and insufficient community participation hamper the efficacy of existing strategies. There is a pressing need for integrated and participatory approaches to flood management that incorporate traditional knowledge, community-based solutions, and sustainable practices. By leveraging local resources, expertise, and community engagement, the Bardiya district can enhance its resilience to floods and build a more sustainable and disaster-resilient future for its residents.

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APPENDICES

Appendix "A"

(Refers to page no. 23)

INFORMED CONSENT FORM

Flood Hazard in Bardiya, Nepal: Causes, Consequences and Effective Mitigation Strategies

Date: …………/……………/…………(day/month/year)

I, (Mr./Mrs./Ms.) …………………………………………………...hereby have signed the consent to declared that:

1. Before signing the certificate of consent, I have explained the objectives and methods of the study.
2. I have had the opportunity to ask questions about the study and any questions that I have asked have been answered to my satisfaction.
3. I have the right to withdraw from the study at any time if I feel uncomfortable.
4. The investigator will keep the information confidential and my personal data will not be declared in any case except the academic purpose.
5. The investigator will provide additional necessary information about the study, if there are any.

I have read and understand the above information and I consent voluntarily to participate as a participant in this research.

Signature/Finger Print ……………………………………….. (Respondent/Informant)

Signature ……………………………………........... (Researcher)

(DSP Hari Bahadur Gurung)

Appendix "B"

(Refers to page no. 22)

LIST OF RESPONDENTS

ID No.: ……………………

Flood Hazard in Bardiya, Nepal: Causes, Consequences and Effective Mitigation Strategies

Ward No. ………….   Date: ………/………../…………

1. Age …………… (in years)
2. Gender (Male//Female)

Respondent Number	Position	Location
1	Ward Chairperson	Rajapur Ward no. 1
2	Ward Chairperson	Rajapur Ward no. 2
3	Ward Chairperson	Rajapur Ward no. 3
4	Ward Chairperson	Rajapur Ward no. 4
5	Ward Chairperson	Rajapur Ward no. 5
6	Ward Chairperson	Rajapur Ward no. 6
7	Ward Chairperson	Rajapur Ward no. 7
8	Ward Chairperson	Rajapur Ward no.9
9	Ward Chairperson	Rajapur Ward no.10
10	Ward Chairperson	Guleriya Ward no.1
11	Ward Chairperson	Guleriya Ward no.2
12	Ward Chairperson	Guleriya Ward no.3
13	Ward Chairperson	Guleriya Ward no.7
14	Ward Chairperson	Guleriya ward no.8
15	Mayor	Rajapur Municipality
16	Mayor	Guleriya Municipality
17	CDO	Bardiya District
18	SP	No. 31 Bn APF Nepal
19	Colonel	Nepali Army
20	SP	Nepal Police

21	DE	Karnali River Management Project
22	Chairman	Geruwa R.M.
23	Ward Chairman	Geruwa Ward no.1
24	Ward Chairman	Geruwa Ward no.2
25	Ward Chairman	Geruwa Ward no.3
26	Ward Chairman	Geruwa Ward no.5
27	DE	Babai River Management Project
28	Prog. Coordinator	CARITAS, Nepal
29	Butghar	Geruwa Ward No. 2
30	Butghar	Geruwa Ward No. 3
31	Butghar	Geruwa Ward No. 5
32	Butghar	Rajapur Ward No. 3
33	Butghar	Rajapur Ward No. 7
34	Butghar	Guleriya Ward No. 5
35	Butghar	Guleriya Ward No. 8
36	Teacher	Rajapur Ward No. 5
37	Local Population	Rajapur Ward No. 7
38	Local Population	Geruwa Ward No. 1
39	Local Population	Guleriya Ward No. 3

Appendix "C"

(Refers to page no. 22)

INTERVIEW QUESTIONS

ID No.: ………….

Flood Hazard in Bardiya, Nepal: Causes, Consequences and Effective Mitigation Strategies

Ward No. …………. Date: ………/………/………

1. Age …………… (in years)
2. Gender (Male//Female)
3. Education (………………………………...)
4. Occupation (……………………………….)

A. Questionnaire for the interview with DE of Karnali & Babai River Management Project

1. Can you provide a brief overview of the role and objective of your organization?
2. Based on the river flowing pattern what are the identified cause of the flooding in this area?
3. Can you provide a brief technical detail of the river from your perspective and why it is causing the flood?
4. Would you agree that climate change and hydrological factors contribute to the flooding?
5. In your view what are the measures that should be adopted to address the issue of the flooding?
6. As, there has been general consensus about the development of stronger and durable embankments, why has it not been possible?
7. What are the major plans and policies that has been developed to mitigate the threat of flooding in this area?

B. Questionnaire for the interview with Chief District Officer

1. Based on our survey, we found various reason for the flooding, based on your information and knowledge can you provide us with the information on the major reason for the flooding?
2. Each year the flood occurs in the villages near to Karnali, Geruwa and Babai River, what are the preparedness and disaster risk reduction strategies developed by the DAO?
3. How do you assess the effectiveness of flood management strategies and infrastructure in mitigating the impact of flooding events?
4. What are the primary challenges faced by our district in managing and responding to flooding emergencies?
5. How do you prioritize resources and efforts in flood preparedness and response planning?
6. What measures have been taken to involve and educate the community in flood preparedness and response efforts?
7. How do you coordinate with other local, regional, and national agencies or organizations in flood management and response activities?
8. Can you discuss any recent initiatives or projects aimed at improving our district's resilience to flooding events?
9. How do you plan to address any gaps or shortcomings identified in our current flood preparedness and response strategies?

C. Questionnaire for the interview with the mayor

1. Can you provide a short overview of the flooding scenario in your area?
2. During our interview with the ward representative, we have found that .... are the causes of the flood, would you like to add any other causes?
3. Each year the issue of the flood is persistent in your area, what are the plans/policies that you have adopted after assuming the post of Mayor?
4. Can you provide in brief, the level of preparedness in your area, and what are the plans and policies that your office has adopted?
5. In your view what are the major barrier for the mitigating the threat of the flood in your area?

6. During our interview with the ward chairperson majority of them were with the view that following measures should be taken.,.... In your view what should be done to mitigate the flooding in your area?

D. Questionnaire with Security Force Personnel/Commander

1. How has the recent flooding impacted the security situation in Bardiya district, and what are the main security concerns arising from this situation?
2. Can you describe the role of the security force in responding to flooding emergencies and ensuring the safety and security of affected communities?
3. What specific measures or disaster response plan does the organization?
4. What type of support/response does the security forces get from local level government and the people during flood-related operations?
5. What are the specific challenges that security force face during the disaster response?
6. What training or preparedness measures are in place to equip security personnel with the necessary skills and knowledge to respond effectively to flood-related incidents?
7. Does the organization provide any necessary training and other necessary support to the community?
8. Looking ahead, what lessons have been learned from past flooding events, and what improvements or adjustments are being considered to enhance the role of the security force in future flood response and preparedness efforts?

Appendix "D"

(Refers to page no. 32)

Rainfall Data in Chisapani, Bardiya, Nepal (Figure 4.2)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1994	11.5	76.7	0	15.2	25	235.5	658.5	386.6	195.1	0	0	0
1995	104	29.7	21.4	0	156.3	301.8	575.2	665.8	285.9	0	8.7	1.8
1996	39.8	59.6	0.7	31	5.4	290.8	698.8	313.1	506.3	124.2	0	0
1997	127.2	6.5	2.6	42.4	36.5	138.7	894.4	717.8	464.9	30.2	39.7	148.4
1998	8.9	38	45.5	94.4	22.1	216	810.8	817.4	565.2	97.2	15.6	0
1999	18.7	0.3	0	0	107.4	397.8	484.9	802.5	396.3	116.3	0	29.1
2000	27	34.5	14.5	15.4	150.5	293.3	648.3	585.2	336.6	0	0	0
2001	22.1	13.8	8	7.5	7.5	580	792	726.4	140.4	44.7	0	0
2002	99.1	53.3	6.2	54.9	194.5	218.6	529.4	707.6	268.5	38.4	6.6	1
2004	1	15.3	0	86.2	91.7	76.5	749.4	501.8	407.4	167	0	0
2005	20.5	223.7	637.7	682.1	261.7	38.7	0	4	0	1	70.4	18.6
2006	0	0	139	0	0	325.6	426.8	624.5	412.6	36.5	0	20
2007	0	74.8	0	0	60.7	315.9	1560	957.5	317.4	4.7	0	2.2
2008	14.9	11	0	61	98.9	598.7	864.6	653.9	371.5	61.2	0	0
2009	0	0	9	0	73	195.7	653.5	855.2	427.8	12.8	1.5	0
2010	25.1	41.3	0.2	0	191.5	627.9	16.2	0	0	0	0	0
2011	0	0	0	9.1	142.2	594.7	762.1	0	225.4	0	0	0
2012	38	39.5	15.7	28.6	33.9	68.8	911.4	605.5	448.6	1.7	0	0.7
2013	61.6	141.1	0	0	36.9	972.8	718.2	824.3	187.4	189.2	3.8	3.4
2014	46.7	28.1	39.8	2.3	18.7	139.4	990.7	1673.1	360.8	64.9	0	26
2015	43.9	4.5	129.4	37.3	7.9	254.7	449.4	1058.1	289.1	26.7	1.5	0
2016	5.8	8	45.7	21.2	136.6	311	1058.8	372.7	474.8	91.6	0	0
2017	8.5	0.1	15.9	10.6	77.5	308.2	585.8	1058.4	177.5	15.8	0	0.4
2018	9.5	20	13.1	22.6	115.9	387.7	557.8	607.2	441	0	0	0
2019	50.7	59.8	4.7	33	9.7	194	669.4	398.8	562.1	40.6	0	80.4
2020	122.91	37.2	0	27.62	88.21	594.82	1078.6	750.73	385.81	0	2.1	0.01
2021	0	0	9.41	309.3	334.3	613.91	752.62	167.52	180.24	0.01	46.02	54.62
2022	59.81	0	11.5	96.75	381.22	631.53	725.42	995.62	394.01	0	0	24.11

2023	0	0	47.04	24.81	94.92	153.4	638.62	1308	218.52	48.4	0.11	4.5

Source: Department of Hydrology and Meteorology (2024)

Temperature Data in Chisapani, Bardiya, Nepal (Figure 4.3, page no. 34)

Max Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1994	21.186	23.146	30.493	34.33	37.654	35.456	32.235	31.1	31.251	30.829	26.063	21.867
1995	19.364	23.271	28.367	35.866	37.548	36.126	31.803	30.77	30.923	31.141	25.946	21.89
1996	20.132	23.451	29.903	35.243	38.303	33.679	30.987	30.619	30.696	28.354	25.683	21.045
1997	19.08	22.964	28.587	31.623	36.811		32.683	30.961	30.831	28.351	24.579	18.432
1998	18.306	22.937	26.112	32.78	35.95							20.832
1999	18.583	25.107	31.593	37.43	35.054	33.536	30.854	30.651	30.516	29.851	25.79	20.27
2000	19.051	21.744	29.141	35.103	34.706	31.61	30.661	30.754	30.253	30.722	26.22	21.706
2001	19.44	25.671	30.019	36.086	36.029	32.113	32.096	32.432	32.47	31.216	26.8	22.261
2002	20.941	24.064	30.19	34.703	34.374	34.533	33.093	32.016	31.086	30.738	25.906	21.587
2003	16.203	23.671	28.145	35.736	37.329	34.57	32.106	31.896	30.596	31.077	26.313	20.909
2004	19.125	25.041										
2005			30.5	36.256	37.293	38.9	31.809	31.522	32.2	30.58	25.896	21.412
2006	22.451	28.525	30.703	35.813	36.016	34.146	32.332	32.229	32.159	31.2	26.44	22.012
2007	20.987	24.694	28.303	35.093	36.503	35.32	31.68	31.022	31.386	30.258	25.709	21.535
2008	19.819	22.92	30.838	35.583	36.229	32.82	30.548	31.19	32.344			
2009	22.536		31.251	37.026	36.809	38.03	33.625	32.216	31.256	23.92	23.92	20.055
2010	17.303	23.967	32.241	38.48		36.91	31.958			30.916	26.096	20.796
2011			30.529	34.973	35.69	33.253	31.393	31.403	32.223	31.799	26.066	21.251
2012	19.903	24.641	31.419	36.976	39.061	38.563	31.674	32.09	32.123	31.174	25.603	20.803
2013	18.909	23.046	30.709	35.269	37.464	32.423	31.509	32.025	33	30.235	25.013	20.39
2014	18.27	22.021	29.254	34.98	37.838	36.823	32.406	32.638	32.703	30.34	25.853	19.974
2015	18.783	24.457	28.09	32.343	37.196	36.38	32.99	32.183	33.153	31.132	26.886	21.387
2016	20.403	26.017	31.829	37.7	36.077	34.063	31.896	33.874	32.2	31.274	26.193	21.667
2017	21	26.175	29.448	36.306	36.883	35.353	31.841	32.025	33.253	31.77	26.283	21.909
2018	18.322	25.371	32.238	35.266	36.596	35.836	32.629	31.774	32.526	30.69	25.41	21.096
2019	20.454	22.582	29.622	35.04	38.732	37.55	33.619	34.522	32.52	31.683	27.103	18.616
2020	18.264	22.931	27.687	33.876	34.532	33.18	32.235	33.809	33.516	32.338	26.153	21.151
2021	20.212	26.267	32.541	36.47	33.422	32.733	33.261	32.406	33.576	31.396	25.27	20.79
2022	18.735	21.714	32.709	37.936	36.43	36.57	33.883	33.558	32.326	28.761	25.063	20.548
2023	19.299	25.807	30.49	35.003	36.161	38.726	33.025	31.696	33.336	31.035	26.68	21.509

Minimum temperature

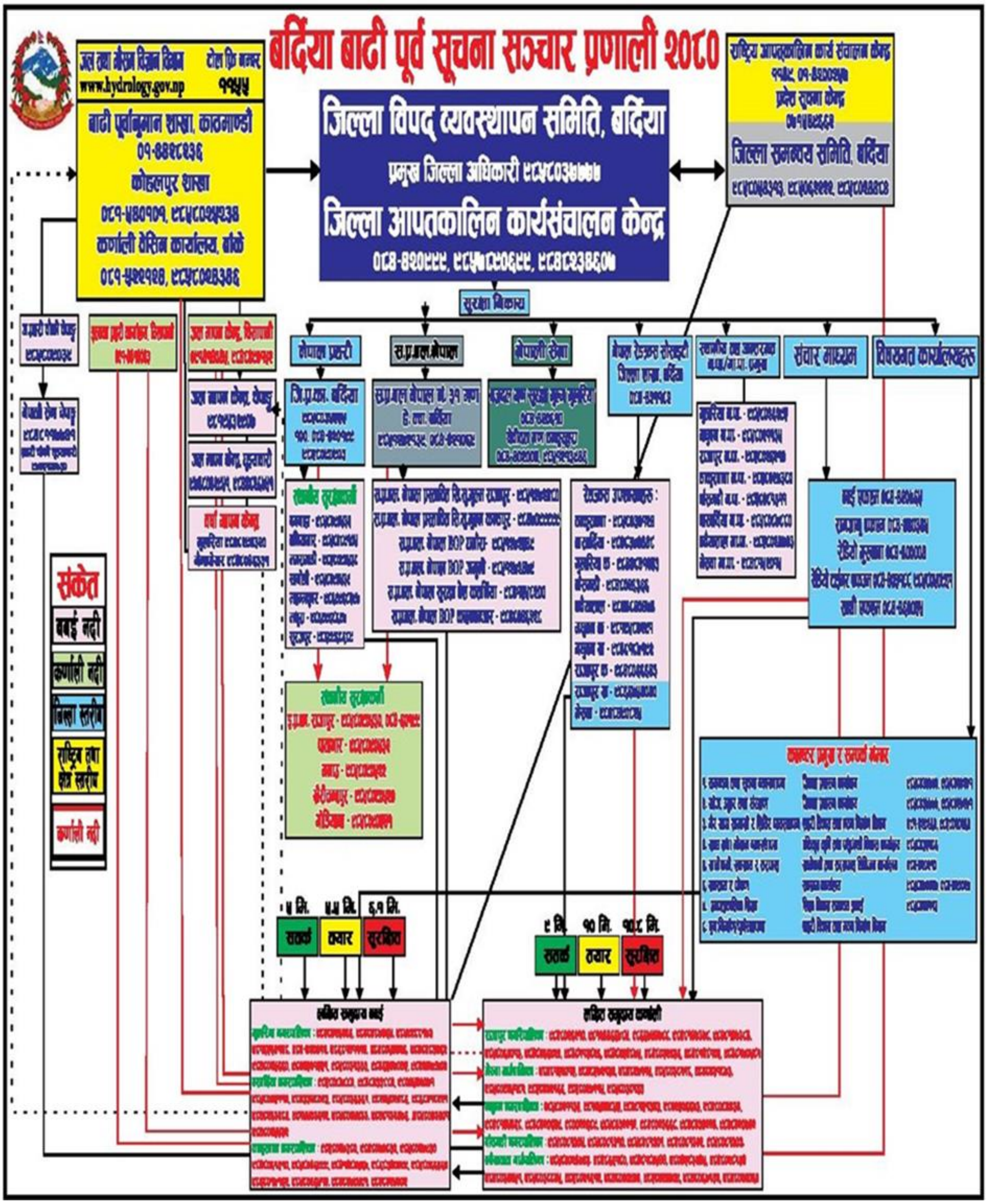
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1994	11.416	12.299	17.799	21.193	26.148	26.553	25.635	25.496	23.916	20.032	15.413	11.925
1995	10.203	12.803	16.422	21.873	25.751	26.08	25.516	24.945	24.273	21.709	15.74	12.47
1996	11.18	13.182	17.987	21.853	26.167	25.48	25.474	25.151	24.113	20.896	15.876	11.222
1997	10.022	11.607	16.664	20.009	23.724	26.423	25.412	25.187	24.066	19.406	16.085	12.119
1998	10.716	13.266	15.558	20.146	25.283	27.433	25.525	25.144	25.126	22.884	18.026	12.312
1999	10.535	14.357	17.206	22.4	24.648	26.23	25.509	24.99	24.66	21.19	15.876	12.777
2000	11.203	11.931	15.516	20.623	24.735	24.943	25.138	24.845	24.04	21.212	17.06	11.838
2001	10.164	13.296	16.461	22.13	22.112	25.293	25.822	25.27	24.433	21.277	16.203	12.348
2002	11.148	13.542	17.97	21.673	24.048	25.486	25.745	25.283	23.766	20.774	16.026	12.506
2003	9.748	12.982	16.448	21.843	24.338	24.89	24.958	25.529	24.243	20.374	15.91	12.196
2004	10.622	13.72	19.145	22.93	25.029	25.963	24.761	25.303	24.456	19.451	14.928	
2005			17.29	21.213	23.932	26.876	25.164	24.97	24.91	21.054	14.866	10.745
2006	10.796	16.246	17.238	21.216	24.296	25.56	25.709	25.245	23.943	21.135	16.19	12.325
2007	9.7	13.852	16.332	21.89	24.235	26.18	24.696	25.061	24.086	21.08	15.413	11.874
2008	10.348	11.979	17.477	21.406	24.045	25.35	24.877	24.687	24.072			
2009	12.525		17.096	22.613	27.061	28.678	24.99	24.603	23.786	14.345	14.323	12.496
2010	9.67	12.467	18.809	23.459		24.373	25.57			20.964	17.066	10.283
2011			16.854	20.596	24.454	25.293	25.174	25.238	25.046	21.696	16.863	11.593
2012	10.3	12.279	16.27	20.323	26.125	28.209	25.829	25.158	24.3	19.78	13.95	10.941
2013	8.445	13.06	16.951	20.79	25.309	24.09	24.409	24.141	23.566	20.454	13.933	10.577
2014	9.812	11.414	16.496	20.773	25.332	26.8	24.5	24.293	23.783	20.033	16.26	11.577
2015	11.119	13.549	16.516	19.953	24.338	25.803	25.47	24.906	24.643	20.635	15.976	11.309
2016	9.929	13.306	17.777	22.89	24.287	25.39	24.829	25.751	24.173	21.009	15.516	12.735
2017	10.835	13.821	16.854	23.116	25.016	25.526	25.17	25.035	24.98	21.125	15.323	12.335
2018	8.967	13.339	18.141	21.643	24.067	26.083	25.696	25.006	24.531	19.09	15.19	10.5
2019	10.235	12.853	15.993	21.396	25.574	26.056	25.303	25.687	24.45	21.264	18.11	11.322
2020	11.258	12.468	16.032	20.313	22.858	24.683	25.387	25.829	25.31	20.983	14.986	10.864
2021	10.67	13.489	18.361	21.776	23.212	25.086	25.603	25.338	25.33	22.183	16.303	12.425
2022	11.748	11.667	18.745	23.02	25.209	26.558	26.303	25.858	24.646	20.209	16.376	12.1
2023	10.941	13.989	17.251	20.583	23.441	27.356	26.103	25.254	25.34	20.974	16.733	12.735

Source: Department of Hydrology and Meteorology (2024)

Appendix "E"

(Refers to page no. 51)

EARLY WARNING SYSTEM IN BARDIYA, NEPAL



Appendix "F"

(Refers to page no.22)

Government of Nepal
Ministry of Home Affairs
Armed Police Force, Nepal
APF Command and Staff College

CUG No. :-9851272030
paacademic2015@gmail.com
https://csc.apf.gov.np
Ref. No. :- (080/81)/

Academic Section,
Sanogaucharan,
Kathmandu

Date: ……/…./….

Respected Sir/Madam,

TO WHOM IT MAY CONCERN

It is our pleasure to inform you that Armed Police Force, Nepal has been running APF Command and Staff College that concurrently conducts Command and Staff Course, and **"Master in Security, Development and Peace Studies (MSDPS)"** a two-year, four semester Master's Level program, affiliated to the Tribhuvan University, Faculty of Humanities and Social Sciences.

In this regard, the Student Officers of 8th APF Command and Staff Course are undergoing a research-writing assignment according to the curriculum of this MSDPS study. Regarding our Student Officers, they are actively serving in Armed Police Force, Nepal for more than 15 years. They are all responsible government service holders and any information provided will be used for the research and study purpose only.

Therefore, I would highly appreciate it if you provided some relevant information and data that may be required for their research study.

For any further query, it would be my pleasure to avail my service.

Anticipating and appreciating your kind cooperation and assistance to the student concerned.

Name of the Student : Hari Bahadur Gurung

Rank : Deputy Superintendent of APF, Nepal (DSP)

Thesis Title : Flood Hazard in Bardiya, Nepal: Causes, Consequences and Effective Mitigation Strategies

Respectfully,

Narendra Sen
Senior Superintendent of APF, Nepal
Acting Commandant
Contact No. 9841374638

Appendix "G"

(Refers to page no. 22)

GLIMPSES OF FIELD VISIT

Appendix "G"

(Refers to page no. 22)

GLIMPSES OF FIELD VISIT