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Understanding Transboundary Early Warning Systems and Their Cultural Context in The Kosi River Basin

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Understanding Transboundary Early Warning Systems and Their Cultural Context in The Kosi River Basin

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Abstract

The Kosi River is a transboundary river that originates in China, passes through Nepal, and meets the River Ganges in India. It flows through a narrow channel in steep and fragile terrain in the upstream region, carrying sediments and debris downstream to the flat plains of Nepal and India. These sediment deposits obstruct the river's flow and cause it to meander, resulting in regular floods during the monsoon season. In 1954, the governments of Nepal and India entered into an agreement known as the Kosi Agreement, which aimed to protect against floods in Nepal and Bihar state in India. The agreement included the construction of embankments to channelise the river into the Kosi Barrage, with the intention of controlling the river's discharge and meandering. However, instead of resolving the flooding issue, the embankments trapped sediments within their walls and raised the riverbed, exacerbating flooding and making it more unpredictable.

Nevertheless, floods have significant linkages between upstream and downstream areas, and early warning systems can mitigate downstream losses by providing information in advance. An early warning system (EWS) is a comprehensive system that involves hazard assessment, monitoring, communication, and response to reduce the impact of hazards through timely information and action. Currently, there is no transboundary EWS in the Kosi River basin, but Nepal and India have their respective EWSs within their national jurisdictions. However, implementing an effective transboundary EWS in the Kosi River basin is challenging due to multiple institutions and approaches at the national level, geopolitical issues related to shared water resources at the transboundary level, and sociocultural factors at the community level. International disaster policies emphasise the importance of transboundary EWS in minimising disaster losses, and both countries are striving to establish such a system in the Kosi River basin. Therefore, it is crucial to investigate how sociocultural, governance, and institutional factors interact and hinder the effectiveness of a transboundary EWS, as well as explore ways to overcome these constraints.

This research adopts the theory of pragmatism as a research paradigm and employs qualitative research methods in human geography. The study includes ethnography, 34 expert interviews, 12 focus group discussions, and 44 community-level interviews conducted in the transboundary region traversed by the Kosi River in Nepal and India.

The findings of this research suggest that the governance of EWS in the study area is characterised by central management, top-down approaches, a focus on disaster response, and a lack of participation from the at-risk population. While bilateral committees have been established at the transboundary level to facilitate collaborative action on flood risk management, they are also centrally led, water governance-focused, and fail to include the participation of at-risk individuals or representation from local government institutions. Consequently, the disaster risk management processes and transboundary early warning systems in the Kosi River basin are complicated by the geopolitics surrounding shared water resources. The recurring themes in this thesis are the lack of participation from at-risk individuals and a limited contextual understanding throughout the EWS processes. Furthermore, sociocultural norms and gender barriers, particularly those affecting women and marginalised groups, restrict access to warnings and prevent meaningful participation in the study area. The findings suggest that women perceived risks differently from men, as they were more concerned about the challenging living conditions and associated risks during flood evacuation, such as sexual harassment, animal attacks, snake bites, diseases, and theft. These concerns significantly influence their actions during flood disasters.

This study provides valuable insights into the constraints faced by transboundary Early Warning Systems (EWSs) in the study area by examining the currently operational EWSs. The findings indicate that the existing EWSs in Nepal and India predominantly rely on a unidirectional risk communication approach, prioritising technology over at-risk individuals' needs, preferences, and contextual understanding. The current approaches overlook the importance of knowledge coproduction with the at-risk population in EWS. Moreover, the study highlights how geopolitics surrounding shared rivers introduces complexities, such as the securitisation of river data and the proliferation of myths concerning the causes of floods in relation to transboundary EWS. Additionally, the empirical findings suggest that internal politics and geopolitics influence transboundary EWS, underscoring the need for a comprehensive analysis of geopolitical influences. The study also emphasises the importance of considering gendered aspects in risk perception and access to risk communication within transboundary EWSs. Furthermore, an inclusive and contextually grounded approach to risk communication and information generation is crucial, addressing geopolitical complexities at

the transboundary level, knowledge gaps, and gender-specific risk perceptions within transboundary EWS.

This study suggests that the process of generating risk information in transboundary EWS should be collaborative, aiming to co-produce knowledge as a sense-making process, while risk communication in transboundary EWS should be approached as a meaning-making process. It further suggests that transboundary rivers are politically significant resources, necessitating the inclusion of geopolitics in assessments. The study recommends that EWSs should be context-specific and participatory, providing specific policy and practice recommendations for the effective implementation of transboundary EWS.

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Glossary of key terms

Kuccha houses: Kuchha houses are small houses constructed using locally available materials like mud, thatch, wood, and low-quality bricks. These houses are commonly found in rural impoverished settlements of Nepal and India. They are more vulnerable to damage caused by natural disasters such as floods.

Thanadar: Thanadar refers to a village constable or a local police officer in India who holds a position of authority within a specific area. They act as a local representative of the police force and play a crucial role in maintaining community safety and security, especially during floods.

Mukhiya: Mukhiya refers to the elected head or chief executive of a village or Gram Panchayat in India, the local self-government institution at the village level. They hold a significant role in rural governance in India, implementing government schemes, resolving disputes, and during flood disasters.

Chaukidar: Chaukidar refers to a guard or watchman responsible for safeguarding river embankments in India; the role of a Chaukidar involves monitoring the embankments, patrolling the area, and ensuring their security.

Panchayat: Panchayat or Gram Panchayat, translated as the village council, is a fundamental governing institution in Indian villages. It operates as a political body, serving as the cabinet of the village.

Dalit settlements: In Nepal and India, Dalit castes, called Scheduled Castes (in India), constitute historically marginalised and socially disadvantaged groups. Traditionally positioned at the lowest in the Hindu caste hierarchy, they routinely face social segregation, restricted mobility, constrained economic prospects, and instances of caste-based violence. The study area of this research includes the settlements, including the population, referred to as *Musahar Basti* (literal translation: settlement of rat-eaters) in Hanumannagar, Nepal, *Maalah Tole* (community of fishermen) in Rampura-Malhaniya, Nepal; *Dom Basti* (literal translation: settlement of pig-rearers) in Bathnaha, India, living close to the Kosi River in the study area.

Declaration

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Gaurab Sagar Dawadi

October 2022

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Chapter 1 Introduction

1.1. Background

Environmental hazards do not respect international boundaries (Smith 2013). In an increasingly interconnected world with rigid national borders, disasters appear more often as transboundary phenomena that transcend political boundaries and cascade through space and time, overwhelming traditional disaster response mechanisms (Ansell et al. 2010). Transboundary disasters are frequently observed in the international river basins (Dewals and Fournier 2013; Shepherd et al. 2013; Smith and Fischbacher 2009). UN Water (2015) reports that there are approximately 276 transboundary river basins worldwide, and 42 per cent of the global population living in 145 countries depend on those shared rivers. Approximately 11 million people are affected annually by transboundary floods worldwide, and climate change can increase the number of affected people to approximately 54 million by 2030 (Luo 2015). However, fewer studies have been carried out in transboundary river basins (Bakker 2009; De Stefano et al. 2012; Marsalek et al. 2006; Schmeier et al. 2016).

“Risk is, and perhaps always has been, a borderless phenomenon and, yet despite this, there has been insufficient academic attention focused on the issues that surround the management of those risks across the various ‘borders’ that exist” (Smith and Fischbacher 2009, p.3).

In South Asia, many transboundary rivers originating from the Himalayas shape the geography, culture, history, and economy of countries on their path (Dutta 2022). The transboundary rivers relate to the development aspirations of many co-riparian countries; therefore, conflicting interests exist in utilising shared water resources, and geopolitics play crucial roles in transboundary interactions (Ansell et al. 2010; Dixit et al. 2022; Levin et al. 2012; Mirumachi 2015; Warner et al. 2017; Zeitoun et al. 2011,2020). The transboundary rivers in south Asia relate to the livelihood of almost 1.5 billion people living in the floodplains; however, at the same time those rivers also relate to the disasters in the region (Dixit et al. 2022). Approximately 70 per cent of annual precipitation falls during the monsoon season (June-September) when most of the disasters related to hydrometeorological hazards occur in the region (Chen et al. 2013). During the monsoon season, rivers flowing with high discharge volume through steep and narrow terrains sweep and erode riverbanks in the

upstream regions and cause floods in the downstream region of flat terrains in Nepal, India, and Bangladesh (Tandon and Sinha 2022). A study by World Bank suggests that over the past 40 years, floods have contributed to 82 per cent of the total fatalities and 80 per cent of economic losses caused by disasters in south Asia (WB 2012).

This study is situated in the transboundary Kosi River basin, traversing the territories of China, Nepal, and India, with the river originating from the Himalayas. The research focuses on the transboundary region between the Nepal-India border, where floods have become a recurrent occurrence (Dixit et al. 2022). In the Kosi River basin, floods, intertwined with class and caste-based conflicts, gender discrimination, socio-cultural barriers, marginalisation, and poverty, are the primary causes of annual losses resulting from disasters (Gentle and Maraseni 2012; Reynolds 1999; Yongjian and Jingshi 1992). Often, floods in the Kosi River basin emerge as an unexpected event due to insufficient advance information, disproportionately affecting the vulnerable and marginalised individuals reliant on subsistence agriculture for their livelihoods (Mishra, 2008).

The governance challenges associated with transboundary river basins are complex due to the intersection of international boundaries, which divide sovereign nations and give rise to divergent interests, management policies, legal frameworks, and political practices (McCaffrey 2019). Consequently, these factors hinder coherent regulation and comprehensive management of transboundary river basins. Furthermore, the complexity of these challenges is compounded by the continuous influence of climate on river flow patterns and the socio-economic and demographic changes occurring within the river basin (McCaffrey, 2003), thereby contributing to the potential for transboundary disasters.

Nonetheless, floods exhibit strong upstream-downstream linkages, highlighting the potential for a significant reduction in losses through early warning systems providing timely information (Gupta et al. 2021). The Early Warning System (EWS) is defined as *“the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organisations threatened by a hazard to prepare and act appropriately and in sufficient time to minimise harm or loss”* (UNISDR 2009, p.12). The EWS encompasses an extensive system that includes understanding the physical and social components interacting with hazards and depends on the social context in which it operates (Garcia and Fearnley 2012). A crucial factor for the success of an EWS is that individuals at risk

must be central to all EWS functions (UNISDR, 2006). A typical EWS consists of four interdependent components: risk knowledge, monitoring and warning, dissemination and communication, and response capacity (Basher 2006).

The Early Warning System (EWS) extends beyond hazard forecasting and involves exposure and vulnerability assessments to forecast the impact of hazards on people and infrastructure, referred to as impact-based forecasting (IBF) (World Meteorological Organisation, 2021). IBF establishes a clear connection between the forecasted hazard and its potential scale, severity, and timing of impacts for effective preparedness and response planning for anticipatory action. Anticipatory action entails proactive measures based on forecasts and predictions before a disaster to reduce impacts and enhance preparedness. It relies on early information to trigger pre-planned actions, including resource pre-positioning, activating emergency response plans, or implementing evacuation measures. Integrating anticipatory action into the EWS framework enhances the efficiency and effectiveness of disaster response, enabling proactive measures to minimise vulnerability and enhance resilience (Weingärtner & Wilkinson, 2019).

The transboundary EWS specifically focuses on hazards that transcend national boundaries, necessitating collaboration and coordination between riparian countries with a shared river basin (McCaffrey 2019). The key distinction between a typical EWS and a transboundary EWS lies in the scale and scope of the hazard risks they address. While a typical EWS operates within a narrow scope within a specific political jurisdiction, a transboundary EWS encompasses multiple interconnected states and countries that face shared risks. The transboundary EWS requires collaboration, cooperation, and information sharing among the countries through joint preparedness and response efforts (Ansell et al. 2010). Transboundary EWSs are particularly relevant in situations where the impacts of hazards extend beyond political boundaries, such as cross-border outbreaks of infectious diseases, large-scale earthquakes affecting multiple countries, transboundary floods, or other hazards (Pandey et al. 2023).

Currently, there is no transboundary EWS in the Kosi River basin between Nepal and India, although both countries operate their own EWSs within their national jurisdictions. In this context, an idealised form of a transboundary EWS in the Kosi River basin would involve communication between the two EWSs, as shown in fig. 1, with individuals at risk at the core of EWS components.

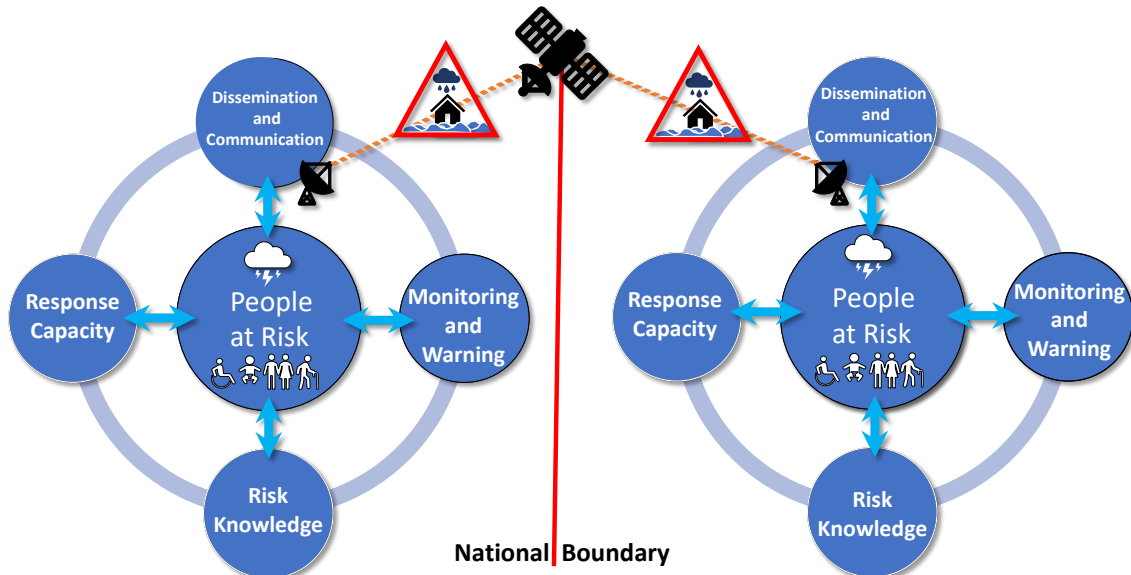


Figure 1: Schematic diagram illustrating the transboundary EWS, where people at risk are in the centre (comprising of people with different vulnerability and capacities), and two separate EWSs are connected by communication system that operates across the national boundary. Source: adapted from Basher (2006).

Nepal and India have made efforts to establish transboundary EWS in the Kosi River basin in collaboration with international and national stakeholders. However, these efforts have faced challenges and have not been successful. Given this context, it is essential to analyse the impact of socio-cultural, institutional, and disaster governance mechanisms on the effectiveness of the transboundary EWS. This research aims to investigate and understand the factors that hinder the establishment of the transboundary EWS and explore potential strategies to overcome these challenges. This research will primarily focus on the various hazards that contribute to floods in the border region of the Kosi River, specifically within the Kosi River basin encompassing Nepal and India. This research will be guided by the following aims and objectives.

1.2. Aims and objectives.

The transboundary Kosi River basin between Nepal and India currently lacks a transboundary Early Warning System (EWS), despite both countries' implementation of individual EWSs within their respective national borders. Previous attempts to establish a transboundary EWS

in collaboration with international and national stakeholders have not been successful. Therefore, this research aims to investigate and gain a comprehensive understanding of the cultural, institutional, and governance factors that influence the transboundary EWS in the Kosi River basin and identify potential strategies to overcome these challenges.

This research will be guided by the following specific objectives:

- To explore the co-production of risk knowledge between institutions and communities within and across borders in the Kosi River basin, focusing on the collaborative processes involved in generating and sharing information related to floods.
- To examine the communication strategies employed for delivering early warnings in the Kosi River basin and assess how effectively communities comprehend and respond to these warnings.
- To gain insight into the perspectives of individuals at risk, government authorities, and non-governmental stakeholders regarding transboundary EWS in the Kosi River basin, aiming to understand their perceptions, experiences, and expectations.
- To understand the geopolitical dynamics between Nepal and India and how these dynamics influence the transboundary EWS in the Kosi River basin.
- To explore various constraints that impede the transboundary EWS in the Kosi River basin, including their institutional, technological, and socio-cultural aspects.
- To provide recommendations for transboundary early warning systems in the Kosi River basin, to enhance collaboration, communication, and its overall effectiveness.

1.3. Research questions

The overarching objective of this research is to understand the factors that affect flood early warning systems in the transboundary context between Nepal and India in the Kosi River basin. To facilitate the objective, the following research question (RQ) was formulated:

What are the cultural, institutional and governance factors that constrain effective trans-boundary flood early warning system in the Kosi River basin?

To answer the main research question, it was simplified into three sub questions (SQs) to investigate the cultural, institutional and governance factors constraining EWS. The three sub-questions based on the main RQ are as follows:

- I. SQ.1: How is risk knowledge co-produced between institutions and communities within and across the border in the Kosi River basin?
- II. SQ.2: How is risk communicated for early warnings, and how do communities understand the risk and warnings in the Kosi River basin?
- III. SQ.3: What are the geopolitical dynamics between Nepal and India and how they constrain transboundary EWS in the Kosi River basin?

The SQ.1 is related to the risk information generation in the EWS, which will be dealt with in *Chapter 5, Knowledge Co-Production, EWS Institutions, and Flood Affected Communities*. The SQ.2 is related to risk communication in EWS which will be dealt with in *Chapter 5, Risk Communication, Risk Perception, and Early Warning Systems*. The SQ.3 is related to the transboundary EWS and geopolitics around it, which will be dealt with in *Chapter 7, Transboundary disaster risk governance in the Kosi River basin*.

The next section will present the structural outline of this thesis.

1.4. Structural outline of the thesis

This thesis is divided into nine chapters. Chapter 1 introduces the thesis, research questions, and its delimitations. Chapter 2 and Chapter 3 are based on secondary literature—Chapter 2 provides the theoretical backgrounds and reviews the concepts related to transboundary EWS; Chapter 3 provides a contextual understanding of the Kosi River basin. Chapter 4 is the methodology chapter, which introduces the methodological approach and research tools adopted to conduct this research. Chapters 5, 6, and 7 are the empirical chapters based on primary data; these chapters present the findings on risk information generation, risk communication, and transboundary EWS and geopolitics affecting it in the study area. Chapter 8 is the discussion chapter that synthesises findings in relation to the main research question. Finally, Chapter 9 concludes this thesis. The detailed description of the chapters and their contents are as follows:

Chapter 1, Introduction, introduces the thesis with background, aims and objectives of this research and research questions. Also, it describes the scope of this thesis.

Chapter 2, Literature review, provides a critical overview of the concepts and definitions used in the thesis and deals with the review of literature on perspectives on risk, risk perception, vulnerability, early warning system, knowledge coproduction in EWS, gender in flood EWS, transboundary disaster risk governance and river basin structures, Transboundary EWS between Nepal and India, bilateral efforts, and challenges in transboundary EWS, EWS in practice. This chapter also interprets the fundamental concepts of risk, vulnerability, risk perception, gender in flood EWS, and knowledge coproduction in relation to this research. Furthermore, this chapter presents the literature gaps and key areas for this research to contribute to filling those gaps in the literature.

Chapter 3, The Kosi River basin: the context, explores the physical, social, and geopolitical context of the Kosi River basin. This chapter also explores the history of floods, the Kosi agreement as an intervention for flood protection, and the current context of floods and flood risk management in Nepal and India, along the Kosi River basin. Furthermore, this chapter explores the institutional context of disaster risk management in the Kosi River basin in Nepal and India. This chapter provides a contextual understanding of the study area, serving as the foundation upon which the subsequent chapters will be built.

Chapter 4, Methodology, sets out the methodological approach implemented in the thesis, theoretical assumptions behind those methodologies, research ethics, research paradigm, and research design adopted in the thesis. This chapter shows that this thesis adopts pragmatism as a research paradigm. This chapter describes the study area of the Kosi River basin, time horizon, and positionality.

Chapter 5, Knowledge Co-Production, EWS Institutions, and Flood Affected Communities, is the empirical chapter based on the qualitative analysis of expert interviews from Nepal and India. This chapter argues that knowledge co-production in EWS is lacking in Nepal while non-existent in India. The NGOs in Nepal include flood-affected communities for training and awareness-raising activities related to flood preparedness. However, in India's Bihar state, consultation does not happen between the at-risk people and the institutions that generate flood warnings. Furthermore, both countries' government officials working in risk information

generation for EWS were sceptical about people's inclusion in EWS. Similarly, there was no mechanism for community consultation during risk information generation for EWS in Nepal and India. Through donors and NGOs, local communities are involved in Nepal for awareness-raising and capacity-building activities related to flood preparedness and disaster response. However, the effective representation of people in this community-level participation has been questionable because it was found that, in most cases, local elites or political leaders were approached by NGOs to provide information on behalf of the affected communities. This chapter demonstrates that the generation of risk information occurs in isolation from the context and the individuals at risk, primarily due to impractical institutional arrangements characterised by a lack of institutional coordination. Furthermore, the chapter shows that the focus of Early Warning Systems (EWS) has been primarily on technical components, neglecting the crucial aspect of addressing the needs and vulnerabilities of the people at risk.

Chapter 6, Risk Communication, Risk Perception, and Early Warning Systems is an empirical chapter based on the qualitative analysis of interviews and focus-group discussions with disaster experts and flood-affected communities in the study area. This chapter presents an argument that highlights the failure of warnings to reach the most affected and deprived individuals, despite the recent technological advancements in early warning systems. This failure is attributed to the disregard of their socio-cultural context and understandings. Also, there are no real-time and formal transboundary risk communication mechanisms between Nepal and India. Rather the warnings are communicated informally across the border by people through the porous international border between Nepal and India. The argument put forth in this chapter is that the current operational risk communication methods in Nepal and India rely on a one-way and top-down transfer of information, which lacks inclusivity and contextual awareness.

Chapter 7, Transboundary disaster risk governance in the Kosi River basin, is based on the qualitative analysis of interviews conducted with experts in government institutions from Nepal and India. This chapter argues that transboundary disaster governance in the Kosi River basin is influenced by geopolitics over the utilisation of shared water resources. This chapter shows that local politicians in Nepal and India are deliberately mishandling the flooding issue by spreading myths about the causes of floods. Despite understanding that embankments have proved futile against floods in the Kosi River basin, no alternatives were sought for flood

risk management except the embankment building so that local institutions, contractors, and politicians could collude and gain from it. This chapter suggests that studies on transboundary EWS must include internal politics and geopolitics, especially when dealing with countries with asymmetrical power relations.

Chapter 8, Discussion, draws on the arguments from empirical chapters (5,6,7) and critically debates around transboundary EWS and its challenges in relation to the main research question presented in Chapter 1 and literature reviews and contextual settings presented in Chapter 2 and Chapter 3. This chapter provides the overview of key research findings, comparison between the empirical and literature findings, overall findings, and overarching themes in the research.

Chapter 9, Conclusion, summarises and concludes the thesis, highlighting the findings in relation to the main research question and recapping the contributions of this thesis to theory, policy, and practice, limitations, key implications of this thesis, recommendations, suggested future research in the area and concluding remarks.

1.5. Research scope

This research focuses on two components of EWS: the Risk Knowledge component and the Dissemination and Communication component. Due to time and resource constraints, researching all four components would be too broad in scope for this PhD. The following are the reasons for selecting these two components:

- I. The Risk Knowledge and Dissemination and Communication components are fundamental to EWS. Without them, the early warning system cannot exist (Hamza and Mansson 2019; Kelman and Glantz 2014). As the terms “early” and “warning” in EWS relate to these components, they are essential for this research.
- II. Basher (2006) argued that EWS typically fails in the Risk Knowledge and Dissemination and Communication components due to a lack of consideration of contextual factors in the Risk Knowledge component and a lack of understanding of risks and warnings at the community level. Therefore, more emphasis is needed on these components of EWS.

- III. In the study area of Nepal and India, disaster management approaches have been response-focused rather than preparedness (Jones et al. 2016; Lee 2016; Ogra et al. 2021). The government structures in both countries are better suited for disaster response than preparedness (Gupta et al. 2021). These arguments suggest that more emphasis is needed on the components relating to disaster preparedness in EWS, namely the Risk Knowledge and Dissemination and Communication components. Therefore, it is essential to research these aspects of EWS.
- IV. The Monitoring and Warning component of EWS focuses on hazard monitoring using geo-computational models and threshold trigger determination for warnings (Grasso 2011; Hamza and Mansson 2019). This component is more suited for physical geography research than social science research, which is the focus of this study.

1.6. Chapter summary

This chapter introduced the background of the research, along with its aims, objectives, and research questions. Additionally, it outlined this thesis's structure and research scope. In Chapter 2, the relevant literature on transboundary early warning systems related to the study area will be reviewed.

Chapter 2 Literature Review and Key Concepts

2.1. Introduction

This chapter comprehensively reviews literature, theories, and key concepts relevant to this research on transboundary early warning systems. The primary objective of this chapter is to define and establish the foundational framework for the research. It systematically defines crucial concepts such as risk, vulnerability, transboundary disasters, and knowledge coproduction, incorporating the author's position and interpretation of these concepts within the context of the thesis. Initially, the discussion focuses on the perspectives on risk, culture, and risk perception, highlighting their relevance to the thesis. Subsequently, this chapter deals with vulnerability, early warning systems, knowledge coproduction and risk communication in EWS, and gender perspective on flood early warning systems. Then the literature review explores the transboundary disaster risk governance, river governance and basin structures, bilateral efforts on transboundary flood risk management, state-of-the-art analysis of transboundary EWS between Nepal and India, and challenges in transboundary early warning systems. The chapter further explores the existing formal EWS and informal community based EWS in Nepal and India. Finally, the chapter critically identifies gaps in the existing literature and elucidates how this thesis intends to contribute towards addressing those gaps.

2.2. Perspectives on risk

Risk is a mental model (Renn 2008); therefore, different scholars' perspectives on risk in social science literature can be broadly categorised over a spectrum ranging from the Realist perspective on one end and the Strong Constructionist perspective on the other (Lupton 1999). From a Realist perspective, the risk is objective and can be measured independently of social and cultural processes. At the same time, the Strong Social Constructionist approach suggests that *"nothing is a risk in itself, but it is a contingent product of historically, socially, and politically created ways of seeing"* (Wisner et al. 2014, p.19). The Realist perspective is most common in techno-scientific literature (e.g., engineering, statistics, economics), which regards risks as the likelihood of loss due to hazard impacts over a specific space and time (Hewitt 2014). One of the drawbacks of the Realist perspective is that it regards scientific knowledge as objective while latently bearing contempt towards people's subjective

understanding (Wisner et al. 2014). However, recently scholars such as Lupton (1999) and Donovan and Oppenheimer (2014) have argued that subjectivity is an inherent component in every human analysis; therefore, technical assessments carried out during scientific assessments may not be purely objective, but the subjectivity on scientists' part is rarely acknowledged in the Realist approaches.

On the other end of the spectrum is the Strong Social Constructionist perspective, which regards risks as socio-culturally embedded in every society. This view is most common in social-science literature (e.g., anthropology, philosophy, sociology, and cultural geography) (Lupton 1999). The theories of sociocultural dimensions of risk could be categorised into three groups:

- I. The "cultural/symbolic" theory on risk by Douglas and Wildavsky (1983) and Douglas (1986, 1992, 1996) and others—which focuses on conceptual boundaries between self and others.
- II. The "risk society" theory of Beck (1992) and other scholars that adopt the risk society theories—which focuses on the macro-social processes of modern society regarding the concept of risk.
- III. The "governmentality" theory of risk by Foucault (1991) and others —which focuses on how the concept of risk is embedded in norms or regulations within a society to encourage voluntary action and self-regulation in response.

While there are some differences among the three perspectives, the common theme is that it recognises risk as a central concept by which society is organised, monitored, and regulated—and that risk is socially constructed (Lupton 1999). Over the spectrum between the Realist and Strong Social Constructionist approaches to risks, some literature stays in the middle of two extremes, termed Weak Social Constructionists, which recognise that risks are objective but are mediated through socio-cultural processes, as shown in fig. (2) (Lupton 1999; Wisner et al. 2014).

The techno-scientific literature on risk falls on the Realist side, regarding risk as an objective and calculable entity. The Governmentality theories of Foucault (1991) fall on the Strong Social Constructionist side; as one of its proponents Ewald (1991, p.199), suggested, "*nothing is a risk in itself; it all depends on how one analyses the danger and considers the event*". The

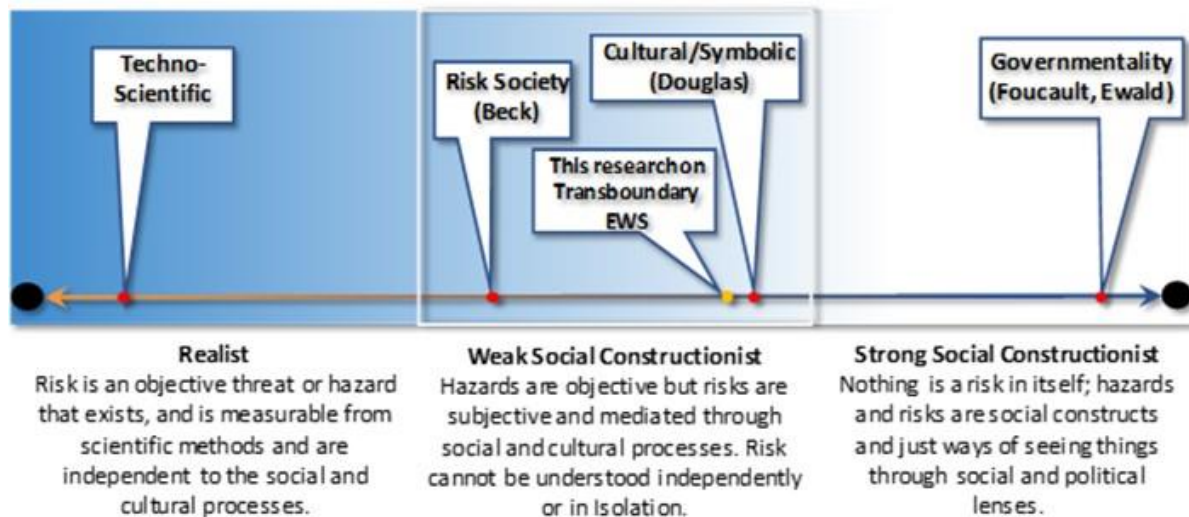


Figure 2: Spectrum of varying perspectives towards risks, where realist and strong social constructionist perspectives are at the extremes while weak social constructionist perspective is at the middle of the spectrum (Source: adapted from Lupton 1999).

Risk Society theories of Beck (1992) fall on the Weak Social Constructionist scale; however, its position is slightly wavering between the Realist and Weak Social Constructionist perspectives, as Beck sometimes uses the term “risk” synonymously with “danger”: “*Risks of modernisation are irreversible threats to the life of plants, animals, and human beings*” (Beck 1992 p.13). While in other literature, Beck took a Strong Social Constructionist position, arguing that “*it is not clear whether it is the risks that have intensified, or our views of them*” (Beck et al. 1994, p.55). Furthermore, in his later articles, Beck argued that risks are “*socially constructed and strategically defined, covered up, or dramatized in the public sphere with the help of scientific material supplied for the purpose*” (Beck 1996, p.4). Therefore, the position of the Risk society theory is between the Realist and Weak Social Constructionist positions (Lupton 1999).

The cultural/symbolic theories of Douglas (1983) suggested that judgments about risks are politically and morally constructed through cultural frameworks, and so are the responses to those risks (Lupton 1999). The cultural/symbolic theories fall on the Weak Social Constructionist position but slightly towards the Strong Social Constructionist side, as Douglas (1983) wrote that multiple dangers exist in the real world; however, only certain dangers are selected and entitled by a particular society as risks for specific reasons, based on their values and concerns. Furthermore, Douglas argued that “*the reality of dangers is not at issue. The dangers are only too horribly real, in both cases, modern and pre-modern. This argument is not about the reality of dangers, but about how they are politicised.*” (Douglas 1992, p.29).

Regardless of the position and alignments of the theories on risk, Weak Social Constructionists argue that risk is not entirely objective and emerges out of belief systems, and what is identified and managed as risk is always filtered through pre-existing knowledge. Weak Social constructionists subscribe to the notion that knowledge about risk is bound to the sociocultural contexts and cannot be value-free; therefore, the risk is continuously constructed and negotiated in society as a part of the interaction and formation of the meaning (Lupton 1999). The Weak Social Constructionist theories suggest that society exists through a dialectical relationship between the physical and social worlds, where each creates the other.

In this research, a Weak Social Constructionist perspective and approach will be adopted in relation to risk. Consequently, risk will not be perceived as an objective reality detached from society and culture, but rather as an inherent component within a society. It will be acknowledged that risk is shaped by societal elements such as logic, belief systems, assumptions, language, and contextual understandings, which collectively attribute meaning to hazards. As such, hazard risk in this study is considered both real and contingent upon the social context. This viewpoint enables the author of this research to assess the socio-culturally embedded nature of risk within the study area.

2.3. Risk perception

Risk perception, conceptualised as individuals' understanding and images of risks (Boholm 1998; Covello 1983; Renn 2008; Slovic 1987), is influenced by various factors. Scholars present divergent perspectives on the relationship between the direct experience of hazards and risk perception. Numerous scholars argue that communities exposed to frequent hazards display greater risk perception (Heitz et al. 2009; Kellens et al. 2013; Miceli et al. 2008; O'Neill et al. 2016; Plapp and Werner 2006; Terpstra 2011; Turner et al. 2014; Zhang et al. 2010). Conversely, other scholars contend that communities that have survived disasters without significant damage tend to underestimate future risks and are less prepared (Mileti and O'Brien 1993; Halpern et al. 2001; Hall and Slothower 2009; Scolobig et al. 2012). As hazards become more complex due to climate change, the value of risk perception based on direct experience diminishes (Lindell and Perry 2012).

Numerous scholars highlight various factors influencing risk perception, including socio-economic factors (Botterill and Maznur 2004; Conway et al. 2021; Kellen et al. 2013; Renn 1984; Slovic and Peters 2006; Fischhoff et al. 1993), socio-cultural factors (class, ethnicity, gender roles), institutional factors (trust in authority), and personal attributes (age, education, attitude, judgment, experience of hazard). Wachinger et al. (2013) propose four broad factors shaping risk perception: 1) type and severity of the hazard; 2) source and quality of information; 3) personal and cultural attributes, including age, gender, religion, education, and marginalisation; 4) context of hazard exposure. They also introduce the concept of the “risk perception paradox”, denoting the weak correlation between risk perception and actions; This paradox arises due to individuals perceiving benefits that outweigh potential negative consequences of hazards and continuing to live in risk-prone areas despite understanding the risks (Wachinger et al. 2013).

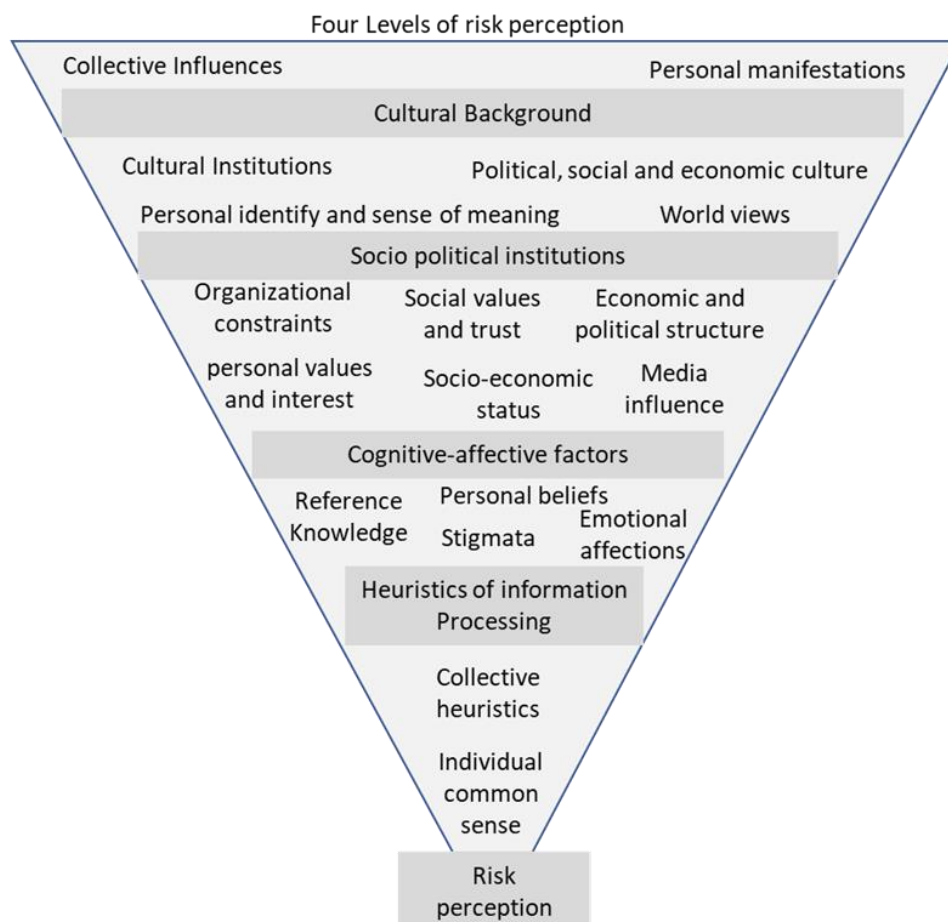


Figure 3 Levels of risk perception (Source: adapted from Renn 2017)

Likewise, Renn (2017) suggested that psychological, social, and cultural factors and their mutual interactions shape risk perceptions, and the factors that shape risk perceptions can be categorised into four levels: cultural background, socio-political institutions, cognitive factors, and heuristics of information processing as shown in fig. (3).

Building on Douglas and Wildavsky (1982), suggesting that risk perception and acceptance is a collective construct in society, several scholars (e.g., Kaspersen et al. 1998; Mileti and Peek 2000; Mileti et al. 2002) argued that people do not respond to risks individually; people often evaluate their situation by comparing their interpretation with others in their community, referred to as “social milling”, which help them decide for actions; therefore, risk perception is contextually situated social activity. Similarly, Morgan et al. (2002) suggested that communities perceive and internalise risks through sociocultural processes, and their perception goes through constant moderation by media, society, and institutions; therefore, the perception of risk is dynamic and variable over time.

Many scholars (Eiser 2012; Wachinger et al. 2013; Lovholt et al. 2014) argue that community-level decision-making following risk perception involves a complex evaluation process influenced by socioeconomic factors such as poverty, access to resources, and livelihood options. For instance, when faced with an imminent flood, individuals engage in a multifaceted risk evaluation process influenced by their socioeconomic and cultural context, particularly during flood evacuation. Zinn (2020) emphasises that people derive meaning from situations during disasters, shaped by their social, physical, and cultural contexts and experiences. These interpretations extend beyond evidence-based rationality, incorporating elements of hope, faith, and intuition, which are partly experiential and partly intuitive. These arguments collectively emphasise that after perceiving risks, individuals evaluate and respond to risks based on their knowledge, values, and judgments, all of which are influenced by sociocultural settings.

Numerous scholars have highlighted the crucial role played by society and culture as intermediaries between risk perception and behavioural action (Halpern et al. 2001; Hall and Slothower 2009; Karanci et al. 2005; Paton 2008; Siegrist and Gutscher 2008). Kruger et al. (2015) propose that even after perceiving risks, the motivation for response actions, such as evacuation, depends on various factors determined by an individual’s cultural and socioeconomic characteristics. For example, vulnerable communities engaged in subsistence

agriculture, stone quarrying, or fishing may be reluctant to relocate despite perceiving risks, as evacuation would mean detachment from their livelihood and skillset (Kruger et al. 2015). Eisenman (2007) argued that evacuation could pose additional risks for vulnerable groups, including women, older people, and disabled individuals, due to challenging living conditions and limited access to resources, which may discourage them from evacuating. Ferris (2010) cited the example of Purdah culture (literally translated as seclusion) in Pakistan, which requires women to be secluded and requires women to be accompanied by male relatives when going to the public place, leads to reluctance among women to evacuate alone, even when they understand the imminent flood risks. Similarly, Haque and Blair (1992) highlighted the reluctance of people in Bangladesh to evacuate to designated shelters during cyclones, fearing theft or looting of their belongings if they leave their homes. These examples underscore the influence of socioeconomic and cultural contexts on risk perception, highlighting its contextual nature.

2.3.1. Culture and risk perception

Culture is a multifaceted and elusive concept (Kruger et al. 2015). Hofstede (1980) proposed that culture encompasses shared behaviours in a society, expressed through language, behaviour, rituals, and traditions, representing the collective programming of the human mind within a specific geographic context. Kruger et al. (2015) argue that culture constitutes a composite characteristic of a society, manifested through a range of norms and discourses that continuously evolve at various scales, rendering culture dynamic. The works of Douglas and Wildavsky (1983) and Douglas (1986; 1992; 1996) have been instrumental in highlighting the connections between culture and risks. They explore how culture influences risk-taking or risk-averse behaviours within specific societies and why certain dangers are perceived as risks in some societies while not in others (Lupton 1999; Donovan et al. 2019). Framing risks within a cultural landscape allows understanding of complex social behaviours that otherwise would appear irrational in that context; however, it also “adds to the messiness already inherent in studies related to risks” (Kruger et al. 2015, p.4).

Kasperson et al. (1988) suggested that socio-cultural context shapes risk perception, which may amplify or attenuate responses to perceived risks at the individual and community levels, generally referred to as “social amplification of risk”. Slovic (1993), building on Douglas and Wildavsky (1982) and Kasperson (1988), argued that as humans evolved as social beings,

culture provided the basis for interpretation and perception of risks. Similarly, Smith and Petley (2009) suggested that risk perception results from the complex interaction of factors determined by society and culture, which provides the overall setting for risk interpretation. McClure et al. (2009) argued that culture plays a significant role in the interpretation and understanding of risk. Klinke and Renn (2012) and George and Kwansah-Aidoo (2017) suggested that language and communication sit at the core of any culture, through which people interpret, understand, and internalise risks. Therefore, culture plays a significant role in interpreting warnings, understanding risks, and acting against disasters.

2.4. Vulnerability

During the 1970s, the term vulnerability was introduced to the disaster literature by researchers including Baird et al. (1975), O’Keefe et al. (1976), and Wisner et al. (1977). It gained widespread application during the 1980s and expanded to include climate change and development literature. Cannon (1994, p.13) suggested that vulnerability defines the state of a society that allows a hazard to escalate into a disaster. Vulnerability describes the potential harm a society could suffer when faced with a hazardous natural, economic, or political situation. As such, vulnerability highlights the conditions that could lead to a disaster (Gaillard, 2010).

Several definitions and interpretations of vulnerability exist in social science, among which Blaikie et al. (1994) defined vulnerability as a composite behaviour of people in a society that leads to the potential for harm caused by hazards. UNISDR (2009, p.30) defined vulnerability as “The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard”. Those definitions showed the inclination towards the realist approach to vulnerability. In contrast, the latest definition by UNDRR defined vulnerability as “The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards” (UNDRR 2022). The latest definition of UNDRR takes a pragmatic or Weak Social Constructionist position in defining vulnerability. Despite that, Kelman (2018) argued that the term “conditions” used in the latest definition still suggests vulnerability as having static characteristics, while the vulnerability is dynamic in any society and has temporal characteristics. Kim et al. (2021) argued that debates on conceptualising vulnerability are continuing and evolving in disaster research; therefore,

there is no specific definition of vulnerability. One of the reasons for such diverse definitions of vulnerability could be due to the application and origin of the term from diverse fields (Hufschmidt 2011).

Lewis (1999) argued that the principal factors contributing to vulnerability are socioeconomic, political, and cultural conditions. Wisner et al. (2014) used the Pressure and Release (PAR) model to explain the characteristics of vulnerability, arguing that it arises from unsafe physical, socioeconomic, and institutional conditions resulting from dynamic pressures (macro-forces and institutional lacking) and their root causes (power, structures, and resources) when hazards intersect with any society.

In the late 1980s, the concept of capacity emerged alongside vulnerability as practitioners recognised people's ability to cope with disasters (Gaillard, 2010). Capacity refers to the resources and assets that individuals possess to withstand and recover from disasters, encompassing the availability of resources and the ability to access and use them (Davis et al. 2004; Kuban & MacKenzie-Carey, 2001). However, Davis et al. (2004) argued that capacity is not the opposite of vulnerability, as highly vulnerable communities may still exhibit a wide range of capacities. Community resources, such as traditional knowledge and indigenous skills, often contribute to capacities, while vulnerabilities often arise from external factors such as unequal distribution of wealth and resources, caste or class-based systems, and governance (Gaillard, 2010).

Davies (2015) suggested that the term "community" generally tends to subsume the people at risk who are spatially situated, socially and economically interlinked, and exposed to similar hazards; however, within each community, there are differences and divisions related to gender, class, caste, ethnicity, religion, and age groups, which causes differing vulnerability and impacts of hazards. Walmsley (2006) argued that within each community, different vulnerability, capacity, needs, interests, and knowledge exists in non-homogenous forms. Therefore, EWS must acknowledge that vulnerability is contextually situated and is addressed based on differing needs.

Following Wisner et al. (2014), this thesis regards vulnerability as the deprivation and marginalisation of individuals residing in flood plains, resulting from the combined effects of

socioeconomic, institutional, and cultural factors of the context, which renders them susceptible to hazard impacts.

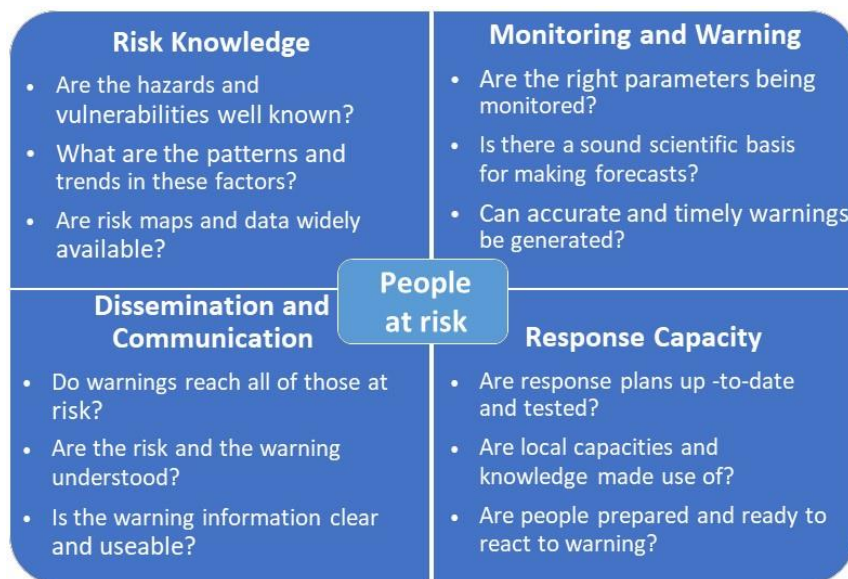
2.5. Early Warning System

The United Nations have emphasised the need for an Early Warning System (EWS) through the Sustainable Development Goals (UN 2015) and Sendai Framework for Disaster Risk Reduction (UNISDR 2018). The EWS is defined as *“an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems, and processes, that enables individuals, communities, governments, businesses, and others to take timely action to reduce disaster risks in advance of hazardous events”* (UNISDR, 2017). Basher (2006, p.2170) suggested that there are four interrelated and interconnected elements in EWS, i.e. 1) Risk Knowledge—*“Knowledge of relevant hazards and vulnerabilities of people and society to those hazards”*, 2) Monitoring and Warning Service—*“a technical capacity to monitor hazard precursors, to forecast the hazard evolution, and to issue warnings”*, 3) Dissemination and communication—*“the dissemination of understandable warnings, and prior preparedness information, to those at risk”*, and 4) Response capability—*“Knowledge, plans and capacities for timely and appropriate action by authorities and those at risk”* as shown in fig. (4). Kelman and Glantz (2014) suggested that the most crucial components in EWS are, 1) the knowledge of both hazard and vulnerability is understood among people at risk and at the expert level; 2) warnings are understood and interpreted clearly by the people at risk, and 3) warnings are provided with adequate time to

respond and 4) capacity building and awareness raising activities are built into the institutional system and regularly exercised.

Figure 4: The components of EWS with people at its core, adapted from Basher (2006).

The early warning systems are structured and organised procedures established by governments, specialised institutions or international organisations which employ advanced technologies, scientific data, and standardised protocols in the four components of early warning information (UNEP 2012). The official communication channels, such as dedicated communication networks, meteorological departments, or government agencies, are typically utilised in EWS to reach the intended recipients; therefore, nationally established EWS is also referred to as formal EWS systems (Zschau and Kuppers 2013). On the other hand, informal early warning systems operate at the grassroots or community level, relying on local knowledge, indigenous practices, and social networks (Nyong et al. 2007). Informal systems



may involve community members, local leaders, or specialised individuals responsible for detecting and sharing warning signs and information within the community (Macherera and Chimbari 2016). Oral communication, drumbeats, community meetings, sirens, or other culturally specific means of communication are various forms within informal systems (Sufri et al. 2020). Zschau and Kuppers (2013) suggested that formal and informal early warning systems are essential in increasing community resilience and minimising the impact of disasters; the formal EWS provide access to scientific data and expert analysis, while informal EWS leverage local knowledge and social networks for effective communication and response. Therefore, the integration and collaboration between the formal and informal

systems can lead to comprehensive and inclusive EWS that cater to the specific needs of people at-risk (Zschau and Kuppers 2013).

Basher (2006) argued that EWS comprises social and organisational processes in which technological means are used to communicate risks to hazard-exposed people to reduce their losses; therefore, people at risk must be at the centre of all processes related to EWS (Basher 2006). Similarly, Kelman and Glantz (2014) argued that the whole purpose of EWS is to trigger response actions from its intended recipients; therefore, what happens after issuing warnings is more important in EWS. Despite that, Hamza and Mansson (2019, p.2) argued that the “human dimension” (people at risk) had received much less importance in EWS than the “technological dimension” (technologies used in forecasts). Kelman and Glantz (2014) argued that the main challenge in EWS is understanding that EWS is a social process and overcoming the entrenched view of EWS as a technical component, where experts externally pass the information to the people at risk.

Hamza and Mansson (2019) argued that EWS typically takes a supply-side approach to risk communication, where experts at the centre generate and send the information outward and downward to the people at risk; however, people at risk need to be involved from the initial design process in EWS and throughout its implementation. Kelman and Glantz (2014) argued that most of the EWS literature stresses the “last mile” approach in EWS—suggesting that warnings need to reach their last mile (the people at risk). However, there is a flaw in that conception, as firstly, it assumes that relevant knowledge about risk is external to the communities, which is against the extensive literature suggesting the importance of contextual knowledge in DRR (e.g., Gaillard 2013; Kruger et al. 2015; Mercer et al. 2010; Weichselgartner and Pigeon 2015; Wisner 1995, Wisner et al. 2014). Secondly, the “last mile” approach implies that people at risk (who need the warnings at first) would be the last to be added to the EWS system as an add-on component (Loster 2012, Kelman and Glantz 2014).

Hamza and Mansson (2019) suggested that effective EWS can be achieved by understanding and addressing the contextual vulnerability factors and constraints that generate diverse perceptions of risk and responses; therefore, EWS must be collaborative and participatory rather than top-down. Similarly, Kelman and Glantz (2014), building on Anderson (1969), suggested that the “end-to-end” process in EWS is misleading as it reinforces the assumption that experts on one end of the process send information to the other end, where people at

risk would be eagerly waiting for that information so that they could react on it. This linear conception of EWS, where knowledge travels from one end to another, does not allow flexibility of feedback from people at risk; therefore, the “end-to-end-to-end” is needed in EWS, which suggests the requirement of feedback loops in EWS and conceptualises EWS as a continuous process built into everyday activity in a society (Kelman and Glantz 2014).

Sukhwani et al. (2019) argued that three levels of barriers constrain the EWS: Knowledge barriers, technological barriers, and institutional barriers. Knowledge barriers refer to varying perceptions of risks among disaster managers and people at risk; complexities caused by uncertainties in the forecast; and differences in language, level of education, and awareness at the community level. The technological barriers refer to uneven access to technologies at the community level. The Institutional barriers refer to the lack of participation of people at risk, lengthy and top-down approaches to risk communication, unclear institutional arrangement, poor contingency planning, and lack of capacities to implement EWS. In addition, Sukhwani et al. (2019) argue that the main drawback in the EWS is the lack of coordination between the components of EWS or each component of EWS operating by a different set of institutions as standalone components as shown in fig. (5).

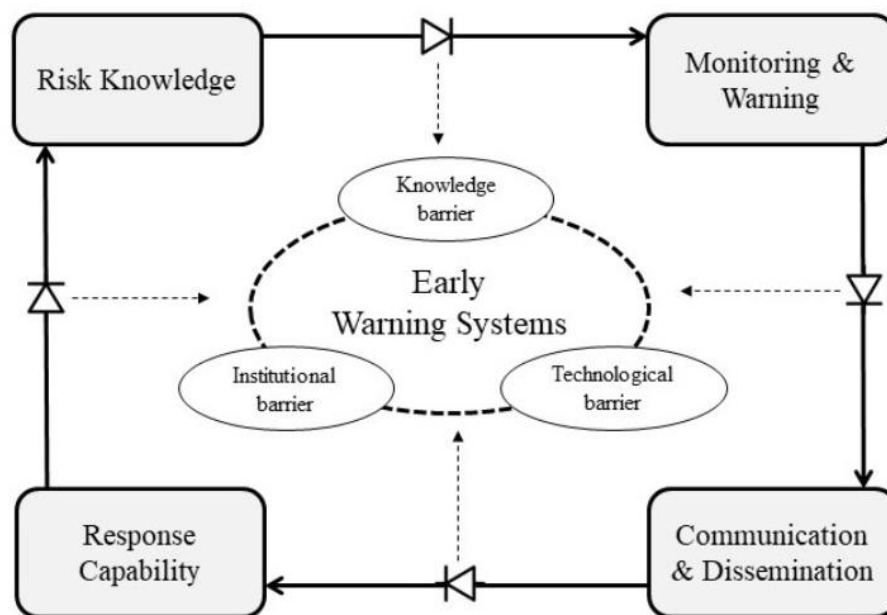


Figure 5: Barriers and inter-component linkage in EWS (Source: Sukhwani et al. 2019).

Budimir et al. (2020) argued that despite the advances in EWS, barriers remain regarding people’s access to warnings, understanding of the warnings, and ability to act based on

warnings. Georgaka et al. (2012) stated that EWS has evolved from the simple watch-and-warn system to the system that uses latest technologies such as satellite images and radars to analyse risks and mobile devices to disseminate warnings; however, it is essential that those technological developments need to be balanced with the challenges at the community level, as those technologies cannot be assumed to be omnipresent, accessible, or affordable.

Brown et al. (2019) and Budimir et al. (2020) argued that often the most vulnerable ones, such as women and marginalised populations in society, are not reached by the EWS due to their lack of access to resources, low level of literacy, language barriers, gender roles, and socio-cultural norms; leading to worsening vulnerability to disasters because EWSs are not contextually situated to cater the needs at the community level. Hamza and Mansson (2019) also argued that shortcomings of the EWSs are attributed to the lack of contextual understanding, lack of public awareness, lack of public participation, difficulty in the interpretation of the warning, not knowing how to react after receiving the warning. Donovan et al. (2019) argued that vulnerability and EWS are related in three ways:

- I. Informal settlements and isolated agricultural communities are excluded from the EWS.
- II. Poverty limits access to technologies where the warnings are disseminated, such as television, radio, or mobile phones.
- III. Socio-cultural structures disproportionately preclude socially, economically, or otherwise marginalised and deprived communities from accessing warnings based on their status within certain societies and can exacerbate their vulnerability.

The above arguments build on the suggestion that EWS needs to be people-centred rather than focusing on technology, and processes involved in EWS need to be collaborative and need feedback loops from the people at risk. Furthermore, EWS needs to adapt to the context of vulnerability relating to people's access to warnings and understanding of the risks.

2.6. Knowledge co-production in EWS

Elinor and Vincent Ostrom first introduced the term coproduction in the 1970s to describe how local communities can contribute to effective security by collaborating with the police departments or to describe community contribution to effective policing, thereby coproducing public services of security with government agencies or police department

(Miller and Wyborn 2020). The term used for public service delivery for an idea of citizens as a co-producer of public services (policing) by active participation became quickly popular. It spread across sectors such as public administration, education, social justice in law, museum studies, climate studies, and social sciences (Filipe et al. 2017).

In social science, knowledge coproduction is interpreted in many ways; however, it can be broadly conceptualised as two themes:

1. The “normative” or pragmatic conceptualisation of coproduction popular in sustainability science—which defines coproduction as a deliberate collaboration between different agencies and agents to achieve common goals in a society (Clark et al. 2003; Lemos et al. 2005).
2. The “descriptive” approach popular in science and technology studies (STS)—which suggests science and society are constantly interacting, shaping, and being shaped by each other in both expected and unexpected ways to coproduce knowledge in a society formed by social structures (Jasanoff 2004).

During the 1980s, coproduction gained prominence in developing countries as a response to critiques of the traditional top-down development model (Carter et al. 2020). The coproduction approach also recognised the limitations of participatory approaches in research and development that relied solely on external experts applying technical knowledge outside the local context (Chambers 1983) and emphasised the importance of engaging with local people and incorporating their experience and perspectives to create more appropriate and effective development interventions (Carter et al. 2020).

Lemos and Morehouse (2005) defined coproduction as a two-way interaction between scientists and stakeholders that depends on three conditions: stakeholder involvement in all phases of research, interdisciplinary collaboration, and the creation of usable science. Therefore, coproduction is the outcome of iterations between producers and users of knowledge, in which both sides respond to each other’s needs and limitations. This approach also considers institutional, organisational, and political mechanisms that shape the process and advocates for specific structures to create usable knowledge in different contexts (Lemos and Morehouse 2005). Similarly, Visman et al. (2018) defined coproduction as a collaborative approach that combines knowledge sources, experiences, and working practices from various

disciplines, sectors, and actors to create new and integrated knowledge for addressing shared societal issues. This approach recognises the importance of diversity in decision-making for better quality outcomes (Visman et al. 2022). Furthermore, Visman et al. (2018) argued that coproduction is a non-linear, context-specific process that can commence at varying stages, follow distinct pathways, and take on various forms depending on several factors, such as the context, individuals involved, the purpose of the work, and availability of funds.

Lemos et al. (2012) assert that the main objective of coproduction is to create valuable and usable information to address shared societal problems. Armitage et al. (2008) and Pahl-Wostl (2009) similarly emphasise the importance of considering coproduction in both process and outcome, promoting collaboration, learning, uptake and use in decision-making, and advancing scientific understanding through joint knowledge production.

Bremer and Meisch (2017) reviewed 130 research papers and identified eight perspectives on coproduction: extended science, constitutive, interactional, institutional, joint services, empowerment, pedagogical, and interactive research. The extended science perspective focuses on new norms and approaches to communicating science beyond the traditional silos of scientists and people at risk. The constitutive perspective highlights how collaboration shapes the representation of risk and hazards. The interactional perspective recognises the wider socio-political ecosystem in which coproduction operates, while the institutional perspective emphasises building governance capacity across institutions. The joint services perspective suggests how coproduction complements public services, while the empowerment perspective focuses on recognising the voice of marginalised populations. The pedagogical perspective highlights how coproduction facilitates social learning, and the interactive research perspective promotes the interaction of credible and legitimate information.

Carter et al. (2020) proposed that coproduction approaches can be classified along a spectrum, ranging from consultative coproduction on one end to immersive coproduction on the other. Consultative coproduction is predefined and static, involving people with different knowledge and experiences coming together at specific points in the process. In this approach, the focus, and questions to be addressed may be predefined, and the outputs may also be designed outside the coproduction space. In contrast, immersive coproduction is emergent, iterative, and flexible, involving a broader range of deeply involved actors

throughout the processes. In immersive coproduction, the focus or problems are not predefined but emerge from interaction with people with different knowledge and experiences and the outcomes are established with the people through co-learning and collaboration (Carter et al. 2020).

Vincent (2022) argued that a coproduction is a constructivist approach that recognises the need for collaborative processes to construct new knowledge, challenge power relations and hegemonic knowledge systems, and promote a sustainable future. The diversity of coproduction approaches has led to varying emphases, with some prioritising outcomes and others prioritising processes and inclusion of multiple voices. Scholars such as Bremer and Meisch (2017), Chambers et al. (2021), and Vincent et al. (2018) have proposed different categorisations that identify various lenses and priorities for coproduction, including researching solutions, addressing complex problems, recognising different knowledge, encouraging empowerment, reframing power, and producing knowledge.

Although coproduction has resulted in tangible progress and improvements that conform to accountability requirements, there are also critiques of the coproduction process. Vincent et al. (2021) argued that coproduction is a resource-intensive process that necessitates a significant investment of time and effort; similarly, there is a risk that it may overlook critical issues of power, politics, and inclusivity during the process (Vincent, 2022). Additionally, Arnott and Lemos (2021) and Jagannathan et al. (2020) argue that coproduction processes are frequently inadequately evaluated, with researchers focusing more on generated knowledge than users. Similarly, Daly and Dilling (2019) suggest that power asymmetries can manifest in various forms in society, and more powerful and elite actors from formal institutions are more likely to actively participate in coproduction processes due to their resources, confidence, knowledge, and skills (Clark et al. 2016). likewise, expert-driven coproduction, where project staff members are funded to facilitate the process, and their performance is linked to the outcome, can exacerbate unequal power relations (Frantzeskaki and Rok, 2018). To achieve inclusive coproduction, Vincent et al. (2021) suggest that it is crucial to acknowledge power differentials, reflexivity, and positionality; proactive measures are essential to realising them. Despite the challenges, coproduction can produce significant and diverse benefits (Visman et al. 2022).

Despite the wider application of coproduction, there is no uniform definition of knowledge coproduction (Norstrom et al. 2020). Miller and Wyborn (2020) argued that the “production” part of the “coproduction” is unproblematic—all fields suggest collaboration and participation achieve the desired outcome in society. However, they suggested the “co” part is problematic—it is difficult to understand whether it means multiple subjects or multiple objects or means collaboration, cooperation, or coordination.

Therefore, knowledge coproduction is evolving approach in participatory research, and despite its differences in conceptualisation, the four themes are common in all approaches of knowledge coproduction, i.e., context-based, pluralistic, problem-focused, and collaborative (Norstrom et al. 2020). Audia et al. (2021) suggested that knowledge coproduction can be achieved through co-design, co-analysis, and co-creation of activities that happen as a loop or continuous processes, which involves improving the policy and practice through local-level collaboration to achieve a common goal.

The knowledge coproduction in EWS in this thesis refers to the participation of people at risk in all four phases of EWS (risk information generation, risk communication, hazard monitoring, and response) and from the design process of EWS so that a uniform understanding of risk could be generated among the risk managers and the people at risk (Hamza and Mansson 2019). Lejano et al. (2021) suggested that knowledge coproduction can be achieved through three processes: The democratisation of risk knowledge (participation of people at risk in the risk information generation), knowledge translation (risk information translated to the language and narratives of people at risk); and decentring of expertise (achieving common understanding through reflexivity and transparency). Mansuri and Rao (2012) argued that there are two types of participation: organic and Induced participation. Organic participation happens necessarily and automatically at the community level by restructuring the social fabric to form a social enterprise, as suggested in CKM (see also Callon 1999; Lane et al. 2011). Induced participation refers to top-down or promoted participation through policy actions or state-implemented participatory programmes (which includes external government organisations working with the consent of the government actors). The induced participation comes in two forms: decentralised participation and community-driven participation. Powerful institutions extrinsically promote induced participation, while intrinsically motivated local actors drive organic participation (Mansuri and Rao 2012).

In defining the standpoint on knowledge coproduction in this research, the researcher references the statement from Donovan and Oppenheimer (2014, p. 159) suggesting that “instead of fighting for top-down process in which scientists have the knowledge and people must respond unquestionably or focussing too closely on a bottom-up approach that denies the importance of scientific inputs, the greater transparency and reflexivity might aid the process”. In this thesis, the knowledge coproduction in EWS refers to collaboration and participation between the risk managers and people at risk from the design of the EWS to have a common understanding through reflexivity and transparency to solve a common problem of the flood.

2.7. Risk Communication in EWS

To define risk communication, Donovan et al. (2019) used the metaphor of a reading process, where an author conveys messages through publications, and readers interpret the written text and make meaning out of them. Twigg (2003) suggested that the most critical factors in risk communication are: 1) how risk is communicated to the hazard-exposed people; 2) how people at risk interpret and understand the messages in risk communication; 3) how the risk communication influences people to choose appropriate actions. Therefore, risk communication in EWS can be understood as the process that leads to making the meaning about hazard risk to the people at risk.

Arvai and Rivers (2013) argue that risk communication needs to be contextually situated because socio-cultural contexts determine how risk information is understood and interpreted in a particular society by giving an example of colours and their significance in different cultures. For example, in south Asia, the red colour signifies prosperity, and the yellow colour signifies peace and positivity, whereas, in western society, the red and yellow colours are used to alarm or caution people as in traffic light systems; therefore, non-contextualised warnings may fail to convey the intended meanings to the at-risk people. Therefore, risk communication is a situated social activity and is a complex process of meaning creation (Arvai and Rivers 2013).

Boholm and Corvellec (2011) argued that risk communication is a relational process because it emerges from the cognitive act, which seeks to establish the relationship between the “risk-object” (hazard) and “object at risk” (people and their assets and livelihood). In EWS, warnings

are disseminated to convey the relationship between the possible hazard and people at risk (Arvai and Rivers 2013). (Creton-Cazanave 2014, p.3) suggested that “warning is a socio-technical process by which the reality of a given situation is assessed in order to establish its meaning, so as to constitute and coordinate action in a context of assumed danger”—suggesting that warnings are less about systems of sending signals and receiving it but more about meaning creation in a particular context (Thévenot 2006). Warnings do not help prevent or change the course of hazards; it only helps adjust the responses in a particular situation in the given moment; therefore, the purpose of EWS is to enhance the anticipatory actions at the community level (Creton-Cazanave 2014).

There are several views by authors suggesting what constitutes as effective risk communication in EWS. Scholars (Lindell and Perry 2003; Morss et al. 2016; Munro et al. 2017; Scolobig et al. 2018; Hamza and Mansson 2019; Mileti and Peek 2000) suggested that warning’s content needs to be understandable, issued from credible sources, and received by the intended recipients in a timely manner to allow proper preparedness and must include recommended action to minimise potential panic in public. Similarly, some researchers (e.g., Bell and Tobin 2007; Budimir et al. 2020; Hagemeyer-Klose and Wagner 2009; O’Sullivan et al. 2012; Rollason et al. 2018; Sukhwani et al. 2019; Sutton et al. 2014; Weyrich et al. 2018) have suggested that warnings need to be in local language and have standardised message format to provide unambiguous information about hazard risk— for quick comprehension of the message and to result in appropriate action. In the same way, Zhang et al. (2004) argued that effective warnings should specify the exact location where the hazard could impact and where the people should evacuate. Villagran de Leon (2014) suggested that the warning’s credibility can be aided by customising it based on the specific context of the local language and disseminating it through multiple sources so that it could be received and understood by different groups within a society. Many scholars (Kuller et al. 2021; Lindell et al. 2017; Rollason et al. 2018) also suggested that warnings should create meaning to people at risk to evoke appropriate response actions.

Nobert et al. (2010) and Demeritt et al. (2013) argued that most EWS focus on technological means to achieve longer lead times in warnings; however, longer lead times do not necessarily lead to better-informed response actions from the people at risk—warnings must also suggest appropriate actions to follow during and before disasters. Similarly, Creton-

Cazanave (2014) provided the example of the 2010 flood in France, where emergency services provided warnings with 24-hour of lead time for possible floods, but due to the lack of additional information on response actions (what to do and where to go), those warnings only served to create chaos at the community level.

Another significant factor in risk communication is people's trust in institutions (Heitz et al. 2009). Many scholars (e.g., Donovan et al. 2019; Rivers 2016; Villagran de Leon 2014) argued that frequent false alarms or failure to issue alarms could both dent people's trust in public institutions. Wachinger et al. (2012) argued that scientists rarely communicate uncertainties to people at risk, which are inherent in all risk analyses; hence people at risk get the impression of blind faith towards scientists, which can harm both people at risk and scientists (Wachinger et al. 2012). Eiser et al. (2012, p.12) argued that risk managers in public institutions often face a dilemma in communicating uncertainties to people at risk because—on the one hand, it could portray institutional honesty; however, it could also weaken the perceived competence of public institutions. Paton (2008) argued that trust develops by active participation and empowerment of the communities, through which collective understanding is developed, to have better risk knowledge and the limits of risk knowledge (uncertainty). Therefore, Eiser et al. (2012) suggested that trust in science and scientific institutions can be achieved through knowledge co-production.

Donovan and Oppenheimer (2014) argued that public trust and people's understanding could be strengthened through reflexivity (understanding one's limitations) and transparency (communicating uncertainties). Furthermore, they argued that in addition to the uncertainties in the scientific assessments, other indeterminacies in society, termed "social uncertainties" (e.g., the safety of the population, people's reaction to false alarms, fear that the public will refuse to cooperate in future); could also be managed through reflexivity and transparency. In addition, scholars (e.g., Mileti et al. 2004; Spiegelhalter and Riesch 2011; Shanahan et al. 2019) suggest that uncertainties must be communicated in the local language through narratives that people understand, and the recommended actions should accompany information about uncertainties. Introducing uncertainty information in warnings is critical, necessitating careful planning and tailored approaches in collaboration with decision-makers and individuals at risk (Fundel et al. 2019; Mwangi and Visman, 2020).

The above arguments suggest that risk communication is the process of meaning-making to the people at risk; therefore, it should be context-specific and participatory. The risk communication in EWS should also communicate uncertainties to the people at risk so that mutual trust is formed between the public institutions and people at risk to have a common understanding of risk. The following section will discuss the risk communication models practised in EWS.

2.7.1. Models of risk communication

This section explores the models of risk communication in EWS. Callon (1999) broadly categorised risk communication into three models: The Public Education Model (PEM), Public Debate Model (PDM) and Coproduction of Knowledge Model (CKM) as shown in fig. (6). These three models broadly characterise the forms in which the public are engaged in different disaster management practices.

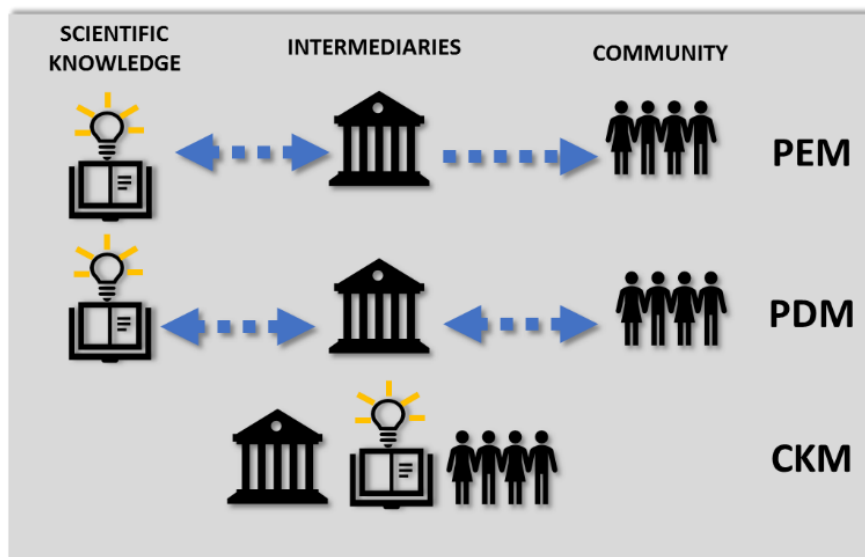


Figure 6: Illustration of the models of risk communication adapted from Callon (1999).

The first model, PEM, is a linear method of risk communication, where scientists are at one end and the public at another; the information flows one way from scientists to the public, and the information is “given” to the public about hazards. In PEM, scientific knowledge (objective and fact-based) is considered superior to public knowledge (subjective and based on general beliefs and experience); Therefore, scientific knowledge tends to replace public knowledge through education; hence the model is known as the “Public Education Model” (Callon 1999). The connection between the scientists and the public in PEM is maintained by intermediaries or legitimate institutions, who maintain the trust between scientists and the

public, as the public must trust scientific information, and scientists must trust that the public will act on the given information in the desired manner. In PEM, the knowledge is often incomplete because scientists cannot model the real world accurately due to the complexities and uncertainties involved (Wynne 1992), which can result in false alarms causing mistrust of the public towards scientists, for which intermediaries intervene to regain the trust by continuously engaging with public (Callon 1999).

The second model, PDM, seeks to improve the relationship between scientists and the public compared to the PEM model. In PDM two-way interaction between the public and scientists is maintained in the presence of intermediaries. This model uses a consultative approach, where scientists first generate and analyse the information, then, in a forum with intermediaries, discuss the generated information with the public. Thus, in PDM, the public is considered as a group of people with contextual information, which can improve scientific understanding. The PDM model seeks to reinforce the trust between scientists and the public by providing the platform for public to speak about themselves, where the scientific decisions are also validated before implementation (Callon 1999). Collins and Evans (2002) argued that the PDM model brings scientific knowledge for debate at least at the knowledge production stage, where public views can be incorporated to enrich the scientific information. However, Wynne (2003) argued that social interaction based on PDM (e.g., collaborative mapping exercises or community meetings) allow some space for the public to speak but also tends to legitimise the scientific decisions as generated through a democratic process. Therefore, even if the PDM seems to incorporate the public in the decision-making process more significantly than the PEM; both the models have deficiencies—exclusion of people in knowledge production is absolute in PEM while negotiated in PDM; therefore, PDM can be called a PEM in disguise, as it still elevates the “given” scientific knowledge (Callon 1999).

The third model, CKM, seeks to overcome the shortcomings of PEM and PDM, where knowledge is co-produced between scientists, experts, and the public through a dynamic and collective learning process involving people with a common matter of concern (i.e., hazard risk). In CKM, there is no hierarchy and generated knowledge does not fall into the domain of expert knowledge or privileged knowledge (Collin and Evans 2002). There are no intermediaries and no need to legitimise the generated knowledge, and there is no distinction between scientists and the public because the public practices science and science itself is

free from the domain of the scientists. In the CKM, the non-specialists or the public itself is involved in the process of knowledge production. Because of the greater understanding of the contextual information, the public involvement in the co-production of scientific knowledge is emphasised as “contextualised science production” (Nowotny et al. 2001), “Extended peer review” (Ravetz 1999) and “Scientific citizenship” (Irwin 2001), which negotiates the relationship between the citizen and scientists. In this model, knowledge is neither “given” nor “taken”; it is co-produced by the public or concerned groups who organise themselves for a common purpose and engage actively to solve a common problem, decide for themselves, and implement what is decided. In CKM, the role of the expert is the same as the role of the public, and it is not merely “the public in decision making” but rather “decision making by the public”, and thus CKM removes the social chasm between scientists and public (Lane et al. 2011). Whatmore (2009) argued that, in order to realise the CKM, there need to be some catalysts in the social fabric, such as catastrophic events (Stengers 2005); common and urgent problems or “matters of concern” (Latour 2004, p.221); or conflict and disasters in the form of “hot situations” (Callon 1999, p.592) that play a dominant role in restructuring society and forming an autonomous social enterprise.

Co-production provides significant benefits, but its success hinges on the collaboration of relevant actors, which demands substantial time, effort, and support (Vincent et al. 2021). Additionally, Visman et al. (2022) noted that co-production is resource-intensive despite being increasingly recognised as essential for EWSSs.

Wardman (2008) argued that risk communication typically employs three imperatives: 1) normative, 2) instrumental, and 3) substantive. The normative imperative of risk communication suggests that it is simply the right thing to do (Pidgeon and Rodgers-Hayden 2007); therefore, risk is communicated as it is moral imperative of government to inform people about the risks they face (Stirling, 2005). On the other hand, the instrumental imperative interprets risk communication as a tool to achieve the desired outcome or manage public responses to risks. Furthermore, the substantive imperative suggests that relevant knowledge is not limited within scientists, therefore participation can enhance the understanding and provide essential information about the risk situation, where non-scientists can also substantively contribute to knowledge (Wardman 2008).

Based on those three imperatives, Wardman (2008) conceptualised four models of risk communication as: Risk Message model (RM), Risk Dialogue model (RD), Risk Instrument model (RI), and Risk Government model (RG), by dividing it along the vertical axes of (normative to instrumental imperatives) and horizontal axes of level of substantive engagement as shown in fig. (7).

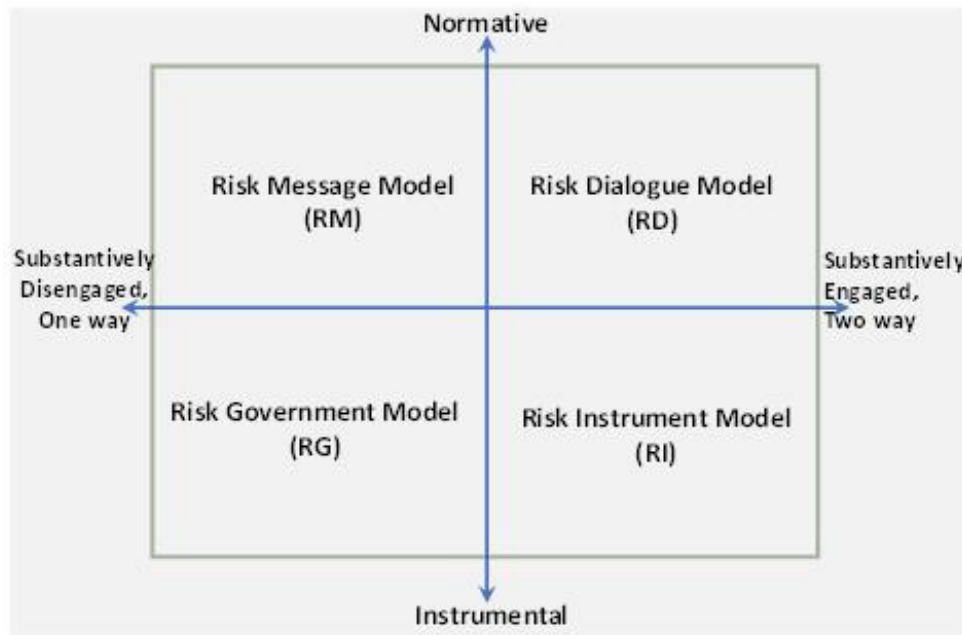


Figure 7: vertical and horizontal axes of risk communication, adapted from Demeritt and Nobert (2014).

The RM model is motivated by the normative imperative but is substantively disengaged. The RM model follows a one-way flow of information between the disaster managers and people at risk (Demeritt and Nobert 2014). The RM model resembles the PEM of Callon (1999), where knowledge flows one-way and top-down. In contrast to the RM model, the RI model engages with people at risk with two-way communication, but those interactions are top-down and driven by risk managers to achieve specific objectives at the community level. The RI model can be interpreted as a PDM of Callon (1999). The RD model, on the other hand, is based on a two-way flow of information but involves bottom-up and participatory approaches to risk communication, which blurs the distinction between risk managers and people at risk. The RD model is driven by normative imperatives but substantively engages with the diverse realities that various participants bring to the discussion in a particular context (Jovchelovitch 2019). The RD model resembles the CKM of Callon (1999), where knowledge does not travel but evolves or is co-produced by substantive engagement of people at risk. However, scholars (e.g., Krauss and Fussell 1996; Mercer 2012; Pidgeon et al. 2005) have argued that conflicts

are intrinsically and profoundly embedded in societies in the form of class and caste differences and power structures, which can skew the interactions and discussion towards the favour of groups, which is addressed by the RG model of risk communication (Demeritt and Nobert 2014). The RG model includes the power dynamics or conflicts that are latent in the society in the process of in-risk communication, and it views risk communication through the lens of Foucault's "governmentality" approach, where the risk communication seeks to steer people's choices in the direction of welfare-promoting activities through education, media, maps, and publications to deter people from specific actions and behaviour during disasters (Dean 1999, Rose et al. 2006).

In summary, scholars such as Allwood (2000) and Arvai and Rivers (2013) argued that risk communication is a situated social activity of meaning creation, and others such as Demeritt and Nobert (2014) argued that all contexts are unique and require unique means of risk communication; therefore, the best practice model in risk communication is a myth.

2.8. Gender in flood EWS

Multiple studies indicate that women are more vulnerable than men due to limited access to information, mobility, decision-making authority, resources, social networks, education, and training; which are attributed to gender-based roles and norms in a society (Mehta 2007; McOmber et al. 2013; Sultana 2010; Shrestha et al. 2016). Gender refers to the advantages and disadvantages associated with being male or female in society and the power systems that regulate their interactions (Shrestha et al. 2016). It encompasses socially and culturally constructed roles and responsibilities based on sex, including those assigned to sexual and gender minorities. These roles and responsibilities are subject to change over time and in specific contexts, intertwined with power dynamics (Mustafa et al. 2015). However, gender remains a frequently misused concept in social sciences and hazards, with limited literature addressing gender inequalities in EWSs, such as conditions, requirements, risk perceptions, vulnerabilities, and personal experiences (Kramarae 2004).

Gender plays a pivotal role in determining social dynamics, access to opportunities, and the distribution of vulnerabilities among women, men, girls, boys, and transgender or intersex individuals facing environmental hazards (Shah et al. 2022). These vulnerabilities are further exacerbated during disasters (Cannon 2002; Enarson and Chakrabarti 2009; Finley and Hearn

Morrow 1998; Ray-Bennett 2009). Therefore, it is crucial to examine gender in EWS in conjunction with other social identity markers, such as class, age, disability, sexuality, ethnicity, and caste, as these factors (McDowell 2008). While some studies shed light on the gendered implications of disasters, most relevant literature originates from disaster management reports and development practitioners, mainly disregarding the experiences of gender minorities, with a few exceptions such as (Cianfarani 2012; Dominey-Howes et al. 2014).

There is a lack of understanding of how gender relations are negotiated and perpetuated in relation to natural hazards and disasters, particularly in the global north and with EWSs (Shah et al. 2022). Additionally, limited attention and literature exist on gender and EWSs in floodplains, where water significantly affects life and livelihoods (Mustafa et al. 2015; Shah et al. 2022).

Gender is a learned and unique aspect of individuals' identities shaped by their culture. Exploring and understanding differences in gender roles, identities, and the gender-based causes of inequalities are crucial for addressing gender gaps (Shrestha et al. 2016). Specific issues affecting EWSs include individuals choosing not to evacuate despite receiving warnings, undermining the system's effectiveness (Mustafa et al. 2015). The common gender-based constraints related to EWS are limited access to warnings, insufficient participation, and minimal or no roles in decision-making processes, which all relate to the underutilisation of capacity for EWS (Shah et al. 2022). Addressing these challenges requires promoting and providing opportunities for women in decision-making roles (Ritchie et al. 2017).

Despite numerous programs aimed at gender inclusion in recent decades, concerns regarding gender disparities and limited engagement of women in EWSs persist (Schmeidl and Piza-Lopez, 2002). The gender inequalities resulting from the inability to access warnings and participate in awareness-raising or decision-making activities stem from societal stereotypes perceiving technology as male-centric (Shah et al. 2022). Factors such as physical attributes, caregiving responsibilities, and cultural norms targeting women specifically impact their actions during disasters (Ritchie et al. 2017). Recognising the disparities in skills and understanding the preferred modes of communication and societal norms between men and women is crucial for EWSs (Handapangoda 2013; Kramarae 2004).

Incorporating a gender perspective in EWSs necessitates gender-based analysis to identify disparities in requirements, resource availability, access to information, and decision-making roles between men and women (Schmeidl and Piza-Lopez 2002). Failure to incorporate a gender and inclusion perspective in disaster research risks perpetuating, exacerbating, or creating new societal inequalities (Daze and Dekens 2017); therefore, gender considerations are essential in EWS.

2.9. Transboundary disasters

Transboundary disasters transcend the boundaries of individual states, national territories, and social divisions among experts, scientists, and the public (LaPorte 2007). Socioeconomic contexts and cultural factors also influence transboundary disasters, determining their scale, impact, and duration (Levin et al. 2012; Lidskog 2011). Thus, transboundary disaster risk governance should encompass political boundaries and consider the cognitive territories shaped by imaginary boundaries, which arise from a combination of geopolitical, social, environmental, and cultural factors (Lidskog 2009; Norman 2014). Lejano and Ingram (2009) and Armitage et al. (2015) argue that transboundary disasters traverse multiple administrative jurisdictions spatially and temporally, causing enduring impacts on people's lives and livelihoods. Therefore, transboundary disaster risk governance must operate horizontally across various administrative jurisdictions, vertically across multiple levels of government, and functionally beyond disciplinary boundaries, necessitating engagement from diverse sectors and stakeholders (Lejano and Ingram 2009).

Transboundary disaster risk governance presents extensive scope and complexity, resulting from sociocultural contexts, institutional shortcomings, governance deficits, and geopolitical factors (Ohlsson 2000), which requires coordinated efforts from multiple sectors, states, and countries (Clegg et al. 2021). Understanding transboundary disasters entails grappling with numerous challenges deeply entrenched in society, often described as "wicked problems" due to their multifaceted nature influenced by geopolitical, social, environmental, and cultural factors. The intricate interaction among these factors remains challenging to comprehend (Dixit et al. 2022).

Lidskog et al. (2009, p.15) argue that current approaches to transboundary risk governance suffer from a "democratic gap", as only a few legitimate government institutions have the

mandate to manage and govern transboundary risks, remaining confined within their knowledge and administrative boundaries. However, addressing complex geophysical phenomena—interwoven with social dynamics and inherent uncertainty—requires more robust risk governance approaches than the existing top-down approaches to risk management (Lidskog et al. 2009). Similarly, Mirumachi and Chan (2014) contend that many transboundary governance debates focus on politics and are influenced by international relations, rendering transboundary governance “actor-centric” and subject to intervention by government elites. Furthermore, transboundary risk governance necessitates coordination among various governments and non-governmental actors to simplify or standardise complex knowledge and find ways to manage uncertainty. During transboundary interactions, a wide range of actors with varying interests often leads to contested processes shaped by discursive considerations to promote different actors’ intentions (Rose 1999; Fisher 2003).

Numerous scholars, such as Ansell et al. (2010), Fisher (2003), Levin et al. (2012), and Rose (1999), argued on the significance of geopolitics in transboundary risk governance. Similarly, Zeitoun et al. (2011) have proposed that power dynamics shape transboundary interactions, wherein dominant states subtly manipulate weaker states to obtain consent without violence. This phenomenon, known as “soft power,” involves including asymmetrical benefits within negotiated agreements (Zeitoun et al. 2011). Expanding on this idea, Mirumachi (2015) contends that when countries with unequal power cooperate in transboundary contexts, powerful states often assume a prominent role in establishing rules and exerting influence, coercion, or intimidation over weaker nations to ensure compliance. Consequently, adopting a geopolitical perspective when assessing transboundary interactions becomes essential, particularly when such disasters impact countries characterised by disparate power dynamics.

Pahl-Wostl (2007) suggested the need for fresh perspectives on the legitimacy of actors and institutions and their jurisdiction in disaster risk management to achieve effective governance of transboundary disasters. Furthermore, Cosens (2010) argued that the conventional organisation of political states based on territorial boundaries is inadequate in a globalised world, and addressing transboundary disasters requires transcending traditional demarcations between the public and private sectors. Therefore, effective management of transboundary disasters necessitates collaboration among multiple stakeholders, including governments, public and private institutions, and individuals at risk (Amaratunga et al. 2020).

2.10. Transboundary river governance and basin structures

Transboundary rivers traverse international borders, with approximately three hundred river basins identified worldwide; only one-third of those rivers have transboundary river governance mechanisms (Islam and Choudhury 2018). Also, there is an absence of a consensus on the definition and metrics of transboundary river governance, which poses challenges in assessing its effectiveness (SIWI 2018). Nonetheless, it is widely acknowledged that transboundary river governance and cooperation is a public good, capable of generating shared benefits, including transboundary flood risk management, climate change adaptation, economic growth, and regional integration (Zeitoun et al. 2013).

Transboundary river governance is shaped by many natural, societal, and political interactions involving processes, actors, and institutions (Islam and Choudhury 2018). The competition and conflicting interests surrounding transboundary rivers, combined with evolving demographic, socioeconomic, and climatic conditions, have drawn the attention of various disciplines and communities to the field of transboundary river governance (Earle and Neal 2017; Islam and Susskind 2013; Mirumachi 2015; Pahl-Wostl 2004; Petersen-Perlman et al. 2017; Subramanian et al. 2012; Turton and Henwood 2002;). Petersen-Perlman et al. (2017) argued that the uniqueness of each river basin, characterised by its distinct climate, demography, hydrology, topography, and sociocultural divisions, renders transboundary river governance a complex and context-specific task. While conflict and cooperation are commonly accepted categories within transboundary river governance (Hanasz 2018), Mirumachi (2015) argued that the complexities of transboundary river issues defy simplistic categorisation. Such attempts may oversimplify the dynamic interactions and variations in natural and societal relations over time and changing political contexts (Zeitoun and Mirumachi 2008).

Transboundary river governance encompasses a range of principles, norms, rules, and decision-making processes that align with the expectations of the involved states and actors (Bréthaut 2016; Earle 2013). The involvement of the affected people and diverse stakeholders is crucial for transboundary river governance, including understanding socio-cultural context and ecological systems and their complex interactions (Sneddon and Fox 2006). Numerous authors (e.g., Allan 2012; Chenoweth and Feitelson 2001; Jagerskog 2002) suggest that in addition to the state actors, informal mechanisms and coalitions among non-governmental

actors also play a significant role in shaping discourse, establishing priorities, and making policy recommendations. However, the existing literature on transboundary interactions primarily focuses on conflicts and cooperation between neighbouring nations, especially concerning hydropower generation and water use, with limited investigations into transboundary river floods and disaster risk management (Bakker et al. 2009; Clegg et al. 2021; Pandey et al. 2023).

Transboundary river basin governance includes forming transboundary governance structures, which are bodies with the autonomy to act independently within the international system, where they can negotiate and enter into agreements with other legal entities (Zeitoun et al. 2013). Schmeier (2013) distinguished three types of transboundary river basin governance bodies based on their effectiveness, determined by the strength of their legal mandates as committees, commissions, and authorities. Among these, the transboundary river basin committees typically lack a legal mandate; as a result, committees are limited to coordination or advisory roles, while transboundary river basin commissions possess a legal mandate, signifying that riparian states have delegated specific powers to manage the shared resources within a river basin. The transboundary river basin authorities are organisations entrusted with a broad mandate, which may include managing overall socio-economic development within the river basin, extending beyond water resource governance (Schmeier, 2013). Furthermore (Earle and Wouters 2015) suggested that multi-level organisational structures are also common in transboundary river governance, including ministerial-level authority or council supported by a basin-level commission that includes thematic committees for solving specific issues such as flooding. Bilateral or multilateral treaties serve as legal frameworks for transboundary governance bodies, providing transparency and accountability in managing shared water resources in the transboundary river basin (Wouters, 2013). Coordination and implementation functions are usually defined within those treaties that regulate the relationships between countries (Wingqvist and Nilsson 2015). Despite the importance of treaties in transboundary river governance, only a few pieces of literature focus on the reasons behind the formation of those treaties and the agencies and interests of the riparian nation. Also, the available literature is focused towards developed countries, with limited focus on the coverage of hazards such as transboundary river floods and consideration of the role of local communities in transboundary river governance (Yaari et al. 2015).

In transboundary river governance, significant attention has been given to power asymmetry and hydro-hegemony, highlighting how stronger states take control over weaker states in negotiations and water-sharing policies (Mirumachi 2016; Mirumachi and Allan 2007; Warner et al. 2017; Zeitoun et al. 2016). Power relations, negotiation capacities, and stakeholder interactions contribute to the dynamic between cooperation and conflict, with non-state actors also influencing transboundary river governance (Bréthaut 2016; Warner and Zawahri 2012; Zeitoun and Mirumachi 2008).

Transboundary river governance in South Asia is complicated due to power imbalances, mutual hostility, suspicion, and the absence of a universally binding international legal framework (Dixit et al. 2021). Despite sporadic multilateral attention, the lack of comprehensive focus raises significant concerns, particularly with India's variable approach as a middle-riparian country depending on the specific river and country involved. The UN Convention on the Law of the Non-Navigational Uses of International Watercourses (UNCIW) is the basis for international transboundary watercourses law. However, the effectiveness of international law principles and provisions relies on the ratification of specific instruments by the concerned states and their commitment to domestic compliance. However, only Bangladesh and Nepal voted in favour of the UNCIW, with China opposing it and India, Pakistan, and Bhutan staying neutral (Dixit et al. 2021). When not all riparian countries become States Parties to these instruments, managing transboundary watercourses becomes difficult, impeding shared benefits in a just, peaceful, and sustainable manner (Chintan 2012). As a result, transboundary river governance in South Asia heavily relies on a limited number of bilateral treaties, lacking guidance from international legal instruments, standards, and judicial precedents (Upadhyay 2012). China cited concerns that the UNCIW disregarded the "principle of territorial sovereignty of a watercourse state"; at the same time, India expressed concerns about the lack of "state's autonomy to conclude agreements without being fettered by the convention" (Upadhyay 2012, p.42). It objected to third-party involvement in the mandatory dispute settlement mechanisms.

Consequently, India abstained from voting, followed by Bhutan and Pakistan (Chintan 2012). Although Nepal and Bangladesh endorsed the UNCIW, its operational efficacy remained limited (Upadhyay 2012). The absence of multilateral treaties governing transboundary rivers in South Asia can largely be attributed to India's utilisation of different upstream and

downstream principles depending on the specific river and country it deals with as a middle riparian (Chintan 2012). Furthermore, China, holding the headwaters of two river systems and several key tributaries of another country, is not part of any treaty arrangement in South Asia or Southeast Asia (Dixit et al. 2021). Non-ratification of such international instruments by powerful riparian countries hampers negotiating solutions to transboundary river issues (Ranjan 2019). The next section will explore the bilateral efforts on transboundary flood risk governance between Nepal and India, which is the focus of this research.

2.10.1. Bilateral Efforts on transboundary flood risk governance between Nepal and India

After the Kosi flood of 2008, the governments of Nepal and India have formed three-tiered institutional mechanisms for bilateral cooperation on flood risk management: at the ministerial level—Joint Ministerial Commission for Water Resource (JMCWR); at the secretary level—the Joint Commission for Water Resource (JCWR); and the technical advisory committee on flood risk management—Joint Standing Technical Committee (JSTC), including government authorities from both the countries (Acharya and Hori 2019). The JMCWR is responsible for the transboundary policy formulation, JCWR is responsible for policy implementation, and JSTC is a coordinating body of technical subcommittees: the Kosi High-level Committee (KHLC), the Joint Committee on Inundation and Flood Management (JCFIM), and the Joint Committee on Kosi and Gandak Projects (JCKGP) as shown in fig. (8).

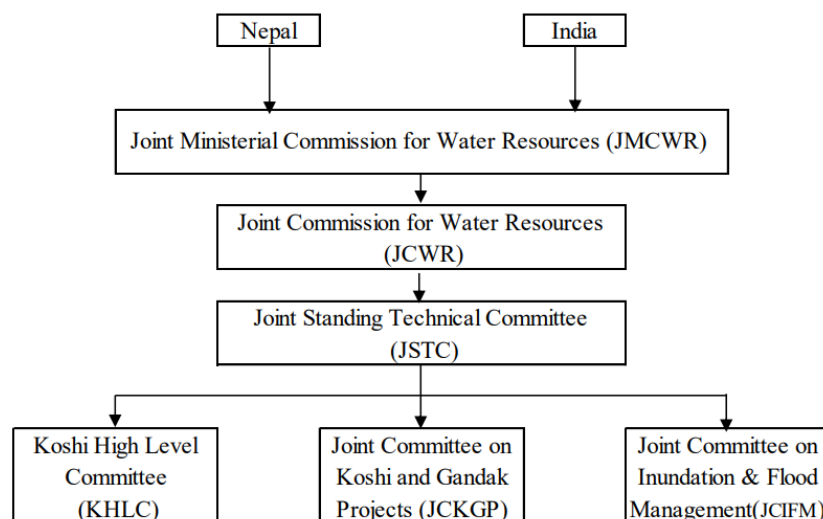


Figure 8: Bilateral institutions formed between Nepal and India to solve the Kosi flood Issue. (Source: Acharya and Hori 2019)

Despite the institutional arrangements, the transboundary coordination and collaboration between Nepal and India has remained complex because (i) there is no mechanism for

communication at the state or district level, nor any local government representatives are involved in those bilateral committees (Dixit et al. 2021); (ii) the bilateral committee on inundation and flood risk management primarily focus on post-disaster response planning, future hydropower projects, and water-sharing, rather than preparedness or transboundary early warnings (Gupta et al. 2021; Shrestha et al. 2021); and (iii) transboundary communication still requires to pass through the extended hierarchy of institutions following international protocols. The latter severely impeding the transboundary communication and delaying decision-making during transboundary disasters (Acharya and Hori 2019).

2.11. Transboundary early warning systems between Nepal and India: the state-of-the-art analysis

This section explores the evolution of transboundary EWS between Nepal and India, the state-of-the-art analysis of transboundary EWS between Nepal and India, and identifying gaps and challenges based on secondary literature.

After the devastating Kosi flood of 1954, which affected the Saptari and Salahi districts of Nepal and caused widespread flooding in the Bihar state of India, the Indian government recognised the need for a transboundary flood forecasting system between the two countries (Mishra, 2008). As a response, India established the Central Water Commission to forecast floods, with cooperation from Nepal to set up hydrometeorological stations for data collection from transboundary rivers originating in Nepal, including the Ganga River and its tributaries (Upadhyay, 2012).

In line with these efforts, a bilateral meeting was held between government officials from the Ministry of External Affairs and the Ministry of Foreign Affairs of Nepal, focusing on transboundary flood forecasting and EWS (Chintan, 2012). Transboundary flood forecasting and EWS were discussed during a visit by the Indian Minister of External Affairs to Nepal in July 1977 (Mishra, 2008). India committed to supporting Nepal by providing the necessary technical equipment and human resources to develop a transboundary flood monitoring and forecasting system, benefiting both countries (Dixit et al. 2021). Further discussions on flood forecasting and EWSs took place in subsequent years, with a meeting in 1982 addressing flood control interventions in the border region between Nepal and India (Mishra 2008). This was also the year when the government of Nepal enacted its first act on disaster relief, the Natural

Calamity Relief Act of 1982, which included provisions for responding to and providing relief to families affected by floods (Upadhyay 2012). The 1988 meeting between Nepal and India on transboundary flood management highlighted the importance of establishing rainfall and flood-level monitoring stations; It included a comprehensive assessment of hydrometeorological sites in eastern Nepal (Mishra, 2008). In the meeting, India committed to supplying hydrological and telecommunication equipment for warning systems and providing training facilities for Nepalese technicians and professionals (Upadhyay, 2012).

In 1990, Nepal underwent a political transition from the panchayat system to multiparty democracy by introducing a new constitution (Chintan, 2012). In 1991, a Memorandum of Understanding was signed between Nepal and India to establish flood forecasting and EWS, emphasising the commitment to ensure continuous and effective system functioning (MoFA, 2022; Upadhyay 2012). By 1995, nine hydrology stations were established at transboundary rivers between Nepal and India, and a master control room was established in Sindhuli, Nepal, to transmit data to the Patna station in Bihar, India (Mishra 2008).

With the formulation of a new constitution in Nepal, international non-governmental organisations (INGOs) such as OXFAM, CARE, and Action Aid became active in disaster risk management (Gade et al. 2020). They demonstrated the implementation of community-based EWSs, providing early flood warning information to flood-prone communities in the Kosi and Karnali River basins (Gupta et al. 2021). Over the next decade, community based EWSs were established by NGOs in various river basins across Nepal, including the Karnali, West Rapti, Babai, East Rapti, Narayani, Bagmati, Kamala, Kosi, and Kankai rivers (Upadhyay 2012). NGOs like Practical Action, LWR, and international research institution ICIMOD implemented pilot projects on transboundary EWS between Nepal and India (Molden et al. 2017). While these community-based systems proved effective in saving lives, scaling them up to the national and transboundary levels has remained challenging for Nepal (Dixit et al. 2021).

Although no formal transboundary EWS exists between Nepal and India, both countries have their respective EWSs (Gupta et al. 2021). The Department of Hydrology and Meteorology (DHM) in Nepal transmits hydrometeorological data from the Sindhuli station in Nepal to Patna as a formal transboundary data exchange, reporting the previous day's information (Dixit et al. 2021). Numerous INGOs have been actively involved in establishing community

based EWSs in Nepal (Gade et al. 2020). However, multiple NGOs working on EWSs have resulted in sporadic and inconsistent efforts in implementing transboundary EWS (Dixit et al. 2021).

While formal EWSs are being pursued, community based transboundary EWSs have emerged as effective alternatives in the case of Nepal and India (Molden et al. 2017). For example, ICIMOD in Nepal implemented a pilot transboundary EWS project in the Ratu River, using low-cost sensors to disseminate warnings from Nepal's Saptari district to downstream villages in Bihar through the Community-Based Flood Early Warning System (CBFEWS) project. This system provided early warnings and saved communities during the flood in August 2017 (Shrestha et al. 2017). Furthermore, SMS-based warnings also emerged as a new means of reaching the people at risk in India and Nepal, offering quicker warning dissemination than traditional mediums such as newspapers, television, and radio. However, challenges remain regarding access, comprehension of SMS-based warnings, power supply, and mobile phone coverage, especially during the monsoon season when floods are most common (Gupta et al. 2021).

India and Nepal have endorsed the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR), a non-binding agreement emphasising the need for enhanced regional collaboration in DRR. The SFDRR includes a global target to significantly improve the availability and accessibility of multi-hazard EWSs and disaster risk information to people by 2030 (UNISDR, 2015). At the Asian Ministerial Conference on Disaster Risk Reduction in 2016, the importance of investing in, collaborating on, and forming global partnerships for multi-hazard EWSs in DRR was acknowledged (AMCDRR, 2016). Both countries have also committed to the Asia Regional Plan for Implementation of the Sendai Framework, which emphasises the need for a shared understanding and approach in addressing regional and transboundary issues, including transboundary risk assessments, data exchange, and cooperation among various non-governmental and informal networks (Gupta et al. 2021). While these global and regional frameworks are non-binding, they represent significant steps towards establishing a transboundary EWS between Nepal and India (Dixit et al. 2021).

2.11.1. Challenges in transboundary EWS

Implementing transboundary EWS and flood risk management in the Kosi River basin has numerous challenges. These challenges stem from limited data availability and an incomplete understanding of upstream and downstream linkages and basin characteristics (Nepal et al. 2014). Additionally, factors such as inadequate land use planning, encroachments on floodplains, insufficient infrastructure, and inadequate drainage management exacerbate the impacts of floods (Dixit 2003). Despite scientific and technological advancements, the Kosi River basin lacks accepted transboundary flood forecasting mechanisms between the governments of Nepal and India (Gupta et al. 2021).

The characteristics of the upstream basin, including spatiotemporal variability in temperature, precipitation, and sediment load, directly influence the behaviour of the Kosi River downstream. Furthermore, the presence of multiple hazards in the river basin such as glacial lake outburst floods, earthquakes, landslides, and large debris flows, which can cause floods in the Kosi River affecting downstream in Bihar, necessitates transboundary collaboration to comprehensively understand the physical, social, and environmental context of the river basin (Chen et al. 2013; Fang et al. 2020; Gupta et al. 2021; Sinha et al. 2014). However, contentious relations between riparian countries and the lack of data-sharing mechanisms have impeded transboundary collaboration in the Kosi River basin (Vila Seone 2021).

Flood risk management efforts in Nepal and India lack multidisciplinary representation, particularly in policy-making discussions related to EWSs, flood control, and disaster risk reduction (Koirala 2020; Ranjan 2019). These discussions often exclude participation from other government departments, universities, academic institutions, and local communities, resulting in the absence of crucial aspects such as gender perspectives, livelihood considerations, and environmental concerns (Chintan 2012; Dixit et al. 2021). Moreover, traditional knowledge and local practices for flood protection are not adequately acknowledged (Choudhury et al. 2021). Bilateral discussions tend to reinforce previous decisions rather than critically reflect on them, leading to policy responses that insufficiently consider the impact of climate change on floods, river flow responses, and increased vulnerability and exposure to these hazards (Dixit et al. 2021; Dutta 2022; Koirala 2020).

Several scholars have highlighted the significance of transboundary data sharing for effective cooperation and EWS (Chenoweth and Feitelson 2001; Choudhury 2021; Dutta 2021; Grossmann 2006). While data sharing is crucial, the focus has primarily been on hydrometeorological and rainfall data, neglecting socio-economic conditions and vulnerability data (Armitage et al. 2015; Choudhury 2021; Rivera 2015; Schmeier 2014). Issues such as incompatible data formats and data quality can also hinder the analysis of transboundary rivers (Bernstein 2009).

Furthermore, transboundary committees established for flood protection in the region have prioritized structural interventions without considering their negative consequences, such as drainage congestion and exacerbation of flooding conditions (Dixit 2003; Sinha 2008). Despite their potential value and significance, traditional knowledge and practices associated with flood management have been undervalued (Mishra 2008; Dekens 2007). The adverse effects of transboundary floods and inundation on marginalized communities in the Kosi River basin have been acknowledged for decades (Regmee 2013). Concerns arise from the omission of the preparation and implementation of the Flood Forecasting Master Plan in the 12th meeting of the India-Nepal Joint Committee on Inundation and Flood Management (Gupta et al. 2021; Mishra 2008).

Securitisation of transboundary rivers in India, driven by border disputes with neighbouring countries, has resulted in limited sharing of river information due to national security reasons (Prasai and Suri 2015; Singh 2010). This securitisation has led to the no-disclosure of any information on transboundary rivers by India. For the Kosi River, only data on the Nepali stretch of the river can be accessed. Access to river data in India requires signing a secrecy agreement, limiting public disclosure (Dutta 2021; Vila Seoane 2021). The Kosi Agreement states the provision for data sharing between Nepal and India under the Section-2 related to the investigation and surveys in the Kosi River basin, where clause iv states:

“All data, specimens, reports and other results of surveys and investigations carried out by or on behalf of the Union in Nepal pursuant to the provisions on this clause, shall be made available to HMG (His Majesty’s Government of Nepal) freely and without delay. In turn, HMG shall, upon request by the Union (Government of India), make available to the Union all data, maps, specimens,

reports and other results of surveys and investigations carried out by or on behalf of HMG in Nepal in respect of the Kosi River.” (MoEWRI 2022, p.2)

Additionally, myths surrounding the causes of Kosi floods hinder transboundary collaboration for disaster risk management and EWSs. These myths are propagated by politicians and media in both countries, perpetuating misunderstandings, and mistrust (Dixit et al. 2021; Gupta et al. 2021).

Bilateral discussions between Nepal and India on transboundary flood risk management have historically centred around embankment construction, hydropower generation, and irrigation on large transboundary rivers like Kosi, Karnali, and Mahakali. The predominant focus on embankments as a comprehensive solution reflects the engineering-oriented approach adopted by water-sector agencies in both countries, neglecting alternative perspectives and approaches to flood control (Dixit et al. 2021; Noolkar-Oak 2021).

The capacity of governments on both sides of the border lacks the effective implementation of well-intentioned policies on transboundary EWS. Local officials bear multiple responsibilities, including disaster management, but budgetary allocations often prioritise response rather than preparation. Furthermore, the existing policies generally lack specific guidelines for achieving high-level objectives, such as establishing EWSs (Dixit et al. 2021).

2.12. Early warning systems in practice:

This section explores the currently operational EWS in Nepal and Bihar state of India. Also, this section explores the community based informal EWS in the Kosi basin established by non-government organisations to fill the gaps in transboundary EWSs between the two countries.

2.12.1. Early warning system in Nepal

In Nepal, the Department of Hydrology and Meteorology (DHM) generates hydro-meteorological forecasts and disseminates early warnings. DHM receives support from a wide range of stakeholders in EWS, such as intergovernmental institutions such as the International Centre for Integrated Mountain Development (ICIMOD) and United Nations organisations, including UNICEF and UNDP, as well as other international agencies, including the International Federation of Red Cross and Red Crescent (IFRC) and the World Wildlife Fund (WWF)-Nepal. The DHM also partners with international non-governmental agencies (INGOs)

to disseminate warnings, raise awareness, and build the capacity of local-level institutions for EWS. DHM has partnered with NGOs such: including Lutheran World Relief (LWR), Practical Action, ActionAid, Care–Nepal, Handicap International Nepal, Lutheran World Federation (LWF), Mercy Corps-Nepal, and Oxfam, as well as non-governmental organisations (NGOs), such as ADAPT–Nepal, DP-Net, Eco-Nepal, the Nepal Centre for Disaster Management (NCDM), and the Nepal Disaster Management Forum (NDMF). To ensure the effective dissemination of warnings, DHM has also collaborated with forums such as the Nepal Forum of Environmental Journalists (NEFEJ) and telecommunications service providers NTC and NCell (DHM, 2018).

The EWSs in Nepal have evolved from a simple watching-and-warning system (manually observing the river gauge and informing downstream) to semi-automated warning systems of real-time river monitoring and, recently, warning through mobile SMS (Budimir et al. 2020). The real-time river monitoring sensors in Kosi at Chatara, approximately 50km upstream of the India-Nepal border, automatically trigger a ‘Warning’ alert when the Kosi River level increases to 5.6m and a ‘Danger’ level alert when the river level increases to 6.8m of the river gauge (Kafle 2020). The electronic display boards are placed at the District Administration Offices (DAO) and in Kosi and municipal officers in Nepal, which display the Kosi River level at Chatara in real-time and trigger automatic alarms when the Kosi River level reaches Warning and Danger levels as shown in fig. (9) (Budimir et al. 2020).



Figure 9: Digital display board at the District Administration Office, Saptari, Nepal, which shows the real-time river level of Chatara River monitoring station (source: field photograph).

When the alarms trigger at DAOs, the Chief District Officers (CDO) verify the warning from the Chatara River monitoring station by phone, then consult with the Ministry of Home Affairs, National Disaster Risk Reduction and Management Authority (NDRRMA), National Emergency Operation Centre (NEOC), and Department of Hydrology and Meteorology (DHM) and coordinates with mayors of the municipalities regarding the risk and possible for response actions. Upon receiving the information from CDO, mayors call an emergency meeting of the Local Disaster Management Committee (LDMC), which includes Ward chiefs, to initiate disaster response planning. At the Ward level, Ward Chief calls Community Disaster Management Committee (CDMC) meeting and activates the Early Warning Task Force (EWTF), which visits door to door to inform people at risk and assist people to evacuate to safety. The EWTF members blow handheld sirens and inform the vulnerable communities over megaphones to pack their valuables and evacuate to safe areas. The EWTF members blow hand sirens in two different ways: short duration (about 10 seconds and repeat) to inform the rising level of the Kosi River and longer duration (30 seconds and repeat) to inform that river has overtopped its banks and to evacuate to safety (GoN, 2018).

The DHM uses different risk communication modes for Nepal's EWS as shown in fig. (10). The DHM website (www.hydrology.gov.np) displays real-time river information of the Chatara monitoring station in traffic light-based colour codes to suggest warning and danger levels. Similarly, the DHM's toll-free number (1155) is operational during the monsoon season, and social media platforms (Twitter and Facebook) are used for information dissemination. In addition, the DHM prepares flood forecast bulletins with three days of lead-time and issues them to disaster response institutions such as NEOC, NDRRMA, security forces (Nepal Police and Armed Police Force), and central government ministries, and INGOs working in disaster risk management in Nepal. To disseminate warnings to the people at risk, DHM sends targeted mass SMS to the mobile phones operating within the Kosi flood planes in Nepal, which contains river information based on the Chatara monitoring station. The SMS warnings were initially sent in English, then to Romanised Nepali language, but from 2019 the SMS warnings were sent in the Nepali language (Shrestha et al. 2021).

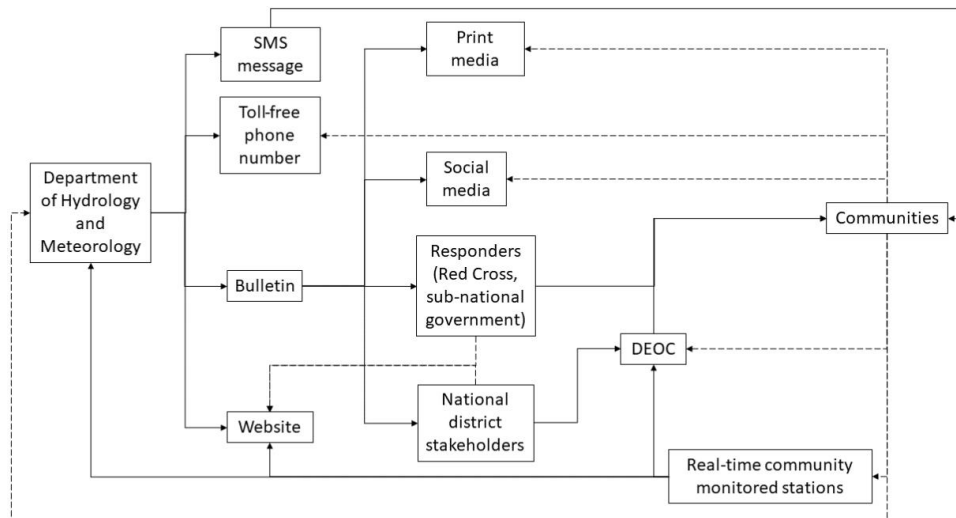


Figure 10: Flow diagram of current practice of EWS in Nepal, where solid line shows the information that are actively sent, and dotted line indicate information that can be pulled or accessible (Source: Budimir et al. 2020)

Regarding the shortcomings of the current EWSs, Shrestha et al. (2021) argued that most of the tributaries of the main rivers in Nepal lack monitoring stations, which leads to the uncertainties in flood forecasts; also, the electronic boards and telecommunication lines do not function during a heavy downpour in monsoon, causing communication disruptions. Similarly, Brown et al. (2019) argued that women and marginalised people in the Kosi basin are disproportionately affected by disasters but are also not reached by the EWS due to the lack of access to resources, low literacy levels, and language barriers to understanding the warnings. Furthermore, Budimir et al. (2020) argued that despite the recent advances in hydrometeorological forecast capabilities in the EWSs in Nepal, there are challenges due to unequal access to the warnings, lack of understanding of warnings, and difficulties in translating the warnings into actions.

2.12.2. Early Warning System in Bihar, India

In India, Central Water Commission is the lead agency for flood forecasting and dissemination of early warnings. For early warning in the Kosi River basin, The Kosi Project office in Nepal monitors the river level at the Kosi barrage and sends the river height and discharge data to the Divisional Flood Control Room (DFCR) of the Central Water Commission (CWC) in Bihar through a wireless telemetry system. The DFCR then prepares flood forecasts based on the river data and meteorological forecasts from India Meteorological Department (IMD) and forwards them to the Central Flood Control Room (CFCR) of CWC in New Delhi. The CFCR monitors flood forecasts collected from multiple DFCRs and prepares flood bulletins with 72

hours of flood forecasts and warnings and circulates the bulletins to government institutions such as the National Disaster Management Authority (NDMA), Ministry of Home Affairs, Railway Board, and Ministry of Water Resource for disaster response planning. In addition, CWC forwards the flood forecasts to the State and District Administration Offices through email or telephone. CWC also disseminates warnings by uploading the bulletins on the Ministry of Water Resources website (india-water.gov.in/ffs), CWC website (cwc.gov.in), sharing on social media platforms (Facebook and Twitter using @CWCofficial_goi), national television (Doordarshan TV), radio (All India Radio), and national daily newspapers during monsoon seasons as shown in fig. (11) (SOPFF 2019).

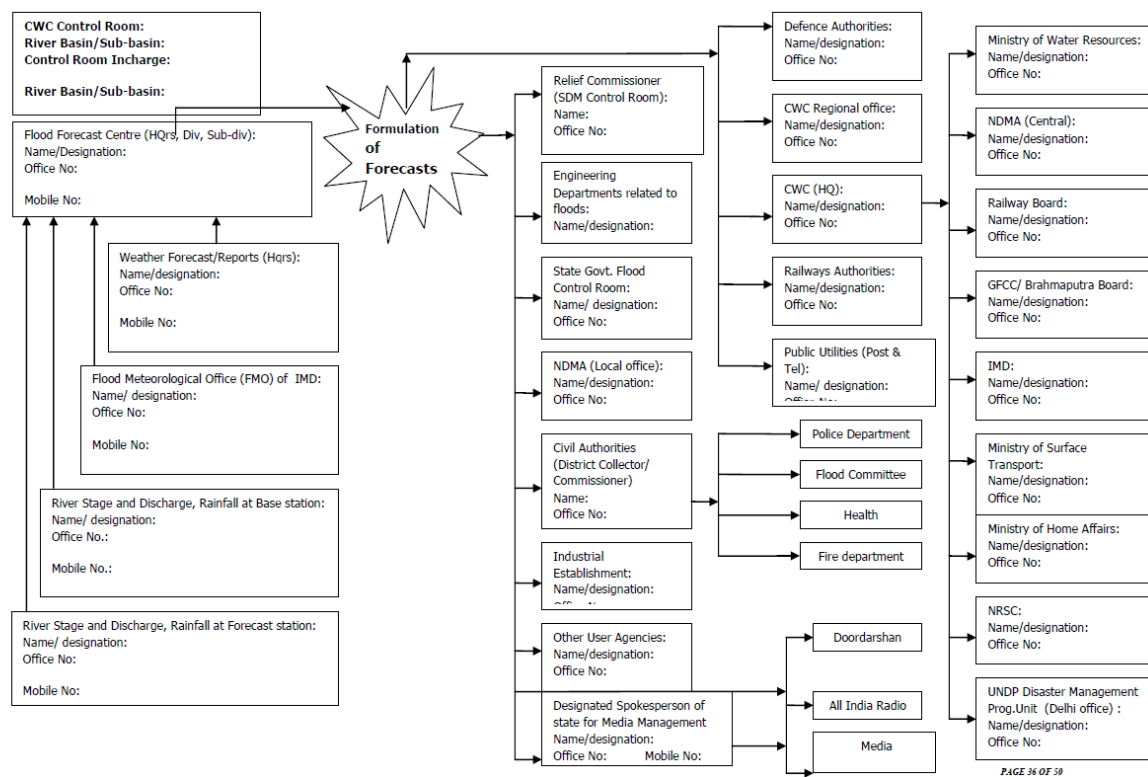


Figure 11: The chart explaining the flow of flood early warning in India. (Source: Standard Operating Procedure for Flood Forecast (SOPFF), GoI 2019)

At the District level in Bihar, warnings flow from three major channels. First channel of warning flows from CWC to NDMA, then NDMA passes the warning to Bihar State Disaster Management Authority, then from the State department to and District Disaster Management Authority. The Second channel of information is from CWC to District Magistrates (DMs), DM passes the warnings to the Block Development Officer (BDO) and District Superintendent of Police (DSP). The BDOs then share the flood information with village Mukhiyas (chief). The DSP's office passes the warnings to the constable of Block Police

Station (Thanadar) by mobile phones, who visit the flood-prone areas to order a mandatory evacuation in case of extreme flood forecasts. Another chain of information flows from Bihar Water Resources Department to a Junior Engineer at the river monitoring stations, who informs the embankment guards (Chowkidar) about warnings and orders Chowkidar to disseminate the warnings to people at risk. Therefore, at the community level, only three people (Mukhiya, Thanadar, and Chowkidar) receive official warning (Acharya and Prakash 2019).

2.12.3. Community based transboundary EWS

The absence of a transboundary EWS between India and Nepal creates a gap that has been addressed by INGOs, including LWR (Lutheran World Relief), Practical Action, Oxfam, and ICIMOD. These organisations have established informal transboundary networks across Nepal and India to involve flood-affected individuals from upstream and downstream areas. To disseminate warnings quickly, they utilise the social media platform WhatsApp. The networks comprise community disaster management committees (CDMCs), journalists, schoolteachers, local elites, businesspeople, NGOs, and humanitarian actors who have direct contact with the at-risk population. INGOs provide training to CDMCs in information dissemination, search and rescue, and evacuation prioritisation. CDMC members employ loudspeakers, megaphones, and sirens to alert those at risk and offer door-to-door assistance for evacuation. Moreover, INGOs facilitate meetings among CDMC members from upstream and downstream areas, fostering interaction, experience sharing, and promoting social cohesion (Gupta et al. 2021).

LWR established an informal transboundary EWS in the Kosi River basin as part of the India - Nepal Transboundary Flood Resilience project'. This initiative involved the installation of flood gauge pillars with yellow and red level markings along the banks of the Kosi River in Nepal's Saptari and Udaipur districts upstream, as well as in Bihar's Supaul district downstream. Around 35 community-level disaster management committees (CDMCs) were also formed. Each CDMC established an Early Warning Task Force (EWTF) responsible for disseminating alerts and providing door-to-door assistance for evacuating the most vulnerable individuals in the village, such as children, the elderly, lactating and pregnant women, and disabled individuals. The EWTFs from Nepal and India created a WhatsApp group to share upstream alerts from the Department of Hydrology and Meteorology (DHM) or updates on the river level recorded by the flood gauge pillars. Subsequently, red flags denoting danger and yellow

flags indicating warning were raised at village centres both upstream and downstream to notify the population about the potential risk of floods (LWR 2019).

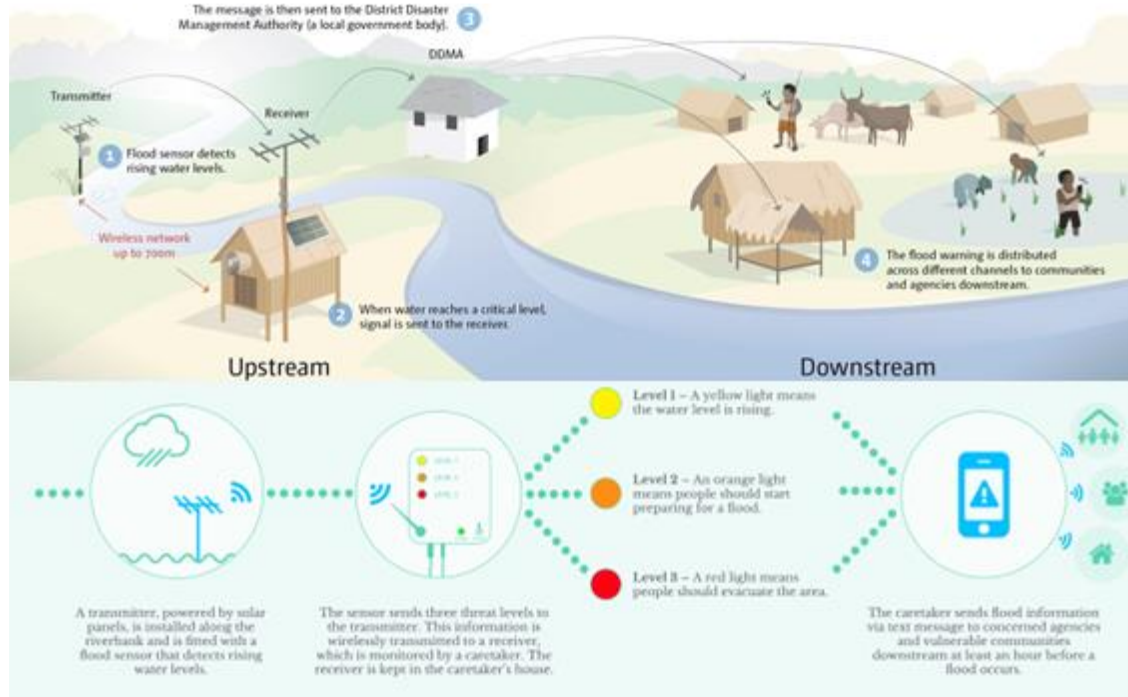


Figure 12: CBFEWS model of ICIMOD for upstream and downstream communication
(Source: UNFCCC 2014)

ICIMOD, an intergovernmental research institution, established transboundary communication between Nepal and India in the Kosi River basin through a pilot project named 'Community-Based Flood Early Warning System' (CBFEWS) in 2015. This initiative focused on the Ratu River, a small tributary of the Kosi River. The project covered four villages in the Mahottari District in Nepal and six villages in the Sitamarhi District in Bihar. In each village, community focal persons were selected to receive and disseminate flood warnings. The project incorporated a cost-effective river monitoring station located on the bank of the Ratu River. This station utilises signals such as blinking lights and beeps to indicate three river levels: yellow for alert, orange for caution, and red for danger, as shown in fig (12) (Shrestha et al. 2021).

Upon receiving warnings, the caretaker of the receiver unit promptly contacts the designated community focal person via mobile phone. The community focal person then notifies the District Administration Office (DAO) in Nepal to facilitate disaster response planning. Additionally, they share the warnings with other community focal persons in Nepal and Bihar through WhatsApp for wider dissemination. The project also arranged cross-border meetings for focal persons to exchange experiences and conduct awareness-raising activities regarding

EWSs. The effectiveness of the CBF EWS was evident during the Ratu River flood on 12 August 2017, as it provided people in Bihar with a significant lead time of up to 7 hours for safe evacuation (Shrestha et al. 2021).

2.13. Gaps in literature and areas for contribution

This literature review has identified a resource limitation pertaining to transboundary EWSs. The available literature primarily revolves around water governance or geopolitical aspects related to the utilisation of shared water resources. Donovan et al. (2019) asserted in their recent study that most EWS studies and recommendations are based on Western countries, thereby lacking a comprehensive understanding of EWS operations in developing countries and the influence of socio-economic factors, such as poverty, low literacy rates, and limited access to resources, on EWS. Furthermore, there is insufficient knowledge and documentation on vulnerability and capacity in the specific area of focus. Similarly, limited information is available regarding how socio-cultural factors, such as power structures, impact access to warnings, interpretation of warnings, and response actions (Donovan et al. 2019). In their recent review of EWS, Kuller et al. (2021) similarly argue that only a few studies have explored the factors affecting EWS in developed countries, with no available studies on how these factors interact within a transboundary context. Consequently, this study aims to partially fill this gap by identifying cultural, institutional, and governance factors that impede transboundary EWS, particularly in developing countries. Additionally, this study seeks to contribute to the existing literature by examining how cultural factors, such as gender roles and marginalisation, intersect with the processes of risk communication and risk information generation within transboundary EWS.

2.14. Chapter summary

This chapter critically examined the existing literature on fundamental concepts, models, and theories pertinent to the study of transboundary Early Warning Systems (EWSs), which form the basis of this research. Moreover, it offered an interpretation and contextualisation of these key concepts with respect to risk, vulnerability, and knowledge coproduction in EWS. In addition, this chapter explored a comprehensive overview of transboundary disasters, transboundary river governance, basin structures, and the transboundary EWS in the region

between Nepal and the Bihar state of India and challenges that arise in implementing transboundary EWS.

Multiple bilateral committees have been formed at different levels (ministerial, secretariat, and technical department) between Nepal and India for collaborative action on managing the Kosi flood. However, those bilateral meetings are centrally led by governments and lack local-level representation and participation of affected people. Furthermore, bilateral committee dialogues focus on water and energy sharing and infrastructure development projects rather than flood risk management. In addition, the securitisation of transboundary river data in India and myths related to the causes of Kosi floods were significant constraints for basin-wide research and collaboration for transboundary flood risk management and EWSs between Nepal and India. Especially myths related to the causes of floods are disrupting the social harmony at the community level between Nepal and India.

Nepal and India have no transboundary EWSs, but both countries have EWSs within their territories in the Kosi River basin. EWS in Nepal focuses on technological interventions in flood forecasting and warning dissemination; however, the warnings sent on mobile phones are not reaching the most vulnerable and deprived ones in the Kosi basin due to their language capabilities, literacy, and access to resources, which also relate to the socio-cultural norms in the region. While in India, the warnings follow centralised governmental mechanisms and an extended hierarchy of institutions but fail to reach the last mile to the people at risk due to the awkward institutional setup for warning dissemination. Most people in Bihar, India, must rely on news broadcasts on radio and television for warnings, which confuse the public because the risk is expressed in Kosi River discharge or traffic light-based colour codes. Some NGOs in Nepal are implementing small-scale, and community based transboundary EWSs to fill the absence of EWS at the national level. The community based EWSs involve passing the warnings from upstream communities to downstream using a WhatsApp group, after which the warning is further disseminated to the affected communities.

By identifying the existing gaps in the literature, this chapter highlights the key areas and opportunities for this thesis to contribute significantly towards bridging these gaps. Moving forward, Chapter 3 will explore the literature concerning the contextual factors relevant to this thesis.

Chapter 3 The Kosi River and Floods: The Context

3.1. Introduction

This chapter provides an overview of the physical, social, and geopolitical context of floods and flood risk management in the Kosi River basin. It first examines the basin's physical features, including the Kosi River's hydrological characteristics that result in downstream floods. Next, the chapter justifies floods as the focus of the research among the multiple hazards in the basin. It then explores the historical context of floods and flood risk management, transboundary agreements, and proposed future projects for flood risk management. The sociocultural setting of the basin is also discussed, including demographics and disaster vulnerability related to caste, ethnicity, and gender. Finally, the chapter investigates policies, institutions, and current practices of EWSs in Nepal and India, including community-based transboundary systems. This chapter provides a contextual background to understand the cultural, governance, and institutional factors affecting transboundary EWSs in relation to the research question of this thesis.

3.2. The Kosi River: physical context

This section deals with the physical context of the Kosi River basin in terms of climate, precipitation, and occurrence of multi-hazards related to the Kosi River floods in the downstream region of the basin in Nepal and India. Also, this section explores the downstream hydrological characteristics of the Kosi River and their relation to the upstream factors and the status of the transboundary early warning system in the Kosi River basin.

In the Kosi River basin, Upstream factors, including various hazards and their interactions, climatic influences, and human-induced factors such as land use changes and infrastructure development, directly impact downstream river conditions in the Kosi River, leading to changes in hydrological characteristics, erosion, and sedimentation (Nepal et al. 2014; Sinha et al. 2018; Sinha 2008). These factors contribute to channel instability and downstream flooding. The interconnection between upstream and downstream areas in the Kosi basin emphasises the importance of integrated approaches and cooperation in transboundary EWSs (Flugel et al. 2018; Nepal et al. 2014). However, there is limited understanding of these linkages, and currently, no formal mechanism exists for implementing transboundary EWSs between Nepal and India in the Kosi River basin.

Efforts to establish formal government-level cooperation in transboundary EWSs have been ongoing for decades in response to the recurring floods in the Kosi River basin. These efforts involve policy-level interventions and physical measures, such as embankment building, through bilateral committees between India and Nepal. However, there is still no mechanism for transboundary data sharing between the two countries.

Nevertheless, community-level cooperation between border villages, supported by multilateral research organisations like ICIMOD and other international non-governmental organisations, has demonstrated the potential of informal transboundary EWSs through pilot projects (Molden et al. 2017; Shrestha et al. 2021). These initiatives utilise cost-effective river monitoring stations, mobile phone alerts, and social media platforms like WhatsApp to disseminate warnings among upstream and downstream communities. Additionally, these international non-governmental organisations facilitate regular meetings, capacity building activities, and experience sharing among stakeholders and communities from Nepal and India to enhance coordination and knowledge exchange (Gupta et al. 2021).

3.2.1. The Kosi River basin

The Kosi River basin is a transboundary basin which includes parts of three countries: China's Tibet autonomous region (TAR), Nepal, and India fig. (13) (Shrestha et al. 2017). Approximately 27 per cent of the Kosi River basin lies in the TAR of China, 44 per cent in Nepal, and 29 per cent in India (Mishra and Sinha 2020). The basin consists of five counties in the TAR of China, 27 districts in Nepal, and 16 districts in the Bihar state of India, covering an approximate area of 52,731 km² and including Mount Everest and Mount Kanchenjunga in its catchment (Chen et al. 2013). The total population of the Kosi River basin is approximately 61 million, including 145,000 in the TAR of China, 11.5 million in Nepal and about 49.6 million in India (Dixit et al. 2022). The population density in the TAR of China is approximately five persons per km², 100–200 persons per km² in Nepal, and approximately 1000 per km² in India's Bihar State (Chen et al. 2013).

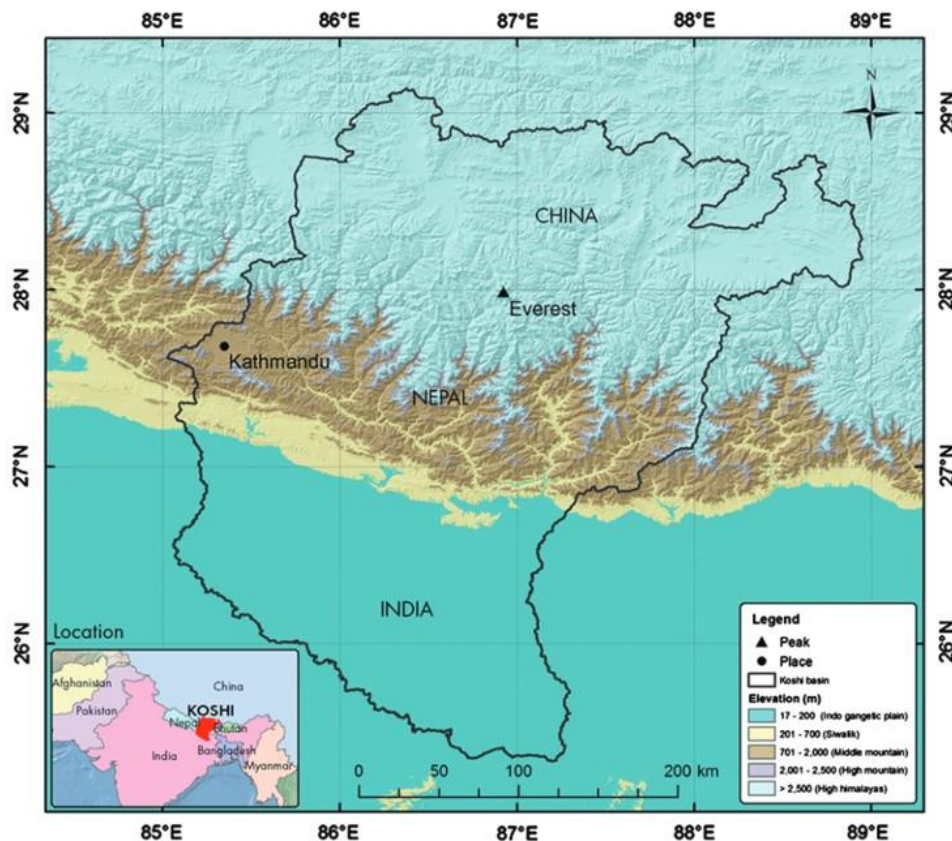


Figure 13: Kosi River basin. (Source: Shrestha et al. (2017))

The Kosi basin includes six physiographic regions from north to south: Tibetan plateau, high Himalayas, mid-mountains, low-mountains, lower hills called Siwalik Range, and flat alluvial plains in Nepal and Bihar (Shrestha et al. 2017). The Tibetan plateau and high Himalayan region have altitudes of up to 8849m Above Mean Sea Level (AMSL) and comprise 36 glaciers and 296 glacial lakes; Mid- Mountain to Siwalik hills range from 6,000m to 2,000m AMSL and include steep slopes and regions of very high precipitation; The flat alluvial plains of Terai region in Nepal and Bihar have low gradient and altitude ranges from 200m to 17m AMSL extending to the Ganges River in India (Sinha et al. 2019). The Kosi River flows in a steep gradient with high velocity as the river flows from TAR of China through high-Himalayas, mid-mountains, and the Siwalik range in Nepal, collecting sediments and debris from the upstream channels (Dixit et al. 2021). The river elevation drops from approximately 8849m to 200m AMSL over 290km as the river flows from the TAR of China and Nepal. As the river enters the flat alluvial plains of Nepal called the Terai region, it loses its velocity, causing it to spread over a wide area, dumping sediment from upstream and meandering (Sinha et al. 2008), suggesting that shifting of the river course and flooding has been the nature of the Kosi River

due to the topographical variations in the upstream and downstream as well as sediment load.

3.2.2. Climate of the Kosi basin

The climate of the Kosi River basin varies from cold and arid in the Tibetan plateau, to subtropical and temperate in the mid-mountains of Nepal, and tropical humid in the plains containing Nepal and Bihar of India (Khadka et al. 2015). The Tibetan plateau and the high Himalayas are regarded as the rain shadow arid zone with the least precipitation, while the rest of the basin has four climatic seasons: pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and Winter (December-February) (Prasad et al. 2021). The mean seasonal precipitation in the Kosi basin based on ten years of observed data (1998 to 2008) suggested average precipitation of 4.9 cm in winter, 24.1 cm in pre-monsoon, 134.5 cm in monsoon, and 8.4 cm in post-monsoon seasons (Bharati et al. 2019); while monsoon season contributes to approximately 80 per cent of the total rainfall in the Kosi River basin (Shrestha 2015).

Nepal's (2016) analysis of the forty years of temperature data (1969 to 2009) in the Kosi River basin suggests an increase in maximum temperature at a rate of 0.058°C per year and minimum temperature at the rate of 0.014°C per year. The climate forecasts in the Kosi River basin by Prasad (2021) suggested a significant rise in temperature from 0.5 to 2°C by 2030, 1.7 to 4.1°C by 2060, and 3-6.3°C by 2090, which could accelerate the glacial melt, resulting in multi-hazards and adverse impacts on mountain ecology, river systems, environment, and society.

3.2.3. Hydrological characteristics

The Kosi River is also called SaptaKosi (translated as seven rivers) in Nepal because it is formed by the convergence of seven rivers: Indrawati, Sunkosi, Tamakosi, Likhu, Dudhkosi, Arun and Tamor (Dixit 2009). The Sunkosi River flows from west to east and drains five rivers flowing from north to south (Indrawati, Bhotekosi, Tamakosi, Likhu, and Dudhkosi); the Arun River originates from TAR from China and flows north to south; the Tamor River originates from the Kanchenjunga Mountain range in eastern Nepal and flows from east to the south; The Sunkosi, Arun, and Tamor Rivers meet at Triveni to form the Kosi River (Dixit et al. 2021). From Triveni, the Kosi River flows southward through a 10-kilometre-long gorge at Chatara and

enters the flat plains of Nepal (Chen et al. 2013). The Kosi River then flows approximately 50km in Nepal, spreading over 10 km in width and enters the state of Bihar in India (Mishra 2008). The Kosi River flows along 210 km in Bihar and meets the River Kamala-Balan, and River Bagmati originating from the mid-hills of Nepal and merges with the Ganges River at Kursela in the Katihar district of Bihar (fig. 14) (Dixit et al. 2021).

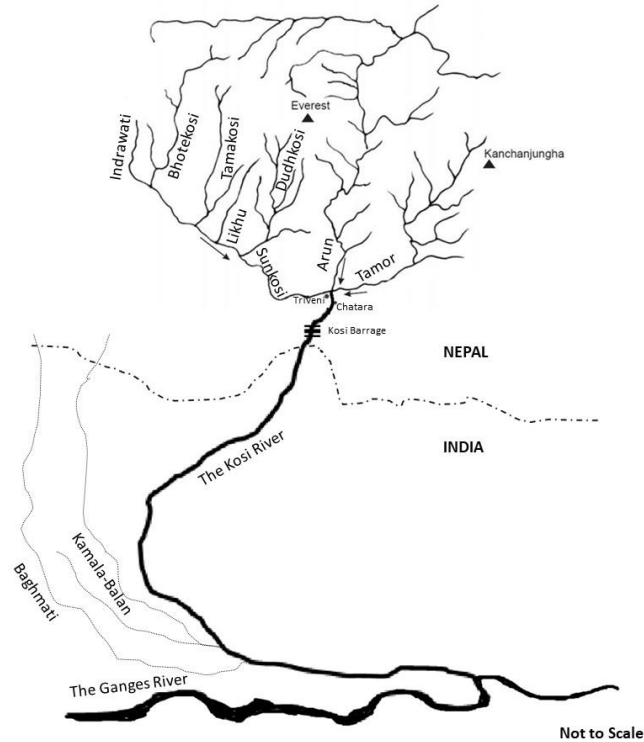


Figure 14: The schematic diagram showing hydrology of the Kosi River. (Source: modified and merged from Mishra 2008, and Dixit et al. 2022).

The discharge in the Kosi River increases up to five times during the monsoon season, as the monthly average discharge of Kosi increases from 500 to 6,000 m³s⁻¹ (Baghel 2014; Sinha et al. 2008). During the monsoon season, the torrential rain and glacial melt increase discharge up to nine meters in a day in the Kosi River (Prasad 2021). The maximum discharge recorded at Chatara monitoring Station was 25,879 m³s⁻¹ in 1968 (Devkota et al. 2012). Also, during the monsoon period, the river discharge frequently overtops its banks due to sedimentation and aggradation (the sediment deposition causing the riverbed to rise), reducing the carrying capacity of the Kosi River (Jain et al. 2014).

The Kosi River is one of the most sediment-laden rivers in the world (Sinha 2009). The Kosi River carries a sediment load of 190 million tonnes annually, generated from erosion, moraines, landslides, and other anthropogenic reasons such as the construction of hill roads

in the upstream region (Latrubesse et al. 2005). A study by Jain et al. (2018) suggested that 80 per cent of the sediment load in the Kosi River is generated in the Siwalik mountains in Nepal, which includes a tectonically active region with weak geology, high relief terrain, and high-intensity rainfall zones. The low slope of the Terai region, combined with the aggradation of the riverbed due to sediment deposit, impedes the flow and the river takes a new course, moving like a pendulum every year (Dixit 2009, Chakraborty et al. 2010). Over the last 200 years, the river had shifted 112 km westward, flowing through at least 12 different channels approximately every 24 years (Dixit et al. 2021), shown in (fig. 10).

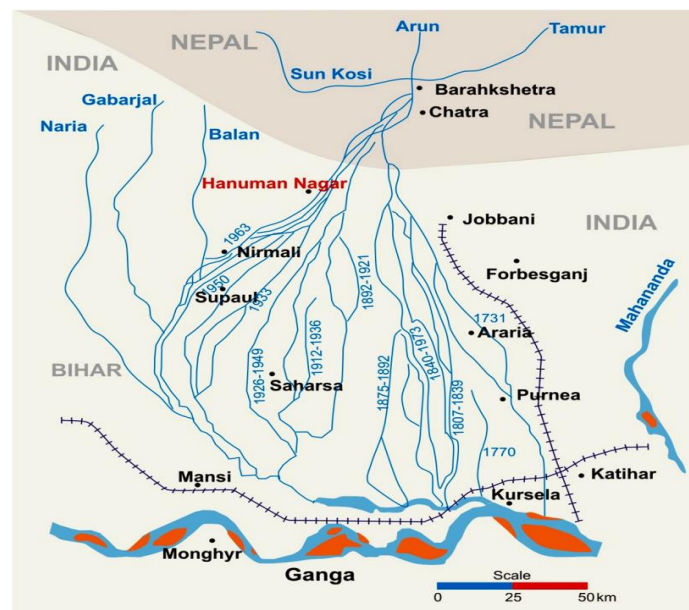


Figure 15: Shifting of the Kosi River and taking new river alignments from 1770 to 1963. Source: Gole and Chitale (1969).

The unpredictable lateral shift of the Kosi River Bihar posed a threat to future infrastructural developments, due to which the Kosi River was embanked on both sides at the southmost alignment in 1963 based on the Kosi Agreement of 1954 between Nepal and India (Dixit 2009). However, the embankments aggravated the flooding problem in the Kosi River basin as they acted as sediment traps leading to the more intense riverbed aggradation within embankments.

This high sediment load is a significant factor in causing flooding in the Kosi River, particularly when combined with the hard engineering approaches deployed over many years to manage flood risk (Sinha et al. 2019). Agarwal and Narain's (1996) study from 1963 to 1974 indicated that the riverbed of the Kosi increased by 12 cm per year after the construction of embankments. Similarly, Dixit et al. (2021) have suggested that in some sections, the Kosi

River flows three meters above the adjacent ground level due to aggradation, causing a risk of floods due to embankment overtopping. Sinha et al. (2014) stated that sediment load and riverbed aggradation causes avulsion (i.e., sudden changes in the river course due to the instability in the river channel) and embankment breaches. An extensive literature (e.g., Chakraborty et al. 2010; Sinha et al. 2014; Meena et al. 2014; Jain et al. 2018) has similarly argued that internal factors (sedimentation and changes in a riverbed) result in avulsion and embankment breaches rather than hydrometeorological causes alone. Therefore, all these arguments build on to suggest that floods in the Kosi River are caused by the hydrometeorological characteristics and internal dynamics (sedimentation and changes in the riverbed).

3.3. Multi-hazard context

This section deals with multiple hazards in the Kosi River basin which can interact and contribute to the Kosi River floods. The Kosi River basin is a tectonically active region with fragile geological formations, steep topography, and a monsoon-dominated rainfall pattern, resulting in multiple hazards occurring at different elevation zones (Bharati et al. 2014; Chen et al. 2013). Those hazards can interact and trigger other hazards to cause cascading multi-hazards downstream (Gill and Malamud 2016). Fang et al. (2020) had classified different hazards in the Kosi River basin into four triggering orders—Glacial Lake Outburst Floods (GLOF) and avalanches in the Himalayan region as first-order hazards; debris flow and landslides in the mid-mountains as second-order hazards; landslide dam outburst floods (LDOF), flash floods, erosion, and flash floods in lower mountain or Siwalik region as third-order hazards; and floods, inundation, and water-borne diseases in the Terai plains of Nepal and Bihar as fourth-order of cascading hazards. The floods in the Kosi River originate from interaction of multiple hazards; as in the Jure landslide of 2014 in the Kosi basin, where localised monsoon rainfall caused the landslide, which resulted in LDOF and caused flash floods downstream (Fang et al. 2020). Furthermore, multiple hazards in the Kosi River basin can occur concurrently and interact or trigger one or more hazards to form a compounding effect on the Kosi floods downstream (Wahid et al. 2017). The following sections will briefly deal with hazards in the Kosi River basin.

3.3.1. Earthquake

The Kosi River basin lies on the collision and subduction zone between the two major tectonic plates (Indian plate and Eurasian plate), where the Indian plate is subducting under the Eurasian plate at the rate of 2 cm per year, resulting in the uplift of the Himalayan region and frequent seismic activity in the region as shown in fig. (16) (Bilham et al. 1995; Okamura et al. 2015). The region is classified as a zone of magnitude eight earthquakes, suggesting the likelihood of high-intensity earthquakes in the region (Bilham 2001). Two significant

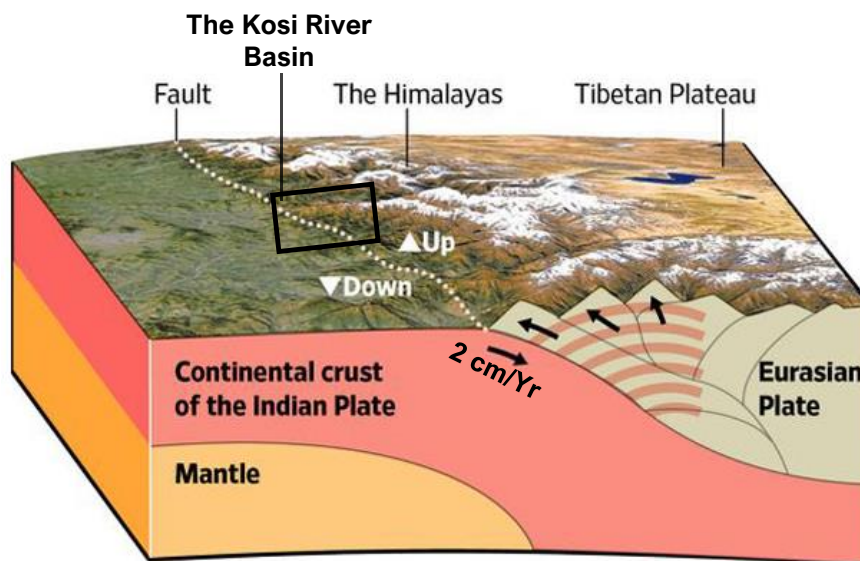


Figure 16: Schematic diagram showing subduction zone between Nepal and India and the location of Kosi River basin over the subduction zone, where Indian plate is subducting at the rate of 2 cm per year under the Eurasian plate (Source: Bilham et al. 1995).

earthquakes greater than eight were recorded in the Kosi River basin: the Shisha Pangma earthquake of approximately 8.1 magnitudes on 26 August 1833 and the Bihar-Nepal earthquake of 8.4 magnitudes on 5 January 1934 (Bilham 1995). The Shisha Pangma earthquake occurred with two intense foreshocks on the earlier day due to which people lived outside their houses when the main shock happened, resulting in approximately 500 fatalities and the destruction of houses and monuments in Kathmandu, Bihar, Tibet and up to Chittagong, Bangladesh (Avouc et al. 2015; Bilham 1995). The Bihar-Nepal earthquake of 1934 resulted in most damage from Purnea, Muzaffarpur, and Champaran districts of Bihar, Lhasa city of Tibet, and Kathmandu valley of Nepal, causing fatalities of approximately 12,000, among which approximately 7,000 fatalities were in Bihar (Sapkota et al. 2016). The earthquake of 1934 changed the river course of the Kosi River eastward, washing away the Supaul-Bhaptiahi railway lines and bridge connecting Darbhanga and Forbesganj districts

(Mishra 2008). Besides these, numerous high-intensity earthquakes up to magnitude seven were documented in the Himalayan region, which can result in hazards such as earthquake-induced landslides, landslide dam outburst floods, glacial lake outburst floods, flooding due to embankment breach, and other hazards resulting in floods in the Kosi River basin (Chen et al. 2013).

3.3.2. Glacial lake outburst floods (GLOF)

There have been at least 24 disaster incidents from the 1950s to 2020 in the Kosi basin to GLOFs in the higher Himalayan region of Nepal (Hu et al. 2022). The risk of GLOFs has increased due to increasing temperature in the Kosi River basin due to climate change (Shrestha et al. 2017). From 1976 to 2007 there was increased rate of glacial retreat from 38m to 74m annually in the Mt Everest region of Nepal (Bajracharya and Mool 2009). The glacial retreat creates moraine-dammed lakes on its path in high altitudes, which breaches suddenly as the lake's volume gradually increases to the point where the moraine walls cannot support it (Richardson and Reynolds 2000). The GLOFs and floods occurring in altitudes greater than 5000 m in the Kosi River basin could also trigger debris flow and secondary landslides, as in Nyalam, where traction caused by debris flow in narrow gullies caused 707 landslides during the Zhangzangbo glacial lake outburst flood in 1981 (Chen et al. 2013). The GLOFs in the Kosi River basin can interact with other hazards such as landslides and debris flow and cause flash floods or river floods in the Kosi River.

3.3.3. Landslides

Landslides are common in the mid-mountain region of the Kosi River basin in Nepal, especially during the monsoon and post-monsoon season, because of steep terrain, young geological formations, and high precipitation zones (Devkota et al. 2013). The increasing trend of landslides in the hilly region of the Kosi River basin also relates to anthropogenic causes such as improper debris management during road construction by cutting hillslopes and deforestation (Petley et al. 2007).

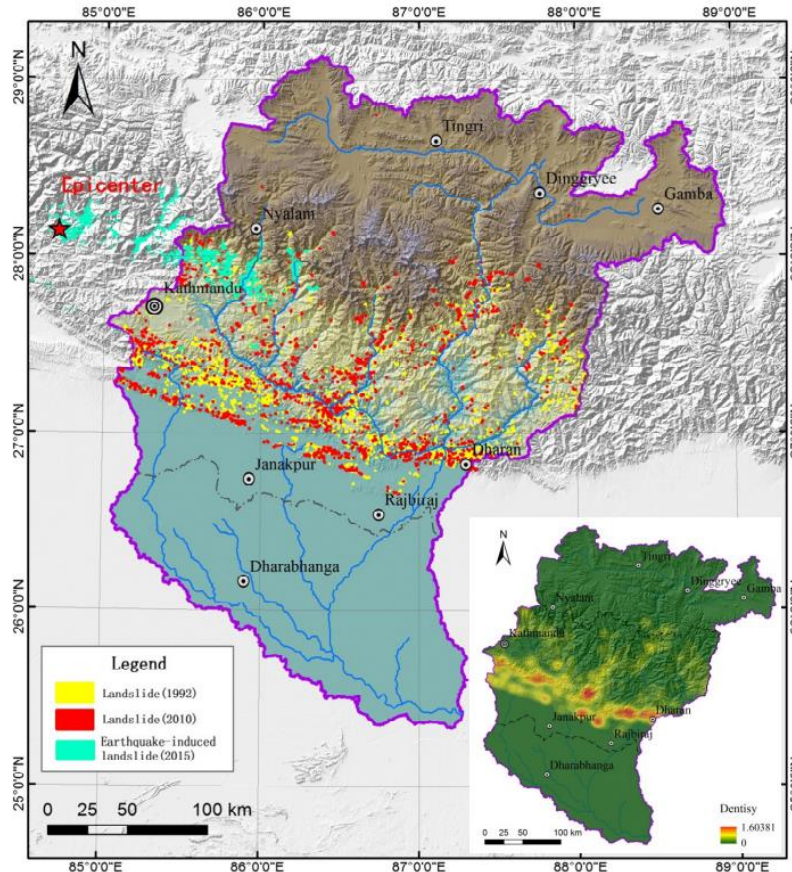


Figure 17: Image showing concentration of rainfall-induced landslides in the mid mountain and Siwalik range with gradient ranging from 20-30 degrees, while concentration of earthquake induced landslides at the mid mountain range with gradient between 40-50 degrees (Source: Zhang et al. 2016)

Zhang et al. (2016) mapped 6,872 landslides in the Kosi River basin, among which 97 per cent of the landslides were in mid-mountain region of Nepal and 3 per cent in the TAR of China, among which 1138 were earthquake-induced landslides as shown in fig. (17). The three main fault lines in the Kosi River basin: Main Central Thrust (MCT)—separating higher Himalayas from lesser Himalayas; Main Boundary Thrust (MBT)—separating lesser Himalayas and mountains; and Himalayan Frontal Fault (HFF)—separating Siwalik region from Indo-Gangetic plains; makes the region tectonically active, contributing to earthquake-induced landslides (Duvall et al. 2020). The study of landslides by Zhang et al. (2016) suggested that most of the rainfall-induced landslides in the Kosi River basin were identified in the slope gradient between 20-30 degrees, while earthquake-induced landslides were identified in a steeper slope gradient between 40-50 degrees in the mid-mountain region of the Kosi River basin. The landslides occurring in the upstream region of the Kosi River basin can cause damming of the tributaries of the Kosi River and can cause landslide dam outburst floods and flash floods in the Kosi River.

3.3.4. Landslide dam outburst floods (LDOF)

In the active tectonic regions of mid-mountain and Siwalik, many tributaries of the Kosi River flow in high gradient channels through narrow mountain gorges comprised of weak geological formations and high-intensity rainfall zones, making the region susceptible to frequent landslides, especially during the monsoon season (Shrestha and Nakagawa 2016). The landslides in narrow gorges of the mid-mountain and Siwalik region of the Kosi basin can block Kosi River's tributaries and create dams from the loose sediments and debris from landslides that can abruptly breach at a certain point, causing floods downstream (Shrestha et al. 2017).



Figure 18: left image showing landslide of Jure blocking the Sunkosi River, Right Image Showing dam formed by landslide. (Source: Panthi 2021)

The Jure landslide of 2014 is an example of landslide dam outburst floods (LDOF) in the Kosi basin as shown in fig. (13). A rainfall-induced landslide occurred at Jure village on 2nd August 2014 in the Kosi River basin, that entirely blocked the Sunkosi River (one of the major tributaries of the Kosi River), causing fatalities of 156 and displacing 436 people from living in the downstream near Kosi River (Acharya et al. 2016). The landslide caused flash floods downstream in the Kosi River and blocked the Sunkosi River, forming a 3 km long and 47 m deep lake, posing the risk of severe flooding in the Kosi River (Geest 2018). The landslide was just 43 km upstream of the Kosi barrage and posed a risk to embankments and Kosi barrage, due to which all 56 gates of the barrage were kept open, and nine districts of Bihar were put on high alert by the central government of India (Ray and Chattoraj 2014).

Small outlets were provided on the lake by Nepalese Army to prevent catastrophic failure of the landslide dam (Panthi 2021); however, thirty-seven days after its formation, the lake was breached on 7th September 2014, causing damage up to 6 kilometres downstream (Shrestha

and Nakagawa 2016). The lake outburst affected five village development committees (VDCs) in Nepal, damaged the national highway of Nepal linking to China, damaged the Sunkosi hydropower station, and other several infrastructures along its way (Acharya et al. 2016). More events such as Jure landslides are possible in the Kosi river basin, resulting in floods and flash floods in the Kosi river downstream to Bihar.

3.3.5. Waterlogging

Waterlogging is another recurring hazard in the Kosi River basin in the flat plains of Bihar and Nepal. The embankments in the Kosi River have functioned as sediment traps, due to which sediments transferred from the upstream rivers are dumped on the riverbed inside embankments, causing aggradation or rise of the riverbed, which in turn obstructs the lateral discharge from entering the Kosi River, and causes inundation outside embankments as shown in fig. (19) (Sadoff et al. 2013). Similarly, Mishra (2008) stated that small rivers (e.g., Khaando, Ratu, Gagan, Tilyuga, Mahuli, Bhutahi, Ratu Rivers) and many other small streams which become active during the monsoon season, but cannot drain into the Kosi River because of embankments, causing waterlogging and stagnation in settlements (Mishra 2008).

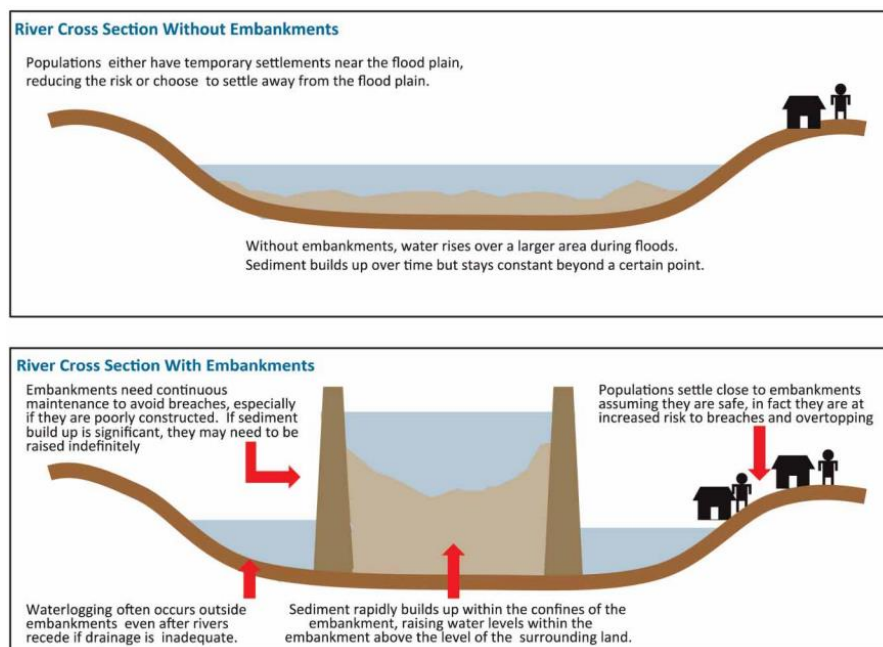


Figure 19: Schematic diagram showing aggradation of riverbed and flooding outside the embankment (Source: Sadoff et al. 2013)

Waterlogging in the Kosi River basin is termed a slow hazard as it affects the health and livelihood of the people slowly and in the long term (Jain et al. 2018). It is one of the reasons

for declining agricultural productivity in the basin due to the increase in soil's salinity, affecting the livelihood of the farmers (Dixit et al. 2021). There was significant increase in waterlogged areas (up to 45 percent) in the Kosi basin, after the implementation of the Kosi Project and subsequent developments such as embankments, railway networks, and roads, that run against the flow direction of the Kosi River (Kumar et al. 2014). Inundation and waterlogging causes contamination of groundwater sources and outbreaks of water-borne diseases (e.g., cholera, black fever, malaria, dysentery, dengue, typhoid, and others) which are the leading causes of women and child mortality in the Kosi River basin (Gupta et al. 2021; Kumar and Singh 2018; Siddiqui 2021). The subsequent section will investigate the implications of upstream factors within the Kosi River basin, which result in downstream floods in the flat plains of Nepal and India.

3.4. The Kosi River floods

Floods have been an annual phenomenon in the Kosi River; one of the reasons for frequent floods in the Kosi basin is the intense and localised rainfall patterns in the mid-mountain region during the monsoon season (Bharati et al. 2019), which contributes to the increase the river discharge up to 20 times and overtopping the river out of its banks (Sinha et al. 2008). The upstream basin factors directly affect the downstream river characteristics in the Kosi River. The tributaries of the Kosi River transfer the sediments and contribute to Kosi River discharge, as illustrated by Sinha et al. (2019) that the Sunkosi River contributes to approximately 56 per cent of discharge at Kosi and 40 per cent of sediment load annually; likewise, the Arun River contribute 38 per cent of discharge and 44 per cent of the sediment load, and the Tamor River contributes 16 per cent of both discharge and sediment load.

In addition to the meteorological causes of the floods, Prasad (2021) suggested that upstream factors (e.g., snow and glacial melt, temperature, soil saturation, land cover) and their variations due to climate change directly affect the downstream flow characteristics in the Kosi River and contribute to the uncertainties in the flood forecast models and complicates EWS. Similarly, Nepal et al. (2014) suggested that multi-hazards in the upstream also relate to the discharge characteristics of the Kosi River in the downstream plains of Nepal and India. The upstream hazards (e.g., GLOFs, landslides, LDOF, flash floods) can complicate flood forecasts and early warnings in the Kosi River basin (Fang et al. 2020).

3.4.1. Rationale for choosing floods as a focus of this research

This study focuses on floods as a significant hazard in the Kosi River basin, considering their occurrence due to hydrometeorological factors or the combined impact of multiple hazards (discussed in section 3.3). The research area, which encompasses the transboundary region between Nepal and India, is also characterised by a flat terrain, which is prone to frequent floods and inundation, making them more prevalent than other types of hazards, which justifies the selection of floods as the focus of this study among other types of hazards.

The large-scale floods impacting transboundary scale have been documented in the Kosi River, among which the most devastating floods have occurred due to embankment breaches (Dixit 2009). The Kosi River flood of 2008 is regarded as the most devastating flood in Nepal and India, which caused widespread and transboundary impacts in Nepal and the Bihar state of India (Jha and Tripathi 2013). Dixit (2009) and Shrestha et al. (2010) argued that the Kosi disaster of 2008 originated from complex causes, including physical, climatic, and institutional factors such as corruption, lack of preparedness, lack of transboundary communication mechanisms, and lack of maintenance of embankments. The following section presents the case study of the Kosi disaster of 2008.

3.4.2. The case study: transboundary Kosi disaster of 2008

On 18 August 2008, Kosi River's eastern flood control embankments were breached at Kusaha village in Nepal. The river took a new course shifting 120 km eastwards and spreading approximately 20 km over dense settlements (Dixit 2009) as shown in fig. (20). The flood-affected 50,000 people in the Sunsari district of Nepal and 3.5 million people in six districts in Bihar (i.e., Supaul, Madhepura, Saharsha, Arariya, Purnia and Khagaria), where the flood preparedness were almost absent (Jain et al. 2018). The flood washed away 4,648 ha of crops in Nepal (UN-OCHA 2009), and the river deposited sand up to seven feet on its course, turning the agricultural fields barren (Shrestha et al. 2010). The government of India, which is managing the Kosi project in Nepal took five months to reroute the Kosi River into embankments (Jha and Tripathi 2013).

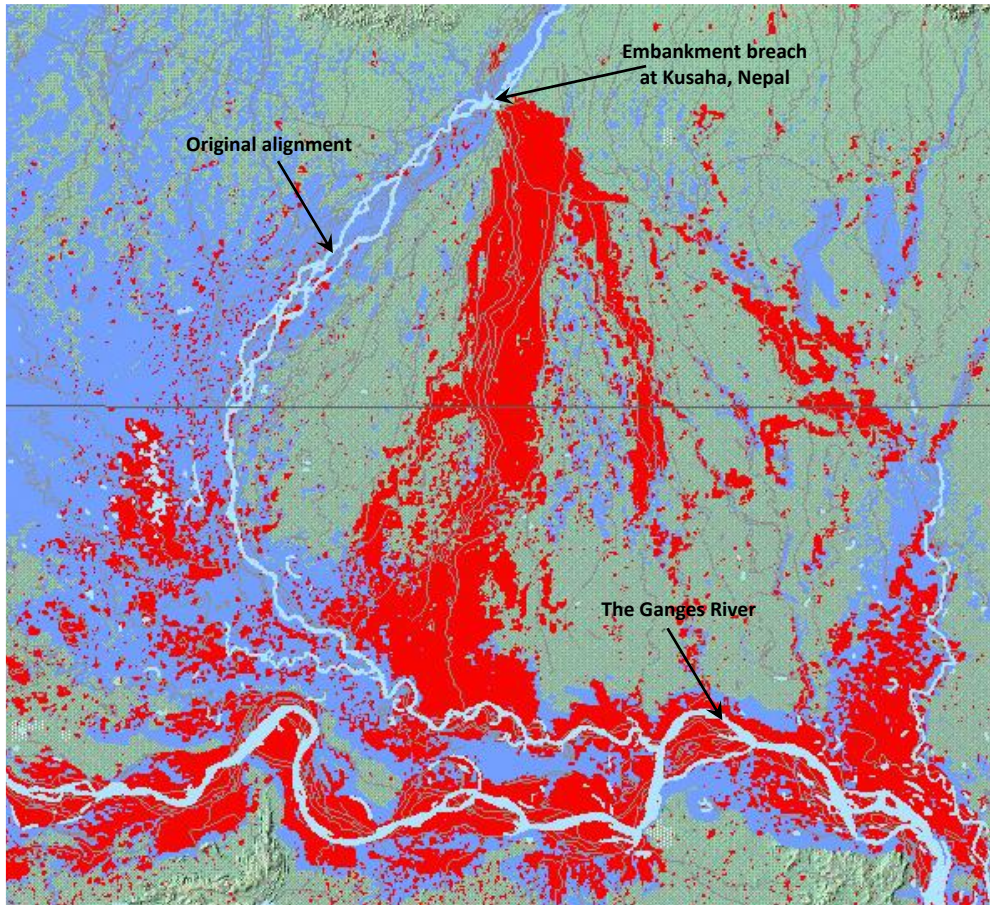


Figure 20: The false colour satellite image of Kosi River breach at Kusaha, Nepal in 2008, where river water is shown in red (Source: NASA 2022)

Extensive scholars (Dixit 2009; Mishra 2008; Shrestha et al. 2010) have argued that the Kosi flood of 2008 cannot be characterised as a meteorological hazard because Kosi embankments had withstood the highest discharge of $25,854 \text{ m}^3\text{s}^{-1}$ on 5 October 1968 without breaking, and the embankments were designed for the discharge capacity of $26,901 \text{ m}^3\text{s}^{-1}$; therefore, embankments must not have collapsed when the discharge was only of $4,729 \text{ m}^3\text{s}^{-1}$ (Reddy et al. 2008). Similarly, Dixit (2009) argued that the river was flowing at only 15 per cent of its channel capacity, and the meteorological records also suggested that precipitation was at the normal range during the event of a disaster; therefore, the Kosi floods have not resulted from the hydro-meteorological causes. Contrary to the argument of Reddy (2008) and Dixit (2009), Sinha et al. (2014) argued that embankment breaches are not only associated with the river discharge—instead, internal dynamics of the river (e.g., sediment load, riverbed aggradation, changes in the slope of the riverbed and riverbanks) causes avulsion (or sudden change of river course) and embankment breaches; even with small changes in the river discharge as in the Kosi flood of 2008.

Many scholars (Dixit 2008, 2009; Kale 2008; Reddy 2008) also argued that Kosi Disaster has resulted from corruption and institutional dysfunction, as the cost of repair and maintenance of embankment was annually reported to the Water Resource Department of Bihar, but the embankments were seldom repaired since their construction. Similarly, Mishra (2008) also argued that impractical management functions of the Kosi project, where the Water Resource Department of India has the role of managing the project in Nepal's territory, and lack of collaboration with Nepal in the project implementation provided a loophole for corruption in embankment construction and repair. Furthermore, Mishra (2008) stated that even when the people living in the village of Kusaha (the breach site) had informed the local authorities in Nepal about the erosion of embankment walls, no action were taken against it because — firstly, the monitoring and repair of the embankment were under the jurisdiction of the Indian government and they had no contact with Indian departments; secondly, the field report by India stated that the condition of embankments were good without even monitoring the embankments (Mishra 2008). Likewise, Shrestha et al. (2010) supported the argument that that governance deficit was the main reason for the Kosi disaster of 2008, referring to a printed media in India, which wrote:

“...such is the racket that the Bihar government spent 2.5 to 3 billion rupees annually on construction and repair works, 60 per cent of it is pocketed by nexus of politicians, contractors, and engineers...As a result, the contractor's bills are approved without verifying them...The same lot of construction materials are shown as freshly purchased year after year... repair and maintenance works which never started are shown as completed, and payments are approved...so much is the income of the engineers in Bihar from the corruption that engineers do not even bother to collect their government salaries...” (Shrestha et al. 2010, p.74).

Furthermore, the false sense of security over embankments also contributed to a lack of preparedness at the community and institutional levels (Dixit 2009), and institutions were shocked and unaware of the actions to follow the embankment breach and waited for the central government's orders (Dixit et al. 2021). Due to this, the government of Bihar could only assist the flood victims after a week of disaster (Mishra 2008). In addition, the transboundary coordination and communication between Nepal and India for disaster

response followed lengthy procedures and international protocols, which required the ministers of foreign affairs of both countries to communicate as shown in (fig. 21), contributing to the disaster loss of many folds due to too slow and uncoordinated disaster response.

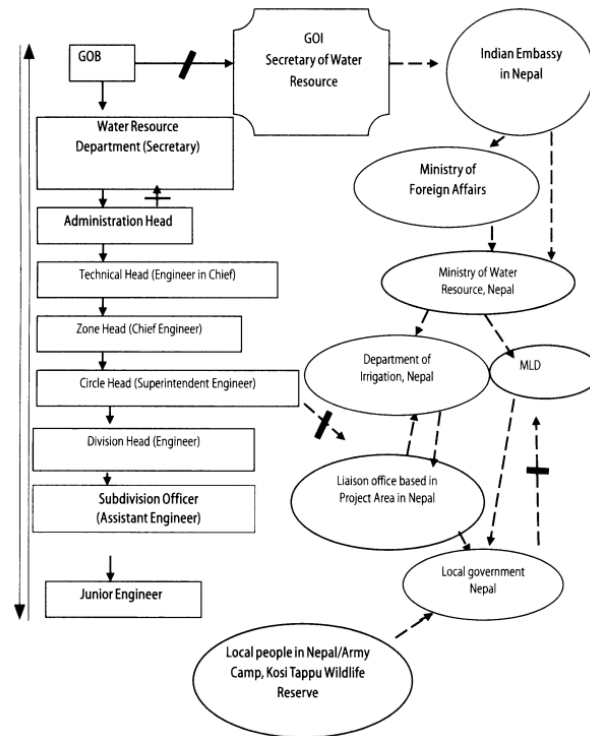


Figure 21: Schematic flow diagram of the transboundary communication during the Kosi flood of 2008. The dotted lines represent the flow of communication in Nepal, and full lines represent communication in India. (Source: Shrestha et al. 2010)

Therefore, the above arguments suggest that disaster in the Kosi River is also linked to institutional factors such as corruption, impractical management roles and functions, and lengthy transboundary communication during disasters.

3.5. Transboundary flood risk management in Kosi River basin and geopolitics

This section deals with the historical context of floods and flood risk management in the transboundary Kosi basin during the British colonial period and in the post-colonial period through the Kosi Agreement. Then it explores the suitability of the embankments for flood risk management in the Kosi basin based on the Kosi agreements and their effects on the lives and livelihood of the people in the basin. Finally, this section deals with the bilateral mechanisms for transboundary flood risk management, proposed projects in the future for

flood risk management in the Kosi basin, and constraints in the transboundary collaboration for an EWS between Nepal and India.

3.5.1. British colonial period of flood risk management

During the colonial period of British India (1858 to 1947), British writers described the Kosi River as an “impudent hussy” because of its unpredictable shifting nature, which interfered with revenue collection and railway infrastructure expansion in northern Bihar (Mishra 2008, p.10). The British engineers studied options for flood control in the Kosi River after the Kosi floods of 1869 and 1870 and recommended upstream interventions in Nepal to control the floods in Bihar (Dixit et al. 2021). In 1893, the Chief Engineer of Bengal province William Inglis surveyed upstream of the Kosi River source to study infrastructural interventions to control the river; and submitted a report suggesting that any intervention would prove futile due to the sediment load of the river (Mishra 2008). Then, in 1897, The Calcutta flood conference in India again recommended embankments to control floods in the Kosi River basin. However, the British government again rejected this recommendation, stating that the embankments have doubtful efficacy referring to the example of the Damodar River basin in West Bengal, where embankments had to be removed because of aggravating the flood problem (Lahiri-Dutt 2003, Dixit 2009). Again, in the Patna flood conference of 1937, engineers from Bihar suggested the construction of embankments in the Kosi River basin, but the chief engineer of Bihar, Capt. G.F. Hall stated:

“As of my knowledge of flood condition increased, I began to doubt the efficacy of the embankments and gradually came to the conclusion that not only was the flood prevention undesirable but that bundhs are primary causes of excessive flooding, and I think that north Bihar needs floods and not their prevention.” (Mishra 2008, p.23).

The above quote suggests that during the colonial period of India, British engineers were aware that embankments were not a suitable option for flood control due to the dynamic nature of the river and sediment load in the Kosi River.

In 1947, India became independent from British rule. On 31st July 1950, India and Nepal signed a peace treaty entitled: Treaty of Peace and Friendship Between the Government of India and Government of Nepal, which established a close relationship between Nepal and India, which

allowed an open border and free movement of goods and people between the two countries (Upadhyay 2012). At that time, Nepal had the Rana regime, which had supported the British government to minimise the freedom movement led by Mahatma Gandhi in India (Mishra 2008). After India's independence, King Tribhuvan and the political parties of Nepal sought support from the newly formed Indian government to overthrow the Rana regime from Nepal and establish a constitutional monarchy; for which the government of India played a crucial role, and the Rana regime was overthrown from Nepal in 1951 (Upadhyay 2012), which brought the government of India and Nepalese political parties to friendly relations and paved the way for bilateral agreements (Maharjan 2018).

After five years of India's independence, in 1953, north Bihar faced a devastating flood, which was highly politicised by Indian press media and the opposition party used this opportunity to criticise the government of India for denying the fundamental human right of safety to the people of Bihar (Dixit et al. 2021). Due to political pressure, the government of India prioritised the flood protection programs in Bihar and formed an expert committee to study and design flood control infrastructure in the Kosi River basin (Mishra 2008). Consequently, in 1953, the Kosi Plan was prepared by the government of India, and it was presented to the Indian parliament for endorsement. In 1954, the governments of Nepal and India signed an agreement for flood risk management, known as the Kosi Agreement (Dixit 2009).

Extensive literature (Baghel 2014; Dixit 2009; Dixit et al. 2021; Gade et al. 2020; Gupta et al. 2021; Mishra 2008; Shrestha et al. 2021) argue that Kosi Agreement was more of a hasty political remedy to resist the pressure than a thoroughly assessed option for flood control because it went against century-long debates on the suitability of embankments in the Kosi River basin during the colonial period of British India (Dixit 2009).

3.5.2. The Kosi Agreement

The governments of India and Nepal signed the Kosi Agreement on 25th April 1954 (amended on 19th December 1966), which was the first agreement on transboundary flood risk management in the Kosi River basin through Kosi Project. The Kosi project had three components: (1) constructing a 4.8 km long Kosi Barrage in Nepal, (2) channelising the Kosi River through embankments upstream and downstream, and (3), utilising the Kosi River for irrigation in India and Nepal. The agreement stated that India would bear the entire cost of

construction, operation, and management of the Kosi Project, while Nepal needed to provide land for the construction of the Kosi project. The agreement also made provisions that both the governments of Nepal and India would maintain law and order in the project area jointly, and a special court would be established to resolve the disputes in the project area. The agreement stated that the irrigation scheme from the Kosi project would irrigate 11,300 ha of land in Nepal and 356,310 ha of land in India. Furthermore, the Kosi agreement did not specify the timeframe for the project, suggesting that the project area would be under control by India for perpetuity. Soon after signing the agreement, the opposition parties and civil societies in Nepal criticised the government for compromising on national sovereignty for the benefit of India and protested from the streets to the parliament, which led to the amendment of the Kosi agreement in 1966.

The amended agreement stated that India would utilise the Kosi project area in Nepal for 199 years as a lease. The project area would remain within Nepal's sovereign and territorial authority, and only the laws of Nepal will be enforced there. Also, the facilities constructed through the Kosi project will be handed over to the government of Nepal after the completion of the Kosi project. Furthermore, the additional irrigation benefits to Nepal were appended in the agreement, stating that India would construct irrigation scheme to irrigate an additional 58,000 ha of land in Chatara and 13,800 ha of land in the Saptari District, Nepal.

3.5.3. The Kosi River embankments

As per the Kosi Agreement, the construction of the embankments started in January 1955, which were spaced 8 to 16 km across the Kosi River, and 45,000 families residing in 380 villages in Bihar and 34 villages in Nepal were within Kosi River embankments at that time, for whom the government assured resettlement to safe areas and compensation (Baghel 2014). By the end of 1973, out of 45,000 families, only 32,540 families received the first instalment of compensation; 10,580 families received the second instalments, but none received the third and final instalments for relocation (Mishra 2008). In addition, the distance between the resettlement land and farmland was at least 10 km away, which people found impractical to commute daily; and the allocated land became waterlogged after embankments were constructed, forcing people to return to their original villages and live within embankments (Mishra 2003). Baghel (2014) estimated that approximately a 1.2million people in the Kosi basin live within embankments.

In the year of the completion of Kosi Barrage in 1962, the first embankment breach happened in Dalwa, Nepal, causing widespread flooding and inundation (Mishra 2008). In response, the government of India repaired the breach site and strengthened the embankment by constructing a ring bund around it (Prasad 2021). The embankment breaches then happened at a regular interval: Jamalpur, Bihar in 1968; Bhataniya, Bihar in 1971; Bahuarawa, Bihar in 1980; Nauhatta, Bihar in 1984; Samaini, Bihar in 1987; Joginia, Nepal in 1991; Kusaha, Nepal in 2008 (Baghel 2014). The embankment breach in Kusaha resulted in the most devastating and costliest flood disaster in of Nepal and India (Dixit, 2009).

In the Kosi River basin, flooding became common after embankments were constructed; however, more embankments were added in response to floods, turning the flood plain of the Kosi basin into a complex drainage landscape (Gade et al. 2020). At the time of the completion of Kosi Barrage in 1962, embankments were 160 km long, and 2.5 million ha of land were designated as flood-prone areas in Bihar (Dixit 2009). The embankments were gradually added in Bihar in response to floods, increasing its total length from 160 km to 3,465 km between 1962 to 1994 (Mishra 2008). Baghel (2014) showed a direct correlation between the length of embankments and flood-prone areas in Bihar by stating that government-designated flood-prone areas increased from 2.5 to 4.3 million ha in 1971, 6.46 million ha in 1982, and 6.88 million ha in 1994; suggesting that embankments contributed to floods rather than solving them.

The Kosi Project was envisaged as a flood control scheme that would bring prosperity to the river basin through irrigation benefits to farmers; on the contrary, the project worsened the flood problem and degraded agricultural livelihood by transforming the Kosi floodplain into a barren and hostile landscape (Dixit et al. 2021). After the implementation of the Kosi project, silt deposition turned farmland barren, livestock farming declined due to multiple animal diseases caused by inundation, and freshwater fish and crab varieties became scarce, affecting the livelihood of smallholder farmers in the Kosi basin (Mishra 2008). The declining livelihood from agriculture caused farmers to migrate to nearby cities in search of livelihood as construction labours (Acharya and Prakash 2019).

3.5.4. Kosi High Dam Project (KHDP)

As the embankments were proving futile for flood protection, Kosi High Dam Project (KHDP) is proposed as the ultimate solution for flood protection in Bihar (Mishra 2008). The KHDP involves construction of a 269-meter-high dam at Chatara, Nepal, with a reservoir capacity of 8,500 million m³, producing 3,489 MW of electricity and irrigating 68,500 ha in Nepal and 1.5 million ha in India as shown in fig. (22) (Bhattarai 2009).

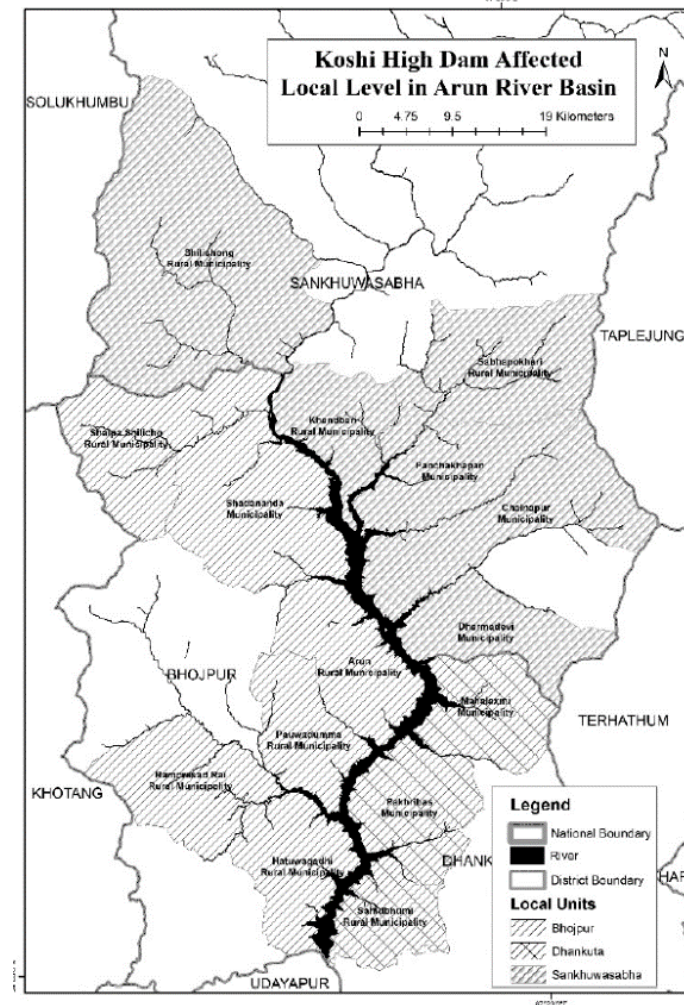


Figure 22: The proposed Kosi High Dam and affected districts in Nepal (source: Rai and Linkha 2020).

The extensive literature has argued against implementing the KHDP, suggesting that it would convert approximately 196 km² of the ecologically sensitive area in Nepal into a reservoir, displacing 65,000 indigenous people from the proposed site (Dixit et al. 2021). Likewise, Sinha et al. (2014) argued that as the Kosi River transfers a sediment load of 90 million m³ annually, the reservoir of the proposed dam would fill with sediment within approximately 30 years and could cause serious damage to the environment and ecology of the Kosi basin. Similarly, Mishra (2015) argued that the proposed site is characterised as a highly tectonically active

region, with the possibility of large-scale earthquakes, such as the 1934 Bihar-Nepal earthquake of magnitude 8.4; therefore, the dam in the proposed area could cause devastating impacts downstream (Mishra 2015).

The KHDP was first proposed at the conference of Kosi flood victims in Nirmali, Bihar, based on which the government of India formed Majumdar Committee in 1951 for the feasibility study of the KHDP (Mishra 2008). However, the committee rejected the proposed project in 1951 due to the estimated cost of 1 billion Indian rupees (INR) and seismic risk in the proposed site in Nepal (Dixit et al. 2021). Nevertheless, the KHDP was kept as a future intervention for flood protection in the Kosi Agreement of 1954 through the Clause 2, stating:

“This agreement for investigation and surveys shall also be applied to surveys and investigations of storage dams or detention dams on the Kosi, soil conservation measures, such as check dams, afforestation, etc., required for the complete solution of the Kosi problems in the future.” (Upadhyay 2012, p.186)

During the prime minister of India’s state visit to Nepal in 1991, the government of India proposed to form a joint committee of experts (JCE) to study and finalise the KHDP, concerning that the embankments and the barrage in the Kosi River have outlived their expected lifespan (Upadhyay 2012). The JCE was formed between the experts from Nepal and India and produced a feasibility report for KHDP in 1997, which estimated the project cost of 500 billion INR (Rai and Linkha 2020). The JCE prepared the project inception report for KHDP in 2004; since then, experts have been negotiating to finalise the detailed planning report for the implementation of KHDP, but due to differing interests and standpoints on benefits sharing and compensation from the project, the KHDP is still in the planning phase (Dixit et al. 2021).

3.6. Socio-cultural context

This section deals with the socio-cultural setting of the Kosi River basin in the downstream region of the flat plain between Nepal and India. Also, this section explores the Kosi river’s significance in terms of the culture and livelihood of the people living in the flood plain and their vulnerability factors, specifically related to caste, ethnicity, and gender.

3.6.1. Cultural interpretation of rivers

Nepal and India share an open national border as well as similar culture, language, and religion; the people-to-people relationship between Nepal and India is commonly referred to as '*Roti and Beti Sambandha*' (translated as bread and daughter relation) due to the relationship established between the two countries through the marriage and employment of people across the border (Timilsina 2019, p.445).

Every ritual in Hindu culture, from birth to death, is associated with rivers or performed at the banks of rivers, suggesting rivers' socio-cultural importance (Singh 2018). In Hindu belief, rivers are given the status of the mother and are referred to as "Kosi Maiya" (translates as Mother Kosi) as a nourisher of life (Mishra 2008). The name 'Kosi' derives from ancient folklore and songs which describe the river as the goddess Kaushiki who emerged from goddess Parvati (the goddess of strength) in the Himalayas to absolve human beings from their sins (Mishra 2008). Similarly, other folksongs describe the Kosi River as a young girl without any bondage or responsibilities who wanders around by carving a new path at her will and blesses the land with fertile soil (Dixit 2008). Some farmers sing prayers to the Kosi River during monsoon to remain calm and not harm their crops (Sebastian 2009). The folklores and stories above illustrate the Kosi river's dynamic nature and relationship with culture, society, and people's agricultural livelihoods in the river basin.

3.6.2. Socio-cultural context of vulnerability

The disaster vulnerability of the people in the Kosi basin depends on factors such as age, gender, access to resources, caste, and ethnicity (Pandey et al. 2010). Agriculture is the basin's primary source of livelihood, supporting approximately 32 million people in the Kosi basin (Fang et al. 2020; Najmuddin et al. 2018). Approximately 50 per cent of the population in the Kosi basin lack access to education, electricity, and sanitation services (Dixit et al. 2021). The cast and gender-based discrimination persist more prominently in the flat plains of the Kosi basin than in the rest of the country due to the lowest literacy rate (Khadka et al. 2015). Brown et al. (2019) argued that women and ethnic minorities are the most vulnerable in the Kosi River basin due to their low literacy, language skills, and barriers to accessing information and resources from society. In addition, Shrestha et al. (2021) suggest that women and the marginalised people are the most vulnerable in the Kosi River basin due to socio-cultural

norms which define their roles based on gender and caste, restricting social interaction and mobility during disasters.

In Nepal and India, the cast-based hierarchical structures directly correlate with the poverty and vulnerability of the people to disaster risk in Bihar and Nepal, as the Dalits (lowest caste) are the most vulnerable and the most deprived ones compared to Brahmins and Kshetriya castes which are regarded as upper castes (Fang et al. 2020). Approximately 48 per cent of Dalits in hills and 46 per cent in plains live below the poverty line, and approximately 50 per cent of Dalits do not own their land (Khadka et al. 2015). Article 341 of the constitution of India designates the most socio-economically disadvantaged Dalit casts in India as Scheduled Casts, which are also the most flood vulnerable groups in Bihar as they live on the bank of the Kosi River for their livelihood (Tasnimuddaulah 2019).

Especially in the Terai region of Nepal and Bihar, social norms determine the division of work between men and women, as men have roles in outdoor and income-generating activities such as farming, livestock rearing, and fishery. In contrast, women have roles in indoor activities such as cooking, caring for children and the elderly, washing, cleaning, food processing, and others (Khadka et al. 2015). Furthermore, unlawful social norms and practices such as child marriage; demand for dowry; regarding women as impure and untouchable during menstruation and after childbirth; son preference (Ghimire 2008; Gurung et al. 2014); along with other gender-based discriminations such as women's exclusion from patrilineal land and property inheritance, lack of decision-making roles, social stigma towards working women, and, lack of education, and others have contributed to the disproportionate impact of disasters towards women (Acharya and Aryal 2008).

During floods, people evacuate to embankments and live in a temporary shelter made of plastic sheets and bamboo in harsh conditions without sanitation or cooking facilities as shown in fig. (23) (Mishra 2008). In the Kosi basin, embankments also serve as evacuation sites during floods, as the flat plains of Nepal and Bihar lack evacuation shelters or higher grounds to refuge during floods (Baghel 2014). Due to this, the people living in flood plain favour embankments and think that floods would have caused more devastation without embankments and demand more embankments (Gade et al. 2020).



Figure 23: Image showing people in Bihar taking refuge on embankments, under a makeshift hut made of bamboos and tarpaulin sheets, where a woman is cooking food for her family (Source: Mishra 2008)

During evacuations on embankments, women suffer the most due to their gender roles (cooking, caring, fetching firewood and water) and face the risk of sexual abuse, trafficking, and gender-based violence (Shrestha et al. 2021). Poor sanitation conditions during evacuations, contamination of surface and groundwater sources due to flooding, and water stagnation causing malaria and dengue outbreak are the leading causes of fatalities among infants, children, and pregnant and lactating women during and after floods in the Kosi basin (Gupta et al. 2021).

3.7. Policy and Institutional context

The Constitution of Nepal 2015 declared Nepal as a federal republic of Nepal, replacing the constitutional monarchy, and restructured Nepal into three tiers of government federal, provincial, and local. The constitution of Nepal decentralised the functions and powers of 753 local government authorities (Metropolitan Cities, Sub-Metropolitan Cities, Municipalities, and Rural municipalities), including the roles of disaster risk management and EWSs. The roles are assigned so that the central or federal government only has the advisory roles, the provincial government has the coordinating roles, and the local governments have the implementing roles. Similarly, Nepal has a recent act on DRR, the Disaster Risk Reduction and Management (DRRM) Act of 2017, which replaced the Natural Calamity Relief Act of 1982. The envisions the shift in working modality from reactive approaches in managing disasters to proactive approaches in managing risks. The act also established the National Disaster Risk Reduction and Management Authority (NDRRMA) as a key institution for managing disasters

in the country under the Ministry of Home affairs (MoHA). The Department of Hydrology and Meteorology (DHM) is primarily responsible for hydrological and meteorological forecasts, flood forecasting and EWSs in Nepal, and the department was moved from the then Ministry of Science, Technology and Environment (MoSTE) to the Ministry of Energy, Water Resources, and Irrigation (MoEWRI) in 2017 as shown in fig. (24) (Nepal et al. 2018).

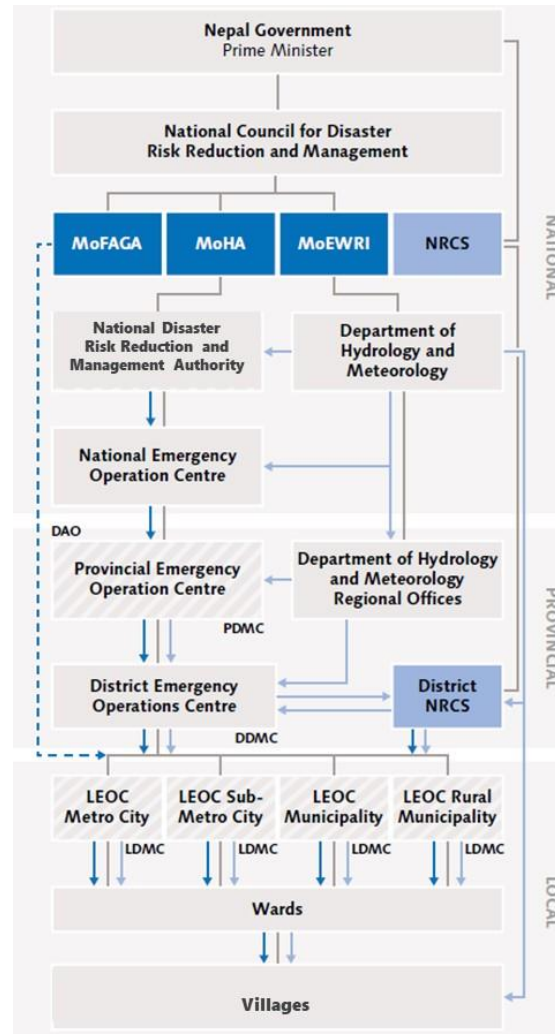


Figure 24: the institutional structure for DRR in Nepal (shaded box suggests non-established institutions, blue box suggests government ministries, and light blue box suggests Red Cross offices) (Source: Meechaiya et al. 2019)

Viz et al. (2020) and Bhandari et al. (2020) argued that, despite the policy changes and institutional restructuring in Nepal, the practice of disaster risk management had not undergone a significant transformation because of:

1. The Ministry of Home Affairs' strong influence on disaster governance and its reluctance to transfer its powers,
2. Institutional structure, capacity, and experience only suited for disaster response,

3. lack of capacity at the local levels and high dependency on donor agencies to conduct DRM activities,
4. Lack of clarity of roles within institutions,
5. Lack of coordination between the existing as well as new formed provincial institutions.

The authors also suggested that because the policies and institutions were recently formed, it would be too early to assume that policy decentralisation policies on DRR will contribute to reducing disaster risks and vulnerability at the local level (viz et al. 2020).

The government of India updated its policies in Disasters in relation to the global policy changes on disaster governance; as a result, the Disaster Management (DM) Act of 2005 was formulated, and following that, the National Policy on Disaster Management was formulated in 2009. Similarly, the National Disaster Management Plan was formed in 2016 (revised on 2019) in line with the UN's Sendai Framework for Disaster Risk Reduction (Ogra et al. 2019). the DM Act established a National Disaster Management Authority (NDMA) at the central level, the State Disaster Management Authority (SDMA) at state, and District Disaster Management Authority (DDMA) at the district level. The Disaster Management Act of 2005 mandates each district to have their disaster management plan, district emergency operation centre (EOC), and conduct disaster preparedness and awareness-raising activities (Das 2012).

The DM Act has mandated the NDMA to formulate policies and guidelines on disaster management, which the prime minister of India chairs. At the state level, SDMA is chaired by the chief minister of state, which establishes disaster management plans and policies at the state level. At the district level, the DDMA is co-chaired by the district magistrate and locally

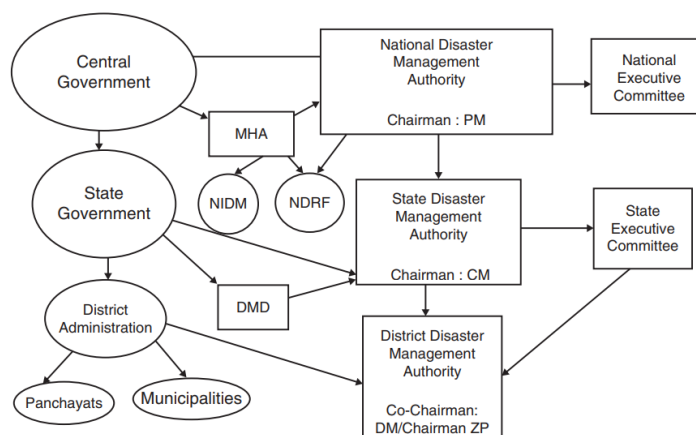


Figure 25: Institutional structure for disaster management in India (Source Gupta 2018).

elected representative, who have roles in implementing disaster management plans at the district level. The local government (Panchayats or municipalities) have the role of capacity building their staff on DRR, raising awareness at the community level, carrying out relief and recovery operations in the disaster-affected areas, and preparing disaster management plans in adherence with the national and district plans, and policies as shown in fig. (25) (Gupta 2018).

The Ministry of Home Affairs (MHA) is India's apex body for disaster management. The Indian meteorological department (IMD) under the Ministry of Earth Sciences is responsible for meteorological monitoring and forecasts. The Central Water Commission (CWC) is nested under the Department of Water Resources, River Development and Ganga Rejuvenation, and the Ministry of Jal Shakti (hydropower). The CWC is responsible for flood forecasting and dissemination of flood early warnings (Shah 2011). Gupta (2017) argued that significant constraints identified in the institutional system of India were:

- I. Overlap of responsibilities and lack of coordination ,
- II. Issues due to extended hierarchy and requirement of unnecessary reporting to multiple authorities,
- III. staff capacity and institutional setup at the local level incompatible with the policy mandates,
- IV. Lack of clarity among staff on their roles and governance mechanisms.

Similarly, Ogra et al. (2021) argued that, despite the policy updates in India aligning with the global policies on disaster risk reduction, the ground realities and practices are still disaster response focussed because those policies were disconnected from the contextual realities related to the social and institutional structures at the local level for their implementation.

The Table 1 presents the comparison of institutional structures for DRM in Nepal and India.

Table 1: Comparison of institutional structures for DRM in Nepal and India and challenges.

Institutional Structures for DRM in Nepal	Institutional Structures for DRM in India
• The constitution of Nepal 2015 has decentralised implementing roles of disaster risk management and early warning systems to local government authorities Central and federal government have advisory roles. • Disaster Risk Reduction and Management (DRRM) Act of 2017: Replaced the Natural Calamity Relief Act of 1982, shifting from reactive approaches to proactive approaches in managing risks.	• Disaster Management (DM) Act was formulated in 2005. National Policy on Disaster Management formulated in 2009, and National Disaster Management Plan formed in 2016 (revised on 2019) in line with the UN's Sendai Framework for Disaster Risk Reduction. • Local government (Panchayats or municipalities) responsible for capacity building, awareness-raising, relief, and recovery operations, and preparing disaster management plans.
• New apex institution formed for disaster risk management by DRRM act of 2017— National Disaster Risk Reduction and Management Authority (NDRRMA), under the ministry of Home Affairs .	• Ministry of Home Affairs (MHA) is India's apex body for disaster management under the Disaster Management Act of 2005.
• Department of Hydrology and Meteorology (DHM) is Primarily responsible for hydrological and meteorological forecasts, flood forecasting, and early warning systems in Nepal.	• Indian Meteorological Department (IMD) responsible for meteorological monitoring and forecasts related to EWS. • Central Water Commission (CWC) responsible for flood forecasting and dissemination of flood early warnings
Challenges in Nepal:	Challenges in India:
• Ministry of Home Affairs has strong influence on disaster governance and is reluctant to transfer its powers. • Institutional structure, capacity, and experience only suited for disaster response. • Lack of capacity at the local levels and high dependency on donor agencies to conduct DRM activities.	• Overlap of responsibilities and lack of coordination • Issues due to extended hierarchy and requirement of unnecessary reporting to multiple authorities • Staff capacity and institutional setup at the local level incompatible with the policy mandates

• Lack of clarity of roles within institutions • Lack of coordination between the existing as well as new formed provincial institutions	• Lack of clarity among staff on their roles and governance mechanisms. • Ground realities and practices are still disaster response focused and Policies are disconnected from the contextual realities related to the social and institutional structures at the local level for their implementation.

In both Nepal and India, there is a lack of coordination among institutions, unclear roles and capacities at local-level institutions, and ineffective incorporation of community-level feedback within institutional structures are common gaps. These gaps hinder the translation of community-level needs into policies, practices, and the establishment of transboundary EWS.

3.8. Chapter summary

The first section of this chapter showed that upstream hydrometeorological factors of the Kosi River basin affect downstream characteristics of the Kosi River and floods in the flat plains constituting Nepal and India. The multiple hazards occurring in different physiographic regions of the Kosi basin: avalanche and GLOFs in the higher Himalayan region; debris flow, landslide, and LDOF in the mid and low mountain regions; cause compounding effects of flooding and waterlogging in the downstream region. Furthermore, the Kosi basin lies in the active tectonic region and subduction zone between the Indian and the Eurasian plates, resulting in the high-magnitude earthquakes in the region. The upstream region of the Kosi basin in the Tibetan plateau and high Himalayan region acts as a sediment generation zone due to erosion and debris flow; the middle portion of the basin function as a sediment transfer zone due to steep topography and high precipitation zones contributing to fast current rivers; and downstream region function as a sediment storage zone in flat terrain, causing the Kosi River meanders.

The unpredictable meandering of the Kosi River caused widespread floods in Bihar, due to which flood control options were assessed first during the British colonial period of India; however, no physical interventions were approved at that time, stating that meandering was

the nature of Kosi River and any infrastructural interventions against it would prove futile. However, after India's independence, north Bihar faced a devastating flood, which opposition parties and Indian press media highly politicised, creating a pressure on the government, leading to the Kosi Agreement between Nepal and India to control floods in the Kosi River basin by containing the Kosi River within embankments and channelising it to the Kosi Barrage for controlling the river discharge in the downstream region in Bihar.

Rather than solving the issue of flooding in the Kosi River basin, the embankments acted as sediment traps, due to which the riverbed gained its height and flooding became unpredictable and devastating due to embankment breaches. In response to flooding due to embankment breaches, more embankments were added, and the height of existing embankments were also raised. This led to more complications from drainage congestion and waterlogging, causing ground water contamination, and an outbreak of multiple waterborne diseases and fatalities. The sediments dumped by rivers on the farmland, during every flood rendered the farmland barren and affecting both lives and livelihood of people in the river basin and forcing them to migrate to nearby cities in search of other livelihood options such as construction laborers.

Many works of literature have argued that institutional dysfunction and corruption had more role in the Kosi River floods than the hydrometeorological causes, as embankment construction provided a good source of illegal earning through corruption, which resulted from awkward institutional arrangements based on the Kosi Agreement. As the embankments are gradually proving futile for controlling floods and outlived their lifespan in the Kosi Basin, the Kosi High Dam Project (KHDP) was proposed as an alternative option for controlling floods. On the contrary, extensive literature is against the KHDP because of its detrimental effects on the environment and ecology, as well as due to the seismic risk in the region, which could cause more severe impacts on the lives and livelihood of people both in the upstream and downstream of the river basin. Despite the negative consequences, the policymakers from both countries are still coordinating and negotiating the implementation of the KHDP as an ultimate option for flood control in the Kosi basin.

Most people living in the downstream areas of the Kosi flood plain between Nepal and India rely on agriculture for their livelihood is characterised by the lowest economy, literacy, and access to resources in both countries. After the implementation of the Kosi project, the

livelihood of the farmers in the river basin deteriorated, and farmers who relied on subsistence agriculture had to migrate to nearby cities in search of labour. Also, due to the socio-cultural norms and gender roles, women and marginalised people face more significant challenges and are most affected during every flood disaster. In the Kosi basin, there is a lack of safe places during disaster evacuation. People take refuge on embankments in emergency shelters, which lack basic cooking, drinking water or sanitation facilities. Women have an additional workload during the evacuation and face sexual harassment and violence. After every flood, outbreaks of diseases such as malaria, dengue, typhoid, and other waterborne diseases due to stagnation and waterlogging further impact vulnerable people (e.g., pregnant, and lactating women, children, and elderly) in the Kosi River basin.

This chapter provides background information about the context to understand the findings from the empirical chapters (Chapters 5, 6, and 7) and to support the arguments in this thesis's discussion (Chapter 8). In the subsequent chapter (Chapter 4), the conceptual and methodological approaches employed in this research will be discussed.

Chapter 4 Methodology

4.1. Introduction

This chapter presents the methodological approach utilised in this thesis, accompanied by the underlying theoretical assumptions guiding these methodologies. This chapter will initiate a discussion on research ethics and the scope of this study, followed by an exploration of the paradigm upon which the research was structured. Subsequently, the research site or study area will be explored, encompassing the methods and approaches employed in the research, as well as the time horizon and positionality.

4.2. Research ethics

This research complies with the King's College London's ethical research policy, which was approved on 07/02/2019 with one year of validity for undertaking research and categorised as a "minimal risk" project, based on an online assessment of the Research Ethics Office with confirmation reference number MRS-18/19-10491 (see Appendix-A). This research uses GDPR-compliant information sheets (see Appendix-B) for informing about the research and consent forms (see Appendix-C) to receive participants' approval before gathering information or photographs. All interviews and focus group discussions were recorded in an audio recorder with password protection and file encryption. All the research participants were briefly informed about the research and handed a copy of the information sheet with researcher's contact details. Written consent was received from all the participants of this research before recording the interviews, and verbal consent was recorded from the participants where written consent could not be achieved. The participants' anonymity has been maintained throughout the research by using codes to refer to the interviewees (see Appendix-E).

4.3. Research paradigm

This thesis subscribes to Pragmatism as a research paradigm as it offers methodological pluralities and flexibility to incorporate diverse perspectives and perceptions into research, which suits the research aims to enquire on social, cultural, governance and geopolitical dimensions of transboundary EWS. The term "research paradigm" refers to the philosophical assumptions or beliefs guiding the researcher to understand the nature of reality (ontology)

and its knowledge (epistemology) (Creswell and Clark 2011; Lincoln et al. 2011). Social science research ontologies can range from Objectivism on one end to subjectivism on the other (Sil and Katzenstein 2010). Objectivism ontology holds that reality is objective and assumes it can be understood through quantitative methods of enquiry, while subjectivism holds that reality is subjective and depends upon interpretation and prefers qualitative modes of enquiry (Kaushik and Walsh 2019). Pragmatism as a research ontology positions itself in the middle of the spectrum and provides the flexibility of adopting either or both ontologies to achieve the outcomes that can be applied (Creswell 2009).

In the same way, the epistemology of Pragmatism also adopts centrality between Positivism and Interpretivism (Morgan 2014; Tashakkori and Teddlie 2003). In contrast to deductive logic in Positivism (i.e., assumed facts leading to conclusion) and Inductive logic in Interpretivism (i.e., observed facts leading to conclusion); Pragmatism adopts both the logics, referred to as abductive logic (i.e., arriving at a solution by iterative if-then logic of both assumed and observed facts based on a context) (Ansell and Boin 2019; Morgan 2014). Morgan (2014) stated that Pragmatism is generally associated with mixed-method research due to its centrality; however, Pragmatism does not suggest using mixed methods; instead, it suggests using multiple methods depending upon the context of research. Similarly, Goldkuhl (2012) argued that Pragmatism emphasises more research questions than the research methods; therefore, all methods are valid as they support actions toward the research objective (Tashakkori and Teddlie 1998). Amaratunga et al. (2002) also suggested that there is no best approach to research, but the choice of research methods needs to be the most suitable to achieve the objectives of a specific study. Pragmatism recognises real-world situations as too complex to be understood by a single method of enquiry and suggests using contextually informed analysis and multiple methods and their triangulation to arrive at conclusions (Creswell 2009).

Boisvert (1998, p.31) argued that *“Pragmatism does not simply mean that if it works, then it is true”* because it does not bypass philosophical theories to reach a conclusion; instead, it seeks complementarities among different theories and adopts a neutral position. Supporting the argument, Bauer and Brighi (2009) also suggested that Pragmatism as a research paradigm benefits the researcher in producing practical solutions with the complementarity of different theories and approaches.

The following section deals with the philosophical underpinnings of Pragmatism and how it relates to risk communication and the risk information generation components of transboundary EWS in this research.

4.3.1. The theory of pragmatism

Pragmatism is derived from the Greek word ‘pragma’, which means action (Pansiri 2005). The theory of Pragmatism originated and evolved in the USA between the 1800s to 1900s based on the philosophical discourses of Charles Sanders Peirce, William James, John Dewey, and George Herbert Mead, who argued that traditional reductionist and expansionist philosophical theories were too detached from the context and too vague to solve social problems (Maxcy 2003). Those philosophers adopted Charles Darwin’s theory of evolution as a foundation of Pragmatism theory, suggesting that just like multiple organisms continuously evolve and adapt in nature; knowledge and society are also in the continuous process of interaction, adaptation, and evolution (Morgan 2014; Rorty 1989; Shields 2008). Festenstein (2002) suggested four tenets of pragmatism theory: holism—a holistic view of the world; fallibilism—understanding that knowledge is evolving and thus imperfect; anti-dualism—realising interconnection rather than discreteness between nature and society; and experimentalism—theories that can be applied to solve real-world problems through hit and trial and learning by doing.

The following section deals with how the theory of pragmatism relates to this research in understanding the risk information generation and risk communication processes in transboundary EWS.

4.3.2. Pragmatism in risk information generation in transboundary EWS

Pragmatism theory recognises the risk information generation process in the transboundary EWS as a “sense-making” process, where experts and people at risk generate a shared understanding of risks and their solutions through social interaction and collaborative actions that happen in situ through experimentation (Ansell and Boin 2019; Evans 2000; Simpson and Hond 2022; Shields 2008). Similarly, Bromley (2008, p.4) argued that collaborative engagement and action are especially essential when dealing with uncertainties, stating that “*indeterminacy is the reason we reason*”; therefore, practical decisions can only be made if led collaboratively through reflexivity, deliberation, and experimentation (Ansell and Boin

2019). Similarly, the concept of fallibilism and bricolage in pragmatism suggests that knowledge is evolving and imperfect; therefore, meaning should be made from the bricolage of understandings or whatever information is available collaboratively rather than waiting for perfect information (Beckert 2003; Duymedjian and Rüling 2010). Therefore, the pragmatist way of risk information generation is through the participation and collaboration of multiple stakeholders to make sense of the situation and act towards it collaboratively.

4.3.3. Pragmatism in risk communication for transboundary EWS

Pragmatism theory recognises the risk communication process as “meaning making” or having a shared understanding among the plurality of perceptions through collaboration (Ansell and Boin 2019). Rorty (1989 p.6) stressed that each people in society understand their world and risks differently in their *“contingencies of languages and the plurality of vocabulary”*; therefore, each rationality and behaviour during risks are also different. With that view, the pragmatist way of risk communication should focus on meaning-making by having a shared understanding of risk among all the stakeholders through participation to generate a creative action towards risks.

4.3.4. Application of pragmatism in this research

The pragmatism theory is most suitable for investigating the constraining factors related to transboundary EWS and identifying practical solutions to overcome those constraints in the context of Kosi River basin. The application of multiple methods in this research aligns with a pragmatist approach, encompassing the utilisation of expert interviews to comprehend the institutional context and governance of EWS within the transboundary context. Furthermore, community-level interviews have been conducted to gain insights into the local context of EWS, examine people’s access to and understanding of warnings, and explore the socio-cultural factors influencing transboundary EWS. Additionally, focus group discussions have been employed to attain a deeper understanding of the socio-cultural aspects impacting EWS and to gather the perspectives of the most vulnerable and marginalised individuals at risk.

The utilisation of multiple methods facilitated a comprehensive examination and validation of information obtained from both experts and individuals at risk, enabling the comparison of policies and practices within the study area. Pragmatic adaptations and modifications were made to the research methods based on specific needs, such as the inclusion of gender-

disaggregated Focus Group Discussions (FGDs) upon recognising that women may not feel comfortable discussing certain topics in mixed-gender FGDs. This adaptation is further detailed in section 4.6.6 of this chapter. The application of pragmatism theory guided the approach to risk information generation within EWS, perceiving it as a sense-making process that entails collaborative knowledge co-production between individuals at risk and experts. This approach aimed to foster a contextually informed and enhanced understanding of hazard risk in the study area. Similarly, the risk communication process within EWS was approached as a meaning-making process, emphasising the importance of warnings that convey the meaning of hazard risk to individuals at risk rather than solely providing information about hazards. Pragmatism theory was employed to propose suitable policies and practices to address the limitations of transboundary EWS, as presented in Chapter 9 of this thesis.

4.4. Research Design

The research design functions as a strategic framework for action that aims to bridge the gap between research question and methods of enquiry (Creswell 2009). At the outset of this thesis, the research question was formulated: “what are the cultural, institutional and governance factors that constrain effective transboundary flood EWSs in the Kosi River basin?”. To answer the research question, it was subdivided into four research components of cultural factors, institutional factors, governance factors, and geopolitical factors related to transboundary EWS. Furthermore, each component involved different methodological approaches and their triangulation from field observation and community interactions as shown in fig. (26).

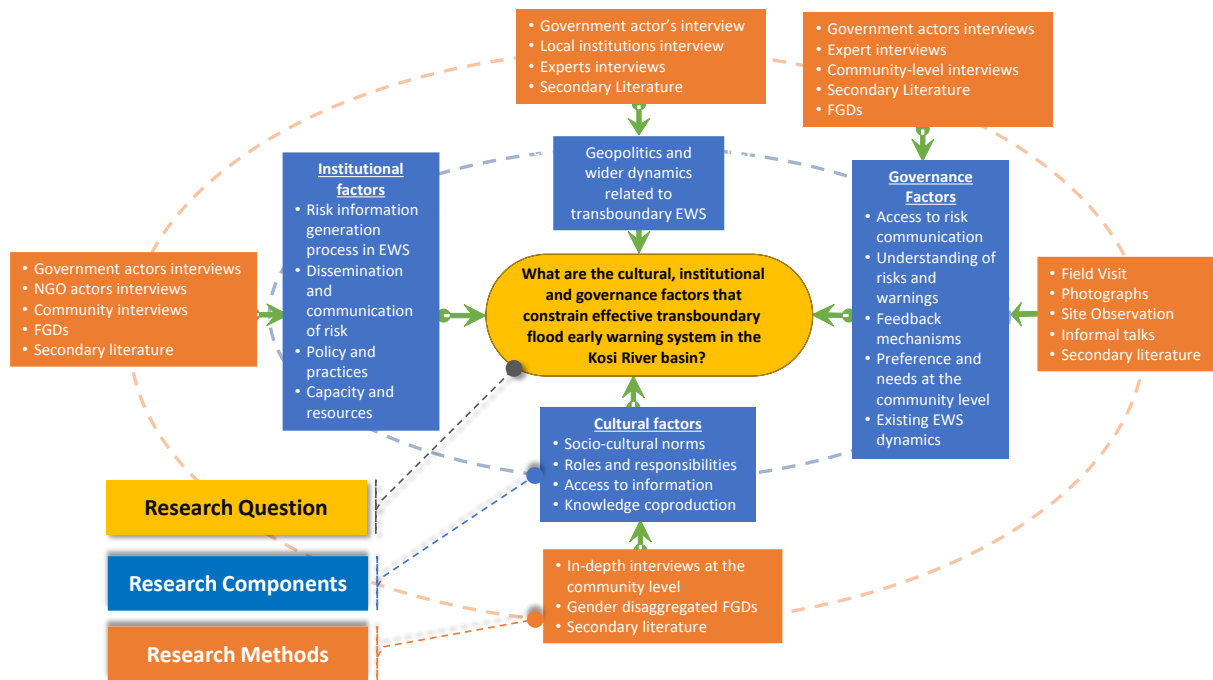


Figure 26: Research design adopted in this thesis on transboundary EWS.

4.5. Research site

The research site comprises the transboundary area along the Nepal-India border, traversed by the Kosi River, as depicted in fig. (27). This selected location offers an ideal setting for investigating transboundary EWS, as it represents a shared landscape between the two sovereign countries affected by the Kosi River floods. While there is free movement across the Nepal-India border, the institutional context and governance of EWS differ significantly in the Indian and Nepalese sections of the research site. Moreover, this location serves as a microcosm reflecting transboundary interactions and geopolitical dynamics between Nepal and India. For this study, interviews and focus group discussions (FGDs) were conducted in Kunauli (market centre), Bathnaha, Haripur, and Kamalpur villages in Bihar, India; and Tilathi, Koiladi, Rampura-Malhaniya, Shankarapura, and Hanumannagar villages in Nepal. These locations were selected due to their proximity to the Kosi River, which experiences regular flooding during the monsoon season.

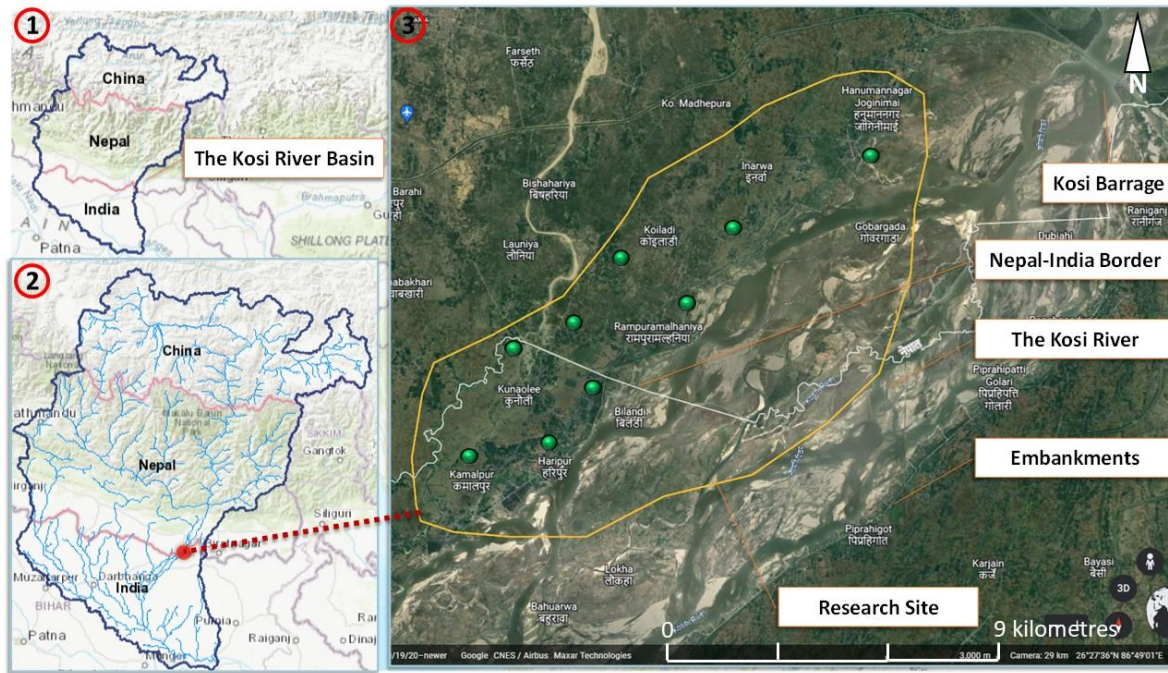


Figure 27: The upper left image (1) shows the transboundary Kosi River basin, the lower left image (2) is the zoomed extent of the Kosi River basin showing drainage network and research site, and the right image (3) shows the satellite image of the research site within the basin, where green dots represent locations of primary data collection. (Source (1, and 2): ICIMOD 2022; source (3): Google Earth 2022)

4.6. Research methods and approach

This section outlines the research methodology employed and the methods utilised for data collection in this study.

4.6.1. Secondary data collection

This research started by collecting and reviewing secondary literature, which included books, and published reports by NGOs, National acts and policies on disaster risk management and standard operating procedures for EWSs in Nepal and India were also reviewed to understand the governance of disaster risk management and EWS in Nepal and India. The Kosi Agreement of 1954 was also reviewed to understand the bilateral relationship between Nepal and India regarding the Kosi River. Similarly, to understand the contextual settings, maps, GIS dataset and satellite imagery of the Kosi River basin, newspaper clips and locally published documents on the Kosi River were collected during the field visit and studied. In addition, the publications, and maps available on government webpages such as the Department of Hydrology and Meteorology in Nepal (hydrology.gov.np), Central Water Commission of India (www.cwc.gov.in), Bihar Water Resource Department (state.bihar.gov.in/wrd), as well as

publications and maps from regional institution ICIMOD on Kosi Basin Information System (geoapps.icimod.org/kbis), were also studied in this research.

4.6.2. Primary data collection

The primary data collected in this research includes ethnographic research, focus group discussions, and in-depth interviews with people in the study area, policymakers, scientists, politicians, and government officials related to flood risk management and EWS in the Kosi River basin. Data collection in this research involved ethnographic research, focus group discussions, and in-depth interviews. These methods were selected based on their efficiency in gathering data.

Ethnography focuses on studying an intact cultural group in a natural setting, using observation to identify norms, beliefs, social structures, and related factors (Creswell and Creswell 2017). The flexible nature of ethnography allows it to adapt to field realities, providing a comprehensive understanding of social phenomena, uncovering underlying meanings in social practices, and challenging stereotypes while amplifying marginalised voices (Williams 2007). Another method, focus group discussions (FGDs), helps generate rich data through interactive group dynamics, allowing participants to build on ideas and offer diverse viewpoints (Seal et al. 1998). FGDs help explore complex social phenomena, validate individual accounts, and efficiently collect data from multiple individuals quickly. Similarly, In-depth interviews with experts offer a focused approach to obtaining detailed information and expert perspectives. The in-depth interviews provide valuable insights that are not easily accessible from secondary sources, helping to understand research subject complexities and accessing the latest progress within specific areas of study (Legard et al. 2003).

Altogether, this research includes the primary data from 182 people related to the Kosi River and floods, which includes 44 community-level interviews, 104 people's voices through 12 focus group discussions, and 34 in-depth interviews with experts in Nepal and India.

Upon obtaining ethical approval from King's College London, primary data collection was initiated. Considering the limited availability of published information on the governance of EWS within the transboundary context of the Nepal-India Kosi River basin, open-ended semi-structured interviews were selected as the method to gather data pertaining to transboundary EWS governance, encompassing risk information generation and risk

communication. These interviews were conducted with experts affiliated with government and non-governmental organisations. Furthermore, semi-structured open-ended interviews were conducted at the community level to gain insights into the context of floods and EWS, as well as to capture people's perceptions within the Kosi River basin. This approach also served to corroborate and validate the information gathered from the experts.

Initially, a list of government and non-government institutions in Nepal and India associated with the Kosi River basin and EWS was compiled, including their respective contact details. Subsequently, a visit to Kathmandu was made to conduct expert interviews. With a prepared list of potential experts, an initial approach was made to an expert affiliated with an International Non-Governmental Organisation (INGO) in Nepal who possessed knowledge and involvement in EWSs within both Nepal and the transboundary context between Nepal and India. The first interview was conducted with this expert, during which relevant reports and publications on EWS were obtained from the expert's organisation, contributing to a better understanding of the transboundary EWS processes.

The initial interviews also served as a pre-test for the interview questions, which were subsequently revised to enhance clarity. Employing a snowball sampling approach based on recommendations from the initial interviewee, other participants for expert interviews in this research were identified. Notably, during this process, one participant informed the researcher about a ministerial-level interaction meeting focused on the Kosi River floods and extended an invitation to attend. Attending the meeting provided an opportunity to engage

with numerous high-ranking government officials, politicians, scientists, and disaster management experts associated with transboundary EWS, as illustrated in fig.(28).



Figure 28: Conference on transboundary issues related to floods, which involved minister of foreign affairs, former water resource minister, ambassador of Nepal to India, head of departments in water resource and irrigation in Nepal, District Administration officers and municipal CEOs from flood affected districts, and other high-ranking officers, academics, and INGO workers in Nepal (Source: field photograph).

Most expert interviews in Nepal were successfully conducted, following which the research site was visited to conduct community-level interviews. In total, this research encompassed 34 expert interviews, involving government officials, scientists, disaster management experts, former politicians, academics, activists, and local NGO workers in Nepal and India. The anonymised list of participants involved in the expert interviews can be found in Appendix E. To ensure efficiency, all expert interviews were scheduled for a one-hour duration, and explicit written consent was obtained prior to audio recording the interviews.

4.6.3. Planning fieldwork at the community level

Following the completion of the initial round of expert interviews in Nepal, preparations were made for fieldwork pertaining to community-level interviews and focus group discussions in the designated study area. To discuss the field activities, consultations were held with Jyotish and Uday, acquaintances who were residents of the study area. Jyotish worked as a municipal engineer, while Uday served as a high-school teacher in Rajbiraj. Furthermore, input was sought from Neeraj, a friend currently pursuing studies at Imperial College London, who hailed from the eastern Terai region of Nepal. Neeraj provided valuable recommendations regarding field-level research, including travel arrangements and suggestions for suitable

accommodation. These recommendations enabled the researcher to manage interview records in the evenings while conducting fieldwork during the day. As per Neeraj's advice, a vehicle was hired for the journey from Kathmandu to Rajbiraj, a six-hour trip. Additionally, to facilitate local travel and border crossings within the study area, a motorbike with a locally registered number plate was procured. Neeraj also recommended a hotel in Rajbiraj that offered reliable internet access. During office hours, Uday and Jyotish kindly offered the use of their motorcycles, which were utilised for the Kosi River field observation and reconnaissance survey.

The FGDs were conducted during the evening hours, selecting a time when the temperature was moderate, and individuals appeared to have more free time available. In contrast, daytime activities comprised community-level interviews as well as interviews with local government institutions, local elites, NGO workers, experts, and activists residing within the study area.

Following the completion of the FGDs and community-level interviews, the researcher returned to Kathmandu. Subsequently, the remaining interviews with disaster management experts and scientists specialising in flood EWSs in the Kosi River were conducted. At that stage, all planned community-level interviews, FGDs within the study area, and expert interviews in Nepal had been successfully carried out. Preparations were made for the second round of interviews, which involved engaging with central and state-level government officers in Delhi in mid-March 2020.

In the first week of March 2020, the researcher travelled to Delhi to participate in the annual meeting of LANDSLIP, a project funded by the SHEAR programme that supported the PhD scholarship. During this meeting, a fellow participant provided contact information for two central government officials and generously extended an invitation for the researcher to conduct interviews at their residence. Immediately after the LANDSLIP meeting, a trip to Istanbul was undertaken to attend a conference on disaster resilience organised by the Royal Academy of Engineering. During this event, two other Indian participants shared contact details for one central government officer in Delhi and an officer working in the Bihar state.

Unfortunately, due to the subsequent outbreak of the COVID pandemic and the implementation of travel restrictions, the researcher was unable to conduct the remaining

interviews in person. As a result, alternative methods such as phone interviews and online platforms including Viber, WhatsApp, and Skype were utilised to facilitate the completion of the remaining interviews.

4.6.4. Ethnography

Ethnography was carried out to understand the context and people in the study area where interviews will be conducted. Ethnography is the study of people in their natural settings using methods that capture their “social meanings and ordinary activities”, which involves the researcher participating in the context without the purpose being imposed on them externally (Brewer 2000, p.10). Initially, the researcher travelled around the Kosi riverbank, observed people’s movements and daily life, and absorbed into the context. Informal interactions and communication were also held with people in small tea shops while buying tea and having breakfast and lunch in local restaurants about the Kosi floods and their impact in general, as shown in fig. (29). During the informal interactions, the questions were basic and general, such as: “does Kosi flood affect this area during monsoon? and up to what level is this place inundated? Where do you go during floods?”. Those questions were to open conversation and adapt the researcher to the local context. The conversation notes were not recorded during the discussions as it would break the interpersonal connection. However, those conversations were later recalled and noted in bullet points after returning to the hotel room.



Figure 29: Informal interaction in a local tea shop about Kosi floods and warnings

The available information and facilities in the study area regarding flood risk management and EWS, as shown in fig. (30), were also visited, and observed. The researcher also intended to observe inside the Kosi Barrage and talk to the Indian government officials operating the barrage and approached the guard at the barrage with a letter prepared by King's College London and an information sheet of research, which the guard took to ask someone inside the barrage but returned saying that letter from the Water Resource Department of India would be needed to allow and observe inside the Kosi barrage. The visit was only for observation; therefore, the researcher did not insist on visiting inside and only observed the barrage from outside.



Figure 30: left image: the blackboard at the Kosi River barrage stating river discharge, which was barely understandable; the Right image evacuation shelter which could barely fit four people, prepared for the whole ward by an NGO, which had a board written “Local Disaster and Climate Change Resilient Emergency Shelter”, built at the cost of 2,258,468.55 NRs which is approximately £14,150.

The visit was also made to the community-based organisation Kosi Victim Society (KVS), which was formed by the flood-affected people from Nepal and India and was working for flood preparedness and advocacy for compensation of the flood victims in the Kosi River basin. A flex was hanging at the organisation's entrance, which stated, “Hey boy! You will never find the answers!” this grabbed the attention of the researcher, as shown in fig. (31). That flex wrote about the interaction of rivers with the livelihood of people living in the Kosi basin which the researcher gradually understood after the first round of expert interviews and field observation. This flex at the entrance of the KVS office also suggests that the place is visited

by many researchers for data collection, and the flex could be aimed at researchers studying Kosi River floods.



Figure 31: The text in Hindi translates as, "Aunt Sugiya says: Hey boy! You will never find the answers, because you even failed to see that rivers have always flown from higher ground to lower ground, and floods have always occurred on this land. Our ancestors and their ancestors too had lived on this land; yes, they had lived and only because they did not start rivalry and animosity against the river, as you are doing now".

In the office, the researcher found local publications as well as collection of books and articles on Kosi floods from researchers from India and Nepal in Hindi, Maithili, English, and Nepali languages. The photographs were taken of many newspaper cuttings and pages of books relevant to this research. The officer at the KVS office also described graphically on a whiteboard about the sediment transfer in the Kosi River, riverbed aggradation, and the history of flooding in the Kosi River, as shown in fig. (32). This meeting provided a greater understanding of the context, the disasters, socio-economy, culture, and the interrelationship of the Kosi River and the people living in the floodplain.



Figure 32: An officer at Kosi Victim Society explaining graphically about the sediment transfer from the upstream in the Kosi River and aggradation of riverbed due to embankments and barrage functioning as a sediment trap in the Kosi River causing floods in the Kosi River basin.

After the field observation and collection of literature, community-level interviews were conducted. For conducting the interview, public places such as Chowks (street intersections) or Bazaars (small market centres) were selected for interviews which would have a continuous flow of people.

4.6.5. Community level interviews

The open-ended semi-structured interviews were conducted at the community level to explore the context of risk communication, people's participation, and involvement in the EWS processes. The open-ended semi-structured interview method combines flexibility and structure to gather in-depth information from participants. This approach enables participants to provide rich and contextualised information, leading to a more nuanced understanding of their experiences and viewpoints. The semi-structured format offers some flexibility, allowing adjustments based on participants' responses and interests, while ensuring that key topics and research objectives are addressed (Adams 2015).

This method could also help in validating and comparing the information from the expert interviews and understand ground realities. Altogether, 44 semi-structured open-ended

interviews were conducted at the community level to understand the people's access to warnings, their interpretation, understanding of risk, and preference for warnings. The number of community-level interviews conducted in the study area is presented in Table (2) and the detailed list in Appendix E.

Table 2: Community level participants and location

Country	Community level interview location	Female	Male
India	Kunauli (Border market)	1	3
	Bathnaha	2	3
	Haripur	1	4
	Kamalpur	1	4
Nepal	Tilathi	3	2
	Shankarapura	2	3
	Koiladi	2	2
	Rampura-Malhaniya	2	3
	Hanumannagar	3	3
	Total (44)	17	27

Community-level interviews were initiated in Hanuman Nagar, in the study area. The interviews were conducted in public spaces within the study area, such as market centres and street intersections, and involved individuals encountered on-site who displayed availability and willingness to participate. A total of 19 participants from India and 25 participants from Nepal were included in the community-level interviews. It is important to note that individuals with disabilities, elderly individuals, and children were not included in the sample. Additionally, participant selection was not based on caste, class, or ethnicity but rather on those encountered on the research site, given the limited scope of this study. Significantly fewer females were observed in public spaces and market centres in the study area, particularly on the Indian side. This observation corresponds with women's limited access to such areas, as previously noted by Acharya and Prakash (2019). The gender-disaggregated focus group discussions and focus group discussions on settlements of marginalised communities were conducted to include the voice of the women and marginalised population in the study area, which is further discussed in section 4.6.6 of this thesis.

In the community-level interviews, participants were approached, and the researcher introduced the project, requesting their willingness to share their experiences with floods in the Kosi River. Before conducting the interviews, consent was sought, and participants were

informed that the interviews would be recorded solely for academic purposes, ensuring their personal information and identities would remain confidential. While some interviewees hesitated to sign the consent form, they provided verbal consent for the interviews. The interviews took place on-site, and participants received a copy of the information sheet.

The community-level interview questions focused on various aspects, including participants' understanding of risk, perceptions and access to risk information, involvement in EWS, government support received, and preferences for risk communication within EWS (refer to Appendix D for interview questions).

During the initial interviews, it became apparent that certain parts of the participants' responses were challenging to comprehend despite the researcher's ability to communicate in Hindi, Nepali, or Maithili. For instance, when asked about the possible causes of flooding in the Kosi River, literal translations of their answers referred to local tributaries such as Jitua, Mahuli, and Ratu causing floods or animals like squirrels and rats being responsible for embankment seepage. Consulting with local acquaintances helped the researcher interpret these responses that the participants were referring to the local tributaries' inability to drain into the main river channel, leading to flooding, or squirrels creating holes in the embankment during the monsoon season, causing inundation in floodplains. Some responses even mentioned clouds tearing apart, like curdling milk, resulting in mountains melting and causing flooding in the Kosi River basin. These explanations indicated that heavy downpours in the upstream mountainous regions were responsible for the monsoon season floods. Despite being able to communicate in the Maithili language, some aspects of the participants' responses remained challenging due to their references to local areas, contexts, and specific language usage. To aid understanding and transcription, the researcher sought assistance from friends, native to the region.

During the community-level interviews, individuals on the Indian side of the study area often mistook the researcher for a government official assessing Kosi River flood damage. Conversely, some individuals in Nepal assumed the researcher was an NGO worker collecting information for relief distribution. People even approached the researcher, requesting assistance assessing their damaged houses and animal sheds due to the floods. It was necessary to repeatedly clarify that the researcher was a student, not a government representative or NGO worker, emphasising the study's association with PhD research by

showing the information sheet and consent form featuring the university logo, which helped reassure them of the researcher's identity. These incidents further highlighted the perception that government officers primarily assess damages on the Indian side of the study area. At the same time, NGOs focus on providing relief items in the Nepalese region. These aspects are further examined and discussed in chapters 5 and 6 of this thesis.

4.6.6. Focus group discussions

Focus group discussions (FGDs) were conducted to understand the perspectives of vulnerable communities affected by floods within the study area. Through focused deliberations among the research participants, FGDs present an opportunity to deeply explore the complexities within the socio-cultural context (Hennink 2013). Consequently, FGDs were implemented within the impoverished settlements and marginalised pockets of communities belonging to the *Dalit* caste, colloquially referred to as *Musahar Basti* (literal translation: "settlement of rat-eaters") in Hanumannagar, *Maalah Tole* (a community of fishermen) in Rampura-Malhaniya, and *Dom Basti* (literal translation: "settlement of pig-rearers") in Bathnaha. One FGD was also conducted with flood-displaced individuals residing in temporary shelters fig. (33). These settlements are situated along the banks of the Kosi River, making them susceptible to the flooding risk.



Figure 33: FGD conducted with flood affected people in Hanuman Nagar in Nepal

The recruitment strategy employed to engage participants in FGDs involved approaching individuals observed outside their residences, briefly engaging them in a discussion regarding

the study, and inquiring about their availability for conducting a small interaction within the community. Referrals were requested from the initial participants, and additional individuals in the neighbourhood were invited by means of vocal communication. Once a group of 5 to 6 individuals had been gathered, the participants were briefly introduced about the research and its objectives, and participants were requested to provide information for the study. Subsequently, their consent to record the interviews was also requested.

Clifford et al. (2010) suggested that the interaction among the interviewees is crucial in FGDs, and the role of a researcher is to facilitate those interactions, which was maintained in this research while conducting FGDs by guiding the discussion and providing an environment that encourages participants to engage in interactive discussion, responding to one another's contributions. The initial phase of the FGDs involved initiating the discussion with general inquiries to open the conversation, such as inquiring about the number of flood events witnessed in the study area and the actions undertaken during those events. Additionally, participants were encouraged to explore the underlying causes of floods in the area.

In the FGDs, although some women were requested to participate, they were unwilling to engage in group discussions and expressed shyness in sharing their views. It was observed that they were concerned about "incorrect answers" or making comments that could potentially embarrass them in front of other community members. During one FGD, when the researcher requested a woman not sharing her views to come into the discussion and share the potential causes of flooding in the Kosi River, she responded aggressively, stating, *"Do you think I am an engineer to ask such questions? Why are you asking me? Ask others. Why do floods occur? Who knows why floods occur...floods occur because they do... how would I know why floods occur..."*. The researcher promptly apologised to the woman for the question posed and encouraged the other participants to resume the discussions. During this incident, the researcher realised the need to conduct gender-disaggregated focus group discussions. This new understanding aimed to acquire first-hand insights into the socio-cultural barriers that persist at the community level, indicating a deviation from the original plan formulated at the outset of the FGDs.

In gender disaggregated focus group discussions, it was socially inappropriate for women to talk to an unknown man in that context, so women were only comfortable speaking when at least one man from their community was present in the discussion, even if he was not

participating in the discussion. During gender disaggregated FGDs, In the beginning, women were reluctant to talk and referred to other ladies to speak, but sooner, the discussion picked up the pace. Women shared problems that are deeply rooted and linked to socio-cultural barriers, such as only men in their household carrying mobile phones, only men involved in discussions and decisions related to evacuation, hardships and difficulties during an evacuation, and reluctance to evacuate.

Altogether 12 FGDs were conducted in the study area, as shown in Table 3. The FGDs were conducted to understand the access, perception, and understanding of the early warnings by the flood-affected and vulnerable population (women, elderly, and impoverished) in the study area. Out of 12 FGDs, six were gender disaggregated. While conducting FGDs, researchers initial plan was to include 5 to 6 people, and most of the FGDs consist of 5 to 6 people, but while having a discussion, some curious people also joined in the middle of the discussion, and three of the FGDs had 10-13 participants. The logbook of all the participants' name and their verbal or written signatures was also maintained as consent for FGDs. The focus group discussions revolved around the interpretation of flood risks by individuals exposed to such risks. These discussions encompassed aspects such as the transboundary origins of floods, historical flood events, and their consequences on the participants' lives and livelihoods. Moreover, the roles and involvement of communities, as well as support received by the government institutions, were discussed along with the resources and capacities accessible at the community level (see Appendix D).

Table 3: Number of FGDs conducted in the study area.

S.no	Location	Country	No. of FGDs	Remarks
1	Hanuman Nagar	Nepal	3	2 genders disaggregated FGDs with women, 1 FGD (with people living in temporary shelters on embankment with mostly women and few men)
2	Rampura Malhaniya	Nepal	3	2 genders disaggregated FGDs with women, 1 gender balanced FGD
3	Bathnaha	India	2	1 gender disaggregated FGD with women, 1 FGD with men only

4	Haripur	India	2	1 gender disaggregated FGD with women, 1 FGD with men only
5	Kunauli	India	1	FGD with men only
6	Kamalpur	India	1	FGD with men only

4.6.7. Data analysis

Qualitative data analysis encompasses a systematic approach to organizing, structuring, and deriving meaning from collected data, aiming to investigate the relationship between categories and themes within the data, thus deepening the understanding of the phenomenon being studied (Marshall and Rossman 2014). The audio records from interviews were transcribed in MS Word, coded, and re-coded for qualitative analysis and generating themes from the interviews using the NVivo software. NVivo, a Qualitative Data Analysis (QDA) software, was chosen for data analysis as it provides several advantages by automating manual tasks, simplifying qualitative data analysis, and enabling researchers to allocate more time for trend identification, theme recognition, and drawing conclusions (Hilal and Alabri 2013). Similarly, Bazeley and Jackson (2007) identified five significant ways in which NVivo simplifies qualitative data analysis:

- Data management: organising various data types, including interview transcripts and published materials.
- Idea management: understanding the conceptual and theoretical aspects that emerge from the study.
- Data querying: formulating and answering specific questions using the software's capabilities and saving query results for ongoing investigations.
- Visual modelling: creating graphs visually representing relationships within conceptual and theoretical data.
- Reporting: utilising collected data and findings to generate comprehensive study reports.

The community-level interview codes were further re-coded and case-classified to perform cross-tabulation and basic quantitative analysis to be presented in graphical forms.

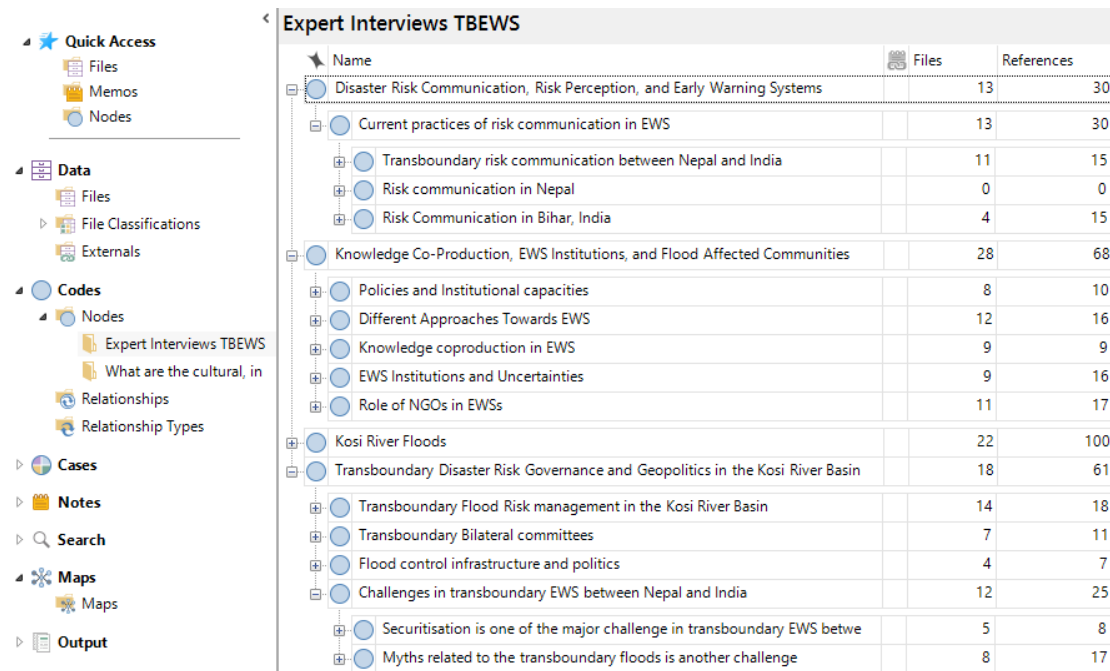
4.6.7.1. Transcription

Following the data collection stage, all 90 recorded audio files, comprising 44 community-level interviews, 12 focus group discussions, and 34 expert interviews, were transcribed into MS Word. The average duration of expert interviews was approximately one hour, community-level interviews averaged 20 minutes, and FGDs lasted about one hour each. Due to the language variations, expert interviews contained a mix of Nepali, Hindi, and English, whereas community-level interviews and FGDs were conducted in the Maithili language. Consequently, automated transcription software could not be used and required manual transcription. Transcribing each expert interview needed at least two days, and the entire manual transcription process spanned approximately three months. Throughout this process, the researcher sought assistance from a native speaker several times to clarify the meanings of certain words or phrases that posed confusion. Although the monotonous nature of continuously listening and transcribing the recorded material persisted for months, it provided a comprehensive understanding of the challenges faced at the community level.

4.6.7.2. Coding and theme generation

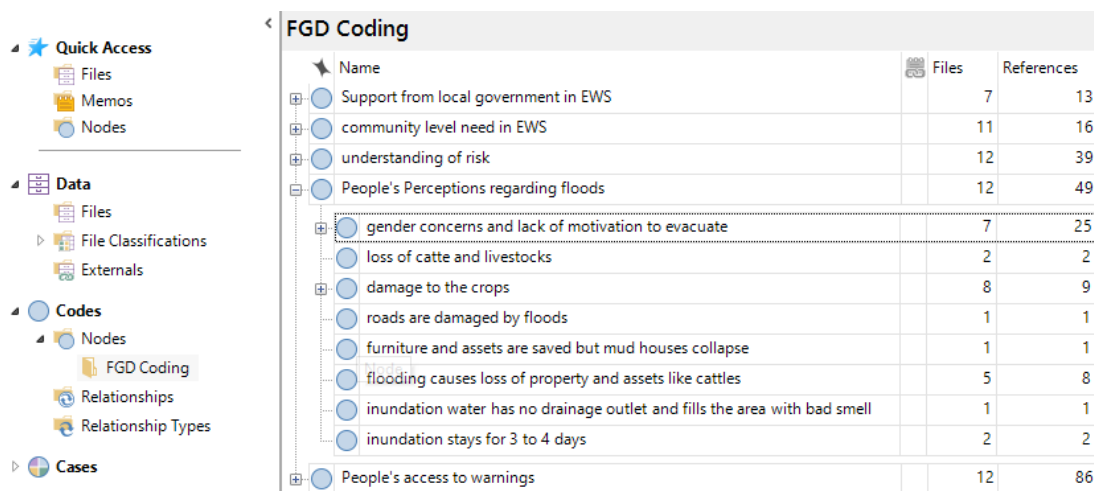
Upon completing the transcription process, the researcher imported all the transcript files into NVivo 12 software, categorising them into three different projects: expert interviews, FGDs, and community-level interviews. The coding helped to generate themes from the qualitative interview data. Wuetherick (2010) suggested that as qualitative data predominantly exist in textual form, coding assumes fundamental significance in data analysis. Similarly, Miles and Huberman (1994) stated that codes function as labels or tags that attribute meaning to the descriptive or inferential information compiled during a study, typically encompassing words, phrases, sentences, or entire paragraphs. The coding process involves identifying pertinent words or phrases mentioned by interviewees or discovered in documents and subsequently examining their connections (Marshall and Rossman 2014). Traditionally, coding was accomplished through manual methods using coloured pens, where data would be sorted, cut, and categorised; however, the utilisation of qualitative analysis software like NVivo has brought about more organised and time-efficient coding processes, surpassing the laborious nature of manual procedures (Hilal and Alabri 2013).

Among the identified themes, the overarching themes were: The absence of community-level participation in the risk information generation process of the EWS, Limited access to information; a top-down approach to existing EWS practices; and technology focus rather than focus on people at risk, complexities, and challenges in the transboundary EWS. The themes of the transcripts from expert interviews, FGDs, and community level interviews conducted in the study area are presented in fig. (34, 35, and 36) respectively.



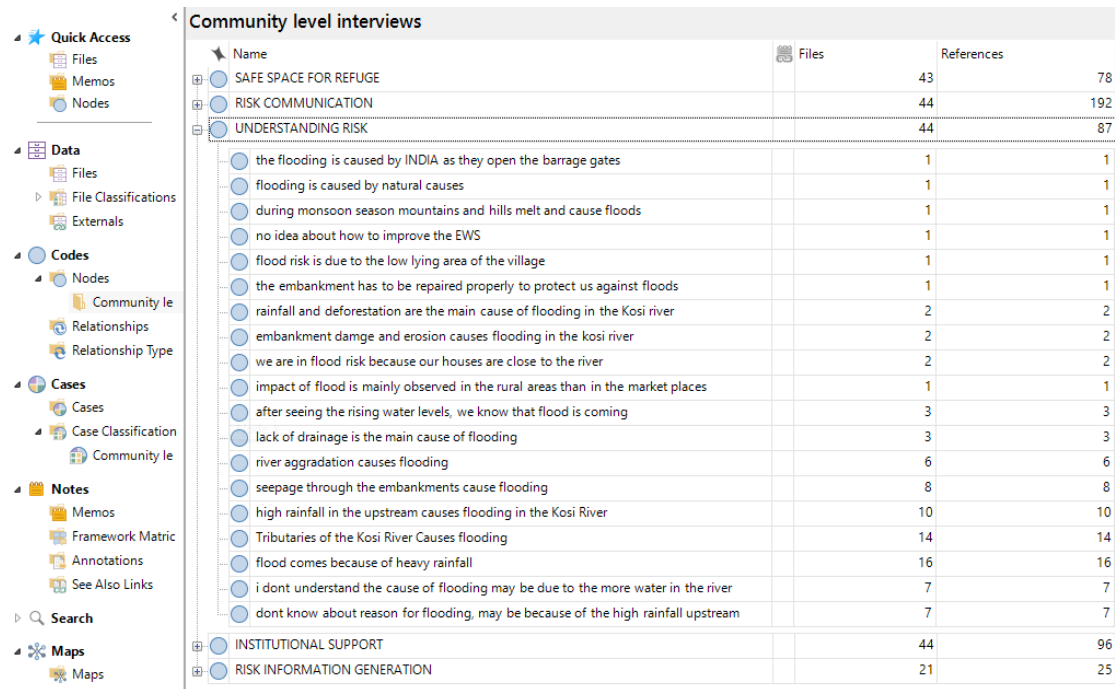
Name	Files	References
Disaster Risk Communication, Risk Perception, and Early Warning Systems	13	30
Current practices of risk communication in EWS	13	30
Transboundary risk communication between Nepal and India	11	15
Risk communication in Nepal	0	0
Risk Communication in Bihar, India	4	15
Knowledge Co-Production, EWS Institutions, and Flood Affected Communities	28	68
Policies and Institutional capacities	8	10
Different Approaches Towards EWS	12	16
Knowledge coproduction in EWS	9	9
EWS Institutions and Uncertainties	9	16
Role of NGOs in EWSs	11	17
Kosi River Floods	22	100
Transboundary Disaster Risk Governance and Geopolitics in the Kosi River Basin	18	61
Transboundary Flood Risk management in the Kosi River Basin	14	18
Transboundary Bilateral committees	7	11
Flood control infrastructure and politics	4	7
Challenges in transboundary EWS between Nepal and India	12	25
Securitisation is one of the major challenge in transboundary EWS betwe	5	8
Myths related to the transboundary floods is another challenge	8	17

Figure 34: Themes generated from expert interview transcripts.



Name	Files	References
Support from local government in EWS	7	13
community level need in EWS	11	16
understanding of risk	12	39
People's Perceptions regarding floods	12	49
gender concerns and lack of motivation to evacuate	7	25
loss of cattle and livestock	2	2
damage to the crops	8	9
roads are damaged by floods	1	1
furniture and assets are saved but mud houses collapse	1	1
flooding causes loss of property and assets like cattles	5	8
inundation water has no drainage outlet and fills the area with bad smell	1	1
inundation stays for 3 to 4 days	2	2
People's access to warnings	12	86

Figure 35: Themes generated from focus group discussion transcripts.

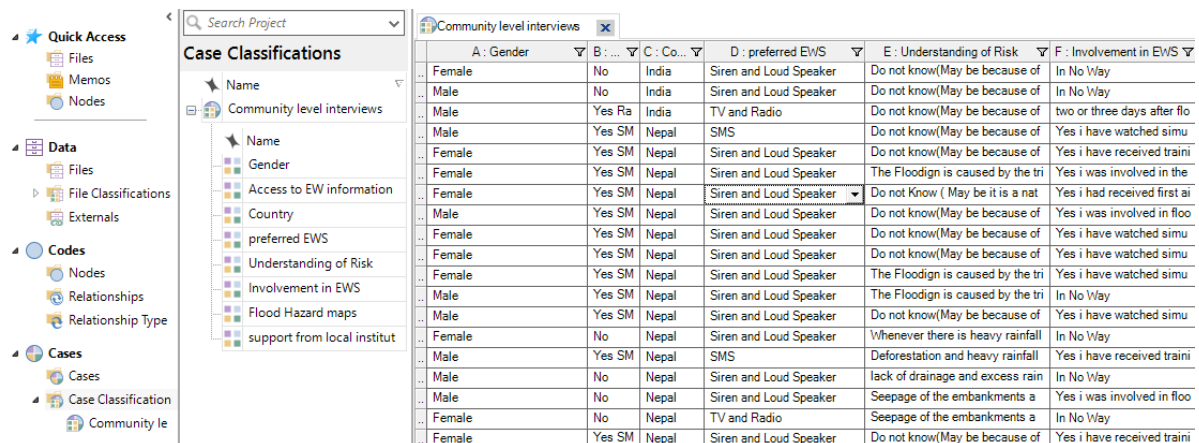


Name	Files	References
SAFE SPACE FOR REFUGE		43
RISK COMMUNICATION		44
UNDERSTANDING RISK		44
the flooding is caused by INDIA as they open the barrage gates		1
flooding is caused by natural causes		1
during monsoon season mountains and hills melt and cause floods		1
no idea about how to improve the EWS		1
flood risk is due to the low lying area of the village		1
the embankment has to be repaired properly to protect us against floods		1
rainfall and deforestation are the main cause of flooding in the Kosi river		2
embankment damage and erosion causes flooding in the kosi river		2
we are in flood risk because our houses are close to the river		2
impact of flood is mainly observed in the rural areas than in the market places		1
after seeing the rising water levels, we know that flood is coming		3
lack of drainage is the main cause of flooding		3
river aggradation causes flooding		6
seepage through the embankments cause flooding		8
high rainfall in the upstream causes flooding in the Kosi River		10
Tributaries of the Kosi River Causes flooding		14
flood comes because of heavy rainfall		16
i dont understand the cause of flooding may be due to the more water in the river		7
dont know about reason for flooding, may be because of the high rainfall upstream		7
INSTITUTIONAL SUPPORT		44
RISK INFORMATION GENERATION		21

Figure 36: Themes generated from community level interview transcripts.

4.6.7.3. Recoding

Following the identification of themes, the researcher proceeded to recode the 44 community-level interview transcript files using case-classification in NVivo. This recoding enabled the researcher to conduct cross-tabulation and perform simple quantitative analysis, presenting the findings in the form of charts and percentages as shown in fig. (37).



Name	Gender	Access to EW information	Country	preferred EWS	Understanding of Risk	Involvement in EWS	Flood Hazard maps	support from local institut
Female	No	India	Siren and Loud Speaker	Do not know(May be because of	In No Way			
Male	No	India	Siren and Loud Speaker	Do not know(May be because of	In No Way			
Male	Yes Ra	India	TV and Radio	Do not know(May be because of	two or three days after flo			
Male	Yes SM	Nepal	SMS	Do not know(May be because of	Yes i have watched simu			
Female	Yes SM	Nepal	Siren and Loud Speaker	Do not know(May be because of	Yes i have received traini			
Female	Yes SM	Nepal	Siren and Loud Speaker	The Floodign is caused by the tri	Yes i was involved in the			
Female	Yes SM	Nepal	Siren and Loud Speaker	Do not Know (May be it is a nat	Yes i had received first ai			
Male	Yes SM	Nepal	Siren and Loud Speaker	Do not know(May be because of	Yes i was involved in floo			
Female	Yes SM	Nepal	Siren and Loud Speaker	Do not know(May be because of	Yes i have watched simu			
Female	Yes SM	Nepal	Siren and Loud Speaker	Do not know(May be because of	Yes i have watched simu			
Female	Yes SM	Nepal	Siren and Loud Speaker	The Floodign is caused by the tri	Yes i have watched simu			
Male	Yes SM	Nepal	Siren and Loud Speaker	The Floodign is caused by the tri	In No Way			
Male	Yes SM	Nepal	Siren and Loud Speaker	Do not know(May be because of	Yes i have watched simu			
Female	No	Nepal	Siren and Loud Speaker	Whenever there is heavy rainfall	In No Way			
Male	Yes SM	Nepal	SMS	Deforestation and heavy rainfall	Yes i have received traini			
Male	No	Nepal	Siren and Loud Speaker	lack of drainage and excess rain	In No Way			
Male	No	Nepal	Siren and Loud Speaker	Seepage of the embankments a	Yes i was involved in floo			
Female	No	Nepal	TV and Radio	Seepage of the embankments a	In No Way			
Female	Yes SM	Nepal	Siren and Loud Speaker	Do not know(May be because of	Yes i have received traini			

Figure 37: Case classification and recoding of community level interview transcripts

4.7. Time horizon and temporal scope of research

This study has focussed on early warnings related to flood hazard in the study area, especially after the Kosi flood of 2008, which was considered the worst river flood in the history of both Nepal and India (Mishra 2008; Dixit 2009; Shrestha et al. 2010). The Kosi flood of 2008

triggered institutional restructuring and policy changes in disaster risk management and EWS in both countries (Dixit et al. 2022); therefore, this research covers the temporal scale of 2008 to 2022 and reflects current issues related to transboundary EWS between Nepal and India in the study area.

The research commenced with a review of the literature in February 2018. Ethical approval for the study was obtained in February 2019, and successful completion of the upgrade examination to PhD status was achieved in May 2019. Subsequently, the researcher devised a plan and initiated data collection activities from mid-May to December 2019 in Nepal and India. A second field visit was initially scheduled for March 2020 to interview central-level government officials and experts in India. However, in early March 2020, travel restrictions and lockdown measures were implemented in response to the COVID-19 pandemic, impeding the planned field visit. Consequently, the remaining interviews in India were conducted via phone calls, Skype, WhatsApp, and Viber applications, albeit with considerable delays. These interviews were eventually concluded by the end of August 2020. Subsequently, approximately seven months were dedicated to data transcription and coding, followed by approximately two months to data analysis. The process of writing the thesis commenced in August 2021 but was significantly impeded by COVID-related health complications, resulting in a substantial delay. Ultimately, the writing process was completed in October 2022, spanning nearly a year.

4.8. Positionality

Skelton (2001, p.89) suggested that it is essential that the researchers need to position themselves within the research as they are not “neutral, scientific observers untouched by emotional and political contexts of research.” Similarly, Sultana (2007) argued that it is critical to pay attention to one’s positionality and reflexivity and power relations inherent in the research process to conduct ethical research, especially in international field research.

Reflecting on the researcher’s position and its potential influence on the study, it is worth noting that being a native of Nepal and possessing fluency in Hindi, Nepali, and local dialects such as Maithili facilitated the researcher’s immersion in the socio-cultural context of the study area during the fieldwork. This linguistic proficiency enabled direct communication with at-risk individuals in their native language, fostering a deeper understanding of the socio-

cultural barriers and capturing the community-level perspectives through 44 community-level interviews and 12 FGDs. Moreover, the researcher conducted 34 in-depth interviews with government officials, scientists, DRR experts, activists, and politicians, engaging with them in their respective languages of Hindi, Nepali, and a mix of English. This linguistic versatility was instrumental in understanding current practices and policies at both the national and transboundary levels. Therefore, the researcher's ability to collect first-hand information by conversing fluently in four languages with individuals at risk, government officials, scientists, and policymakers significantly contributed to the richness and depth of the research.

The researcher's background as a native of Nepal and previous experience working in an INGO for disaster risk management in Nepal, as well as familiarity with the field study area, may have had a latent influence on how research participants approached issues related to transboundary EWS and how the researcher assessed and framed the problems within the study area. Additionally, the researcher's affiliation with a well-known British university, such as being a researcher from the University of London, UK, could have also had a latent influence on the research by providing access to interviews with high-ranking government officials and donor agencies, which is typically uncommon for a general researcher. Some participants in the study mentioned their acquaintance with individuals from King's College London, such as Tony Allen and Naho Mirumachi. As the researcher's name was associated with a British university, it facilitated the opportunity to interview government officials in India, including Assistant District Magistrates and local disaster management officers, who are seldom accessible to researchers. Furthermore, the researcher's affiliation with academia as a politically neutral institution may have fostered a greater level of comfort for expert interview participants to openly share critical comments regarding government systems and working methods with the researcher. These observations made the researcher reflect that the experts might have perceived the researcher as an insider with whom it was safe to share their critical remarks.

Despite conversing in the local language at the community level, the researcher's attire was noticeably different, carrying a camera, a bag, and papers, all indicating the outsider's status. Upon deeper reflection, the researcher realised that the fundamental difference between the researcher of this study and the interviewees at the community level was that while floods held immense significance for the lives and livelihoods of the community members, they did

not have the same personal impact on the researcher. The researcher had the privilege of choice and option in life, whereas the community members did not. Consequently, regardless of the researcher's desires, the researcher could not be considered an insider in that context.

Even though the researcher of this thesis is ethically bound to function as an independent entity, it should also be acknowledged that 148 people at the community level supported this research by contributing their time directly through interviews and many others indirectly, probably with the hope of having a better living condition in the Kosi River basin. Similarly, there might have been many researchers before who had also studied people's vulnerability and hardships and moved on with their life with PhDs; however, for those vulnerable people in the basin, their lifestyle and vulnerability have remained the same as frozen in time, only serving as case studies for researchers and waiting for another researcher to question again. Therefore, it would be more unethical for a researcher if the research does not give back or contributes to improving their situation. The situation could only be improved if the research translates into policies and practices that could be observed in the research context. The researcher also maintains reservations that this research could do any good to people at risk by only publishing papers where multiple barriers limit people from accessing information. Therefore, the research needs to go to the community level to raise awareness and create improvement—in whatever small form. Hence, the researcher of this research would like to position as an independent researcher trying to amplify the unheard voices of the people at risk through this research so that at least some practical outcomes could be achieved to reduce people's vulnerability to transboundary disasters.

4.9. Chapter summary

This chapter presented the research methods implemented in the study area to answer the research question with a theoretical underpinning of pragmatism behind the research design. Along with secondary literature, this research has collected and analysed primary data through field observation, 34 semi-structured open-ended interviews with experts, 44 interviews with people living in the study area, and 12 focus group discussions. The qualitative analysis of the primary data was done through transcription, coding, and theme generation in NVivo 12 software, and the 44 community-level interviews were further recoded to perform cross-tabulation and basic quantitative analysis to present graphically. This chapter has also presented the time horizon and temporal scope of this research covering 2008-2022,

after the Kosi flood of 2008, when policy changes and institutional restructuring occurred in both countries. This chapter also presented the researcher's positionality as an independent investigator trying to amplify the unheard voices through research so that practical outcomes could be achieved to reduce people's vulnerability to disasters. The following chapters, 5, 6, and 7, will discuss the findings of this study.

Chapter 5 Knowledge Co-Production, EWS Institutions, and Flood Affected Communities

5.1. Introduction

This chapter will draw on primary data sources from semi-structured interviews conducted with the disaster management experts and flood-affected people in the study area. The chapter will explore the differing perspectives of disaster management experts working in government institutions and non-governmental organisations (NGOs) regarding community inclusion in EWSs and knowledge coproduction during the risk information generation. In this chapter, “knowledge coproduction” refers to the collaborative process of understanding risk between the disaster management experts who generate the risk information and the people at risk for whom that particular risk information is essential. “Risk information generation” in EWS refers to understanding hazard risks and their impacts in a particular context, including people’s vulnerability and exposure to those hazards. This chapter will also present data from the community level interviews regarding (i) how contemporary institutions include their knowledge in EWSs and (ii) what institutional support is available at the community level for understanding hazard risk. This chapter will seek to understand the following parts of the research question:

SQ.1 How is risk knowledge co-produced between institutions and communities within and across the border in the Kosi River basin?

5.2. Policies and Institutional capacities for EWS

This section is based on the interviews conducted with experts in governmental institutions related to EWS in Nepal and India. It explores the expert’s perspectives on existing policies and institutional capacities for implementing EWS. This section shows that the policies on EWS in both countries do not deal with the institutional constraints at the local level for implementing EWS. The NVivo map generated from the coding of interviews with experts fig. (38) suggests that policies and institutional capacities are unmatched for the implementation of EWS at the national and transboundary levels.

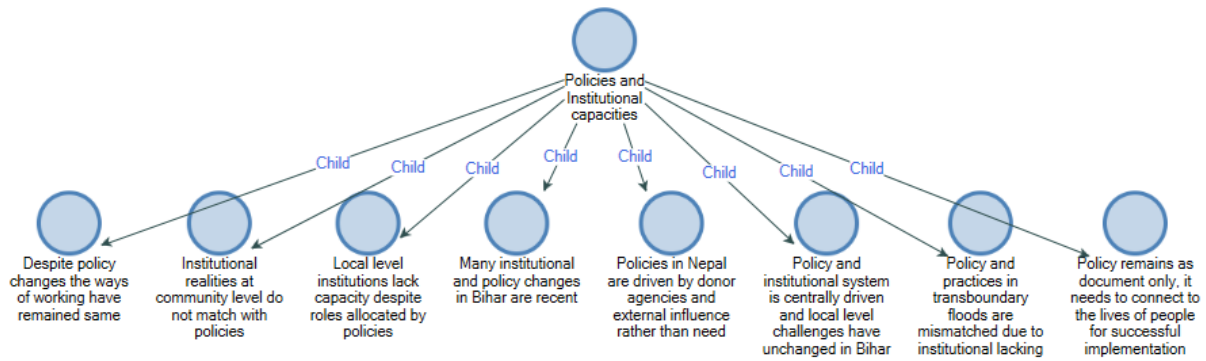


Figure 38: NVivo map showing policy and institutional capacity for EWS.

The experts working in the government of Nepal (E1 and E11) argued that in Nepal, policies on DRM have mandated the overall responsibility of EWS to the local-level institutions; however, those policies have overlooked the reality that local level institutions lack capacities and resources to implement the tasks mandated in those policies. Therefore, local government institutions cannot conduct specialised tasks required in EWS without significant capacity building and resource allocation.

“...The new DRRM act and policies on DRM in Nepal have allocated overall responsibility of DRR and EWS to the local government institutions...the central government has only coordinating roles but no implementing roles...but the local level institutions are newly formed and are already overwhelmed by their routine municipal tasks and have limited budget and human resources...so with the current capacity, it is unrealistic to expect that they will be able to conduct specialised tasks in EWS without support.”(E1)

The above statements by E1 and E11 imply that policies in Nepal do not deal with the constraints at the local level for their implementation without additional support. Similarly, Gupta et al. (2021) argued that both the governments of Nepal and India have failed to formulate practical policies and suitable institutional structures for implementing EWS, due to which the local-level institutions continue to prioritise post-disaster activities over preparedness (see also Ogra et al. 2021). Contrary to the statements by E1 and E11, Russel et al. (2021) on the disaster governance in Nepal argued that the narratives of lack of capacity at the local level are a “plot” to emphasise a normative solution of institutional capacity building from the central to local government institutions to promote external agents’ influence and to reinforce the top-down approach in risk governance. The findings of this

study, however, refute the argument of Russel et al. (2021) in the context of the Kosi River basin, as local level institutions in the study area were found to have insufficient resources (technical and financial) to conduct activities related to EWS, agreeing with the study of Jones et al. (2016) and Gupta et al. (2021). They also argued that in the Kosi River basin, the local government institutions lacked capacity as well as resources related to the disaster preparedness activities at the community level.

The disaster management activists in Nepal (E16 and E30) and an expert working in an INGO (E25) argued that policies and practice are mismatched because—i) the ways of working and the institutional structure for DRR have remained unchanged despite the policy changes; ii) those policies are supply-driven or led by donor agencies based on international commitments rather than based on the need at the local level. E25 argued:

“...In Nepal, everything has changed from monarchy to democracy, but the bureaucracy in Nepal has unchanged from the past to the current federal republic system...institutional arrangements have changed, but the mechanisms have remained the same...it is still functioning top-down and is centrally driven...everything is controlled by ministries...therefore those institutions lack the understanding of need at the local level...” (E25).

Similarly, E16 argued:

“...I think Nepal is the only country in the world which has ratified every policy of UN...MDG, SDG, ISDR, SFDRR, on water, climate change,...you name it...if you go to ministries, you will see cabinets filled with policies, strategies, and action plans...but everything is on paper only; none has been implemented...donor agencies fund them...and government officials ratify everything because they can travel to foreign countries...this is the chronic issue of bureaucracy here in Nepal...” (E16).

Ogra et al. (2021, p.3) used the term “Scale discordance” in the institutional and policy context, which refers to a mismatch between the existing policies or knowledge and the unique context of their implementation and decision-making (Gordon et al. 2016). The authors argued that while downscaling the global policies to the local context, the uniqueness of the context requiring specific interventions is often missed; therefore, those policies would

be less helpful in solving the local problems. The findings of this study also suggest that scale discordance exists in the context of DRM and EWS in Nepal, where the policies and institutional context does not match with the local realities for implementation.

While in Bihar, an Additional District Magistrate (E27) mentioned that many institutional restructuring and technological developments in Bihar have only occurred in the last five years, and the Kosi flood of 2008 was the main reason behind the changes. Similarly, Jones et al. (2016) have also asserted that the Kosi flood of 2008 acted as an event that opened eyes about the institutional and capacity deficiencies in the Bihar state government, which resulted in institutional restructuring and focus on flood preparedness, which are evident by the policy reforms and capacity building activities. At the national level also after 2008, the disaster management policy was formulated in India—suggesting paradigm shift from disaster response and relief focus to the overall disaster management and managing risks; and in 2010 the Standard Operating Procedures (SOP) for the flood preparedness and response was prepared in India. Initially, the Revenue Administration Department conducted disaster management activities in Bihar, but after 2008 the Disaster Management Department was established as a separate entity. Therefore, policy formulation was the main priority after the Kosi floods, after which the government's focus is gradually shifting from policy updates to capacity building of the government employees on disaster risk management. In addition to these, the Mukhiya Bikas program and Apada Mitra programs were also launched in Bihar to train village Mukhiyas on warning dissemination to the communities. Therefore, institutional development and awareness-raising activities are of current focus in Bihar.

Contrary to the statements by E27, the local activist (E28) and a local NGO worker in Bihar (E29) argued that despite the changes in policies, the institutional systems in Bihar have remained unchanged because it is still centrally managed, top-down, and involves extended hierarchy of institutions, where the focus is still on disaster management rather than on preparedness.

"...The problem in Bihar is that everything happens on paper only, but not in reality...the government officers have been saying that they have been implementing early warning systems in the Kosi River basin for the last twenty years...nobody knows where they have implemented what...they must have implemented it in papers..." (E29).

The above argument also agrees with Orga et al. (2021), suggesting that despite policy changes, the DRR governance in India is a disaster response focussed, and policy changes do not translate into the ways of working at the local level for their implementation. In the same way, Sinha et al. (2012) also stated that Water Resource Department (WRD) in India is the apex institution for flood risk management. However, due to institutional mandates, it is not authorised to issue flood warnings directly to at-risk people. It must pass warnings through state-level departments, then to the district, and village-level authorities, involving a long chain of institutional hierarchies. Ogra et al. (2021) further argued that overcoming the gaps between policy and action requires a situated understanding of disasters and institutional reality at the local level.

This study has found that, in Bihar, the institutional restructuring and technological developments occurred after the Kosi flood of 2008, which acted as an eye-opener and revealed institutional and capacity deficiencies for disaster risk management at the national, state, and local levels, triggering institutional restructuring and policy updates for flood early warning (Dixit et al. 2022; Gupta et al. 2021; Mishra 2008).

This section showed that policies in both countries do not match the practicalities of institutional capacities at the local level for their implementation; therefore, despite the availability of policies, the local level institutions continue to prioritise post-disaster activities over preparedness. The following section will explore the different approaches by Nepal and India towards EWS in the Kosi River basin.

5.3. Different approaches towards EWS in the Kosi River basin

This section presents interview data from experts affiliated with governmental institutions and non-governmental organisations (NGOs) involved in the EWS implementation in Nepal and India. This section provides details on the engagement of different actors, their approaches, and the complexities surrounding the transboundary EWS fig. (39). Findings reveal that in Nepal, people's involvement in the EWS is primarily limited to verifying ground information and participating in awareness-raising activities led by donor agencies and NGOs. Conversely, in Bihar, at-risk individuals are excluded from participating in the EWS. Moreover, the section highlights that in both countries, government institutions responsible for

generating warnings operate in isolation from the at-risk population and disseminate warnings through a top-down approach.

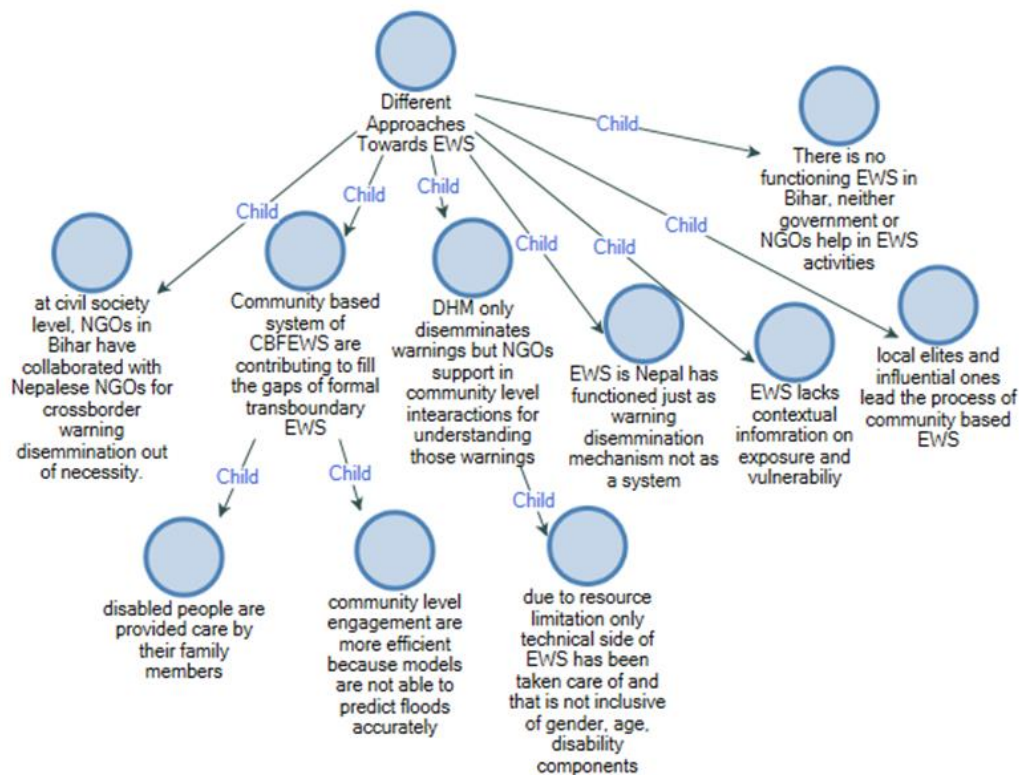


Figure 39: NVivo map showing different approaches for EWS by Nepal and India in transboundary Kosi River basin.

Mahmud et al. (2012) and Keoduangsine and Goodwin (2012) have emphasised the disconnection between warning-generating institutions and implementing communities, resulting in ineffective EWS that lack vital contextual information, including people's vulnerability, exposure, and access to technology. Additionally, experts in disaster risk reduction (DRR) from international non-governmental organisations (INGOs) interviewed for this study (E9 and E23) argued that "EWS in Nepal does not even qualify to be defined as an early warning system" (E9) because it only functions as a one-way warning disseminating mechanism from the central to the community level and "lacks the essential components of EWS such as understanding people's vulnerability and exposure to hazards" (E23). The interviewees further highlighted that the DHM generates hazard information independently of the at-risk population, disseminates warnings without considering their accessibility or comprehensibility, and expects immediate action from those at risk.

According to an expert from an NGO in Nepal (E24), the DHM solely focuses on disseminating warnings regarding imminent hazards in the Kosi River basin. At the same time, NGOs provide

support by facilitating community-level interactions to enhance the understanding of these DHM warnings.

“...In our project areas, we tell them (people at risk) that they will receive the flood warnings from DHM in their mobile through SMS, and if the SMS says Warning level, then do certain activities and if it says Danger level then evacuate to the higher ground...” (E24).

The above quote from E24 implies that the people at risk in Nepal, who need warnings at the earliest, are involved at the last stage in the EWS as an add-on component (Zommers and Singh 2014); also, the EWS appears as a one-way flow of information, where warnings are ‘given’ to the people at risk (Callon 1999), without the flexibility to incorporate feedback from them (Kelman and Glantz 2014).

In contrast, local activists (E28) and (E29) in Bihar revealed that no effective EWS reaches the individuals at risk, and government institutions and non-governmental actors do not consult or inform them about capacity-building or awareness-raising activities for EWS. Consequently, NGOs in Bihar have collaborated with Nepalese NGOs, out of necessity and through community-level initiatives, to establish networks of upstream and downstream communities in the Kosi River basin using WhatsApp as a means of creating a community-based EWS (as discussed in Chapter 6, Section 6.2.1). NGO workers in Nepal (E21) and Bihar (E29) confirmed that certain international NGOs in Nepal, such as LWR and ICIMOD, work on a limited scale with transboundary communities in the Kosi River basin to establish informal EWS. These findings indicate that warnings from the DHM in Nepal cross the porous India-Nepal border through civil society initiatives to reach Bihar, compensating for the region’s lack of transboundary EWS.

Considering the system’s future development, an expert from a multinational research institution (E4) suggested that a community-based flood early warning system (CBFEWS) could address the shortcomings of transboundary EWSs in the Kosi River basin. E4 highlighted the importance of involving at-risk communities in Nepal and India through community-level meetings, key informant interviews, and focus group discussions (FGDs) to assess their needs and understanding the social and cultural context in which the warnings will be disseminated. Conversely, Gupta et al. (2021) have argued that while community-based EWS may benefit

specific at-risk individuals in Bihar, it contradicts the Indian government's top-down and formal EWS implementation strategies (also discussed in Chapter 5, Section 5.2.3). Furthermore, during the interview, E4 mentioned that local leaders and elites play a role in facilitating community interactions for the CBFEWS, with influential figures such as landlords assigning responsibilities to the participating individuals.

"...We sit with the locals and work with the local elites to assign people's roles in CBFEWS while preparing call trees for communication and assigning their roles like who will be taking care of the equipment, who will be doing what, and who will be reporting to whom...as we do not know much about them, we cannot assign fitting roles for those people...neither do we have time for it...Therefore, we work with local elites, who would be someone influential in that village, and whose orders everyone will obey..."(E4).

Furthermore, an expert working in INGO in Nepal (E12) also stated that local elites help invite participants and serve as key informants during the community level interactions for EWS. Similarly, another expert working in INGO in Nepal (E23) stated that *"mostly, influential ones in the community speak more in the meetings, but others are shy to talk...we do not know if those consultations were meaningful ...it needs critical assessment"* (E23).

The above quotations by participants (E4, E12, and E23) indicate that although CBFEWS may seem collaborative and an alternative to formal EWSs, there is a risk of elite capture, whereby local elites or powerful individuals in the community can manipulate the process for their own benefit. This aligns with the findings of Mansuri and Rao (2013) and Schipper et al. (2014), who argued that participatory projects led by NGOs may mask existing inequalities and fail to ensure the representation of marginalised groups. Similarly, in the Kosi Basin in Nepal, local elites play a significant role in facilitating community-level participatory projects conducted by NGOs, suggesting a likelihood of elite capture. This finding is consistent with the study by Adhikari and Goldey (2010), highlighting the prevalence of elite capture in community-based projects in Nepal, which is often overlooked by NGOs. Furthermore, Jones et al. (2014) emphasised the disregard for power asymmetries and differing interests among involved groups by donors and NGOs, which contributes to elite capture in NGO-led activities in Nepal. Consequently, seemingly participatory activities conducted by NGOs at the local level may

inadvertently exacerbate vulnerabilities by disregarding social differences and inequalities, as noted by several scholars (Gladfelter 2018; Marston et al. 2016; Titz et al. 2018).

These findings indicate that NGOs in Nepal focus on awareness-raising activities, whereas in Bihar, neither NGOs nor local government authorities undertake capacity building or awareness-raising activities at the community level. In Nepal, the efforts of NGOs and donor agencies contribute to raising awareness to some extent. A comparative study by Jones et al. (2016) on disaster governance in Nepal and Bihar also revealed significantly higher awareness levels in Nepal due to NGO-driven awareness activities. However, the authors noted that NGO and donor involvement has led to dependence at the local level, and the sustainability of these activities remains a challenge, as local governments have not been able to institutionalise them through their own resources. Hence, awareness at the local level in Nepal could be sporadic and dependent on the availability of support from donors and NGOs. Mansuri and Rao (2013) similarly argued that non-state actors (donors and NGOs) cannot replace non-functioning state actors (local government institutions) in the long term, and collaboration between donor agencies and local governments is necessary to institutionalise these practices within the formal government system.

These study findings suggest a lack of knowledge co-production between government scientists responsible for generating warnings and the at-risk population in the study area. Numerous scholars (Wisner 1995; Mahmud et al. 2012; Keoduangsine and Goodwin 2012; Kelman and Glantz 2014; Parker 2017; Imperiale & Vanclay 2019, 2020; McLindin 2019; Perera et al. 2020) have highlighted that the disconnection between EWS institutions and the at-risk population hinders the contextual understanding and appropriate response to warnings. Similarly, this study reveals that EWS institutions in Nepal and India generate warnings externally, without incorporating feedback from the at-risk population, thereby limiting opportunities for knowledge co-production within the EWS.

This section highlighted the linear and one-directional approach of the EWS in Nepal, where warnings are issued to at-risk individuals without soliciting feedback. Although some NGOs in Nepal undertake information dissemination and awareness-raising activities at the community level through donor-funded projects, these activities are limited in scope and tied to specific projects. Conversely, Bihar lacks an effective EWS that reaches the vulnerable population, leading to the collaboration between NGOs in Nepal and Bihar to establish

informal, community based EWS as a response to the absence of early warnings in Bihar. While community based EWS presents a potential alternative for future development, there are concerns regarding the representation of the most vulnerable individuals, as local elites predominantly lead the process. The subsequent section will explore the co-production of knowledge in the risk information generation for EWS in the Kosi River basin.

5.4. Knowledge co-production and public participation in EWS

This section presents the perspectives of experts working in government institutions regarding EWS. It reveals that experts in central government institutions expressed scepticism towards involving the public in the risk information generation process, focusing instead on enhancing the technical aspects of warnings to improve the effectiveness of EWS, without actively collaborating with people at risk. The fig.(40) shows the themes regarding the knowledge coproduction in the EWS in Nepal, India.

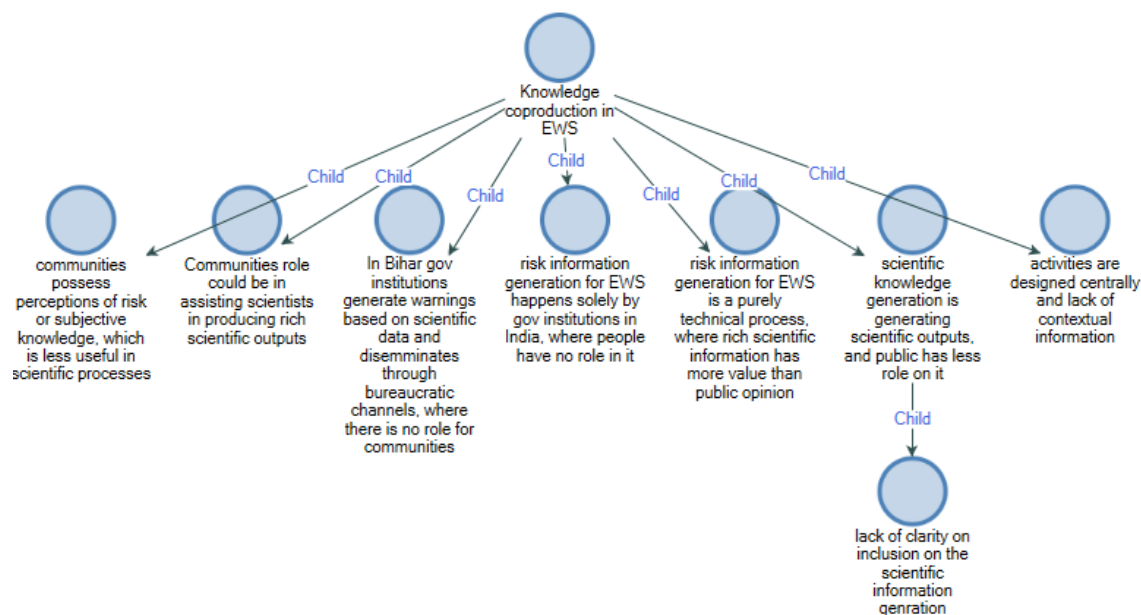


Figure 40: NVivo map showing Knowledge coproduction in EWS and complexities relating to it based on the coding of expert interviews.

The concept of knowledge co-production in the risk information generation process of EWS involves the active participation of people at risk from the initial design stages. This collaborative approach brings together scientists, people at risk, and other stakeholders to exchange ideas and information, fostering a comprehensive understanding of hazards and their potential impacts within a specific context (Hamza and Mansson 2019; Kelman and Glantz 2014). Consequently, knowledge co-production in the generation of risk information for EWS can be viewed as a sense-making process, where diverse knowledge sources from

different sectors contribute to a collective understanding of risks and realities (Ansell and Boin 2019; Beckert 2003; Duymedjian and Rüling 2010; Evans 2000; Shields 2008; Simpson and Hond 2022).

During interviews, Nepalese government officials expressed scepticism regarding the inclusion of local communities in the risk information generation process of EWS and their potential contribution to scientific understanding. A flood management expert from a government institution (E8) was uncertain about local communities' role in generating risk information for EWS. However, E8 suggested that at-risk communities could assist experts by verifying scientific outputs or monitoring embankments for potential breaches. These statements indicate a lack of community inclusion in EWS, although the expert acknowledges the potential for people at risk to provide valuable contextual information for enhanced decision-making. Similarly, Sai et al. (2018) highlighted the value of local knowledge in the technological aspects of EWS, such as localising flood warnings and forecasts, to address the limitations of generalised forecasting with more localised flood impact-based information. Another expert from the flood monitoring department in the DHM (E5) stated that DHM's work is mainly in the scientific knowledge generation, and "of course, in the scientific process, there is less role for the public" (E5). Despite a significant body of literature emphasising the importance of social context (e.g., Imperiale & Vanclay, 2019, 2020; Kelman and Glantz 2014; Wisner 1995), the statements by E5 indicate an expert perception that risk information generation in EWS is disconnected from the people at risk.

Similarly, an expert from the Water Resource Department of Nepal (E11) was also sceptical about people's involvement in EWS during the risk information generation process and argued that local communities have "some knowledge" about their settings; however, "*their knowledge is subjective and based on feelings and emotions they have experienced rather than the objective facts*" (E11). Contrary to those perceptions, Lupton (1999) and Donovan and Oppenheimer (2014) argued that experts' understanding of the world could not be purely objective, as it involves judgements, assumptions, and uncertainties in every scientific understanding. It can be argued that these views by experts are problematic as it precludes knowledge co-production and collaboration with at-risk people.

Another government official from the National Disaster Risk Reduction and Management Authority (NDRRMA) (E20) also argued that risk information generation for EWS is a purely

technical process, where rich scientific information has more value than the information received from the public.

“...I think for preparing the hazard maps and models related to EWS, you do not need to involve communities. It is purely a hydrological modelling exercise. What you need are detailed sections, remote sensing, and high-resolution imagery. Also, the Kosi River is complex, where massive energy is dissipated to the plains and river shifting occurs. We need advanced models there...how can community participation contribute to those scientific understandings?” (E20).

The above quote by E20 and the interviews with experts in government institutions (E8, E5, E11, and E20) suggests that experts have understood that EWS as a technical process and emphasised technological components in EWS rather than the social components (people at risk and their socio-cultural context) (Hamza and Mansson 2019). As further discussed in sections 6.2.2 and 6.2.3 of Chapter 6, the focus on technological components in EWS is problematic as it runs counter to the arguments by extensive scholars (e.g., Kelman and Glantz 2014; Hamza and Mansson 2019; Imperiale and Vanclay 2020; Paton 2008) and precludes knowledge co-production in EWS. Those authors argued that no matter how accurate the warnings are, if it is not correctly interpreted, understood, and acted upon, EWS will not be effective; therefore, the focus of EWS should be on people rather than technology. Similarly, Kelman and Glantz (2014) argued that constricted and entrenched view of EWS as a technical process, where experts remotely give warnings to people at risk to act upon, reinforces the top-down approach and assumes EWS as a linear and end-to-end process of moving between the two ends (experts and people at risk) without any opportunities for feedback. Therefore, “end-to-end-to-end” is needed in the EWS to allow multiple feedback loops and collaboration between experts and people at risk (Kelman and Glantz 2014).

Parker (2017) has argued that excluding the people at risk during the risk information generation process can aggravate the vulnerability of the most disadvantaged communities. Similarly, this study has found that in Bihar, the knowledge co-production and community inclusion in EWS are non-existent. An Additional District Magistrate (E27) and a local activist in Bihar (E26) stated that the Indian meteorological department (IMD) is the lead agency that generates the hydro-meteorological forecasts based on rainfall parameters and passes them to the Central Water Commission (CWC), which generates flood warnings based on the river

data and information received from IMD. Furthermore, the flood warnings from the CWC then pass through the chain of state and district-level government institutions for dissemination to people at risk and implementation of warnings into action. E26 added that IMD and CWC work in complete isolation from local governments and people at risk during risk information generation for EWS, and there is no mechanism for people at risk to have upward communication with the central-level institutions that generate warnings. E26 and E27 imply that early warnings in Bihar follow a centralised and top-down approach and are disconnected from at-risk people. McLindin (2019) and Perera et al. (2020) have also asserted that India's centralised warnings system fails to reach the vulnerable and most at-risk people in Bihar because the institutions that generate warnings are disconnected from the socio-cultural context of people where the warnings will be disseminated, thereby putting vulnerable and marginalised groups at significant risk of flooding.

During the interview, E27 tried to justify that EWS can only be successfully implemented if it follows the formal government channels in Bihar. E27 also emphasised the need to capacitate the local government officers and village Mukhiyas to disseminate the warnings quickly rather than collaborate with the people at risk. The arguments by E27 imply that he has understood EWS as a linear process of hazard warning from central level institutions to the people at risk. As discussed in Chapter 6, Section 6.2, many scholars have argued that the top-down approach of early warning from central government institutions without understanding the local context precludes the possibility that warnings will reach the people at risk or be implemented in the desired manner (Imperiale and Vanclay 2021; Kelman and Glantz 2014).

This section showed that people at risk are excluded from the risk information generation process in both countries, and knowledge co-production is non-existent. Furthermore, the experts working in government institutions that generate risk information and warnings were sceptical that people's inclusion in the risk information generation process could add any value to the EWS. Therefore, in the linear and top down EWS implemented in the Kosi River basin, people at risk are only passive recipients of the hazard information. The following section will explore how the early warning institutions communicate hazard risks and to the people at risk.

5.5. Early warning Institutions and uncertainties

This section focuses on interviews conducted with experts in government institutions responsible for generating and disseminating warnings to individuals at risk in the Kosi River basin. The subsequent discussion demonstrates that although flood forecasts of up to three days are available in Nepal and India, these forecasts were primarily utilised for disaster response planning rather than being communicated to the at-risk population. In Nepal, government officials only share warnings 1 to 2 hours before anticipated floods, aiming to prevent potential false alarms due to the geographical and hydro-meteorological complexities of the Kosi River basin. Additionally, these officials expressed reluctance in conveying model uncertainties to the at-risk individuals, citing concerns related to the erosion of public trust and potential reputational risks for the institutions involved fig. (41).

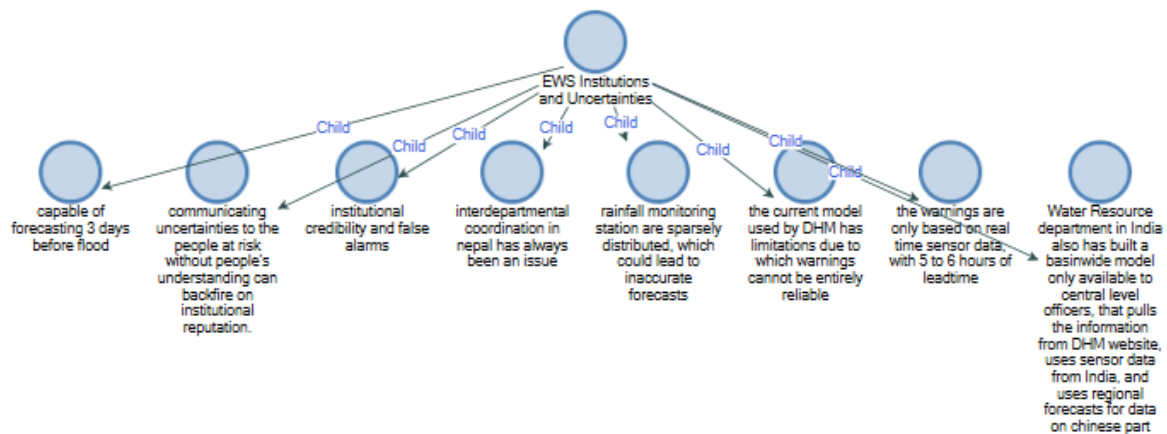


Figure 41: NVivo map showing EWS institutions and how they manage uncertainties in EWS .

The expert from the DHM (E6) stated,

"...Initially, we only had observation-based systems, but after 2015, we started using global forecast models. In 2017, we started developing our computer model called Mike-11. The test runs were done for two years to calibrate the model, but after 2019, we operationalised the model for flood forecasting. Currently, the model has three days of lead time for the Kosi River basin..." (E6).

Furthermore, another expert from DHM (E14) stated that only the warnings based on real-time river sensors are disseminated to the people at risk through SMS and displayed on the DHM's website.

“...In Kosi, we have three days flood forecasting system available...However, the warning SMS we send to the public needs to be 100 per cent correct.....we have not sent the SMS warning based on the forecast model’s output until now...we only use real-time sensor data because it is 100 per cent accurate...The forecast model’s output is for us to have early information, and it also helps the disaster response actors for their planning...”(E14).

Furthermore, the E6 argued that, in the Kosi River basin, the rainfall monitoring stations are, *“sparsely distributed and cannot always forecast floods accurately due to the high rainfall variability and rugged terrain of the basin”* (E6); therefore, the forecast model cannot be solely relied upon for informing the people at risk to warn and evacuate, as this could lead to the *“...misinformation to the public...”*.

Similarly, E14 added that the warnings sent by DHM need to be *“100 per cent accurate...otherwise, no one will believe the DHM next time when they see our warnings”* (E14), therefore the SMS warnings are sent based on the real-time sensors’ data only, to avoid false alarms, perceiving that it could breakdown the institutional reputation and the public’s trust. Moreover, the DHM officials verify the river sensor data with gauge readers before disseminating the warnings, to ascertain that there are no errors, further decreasing the lead times to up to one to two hours.

The quotes from DHM experts suggest that although warnings with a three-day lead time can be provided to individuals at risk, government officials opted to issue warnings with only 1 to 2 hours of lead time to avoid false alarms. Additionally, the view expressed by E14 regarding the real-time sensors being *“100 per cent accurate”* is problematic, considering their spatial limitations. Furthermore, the experts’ statements highlight concerns about the definition of a warning, as warnings can only indicate the likelihood of an event to a certain extent (Rollason et al. 2018) rather than guaranteeing a flood.

When questioned about the reasons behind the DHM’s failure to disseminate warnings based on three-day forecasts, including the associated uncertainties, to provide individuals at risk with more lead time, E14 stated that *“...to do that first they need to know about the concept of model uncertainty ...which is highly specialised concept...and I don’t think most people at the community level would understand that...and doing that can also cause backfire because*

people may think why is DHM not able to produce accurate warnings ...so it can also backfire on our image in public...and people may not take our warnings seriously” (E14).

According to E8, an expert from the flood forecasting department of DHM, the Mike-11 model used by the department has certain limitations. It can only forecast rainfall-induced floods in the Kosi River during the monsoon season and cannot predict floods occurring at other times of the year, as it is only run during the monsoon season. Additionally, the model cannot forecast floods caused by embankment failure, such as the 2008 Kosi disaster, and does not account for recent constructions upstream that can impact flow dynamics, such as roads, culverts, canals, or other drainage structures. These limitations significantly affect the accuracy of the model’s outputs. These statements from E8 suggest that the experts at DHM were aware of the model’s limitations in flood forecasting, which could contribute to the DHM’s decision not to disseminate warnings based on the forecast model.

The above arguments suggest that the officials at DHM prioritised avoiding false alarms and protecting institutional reputation and public trust over providing timely warnings with uncertainties to the people at risk. Their concern about model uncertainties potentially leading to false alarms led them to rely on real-time river sensors for flood warnings, which they considered more accurate but resulted in significant delays. Moreover, before issuing warnings, the DHM officials cross-verified the river sensor data with gauge readers, reducing lead times to 1 to 2 hours. This finding aligns with Demeritt and Nobert’s (2011) study on flood early warnings, which revealed a consistent preference for certainty over timeliness among forecasting agencies. The authorities in these agencies opted for “nowcasting” based on real-time river gauge measurements as they were perceived to provide better data and greater certainty of flood occurrence (Demeritt and Nobert, 2011, p.130). This institutional aversion to false alarms stemmed from concerns about institutional reputation and public trust.

This finding also relates to Donovan and Oppenheimer (2014), where scientists expressed concerns about false alarms and the potential impact on people’s response to future warnings. Scientists also hesitated to communicate uncertainties in their assessments, fearing that the public would perceive the findings as unreliable due to the high uncertainty. However, the authors argued that managing uncertainties, including scientific and context-based social uncertainties, is possible through reflexivity (acknowledging scientific limitations)

and transparency (communicating uncertainties and limitations by involving people at risk). Other studies, such as Fischhoff and Davis (2014) and LeClerc and Roslyn (2015), support this argument, suggesting that communicating uncertainties in warnings enhances risk understanding and improves response actions during disasters. Nevertheless, scholars like Mileti et al. (2004), Spiegelhalter and Riesch (2011), and Shanahn et al. (2019) propose that communicating uncertainty alone does not yield significant differences because “people do not think in probabilities” (Mileti 2004, p.3). Therefore, it is crucial to translate uncertainties into narratives and recommended actions that align with people’s understanding. These arguments collectively highlight the importance of timely communication of warnings with scientific uncertainties, conveyed through narrative-based recommended actions, for effective transboundary EWS.

The findings of this study align with the study by Budimir et al. (2020) in Nepal, who also argued that DHM officials lacked confidence in the reliability of weather forecasts, showed concerns over false alarms leading to the breakdown of trust, and were unwilling to communicate the uncertainties in the forecasts in their study of EWSs in Nepal. Building on Budimir et al. (2020), this study has also found that the government officials were sceptical about communicating uncertainties along with warnings because the officials perceived that the public could understand those model uncertainties as institutional deficiencies or lack of capability to generate accurate warnings, which may give the impression that DHM warnings are unworthy to act. This perception supports the argument that DHM officials are more concerned about institutional reputation and public trust than timely warning dissemination.

In Bihar, all the interviewees at the local level were unaware that the central government institutions in India used forecast models to generate flood forecasts or warnings in the Kosi River basin. However, one expert from the Ministry of Energy, Water Resource, and Irrigation in Nepal (E2) stated that the Water Resource Department of Bihar also had developed their flood forecasting model called Flood Monitoring Information System (FMIS) for the Kosi River basin, from the funding support of the World Bank Group. The FMIS model includes the whole of the Kosi River basin, which automatically draws data from global forecasts for the rivers of China, draws real-time river data from the DHM website for rivers in Nepal, and uses real-time river station data in India to forecast floods in the river basin with three days of lead time. However, E2 added that the FMIS model’s outputs are accessible only to India’s central

and state government institutions for planning disaster response activities. This finding suggests a lack of interdepartmental coordination and isolation of warning generators from the local government institutions in Bihar, which agrees with the extensive literature on disaster governance in India (e.g., Acharya and Prakash 2019; Chakrabarti et al. 2011; Goyal 2019; Nanditha and Mishra 2021; Nath 2019; Ogra et al. 2021).

This section showed that flood forecasting models in Nepal and India can forecast floods three days in advance; however, government officials only use those flood-forecast models' outputs for disaster response planning. In Nepal, the government officials that generate and disseminate warnings were sceptical about the forecast model's accuracy due to multiple uncertainties; therefore, warnings were disseminated to the people at risk based on real-time river sensors' data to avoid possible false alarms. The following section will explore the roles of non-government actors in EWS in the Kosi River basin.

5.6. The role of non-governmental actors in EWS

In this section, data from interviews conducted with experts from non-governmental organisations and donor agencies highlights cross-border disparities in access to warnings for at-risk populations, stemming from the different roles played by NGOs and donors in the two countries as shown in fig. (42). Specifically, the section demonstrates that in Nepal, donor agencies and NGOs take the lead in community inclusion for awareness-raising activities and understanding of warnings sent by DHM. However, these activities by NGOs and donors have been irregular, small-scale, and project based. In contrast, in Bihar, the involvement of donors and NGOs is less significant than in Nepal, resulting in inadequate access to warnings and awareness at the community level.

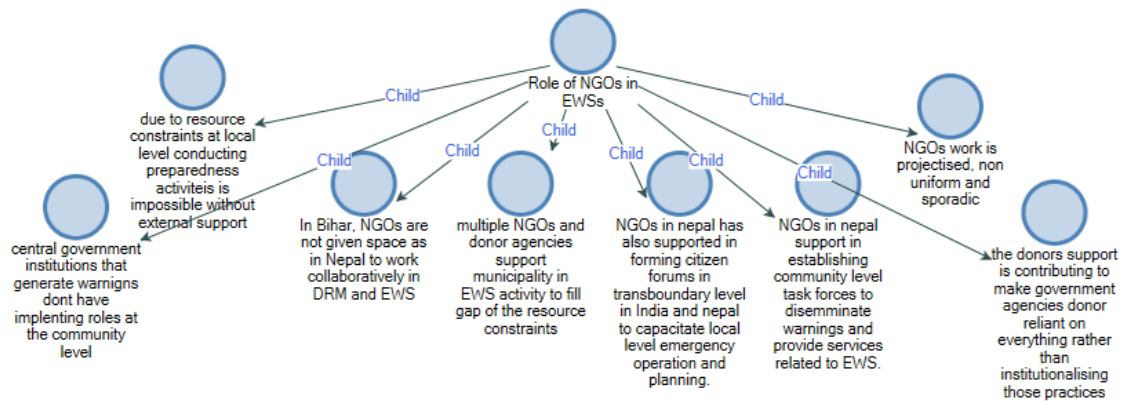


Figure 42: NVivo map showing the role of NGOs in EWS in Nepal , India and in the transboundary context between the two countries.

The government officials in Nepal (E1, E6, E11, and E14) argued that government institutions that generate warnings in Nepal do not have direct contact with the communities at risk because the institutional structure of Nepal is designed in such a way that the central governmental institutions are only given the supporting roles while local government institutions have the implementing roles in EWS. Furthermore, E14 stated:

"...We have not been able to work with the flood-affected communities directly...that is our constraint, and we expect NGOs to support us, but it is not happening in a meaningful way because they are too much donor-driven...also there are too many duplications and gaps in their work..." (E14).

According to experts from a donor agency (E22), an INGO (E25), and a local NGO worker (E7), multiple donor agencies in Nepal are engaged in awareness-raising and capacity-building activities related to EWS to compensate for resource constraints at the local government institutions. Panday (2013) supports this finding, noting that the Nepalese government receives 60 per cent of its disaster preparedness budget from bilateral and multilateral donor agencies, which is implemented by NGOs due to the limited capacity of local government institutions.

The CEO of a municipality in Nepal (E31) suggested that donor agencies and INGOs support EWS activities in Nepal, including regular training, mock drills, and simulations. These agencies also help stockpile relief items at the municipal and community levels. According to the same expert, community task forces are formed and trained in each ward for disaster preparedness

and emergency response. Similarly, a local NGO worker in Nepal (E7) mentioned that community-level task forces were established through donor support to disseminate warnings, provide first-aid treatments, conduct search-and-rescue operations, and support the evacuation of vulnerable people, including children, the elderly, the disabled, and lactating and pregnant women. Additionally, a ward chairman from Nepal (E32) argued that resource constraints limit flood preparedness activities. However, with the support from donor agencies and NGOs, such activities are possible at the community level.

However, E22 and E25 argued that community task forces are only established in a limited number of project areas supported by donors and are not uniformly practised in the Kosi River basin:

“... When there are EWS projects by donor agencies, community inclusion happens based on specific mandates of the project, but those things have not been a uniform and continuous practice in the Kosi River basin, because local level government institutions have not been able to sustain those activities through their own resources ...” (E25).

The above quote by E25 implies that multiple donor agencies are involved in Nepal to make up for the resource constraints at the local level to conduct awareness-raising activities related to EWS; however, those interventions have become unsustainable, as the local level institutions have not been able to institutionalise those practices. Mansuri and Rao (2013) argued that donors’ involvement alone could not substitute for the non-functional local-level institutions, and donor agencies must collaborate with local institutions to make them responsible for sustainable development interventions.

Another expert from a donor agency in Nepal (E15) criticised the risk governance mechanism in Nepal, stating, *“we are here to support the government, we are not here to create a parasite...the problem in Nepal is, they want donors’ support in everything and forever...”* (E15). Furthermore, E15 argued that the problem in Nepal is the government’s desire for donors’ support in EWS indefinitely. According to E15, donor agencies should only inform governments about available technologies; if deemed useful, the government should allocate resources to sustain them. However, local-level institutions in Nepal have become overly reliant on donor support, leading to challenges in sustainability and continuity of activities

after the donor's exit. This argument is supported by Jones et al. (2016), who compared the disaster governance systems of Nepal and India and found that the government of Nepal has become dependent on external institutions for DRR activities.

In Bihar, a DRR expert from a policy institution (E25) and a local NGO worker (E29) argued that non-governmental actors in Bihar are less involved in DRR and EWS activities than in Nepal. They attribute this to disaster management policies in India, which prefers formal governmental channels for implementing such activities. Without clear policies, collaboration with NGOs is contingent upon government officers' attitudes and perceptions towards NGOs.

"...In Bihar, the NGOs are not given space for collaboration as in Nepal, and it also depends upon the attitude of local government officers. The previous local level officer was supportive for NGOs to collaborate ... but now there is a posting of a new officer who believes that government structure is self-sufficient and does not need support from NGOs...If you tell him anything regarding collaboration, he becomes very angry..." (E29).

The statements made by E29 suggest that the involvement of non-governmental actors in DRR and EWS is less significant in Bihar than in Nepal, likely due to the lack of collaboration between the state and local government institutions and NGOs, as highlighted by Jones et al. (2016). This lack of collaboration also resulted from impractical institutional structures, limiting the ability of local institutions to allow non-government actors to lead these activities. This finding is consistent with a recent study by Syal et al. (2021) that highlighted NGOs' ad-hoc and inconsistent involvement in disaster governance activities in Gujarat, Delhi, and Bihar. The authors of the study argued that policies in India restricting NGOs from accessing foreign funds for development had been a significant constraint in limiting NGOs' involvement in Bihar. Additionally, Jones et al. (2016) suggested that factors such as India's higher wealth, lesser financial constraints at the local level, and a history of ethnic conflict, lawlessness, and corruption make Bihar less attractive to international NGOs and donor agencies for involvement.

This section highlighted that donor agencies and NGOs lead capacity-building and awareness-raising activities in Nepal due to resource constraints at local-level governmental institutions. However, these activities could be more uniform, project-based, and donor-driven. In

contrast, in Bihar, the involvement of non-governmental actors in EWS is less significant than in Nepal. Both governmental institutions and non-governmental actors are inactive in capacity-building and awareness-raising activities related to EWS. The following section will examine the policies and institutional capacities related to EWS in the study area.

5.7. Reflections from people at risk

The following sections present the data from the 44 interviews conducted at the community level in the study area. The following section, 5.7.1, deals with people's responses on how they have participated in the EWS and 5.7.2 deals with what form of information and institutional support is available at the community level.

5.7.1. People's participation in EWS activities

This section highlights the limited community participation in EWS in Nepal and India. Although some NGOs in Nepal involve people at risk in EWS awareness-raising activities in areas supported by donor agencies, overall community involvement in risk information generation for EWS is lacking in both countries. In Bihar, people at risk do not have the opportunity to participate in any EWS-related activities conducted by either NGOs or governmental institutions.

The community-level interviewees unanimously reported that government institutions in Nepal and Bihar do not involve or consult with people in EWS activities. However, some interviewees from Nepal mentioned that only some local NGOs and Red Cross agencies involve communities in awareness-raising activities and provide food support during disasters. In contrast, those from Bihar reported receiving support only in post-disaster situations from local government institutions. The following are some quotes from community-level interviews conducted in Hanuman Nagar (Nepal) and Kamalpur (India).

"...Governmental organisations do nothing here; they do not consult, involve, or give training. At least the NGOs do something for us, but the municipality or wards does nothing...NGOs give training before floods, conduct street dramas and flood simulations, as well as provide puffed rice, chow-chow (ready to eat noodles), and biscuits to eat during floods..." (C37, Hanumannagar, Nepal).

“...Government do not involve us in anything...they do not even come here or talk to us before flooding...they only come here after a flood occurs...usually they come in 3-4 days after flooding, until then we must keep ourselves alive... 3-4 days after flooding, government institutions come to take stock of the damage and provide relief materials...” (C44, Kamalpur, India).

In the community level interviews, 45 per cent (20) of the interviewees (19 from Nepal and 1 from India) mentioned that they had participated in awareness-raising activities conducted by NGOs through flood simulations, street dramas, or community-level training on how to evacuate and save belongings during floods, and what activities should follow when the flood warnings are received as shown in fig.(43). The following is a quote from one community-level interviewee at Tilathi in Nepal.

“...Yes, I have participated in the flood preparedness training. I have participated in one simulation activity done by Kosi Victim Society (NGO), and I have taken the first aid training from Red Cross....” (C8, Tilathi, Nepal).

One interviewee from India mentioned that he had not received any flood preparedness or EWS training in India but had travelled to Nepal to participate in awareness raising activity after being informed by his friends from Nepal. The following is a quote from a community-level interviewee at Bathnaha in India.

“...I have not participated in any activities related to floods in India, but I have travelled across the border to learn about it in Nepal. I got information from my friends that an NGO is giving training on flood preparedness in Saptari District, Nepal, and I crossed border to participate in it... From the government of India, we do not get any information or any chance to involve in flood awareness activities here...” (C27, Bathnaha, India).

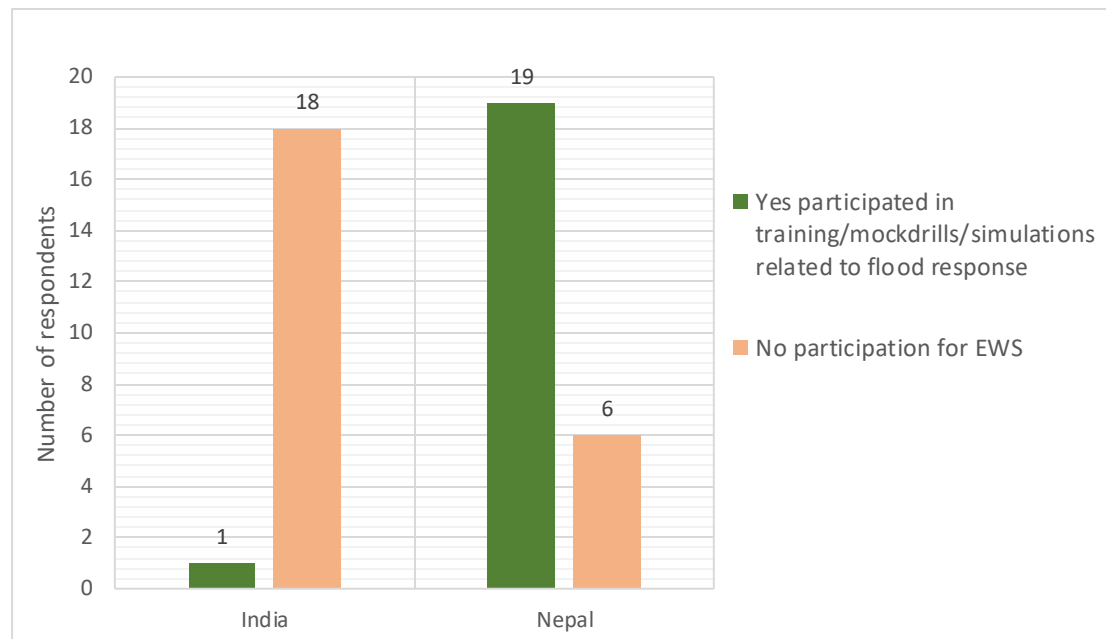


Figure 43: Involvement of people at risk in awareness raising activities related to EWS. The figure shows that most of the respondents in Nepal participated in training and capacity building activities related to EWS conducted by NGOs. However, in Bihar, none of the respondents stated that they had participated in capacity building activities, except for one respondent who stated that he had travelled to Nepal to receive training.

However, 57 per cent (24) of the interviewees (18 from India and 6 from Nepal) mentioned that they had not received any training or participated in capacity building activities related to EWS either by governmental institutions or NGOs. The following are the quotes from community level interviews in Nepal and India suggesting the same:

"...I have not participated in any activity related to flood preparedness by government or municipality or NGO, go and see my house has fallen due to flood and I have received no support from government..." (C12, Shankarapura, Nepal)

"...we don't have access to any information about flood...no one is there for us...government is doing nothing for us neither NGOs...there is nothing at all we can do about floods rather than praying to God (Ram Bharosey) ..." (C35, Haripur, India)

The above findings from the community level interviews also assert with Jones et al. (2016), suggesting that in Nepal, the awareness raising activities on DRR and EWS is pushed by external development actors such as donor agencies and NGOs; Similarly, the

progress in community participation and involvement has been more significant in Nepal as compared to Bihar.

This section showed that people at risk in Nepal are only involved towards the end of the EWS process during capacity building and awareness-raising activities, which NGOs primarily lead. While in Bihar, neither governmental institutions nor NGOs involve the people at risk in flood preparedness activities before disasters; people at risk only receive support in post-disaster situations.

5.7.2. Information and support available from the local level Institutions

The following section deals with the community-level interviews about the institutional support and information available on EWS at the local governmental institutions. The section shows that local institutions in both countries do not provide support in disaster preparedness and EWS, while in Nepal, some NGOs provide logistic support and capacity building for EWS at the community level.

While enquiring about the support received from the local government institutions regarding flood preparedness or EWS, all the respondents from the study area mentioned that they had not received any support from the local government institutions. At the same time, 36 per cent of the respondents from Nepal (16) mentioned that NGOs such as Oxfam, ICIMOD, LWR and KVS had supported them in capacity building, as well as by providing logistic support for flood preparedness such as sanitation and hygiene kits, and evacuation kits containing floating vests, torchlights, ropes, and tarpaulin sheets at the household level. In contrast, in Bihar, all the respondents stated that neither local government institutions nor NGOs had supported them before the floods. However, people at risk mentioned that they only receive support from local governmental institutions in a post-disaster situation, where local governments distribute relief packages (containing puffed rice, plastic utensils, a packet of salt, and oil) and cash support, which is deposited in the flood victim's bank accounts. The above results suggest that NGOs in Nepal drive awareness-raising activities and provide logistic support at the community level in Nepal; In Bihar, support from local level institutions is only available after disasters occur.

Similarly, regarding the availability of hazard risk information such as hazard maps or printed educational materials on flood preparedness and EWS at the community level, 89 per cent

(39) of the respondents in the study area mentioned that they were unaware of the availability of any such information. While twelve per cent (3) of the respondents from Nepal stated that they had seen hazard maps outside the municipality buildings but could not interpret or understand them, and only eight per cent (2) in Nepal stated that hazard maps and other documents related to EWS prepared by NGOs are available at the local level institutions and they understand that information. In contrast, in Bihar, all the respondents (19) stated that no such information is available locally (fig. 44). The above results imply that hazard information and their outreach are limited in Nepal, while no information on hazard risk is available at the community level in Bihar.

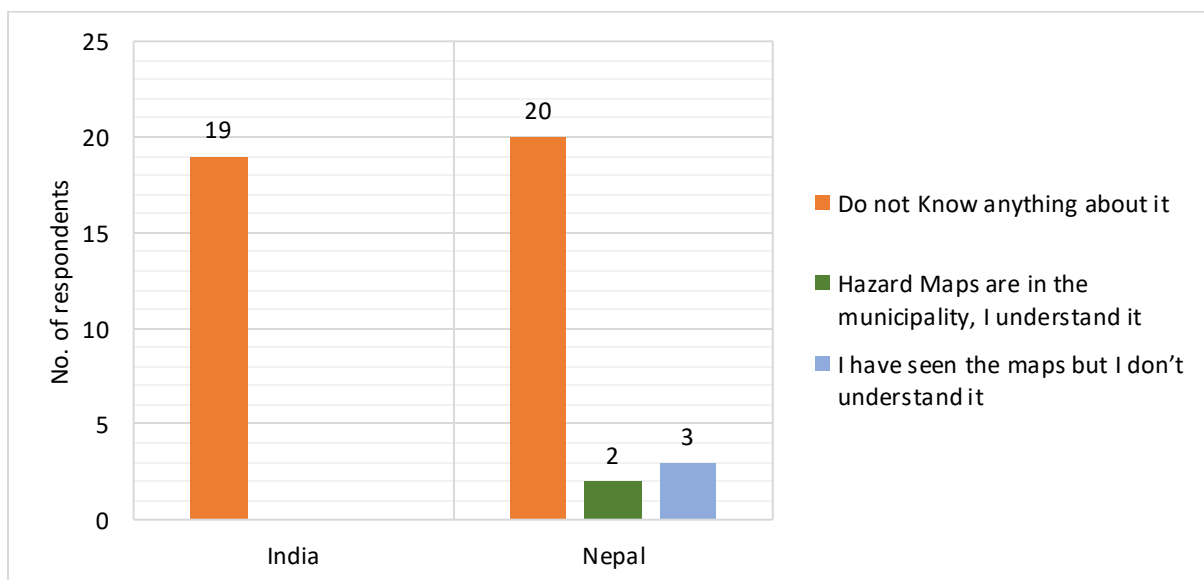


Figure 44: Availability of hazard risk information at the community level. The figure shows that most respondents were unaware if hazard risk information is available at the community level institutions in both countries. only two respondents from Nepal stated they were aware of the hazard maps and understand them, but three respondents stated they had seen the maps but could not interpret them.

The above section showed that in Nepal, NGOs provide support for EWS and flood preparedness through capacity building, as well as provide logistic support during disasters to the people at risk; in contrast, no such capacity building activities are run by local-level institutions in Bihar, but cash and kind support are available only in the post-disaster situation. Similarly, the availability of hazard information at the local level institutions and their outreach is limited in Nepal, while it is non-existent in Bihar.

5.8. Chapter Summary

This chapter demonstrated that people at risk have limited participation in EWS in Nepal, while in Bihar, people at risk do not have an opportunity to participate in EWS. The NGOs in Nepal include affected communities for training and awareness-raising activities related to flood preparedness; however, in India's Bihar state, consultation does not happen between the people at risk and non-governmental institutions or governmental institutions that generate the flood warnings. Furthermore, the experts in governmental institutions that generate hazard information and warnings were sceptical about people's inclusion in EWS processes; they believed that risk information generation is purely a scientific process, where scientific data has more role than people's perception.

In Nepal, the DHM has developed forecasting models from the donors' support, which use the latest technologies and computer models to predict floods three days in advance. However, the model-based forecasts were not disseminated to the people at risk because the experts feared that uncertainties caused by multiple factors (e.g., topographical complexities, sparse rainfall monitoring stations, dynamic river morphology, and limited inclusion of flow altering infrastructures in those models) could result in false alarms, jeopardising institutional reputation and public trust. Therefore, the flood forecasts with three days of lead time are only disseminated to the disaster response institutions for their preparedness for disaster response relief operations. Instead, the government institutions send warnings to people at risk based on real-time river sensors data, which experts regard as more accurate than model-based warnings. However, real-time warnings had a lower lead time of approximately 1 to 2 hours before floods, and people at risk deemed those warnings useless because they would already have understood by that time that flood risk is imminent.

The Kosi flood of 2008 served as an eye-opener for the government of India, revealing several deficiencies in the institutional system related to hazard risk communication, disaster preparedness, response, and relief, and caused institutional restructuring and policy reforms in DRR and EWS in Bihar. Despite that, due to the centralised warning mechanism, which involves long chains of institutions to send warnings, officials at the local level government only have 30 minutes to 1 hour of lead time to inform and evacuate the people at risk. Moreover, the central government institutions that generate warnings do not have the

authority to send warnings directly to the people at risk, but warnings must only be disseminated and communicated through local government institutions.

There are no mechanisms for community consultation in the centralised and government-led risk information generation process, and knowledge co-production is extremely lacking in Nepal, and it was non-existent in India. Even though some non-governmental actors in Nepal consult with people at risk based on projects' mandates, those consultations also pose a risk of elite capture, which can exacerbate the vulnerability of marginalised people because of false representation. The NGOs' have a limited entry into the disaster management sector in Bihar than in Nepal, and awareness-raising activities do not run at the community level, either by government institutions or non-government actors.

The people at risk in Nepal and India stated that they do not receive any support from the local-level institutions in disaster preparedness or EWS. In Nepal, most respondents stated that only NGOs and donor agencies conduct awareness-raising activities such as mock drills and simulations at the community level. In contrast in Bihar, respondents stated that neither NGOs nor the local level institutions run awareness-raising activities.

This chapter showed that knowledge coproduction is non-existent for EWSs. Furthermore, the results from the chapter suggest that risk information generation in isolation, awkward institutional arrangements, lack of connection between DRR institutions and people at risk, overemphasis on technologies, and complete disregard for the social context of the people at risk, have complicated EWS in the Kosi River basin. Chapter 8 will discuss the implication of these results in the context of this PhD thesis. The subsequent Chapter 6 will explore the risk communication, risk perception and different practices of EWS in Nepal, Bihar state of India and the transboundary context between the two countries for EWS.

Chapter 6 Risk Communication, Risk Perception, and Early Warning Systems

6.1. Introduction

This chapter will investigate different mechanisms of risk communication for transboundary EWSs in the study area. This empirical chapter is based on 34 semi-structured interviews conducted with experts, 44 community-level interviews, and 12 focus group discussions (FGDs) held with vulnerable and flood-affected people living in the study area. This chapter explores how Nepal and India approach risk communication within their respective EWSs. It focuses on the role of technology and the extent to which the current approach engages with people at risk. The chapter also reflects on the risk perceptions held by different groups and how people's perception relates to EWS. This chapter explores the sub-question (SQ.1) of the main research question:

SQ.2 How is risk communicated for early warnings, and how do communities understand the risk and warnings in the Kosi River basin?

6.2. Current practices of risk communication in early warning systems.

The following section is based on the interviews conducted with experts working in governmental and non-governmental institutions related to EWS in Nepal and India, reflecting the current risk communication practices in both countries and the transboundary context. This section argues that risk communication in EWS employs a top-down and technology focussed approach without understanding the context of people at risk, in which the warnings will be implemented.

6.2.1. Transboundary risk communication between Nepal and India

This section deals with the transboundary risk communication in the study area based on the semi-structured interviews conducted with experts working in government and non-government institutions in Nepal and India. As shown in fig. (45), there is no transboundary EWS between Nepal and India in the Kosi River basin. However, DHM in Nepal sends previous days' hydrometeorological data of the Kosi River to the CWC office in Patna, Bihar. Furthermore, NGOs in Nepal and Bihar have collaborated for the community-based transboundary EWS in the Kosi River basin, facilitated by International NGOs and donor

agencies, which is contributing to filling gaps in the absence of transboundary EWS in the Kosi River basin—albeit to a small scale.

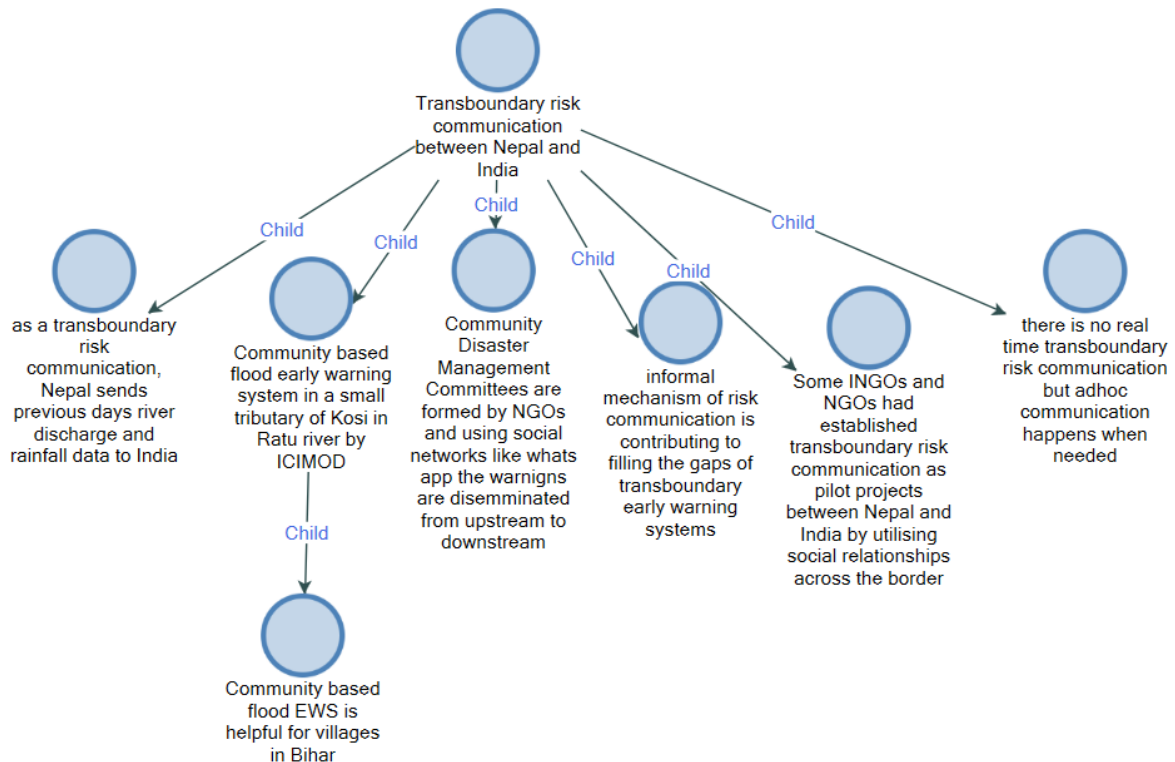


Figure 45: The NVivo map showing themes and subthemes relating to the transboundary EWS in the Kosi River basin based on expert interviews.

A government official from the Ministry of Energy, Water Resources, and Irrigation in Nepal (E2) stated that there is no real-time transboundary risk communication between Nepal and India. Ad-hoc communications are made during flood disasters in the Kosi River basin, involving central government ministries such as the ministry of foreign affairs of both countries. As a formal mechanism, the hydrological data from the previous day is shared by Nepal with India daily. Also, informal communication between the government officials from DHM and CWC happens in case of extreme flood forecasts during monsoon season. E2 stated, “...in case of extreme flood forecasts for rivers of Nepal displayed in the DHM website, the senior officials from CWC used to call me directly when I was DG (Director General) of DHM...so, communication happens as a colleague or friends in an equal level of government institutions...their (CWC’s) main concern would be the possible impact for Kosi flood to the Kosi barrage...because if the Kosi barrage is destroyed by flood, then the whole of the Bihar will be swept away...” (E2). Furthermore, E2 added that the “raw river data” containing river discharge and river gauge heights are sent daily from DHM to CWC as per the bilateral

agreement of 1988 between Nepal and India. Based on the bilateral agreement, 46 hydrological stations were funded and established by India on the transboundary rivers flowing from Nepal to India, and Nepal sends data from those stations daily to Patna, India. E2 added, *“from our master station at Sindhuli; we send raw river data to CWC office in Patna, India, through wireless communication, where we report previous day’s data ...”* (E2). This implies that there is no real-time risk communication between Nepal and India except for the data sharing by DHM to CWC; however, ad-hoc and informal communication happens between the two countries. The latter is backed up by extensive literature (e.g., Acharya and Hori 2019, Biswas 2011; Gade 2020; Gupta et al. 2021; Molden et al. 2017; Shrestha et al. 2010; Shrestha et al. 2021).

The experts in DHM, Nepal (E6 and E14) stated that the mobile networks of Nepal could be received up to a kilometre inside the Indian border; therefore, the experts also assumed that people across the border could also have access to the warning sent by DHM using the mobile SIM cards registered in Nepal. E14 stated that people across the border from India call on the toll-free numbers, inquiring about the status of the Kosi River and the possibility of flooding in Bihar. E14 also stated that NGO workers of Bihar follow the Twitter account of DHM, and mostly retweet and share the DHM’s flood alerts about the Kosi River:

“...people call us from across the border (Bihar), on our toll-free number... our mobile networks are accessible in villages near the border... and they ask us in Hindi about the possibility of flooding in their village....I think most of them are NGO workers in Bihar...I have also noted that many NGO workers in Bihar follow us in Twitter...they always re-tweet and share our updates about the Kosi floods...” (E14)

Corroborating the data from the community-level interviews from border areas in Bihar, Community level interviewees at the border villages of Kunauli and Bathnaha (C3, C21, C31) confirmed that most of the people living in border areas carry both mobile SIM cards from Nepal and India. In doing so, they receive the warnings sent by DHM in Nepalese mobile networks (NTC and NCELL); however, the reception of those mobile networks inside the Indian territory in Bihar is limited and only up to one or two kilometres (See also 6.3.4).

“...Here in the bazaar area (marketplace), many people use both SIM cards from Nepal and India, I also have both NCELL (Nepalese sim) and Airtel (Indian sim) on

my mobile. NCELL network of Nepal is accessible up to Damara here in Bihar (approximately 2 km inside border) I get flood warnings from Nepal in NCELL...and whoever comes here from the nearby villages for shopping will also automatically know about flood warnings through people's interaction here in marketplace..." (C3, Kunauli, India)

The government officials in Nepal (E2 and E6) also stated that some NGOs in Nepal had established transboundary risk communication as pilot projects between Nepal and India by utilising social relationships across the border. E2 said, *"...NGOs like ICIMOD and LWR are utilising open border, common culture, and the social relationships between Nepal and India for transboundary risk communication...the relationship between Nepal and India is commonly called as 'Roti and Beti' (bread and daughter) because people living there have jobs as well as family relations by marriage across border..."* (E2). Similarly, the experts working in NGOs in Nepal (E4, E7, E9, E12, E18, E19) and Bihar (E28 and E29) also asserted that informal community-based transboundary risk communication mechanisms established by NGOs in the Kosi River basin are contributing to filling the gaps of formal EWSs between the two countries.

For establishing community based transboundary EWSs, NGOs are using social media applications such as WhatsApp to communicate between the network of communities upstream and downstream of the Kosi River basin. The expert working in LWR in Nepal (E17) stated that LWR had established an informal risk communication network in the Kosi River basin for a project called 'India-Nepal Transboundary Flood Resilience'. In this project, flood gauge pillars with yellow and red level markings were established at the bank of the Kosi River in the Saptari and Udaipur districts of Nepal upstream, and the Supaul District of Bihar downstream, and approximately 35 community-level disaster management committees (CDMCs) were formed in Nepal and in Bihar. Within each CDMC, an Early Warning Task Force (EWTF) was also formed, whose role would be to communicate risk in the community by visiting door-to-door and prioritising evacuation of the vulnerable and disabled people in the village. The transboundary communication networks of EWTFs from Nepal and India were established using the WhatsApp group, where the warnings from upstream are shared with the downstream communities. The WhatsApp group includes the community members in Nepal and Bihar, who have broader outreach in their communities (e.g., local schoolteachers,

flood-affected people, shopkeepers, local health workers) so that the warnings received from Nepal can be disseminated quickly. Whenever EWTF members in Nepal observe the rise in river level or receive SMS messages from DHM, yellow (for warning) or red (for danger) flags will be raised at the village market centres to inform the community about flood risk. At the same time, the warnings are also shared in a WhatsApp group to inform the downstream communities in Bihar. E17 added, *"...We have very strictly told the EWTF members that information must be reliable to avoid rumours...therefore the gauge readers must verify their information with DHM first...we have given them the toll-free number of DHM (1155), where they first need to verify the flood warning, then only inform the downstream communities through the WhatsApp group..."* (E17). This statement suggests that NGOs in Nepal trust the warnings disseminated by DHM as authentic and reliable to trigger their actions; in other words, the NGOs trust DHM for their accurate warnings, and to maintain this public trust, the DHM intentionally holds the warnings until they were sure about flooding, resulting in a significant reduction of lead time in warnings as discussed in Chapter 5, Section 5.5 of this thesis.

Another NGO, ICIMOD in Nepal, has also established transboundary communication between Nepal and India in the Kosi River basin for a small tributary of the Kosi River, Ratu. The expert from ICIMOD (E18) stated that, in a pilot project called 'Community-Based Flood Early Warning System' (CBFEWS) in the Kosi River basin, ICIMOD had established low-cost telemetric river level sensors with transmitters at the riverbanks of the Ratu River (a tributary of the Kosi River) which sends signals to the receiver unit at the nearest village. The caretaker of the receiver unit then passes the warning (blue for alert, yellow for warning, and red for danger) to the focal persons in the community as per the established communication plan, and the focal person further disseminates the warnings in WhatsApp to other focal persons living in Nepal and Bihar. The community-based system covers the network of *"four villages with approximately 36,000 population in Mahottari District, Nepal and six villages with approximately 60,000 in Sitamarhi District of India"* (E18). The statements by E18 imply that in the absence of a formal transboundary risk communication mechanism, the community-based EWS contributes to fill the gaps by connecting the upstream and downstream communities—albeit at a small scale (Cramer et al. 2016; Molden et al. 2017; Shrestha 2017). Furthermore, one NGO worker in Bihar (E29) also confirmed that community-based risk

communication is helpful in Bihar, where the people at risk do not have access to the warnings:

“...recently, I participated in a meeting held in Tilathi-Koiladi village of Nepal, which ICIMOD organised about transboundary community-based EWS...three of the Gram Panchayat Mukhiyas from Bihar, one newspaper media from Patna, and many local NGOs of Bihar also attended the meeting...we learned there about EWSs in Nepal, and how to communicate warnings from Nepal to Bihar using WhatsApp...it was beneficial for us in Bihar, where we do not get any information from government...” (E29).

Even though the above quotes imply that NGOs in Nepal are contributing to filling the gaps of transboundary EWS between Nepal and India to a certain extent; it is also important to understand that in the terai region of the Kosi River basin, disaster vulnerability strongly relates to the caste dynamics and gender-based discriminations as suggested by several scholars (e.g., Acharya and Prakash 2019; Gupta et al. 2021; Jha and Gundimeda 2019; Pritchard and Thielemans 2014), which are given less attention by those NGO led community-based EWS projects. Section 6.3.4 below further deal with the vulnerable people’s access to warnings and Section 5.6 of Chapter 5 deal with the role of NGOs in the EWS.

This section showed the lack of a formal mechanism for risk communication between the two countries. Nonetheless, civil society initiatives have established community based transboundary EWSs operating at a small scale to bridge the gaps of transboundary EWS. The next section 6.2.2 explores the risk communication for EWS in Nepal.

6.2.2. Risk communication in Nepal

The following section presents the interview data from experts working in government and non-government institutions in Nepal related to the risk communication for EWSs in the Kosi River basin. This section shows that risk communication in Nepal follows a centralised and top-down approach, where warnings are given to the people at risk without understanding if those warnings are accessible or whether people can interpret those warnings as shown in fig. (46).

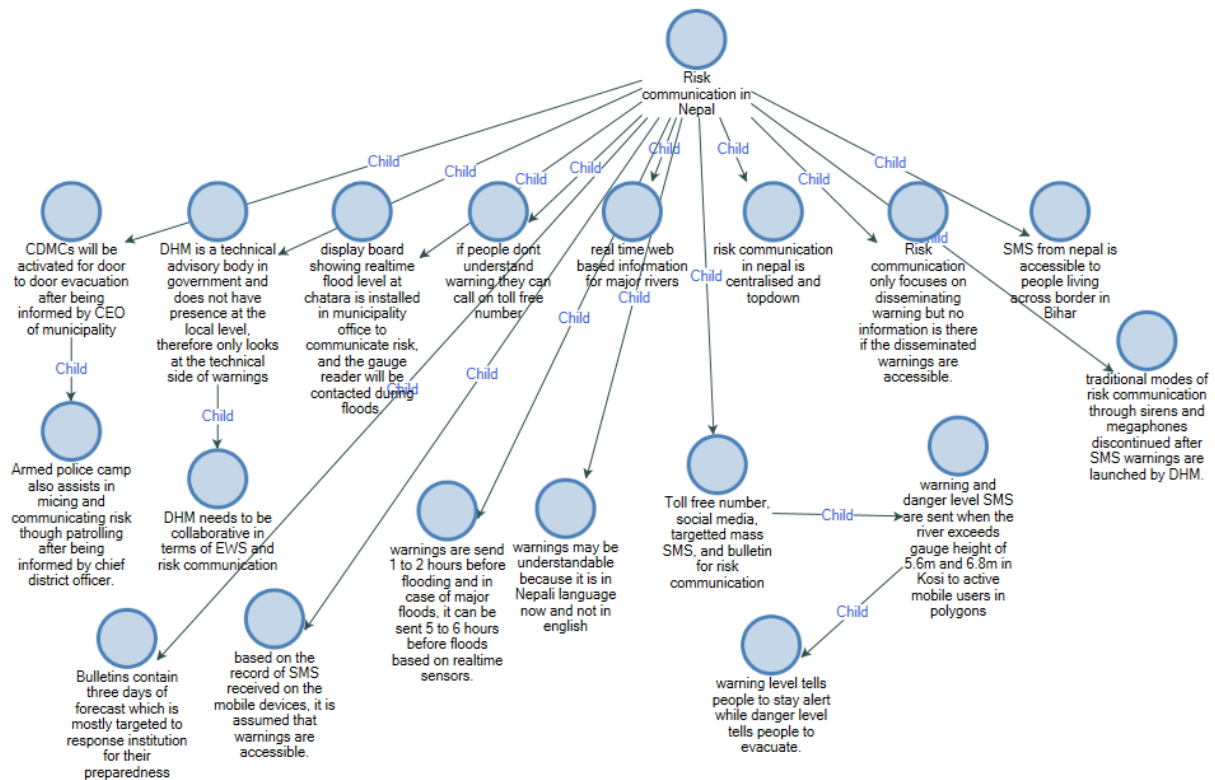


Figure 46: NVivo map showing the theme risk communication in EWS in Nepal and its subthemes.

Experts working in the government of Nepal (E6, E8, E14) stated that with the recent technological improvements, people at risk in the Kosi River basin are receiving warnings through different means: targeted mobile Short Message Services (SMS), flood bulletins, web-based information, and social media platforms (Facebook and Twitter). The expert E14 stated that Department of Hydrology and Meteorology (DHM) has collaborated with the telecommunication service providers of Nepal (Nepal Telecom and NCELL) and divided the flood-prone areas of Nepal into 42 polygons or spatial units for the dissemination of warnings through SMS, among which, the Kosi River basin covers 5-7 polygons:

“When the river level of Kosi exceeds the gauge heights of 5.6 m and 6.8 m at Chatara hydrological station, then the ‘warning level’ and the ‘danger level’ SMS are sent respectively to the active mobile network users within those polygons” (E14).

Another expert from DHM (E8) added, *“the SMS stating the Warning Level tells people to stay alert as the river level is rising, and the SMS stating Danger Level tells that river has already topped its banks, and people living close to the river should evacuate immediately”* (E8). Similarly, E14 stated, *“I send the SMS directly from this computer, I usually send ‘warning SMS’*

1 to 2 hours before flooding takes place in the Kosi...and if it is going to be a major flood event, then warnings can be sent 5 to 6 hours before floods...” (E14).

From the community level interviews, it was observed that SMS warnings are sent only about 1 to 1.5 hours before floods, which provided no time for preparation, and the warnings were hard to comprehend and decide for action because they provided vague information regarding the exposed area and possible time of occurrence (see section 6.3). The following picture of a mobile SMS fig. (47) taken from a resident’s mobile in the study area also suggests that the warnings are long, containing vague and unclear messages regarding the possibility, timing, exposed area, or action to be taken by the recipient. This finding agrees with Budimir et al. (2019), who suggested that SMS warnings provide short lead times varying from 1-6 hours and that warnings do not contain concise and standardised messages or recommended actions.



Figure 47: Mobile SMS sent by DHM in the Nepali Language which translates as: *"17th September 2019, Morning 9 o'clock, the Kosi River at Chatara station has crossed the 'Warning level', and there is a possibility that river may reach close to the 'Danger level' therefore, observe high alert until this evening in the riverside areas of Sunsari and Saptari districts. Flood Forecasting Section, DHM".*

When government officials at DHM in Nepal were asked if they were aware whether the warnings reach the people at risk in a timely and understandable manner, respondent E14 stated that people at risk have access to the warnings and stated, *"when I send SMS, I have a record that approximately 200,000 people in the Kosi River basin receive the SMS warnings..."* (E14). Also, E6 added, *"...180,000 people had received SMS warnings during the last year (2018) flood in the Kosi River basin...and even if one person in a community receives the warning, it could help save the whole community...so I think people have access to the*

warnings ...” (E6). The above statements imply that based on the data about the number of SMS recipients in the Kosi River basin, the experts had an assumption that warnings are accessible to the people at risk. However, it is important to note that the population of the Kosi River basin within Nepal is approximately six million (Chen et al. 2013), with a literacy rate of 57 per cent (Nepal and Neupane 2022; Yadav and Ibrar 2022), 83 per cent of the population dependent on subsistence agriculture as their primary source of income (Wahid et al. 2017), and 40 per cent of the population living below poverty line (Gupta et al. 2021). Therefore, as per the experts’ data, it can be implied that only about three per cent of the population (200,000 out of six million) are being reached by the SMS warnings. The expert’s calculations rest on the assumption that all people in the Kosi River basin own mobile phones and can interpret warnings; given the average income level, literacy, and poverty status, it appears highly unlikely.

Responding to the question on whether people at risk understand the SMS warnings sent by DHM, The Expert working in DHM (E14) stated that DHM’s role had been more on the *“technical side”* of the risk communication in EWS, and *“...we (experts in the DHM) have not been able to work directly with the communities because DHM is a central technical advisory body and we do not have presence in the local level, we have to rely on local bodies for that...so, we do not have information whether people understand our SMS or how they react to it...”* Furthermore, E14 admitted that the DHM needs to improve on that aspect of risk communication and collaborate with the people at risk. On the contrary, another expert from DHM (E8) stated that people at risk should understand the SMS warnings because they are sent in the Nepali language, and stated, *“...we used to send SMS in the English language earlier, which we changed later to the Romanised Nepali, and now we send SMS in the Nepali language...so I think they understand our SMS warnings”* (E8). The above statements suggest that DHM is disconnected from the context where warnings were being sent. The DHM officials assumed that just because the warnings were being sent in the Nepalese language, it was accessible; however, most people in the Kosi River basin speak Maithili as their first language (also discussed further in Section 6.3.3). The DHM officials were unaware if warnings were accessible to people at risk or if the receivers could interpret and understand those warnings. The forecasters in DHM agreed that they lacked contextual information and

justified its cause as the DHM was established as a central technical advisory body for flood EWS and lacked institutional presence at the district or local levels.

Corroborating the information from experts with the people at the community level in Nepal, most of the community-level interviewees who had received SMS warnings from DHM (67 per cent) also complained that the SMS warnings were not helpful because it only allowed 1 to 2 hours of preparation before a flood occurs, which was inadequate for flood response (see also 6.3.2).

In addition to the targeted mass SMS, DHM operates the toll-free hotline number 1155 during monsoon seasons, where people at risk could directly call to get flood information. E14 stated, *"...after we send SMS, some people understand it, and some do not...whoever understands it they do not call us... whoever does not understand the SMS can call our toll-free hotline of 1155, which operates 24 hours during monsoon season...."* (E14). However, this study found that only DRR practitioners and NGO workers were aware of the toll-free number of DHM in the study area. This finding agrees with Budimir et al. (2019). Based on the study of multiple river basins in Nepal, the authors suggested that concerning the possibility of many incoming enquiries and only two people available to answer the calls in the DHM, the toll-free number of DHM is not intentionally disseminated.

The above statements imply that warnings are being sent by government officials operating at the central level institutions in Nepal and in complete isolation from people at risk. The experts had no idea whether the people at risk have access to those warnings or understand them. The currently implemented model of risk communication for EWS in Nepal resembles the Public Education Model (PEM) suggested by Callon (1999), where scientific knowledge is institutionalised and governed independently and given to the people at risk (Lane et al. 2011). Extensive literature (Arvai and Rivers 2014; Boholm 2008; Covello and Sandman 2001; Hamza and Mansson 2019; Kellens et al. 2013; Kelman and Glantz 2014; Renn 1998, 2009) has argued that risk communication in EWS is a two-way exchange of information between risk managers and people at risk to have a shared understanding of risk rather than 'giving' warnings to the people at risk (Callon 1999).

Likewise, E14 also mentioned that flood forecast bulletins with three days of lead time are emailed daily to the government institutions and DRR stakeholders in Nepal working in

disaster response and recovery. The bulletin will contain the status of the river (rising or falling trend), and flood forecasts with 72 hours of validity based on the hydro-meteorological flood model of DHM called Mike-11. The Mike-11 is a flood model developed by DHM with the funding support of the World Bank and includes data from 22 hydrological monitoring stations and 38 meteorological stations in the Kosi River basin to forecast floods in the Kosi River.

E14 stated, “...during monsoon season, at 7 am, we email flood bulletins to the National Emergency Operation Centre (NEOC), Ministry of Home Affairs (MoHA), disaster focal persons in all the Ministries, Armed Police Force Headquarter, Nepal Army Headquarter, Red Cross Centre in Nepal, and other INGOs in Nepal working in DRR...also we upload the bulletin in our website (*hydrology.gov.np*) ...” (E14). The above quote by E14 implies that flood bulletins focus on managing disasters rather than risks (Etinay et al. 2018), as it targets the disaster response institutions in Nepal. Also, this study has found that the bulletins are designed for technical audiences rather than the public as they contain graphs to illustrate river trends and maps with large coverage areas—suggesting possible impact at the district level rather than basin or sub-basin level. The above interviews imply that risk communication mechanism for EWS in Nepal is centralised, expert-led, and technology-focused and the warnings flow “outwards and downwards” (Hamza and Mansson 2019, p. 5) from central governmental institutions to the people at risk.

In addition to the bulletins, E14 and E6 stated that flood information is also displayed on the DHM’s website (*hydrology.gov.np*), where real-time river level information of the Kosi River can be accessed based on the telemetric river sensor data from Chatara monitoring station. E6 stated that DHM’s website displays the river status as per the traffic light system, suggesting green for “Below warning level”, yellow for “Warning level”, red for “Danger level”, and automatic alarms are triggered in DHM’s flood control room when the river level reaches “Danger level”.

Experts working in NGOs in Nepal (E7, E12, E23, E24, and E25) were critical about the risk communication approach in Nepal and stated that it follows a “*supply-side approach to risk communication*” (E12), where the warnings flow one-way and in a “*top-down manner*” (E23) from the DHM to the people at risk without understanding “*What kind of information they need, and how they interpret or understand warnings or react to those warnings*” (E12). Also, a local NGO worker (E7) stated:

“...government institutions have never consulted communities regarding their information need, or what language they speak...neither anyone knows whether the most deprived ones, marginalised or the most vulnerable ones have access or understanding of warnings...government is doing nothing more than pushing the button to send the warnings...” (E7).

The expert E25 also stated that DHM in Nepal focuses only on disseminating warnings; however, sending warnings alone cannot guarantee that people will act on them. After warnings are received, people think about the safety of their lives and livelihood assets before making decisions; therefore, those concerns must first be addressed at the local level for warnings to be effectively implemented.

“...In recent flood what happened is everyone informed every other people...by calling, forwarding SMS, sharing in Twitter and Facebook...but apart from that, nobody did anything...but only sending warnings does not guarantee that people will act on it... I have seen that people will not leave behind their assets, their buffaloes, and goats to drown in flood and run alone...until they are sure about the safety of their valuables, they will not move even if they know that flood is coming...” (E25).

While interviewing the local government officials in Nepal, a CEO of a municipality (E31) stated, *“even before I get SMS from DHM, I will know about flood...the gauge reader Hari Bahadur Karki from Chatara Station in the Kosi River directly calls me on my mobile to inform about the rising trend of river...then I inform all the Ward offices...after which, the office secretaries go to villages close to the Kosi River and tell one or two people there about the situation...then message will automatically circulate in that village...” (E31).* Also, he mentioned that some flood-prone municipalities in the Kosi River basin had installed digital real-time river level display boards which will automatically activate sirens at the municipal office when the river level reaches to “danger level”; and since the DHM has started sending

the mobile SMS warnings, *“the municipalities have also stopped the old ways of informing people by loudspeakers and megaphones”* (E31).



Figure 48: Consultation with ward-level officials in Tilathi-Koiladi Village Development Committee, Ward no.5, Nepal.

At the ward level interviews as shown in fig. (48), local government officials (E32 and E33) stated that after being informed by the CEO of the municipality, the ward chairman calls an emergency meeting of the Community Disaster Management Committees (CDMCs) and activates the community level early warning task force. The task force’s role is to visit door-to-door to inform people at risk and prioritise evacuation of the most vulnerable ones at the village. In addition, E33 stated that Armed Police Force (APF) would also be mobilised by the Chief District Administrator (CDO) in case of a significant flood event, who will patrol the villages close to the river and announce using a megaphone: *“be alert...do not sleep inside your houses, rather to sleep in Goth (Animal Shed) and be careful because flood is coming...”* (E33). However, it is important to note that CDMCs and taskforces only operate in some of the donor-funded communities and until the funding is available, while many other villages have neither CDMCs nor task forces, as discussed in Chapter 5, section 5.6 of this thesis. The above statements from the local level officials also imply that, as DHM is using mobile SMS for sending the flood warnings to the people at risk, the local government officials have also stopped using personal modes of risk communication such as sirens and megaphones to disseminate warnings, with the assumption that SMS warnings are accessible to all the people at risk. On the contrary, it was observed that as the local governments have stopped using

sirens and megaphones, the most vulnerable ones are entirely being cut off from the flood warnings, which will be further dealt in the section 6.3.4.

This section showed that the approach to risk communication for EWS follows a centralised and top-down method in Nepal. The Department of Hydrology and Meteorology (DHM) in Nepal possessed the capability to forecast floods three days in advance specifically for the Kosi River basin, utilising a flood forecast model known as Mike-11. The DHM disseminates warnings through various channels, including targeted mass SMS, flood bulletins, toll-free hotlines, web updates, social media updates, and TV and radio broadcasts. However, only the flood bulletins contained three days of flood forecasts, which were exclusively provided to government institutions for disaster response planning. Additionally, the forecasts presented in these bulletins comprised graphs and maps that were unsuitable for a non-technical audience.

Conversely, warnings disseminated through other accessible channels for the general public were based on real-time flood information, resulting in significantly shorter lead times (i.e., the duration between the warning and predicted flood) of approximately 5 to 6 hours (Kuller et al. 2021). The experts responsible for issuing warnings from government institutions lacked information on whether they were accessible to at-risk individuals or correctly comprehended by them. Moreover, the warnings were non-standard, lengthy, and lacking specificity regarding the location, timing, likelihood of flooding, or recommended actions. These particular issues pertain to the existing operational practices of EWS, which deviate from the contextual requirements of risk communication and present a significant hindrance in implementing transboundary EWS.

The effective transboundary EWS requires coordination and collaboration to communicate warnings across borders to mitigate the impact of disasters. The specific issues highlighted in the risk communication in Nepal pose obstacles to the implementation of transboundary EWS in the following ways:

Firstly, the lack of standardised and accessible warnings in Nepal challenges harmonising and integrating them into a cohesive transboundary EWS. The non-standard warnings disseminated through various channels complicate efforts to achieve consistency across borders. Furthermore, the accessibility of warnings to at-risk populations raises concerns, as

there is a lack of information regarding their reach and comprehension by the intended recipients. In transboundary EWS, where timely and effective communication is important, the absence of standardised and accessible warnings hampers coordinating actions across borders.

Secondly, the issue of insufficient lead time in real-time warnings exacerbates the challenges, and although the flood bulletins in Nepal provide three days of flood forecasts to government institutions, the warnings disseminated to the public through other channels offer significantly shorter lead times of only 5 to 6 hours. In transboundary EWS, where collaboration and cooperation between entities are critical, insufficient lead time impairs the ability to take coordinated actions.

Another issue is the non-specific nature of warnings issued in Nepal. The lack of details regarding the exposed location, timing, possibility of flooding, or recommended actions poses challenges in a transboundary context. Different regions may have varying levels of vulnerability and different response capacities, making specific and contextualised warnings essential. Implementing appropriate measures to mitigate risks becomes challenging without clear and specific information. Furthermore, the lack of feedback mechanisms within the risk communication process contributes to the hindrance of transboundary EWS and the absence of information on whether warnings effectively reach the people at risk and are understood. The subsequent section 6.2.3 will explore the context of risk communication in Bihar, India.

6.2.3. Risk communication in Bihar

The following section is based on interviews with experts working in government and non-government institutions in India. The following section shows that risk communication in Bihar involves a centralised, technological, and top-down approach to EWS, and warnings fail to reach the people. People mostly must rely on the information aired on the radio or television to access the warnings, which too are vague and difficult to comprehend. The fig. (49) shows the themes and subthemes regarding the risk communication in Bihar, India.

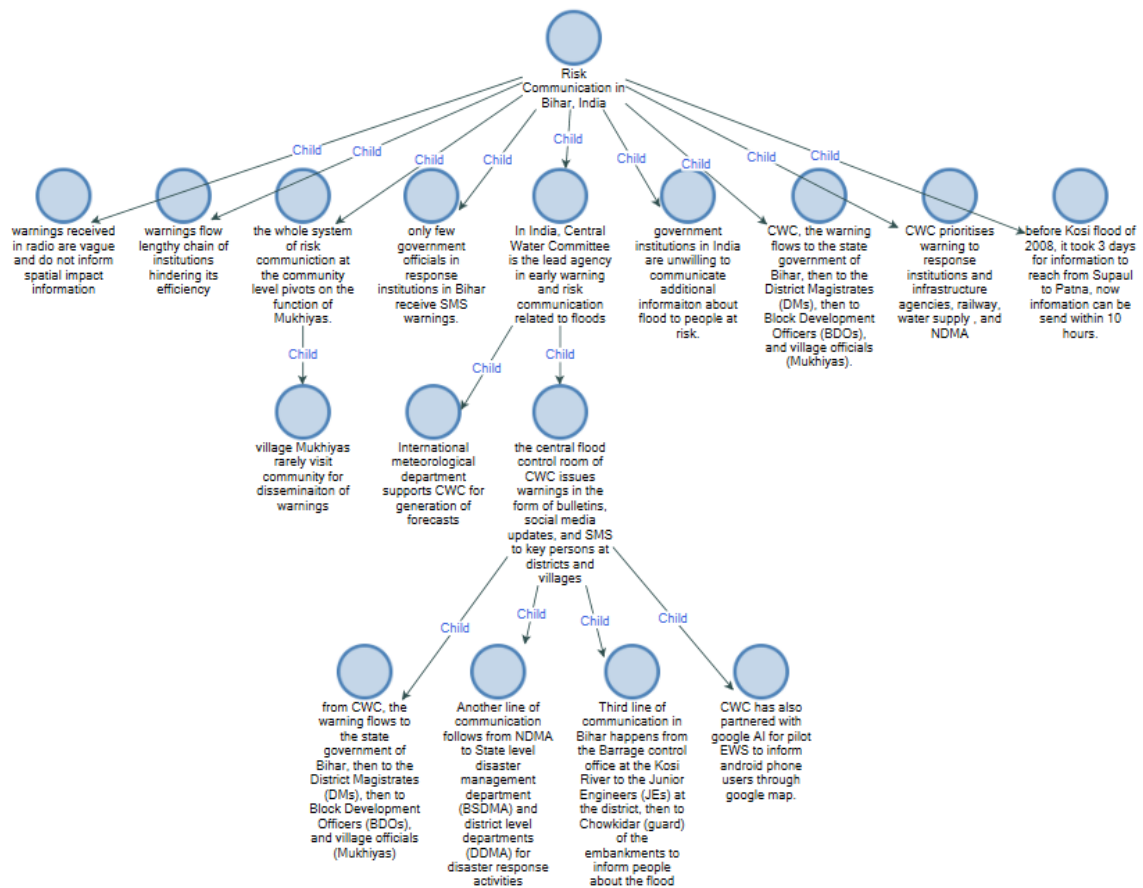


Figure 49: NVivo map showing the theme risk communication in Bihar, India, and its subthemes.

A local government officer (E34) and an Additional District Magistrate (E27) in Bihar stated that, for flood risk communication, IMD provides forecasts to the CWC (Central Water Commission), and based on the warnings, the Central Flood Control Room of CWC at Delhi issues warnings in the form of bulletins, social media updates (Facebook and Twitter using @CWCofficial_goi), and SMS to the “key persons at the district and village level” (E34) in Bihar. E27 added that CWC first sends the flood bulletins to the central government institutions such as the Ministry of Water Resource, Ministry of Home Affairs, Railway Board, National Disaster Management Authority (NDMA). Then from CWC, the warning flows to the state government of Bihar, then to the District Magistrates (DMs), then to Block Development Officers (BDOs), and village officials (Mukhiyas). Another line of communication follows from NDMA to State level disaster management department (BSDMA) and district level departments (DDMA) for disaster response activities. The third line of communication follows from the Barrage control office at the Kosi River to the Junior Engineers (JEs) at the district, then to Chowkidar (guard) of the embankments to inform people about the flood. In addition to these, E27 stated that,

since 2019, CWC has partnered with Google to use Artificial Intelligence in EWS called 'Pilot EWS' in some parts of Bihar to inform android phone users about the flood risks through Google Map apps, and the warnings are broadcasted in national radio and television. The above statements by E27 imply that risk communication for EWS in Bihar is disaster response focussed, as suggested by Ogra et al. (2021), and follows a lengthy chain involving multiple pathways of bureaucratic institutions before reaching the people at risk (Dixit 2009; Mishra 2008; Shrestha et al. 2010). Similarly, Acharya and Prakash (2019) argued that even though risk information flows to the village level, it does not reach the people at risk, and the only ways to get early warnings are through radio or television.

Responding to the question on whether the expert regards the communication channel to be lengthy to reach the people at risk during flooding, E34 claimed that risk communication in Bihar has become quicker after the Kosi flood of 2008 due to the institutional reforms and stated, *"before the Kosi flood of 2008, it used to take three days for the information from Patna (capital of Bihar State) to reach Supaul District (district close to Nepal-India border)...but now, it will only take one day or even within 8 to 10 hours the warnings can reach the villages in Supaul District, Bihar...Also, we are sending flood warnings using SMS to the key people at the village level using BSNL and Airtel networks...therefore, the information flow is faster now...."* (E34). On the contrary, a local activist in Bihar (E26) argued that even though some institutional reforms have occurred after the Kosi flood of 2008, the risk communication in Bihar still follows lengthy formal institutional channels that heavily rely on the village-level authorities for information dissemination, as well as the evacuation of people at risk.

"...here in Bihar, CWC does not send warnings directly to the local people, on the contrary, it passes through a long governmental channel to reach the village level officials for its implementation...the warnings pass from CWC to state government, then district authorities, block-level authority, village Panchayat, and finally to the Mukhiya and Thanadars...Therefore, the whole system of risk communication in India pivots on the mercy of village Mukhiyas and Thanadars for informing people..." (E26).

The above quotes by E26 agree with the study of floods by Acharya and Prakash (2019) in the Gandak River basin in Bihar, India (adjacent to the Kosi River basin). In their study, the authors also argued that only three people at the village level in Bihar (village chief, embankment

Chaukidar, and Thanadar) receive early warnings and circulate them to the at-risk people. Likewise, the NGO workers from Bihar (E28 and E29) also stated that only a few selected government officials in Bihar receive warnings at the village level, and those warnings are intended to support the disaster response activities (see also Ogra et al. 2021) rather than for early warning to the people at risk.

The local activist in Bihar (E26), and NGO workers (E28 and E29) also claimed that village Mukhiyas never visit the local communities after receiving warnings (see also Acharya and Prakash 2019), but only when the extreme flood is forecasted, then Thanadars visit communities and announce the flood warnings using megaphones and at the same time also order the people at risk to evacuate their villages. Similarly, the experts also stated that most people living in villages could only know about floods through television or radio, and those households that cannot afford television or radio can only know about floods after experiencing them. When the flood enters the villages, the “Halla” (shouting or cumulative noise to inform people living in a community) spreads into the village, by which people know that a flood is approaching. Similarly, Acharya and Prakash (2019, p. 63) also suggested that “Halla” is the primary form of warning when floodwater approaches villages in Bihar, as residents start shouting collectively to inform other people in their vicinity to gather their valuables and go to the higher grounds as the flood is approaching.

Furthermore, E28 and E29 also argued that information received on national radio and television are vague and only informs about the river discharge values and river levels, which is difficult to interpret and understand about the possibility and impact of flooding at a specific location. This is illustrated in the following quotes from E28:

“...mostly in television and radio, they only tell you the river discharge and levels...like Kosi is flowing with this much discharge and has passed the yellow level and you become alert...like that...but I have never seen or heard that the river will reach this area in this time...or for example like flood water will reach Saharsa district in 3 hours...from their information on TV and radio, no one understands whether flooding will occur or not, or when and where will it occur...”(E28).

Although an extensive literature (e.g., Acharya and Prakash 2019, Gade 2020; Perera et al. 2020; Shrestha et al. 2021) has suggested the importance of radio for flood risk alerts,

especially for the most disadvantaged population in Bihar, some scholars (Acharya and Poddar 2016; Mishra 2008) have argued that flood alerts aired on radio and television only provides information regarding the discharge of the river in cusecs, and river level in colour codes of yellow, orange and red, which people find difficult to understand. Similarly, E26 argued that government institutions in India are unwilling to share any additional information to the public that can aid in disaster preparedness and understanding of the warnings because the institutional structure is disaster response focussed and adapted to the governance of disasters than managing risks.

“...possible flood impact to a location is quite a simple thing to calculate...and there are charts available with CWC on which, from the given river discharge and level given in radio or television, you can easily calculate the timing of the flood in any place...I asked people in CWC to give me the chart so that I can calculate myself that if television says that Kosi has reached the Red mark, then by what time will it get to my home...but they said...they do not have authority to share the chart to the public...it is for official use only...”(E26).

The above statements by E26, E28, and E29 imply weaknesses at the implementation level in Bihar, as suggested by Ogra et al. (2021). This finding suggests that institutional structure and ways of working at the local level constrain risk communication. The finding also agrees with Dixit (2009) and Shrestha et al. (2010), who argued that the cascading flow of warnings in Bihar that involve an extended hierarchy of institutions is one of the most significant hindrances to risk communication in EWS.

This section highlights the top-down nature of risk communication for early warnings in Bihar, India, where warnings undergo a lengthy chain of institutions before reaching the intended recipients. The study findings suggest that the risk communication approach in Bihar shares similarities with Nepal, as both regions adopt a centralised and top-down approach. The warnings generated by the Central Water Commission (CWC) follow a bureaucratic process, leading to delays and reduced lead time at each stage before reaching village-level officers. However, these officers are burdened with impractical responsibilities, such as disseminating warnings to a large number of at-risk individuals and managing evacuations. Consequently, a significant portion of the population in Bihar does not receive the warnings. Scholars such as Acharya and Prakash (2019) and Kumar et al. (2020) have argued that flawed institutional

structures, limited collaboration with non-governmental agencies, and inadequate coordination between the CWC and local government bodies contribute to the restricted access to warnings for at-risk individuals, despite India's technological advancements. Similarly, Ogra et al. (2021) have highlighted the lengthy bureaucratic structure, top-down approach, and insufficient engagement with the people and their specific contexts as prevailing challenges in disaster risk management in India. Therefore, these findings support the argument that the lengthy bureaucratic chain and impractical institutional arrangements at the local level impede access to warnings for a significant portion of the at-risk population in Bihar.

The identified issues in risk communication practices in Bihar present hindrances to the successful implementation of transboundary EWS. Firstly, the bureaucratic process introduces delays and reduces the lead time for warnings at each stage. This bureaucratic structure impedes swift coordination of warnings across borders in transboundary EWS, where timely risk communication is crucial. Also, the impractical burden placed on village-level officers in Bihar impeded the risk communication to the at-risk population. This limited access to warnings hampers the reception of critical information about potential risks, thus hindering timely response and preparedness efforts. Moreover, the lack of collaboration between government agencies and non-governmental organisations and inadequate coordination between the CWC and local government bodies obstructs the smooth flow of warnings and interagency coordination—both critical aspects of transboundary EWS.

Furthermore, perceiving EWS primarily as a technical process detached from the social context, with limited engagement with at-risk individuals, diminishes its effectiveness in transboundary contexts. Transboundary EWS necessitates a comprehensive understanding of specific vulnerabilities, response capacities, and contextual needs. Neglecting the social aspects and relying excessively on technical components undermine the relevance and efficacy of warnings in transboundary settings. To summarise, the identified issues in risk communication practices in Bihar hinder the implementation of transboundary EWS by impeding swift coordination, limiting access to warnings, hindering interagency collaboration, and neglecting the social dimensions crucial for effective risk communication.

In contrast to the top-down, centralised, and one-way risk communication observed in the study area, extensive literature (Boholm 2008; Covello and Sandman 2001; Hamza and

Mansson 2019; Kellens et al. 2013; Kelman and Glantz 2014; Renn 1998, 1991, 2009) argues that providing warnings alone does not guarantee people's access and action. Instead, risk communication for EWS should involve a two-way process that facilitates interaction between at-risk individuals and risk managers to convey the meanings of hazard risks. Moreover, the study reveals that government officials in Nepal and India perceive EWS primarily as a technical process, prioritising technology over collaboration with at-risk individuals. However, Kelman and Glantz (2014) contend that EWS is a social process incorporating technical components to enhance people's understanding. Therefore, the technical aspects of EWS should be embedded within the social context rather than treated as external to the at-risk individuals. Expanding on Kelman and Glantz's perspective, it can be argued that understanding EWS as a duality comprising both technical and social dimensions is problematic as it reinforces a top-down and end-to-end approach. Such an approach involves generating warnings at one end (forecasters) and transmitting them to the other (at-risk individuals) without meaningful interaction. Moreover, perceiving EWS solely as a technical process leads to a lack of contextual knowledge for forecasters and a limited understanding of warnings for at-risk individuals, as evident in the studied area. Therefore, to ensure the effectiveness of EWS, it should be tailored to the specific contextual needs of the at-risk population. The following section will explore the contextual reality of access to risk communication, and their perceptions and understandings of hazard risk.

6.3. People's perceptions of flood risk and risk communication

This section is based on 44 community-level interviews and 12 focus group discussions in the study area, exploring people's perceptions and understanding of risk, access to warnings, and preferences. The community-level interviews demonstrate that most at risk do not comprehend the cause of floods in the Kosi River basin. The study also investigates the reach of warnings through SMS, revealing that most people in the Nepal side of the study area receive warnings, and they get informally communicated to some adjacent villages across the Nepal-India border. However, in Bihar, most people lack access to the warnings. The section explores the failure of warnings to reach the most vulnerable people in the study area. Focus group discussions suggest that the most vulnerable people prioritise other risks, such as harassment, theft, and trouble during flood evacuations, over the risk of hazards they face. These perceptions influence their motivation and action after receiving warnings.

6.3.1. People's understanding of hazard risk

This section shows that while people at the community level understood that they were at risk of flooding, there were diverse understandings related to the causes of floods or did not understand what causes floods in the Kosi River, as shown in fig. (50).

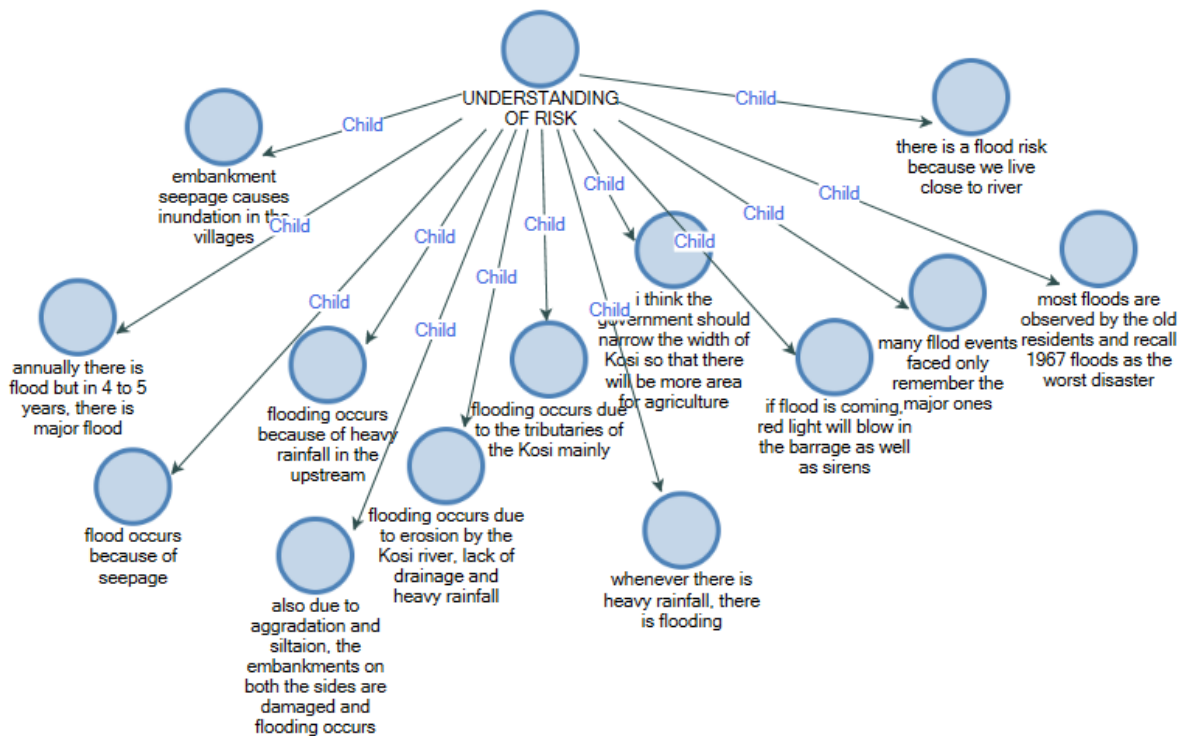


Figure 50: NVivo map showing people's understanding of hazard risk and causes of Kosi River floods .

Authors such as Amaratunga et al. (2018) and Rollason et al. (2018) have argued that understanding risk is one of the essential components for disaster risk reduction at the local level, as it can play a vital role in better preparing communities at the time of disasters; and understanding causes of hazards and their dynamics would allow people to decide on appropriate actions during disasters. During the community-level interviews, all the respondents (44) stated that they were aware of the risk of flooding because they live close to the river, and in every monsoon season, they suffer a loss due to Kosi floods, especially in agricultural livelihood (i.e., crops and livestock rearing). This quote from a community-level interview at Bathnaha, India, suggests the same:

"...Yes, I know we are at risk of flooding... flooding and inundation happen here every year, but in every 4 to 5 years, massive flooding happens ... and we have to

evacuate to embankments or barrage to save our lives... Kuccha houses get damaged every year... during the monsoon season, 75 per cent of all the village will be inundated ...all of our crops in the field get damaged, and cattle will also die due to multiple disease brought by floods...” (C30, Bathnaha, India).

When further questioned about the causes of floods in the Kosi River basin, 52 per cent (23) of the interviewees mentioned that they did not know the cause. Some speculated that heavy rainfall in the mountains upstream could be a factor, as flooding appears to coincide with rainfall. Others believe flooding is a natural occurrence in the region since it happens yearly during monsoon season, as shown in fig. (51). The following quote from the community interview suggests the same:

“...Flood comes and goes...I do not know why it comes but it comes every year...that is for sure...may be due to the heavy rainfall in the hilly areas of Nepal...” (C1, Kunauli, India)

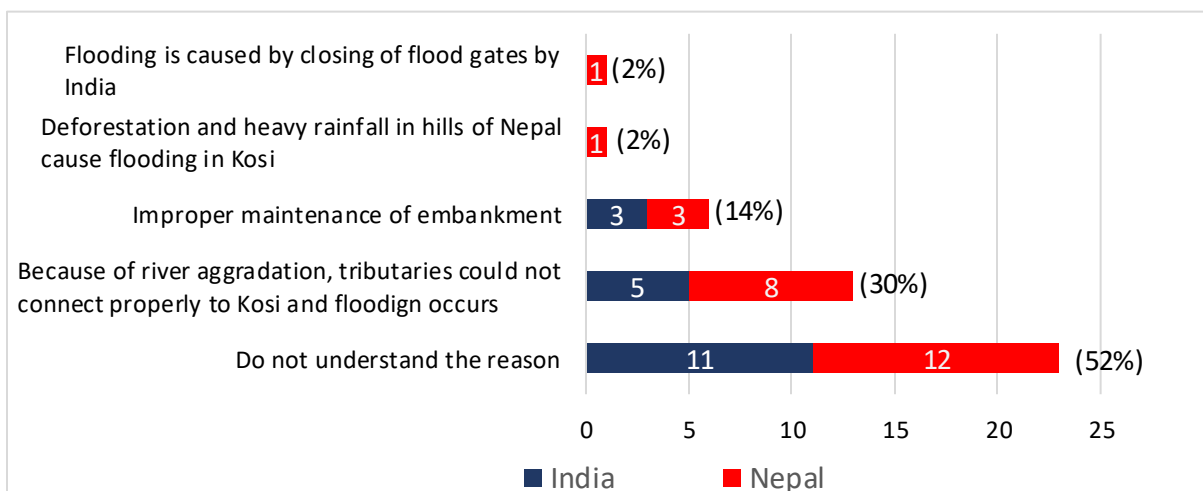


Figure 51: Understanding of the reasons for flooding in the Kosi River basin, which suggests that most people at risk do not understand the reasons for flooding while others have varying perceptions regarding the causes of flooding in the Kosi River.

In 44 community-level interviews, 48 per cent of the interviewees (8 in India and 13 in Nepal) reported understanding the reason for flooding in the Kosi River. Among them, 30 per cent (8 in India and 5 in Nepal) attributed flooding in the Kosi basin to riverbed aggradation, whereby the Khaando and Mahuli rivers' tributaries could not drain into the Kosi River, resulting in annual flooding and inundation in the settlements.

“The main reason for flooding in our village is because the land is flat. Secondly, the Kosi River runs inside the embankments and dumps sand on its riverbed every

year, because of this, in areas like Dalwa and Kusaha, the Kosi flows at a higher level than settlement there...also during a heavy downpour in monsoon, the rainwater and water from tributaries of Kosi cannot drain into the river, so flooding occurs from both inside and outside of embankment in our village.” (C21, Rampura-Malhaniya, Nepal)

Similarly, 14 per cent of the interviewees (3 in Nepal and 3 in India) mentioned that flooding happens due to the poor maintenance of embankments. During the heavy discharge in the Kosi River, embankment erosion happens, and river water seeps through the embankments to the settlements causing floods and waterlogging.

“...our village is situated between the Khando River on the west side and the Kosi River on the east side...we have to face the seepage from Kosi embankment and flooding caused by Khando annually...water gets inside our village but cannot drain out because our village is surrounded by embankments...” (C28, Hanumannagar, Nepal)

During a community-level interview, one interviewee from Nepal stated that deforestation in the hills of Nepal is the reason for flooding in the Kosi River. He explained that the Nepalese government had cleared jungles for settlement expansion and road construction in the Chure mountain range, leading to widespread landslides upstream of the Kosi River. The landslide debris is transported downstream by the tributaries of the Kosi River and dumped on the flat plains of Terai, resulting in river aggradation, and flooding yearly in the Kosi River basin.

“...If you know how much deforestation has happened in the upstream you will find out the reason for flooding in Kosi...55 per cent of the total forest land was cleared for settlement in the Chure mountain range upstream causing landslides...the landslide debris are carried by rivers and dumped here in terai causing floods.....the deforestation is the main reason for flooding in the Kosi River....” (C15, Shankarapura, Nepal)

Another interviewee in Nepal claimed that flooding results from India's closure of the floodgates of the Kosi barrage. He argued that Indian Water Resource Department officials who supervise the Kosi barrage deliberately shut the floodgates during the monsoon season

to prevent Bihar from flooding. Consequently, the territories of Nepal become inundated since the Kosi River is obstructed at the Kosi barrage during the monsoon season.

“...The main reason for flooding in the Kosi River is because of the role of India...flood is the outcome of the intentional tactic of the director of the Kosi project to close the Kosi barrage gates during floods to save Bihar and cause inundation in Nepal... I can guarantee that because I have seen them doing it...”

(C25, Rampura-Malhaniya, Nepal)

The results suggest that 58 per cent of respondents in Bihar do not understand the causes of flooding, while 42 per cent attribute it to improper embankment management. In Nepal, 48 per cent of respondents are unaware of the causes of flooding, and the remaining 52 per cent have varying opinions, including riverbed aggradation, seepage from embankments, and deforestation. These findings indicate that people in the study area are aware of the impacts of hazards but lack a uniform understanding of their causes, which is consistent with Jones et al.’s (2016) argument that NGO-led awareness-raising activities have contributed to a better understanding of hazard risk in Nepal than in Bihar, as discussed in Section 5.6 of Chapter 5. The lack of uniform understanding of hazard risk may also contribute to speculations and myths about floods, which is discussed further in Chapter 7, Section 7.4.2, and has implications for disaster preparedness and actions during disasters, as noted by Gupta et al. (2021). The following section will discuss people’s access to and preferences for warnings, as well as their perceptions of risk.

6.3.2. People’s access to warnings

The following section is based on the 44 community level interviews conducted at the study area inquiring about the people’s access to warnings. The findings from the study suggest that half of the population (22 out of 44) had access to warnings while the other half did not have access. However, the access to warnings is skewed towards Nepal as 72 per cent of the interviewees (18) mentioned that they had access to warnings primarily through SMS. In

contrast, only 21 per cent of the respondents from Bihar had access to the warnings but 79 per cent of the respondents did not receive warnings as shown in fig. (52).

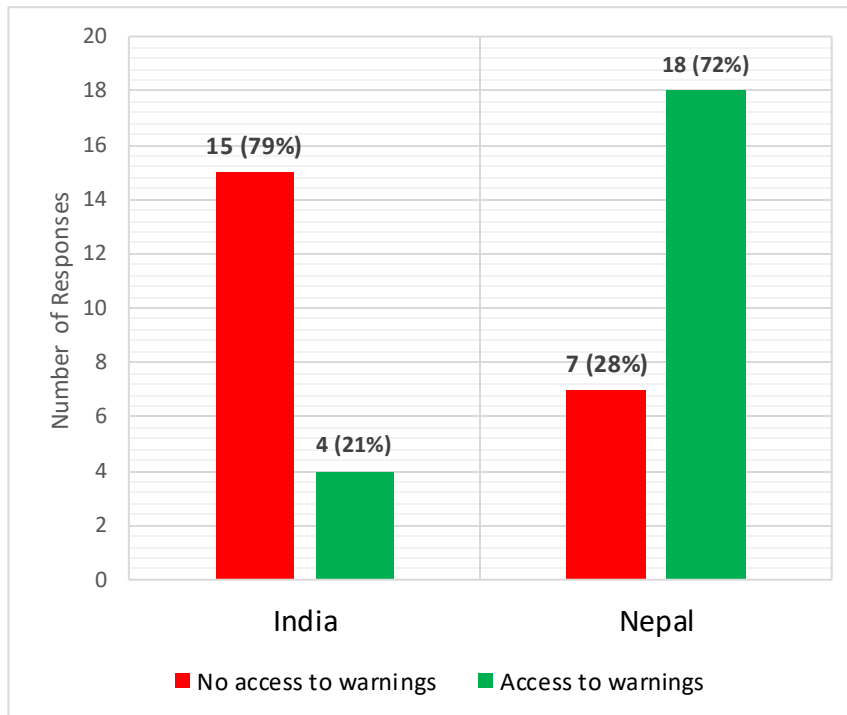


Figure 52: The bar chart showing access to early warnings in India and Nepal, suggesting that Nepal has greater access to warnings compared to India.

The result implies that the warnings are more accessible in Nepal than in Bihar because of the direct method for risk communication through targeted mass SMS. This result also corroborates with the findings of Jones et al. (2016), suggesting that even though the institutional capacity for EWS is much greater in Bihar, the progress in EWS has been more significant in Nepal because multiple NGOs and donors lead the process of EWS in Nepal compared to the state-led approach in Bihar.

However, among the 72 per cent (18) respondents in Nepal who stated that they had access to the warnings through SMS, 67 per cent of them (12 among 18) stated that the SMS warnings were not helpful because of insufficient lead times. Following is a quote from a community level interview from Nepal:

"...Yes, I received a warning... but what can be done with just one hour of warning?... it is not just about me alone running to the embankment...isn't it? I must take care of my children, my cattle, important papers like Lalpurja (property ownership certificates) and Nagarikta (citizenship ID) ...move furniture and grains

to the upper floor...Is it possible to do everything in one hour? ...” (C6, Tilathi, Nepal).

Similarly, the people from Nepal also mentioned that the flood warnings are received only for the Kosi River but not for its tributaries, while annually the cause of the flooding in the Kosi River basin is due to the tributaries of the Kosi River. The following quotes suggest the same:

“...Yes, we get warning in mobile, only when Kosi is rising, but there is no warning when there is a flood in Khando River, Ratu River or Jitaha River, while mostly the damage is caused by those small rivers than Kosi in our village....” (C16, Koiladi, Nepal).

“...We live close to the tributaries of the Kosi River called Khando and Jitaha... just look at those areas, what happened with just two days of rainfall (showing inundated fields) ...look at the damage to our crops.... those small rivers are causing more difficulty than the Kosi River now...but where are the warnings for those tributaries?” (C34, Hanumannaga, Nepal).

The above quotes from the community-level interviews suggest that people received flood warnings only 1 to 2 hours before floods and regarded those warnings as unhelpful because, in the short lead time provided in those warnings, people could only save themselves but not their assets. The quotes also suggest that warnings are unavailable for the tributaries of the Kosi River, which causes frequent flooding and inundation in the Kosi River basin. These findings agree with the study of EWS governance in Nepal by Brown et al. (2019) and the study of risk communication in Nepal by Budimir et al. (2020), arguing that despite the technological advancements in EWS, timely access to those warnings is lacking in Nepal.

Similarly, while exploring the access to warnings based on gender, the community level interview data suggested that there is equal access to warnings in Nepal, with 36 per cent of males and females receiving the warnings, while 16 per cent of males and 12 per cent of females not having access to the warnings. While in India, 11 per cent of men and 4 per cent of women had access to the warnings, 58 per cent of men and 21 per cent of women interviewed for the study did not have access to warnings as shown in fig. (53).

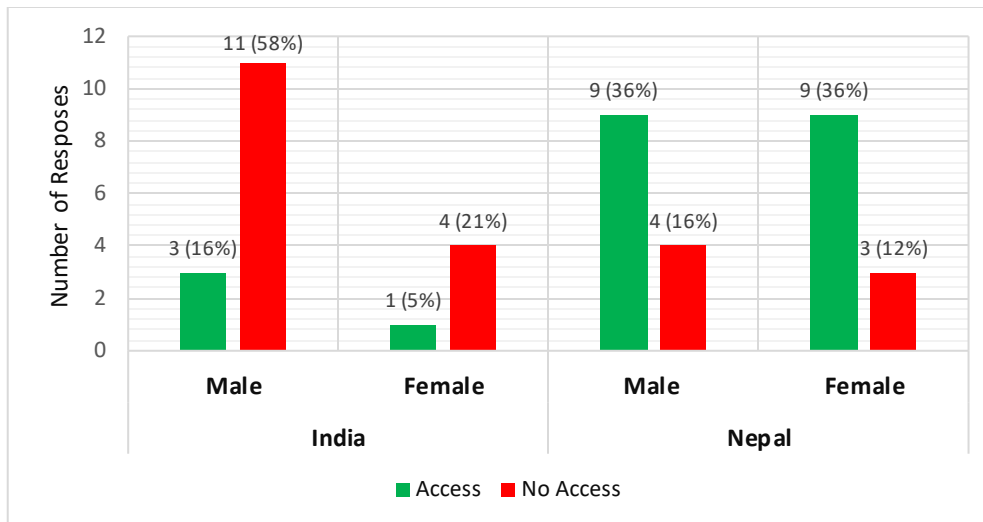


Figure 53: The access to warnings in Nepal and India, differentiated based on gender.

Many scholars such as Gupta et al. (2021), Jha and Gundimeda (2019), Pritchard and Thielemans (2014) have suggested that access to warnings in the Kosi River basin depends on caste dynamics, social deprivation, and gender. The community-level interview was conducted based on the in-situ availability of people in public places, and participants were not chosen based on caste, class, or socioeconomic status. Among the 18 people who stated they had access to warnings in Nepal, nine were male, and nine were female. In comparison, out of 4 people with access to warnings in Bihar, three were male, and one was female. The difference in the result of community-level interviews and literature could be due to limited access to women interviews were being conducted or due to the small sample size of community-level respondents (i.e., 44). The gender composition of the sample included 13 males and 12 females in Nepal and 14 males and 5 females in Bihar based on the in-situ availability of people in public places. The discrepancy in results could also be due to the socio-cultural barriers limiting women from going to public places and market centres and interacting with other men, as suggested by Prakash and Acharya (2019). Khadka et al. (2015) also suggested that 46 per cent of people live below the poverty line in the Kosi plains—where men work in subsistence agriculture, and women have roles in household chores—which also relates to the limited access of women to the market centres and public places community-level interviews were being conducted. Similarly, Gustafson (1998) argued that different methodological approaches sometimes give different or even contradictory results of gender differences; therefore, the methodological approaches in research should be qualitative and socio-culturally informed to reveal the gender differences because men and women are

differently exposed, perceive, and handle risks differently and are differently affected by disasters (Gustafsson 1998). This discrepancy in result was overcome in further investigation of the gender-based access to warnings through gender disaggregated focus group discussions, as discussed in section 6.3.4.

From the community-level interactions, it was observed that because of mass SMS, the warnings were accessible to most people in Nepal. In contrast, in Bihar, warnings were limited to some communities due to the porous international border between Nepal and India, due to which warnings received in Nepal get communicated through people's interaction in Kunauli and Bathnaha villages in Bihar. However, further inside, in Haripur and Kamalpur, most people stated that they do not have access to the warnings, and only some people who have television and radio could get warnings aired on national television or radio, as illustrated in image fig. (54).

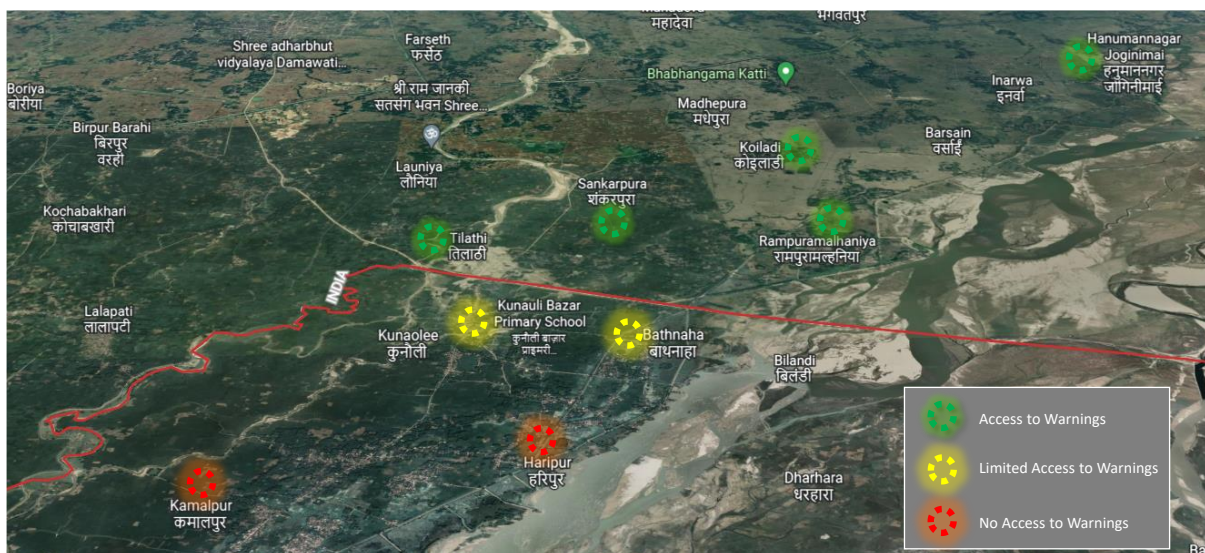


Figure 54: The image shows access to the warning in the study area, suggesting that early warnings were accessible to most people in Nepal. In contrast, limited people in Bihar had access to the warnings in villages close to the Nepal-India border (Kunauli and Bathnaha) due to the porous international border and people's interaction across the border. However, warnings were not accessible further away from the border in the Haripur and Kamalpur villages of Bihar (Image source: Google Earth, 2022).

This result suggests that Nepal had greater access to warnings than Bihar in the study area, which could be due to the direct method of risk communication in Nepal, as suggested by (Kuller et al. 2021), compared to Bihar, which involved an extended hierarchy of institutions for disseminating warnings. This argument is further justified by the finding that all the 18 respondents in Nepal who had access to warnings received it in SMS. Even though the direct method of risk communication in Nepal could have led to greater access to warnings

compared to Bihar; most of the people who had access to warnings through SMS in Nepal stated that SMS warnings were not helpful because (1) they provided insufficient preparation times of only 1 to 2 hours before floods, and (2) because warnings were received exclusively for the main channel of the Kosi River but not for its tributaries that causes floods most of the times. In contrast, warnings were not available to most people in Bihar and people had to rely on radio and television for warnings.

6.3.3. People's preferences on risk communication

This section deals with the people's preference on the mode of risk communication based on the community level interviews. This section shows that government institutions are sending warnings to the people at risk irrespective of people's preference on the mode of risk communication and the language used for risk communication.

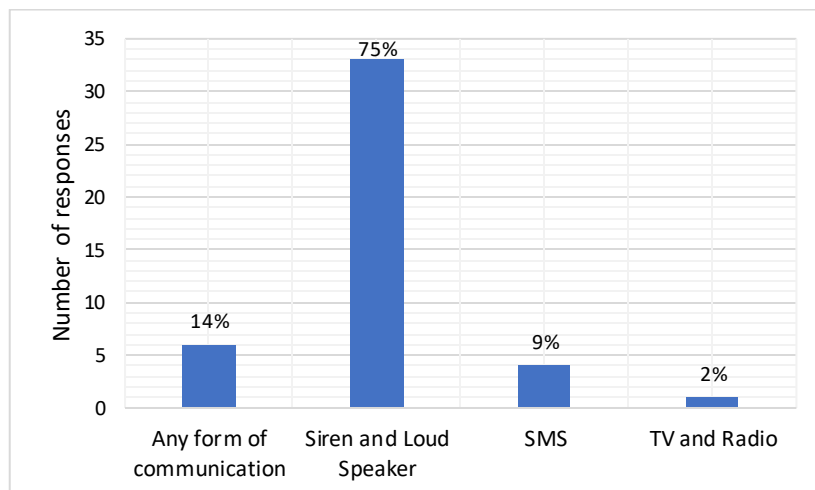


Figure 55: The chart showing people's preference on the mode of risk communication, where 75 per cent of the respondents stated that they prefer sirens and loud speaker for risk communication.

From the 44 community level interviews about their preferred mode of communication fig. (55), 75 per cent of the interviewees stated that their preferred mode of risk communication were sirens and loudspeakers. Following that, 14 per cent of the responders mentioned that any form of communication would be useful for them because they did not have access to any forms of warnings. Furthermore, only nine per cent of the respondents stated that SMS warnings were preferred, and two per cent stated their preference as television and radio. This result suggests that people preferred low-tech and an in-person style of risk communication rather than technology-based SMS warnings to understand the risk information better. This result also asserts with the study by Budimir et al. (2019), which

suggested that people preferred the in-person style of communication over SMS warnings because of their low literacy level in the Kosi River basin. However, as discussed in section 6.2.2, by E31, the local government institutions in Nepal have discontinued using sirens and loudspeakers, regarding them as the “*old ways of warnings*” (E31) since the DHM started sending the warnings through mass SMS. In a similar context, Kelman and Glantz (2014) argued that as the technology has evolved, the EWSs have also been changed from manual systems of warnings to SMS warnings; however, those developments in EWS need to be balanced with the local level challenges, as technologies cannot be assumed to be omnipresent and accessible to everyone in a society.

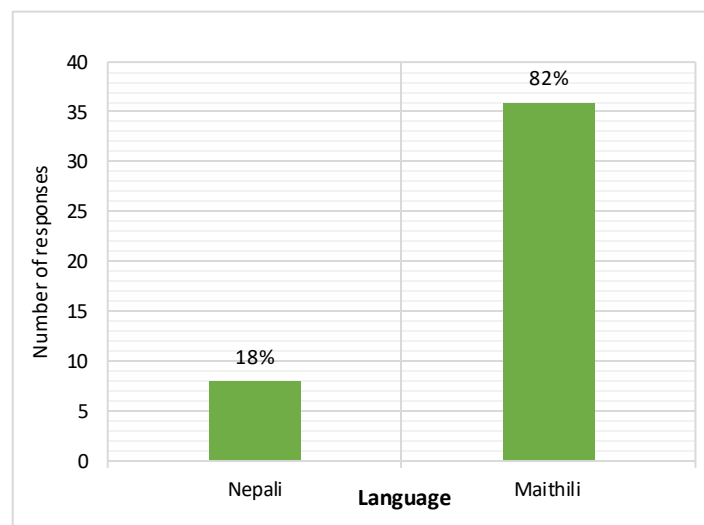


Figure 56: People’s preference over language in flood warnings, which suggests that people prefer to receive warnings in the Maithili language.

The language used in EWS is also an important thing to consider. This research suggests that, on both sides of the border, 82 per cent of the respondents (36) stated that they prefer to receive warnings in the Maithili language rather than the Nepali language so that the warnings could be better understood (fig. 56). The result corroborates with Kelman and Glantz (2014), suggesting that people want to receive warnings in their native language to understand better the information provided in the warnings. The results also imply that government institutions are not considering the preferences and needs of the recipients while disseminating the warnings.

This section showed that warnings given to the people at risk are unmatched by the needs and preferences of those at risk. The following section will investigate the access of risk communication to the most vulnerable in the study area and their perceptions of risk.

6.3.4. Vulnerable people's access to warnings

In this thesis, the term vulnerability, as discussed in Chapter 2, is based on the definition of Wisner et al. (2014), which refers to the deprivation and marginalisation of people living in flood plains, resulting from the combined effects of social-economic, institutional, and cultural factors of the context, which makes them susceptible to hazard impacts. The following section presents data from 12 focus group discussions (FGDs) conducted in the study area, out of which three FGDs were conducted in each village of the Hanuman Nagar and Rampura-Malhaniya in Nepal; and two FGDs were conducted in each village of Bathnaha and Haripur, and one each in Kunauli and Kamalpur villages. The FGDs were conducted to understand the access, perception, and understanding of the early warnings by the flood-affected and vulnerable population (women, elderly, and impoverished) in the study area. Out of 12 FGDs, six gender-disaggregated FGDs with women groups were conducted in the study area with two each in Rampura-Malhaniya and Hanuman Nagar in Nepal; and one each in Bathnaha and Haripur villages in India to gather the viewpoints from women living in the study area. The themes generated from the vulnerable people's access to warning as shown in fig. (57) suggests diverse sources as well as responses to warnings.

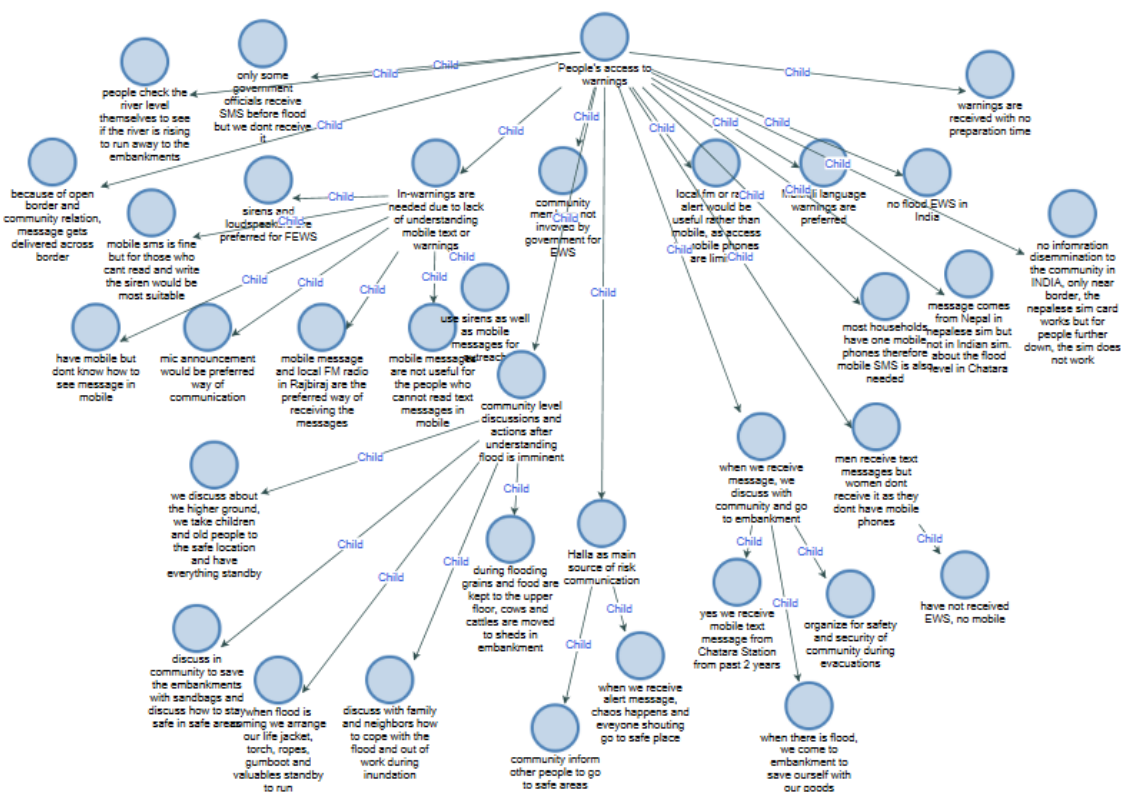


Figure 57: NVivo map showing vulnerable people's access to warnings in the study area based on focus group discussion.



Figure 58: Gender disaggregated FGD conducted at Rampura-Malhaniya Village, where women stated that they do not have access to the warnings and cannot read the SMS warnings.

In FGDs conducted with groups of women at Rampura-Malhaniya (fig. 58) of Nepal, people mentioned that they do not have access to the warnings because only the male household heads own mobile phones and, even if they had a mobile phone, they could not read and understand the warnings in the SMS without their spouse's support due to low literacy levels. Following is a quote from FGD conducted with women in Rampura-Malhaniya village, Nepal:

"...The mobile is good only for those who are educated...we cannot read the message on the mobile...also only men have mobile in our households, and they must go far away for their work...so how can we know about SMS warnings? It is only useful for those who have mobile phones on their hands..." (Gender disaggregated FGD, Rampura-Malhaniya, Nepal)

These results also conform with the study by Budimir et al. (2020), in which 47 per cent of the women respondents in the Kosi Basin stated that only their spouse owns and uses mobile phones. Similarly, Acharya and Prakash (2019) also argued that access to risk information in the Kosi River basin shows serious gender concerns, as women do not get warnings directly and must wait for men in their household to bring the news to them. Similarly, many scholars (e.g., Meechaiya et al. 2019; Brown et al. 2019; and Budimir et al. 2020) also argued that women, marginalised populations, and people with low socioeconomic status are much less likely to be reached by early warnings systems and the EWS is "gender unaware" in the study area.

While in gender disaggregated FGD conducted in Rampura Malhaniya, Nepal, the group of women mentioned that they used to receive warnings through sirens and loudspeakers from local level government officials and Red Cross. However, since the DHM started sending warnings through SMS, the use of megaphones and sirens were also discontinued by the local level governments, and people at risk do not receive warnings in any form. Following is the quote of an interview with a women group in Rampura-Malhaniya Nepal:

"...They do not announce in mic (megaphones and loudspeakers) anymore...for us, mic announcement is only useful...at least we could listen to the announcement even while we are busy in our work in home or in agricultural field..." (Gender disaggregated FGD, Rampura-Malhaniya, Nepal)

In an FGD conducted with flood-displaced people living in temporary shelters at Hanuman Nagar, Nepal, people also stated that they did not have access to the flood warnings because they could not afford mobile phones and even if they could, they could not read or understand the SMS warnings.

"...We do not receive the warnings about the flood because we do not have mobile phones...whoever has mobile, receive the message...also, we cannot read the message, even if we had mobile..." (FGD, flood-displaced people, Nepal)

Similarly, the FGD with flood displaced people, in Hanuman Nagar also stated, *"...we cannot read the message...so siren and Mic is only useful for us...so that we would know a flood is coming..."*. (FGD, Hanuman Nagar, Nepal).

While conducting FGDs across the border in Kunauli, Bihar, people mentioned that mobile networks of Nepal can be received in villages of India near the Nepal-India border, therefore people living in those villages carry mobile SIM registered in Nepal to receive flood warnings. The warnings are passed on and communicated through people's interaction in the marketplace in Kunauli when they come to buy daily essentials and groceries.

"...we eat lunch here in India and go to the other side in Nepal to eat Paan (mouth freshener wrapped in beetle leaves)...likewise people from Nepal and surrounding villages come here (market place) regularly to buy groceries, drink tea, and interact with their friends...so if anyone receives flood warnings here or in Nepal, it will

automatically be communicated through people's interaction because everything is connected here..." (FGD, Kunauli, India).

The above statements imply that the marketplace also performs as a social space where warnings can be accessed through interaction. Acharya and Prakash (2019) likewise suggested that in the Bihar state, 'bazaar' or marketplaces serve as a significant platform for social interaction, during which warnings are communicated. Similarly, one of the responders in a community-level interview (C3) mentioned that people living close to the Nepal-India border use both Nepalese and Indian SIM cards to avoid international call charges between the countries, and while doing so, the warnings sent by DHM is also received in their mobile phones in Kunauli, Bihar. Those warnings get communicated to the people living nearby and some villages close to the border through interaction when they shop their daily essentials in the marketplace.

However, Acharya and Prakash (2019) also argued that in Bihar, women are not allowed to go alone in the marketplace without being accompanied by men, and neither allowed to interact with other men in the marketplace; Therefore, women's access to the warnings through public interaction in the marketplace becomes questionable due to socio-cultural barriers for women.

While discussing with people living in Bathnaha, India, which is further inside the India-Nepal border, the responses were divided as some people mentioned that flood warnings could only be accessed through radio and television for people who could afford it, but others only know about flood when they experience it. Also, some participants in FGD mentioned that they have the phone number of the Watchman (Security Guard) of the Kosi Barrage (fig. 59), who they call to know about the possibility of flooding in their area. Likewise, some respondents of the FGD mentioned that the Panchayat Head and Thanadar (local police officer) inform about flooding when floods start to erode embankments and tell people living there to evacuate to higher ground. Following is the quote from FGD conducted at Bathnaha, India:

"... during floods, when the Kosi river starts cutting embankments, then only our Sarpanch (Panchayat Head) and Thanadar (local police officer) come to inform us about flood and tell us to leave our houses and go to higher grounds...after that, in about less than an hour, the whole village will be submerged...we cannot do

anything except quickly gathering our things and running with our family to the higher grounds...” (FGD, Bathnaha, India).



Figure 59: [Left image] respondents from Bathnaha explained that the only way for accessing flood information for him is by calling the Security Guard of the Kosi barrage. [Right Image] a resident of Bathnaha, explaining warnings can only be accessed through radio, but are difficult to interpret and understand.

During the FGDs conducted in Haripur and Kamalpur villages of Bihar, respondents in FGD mentioned that they do not get warnings and the only way to access the warnings about the Kosi flood is through the news broadcast in radio (fig. 60), however, the information provided in the radio is also difficult to understand because the news will be in Hindi or English language and the information will not be specific to their location. Similarly, Acharya and Prakash (2019) also argued that the warnings aired on radio in Bihar are vague regarding time and location and mostly contain the obscure values of river level and discharge, which people find difficult to interpret.

“...we only get information from the radio, we get news about floods in Kosi during monsoon season...everyone will keep listening to the radio every time during monsoon...we listen to All India Radio...Weather Department will give news on bad weather and the possibility of floods in Kosi...we listen to news from Rajbiraj FM (from Nepal) and Bhurkuwa FM (local FM) ... but it only says villages near Kosi are at risk of flooding but it does not say which one...” (FGD, Haripur, India).



Figure 60: FGD in Haripur, India, where people explained that the warnings are accessible through radio during the monsoon season, but the warnings are not specific to their location, therefore, difficult to comprehend.

Similarly, in Kamalpur, during the FGD, people stated that they do not have access to the warnings and only when they see the chaos in their community, they will understand that flood is coming. Following is the quote from FGD conducted in Kamalpur:

“...We don’t receive warnings here...who will send us warning here in edge of Bihar?...we only know about flood in Kosi after it occurs...when people start doing Shor Sharaba (chaos and noise) and Halla (shouting about floods)...running here and there...packing things and moving their grains to upper floor...when we see that ... we will understand that flood is coming...” (FGD, Kamalpur, India)

The FGDs in the study area suggest that warnings are not accessible to women and marginalised populations in the study area. In the impoverished settlements in Nepal, people only had one mobile in the household, which men carried. Most of the men in those households worked as construction labourers in nearby cities. At the same time, women stayed in the house and stayed busy with household duties and took care of children and the elderly ones in their household. Therefore, even if men receive warnings, they cannot be passed on to other members of their families. Also, due to low literacy levels, women in the study area cannot read the SMS warnings sent on mobile phones without their spouse’s support.

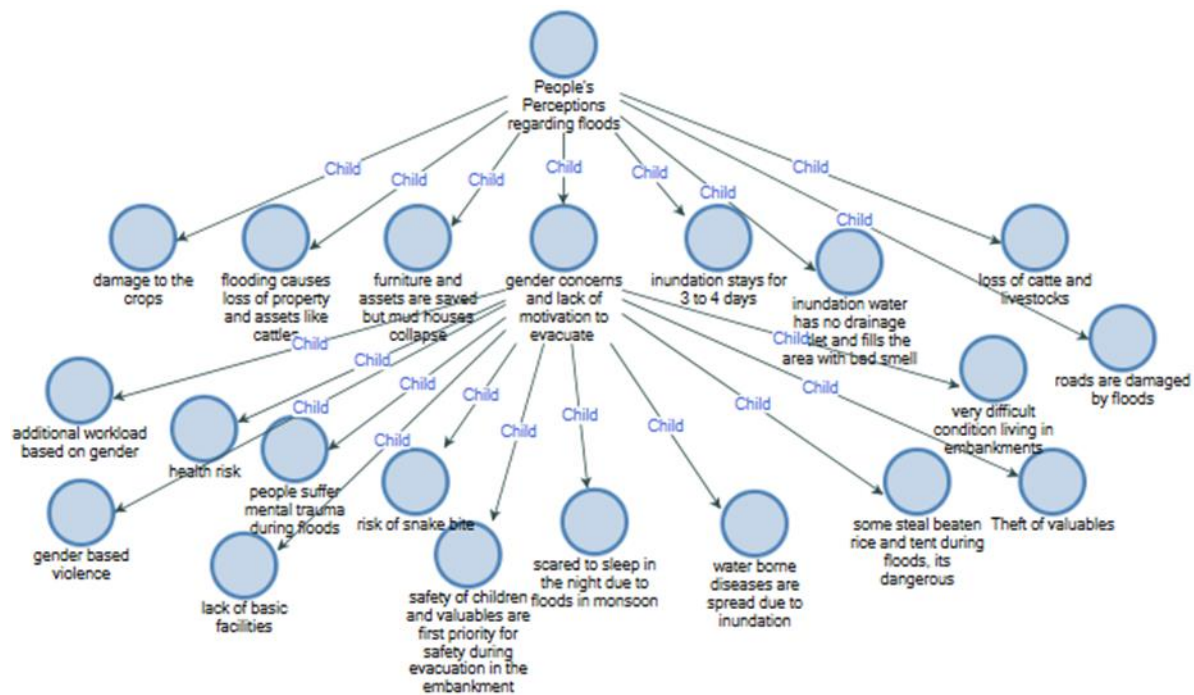
In contrast, most people rely on radio and television to receive warnings through flood news broadcasts in Bihar. This finding agrees with literature (e.g., Acharya and Prakash 2019; Gade 2020; Perera et al. 2020), which also argued that warnings over radio and television are essential in Bihar as most people access flood information through those mediums. Radio alerts are critical to the most deprived ones as they can only afford a radio where they can receive warnings. Some also mentioned that they rely on indirect sources like calling the security guard at the Kosi barrage for flood information, accessing information through interaction with others at the market centres, or from Thanadar or Mukhiya—albeit late, after flood starts eroding embankments.

The early warnings are not accessible specifically to the women and impoverished communities in the study area. This result agrees with Prakash and Acharya (2019) and Budimir et al. (2019); the authors also argued that marginalised populations and people with low socioeconomic status are much less likely to be reached by EWSs in Nepal and Bihar.

This section showed that vulnerable people could not access risk communication in Nepal and India. Also, due to the adoption of newer technologies without understanding the context of people at risk, the most vulnerable ones are further being cut off from the warnings in Nepal. While in Bihar, the warnings are only accessible through radio for the most vulnerable ones; however, the information provided in those warnings is vague and not location-specific, which people find difficult to interpret and understand. The following section will investigate the people's perception of floods and their response actions during disasters in the study area.

6.3.5. People's perceptions about floods and their actions during disasters

The following section is based on the 12 focus group discussions conducted in the study area, enquiring about people's perceptions and actions when they receive flood warnings or understand that flood risk is imminent. During the gender disaggregated FGDs conducted with the women group regarding how they understand and perceive risk and respond to warnings, participants mentioned that difficult living conditions, theft, animal attack, and harassment by men during evacuations were more concerning than the risk of hazard; therefore, they prefer not to evacuate until the evacuation becomes the last resort for their survival. Similarly, it was observed that people collectively interpret and evaluate risk in a community and make



In an FGD conducted in Hanuman Nagar, Nepal, inquiring what happens after they receive the warnings and how they act after knowing that their village is becoming inundated, people mentioned they would be in a state of panic after knowing that flood is occurring. Also, the participants of the FGD suggested that after knowing that a flood is imminent, they quickly gather their valuables and belongings, move grains and furniture to the upper floors, and evacuate to embankments with their valuables in their community-owned fishing boat. Following is the quote from FGD conducted with flood-displaced communities living in temporary shelters in Hanuman Nagar, Nepal:

embankment in our fishing boat. we also alert other people in our community to pack their valuables and move to higher ground...” (FGD, Flood displaced community living in temporary shelters in Hanuman Nagar, Nepal).

However, in a focus group discussion with a group of women in Rampura-Malhaniya village of Nepal (fig. 62) and Bathnaha, India, women mentioned harsh living conditions during the evacuation, because of which they were reluctant to evacuate even after knowing that their houses are being flooded. The women mentioned that they would suffer the most during the evacuation, as they would have to live on the embankments for days under the makeshift huts built by tarpaulin sheets without basic amenities like drinking water and cooking fuel or toilet facilities. In those conditions, women will have an additional workload of cooking for their family, cleaning utensils, taking care of children, and looking after their valuables. Furthermore, during an evacuation, there are risks of harassment by men, risk of waterborne diseases, the threat of animal attack and snakebite during evacuation; Therefore, considering all the troubles and threats, women stated that they prefer to until the last moment when floodwater reached their home or when evacuation becomes a last resort to survive.

“...men will not have problems, but we will have to face a lot of problems there...going to the toilet is the biggest challenge...we have to go far from the tents (temporary shelters) to an isolated area or jungle early morning in the dark before everyone awakes ...there is a risk of harassment by other men...also there is a risk of snakebites and wild animal attack....it is really difficult” (FGD, Rampura Malhania, Nepal).



Figure 62: The FGD held with women group at Rampura-Malhaniya, discussing the troubles during flood evacuations.

Likewise, during FGD in Bathnaha, India, people mentioned the harsh living conditions, risk of waterborne diseases, and risk of theft of valuables such as jewellery and mobile phones during evacuation. People are reluctant to leave their houses even during the flood. However, people also mentioned that local police officers forcefully evacuate the people living in the flood plain in Bihar during floods. The following quote from FGD in Bathnaha, India suggests the same:

“... we have to survive there (on embankments) by licking salt and eating puffed rice for days...also most of our buffaloes and goats will get infections on their legs and mouth due to dirty water and die...there is also a risk from thieves stealing our money, jewellery, and mobile phones while living there on embankment...therefore people do not want to leave their houses...but here in Bihar, if we do not go, police will hit us with danda (baton) and force us to run...” (FGD, Bathnaha, India).

The above responses from FGDs conducted at Rampura Malhaniya, Nepal and Bathnaha, India, suggest that for women who took part in FGDs perceived risks of harassment and difficulties during an evacuation are more salient and concerning than the risk of impending hazards. Therefore, their perception of risk influences their motivation and behaviour during disasters. This result relates to the study of EWS in Bangladesh by Haque and Blair (1992). The authors observed that even though everyone in the study area received warnings and understood that hazard risk was imminent, people chose not to evacuate, fearing the burglary of assets, making EWS ineffective. In addition to these, extensive literature (e.g., Lindell and Perry 2003; Wachinger et al. 2013, Kaspersen et al. 2013; Kelman and Glantz 2014; Hamsa and Mansson 2019) also suggests that people’s perception of risk is a significant determinant in EWS and relates to peoples’ behaviours during disasters.

The participants of FGDs in Bathnaha, India, also mentioned that, when they know about the impending risk of flooding, male household heads in the community quickly gather and discuss the flood risk in the village and decisions to take during the flood. Some men work on strengthening the weak points in the embankments by stacking sandbags, while others arrange hand-rickshaws to transport goods and people to the embankment for safety. Following is the quote from FGD conducted in Bathnaha:

“...after we know about floods, men from each household gather and discuss what to do...then some men arrange Thela (hand-rickshaw) to move children, elderly to the embankment...also some men work on strengthening the embankments in our village by putting sandbags at the weak points to block seepage...” (FGD, Bathnaha, India).

The above quote from the FGD in Bathnaha illustrates gender discrimination towards women in the study area as women did not have any role in consultation, decision, or action regarding flood preparedness and evacuation, and only men led all the processes. The argument also asserts with Acharya and Prakash (2019), stating that in Bihar, understanding and processing of warnings received from radio, discussing the warnings with other members of society, and taking decisions for action are all led by men; social barriers prevent women from engaging in such activities but are expected only to follow the decisions.

The FGD participants from Haripur and Kamalpur of Bihar mentioned that the chaos spreads in their village whenever the warnings are received on the radio. People speculate and try to understand the risk by discussing with other local elites and influential ones in the village and at the same time start safeguarding their important documents, cash, and valuables. Most of the other community members follow what has been decided by elites and influential ones for action. Following is the quote from the FGD in Haripur, India:

“...we cannot think properly at that time.....because everyone will be in a panic and running here and there doing ‘Halla’ (shouting) in the community...we quickly gather things like cash, jewellery, bank documents, Aadhar Card (national ID)...move furniture and grains to the upper floor...at that time elderly and influential men in our community discuss what is best to do and what decision should we take...then we follow what everyone else will be doing...”. (FGD, Haripur, India).

Douglas and Wildavsky (1983) state that risk perception and acceptance is a collective construct in society, and people evaluate risk collectively during disasters. In the same way, the above quote suggests that people in the study area evaluate risks collectively and take response action based on discussion rather than responding to disaster individually. This

finding also agrees with multiple scholars (e.g., Eiser et al. 2012; Johnson and White 2010; Mileti et al. 2002; Renn 2017; Smith and Petley 2009; Smith 2013).

This section showed that vulnerable people perceived the risks of harassment, water-borne diseases, theft, and difficult living conditions during an evacuation to be more worrying than the hazard risk they face, which could determine their motivation and action after receiving warnings or during disasters. Gustafson (1998) argued that risk perception is gendered, and women perceive risks differently than men, which is contributed by gender structure, gender ideology, and gender practices. The author further suggested that in a society where power relations between men and women differ substantially, women's risk perception and fear also substantially relate to male sexual violence (Gustafson 1998). Similarly, this study has found that women perceive risks differently than men. The result of gender disaggregated FGDs conducted with women groups revealed that harsh living conditions in temporary shelters during evacuations, along with other risks: risk of sexual harassment, risk of animal attacks and snake bites, the risk of waterborne diseases, risks of theft of jewellery and mobile phones during an evacuation, to be more concerning to women than the risk of flood hazards. Therefore, women were reluctant to evacuate until it became a last resort to survive. These findings suggest that women were more concerned about risks they have to face during evacuations, than the risk of flood hazard, and their perception was a significant motivating factor for their behaviour during disasters, as suggested by extensive literature (e.g., Eisenman et al. 2007; Haque and Blair 1992; Hamsa and Mansson 2019; Lindell and Perry 2003; Kaspersen et al. 2013; Kelman and Glantz 2014; Wachinger et al. 2013) that sociocultural factors affect risk perception which translates into actions during disasters.

Also, this section showed that risks are interpreted and understood collectively in the study area. However, due to the social barriers and gender discrimination towards women, only men lead the process of consultation and decision-making for actions to take during disasters, and women have no role except following those decisions.

6.4. Chapter summary

This chapter has demonstrated that risk communication in EWSs in Nepal and India follows the centralised and top-down approach for disseminating warnings to the people at risk. In Nepal, early warnings are disseminated through mobile SMS to the people at risk, but those

warnings were non-standard, lengthy, and non-specific regarding the exposed location, time, possibility of flooding, or recommended actions to follow. The experts in government institutions, which sends early warnings to the people at risk, had no contextual understanding of whether the warnings were accessible or understood by their intended recipients. Furthermore, this expert-led process of risk communication is also not serving the needs of the people at risk, as the warnings were vague in terms of language, time, and location and did not match with the people's preferences. In contrast, In Bihar, warnings flow top-down through a lengthy chain of bureaucracy before reaching the local level institutions for its dissemination to the people at risk. However, due to the awkward institutional arrangement at the local level, where only few government officials are solely responsible for disseminating the warnings and evacuating the people at risk, warnings fail to reach most people in Bihar, India.

There is no formal mechanism for risk communication between the two countries; however, informal, and ad-hoc interaction happens between the government officials of Nepal and India in case of extreme event forecasts. Also, to make up for the absence of a formal transboundary risk communication mechanism, some NGOs in Nepal and India have collaborated for sending the warnings received in Nepal to Bihar involving the flood-affected communities living upstream and downstream in the Kosi River basin. Furthermore, because of the porous international border, shared culture, family relations, and people's regular movement across the border, warnings sent to Nepal also get disseminated informally to some villages in India through the interaction of people living across the border.

Furthermore, the risk communication in Nepal and India fail to reach the most deprived and vulnerable ones (especially women) in the Kosi River basin because of their (i) lack of affordability of technology to access the warnings (mobile, television or radio), (ii) lack of ability to interpret the warnings due to their literacy status and language barriers, and (iii) gender roles and socio-cultural barriers for women. The most vulnerable people in flood plains perceived risks of harassment by men, animal attacks, snakebites, waterborne diseases, and theft of valuables to be more worrying and significant than the risk of hazards they faced, influencing their motivations and actions after receiving the warnings or during disasters.

The results suggest that both countries employ a centralised and top-down approach to flood early warnings, which completely disregards people's access, needs, preference, understandings, and social context; therefore, the warnings fail to reach the most vulnerable and deprived ones in the study area. Furthermore, the risk communication process operates one-way and in isolation from its intended recipients complicating the transboundary EWS in the Kosi River basin. The chapter 8 will discuss the implication of these results in relation to the main research question of this thesis. The next chapter 7 will explore the transboundary disaster risk governance and EWS in the Kosi River basin.

Chapter 7 Transboundary Disaster Risk Governance and EWS in the Kosi River Basin

7.1. Introduction

This chapter explores the geopolitical context between Nepal and India and its effect on the transboundary EWS between the countries. In this chapter, geopolitics refers to the countries' struggle to control geographical entities (water resources) for their political advantage (Flint 2021). This empirical chapter is based on 34 semi-structured interviews conducted with disaster management experts, government officials, and activists related to flood risk management in the Kosi River basin. This chapter explores (i) the transboundary disaster risk governance in the Kosi River basin, (ii) politics around embankments, and (iii) challenges and constraints for transboundary EWS.

This chapter shows that geopolitics over the water resource utilisation complicates the transboundary relations between Nepal and India, affecting collaboration for disaster governance and transboundary EWS. Also, this chapter shows that different actors and citizens in the Kosi River basin have varying interests related to the floods and flood control infrastructures, which has contributed to the flood problem in the basin. Furthermore, the securitisation of river data and myths around floods poses significant challenges for collaboration in the Kosi River basin.

This chapter seeks to understand the following sub-question (SQ) related to the main research question:

SQ. 3 What are the geopolitical dynamics that constrain transboundary early warning system (EWS) in the Kosi River basin?

7.2. Transboundary flood risk management in the Kosi River basin

This section highlights the complex geopolitics that underlies transboundary disaster risk governance between Nepal and India, specifically concerning water resource utilisation. The Kosi Agreement, initiated in 1954, was the first-ever pact between these two countries to manage disaster risks. However, it negatively impacted people's lives and the environment in the Kosi River basin, exemplified by the Kosi flood disaster of 2008, the most expensive flood catastrophe recorded in Nepal and India (Dixit 2009). Despite numerous bilateral committees established after the 2008 Kosi disaster to improve transboundary disaster risk management, they have primarily focused on disaster response and water resource management rather than flood preparedness or EWS in the Kosi River. Although experts from governmental and non-governmental institutions in Nepal and India acknowledge the necessity of transboundary EWS in the Kosi River basin, there are no policies, institutions or working models for its implementation (Bandyopadhyay 2016; Gupta et al. 2021; Shree 2020). The fig. (63) shows the themes and subthemes regarding the transboundary flood risk management in the Kosi River basin.

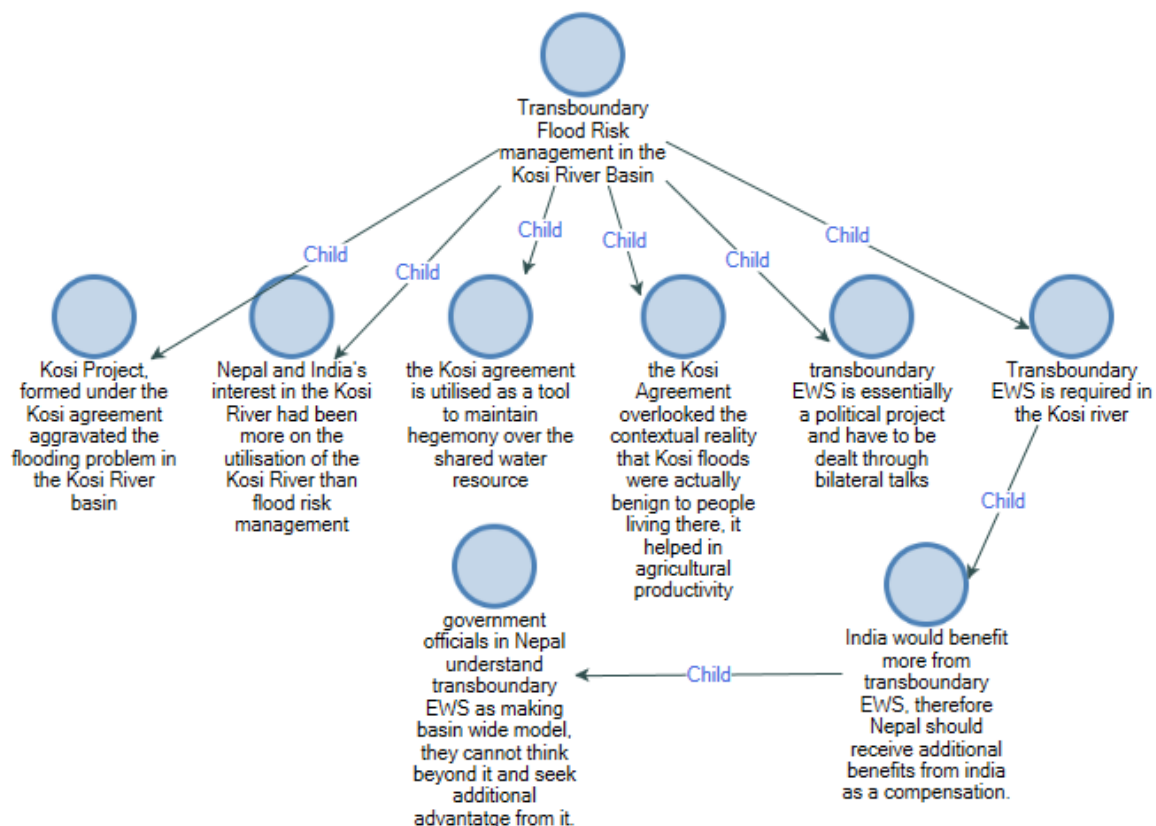


Figure 63: NVivo map showing themes related to transboundary flood risk management in the study area.

The water resource expert in India (E26) stated:

“...flooding has been a natural phenomenon in the Kosi River for ages...people had adapted their lifestyle around floods and floods were benign to their agricultural livelihood because it carried nutrient-rich soil...so people were not bothered about floods. However, Kosi appeared as a threat to railway infrastructure expansion in the post-colonial era of India, and the media sensationalised the floods in Kosi as ‘sorrow of Bihar’ highlighting only destructive aspects ...because of which the river was jacketed within embankments, and the benign floods turned into disasters....”
(E26).

The above statement aligns with extensive literature (e.g., Acharya and Hori 2019; Baghel 2014; Dixit 2003; Dixit et al. 2021; Gupta et al. 2021; Mishra 2008), suggesting that the Kosi Agreement of 1954 marked the first transboundary agreement for flood risk management between Nepal and India but was put forward by only highlighting the Kosi River’s destructive aspects, overlooking the river’s interaction with the environment and people.

The water resource experts from Nepal (E16 and E30) and India (E26, E28, and E29) stated that the Kosi Project, formed under the Kosi agreement aggravated the flooding problem in the Kosi River basin. This is illustrated in the following quote from interviewee E16:

“...the Kosi agreement became the worst example of transboundary cooperation for disaster risk governance between Nepal and India because the Kosi project formed under the Kosi agreement has failed in all its objectives...due to the construction of embankments, the flood problem worsened, the livelihood of people degraded, and more land has gone out of agricultural production and became barren due to siltation than is irrigated by the Kosi project...” (E16).

Similarly, a social activist from the study area (E21) stated:

“...the Kosi agreement created new disasters instead of reducing it...initially, there was only the problem of erosion in Nepal...flooding was the only problem in Bihar...but after the implementation of the Kosi project leading to the construction of embankments, the problem of flooding moved upstream to Nepal and became a regular phenomenon here...” (E21).

The above quotes suggest that the Kosi Agreement of 1954 was the first bilateral agreement between Nepal and India for managing flood risks in the Kosi basin. As part of the agreement, the Kosi Project was established and fully funded by the Indian government, managed in the Nepalese territory (Upadhyaya 2012) (also discussed in Chapter 3, Section 3.5.2). The Kosi Project involved the construction of embankments and the Kosi Barrage for regulating river discharge, along with irrigation and electricity benefits in the Kosi basin (Dixit et al. 2022). However, the embankment construction had unintended consequences on people's lives and the environment in the Kosi River basin (Dixit et al. 2022; Gupta et al. 2021; Mishra 2008; Sinha et al. 2014). Therefore, the Kosi Agreement could be seen as an intervention that created disaster risks by exacerbating the flooding problem and increasing vulnerability in the Kosi basin, owing to a lack of contextual understanding of the river's interaction with the environment and livelihoods of people, as supported by extensive literature (e.g., Alli et al. 2013; Devkota et al. 2018; Dixit et al. 2022; Gupta et al. 2021; Somanathan 2013).

During the expert interviews, all the respondents from Nepal and India stated that transboundary EWS is required in the Kosi River basin. However, the government officials from Nepal (E1, E2, E3, E6, E8, E11, and E14) argued that India would benefit more from transboundary EWS than Nepal in terms of lead time as it is a downstream country; therefore, Nepal should receive compensation from India against the uneven benefits before establishing it in the Kosi River basin.

"...Transboundary EWS is required based on moral grounds...but transboundary EWS in the Kosi River will be more beneficial to India than Nepal because it is a downstream country...if India needs transboundary EWS to save people of Bihar, then it must formally approach us with additional benefit compensation such as upgrading our hydrological monitoring system or other equipment support for EWS...Otherwise, there is not much use to us...we would rather have transboundary EWS with China, as it is our upstream country..." (E14).

In the same way, a government official from Nepal (E8) claimed:

"...why would India need to collaborate with us for transboundary early warning system? India is already freely downloading our real-time hydrological data from DHM website to make basin-wide models in the Kosi River basin...They have

designed their system in such a way that their hydrological models directly pull the river data from our website...they already have whatever data needed from us ...so I do not think India would be compelled to collaborate with us for transboundary EWS...” (E8).

Contrary to the statements made by E8, disaster management expert working in an NGO in Nepal (E19) argued that:

“The government officials in Nepal understand the transboundary EWS as making a basin-wide model...and could not think beyond data and equipment...this myopic view of experts in a decision-making position is problematic in itself and creating a challenge for collaboration” (E19).

The above quotes suggest that experts in Nepal perceive transboundary EWS as a technical process, discussed in Chapter 5 of this thesis. Moreover, statements by Nepalese government experts (E1, E2, E3, E6, E8, E11, and E14) demonstrate ambivalence towards collaborating with India for transboundary EWS, possibly due to resentments over unequal benefits in past water agreements (Ho 2016), or the perception that India seeks to control shared water resources through negotiations, as argued by several scholars (e.g. Bagale 2020; Dixit et al. 2022; Gupta et al. 2021; Noolkar-Oak 2022; Upadhyay 2012). Similarly, Upadhyay (2019) and Karki and Kc (2020) contend that a general sense of mistrust towards India persists among civil society and government institutions in Nepal, and any attempt by India to collaborate is viewed as an effort to exploit Nepal’s natural resources. This mistrust and ambivalence among Nepalese experts pose significant challenges for transboundary EWS in the Kosi River basin.

The experts working in the government of Nepal (E1, E3, and E8) and India (E27) stressed that *“flooding in the Kosi River basin is an international issue between the two sovereign countries”* (E27); therefore, *“transboundary EWS is essentially a political project and have to be dealt at through parliament level talks between both countries”* (E3). The above quotes from government officials in Nepal and India suggest their perception of EWS is extra-jurisdictional and beyond their capacity. In a similar context, Dutta (2022, p.3), in the study of water-related conflicts and challenges between Nepal and India, argued that government experts often define transboundary floods as *“wicked first-order problems”* originating from multi-layered complexities and beyond their institutional scope; however, those problems have primarily

occurred from institutional inefficiencies at the local level (Dutta 2022). Similarly, it can be argued that experts' perception of flood risk management as extra-jurisdictional is problematic and shows reluctance to deal with floods at the local level, even when the flooding problems were created at the local level (due to the construction of embankments) and their effects are also observed primarily at the local level (to the people at risk); therefore, those floods need to be dealt at the local level through transboundary collaboration between Nepal and India.

Zeitoun et al. (2020) argued that transboundary rivers are also political resources (the resource used in political decision-making) and relate to the political dynamics and competing interests over shared water resources (Rai et al. 2017). Upadhyay and Gaudel (2018) argued that the Kosi River is linked to both Nepal and India's development aspirations and economic prosperity, which appears to supersede the interest in flood risk management. Sahu (2019) argued that Nepal is primarily interested in hydropower production and selling electricity to India from the Kosi River, while Basu (2022) argued that India's primary interest in the Kosi River is meeting its water demand for industrial use and irrigation in Bihar. Similarly, in this study, an activist from Nepal (E21) and activists in Bihar (E26 and E28) stated that Nepal and India's interest in the Kosi River had been more on the utilisation of the Kosi River than flood risk management; therefore, the issue of transboundary floods has been side-lined for the decades. This is illustrated from the quote of E26:

"...India is more concerned about keeping up with its ever-increasing demand for irrigation, industry, and consumptive uses...and also Nepal's interest is more on earning hydro-dollars from the Kosi River...none of the countries priority is on flood risk management in the Kosi River...therefore the issue of flood has remained unaltered for decades..." (E26)

The above statements by E21, E26, and E28 suggest that transboundary EWS in the Kosi River basin is embedded in a competing geopolitical priority over utilising shared water resources side-lining disaster management in Nepal and India. The results suggest that The Kosi River is a shared political resource linked to Nepal and India's development aspirations and competing interests related to water governance (irrigation, hydropower, water supply). This result agrees with extensive literature (e.g., Basu 2022; Dixit 2009; Dixit et al. 2022; Gupta et al. 2021; Mishra 2008; Sahu 2019; Shrestha et al. 2010; Upadhyay and Gaudel 2018).

Power relations often play an important role when countries with asymmetrical power engage in transboundary interactions (Zeitoun and Warner 2006, p.46); in those interactions, powerful countries often influence the weaker ones by using soft powers—to set rules and secure compliance through formal agreements (Mirumachi 2015). Likewise, experts from Nepal (E2, E5, E19 and E25) stated that India had utilised the Kosi agreement as a tool to maintain hegemony over the shared water resource, and *“the Kosi Agreement has nothing to do with flood risk management...it is a geopolitical instrument of India applied to meet its water demands”* (E5). The above statement agrees with Bagale (2020) and Noolkar-Oak (2021), where authors in their studies of transboundary river agreements between Nepal and India also argued that bilateral agreements between Nepal and India appear more as a product of regional geopolitics than collaboration. These findings build on the argument that geopolitics play crucial roles in the transboundary Kosi River basin, as argued by extensive literature (e.g., Biswas 2011; Dixit et al. 2021; Bobbette and Donovan 2019; Donovan 2020). Mirumachi (2015) and Zeitoun et al. (2020) argued that power relations play crucial roles when countries with asymmetrical power relations interact in a transboundary context. Similarly, it can be argued that the studies on transboundary EWS must also consider power relations and geopolitics as it influences transboundary EWS.

7.2.1. Transboundary bilateral committees

This section explores the transboundary bilateral committees formed between Nepal and India for flood risk management in the Kosi River basin. This section suggests that bilateral committees are centrally led and lack participation of people at risk and representation of local government authorities in both Nepal and India, resulting in a lack of contextual understanding. The themes from the bilateral committees are shown in fig. (64).

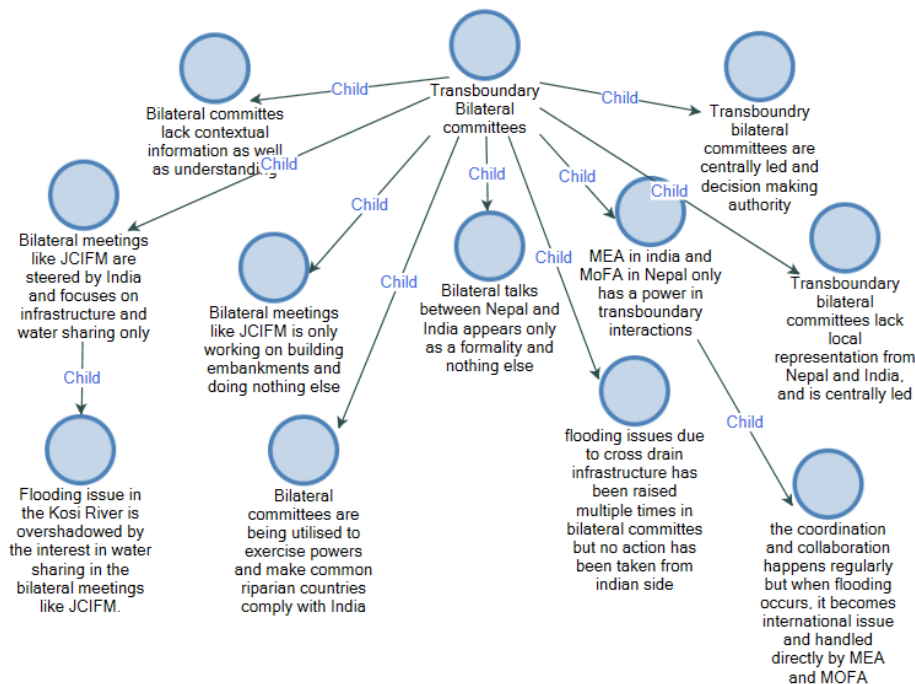


Figure 64: NVivo map showing themes of transboundary bilateral committees.

Uprety and Salman (2011) and Acharya and Hori (2019) argued that many bilateral committees between Nepal and India were formed, especially after the Kosi flood of 2008, for collaborative action on flood risk management. However, those bilateral committees lack decision-making roles and are centrally driven by ministries, making them ineffective. A government official from Nepal (E1) similarly stated:

“...after the Kosi flood of 2008, many joint committees have been formed for the flood risk management in the Kosi River basin, but the focus of those committees have been more on the construction of embankments and disaster response...no work has been done on disaster preparedness...also the officials in those committees have no authority for decision making, they have to consult central government for everything....” (E1).

The above statements imply that bilateral committees are centrally led and lack decision-making authority. Similarly, an activist from the Kosi Basin in Nepal (E10) stated that bilateral committee meetings between Nepal and India are dominated by central government authorities who lack contextual understanding. Furthermore, E10 claimed that those bilateral interactions do not provide space for people at risk or local government actors to express their views. This is illustrated in the following quote by E10:

“...There is not even a single representation of flood-affected people, local level authority, or activist in those bilateral meetings...What kind of jokes are they running in the name of bilateral meetings?... They are blocking contextual knowledge and doing foolish things in the name of flood protection...they are completely overlooking our riparian rights... we do not tolerate this repugnant way of exclusion of people...” (E10)

The above quote implies that bilateral meetings between Nepal and India do not include flood-affected people or the local level government actors and are therefore unaware of the contextual information. This statement asserts with extensive literature (e.g., Acharya and Hori 2019; Dixit et al. 2021; Gupta et al. 2021; Pandey et al. 2022) arguing that bilateral dialogues between Nepal and India are state-centric, which lack local level participation and representation of local government authorities in the Kosi basin. Likewise, Noolkar-Oak (2021) argued that the disconnection of central governmental actors from ground reality has contributed to the Kosi River basin’s complex ecological and geopolitical landscape.

Zeitoun et al. (2011) suggested that transboundary interactions are shaped by power relations and powerful states often subtly influence low power states, resulting in consent without violence, termed as ‘soft’ power for embedding asymmetrical benefits in the negotiated agreements. In the same way, a local activist from Nepal (E10 and E30) and an expert from the government of Nepal (E6) argued that India uses bilateral forums like JCIFM (Joint Commission for Inundation and Flood Management) to exercise its powers with the neighbouring countries and to make them comply with its water demands. This is illustrated in the following quote from E6:

“...in the last JCIFM meeting, India proposed that Nepal can use Indian satellites for transboundary EWS...but with a condition that all the hydro-met data of Nepal

will be stored in an Indian-server located in Delhi, and Nepal will only have secondary access to it...which is against the sovereignty of Nepal...in that way, they use bilateral platforms like JCIFM for exercising their powers...Their interest is only in our waters...they are not interested in flood risk management or transboundary early warning systems...” (E6)

The above statements suggest that bilateral committee meetings appeared more as a formality and a platform for powerful country (India) to push its agenda through negotiated agreements, as suggested by Zeitoun et al. (2011) and Mirumachi (2015), than having a genuine interest in flood risk management.

An activist from Bihar (E26) and an activist from Nepal (E30) argued that bilateral talks between Nepal and India have been going on for decades, but *“the bilateral talks have only remained as a formality, and it has not solved any issues regarding floods as of now...”* (E26). Likewise, E30 argued that *“...JCIFM meetings have been going on for decades, but they have not decided or done anything apart from recommending more embankments in the name of flood management...therefore JCIFM meetings only work like the geopolitical apparatus of India, which is hardwired to perpetuate the same technology and paradigm from the last six decades... and is not willing to look for alternatives...”* (E30). The above statement agrees with Gupta et al. (2021); in the study of transboundary flood risk management between Nepal and India in the Kosi and Gandak River basins, the authors also argued that JCIFM has not looked for any alternatives for flood control rather than embankment building.

Likewise, a local activist in the Kosi River basin from Nepal (E10) and an expert working in an NGO in Nepal (E19) stated that transboundary interactions in JCIFM are steered by Indian authorities and primarily focus on infrastructures and water sharing. Furthermore, E10 argued that Nepalese authorities attend those meetings unprepared and do not even raise the most pressing issues, such as cross-drainage infrastructures in Bihar causing inundation in Nepal. Furthermore, E10 claimed:

“...during the annual coordination meetings that happen before every monsoon season, Indian delegates come well prepared and up to date with data and facts, but delegates from Nepal appear like they came to attend a party...they just talk, eat, and go home agreeing to whatever is said by Indian counterpart...” (E10).

The arguments by E10 suggest the weakness of the Nepalese side and that the delegates are not raising the issues of national concern and not suggesting alternative options for flood protection in the JCIFM meetings themselves. Similarly, a government official of Nepal (E6) argued that *“bilateral meetings focus on infrastructure development and water sharing, which overshadows the issues of flooding”* (E6). These arguments suggest that transboundary interactions between India and Nepal are typified by a patron-client relationship, as Dixit (2022) argues, focusing on infrastructure and water-sharing rather than flood risk management.

Contrary to the above statements by E6, E10, and E19, a government official from the Ministry of Water Resources in Nepal (E2) argued:

“...it is not true that we have not raised those (flooding) issues in the bilateral meetings....we have raised those issues multiple times that state government of Bihar is constructing cross drainage infrastructure to temporarily dam the floodwater in the upstream, causing backwater surge and inundation in Nepalese territory...but they have always responded that they will report the issue to appropriate institutions for further action...I do not know which one is their appropriate institution ...but no action has been taken so far....” (E2).

In the same way, Dixit et al. (2022) have mentioned that state agencies in Bihar have constructed road infrastructure and embankments across the flow direction, causing localised inundation in Nepal, which is the result of a dysfunctional institutional system in Bihar that is failing to understand that drainage obstruction further aggravates the problem of flooding rather than solving them (see also Shrestha et al. 2010). The above argument suggests that lack of coordination among the institutions and institutional dysfunction could also be a factor relating to the flooding in the Kosi River basin.

A former water resource minister from Nepal (E16) stated that *“...bureaucracy in India is worse than in Nepal...The government officials in India do not listen to their scientists or water experts over transboundary issues...all transboundary interactions are directly dealt with by the Ministry of External Affairs (MEA) in India, which has veto power over handling the international issues...so even if scientists and water experts in India are in favour of transboundary collaboration with Nepal for flood risk management...MEA intervenes it....”* In

the same way, an Additional District Magistrate of Bihar (E27) also stated, “...*transboundary dialogues and cooperation between Nepal and India have already been taking place from decades...annually we discuss monsoon disaster response plans and other issues with Nepal...but when flooding occurs, it becomes an international issue and goes out of our hands....then Ministry of External Affairs and the Ministry of Home affairs handle it...we have to take approval from them for any communication or action....*” (E27). The statements by E16 and E27 agree with Shrestha et al. (2010), stating that all the transboundary interactions in India must be approved through the Ministry of External Affairs, which significantly impacts transboundary collaboration and communication, especially during disasters.

This section showed that bilateral committees between Nepal and India were state-centric and disconnected from ground reality, which functions more as a platform for a powerful country to exercise soft power (Zeitoun et al. 2011) than a platform for collaboration for flood risk management and transboundary EWS.

7.3. Flood control infrastructures and politics

This section explores how embankments were selected as flood control measure and its implications on the disaster risk in the Kosi River basin. This section shows that embankment construction was inappropriate for flood risk management in the Kosi River basin, which was intensified after the Kosi flood of 2008, furthermore, the section deals with the differing interests related to the embankment construction in the study area, as well as the proposed

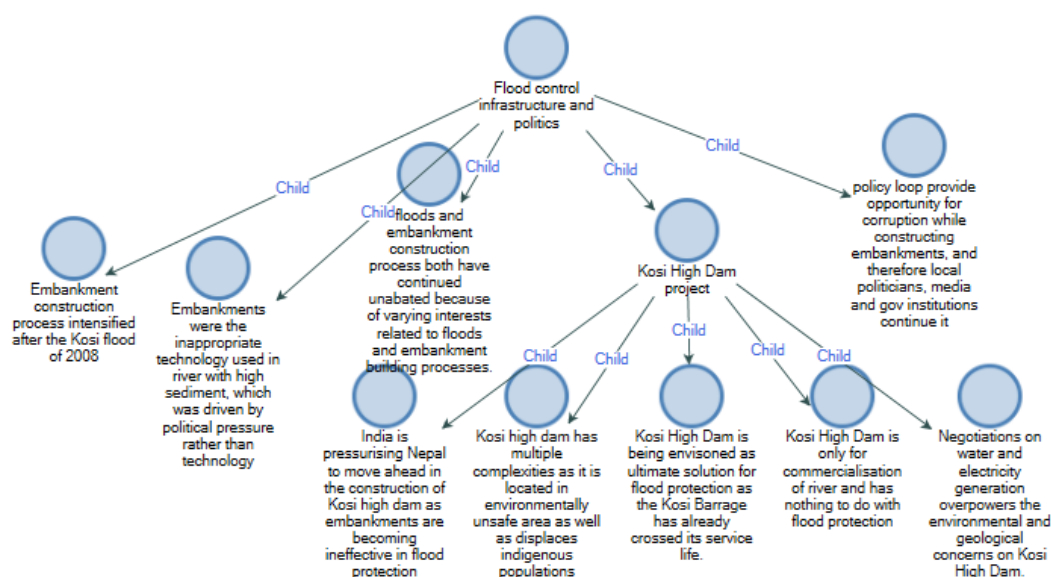


Figure 65: NVivo map showing themes related to the flood control infrastructure and politics in the study area.

project of Kosi High Dam as an ultimate solution for flood protection in the Kosi River basin. the fig. (65) shows the themes related to the transboundary flood control infrastructure and politics in the study area.

Dixit et al. (2022) argued that embankments and barrage in the Kosi River basin were constructed in response to the political interests of that period, where project costs and benefits guided bureaucrats, and technocrats maintained that infrastructural solutions would address the problem of flooding. In the same way an activist from Nepal (E30) argued that embankments were the inappropriate technology used for flood protection in the Kosi River basin, which resulted from a political decision rather than a technically assessed option. Furthermore, activist from Bihar (E26) stated:

“Even though multiple floods have proven that embankments do not work for flooding in the Kosi River basin; the state government of Bihar has unaltered the process of embankment construction because local politicians and contractors gain from it...” (E26).

Similarly, another activist from Bihar (E28) stated that:

“...Embankments have served no one in the river basin but the corrupt politicians, bureaucrats, and contractors who work as an iron triangle for embankment construction to gain from it...” (E28)

The above quotes suggest that, even though multiple disasters caused by embankment failure and annually occurring floods in the Kosi basin suggest that embankments are becoming futile against floods, the government of India, which is managing the Kosi Project, has continued embankment expansion without seeking any other alternatives. This could be because local politicians, local government officers, and contractors gain through corruption while constructing embankments using low-quality materials, which extensive scholars also assert (e.g., Dixit 2009; Mishra 2008; Nakamizo 2021; Shrestha et al. 2010). Furthermore, E26 argued that:

“...the local politicians and media have also brainwashed the people living in the Kosi flood plains that only embankments can save them from flooding, therefore

people appear demanding more embankments during every television media coverage after floods...” (E26).

The NGO worker in Bihar (E29) also argued that local politicians and media in Bihar impart the impression to the public that only embankments could save their area from flooding to generate the demand for embankments from the community level; so that corruption (during construction of embankment) could be continued unabated. This finding was also substantiated from the community-level interviews—contrary to the perception of experts (E26 and E28) that embankments are the primary cause of flooding and all the problems in the Kosi River basin (also dealt with in section 7.4); all the interviewees at the community level perceived embankments as solutions or evacuation site during floods and stated the needs for more embankments. These arguments are also supported by Gade et al. (2020), suggesting that contradictory perceptions exist among experts and people at risk towards embankments in the Kosi River basin—experts regard them as problems, while people at risk regard them as solutions. It can be argued that these perceptions of the people at risk towards embankments as a solution and demand for more embankments could also be the result of the impression given by the local politicians and media to continue building embankments in the name of flood protection as suggested by Acharya and Prakash (2019), Gupta et al. (2021), and Mishra (2008).

An activist from Bihar (E28) stated that after the Kosi River flood of 2008, the embankment construction process intensified in Bihar, adding more embankments, and strengthening the existing ones in the name of flood protection. Furthermore, E28 added, *“after the embankment repairs following the Kosi flood of 2008, the local government officials in Bihar organised a press conference and stated that they had made permanent solutions against floods...and the embankments will protect the people for the next 30 years...they come with the specific date of 30 years because by then, every official in Bihar will be retired ...”* (E28). Building on to Acharya and Prakash (2019) and Gupta et al. (2021), this study has found that local government officials also impart a false sense of security from embankments to the public so that the public maintains demand for embankments. This argument is supported by Baghel (2014), who suggested that the government of Bihar uses the embankments as governmentality apparatus to maintain the public’s preference so that massive investment in embankment construction could be continued.

Pritchard and Thielemans (2014) argued that floods are both a curse and a blessing in the Kosi River basin—it causes damage but also support the agricultural livelihood of the most deprived farmers living on subsistence agriculture. Likewise, Dixit et al. (2022) argued that diverse groups of people (who are differently affected by floods), and diverse interests related to floods co-exist in the Kosi River basin. In the same way, an NGO worker (E29) and an activist (E28) from Bihar stated that flooding and embankment building processes run parallel in the Kosi River basin because of varying interests related to the floods; *“some want floods to happen, some do not, while some benefit from the floods”* (E28). Furthermore, E29 elaborated that the people living in the Kosi flood plain in Bihar can be divided into three categories:

“...The first category is of the traditional farmers who want flooding to happen as it is beneficial for their subsistence agriculture...The second category is of the people who have migrated to the Kosi flood plains and are made to believe that flooding can only be controlled by adding more embankments; and the third category is of the construction mafias and contractors, who gain from flooding, by building embankments using low-quality construction materials, colluding with local government officials and politicians...” (E29).

The above statements imply that floods in the Kosi River basin are complex—actors with diverse interests related to the floods and people with diverse vulnerability exist and operate in the Kosi River basin, leading to a business-as-usual situation in flood and flood risk management. The above statement by E29 also suggests that diverse perspectives exist in the Kosi River basin, which justifies the differing perspectives among respondents in the community-level interviews and FGDs discussed in Chapters 5, section 5.3.1 and Chapter 6, Section 6.7.

This section showed that embankment construction based on the Kosi agreement caused adverse consequences in the Kosi basin. Interviewees have argued that the embankments in the Kosi River basin have served only the politicians and contractors who earn from corruption during the construction of embankments with low-quality materials. Furthermore, local politicians and media as well as local government officers maintain in public that embankments are appropriate option for flood protection to create a demand for embankments from the community level. The next section will deal with the future project in the Kosi River basin called Kosi High Dam Project.

7.3.1. The Kosi High Dam Project

This section deals with the Kosi High Dam Project (KHDP), which is regarded as the successor to the embankments in the Kosi River basin, being discussed as a future intervention. India proposed the KHDP as the ultimate solution for flood risk management in the Kosi River basin (Mishra 2008), which involves the construction of a 269-meter-high dam in Chatara Nepal, with a reservoir capacity of 8,500 million m³, producing 3,489 MW of electricity and irrigating 68,500 ha in Nepal and 1.5 million ha in India (Bhattarai 2009) as discussed in chapter 3 of this thesis.

The government officials from Nepal (E8 and E14) stated that as it has already been sixty years since the construction of the embankments and Kosi barrage, and both the infrastructure are already over their service life, the government of India is pressurising Nepal for the construction of the high dam in the Kosi River *“as an ultimate solution”* (E8) in the Kosi River basin. Similarly, another government official from Nepal (E14) stated, *“...India’s main intention from the Kosi High Dam Project is a power generation and Irrigation in Bihar rather than flood control...I also suspect that India is pressurising Nepal to proceed with the construction of the high dam by troubling with river back-flow and inundation...so that Nepal will ultimately surrender and agree to construct high dam...”* (E14). The above statements suggest that as the embankments are proving to be futile for flood protection in the Kosi River basin, government of India is seeking to establish another large infrastructural intervention for water retention to protect area for flooding, which will also bring the additional benefits of electricity and irrigation in the study area. Similarly, Dixit (2020) and Tandan (2021) argued that despite recognising the detrimental impacts of the Kosi High Dam project, Nepal’s willingness to engage with India demonstrates the powerplay that defines the hydro-political configuration between Nepal and India and reveals Nepal’s weakening grip on its natural resources.

An activist from Bihar (E28) similarly stated:

“Nowhere in the world are high dams built for flood protection...it is only for hydropower generation...and it is absolutely inappropriate to construct a high dam in that geologically unstable and seismic prone region...it is politician’s agenda who

want to earn from the commercialisation of river water...high dams have nothing to do with flood protection” (E28).

Another water expert from Bihar (E26) also argued that the proposed KHDP has multiple complexities related to it as it is planned in a geologically and ecologically fragile location and displaces approximately 60,000 indigenous populations in Nepal; therefore, neither is the project environmentally feasible nor socially appropriate. Authors such as Linkha (2020) and Dhungel and Pun (2008) also agree with E26 and E28 and suggest that KHDP has severe consequences on the environment and ecology, resulting in the loss of approximately twelve thousand hectares of fertile agricultural land and could cause detrimental effects than benefits to both Nepal and India.

Furthermore, E26 stated that bilateral talks related to the Kosi High Dam project had continued for more than thirty years seeking agreements between the politicians of Nepal and India; however, neither the politicians of Nepal nor India are concerned about the environmental or social concerns of the project. This is illustrated in the following quote from E26:

“...environmental concerns and displacement are not even the agenda in discussion during the negotiation...both countries could not reach on negotiation point due to their stand on compensation from the project and share of water and electricity...”
(E26).

The above quotes suggest that both countries primarily concentrate on economic benefits and shares of water and electricity from the project than on the possible consequences to the environment and society due to the project. This argument agrees with Dixit et al. (2022) and Tandon (2021), arguing that local realities (e.g., seismicity of the location, fragile geology, slope failure, landslides, and debris flows) are primarily overlooked in the negotiations between Nepal and India related to the Kosi high dam project, which could deteriorate the environmental and ecological landscape and exacerbate the flooding problems in the settlements upstream and downstream. This argument also suggests that geopolitics strongly influences the transboundary interaction related to the possible project of KHDP.

This section showed that the high dam project is being viewed as a possible technological option for flood protection in the Kosi River basin in future but could cause severe

environmental consequences and displacement of indigenous people (see also Chapter 3, Section 3.5.4). Irrespective of its potential harm, due to the potential economic benefits, the governments of Nepal and India are still discussing the KHDP.

7.4. Challenges in transboundary early warning systems between Nepal and India

This section explores the challenges in transboundary EWS in the Kosi River basin and suggest that securitisation of the transboundary river data and myths among citizens and experts of Nepal and India are among the significant challenges in the transboundary collaboration and establishment of an EWS. In addition to these, lack of uniformity in the data management system, data quality, and varying formats of the river data among India and Nepal is also a concern for transboundary collaboration. The Themes related to the challenges in transboundary EWS between Nepal and India is shown in fig. (66).

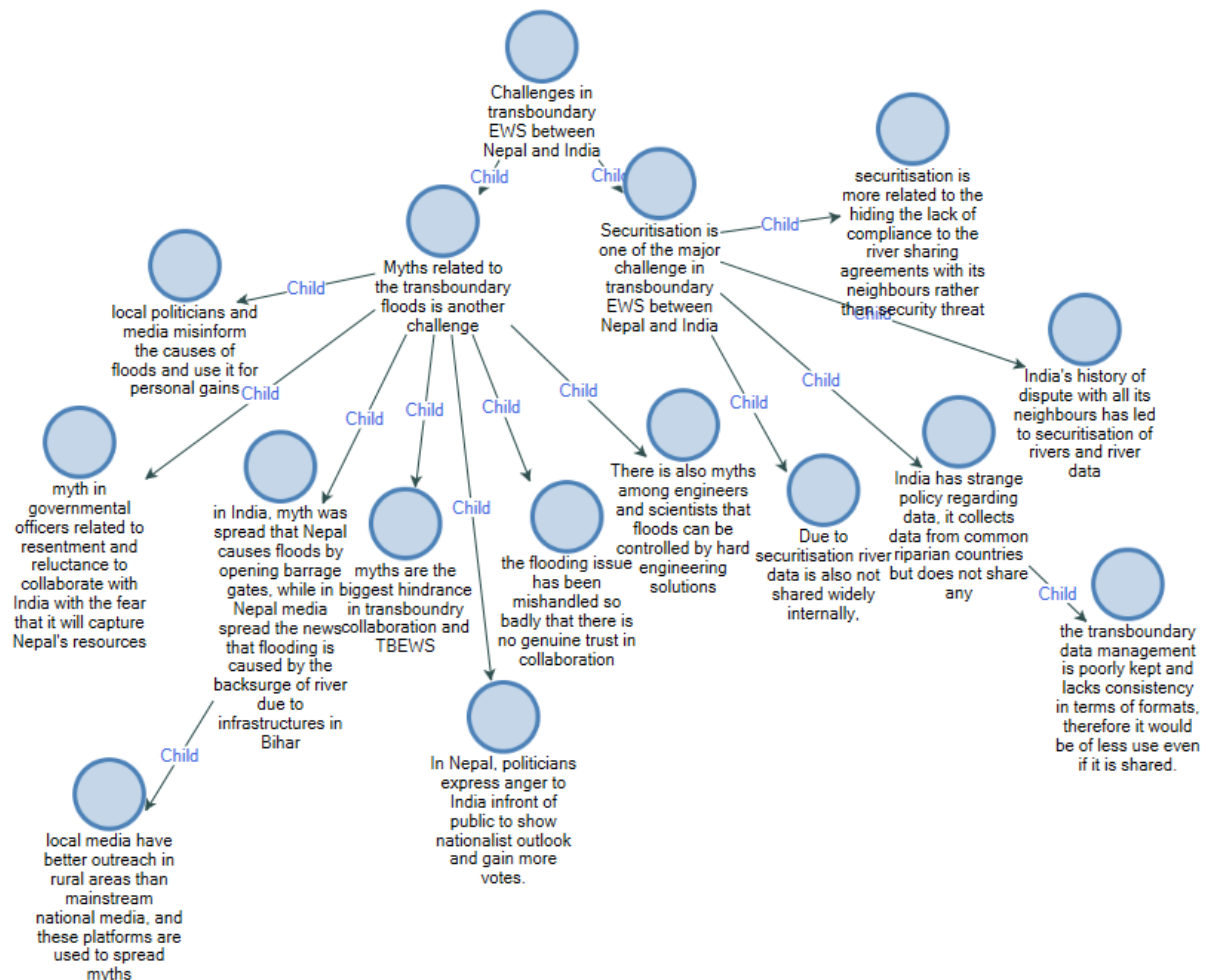


Figure 66: NVivo map showing themes related to the challenges in transboundary EWS in the Kosi River basin.

7.4.1. Transboundary river data and securitisation

This section will show that securitisation of transboundary rivers' data in India, different data formats, and poor data quality were the challenges for transboundary EWSs between Nepal and India.

Dutta (2021) argued that information on the Kosi River is classified upon entering India, impeding transboundary collaboration for flood risk management in the Kosi River basin. Similarly, Jain et al. (2007) and Webster et al. (2010) found that individual states collect hydrological data in India and rarely share interstate or internationally, hindering flood forecasting in transboundary rivers. Villa Seoane (2021) explained that while Indian laws like the Right to Information Act of 2005 and the Hydro-meteorological Data Dissemination Policy of 2013 regulate access to hydrological data, the government denies requests related to transboundary rivers due to security concerns. Prasai and Surie (2015) similarly argued that the lack of data-sharing mechanisms between Nepal and India affects collaborative disaster risk management, with nations suffering the most during extreme flood events. Similarly, during the interviews, an expert working in the government of Nepal (E6), an expert working in a policy institute in Nepal (E25), and an expert working in a donor agency in Nepal (E22) stated that the securitisation of rivers in India posed the most significant difficulty in transboundary collaboration for flood risk management as it limits both external data sharing (with common riparian countries) and internal data sharing (within the government institutions in India). Likewise, a government official in Nepal (E6) stated:

"...When I was in IMD (India Meteorological Department) office in Delhi, they told me that CWC does not even share data with them due to securitisation...accessing transboundary river data is complicated in India...data is only released if Indian research institutions such as IIT (Indian Institute of Technology) formally requests it by signing non-disclosure agreements..." (E6).

The above statement implies that even though the securitisation policy in India hinders external and internal data sharing, the government of India is lenient in sharing the data for research purposes. Therefore, one way of accessing transboundary river data could be through the involvement of governmental research institutions from Nepal and India for basin-wide research and collaboration in the Kosi River basin.

An expert working in a donor agency in Nepal (E22) stated, “...*India has a strange data-sharing policy that allows taking all the data from Nepal but does not allow sharing any of its water-related data with Nepal...which is the major challenge for transboundary collaboration for disaster risk management in the Kosi River basin*” (E22). The above quote agrees with Siddiqui’s (2022) argument based on his study related to the legal assessment of transboundary agreements in the Kosi River, stating that even though the Kosi agreement of 1954 has a clear provision for data-sharing between the governments related to the Kosi River, the government of India only shares the data of Kosi River, which is within Nepal. However, for the Kosi River in India, no information is shared with Nepal due to the securitisation policy in India.

Securitisation refers to a process in which a country declares a particular subject or an issue as a threat to national security (McDonald 2008). A water resource expert from Nepal (E16) stated that India’s border disputes and unpleasant relations with its neighbours have led to the securitisation of transboundary rivers in India, which limits sharing of river data internally and externally. This is illustrated in the following quote of E16:

“...because of India’s history of unpleasant relations with all its neighbours and because of boundary disputes, India sees everything in its neighbourhood as security threat...transboundary rivers as well...which led to the securitisation of transboundary rivers...but I do not call it a securitisation...I call it paranoia...because this hinders transboundary collaboration...” (E16).

The above quote suggests that securitisation of transboundary river data is a significant challenge for transboundary collaboration between Nepal and India in the Kosi River basin because it limits information sharing and basin wide research between Nepal and India. Several scholars such as (e.g., Dutta 2021; Vij et al. 2020; Ray et al. 2015; and Singh 2010) also suggested that India’s history of conflict with its neighbouring countries related to border disputes could have led to the securitisation of transboundary rivers in India, which restricts sharing of any transboundary river information with the justification of national security threat.

Contrary to E16, a government official from the Ministry of Energy, Water Resource, and Irrigation in Nepal (E2) stated that:

“...securitisation has nothing to do with a security threat to India...India has signed multiple water-sharing agreements with its co-riparian countries but has not complied with any of those in terms of resource use; therefore, if India shares river data, it would be evident, and India could be in a difficult position in front of international communities...therefore India is using securitisation as a tool for maintaining hegemony over shared water resources ...”(E2).

The above quote by E2 implies that India is using securitisation as a tool to maintain its hegemonic water relationship with its co-riparian countries. This argument aligns with extensive authors (e.g., Barua et al. 2018; Prasai and Suri 2015; Ray et al. 2015); In studies about access to transboundary river information in India and their implication for cooperation between co-riparian countries in the Ganges River basin, the authors argued that India is using securitisation as a geopolitical tool for maintaining hegemony over shared water resources.

In addition to the securitisation policy in India, Surie (2015) and Dutta (2022) argued that inconsistent data formats and poor data quality are also a challenge in transboundary collaboration in the Kosi River basin. In the same way, a water resource expert in Nepal (E16) stated:

“...The quality of hydro-meteorological data is poor...months of data are missing...both Nepal and India are using different data formats...in addition, the hydro-meteorological sensors are also inadequate and sparsely distributed in the Kosi River basin...which all contribute to the inconsistent format and quality of available data between Nepal and India...” (E16).

The above argument suggests that poor data quality and inconsistent data management system is also a challenge for transboundary EWS in the Kosi River basin which is also contributed by the improper data management practices and sparse distribution of hydro-meteorological stations as discussed in Chapter 6 of this thesis.

This section showed that securitisation of the river data in India poses a significant challenge in transboundary collaboration for disaster risk management and EWS in the Kosi River basin. Furthermore, the securitisation of the data is strongly linked to the geopolitics over the use of river water. In addition to securitisation, the lack of uniformity in the data management,

poor data quality, and varying formats of the river data among the common riparian countries are also challenges for transboundary collaboration.

7.4.2. Myths and resentments

This section will show that a significant myth exists regarding the causes of the floods and benefit shares from the past transboundary collaborations between Nepal and India, contributing to the disruption of social cohesion and conflicts at the community level.

The experts from Nepal (E19, E30, E25) and Bihar (E26, E28, and E29) stated that local politicians and media in Nepal and India misinform the people living in the flood plain regarding the causes of floods to evade the responsibility of flood protection. Furthermore, E30 stated:

“...whenever there is a flood in Bihar, the politicians and media label it as a Nepalese flood...and misinform people that flooding has been caused by opening the gates of the Kosi Barrage by Nepal...the people in Bihar do not even know that the Water Resource Department of India operates the Kosi barrage in Nepalese territory and control the discharge in the Kosi River....the government of Nepal do not even have access to the barrage” (E30).

Similarly, a water expert from India, E26, stated:

“...another myth that runs parallel in Nepal is that flooding in Nepalese territory is caused by the back surge of the Kosi River due to the cross-drainage infrastructures such as roads and bridges constructed in Bihar....” (E26).

Mishra (2008) also stated that state agencies and politicians in Bihar use the local media to propagate the myth related to the cause of floods and justify flooding as an external, uncontrollable, and inevitable disaster to evade their responsibility for flooding in the Kosi basin. Similarly, a water expert from India E26 and an expert working in NGO in Nepal E19 stated that local media have better outreach in both countries than the mainstream national media; politicians use the local media to propagate myths related to the causes of flooding in the Kosi River and give the impression that flooding is an uncontrollable and extra-jurisdictional disaster. These statements also agree with the study of floods in Bihar by Acharya and Prakash (2019), and the study of the Kosi River basin in Nepal by Adhikari (2019),

arguing that politicians and local media have contributed to spreading the myths among the public related to the causes of floods in the Kosi River basin.

In addition to the myths related to the causes of floods in the Kosi River, the water expert and activist E26 from India stated that experts in Nepal show resentment and reluctance to deal with India, which is also a constraint for transboundary collaboration for EWS. E26 stated:

"...there is a widespread resentment among the experts and citizens in Nepal that India is robbing them through Kosi agreement, which only intends to exploit Nepal's water resources...while we participate in meetings in Nepal, we hear words such as frauds and cheats against us...they argue with baseless claims that all the benefits are taken by India by Kosi River and Nepal is left with only sufferings...I tell them look into disaster loss data, which country is suffering more, Bihar or Nepal?."

(E26).

The above statement implies that myths related to the Kosi River floods exist not only at the community level but also and the expert level in Nepal, relating to the resentment and reluctance for collaboration (as discussed in section 7.2.1.).

Gupta et al. (2021 p.6) argued that 'Anti-Indianism' is a significant supporting factor for politicians in Nepal because India has a direct influence on every aspect of people's life in Nepal. Furthermore, especially during elections, the politicians of Nepal often blame India for interfering in internal politics, exploiting its natural resources, and causing floods in the Nepalese territory. Similarly, this study has found that politicians in Nepal mishandle the issue of floods and blame India for causing floods in the Nepalese territory. This is evident from the statement by E19, *"politicians from Nepal express anger in front of the public to show their nationalist outlook during elections to secure more votes"* (E19). Supporting this argument, Karki and KC (2020) also argued that Nepalese perceive that India benefits alone by exploiting Nepal's most valued water resources through bilateral negotiations; Nepalese politicians often bolster this perception via public speeches to show their nationalist and anti-Indian outlook. Similarly, a DRM expert working in a policy institute in Nepal (E25) stated that:

"Politicians in both the countries have mishandled the issue of flooding in the Kosi River to such an extent that there exists no genuine trust or interest in collaboration" (E25).

The above statement agrees with Upadhyay (2019), stating that a general sense of mistrust prevails in relations between Nepal and India and that every attempt at collaboration is perceived with negativity and suspicion. The above results also suggest that the border between Nepal and India is effectively being used to amplify political positions and consolidate power (Belcher et al. 2015; Brambilla and Jones 2020; Jones 2016). Therefore, transboundary interactions need to be assessed in a nuanced way to understand the dynamics of power and conflict at the community level, as suggested by Balibar (2015) and Brambilla and Jones (2020).

In the same way, water experts from Nepal (E30) and India (E26) argued that myths exist not only among the citizens but also among the experts:

“...Not only among people at risk, but experts also possess myths...they see every flood as a problem....by only looking at the destructive aspects of the floods and trying to solve it through the hard engineering solutions such as embankments...completely overlooking the dynamic nature of the river and its interaction with people and environment....” (E30).

The interviewees (E19, E26, E20, E25, E28 and E29) stated that the myths are the biggest hindrances to any transboundary collaboration between Nepal and India. Furthermore, E19 stated, *“...we need to break multiple myths among experts and public to have transboundary collaboration because those myths are causing conflicts and gradually eroding the social cohesion between the people of Nepal and India....”* (E19). Likewise, Upadhyay and Gaudel (2018) also argued that myths about the causes of Kosi River floods have contributed to eroding the social cohesion between the people of Nepal and India; and Kaphle (2016) has given the example of a violent clash between the people of Nepal and India in the Kosi River basin in 2016, injuring 12 people related to the Kosi River flooding.

This study has identified myths as a significant constraint for transboundary collaboration between Nepal and India for EWS. This study has found that local politicians and media in both countries misinform the people in the Kosi basin regarding the causes of floods to evade their responsibility for flood protection. Those myths were found to be contributing to suspicion and rift at the community level between Nepal and India and constraining

transboundary collaboration. However, it can be argued that myths related to the causes of floods could be overcome through awareness-raising activities at the community level.

This section showed that significant myths exist around the causes of floods and the flood control measures in the Kosi River basin, which are mishandled and perpetuated in both countries by politicians and media, especially during elections, to gain more votes. These myths are contributing to disrupting the social cohesion among the people of Nepal and India and pose a threat to future transboundary collaboration. Also, by spreading the myth, the politicians evade the responsibility of flood risk management by giving the impression to the public that floods are external and inevitable disasters.

7.5. Chapter summary

This chapter demonstrates that disaster risk management has become a challenge in the Kosi basin due to the lack of transboundary EWSs. All the respondents mentioned that transboundary EWS is needed in the Kosi River basin; however, government officials from Nepal claimed that India would benefit more from it; therefore, India should approach Nepal for transboundary EWS with compensation for unequal benefits with technical assistance and equipment support.

Similarly, this chapter shows that transboundary disaster risk governance in the Kosi River basin is embedded with complex geopolitical settings and challenges. The Kosi Agreement between Nepal and India in 1954 was the first transboundary joint venture for flood risk management in the Kosi River Basin; however, the Kosi Agreement proved ineffective and resulted in unintended social and environmental consequences—the Kosi Agreement contributed to disaster risk creation. It was argued that the Kosi Agreement was less concerned about flood protection but instead a geopolitical tool used by India for the hegemonic utilisation of shared water resources.

The bilateral institutions such as JCIFM, which were formed to resolve the issue of flooding in the Kosi River basin, continue the business-as-usual approach of flood protection through embankments. Moreover, the bilateral dialogues appear as a formality, only to discuss the need for additional embankments without seeking any alternatives, further degrading the basin environment. It was also argued that corrupt politicians, bureaucrats, and contractors gain through corruption during embankment construction and maintenance; therefore, they

want floods to occur. Also, the media and local politicians give the false impression to the public that floods have occurred through external sources and are inevitable and can only be controlled by adding more embankments to the flood plain.

Similarly, the central level authorities dominate the transboundary interactions through bilateral meetings. Furthermore, those bilateral meetings do not provide opportunities for public participation or local level representation; therefore, those bilateral interactions are disconnected from ground realities. Also, those bilateral interactions functioned as a platform for power interplay by powerful states to push their agendas, leading to skewed benefits. In the same way, India has proposed the Kosi High Dam project in the Kosi basin as an alternative to the embankments, which was widely regarded as an environmentally, socially, technically, and financially inappropriate option for flood control in the Kosi River basin.

For transboundary collaboration, lack of data sharing and myths were identified as significant challenges. Myths contribute to losing trust, raising suspicion in every collaboration, and eroding social cohesion between the two countries. It was argued that securitisation of the transboundary river data leading to the restriction of data sharing is linked to geopolitics and adds complexities to the transboundary collaboration. Similarly, it was argued that the local politicians and media deliberately implant myths regarding the causes of floods to create demand for embankments from the community level. The myths regarding the causes of floods and unequal share of benefits between Nepal and India pose another significant challenge for transboundary collaboration in the Kosi Basin. The next chapter 8, will discuss the implication of results from chapter 5,6, and 7 in relation to the questions formulated in Chapter 1.

Chapter 8 Discussion

8.1. Introduction

This chapter will discuss the implication of the results of the empirical chapters (Chapters 5,6 and 7) in relation to the main research question and sub-questions detailed in the introduction (Chapter 1) of this thesis; based on the literature review and context (Chapters 2 and 3), and conceptual frameworks set out in the methodology chapter (Chapter 4). This chapter provides an overview of the key research findings; then, this chapter compares the empirical findings with findings of different literature. Furthermore, this chapter presents the research's overall findings and overarching themes.

8.2. Overview of the key research findings

8.2.1. Risk information generation in EWS

SQ.1: How is risk knowledge co-produced between institutions and communities within and across the border in the Kosi River basin?

This study has found that knowledge co-production is non-existent in the Kosi River basin between the government institutions that generate warnings and the people at risk. Similarly, in both countries, risk information generation in EWS happens centrally and externally to the people at risk and their situated context. Also, the risk information generation process in EWS does not have the flexibility to incorporate feedback from people at risk to support contextual understandings. The scientific experts in government institutions that generate risk information had the impression that people at risk possess subjective knowledge related to experiences of disasters rather than objective facts and such subjective understandings could not contribute to the generation of scientific information in EWS. This view is problematic as it precludes knowledge co-production with people at risk (Agarwal 1995; Rai and Khawas 2019; Trigolić et al. 2021). The government officials also emphasised improving technological capabilities in EWS to make it effective rather than collaborating with the people at risk. Despite the government official's focus on technological intervention in EWS, most people at risk preferred low-tech and in-person modes of risk communication, such as sirens and loudspeakers, to SMS warnings. This finding relates to the low level of literacy in the study area. Also, most people in the study area spoke Maithili as their first language; therefore, they

preferred to receive warnings in Maithili rather than the currently used languages (Nepali or Hindi) so they could understand the warnings more clearly. This result suggests that government institutions are not considering the contextual factors such as people's preferences and needs at the local level while generating risk information and disseminating the warnings.

This study has also found that many institutional restructuring and technological developments occurred in Nepal and India after the Kosi flood disaster of 2008, and this was one of the driving factors behind the recent institutional restructuring and policy updates on flood EWSs. Despite the policy changes, the ways of working have remained the same as the institutions are still: i) centrally managed and following a top-down approach; ii) involving an extended hierarchy of institutions for risk communication; iii) lacking capacity and resources at the local level, and iv) focusing on disaster response than preparedness. Due to this, the policies and the ground realities at the local level do not match, and institutional challenges remain unaddressed.

8.2.2. Risk communication in EWS

SQ.2: How is risk communicated for early warnings, and how do communities understand the risk and warnings in the Kosi River basin?

There is no real-time transboundary EWS between Nepal and India in the Kosi River basin. However, each country operates their separate EWSs to communicate risk within its territory. In Nepal, the Department of Hydrology and Meteorology (DHM) can forecast floods in the Kosi River basin three days in advance using flood forecast models, which are circulated to government institutions and stakeholders in the form of flood forecast bulletins for disaster response planning. The DHM disseminates flood warnings through mobile SMS to at-risk people in the Kosi River basin. However, the SMS warnings are based on real-time river monitoring sensors rather than model forecasts; therefore, people at risk receive warnings with inadequate lead times of approximately 1 to 2 hours. In addition, the SMS warnings are sent in a non-native language and are non-standard, lengthy, and non-specific regarding the location and time of the hazard impact or recommended action to follow—causing chaos and confusion at the community level. The DHM officials responsible for disseminating warnings were aware that the forecast models contained uncertainties due to the hydrometeorological

complexities of the Kosi River basin, which could lead to false alarms, damaging institutional reputation. Therefore, the officials preferred to disseminate fairly accurate warnings based on real-time sensors, but at the cost of significantly reducing lead times. The officials were also reluctant to disseminate warnings with uncertainties because they perceived that the public could interpret those model uncertainties as institutional deficiencies to produce accurate warnings, damaging the institutional reputation. The officials in DHM were unaware if the SMS warnings were accessible, correctly interpreted, or helped people at risk in taking appropriate actions during disasters. The warnings served as a one-way flow of information. The perception of government officials in Nepal suggests a strong aversion towards false alarms and more concern about institutional reputation than disseminating timely warnings.

In Bihar, India, the Central Water Commission (CWC) also generates three days of warnings based on hydrometeorological data. However, rather than sending it directly to the people at risk, it relays those warnings involving an extended hierarchy of government institutions. The warnings pass from the central government to the state, then district, then village level institutions to disseminate warnings to the people at risk, reducing the lead time in each step. At the village level, only a few government officials receive warnings. They also have the impractical responsibilities of disseminating them to thousands of people at risk and evacuating them to safety. Due to the awkward institutional arrangement at the local level, the warnings failed to reach most people in Bihar. Most people in the Kosi River basin in Bihar access flood warnings aired on radio and television, but those warnings were vague, non-specific regarding the exposed location or time of hazard impact, and difficult to understand. Furthermore, the warnings are expressed in colour codes (red warning, orange warning, or yellow warning); and contain the volume of water discharged from river monitoring stations, which people find confusing.

In both countries, the government institutions that disseminate warnings are disconnected from the local context where warnings are being sent. Thus, government officials disseminating warnings are unaware of whether the warnings are accessible or correctly interpreted and understood by the intended recipients. The government institutions were only 'giving' warnings to the people at risk without any opportunity for feedback from the people at risk. It can be argued that just giving warnings alone does not guarantee that people will access and act on them; rather, the risk communication in EWS must be a two-way

process to communicate the shared understanding of risk in a context. Therefore, risk communication in EWS is the process of meaning-creation rather than giving information to the people at risk.

The gender disaggregated focus group discussion (FGD) results suggest that vulnerable people (especially women and marginalised groups) cannot access flood warnings because of : i) a lack of access to mobile phones to receive warnings; ii) low levels of literacy to comprehend warnings; iii) socio-cultural norms restricting them from venturing out in public places to access warnings and limiting them to participate in discussions in community meetings with men, and iv) gender roles of cooking, caring, and other household chores limiting interactions to the outer world. This study also suggests that women perceive risks differently than men. Women were more concerned about harsh living conditions in temporary shelters during flood evacuations, where they will also be exposed to the risk of sexual harassment and violence, animal attacks, snake bites, waterborne diseases, and theft of jewellery and mobile phones. Women mentioned that risks during evacuation on embankments were more concerning to them than the risk of flood hazards, which was a significant motivating factor determining their response actions during floods.

Nepal and India share an open border in the study area. Therefore, even without a formal transboundary risk communication mechanism, the porous international border between Nepal and India contributes to filling the gap of transboundary risk communication to a certain degree. The mobile telecommunication networks of Nepal can be received up to a kilometre inside the border in Bihar so people living in market centres close to the border use mobile SIM cards of both countries to avoid international calling rates. In doing so, people in Bihar also receive warnings sent by DHM to people in Nepal, which get disseminated to nearby villages close to the border in Bihar (Kunauli and Bathnaha). However, the percolation of such warnings is limited to villages close to the border. There is no access to warnings in villages far from the border (Haripur and Kamalpur) in Indian territory. Some NGOs in Nepal have utilised community networks to establish community-based transboundary EWS in the Kosi River basin to make up for the absence of formal EWS—albeit on a small scale. This was done by forming community networks upstream (Nepal) and downstream (Bihar) so, warnings received from upstream can be forwarded to the downstream using a social media application (WhatsApp).

Levels of understanding of flood risk were found to be lacking on both sides of the border. The people in the study area knew they were at risk because they face floods annually but did not have a uniform understanding of what causes those floods. This lack of understanding of the causes of floods has led to speculations and myths related to floods which have implications for disaster preparedness and people's response actions during disasters. In Nepal, some NGOs support local governments by conducting community level awareness-raising activities due to the capacity and resource constraints at the local level. However, many NGO-led activities in Nepal were found to lack representation and participation of the vulnerable groups. Those community-level interactions run by NGOs were also primarily driven by elites and influential people at the local level. Therefore, it is argued that the seemingly participatory activities conducted by most of the NGOs at the community level in Nepal could unintentionally contribute to exacerbating the vulnerabilities by ignoring the differences and inequalities existing at the community level. While in Bihar, there is no shortage of public funds at the local level, as in Nepal, NGOs and donor agencies are not active at the community level in conducting awareness-raising activities. Due to this, neither local government institutions nor NGOs in Bihar conduct awareness-raising activities. Partly because of this, awareness of flood risk was significantly less in Bihar than in Nepal.

8.2.3. Geopolitical dynamics in the transboundary EWS

SQ.3: What are the geopolitical dynamics that constrain transboundary EWS in the Kosi River basin?

This study has found that transboundary EWS between Nepal and India in the Kosi River basin is embedded in a complex geopolitical landscape of conflicting interests related to utilising shared water resources. The Kosi River is also a shared political resource linked to the development aspirations of both countries and that these relate more to water governance than disaster risk management or EWS. The Kosi Agreement of 1954 was the first transboundary agreement between Nepal and India for flood risk management in the Kosi basin, leading to the establishment of the Kosi Project, which the Government of India entirely funds and manages in the Nepalese territory. The Kosi Project involved the construction of embankments for channelising the river and the construction of Kosi Barrage for controlling the river discharge as a flood mitigation strategy with added benefits of irrigation and electricity in the Kosi basin. However, rather than solving the flooding problem, the

construction of embankments worsened the flooding condition and caused unintended consequences to people's lives, livelihood, and environment. The embankments functioned as sediment traps, causing aggradation of the riverbed, avulsion, and multiple flooding due to embankment breaches. In response to the embankment breaches, more layers of embankments have been added, but flood problems became worse, long-lasting, and unpredictable due to drainage congestion. The project intervention led to "disaster risk creation" (Lewis 2012) due to the lack of understanding of the interaction between the river and the people in the river basin.

Even though annually occurring floods and multiple disasters caused by embankment failures in the Kosi basin suggest that embankments have become futile to protect floods in the Kosi River basin, construction of embankments have continued without seeking any other alternatives for flood risk management in the Kosi basin. Interviews with experts and people at risk suggest that this could be due to the corruption and collusion between local politicians, local government officers, and contractors to gain through the embankment construction using low-quality materials. In addition, this study has also found that local politicians and media also impart a false sense of security over embankments by suggesting that embankments only can save them from flooding; so that the demand for embankments is maintained from the community level.

This study has found that multiple bilateral joint committees (ministerial level, department level, technical) have been formed between Nepal and India for flood risk management in the Kosi River basin. However, those committees focus only on embankment building and disaster response rather than disaster preparedness. Furthermore, this study has also found that bilateral interactions between Nepal and India are centrally led and disconnected from the ground realities as they lack the participation of people at risk and representation of local government institutions of both countries. Bilateral committee meetings appear to act more as a formality and platform for the powerful country (India) to push its agenda through negotiated agreements than having a genuine interest in flood risk management or transboundary EWS.

Securitisation of transboundary river data:

India has securitised transboundary river data, due to which river information could not be shared internally or externally as it poses a national security threat to India. The securitisation policy in India could be due to India's history of conflict with its neighbouring countries related to border disputes. The CWC in India downloads the openly accessible hydro-meteorological data from the DHM website in Nepal but cannot share any of the river information in India with Nepal due to 'securitisation'. The literature suggests that India uses securitisation as a geopolitical tool to maintain its hegemony over shared water resources. Irrespective of the reasons, the securitisation policy has posed a significant challenge for EWS as it limits basin-wide research.

Myths:

Another challenge for transboundary collaboration was the myths and misinformation related to the causes of floods in the Kosi River. Local politicians and the local newspaper media in both countries misinform the people in the Kosi basin regarding the causes of floods for their benefit. In Bihar, politicians, and media label the Kosi River floods as "Nepalese floods" and convey to the people at risk that Nepal has caused flooding by opening the Kosi Barrage gates, even though the Water Resource Department of India operates the Kosi barrage in Nepal. Another myth running parallel in Nepal is that Bihar deliberately causes floods in Nepalese territory by constructing flood control infrastructures in Bihar to back-flow the Kosi River. Those myths exist due to the lack of awareness about the causes of floods in the Kosi River basin. Those myths could also be deliberate stunts of politicians in India to create public demand for embankments and to continue embankment construction and corruption unabatedly. In Nepal, myths are deliberate attempts to secure more votes during the election by blaming India for the disasters in the Kosi River. 'Anti-Indianism' is a significant supporting factor in Nepal because India directly influences every aspect of people's life; therefore, the politicians of Nepal often try to appear nationalist by appearing negative to India and blaming it for causing disasters. Those myths contribute to suspicion, recrimination, and rift between the people of Nepal and India at the community level. Those myths related to the Kosi River floods and their causes could be overcome through awareness-raising activities at the community level.

8.3. Comparisons between the empirical and the literature findings

Knowledge Co-Production, EWS Institutions, and Flood Affected Communities

Empirical findings from this study highlight the inadequate policies and lack of capacity of local level institutions in Nepal and India regarding implementing transboundary EWS, resulting in a focus on post-disaster relief rather than preparedness. While Russel et al. (2021) refuted the narrative of local-level capacity deficiencies, suggesting it as a plot for central-level intervention, this study contradicts their argument. It suggests that local institutional capacity and resources are lacking in implementing EWS activities in the Kosi River basin. NGOs provide support in Nepal to complement the resource gap of local-level institutions. However, NGOs have limited entry into development activities in India. Community-level findings and input from local government institutions support these results, indicating that the continuity of EWS preparedness activities in the Kosi River basin is challenging without donor and NGO support within the Nepalese context. These findings align with Jones et al. (2016) and Gupta et al. (2021) in emphasising the lack of community-level capacity and resources for disaster preparedness in Nepal and Bihar.

Ogra et al. (2021) used the term “Scale discordance” to describe the mismatch between policies or knowledge and their implementation in disaster management in India. The empirical evidence from this study supports the presence of scale discordance in Nepal and India, particularly in the context of transboundary EWS. The findings from this study align with Ogra et al. (2021), suggesting that Institutional restructuring and technological advancements were prompted by the 2008 Kosi flood in Bihar, leading to policy changes in both Nepal and India. However, despite these changes, local-level capacity constraints and working methods have remained unchanged, operating in a top-down manner that prioritises disaster management over preparedness.

Scholars like Mahmud et al. (2012) and Keoduangsine and Goodwin (2012) highlight the disconnection between flood warning institutions and communities, resulting in ineffective EWS that lack contextual information. The empirical findings from this study reveal the absence of crucial components transboundary EWS, such as understanding people’s vulnerability and accessibility to technology. Both Nepal and India rely on centralised warning dissemination without considering the needs and feedback of at-risk populations.

Knowledge co-production in risk information generation involves the active participation of individuals at risk, fostering a comprehensive understanding of hazards and their contextual impacts (Hamza and Mansson 2019; Kelman and Glantz 2014). However, empirical findings reveal scepticism among government officials in Nepal and India regarding community involvement in EWS and the potential contributions of at-risk populations to scientific understanding. These officials prioritise technical aspects and overlook social components and knowledge co-production. Empirical findings indicate that in Nepal, flood warnings rely on real-time river sensor data rather than forecast model output due to uncertainties caused by inadequate rainfall monitoring stations and model accuracy. This cautious approach aims to avoid misinformation and maintain public trust but results in significant delays, with warnings issued only 1 to 2 hours in advance. Experts face challenges in communicating uncertainties to the public, fearing reputational damage. These findings align with Budimir et al. (2020), highlighting officials' lack of confidence in weather forecasts, concerns about false alarms eroding trust, and reluctance to communicate uncertainties.

This study highlights the contrasting policy landscapes in Nepal and India regarding the involvement of NGOs and donor agencies in Disaster Risk Management (DRM) and EWS implementation. In Nepal, Donors and NGOs support local government authorities engaging in EWS activities. However, the presence of donors and NGOs is inconsistent in the Kosi River basin and Nepal overall. Additionally, local government institutions in Nepal have struggled to institutionalise donor support, resulting in a dependence on external institutions for disaster risk reduction efforts. Furthermore, the study underscores the risk of elite capture in NGO-led interventions, where influential individuals at the community level dominate the process. This finding aligns with previous research by numerous scholars (e.g., Jha and Gundimeda (2019); Acharya and Prakash (2019); Pritchard and Thielemans (2014); and Gupta et al. (2021)) highlighting the oversight of caste and gender-based inequalities in NGO-led projects in Nepal, particularly in the Kosi River basin where vulnerability is closely related to caste dynamics and gender discrimination.

In contrast, there is limited involvement of non-governmental actors in Bihar. This difference can be attributed to India's disaster management policies prioritising formal collaboration with governmental channels. Furthermore, policies that restrict NGO access to foreign development funds, along with a history of ethnic conflict, lawlessness, and corruption at the

local level, create challenges for donor agencies in Bihar, as suggested by Jones et al. (2016) and Syal et al. (2021).

Furthermore, the findings reveal significant gaps in information availability and understanding of flood risks. The community-level interview results suggest that 89 per cent of the respondents stated that no information is available at the local level regarding flood preparedness and EWS. In Nepal, only 12 per cent stated they had seen hazard maps displayed outside municipal buildings, but they could not interpret the information. Only 8 per cent of Nepal respondents stated they had access to hazard maps. In contrast, all respondents from Bihar indicated a complete absence of local-level information regarding flood preparedness and EWS. These findings indicate limited accessibility and dissemination of hazard information in Nepal, while Bihar lacks information at the local level on flood risks and EWS. This finding aligns with the comparative study of Nepal and Bihar by Jones et al. (2016), suggesting that Nepal has progressed in disaster preparedness activities as external development agencies lead those activities, while in Bihar, preparedness is lacking as NGOs are not active in Bihar as in Nepal.

Disaster Risk Communication, Risk Perception, and Early Warning Systems

The empirical findings from the study indicate a lack of real-time transboundary risk communication between Nepal and India. However, during flood disasters in the Kosi River basin, ad-hoc communications occur involving central government ministries such as the Ministry of foreign affairs in both countries. Under the bilateral agreement of 1988, DHM sends daily raw river data, including river discharge and gauge heights, to CWC. There is no real-time risk communication between Nepal and India, apart from the data sharing between DHM and CWC. However, ad-hoc and informal communication occurs between the two countries. Extensive literature (e.g., Acharya and Hori 2019, Biswas 2011; Gade 2020; Gupta et al. 2021; Molden et al. 2017; Shrestha et al. 2010; Shrestha et al. 2021) aligns with this finding and suggest that lack of formal transboundary EWS between Nepal and India is creating hindrance in flood risk management between the two countries.

The empirical findings indicate that open borders between Nepal and India, common language, and shared culture facilitate informal transboundary communication at the community level. Community-level interviews confirm that many individuals carry mobile SIM

cards from both Nepal and India in the border region, allowing them to receive warnings sent by the Department of Hydrology and Meteorology (DHM) through Nepalese mobile networks (NTC and NCELL). However, the reception of these networks inside the Indian territory of Bihar is limited to one or two kilometres. Furthermore, leveraging the social relationships across the border, some NGOs in Nepal have collaborated with NGOs in India to establish community-based transboundary flood EWS utilising social media applications like WhatsApp to facilitate communication among the upstream and downstream communities. This initiative helps bridge the gaps between the two countries' formal EWSs, although at a limited scale. Similarly, many scholars (Shrestha 2017; Molden et al. 2017; Cramer et al. 2016) also suggest that community-based informal transboundary EWS contributes to filling the gaps of formal transboundary EWS.

The empirical findings also suggest that in Nepal and India, risk communication for EWS currently adopts a centralised and top-down approach, disregarding the accessibility and comprehension of warnings by at-risk individuals. Government officials at central-level institutions generate warnings independently, detached from the affected communities. The current operational model of risk communication resembles Callon's (1999) Public Education Model (PEM), which institutionalises and disseminates scientific knowledge to at-risk people without their active involvement. These findings are corroborated by the community-level interactions, suggesting the lack of engagement between warning institutions and communities, neglecting the need to assess understanding and address contextual requirements for interpreting government warnings.

The empirical results corroborate with community-level interactions, indicating that all respondents acknowledged that they are at risk of flooding. However, 48 per cent of respondents lack awareness of the specific causes of flooding, while the remaining 52 per cent hold diverse opinions, including factors such as riverbed aggradation, embankment seepage, and deforestation. This reveals a lack of consistent understanding among the population regarding the underlying causes of flooding. The results suggest significant disparity in access to warnings between Nepal and Bihar. In Nepal, 72 per cent of respondents reported accessing warnings primarily through SMS, whereas only 21 per cent of respondents from Bihar had access to warnings, with 79 per cent receiving no warnings. These results suggest that warnings are more accessible in Nepal than in Bihar due to the direct method of

risk communication through targeted mass SMS. However, among the 72 per cent of respondents in Nepal who had access to SMS warnings, 67 per cent found the warnings unhelpful due to insufficient lead times. Regarding communication preferences, 75 per cent of the interviewees from the 44 community-level interviews expressed a preference for sirens and loudspeakers. Additionally, 14 per cent mentioned that any form of communication would be useful as they had no access to any warnings. Only 9 per cent of respondents preferred SMS warnings, while 2 per cent preferred television and radio. These findings indicate that people in the study area prefer low-tech and in-person modes of risk communication, giving priority to sirens and loudspeakers to better understand the risk information. The research findings indicate that 82 per cent of respondents prefer to receive warnings in the Maithili language rather than Nepali, as it enhances their understanding. This finding aligns with a study by Budimir et al. (2019), which emphasised the preference for in-person communication among people in the Kosi River basin due to low literacy levels. However, it is worth noting that local government institutions in Nepal have discontinued the use of sirens and loudspeakers for warning dissemination following the implementation of mass SMS warnings by the DHM. This discontinuation has left the most vulnerable population disconnected from flood warnings.

Vulnerable people, particularly women, face barriers to accessing warnings. It was observed that only male household heads own mobile phones, and low literacy levels prevent women from understanding SMS warnings without their spouses' assistance. These findings align with Budimir et al. (2020) and Acharya and Prakash (2019), highlighting the gender disparities in accessing risk information in the Kosi River basin. Scholars such as Meechaiya et al. (2019), Brown et al. (2019), and Budimir et al. (2020) have also emphasised that EWSs in the Kosi River basin are "gender unaware" and tend to neglect women, marginalised populations, and those with low socioeconomic status.

It was identified that villages near the Nepal-India border receive mobile network signals from Nepal. People living near the border use Nepalese and Indian SIM cards to avoid international call charges; in doing so, they receive warnings from the DHM on their mobile phones in border market centres. Warnings also get communicated through interactions in the marketplace when individuals shop for daily essentials. This finding aligns with the research from Acharya and Prakash (2019) suggesting that market centers act as a platform for

dissemination of warnings through people's interactions in the Kosi River basin. However, the scholars also suggested that sociocultural barriers prevent women in Bihar from accessing warnings through public interactions in the marketplace.

People's Perceptions and Actions during Floods

The empirical findings from FGD highlights the dominant role of male household heads in flood preparedness and decision-making. Men discussed flood risks and took actions such as reinforcing embankments and arranging transportation. This demonstrates gender discrimination, as women were excluded from consultations and decision-making processes. Multiple scholars (e.g., Acharya and Prakash (2019); Shrestha et al. 2021; Budimir et al. (2020)) also noted the prominent role of men in Bihar's flood response, while women were expected to follow decisions without active participation. The empirical findings also revealed that upon receiving flood warnings, people engaged in discussions with influential individuals to understand the risks and act collectively. This collective evaluation of risk and response aligns with the concept of risk perception as a collective construct in society, as argued by Douglas and Wildavsky (1983) and supported by other scholars. However, the collective evaluation of risks and decisions made are entirely led by male household heads, and women only have the role of following those decisions.

The study also revealed that particularly women, perceive the risks and challenges associated with evacuation as more concerning than the hazards themselves. Influenced by sociocultural factors, gendered risk perception plays a significant role in determining behaviour during disasters. Women's perceptions of risks and their impact shape their actions, as supported by various studies (e.g., Eisenman et al. 2007; Haque and Blair 1992; Hamsa and Mansson 2019; Lindell and Perry 2003; Kasperson et al. 2013; Kelman and Glantz 2014; Wachinger et al. 2013).

Transboundary Disaster Risk Governance and Geopolitics in the Kosi River Basin

Transboundary flood risk management in the Kosi River basin

The empirical findings indicate that transboundary EWS in the Kosi River basin are embedded within complex geopolitics concerning the utilisation of shared water resources, side-lining of disaster management efforts in both Nepal and India. India's primary focus on the

transboundary Kosi River lies in meeting its water demands for irrigation and industrial use (Basu, 2022), while Nepal is primarily interested in hydropower production and selling electricity to India (Sahu 2019). The findings from this study aligns with the findings of Bagale (2020) and Noolkar-Oak (2021), who argued in their respective studies of transboundary river agreements between Nepal and India that these agreements appear to be driven more by regional geopolitics than genuine collaboration. The empirical findings corroborate the existing body of literature emphasising the influence of geopolitics in the transboundary river interactions (e.g., Biswas 2011; Dixit et al. 2021; Bobbette and Donovan 2019; Donovan 2020) and suggest that transboundary EWS between Nepal and India is influenced by power relations and geopolitics over the utilisation of river asserting to Mirumachi (2015) and Zeitoun et al. (2020).

The empirical findings suggest that transboundary bilateral committees for flood risk management between Nepal and India are centrally led, and do not include flood-affected people or the local level government actors and are therefore unaware of the contextual information. This finding aligns with extensive literature (e.g., Acharya and Hori 2019; Gupta et al. 2021; Dixit et al. 2021; Pandey et al. 2022) arguing that bilateral dialogues between Nepal and India are state-centric, which lack local level participation and representation of local government authorities in the Kosi basin. Likewise, Noolkar-Oak (2021) argued that the disconnection of central governmental actors from ground reality has contributed to the Kosi River basin's complex geopolitical landscape.

Flood control infrastructures and politics

This finding substantiated from the community-level interviews suggest that—contrary to the perception of experts that embankments are the primary cause of flooding and all the problems in the Kosi River basin; all the interviewees at the community level perceived embankments as solutions or evacuation site during floods and stated the needs for more embankments. These arguments are also supported by Gade et al. (2020), suggesting that contradictory perceptions exist among experts and people at risk towards embankments in the Kosi River basin—experts regard them as problems, while people at risk regard them as solutions. This finding suggests that these perceptions of the people at risk towards embankments as a solution and demand for more embankments could also be the result of the impression given by the local politicians and media to continue building embankments in

the name of flood protection, which is also supported by Acharya and Prakash (2019), Gupta et al. (2021), and Mishra (2008).

The empirical evidence indicates that despite the ineffectiveness of embankments for flood protection in the Kosi River basin, both the governments of Nepal and India are considering a large-scale infrastructural intervention for water retention to mitigate flooding. However, this approach overlooks the negative impacts of the proposed Kosi High Dam project (Dixit 2020; Tandan (2021); Linkha (2020) and Dhungel and Pun (2008)), as highlighted by multiple scholars that both countries prioritise economic benefits and water/electricity shares from the project over potential environmental and societal consequences. This perspective aligns with Dixit et al. (2022) and Tandon (2021), who emphasise that the negotiations between Nepal and India regarding the Kosi High Dam project often neglect local realities, such as the seismicity of the location, fragile geology, slope failure, landslides, and debris flows.

Challenges in transboundary early warning systems between Nepal and India

The empirical findings highlight significant challenges in transboundary collaboration and the establishment of an EWS between Nepal and India. These challenges include the lack of uniformity in the data management system, data quality issues, varying formats of river data, securitisation of rivers, and the presence of myths related to the causes of floods. Dutta (2021) points out that information on the Kosi River becomes classified upon entering India, impeding collaboration for flood risk management. Jain et al. (2007) and Webster et al. (2010) note that individual Indian states collect hydrological data but rarely share it interstate or internationally, hindering transboundary flood forecasting. Villa Seoane (2021) explains that Indian laws regulating access to hydrological data are often interpreted to deny requests related to transboundary rivers due to security concerns. This lack of data-sharing mechanisms affects collaborative disaster risk management between Nepal and India (Prasai and Surie, 2015). Securitisation of rivers in India further limits external and internal data sharing, posing a significant challenge for transboundary collaboration in flood risk management. However, the study finds that the Indian government is lenient in sharing data for research purposes, suggesting the involvement of governmental research institutions from Nepal and India for basin-wide research and collaboration in the Kosi River basin. Additionally, scholars such as Dutta (2021), Vijet al. (2020), Ray et al. (2015), and Singh (2010) suggest that India's history of border conflicts with neighbouring countries has led to the

securitisation of transboundary rivers, impeding the sharing of river information under the pretext of national security threats.

Another challenge identified is the presence of myths related to the causes of floods. Mishra (2008) highlights how state agencies and politicians in Bihar use local media to propagate these myths, portraying flooding as an external, uncontrollable, and inevitable disaster to evade responsibility for flooding in the Kosi basin. Local media, which have better outreach than national media, play a role in spreading these myths among the public. These findings align with studies by Acharya and Prakash (2019) on floods in Bihar and Adhikari (2019) on the Kosi River basin in Nepal, which emphasise the role of politicians and local media in perpetuating myths about the causes of floods in the Kosi River basin.

8.4. Overall findings

Based on the main research question, The findings of the research are presented as follows:

- Cultural factors play a significant role in constraining transboundary flood EWSs in the Kosi River basin. Specifically, socio-cultural norms, gender barriers, low literacy levels, and limited access to risk communication and knowledge co-production have a pronounced impact on women and marginalised individuals in the study area. The findings of this study highlight that when flood risk becomes imminent, the community-level response is characterised by a consultation process within the community, which involves collaborative and consultative activities led by the community rather than being driven by individuals or households. However, socio-cultural barriers prevalent in the study area impede women's active participation in these community-level discussions, which men typically lead. Furthermore, the study reveals that women perceive risks differently from men, with their primary concerns revolving around the increased workload, harsh living conditions, and gender-based harassment during evacuation rather than the immediate risk of floods. These gender-specific perceptions significantly influence women's behaviour during flood events.
- Institutional factors, encompassing structures, procedures, arrangements, and decision-making processes, significantly contribute to the constraints encountered by transboundary EWSs. One major constraint is the absence of transboundary policies and institutions with basin-wide mandates, resulting in a lack of collaboration and

coordination among existing government institutions at the transboundary scale. In Nepal, the government institutions responsible for EWSs adopt a reactive approach to managing uncertainties by refraining from disseminating critical information to at-risk people. Their primary concern revolved around avoiding false alarms, as they perceived such incidents as potential threats to the institutional reputation rather than prioritising the timely dissemination of warnings. Similarly, in Bihar, the effectiveness of warnings is compromised due to the lengthy hierarchy of institutions and impractical institutional arrangements at the local level. Furthermore, a mismatch between existing national-level policies and the institutional realities at the local level in both countries, particularly regarding resource availability and capacity, poses a significant constraint on effectively implementing activities related to transboundary EWSs. These findings highlight the substantial constraints at the national level and in the transboundary EWS.

- Governance factors encompass the comprehensive mechanisms which involve a broader system of actors, institutions, policies, and processes that shape and influence decision-making, accountability, and the distribution of power and resources, particularly in the transboundary context. One key challenge lies in the presence of corruption and collusion at local-level institutions involved in constructing embankments under the guise of flood protection, despite the understanding that embankments are ineffective against floods and worsen the flooding situation. Another significant constraint is the absence of appropriate policies, institutions, or working modalities to facilitate the implementation of transboundary EWSs between Nepal and India. Although several bilateral committees have been established to foster collaborative action on flood risk management in the Kosi River basin, these committees are primarily state led, centrally managed, and fail to incorporate the participation of individuals at risk or the representation of local government institutions, thus remaining detached from the local context. Additionally, the securitisation of transboundary river data in India and the perpetuation of myths regarding the causes of floods impede the effective governance of transboundary EWSs.

8.5. Overarching themes in the research

The central theme consistently emphasised in this thesis is the inadequate involvement of individuals facing potential risks in generating and communicating risk information related to EWSs in Nepal. This limitation restricts the development of a comprehensive and inclusive approach to transboundary EWS. The disconnection between these processes and the community's contextual reality has several implications, including a lack of awareness, the spreading of myths and misinformation, recrimination, mistrust, and resentment. These factors hinder collaboration and impede the effectiveness of the transboundary EWS. At the community level in both countries, the existing EWSs employ a one-way risk communication approach that does not incorporate feedback mechanisms. Additionally, socio-cultural barriers further restrict the participation of women and marginalised populations in the study area.

On a national level, risk communication and information generation are detached from contextual awareness regarding people's access to information, their preferences, and their understanding of the warnings they receive. In both countries, there is a lack of collaboration in knowledge co-production between government experts responsible for generating warnings and individuals at risk.

Similarly, at a transboundary scale, the unique context of open borders, shared culture, and a common language facilitates informal risk communication through community-based networks. This informal communication partially compensates for the absence of a formal transboundary EWS, although with limited spatial coverage. However, the formal bilateral mechanisms for transboundary flood risk management and EWSs are centrally led and lack representation from local government institutions and the participation of local people. Consequently, discussions on transboundary EWS are disconnected from contextual reality. The lack of participation in the current EWS processes emerges as the overarching theme in this study, impacting the community, national, and transboundary levels in Nepal and India. This lack of involvement fails to address at-risk communities' unique requirements and understanding. The limited knowledge co-production between government experts responsible for generating warnings and individuals at risk indicates a lack of incorporation of the local communities' contextual understanding. This undermines the accuracy and

effectiveness of transboundary EWS, as it neglects the valuable knowledge and insights of those directly affected by the risks.

Furthermore, the absence of representation from local government institutions and the failure to incorporate people's participation in formal bilateral mechanisms constrain transboundary EWS. Without adequate representation, local communities' perspectives, needs, and concerns are overlooked in decision-making processes related to EWS. This lack of participation restricts the development of a comprehensive and inclusive approach to transboundary risk management. The disconnect between risk communication and the community's contextual reality also presents a significant constraint. When risk communication does not align with the specific needs, preferences, and understanding of local communities, the effectiveness of transboundary EWS is compromised. The lack of contextual relevance limits preparedness and appropriate response to transboundary risks. These unique themes collectively hinder the effectiveness of transboundary EWS by impeding participation, knowledge co-production, representation, and contextual alignment. Addressing these constraints is crucial to enhance the effectiveness of transboundary EWS and improve disaster risk management in the Nepal-India transboundary region.

The fig. (67) illustrates the factors and their interconnections (causal and triggering relationships) related to transboundary EWS within the study area. The unidirectional arrows represent cause and effect, while bidirectional arrows indicate mutually influencing factors. The recurring and overarching theme throughout the research was the insufficient involvement of at-risk individuals and the absence of contextual information within all EWS processes.

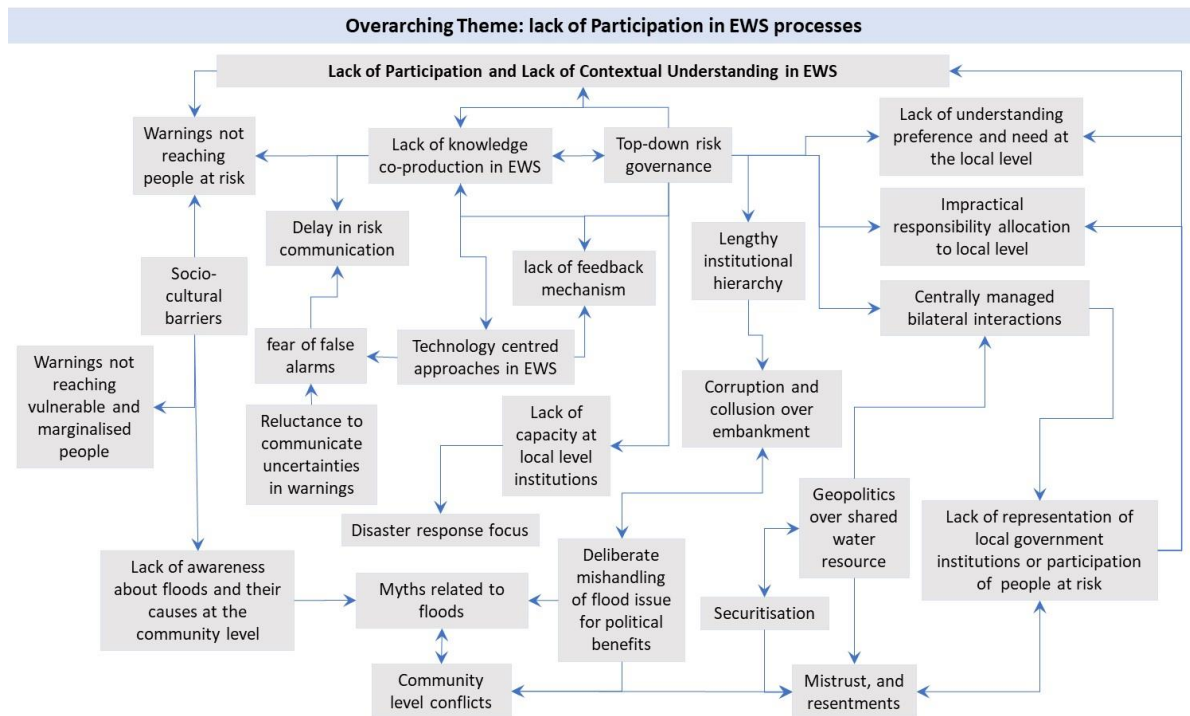


Figure 67: Schematic diagram of the overarching theme of this thesis.

8.6. Chapter summary

This chapter has discussed the implications of the empirical findings to the research question: what are the cultural, institutional, and governance factors that constrain effective transboundary flood EWS in the Kosi River basin, and its sub-questions. This study has found that cultural factors such as socio-cultural norms and gender barriers limit the access to risk communication and participation of women and marginalised people in the study area. Similarly, the institutional factors that act as constraints for EWS were identified as centrally operated and top-down institutional structures which lacked feedback mechanisms from the people at risk and institutional disconnect from the local context where the warnings are sent. The local level institutions also lacked capacities to conduct EWS activities at the community level. The donor agencies and NGO's support in Nepal make up for the lack of capacity at the local level; however, their involvement was sporadic and minor in scale, and participatory activities conducted by those NGOs in Nepal caused doubts about the inclusion of marginalised people and women due to the possibility of elite capture in those projects. This study has found that no EWS exists between Nepal and India in the transboundary Kosi River basin. However, during disasters, ad hoc communication is established between the government of Nepal and India, including an extended hierarchy of institutions and ministries

of foreign affairs of both countries to communicate the risk. In addition, even though embankments have proved futile against flood protection and have caused more complications than benefits, the embankment building process has continued without seeking alternatives, which could be due to the corruption during the construction of embankments. Even though there was a consensus among experts in government and NGOs in both countries that transboundary EWS is needed, neither policy, institutions, nor working modalities were available to implement transboundary EWS between Nepal and India. Many bilateral committees were formed for collaborative action on flood risk management in the Kosi River basin; however, those bilateral committee interactions were central government-driven, top-down, and functioned more as a platform for a powerful country to exercise soft power rather than a platform for transboundary collaboration. In addition, the securitisation of transboundary river data in India was identified as a significant factor limiting basin-wide research for transboundary EWS. The myths and lack of understanding related to the causes of floods were identified as another constraint disrupting social cohesion at the community level.

The overarching theme throughout this thesis was the lack of participation of people at risk in the risk information generation and risk communication processes of the EWS, resulting in the disconnect of those processes from the contextual reality at the community level. This thesis then dealt with the contribution of this thesis in the understanding of EWS and filling the gap of lack of literature in the study area and advanced the discourse on EWS as a social process where risk communication needs to serve as a meaning creation and risk information generation needs to include the people at risk and serve as the sense-making processes linking to the pragmatism theory.

The next chapter (Chapter 9) will be the concluding chapter of the thesis.

Chapter 9 Conclusion

9.1. Introduction

This chapter concludes the thesis by summarising key research findings in relation to the aims and objectives of the research and the research questions formulated at the outset of this thesis. This chapter also provides the contribution of this thesis to theory, policy, and practice. Furthermore, this chapter will elaborate on the limitations of this research, key implications, recommendations and suggested further research in the field of study.

At the outset of this thesis, the research aims were set to comprehensively investigate the cultural, institutional, and governance factors influencing the transboundary EWS in the Kosi River basin and identify potential strategies to overcome these challenges.

The following specific objectives guided this research:

- To explore the co-production of risk knowledge between institutions and communities within and across borders in the Kosi River basin, focusing on the collaborative processes involved in generating and sharing information related to floods.
- To examine the communication strategies employed for delivering early warnings in the Kosi River basin and assess how effectively communities comprehend and respond to these warnings.
- To gain insight into the perspectives of individuals at risk, government authorities, and non-governmental stakeholders regarding transboundary EWS in the Kosi River basin, aiming to understand their perceptions, experiences, and expectations.
- To understand the geopolitical dynamics between Nepal and India and how these dynamics influence the transboundary EWS in the Kosi River basin.
- To explore various constraints that impede the transboundary EWS in the Kosi River basin, including their institutional, technological, and socio-cultural aspects.
- To provide recommendations for transboundary early warning systems in the Kosi River basin to enhance collaboration, communication, and overall effectiveness.

The main research question based on the aims and objectives formulated in Chapter 1 was: What are the cultural, institutional and governance factors that constrain effective transboundary flood early warning system in the Kosi River basin?

The following section provides the synthesis of findings related to the aims and objectives of this research.

9.2. Synthesis of the findings related to aims and objectives of this research.

Cultural factors:

This study revealed that cultural factors, such as sociocultural norms and gender barriers, significantly constrain the implementation of transboundary EWS in several ways:

Firstly, these cultural factors restrict access to risk communication for women and marginalised individuals in the study area. Limited access to technologies, low literacy levels, gender roles, and sociocultural barriers hinder their ability to receive timely and relevant warnings in a transboundary context. This inequality in access undermines the effectiveness of transboundary EWS, as it prevents the inclusive dissemination of critical information to all at-risk populations across borders.

Secondly, the gender disparity observed in community consultations and decision-making processes further exacerbates the constraints on transboundary EWS. The exclusion of women and marginalised individuals from these processes hamper the co-production of knowledge and the integration of diverse perspectives necessary for effective risk management across borders. Their voices and experiences are not adequately represented in the decision-making processes, leading to incomplete risk assessments and response strategies.

Thirdly, the study findings indicate that women perceive risks differently from men, prioritising concerns about harsh living conditions and risks during evacuation. This divergence in risk perceptions can hinder the harmonisation and coordination of risk management efforts in a transboundary context. Failure to acknowledge and address these differing perceptions can result in misaligned actions and responses across borders, impacting the overall effectiveness of transboundary EWS.

Lastly, cultural factors influence women's actions during disasters, even when aware of imminent risks. Gender-specific concerns such as sexual harassment, animal attacks, and theft of valuables affect their motivation and ability to respond promptly and effectively to transboundary hazards. These factors introduce variations in preparedness and engagement levels among different groups, thereby hindering the coordination and synchronisation of actions and responses in transboundary EWS.

In conclusion, the cultural factors of sociocultural norms and gender barriers impose significant constraints on transboundary EWS. The limited access to risk communication, exclusion from decision-making processes, divergent risk perceptions, and gender-specific considerations hinder the effectiveness, inclusivity, and coordination of transboundary EWS efforts. It is essential to address these constraints and ensure equitable participation, cultural sensitivity, and gender responsiveness to enhance the overall effectiveness of transboundary EWS.

Institutional factors:

The study findings revealed that Institutional factors played a significant role in implementing transboundary EWS. Nepal and India exhibit a centralised and top-down institutional framework, which lacks effective feedback mechanisms from the at-risk people. This disconnection between government institutions and local contexts results in limited awareness of whether the intended recipients accessed, understood, and acted upon warnings.

In Nepal, a reactive approach is adopted, with flood forecasts primarily disseminated within the government circle rather than directly to the people at risk. This approach aims to avoid public trust deficits from false alarms, leading to warnings with shorter lead times of only 1 to 2 hours, despite having three days of available forecasts. Similarly, in Bihar, flood forecasts with three days of lead time are generated by central government institutions. However, they are primarily shared with disaster response agencies, following a similar top-down approach. The flow of flood early warnings in Bihar follows an extended hierarchy of institutions, resulting in reduced lead times at each step. At the village level, only three government officials receive the warnings, burdened with the impractical responsibility of disseminating them to a large population and facilitating evacuations. Consequently, a significant portion of

the population in Bihar lacks access to these warnings, relying instead on news broadcasts that often provide limited information, such as river discharge values and colour codes, making interpretation challenging.

Despite policy updates, Nepal and India's institutional context and operational modalities have remained unchanged. Local-level institutions cannot effectively carry out EWS-related activities. While donor agencies and non-governmental organisations (NGOs) support awareness-raising activities on EWS in Nepal, local-level institutions have not been able to independently institutionalise these practices, relying on donor support to sustain them. NGO-led initiatives and community-level interactions are sporadic and limited in scale, raising concerns about the representation and inclusion of marginalised populations. In Bihar, the involvement of NGOs is less significant, and local government institutions also struggle to conduct independent awareness-raising activities, resulting in a significant lack of awareness at the community level.

These institutional factors impose constraints on the implementation of transboundary EWS. The centralised and top-down approach hampers effective coordination and feedback mechanisms among common riparian countries involved in transboundary EWS. The lack of communication and collaboration across borders undermines the adaptability and improvement of transboundary EWS. Moreover, the bureaucratic hierarchy and impractical institutional setup at the local level led to reduced lead times in warning dissemination, restricting the preparation and response capacity of at-risk populations. Additionally, the limited capacity of local institutions, sporadic NGO-led initiatives, and incomplete representation of diverse perspectives impede awareness and participation at the community level, undermining the inclusivity and effectiveness of transboundary risk communication efforts. The overemphasis on technical aspects and the neglect of social and contextual factors in EWS implementation further constrain the relevance and accuracy of warnings for at-risk populations across borders.

In summary, addressing these institutional constraints is crucial to enhance the implementation of transboundary EWS. It requires a shift towards collaborative, inclusive, and context-specific approaches incorporating local knowledge, promoting effective communication and coordination, and empowering local-level institutions. By overcoming these constraints, transboundary EWS can improve communication, coordination, and

responsiveness, thereby enhancing the ability to address shared risks and mitigate the impact of disasters in transboundary contexts.

Governance factors:

This study revealed that governance factors significantly constrain the implementation of transboundary EWS in the Kosi River basin between Nepal and India.

Firstly, no formal EWS exists between Nepal and India in the transboundary Kosi River basin. During disasters, ad hoc communication channels are established between the governments of Nepal and India, involving an extended hierarchy of institutions led by the ministries of foreign affairs from both countries. These ad hoc arrangements lack a structured and coordinated transboundary EWS framework, hindering the timely and coordinated dissemination of warnings and the exchange of critical information across borders.

At the national level in both countries, the governance of EWS follows a top-down and centrally managed approach that primarily focuses on disaster response. However, the participation of people at risk in decision-making processes is limited. Central government institutions generate and disseminate warnings without fully understanding the local context in which they are to be implemented. This lack of contextual understanding and involvement of the intended recipients of warnings hinders the effectiveness of risk communication in transboundary EWS.

Another governance factor is the persistence of embankment construction, despite understanding that they are ineffective against floods and may cause more harm than benefit. The continuation of this practice can be attributed to opportunities for corruption during the construction of embankments. Additionally, local politicians and the media perpetuate a false sense of security associated with embankments, leading to community demand for more. This diverts attention and resources from more effective risk reduction measures and perpetuates a cycle of ineffective flood management.

While government experts and non-governmental organisations (NGOs) recognise the need for transboundary EWS, the necessary policies, institutions, and working modalities to implement such systems between Nepal and India are lacking. Bilateral committees have been formed for collaborative flood risk management in the Kosi River basin. However, these

committees are dominated by central authorities and operate top-down, functioning more as a platform for a powerful country to exert soft power rather than fostering genuine transboundary collaboration. Moreover, the decision-making power of government officials within these committees is limited, and the participation of local government institutions and people at risk is insufficient, resulting in a disconnect from the local contextual realities.

The securitisation of transboundary river data in India further constrains basin-wide research for transboundary EWS. Limited access to data restricts the comprehensive understanding of the river system, hindering effective vulnerability and exposure assessment. Additionally, myths and misinformation surrounding the causes of floods disrupt social cohesion at the community level, creating barriers to collective action and response.

In summary, the identified governance factors, including the absence of a formal EWS framework, top-down and centrally managed approaches, limited participation of people at risk, persistence of ineffective embankment practices, lack of policies and institutions for transboundary collaboration, securitisation of river data, and misinformation, collectively constrain the implementation of transboundary EWS between Nepal and India in the Kosi River basin. These governance constraints hinder effective communication, coordination, and responsiveness across borders, limiting the capacity to address shared risks and mitigate the impact of disasters in the transboundary context. Overcoming these constraints requires addressing governance gaps, enhancing stakeholder participation, improving data-sharing mechanisms, and fostering context-specific risk communication for transboundary EWS. Table 4 presents constraining factors in Nepal, India and at the transboundary level between the two countries in the Kosi River basin.

Table 4: Constraining factors for transboundary EWS in the Kosi River basin.

Constraining Factors	Nepal	India	Transboundary level
Cultural	▪ Socio-cultural barriers towards women ▪ Male led process of consultation and decision-making. ▪ Gender roles ▪ Lack of access to warnings to women,	▪ Socio-cultural barriers towards women ▪ Male led process of consultation and decision-making. ▪ Gender roles ▪ Lack of access to warnings to women,	▪ Myths related to causes of Kosi floods leading to conflicts. ▪ Reluctance for collaboration among experts ▪ Mistrust, and resentments over

	marginalised, and most vulnerable ones. ▪ lack and participation and representation of the women and marginalised people at risk. ▪ differing risk perceptions based on gender. ▪ Hardships, additional responsibilities, gender-based violence and harassment during evacuation demotivating to take actions. ▪ Lack of awareness at the community level ▪ Lack of understanding of risk (See section 6.3)	marginalised, and most vulnerable ones. ▪ lack and participation and representation of the women and marginalised people at risk. ▪ differing risk perceptions based on gender. ▪ Hardships, additional responsibilities, gender-based violence and harassment during evacuation demotivating to take actions. ▪ Lack of awareness at the community level ▪ Lack of understanding of risk (See section 6.3)	past bilateral treaties. (See section: 7.4).
Institutional	▪ Lack of capacity at the local level (See section 5.3) ▪ Delay in warning –fear of false alarms ▪ Reluctance to communicate uncertainty (See section 5.5). ▪ Lack of institutional coordination ▪ Disconnected from local context (see section 5.2). ▪ reliance on donors and NGOs on awareness raising activities and participation- small scale, sporadic activities by NGOs (See section 5.6). ▪ Lack of capacity to institutionalise	▪ Lengthy hierarchy of institutions ▪ Impractical institutional setup for EWS. ▪ Lack of institutional coordination ▪ lack of mechanism for upward communication from people at risk. ▪ Barriers for external development actors and NGOs. (See section 5.3)	▪ Lengthy hierarchy of institutions for communication with involvement of Ministries of foreign affairs. ▪ lack of local participation and representation of local government institutions in bilateral committees. ▪ lack of decision-making roles ▪ Disconnected from the local context (See section 7.2). ▪ Bilateral institutions— platform for powerplay, rather

	awareness raising activities by local government bodies. (See section 5.6)		than collaboration (See section 7.2.1)
Governance	▪ Centrally managed and top-down ▪ Technology centred. ▪ Lack of feedback mechanism ▪ Co-production extremely lacking. ▪ lack of coproduction of knowledge ▪ exclusion of people at risk ▪ lack of knowledge coproduction (See section 5.3) ▪ No consideration on preference over modes or risk communication or language ▪ Disconnected from local context (See section 6.2.2). ▪ Small scale unsustainable projects at the local level ▪ deliberate mishandling of flood issue for political benefits (see section 7.4.2).	▪ Centrally managed and top down ▪ Technology centred. ▪ Lack of feedback mechanism from people at risk (See section 5.3) ▪ No alternatives pursued even after embankments failed to protect against floods . ▪ Corruption and collusion for embankment construction (See section 7.3) ▪ Disaster response focus (See section 5.2) ▪ Mishandling of flood issues for political benefits (See section 7.4.2)	▪ Central government managed, ▪ Post disaster focussed (See section 7.2) ▪ Securitisation of transboundary river data (See section 7.4.1) ▪ Geopolitics over water use (see section 7.3.1) ▪ Lack of policy or institutions for transboundary EWS (See section 7.2) ▪ Lack of local level communication between both countries. (See section 7.2.1)

9.3. Contributions to theory

This section presents the theoretical contributions based on the analysis and findings of this research.

This thesis has shown how future research in EWS could use pragmatism theory to understand complex problems in transboundary EWS. Pragmatism theory is particularly useful in the study of EWSs because it focuses on how to approach problems through experimentation and collaborative action, including people's perception and understanding of their situation (Ansell and Boin 2019); as well as an understanding of situated context or "law of the situation" to deal with problems (Monin and Bathurst 2008; Terry 2015). The pragmatism

theory regards all knowledge as “fallible” and constantly evolving (Dieleman 2017); therefore, the “*quest for certainty is automatically vanquished*” (Dewey 1930) in pragmatism, suggesting working on whatever information is available collaboratively to construct a “bricolage” (Clarke 1999) of understanding to solve problems (Ansell and Boin 2019). This quality of pragmatism has attracted scientists recently to deal with dynamic uncertainties in social science research (Ansell and Boin 2019; Elkjaer and Simpson 2011; Farjoun et al. 2015). This thesis suggests approaching risk communication process in EWS as a “meaning making” process between disaster managers and people at risk through interaction and “deliberation” (participating and critically discussing) to have a common understanding of a situation to offer actionable advice to move forward (Simpson 2009; Ansell and Boin 2019). Similarly, this thesis suggests approaching risk information generation in EWS as a “sense-making” process (Weick et al. 2005) that involves: 1) “perspective-taking” (understanding perspectives of others); 2) “reflexivity” (understanding one’s limitations); 3) “enactment” (learning while doing); and 4) “abduction” (creating reasoning backward from the problem) (Ansell and Boin 2019; Boin et al. 2016; Martin 2007; Rorty 1979, 1989).

Global policies on DRR emphasise the need for transboundary EWS; However, studies on transboundary EWS are lacking, especially in the south Asian context between Nepal and India, and the existing literature on the transboundary contexts also gravitates toward water governance than EWS (Pandey et al. 2022). Therefore, this thesis contributes to filling the literature gap on transboundary EWS between Nepal and India in the Kosi River basin. This thesis has provided theoretical contributions to understanding the factors constraining the transboundary EWS and how those factors could be overcome. In doing so, this thesis has shown the interrelationship of EWS with regional geopolitics, internal disaster governance, socio-cultural barriers, and their effect on EWS governance in the study area.

This thesis provides better understanding of the risk information generation and risk communication components of EWS between Nepal and India and explores the socio-cultural, governance, and geopolitical factors that constrain effective transboundary flood EWS in the Kosi River basin and discusses how those constraints can be overcome. This thesis provides an understanding of contrasting perspectives of different actors on the governing side of the EWS (scientists and experts at the government institutions and NGOs) and the governed side (people at risk) and how those perceptions translate into EWS governance in the

transboundary context along with the influence of geopolitics over water resource utilisation between Nepal and India.

This thesis has advanced the discourse of Kelman and Glantz (2014, p.89), suggesting that *“the fundamental tenet is that each EWS needs to be viewed as a social process”*. Similarly, this thesis emphasises the importance of knowledge co-production and participation in EWS processes (i.e., risk communication and information generation processes of EWS) for generators of the warnings to understand the context better; and for the people at risk to better understand the risk.

This research has also provided a better understanding that women and the marginalised population—contributing the most significant proportion of fatalities in every disaster—are often missed out on the EWS due to socio-cultural barriers and gender inequalities. In addition, women perceive and respond to risks differently than men—they perceived risks during evacuations to be more concerning than the risk of hazards, which translates into their lack of motivation for evacuation during disasters. Therefore, special attention is required to include women and marginalised people in the EWS processes.

This thesis has brought a broader understanding of institutional context (institutional structure, centralised and top-down approach, and institutional capacity) in relation to transboundary EWS dynamics between Nepal and India and emphasised the need for collaborative and bottom-up approaches rather than supply-driven or top-down approaches in EWS to avoid “scale discordance” (the mismatch between knowledge and practices, against the need of local context) as suggested by Ogra et al. (2021, p.3).

This thesis has advanced the discourses on the concepts of “borders beyond the lines” (Brambilla and Jones 2020) by showing that the borders between Nepal and India are effectively being used to amplify political positions and consolidate power in both Nepal and India. Therefore, borders must be viewed more nuanced to understand their functions in shaping power and conflicts because they not only mark territories and delineate the differences; but also create differences (Balibar 2015; Belcher 2015).

This thesis has shown that the Kosi Agreement of 1954, the first transboundary agreement for flood risk management between Nepal and India, and subsequent infrastructural intervention led to “disaster risk creation” (Lewis 2012) in the Kosi River basin by aggravating

flooding conditions and vulnerability in the Kosi basin. This finding suggests the importance of understanding the social context, where the interventions are targeted as suggested by extensive literature (e.g., Alli et al. 2013; Devkota et al. 2018; Dixit et al. 2022; Gupta et al. 2021; Somanathan 2013); as well as understanding the socio-material interactions of those interventions (McGowran and Donovan 2021).

This thesis provides a better understanding of factors (cultural, institutional, and governance) that affect transboundary EWS and asserts that power dynamics and geopolitics over utilising shared resources affect transboundary interactions. This study builds on Zeitoun et al. (2011) arguing that power relations shape transboundary interactions where powerful countries often use “soft power” for embedding asymmetrical benefits in the negotiated agreements; and Mirumachi (2015) arguing that when countries with asymmetrical power interact in a transboundary context, powerful states often play a significant role in establishing rules and influence, force, or intimidate the weaker ones to secure compliance. This thesis suggests that power dynamics between countries also influence transboundary EWS, especially in the interaction between countries with asymmetrical power; Therefore, studies on transboundary EWS must include power dynamics in their assessments.

9.4. Contributions to policy and practice

The pragmatic ideas are applied to the findings of this thesis to recommend on policy and practices, which are as follows:

Risk communication in transboundary EWS needs people’s participation.

This thesis found that risk communication in the study area employed a centralised and top-down approach to early warnings, completely disregarding people’s access, needs, preferences, understandings, and social context. The findings suggest that people make meaning of their surroundings through their actions, perception, and knowledge of their setting; therefore, disaster managers’ role should be to create and communicate those meanings through a collaborative process (Ansell and Boin 2019). Similarly, scholars such as Arvai and Rivers (2014) also suggest that risk communication is a situated social activity where involved actors (sender and receiver) work on making sense of risk from the hazard; therefore, risk communication in EWS is more of a process of meaning creation rather than giving information about the hazard to the people at risk. Therefore, people at risk must be

involved in the communication process to make it effective. Risk communication also needs bottom-up feedback mechanisms to create a shared understanding of hazard risk and the actions required to follow.

Transboundary risk communication needs multiple channels to fit the capacity of the recipients.

This thesis has also shown that risk communication in the study area failed to reach the vulnerable and marginalised population (especially women) because of their (i) lack of affordability of technology to access the warnings (ii) lack of ability to interpret the warnings due to their literacy status and language barriers, and (iii) socio-cultural barriers and gender roles.

It would be unpragmatic to suggest that socio-cultural barriers and gender related issues that was held for centuries could be solved through certain interventions but by improving the access to risk communication especially targeting to the women and marginalised population at risk, the impact can certainly be minimised. Lovholt et al. (2014) also suggested that cognitive factors in evacuation behaviour must be considered in EWS especially those factors that hinder the evacuation motivation, by having targeted risk communication to reduce those impacts. Therefore, asserting to Villagrán de leon (2014), it can be suggested that the technologies used in EWS must fit the capacity and limitation of the intended recipients, and multiple parallel channels of risk communication must be used using digital media (SMS, TV, Radio, website) along with traditional media such as sirens, alarms, or door-to-door communication, to ensure that access to warnings is not limited to the access to technologies by the target audiences.

Transboundary warnings need to be communicated directly from their original source to the people at risk.

This thesis suggests that warnings disseminated from the original source in Nepal through mobile SMS had better outreach than the warnings that had to pass through the extended hierarchy of institutions in Bihar. Hamza and Mansson (2019) also suggested that warnings disseminated directly from the original source to the target group will be more effective than the warning that cascades through complicated channels, and that warnings need to allow a reasonable window of time for people to respond and act to those warnings.

Warnings need to have standardised language in transboundary EWS.

The study has found that the warnings used in risk communication were lengthy, non-specific regarding the exposed location and time, likelihood of hazard occurrence, or recommended actions to follow to the recipients of the warnings. Also, for an effective EWS, warnings need to be timely, brief, using context-specific language, precise about the location and time of expected impacts, and uncertainties in the warnings, and clear instructions on the recommended actions after receiving those warnings (Kuller et al. 2021).

Dealing with uncertainties in the warnings by communicating the uncertainties

This thesis has found that, even though warnings with three days of lead time were available in Nepal, people at risk only received warnings 1 to 2 hours before floods. The experts feared that circulating warnings based on forecasts could result in false alarms due to uncertainties that could jeopardise the institutional reputation and public trust. Experts in government institutions also argued that communicating uncertainties could jeopardise the institutional reputation as people at risk would regard those uncertainties as institutional deficiencies. In this regard, the pragmatism theory suggests that all knowledge processes are dynamic, evolving, and imperfect (Dewey 1930; Dieleman 2017). Therefore, rather than waiting for the perfect information—which is impossible—it is best to create an understanding of whatever information is available to make sense of the situation (Ansell and Boin 2019; Clarke 1999). Moreover, through deliberation and collaboration with people at risk during the risk communication process, there will be a shared understanding of risk and uncertainty, and the institutional trust will not be hampered. This thesis, therefore, suggests that uncertainties are better managed when it is communicated to the people at risk with reflexivity (understanding the scientific limitations) and transparency (communicating uncertainties and limitations by involving people at risk), as suggested by Donovan and Oppenheimer (2014).

Risk information generation in transboundary EWS requires knowledge coproduction.

This thesis has found that in Nepal and India, knowledge co-production between the government scientists and people at risk in risk information generation processes of EWS was non-existent. In this regard, the theory of pragmatism suggests deliberation as an effective and legitimate decision-making process, which helps to bring out creative ideas and solutions to problems and relieves “*pathological entrapment of knowledge*” among scientists and

relieves scientists from the projected image of the “great man” (Ansell and Boin 2019; Boin et al. 2016; Hart 1994). Furthermore, Kasdan (2011) suggested that deliberation makes people understand that decision-makers are not just distant information processors but also creative, moral, and knowledgeable actors and improves working through uncertainties in scientific decision-making (Kasdan 2011). Therefore, as Ansell and Boin (2019) suggested, risk information generation is a “sense-making” process between the at-risk people, scientists, and stakeholders for a common understanding of the situated context of risk; Therefore, this thesis suggest that the risk information generation in EWS must include knowledge co-production between people at risk, scientists, and stakeholders in a participatory process.

Institutional restructuring is required at the local level in line with policy updates for effectiveness in transboundary EWS.

Even though there have been policy changes and institutional restructuring related to disaster risk management and EWS in Nepal and India, the local level context and the working modalities have remained unchanged; as Ogra et al. (2021, p.3) suggested, “scale discordance” can be observed between the policy and practice for EWS in the study area. Therefore, local level capacity building and institutional restructuring to adapt to the policy changes are required both in Nepal and India for the effectiveness of EWS.

Awareness raising activities must be launched for breaking the myths in the transboundary context for transboundary EWS.

This thesis has found that awareness and understanding of the causes of floods are lacking in the study area, which has given space for myths related to the causes of floods, this can gradually damage the social cohesion between the people of Nepal and India at the community level. Hamza and Mansson (2019) suggested that warnings cannot be effective if their recipients lack sensitisation and awareness. Therefore, asserting with Gupta et al. (2021), awareness-raising activities related to the causes and occurrence of hazards are required at the community level in Nepal and India to break the myths and facilitate transboundary collaboration.

Participation and representation are required in transboundary interactions.

The study has found that the transboundary interaction between Nepal and India through bilateral committee meetings is centrally led and lacks local-level representation and participation of the people at risk; therefore, those interactions are disconnected from the contextual reality. Therefore, those bilateral meetings need the representation of local authorities (district magistrates or municipal mayors) and the participation of the people at risk for their decisions to be informed of the local context and needs of the people.

Lack of data-sharing for transboundary EWS can be solved by involvement of independent government research institutions.

This thesis has found that securitisation poses a significant challenge in data sharing between Nepal and India and is adding complexities to the transboundary collaboration and basin wide research on EWS. However, the study has also found that government of India is lenient on the securitisation policy if the data is being used by governmental research institutions in India for the research purpose. Therefore, one of the ways for working around the securitisation policy could be by forming a neutral transboundary research group composed of national research institutions of Nepal and India (e.g., as IIT and Tribhuvan University) to conduct basin wide research on transboundary EWS in association with technical institutions (e.g., IMD, CWC, and DHM) and local NGOs, and people at risk.

Risk governance approach needs to be changed by providing space for river.

Disaster managers perceive nature and society as dichotomies and conflict between the two as disasters; therefore, engineering interventions are employed to segregate those dichotomies to manage disasters (Meriläinen and Fougère 2022). On the contrary, anti-dualism is the common theme within the pragmatism theory (Lorino 2018) and disregards concepts such as: thought versus instinct, mind versus body, or society versus environment—as those dichotomies are more interdependent than oppositional (Ansell and Boin 2019).

As the interaction between nature and society has gradually been understood worldwide, the flood risk management approach has also been gradually shifting from structural measures (physical flood protection interventions) to non-structural measures (adapting to rivers) (Kuller et al. 2021) such as the “Room for River” interventions in the Netherlands and “Making

Space for Rivers” in the UK (Defra 2005; Stokkom and Smith 2002). Likewise, the Kosi River needs to be viewed holistically in terms of interaction with nature and society, and solutions are required that encourage coexistence with the river, such as by providing space for the river to meander rather than constraining it further with embankments or redistributing river in its old paleochannels—for which research is needed. These could be done by adopting land-use policies and hazard zonation maps of the Kosi River flood plains.

9.5. Limitations

Limited resource

One of the main limitations of this research was the limited resources and time for data collection in the PhD studies. Even though the scholarship funding under which this research was conducted was more generous in terms of availability of funds to conduct the research, as research conducted by an independent researcher with a specific window for fieldwork and data collection, this research has a limited coverage area as well as the scope of investigation in this research.

Language issues

One of the limitations of this study pertained to language. Although the researcher communicated and conducted field-level interviews in Hindi and Maithili, these were not the researcher’s native language. Consequently, when conversing with native speakers, there may have been inadvertent misinterpretations of viewpoints, particularly concerning language-specific nuances. To ensure accuracy in capturing the local context, the researcher consulted with acquaintances from the study area with Maithili as their native language. Their input was sought to elucidate the meanings of phrases such as “Jitua and Ratu cause floods in the Kosi”, which refers to the Jitua and Ratu rivers as tributaries of the Kosi River that predominantly contribute to flooding in the Kosi floodplains.

Memory of trauma

Like any research on disasters, engaging in discussions about such events with affected individuals has the potential to evoke memories of trauma and suffering. Even for the researcher, mentioning the Nepal earthquake 2015 evokes sadness, despite it occurring seven years ago. Similarly, discussing floods with participants at the community level could trigger

traumatic memories. However, during the interviews, no instances were observed where individuals became upset or sad. While unintended, this research inadvertently prompted participants at the community level to revisit those challenging times, where they may have associated the events with the loss of loved ones or valuable possessions.

Power relations

This study could not investigate the power relations affecting EWS at the community level apart from people's participation in the meetings related to EWS. This needs a thorough investigation of the situated context and ethnographic research into power and roles within a society, which could also have a similar impact as gender roles. However, those areas are unexplored in this research. Similarly, regarding gender roles, this research has only explored one aspect of vulnerability, i.e., gender roles affecting women and marginalised people to access warnings and their behaviours. However, there could be other multiple social barriers in the context which could have similar effects on the vulnerable people at risk. However, due to the limited scope, nature of those barriers is not included in this research.

Lack of views from central government officials in India

One of the limitations of the research is the lack of views from central-level government officials of India in this research. The interviews were planned with central-level government officials working in EWS in India (CWC, IMD, NDMA). However, due to the travel restrictions caused by the COVID-19 outbreak, interview data could not be collected through in-person meetings. Even while the interviews were conducted virtually, the officers in India were unable to allocate time due to their additional responsibilities during COVID. Therefore, the views of central government officials in India could not be incorporated into the study. however, the views of local government officials and people at risk reflected the practices of the central government of India.

Lack of classification of community level interviews about class, caste, and ethnicity

This research has not collected, and classified community-level interviews based on class, caste, ethnicity, age, or disability, contributing to the vulnerability of people in the study area. The community-level interviews were classified based on gender, which was also non-uniformly distributed over the study area as interviews were conducted with people who

were met in situ. The focus group discussions conducted in the marginalised settlements were assumed to include the perception of the vulnerable population. A thorough investigation of class and caste-based dynamics affecting EWS could be an area for further research.

Lack of inclusion of traditional and local knowledge on flood risk management

This research has not included or documented local knowledge and practices that could influence transboundary EWS. Through community-level interviews, efforts such as embankment strengthening and discussions on minimising flood damage were identified. Furthermore, local communities often rely on traditional knowledge of natural signs, such as river behaviour and rainfall patterns, to predict and respond to floods, including evacuation. This community-level knowledge and practices have the potential to influence transboundary EWS and offer valuable insights for enhancing flood risk management. Therefore, exploring these aspects further could be an area for future research.

Limits to generalisability of research

Another limitation of this research could be related to the uniqueness of the context, which may limit generalisability to other settings. The context of this research is unique, as Nepal and India have common cultures across the border, and the border is also open for the people across each country to pass without restrictions. Therefore, the contextual findings may not apply to wider settings; however, the research findings related to the governance of EWS, risk communication, and risk information generation in EWS, power dynamics between the two countries affecting the transboundary interactions, access to risk communication and risk perception based on gender and marginalisation, and the importance of knowledge co-production and participation in EWS could have more comprehensive application and generalisability. Despite that, every research setting is unique and must be approached with a clear understanding of contextual information.

9.6. Key implications of this thesis

This thesis emphasises understanding situated context and collaboratively working on available information to construct a bricolage of knowledge to solve problems (Ansell and Boin 2019; Clarke 1999; Dewey 1930). This study suggests approaching the risk communication in EWS as a 'meaning-making' process through participation and interaction

(Simpson 2009) and the risk information generation process as a ‘sense-making’ process (Weick et al. 2005) by involving – i) ‘perspective-taking’ (understanding perspectives of others); ii) ‘reflexivity’ (understanding one’s limitations); iii) ‘enactment’ (learning while doing); and iv) ‘abduction’ (creating reasoning backwards from the problem) (Ansell and Boin 2019; Boin et al. 2016; Martin 2007; Rorty 1979, 1989). This can also significantly aid in dealing with uncertainties in EWS (Elkjaer and Simpson 2011; Farjoun et al. 2015).

This thesis also fills gaps in literature related to the transboundary EWSs context between Nepal and India and provides theoretical contributions to understanding the constraining factors in EWS related to socio-cultural, institutional and governance barriers in EWS. It also reflects on how those constraints might be overcome. In doing so, this thesis has also shown the interrelationship of EWS with socio-cultural barriers, internal disaster governance mechanisms, and regional geopolitics in the study area.

This thesis has advanced the discourse of Kelman and Glantz (2014, p.89), suggesting that *“the fundamental tenet is that each EWS needs to be viewed as a social process”*. This research has also provided a better understanding of how women and the marginalised populations often miss out on awareness-raising activities and EWS due to socio-cultural barriers and gender inequalities. In addition, this study substantiated that women perceive risks differently than men, which translates into their lack of motivation for evacuation during disasters; therefore, special attention is required to include women and marginalised people in the EWS processes (Acharya and Prakash (2019); Brown et al. (2019); and Budimir et al. (2020); Meechaiya et al. (2019))

This thesis provides a better understanding of factors (cultural, institutional, and governance) that affect transboundary EWS and asserts that power dynamics between the two countries affect transboundary interactions and builds on Zeitoun et al. (2011) and Mirumachi (2015) that transboundary EWS must also include power dynamics, especially when dealing with powerful and weaker countries.

9.7. Recommendations

The pragmatic ideas were applied to the findings of this thesis to recommend on policy and practices, which are as follows:

— **Risk communication in EWS needs people's participation.**

Risk communication is more of a process of meaning creation rather than giving information about the hazard to the people at risk. Therefore, the people at risk must be involved in the risk communication process of transboundary EWS, and it needs bottom-up feedback mechanisms to create a shared understanding of hazard risk and actions that are required to follow.

— **Risk communication needs multiple channels, and the modes of risk communication should adapt to the capacity of intended recipients.**

The technologies used in transboundary EWS must fit the capacity and limitations of the intended recipients. Multiple parallel risk communication channels such as SMS, TV, Radio, and websites must be utilised along with traditional media such as sirens, alarms, or door-to-door communication, to ensure that access to warnings is not limited to the access to technologies by the target audiences.

— **Warnings need to be communicated directly from their original source to the people at risk without involving long institutional chains.**

The warnings disseminated directly from the original source to the target group will be more effective than the warning that cascades through complicated channels. It is recommended that warnings need to allow a reasonable window of time for people to respond and act to those warnings.

— **Warnings need to have standardised language for easy comprehension.**

For effective EWS, warnings need to be timely, concise, with context-specific language, precise about the location and time of expected impacts, uncertainties in the warnings, and clear instructions on the recommended actions after receiving those warnings.

— **Dealing with uncertainties in the warnings by communicating the uncertainties**

The uncertainties in the risk knowledge components can be better managed if it is communicated to the people at risk with reflexivity (understanding the scientific

limitations) and transparency (communicating uncertainties and limitations by involving people at risk), as suggested by Donovan and Oppenheimer (2014).

— **Risk information generation requires knowledge coproduction.**

The risk information generation process in the EWS is a “sense-making” process between the at-risk people, scientists, and stakeholders for a common understanding of the situated context of hazard risk. Therefore, the risk information generation in EWS must include knowledge co-production between people at risk, scientists, and stakeholders in a participatory process.

— **Institutional restructuring at the local level in line with policy updates**

The “scale discordance” (as suggested by Ogra et al. 2021) was observed between the policy and practice for EWS in the study area. Therefore, the local level capacity building and institutional restructuring are needed in line with the policy changes in Nepal and India for the effectiveness of EWS.

— **Awareness raising activities for breaking the myths.**

Awareness-raising activities related to the floods and their causes are required at the community level in Nepal and India to break the myths and facilitate transboundary collaboration.

— **Participation and representation are required in transboundary interactions.**

The study has found that the transboundary interaction between Nepal and India is centrally led and lacks local-level representation and participation of the people at risk. Those interactions are disconnected from contextual reality; therefore, bilateral interactions need the participation of local government representatives of both countries (district magistrates or municipal mayors) and the participation of the people at risk so that the decisions are informed of the local context and needs of the people at risk.

— **Lack of data-sharing can be solved by involvement of independent government research institutions.**

The securitisation of transboundary river data in India has constrained the transboundary collaboration between Nepal and India for the EWS. One of the ways to work around the securitisation policy could be by forming a neutral transboundary research group composed of national research institutions of Nepal and India (e.g., IIT and Tribhuvan university) to conduct basin-wide research on transboundary EWS in association with technical institutions (e.g., IMD, CWC, and DHM) and local NGOs, and people at risk.

— **Change in risk governance to flood risk management by providing space for river.**

The infrastructural interventions for flood risk management in the Kosi River basin need to shift towards more nature-based solutions. Adaptive measures, such as the “Room for River” interventions in the Netherlands and “Making Space for Rivers” in the UK and redistributing the Kosi River to its old paleochannels could be sustainable ways to live with the nature of the river, which requires further research.

— **Need to invest in foundational training on the understanding of transboundary EWS.**

The study suggests significantly less awareness at the community level among the people at risk and among the leaders and generators of the risk information in the government institutions responsible for disseminating warnings. A series of training programs should be launched specifically targeting different levels of audiences to improve the risk communication and risk information generation processes of EWS.

9.8. Suggested further research

Due to the limited scope of this research, out of four components of the EWSs (i.e., risk knowledge, monitoring and warning, dissemination and communication, and response capabilities), only two components of EWS (Risk Knowledge, and Dissemination and communication) components of EWS were researched in detail this study. Basher (2006) and Villagrán de Leon (2014) suggested that failure in any of the components of EWS can result in the system becoming defunct. Therefore, future research could be on risk monitoring and warning and response capacity components of the EWSs to have a more precise picture of EWS governance in the transboundary context between Nepal and India.

Similarly, due to the limited scope, this study has not explored the multi-hazard interactions in the Kosi River basin and how those hazard interactions contribute to creating impacts in the transboundary hazards and EWSs. Also, this thesis did not consider the implication of climate change in the Kosi River and their tributaries affecting the hazard intensity or occurrence in the downstream areas to the people at risk.

This study has identified some cultural barriers contributing to the lack of access to warnings and participation to the people at risk and difficulties faced by women during the evacuation, which translated to the evacuation decisions. The further studies could be on how to overcome or reduce the impacts of those cultural barriers to the vulnerable and marginalised people at risk. This would require detailed case studies and lived experiences of women and marginalised population living in evacuation camps to have better insights on the problems they faced and identifying the root causes to mitigate those problems.

There is an avenue for research on how caste, ethnicity, marginalisation, and power relations affect EWS in the transboundary context between Nepal and India. This study has found that women perceive risks differently, translating to their motivation and behaviours during disasters; similar results could also be valid for caste and ethnicity, which requires detailed investigation.

Another avenue for future research could be on the scaled-up of this research including all components of EWS in a basin-wide study between China, Nepal, and India. This study has revealed several factors that affect the transboundary EWS in the Kosi River basin between Nepal and India, which has an open border, shared culture and porosity and ease of access across the border. However, the findings could be different between the upstream and downstream countries, China, and Nepal, which has closed border, and significantly less information has been known about the hazards in the upper region of the Himalayas.

There is also avenue of research on how local and indigenous knowledge could complement the scientific understanding in the transboundary EWS. By combining local and indigenous knowledge, transboundary EWS can provide a more detailed understanding of risks and vulnerabilities in the local setting. This approach also ensures that the warnings are culturally appropriate and easier for affected communities to understand and act on. Knowledge

coproduction with local and indigenous communities in the transboundary EWS promotes a sense of ownership, further strengthening the system's effectiveness.

Future research could also be conducted on the study of nature-based solutions for flood risk management in the Kosi River basin. Future research is needed to apply the concepts such as “Making Space for Rivers” as in the UK or the “Room for Rivers” approach in the Netherlands in the Kosi River basin for sustainable flood risk management by spreading the river to old paleochannels rather than further constraining it with embankments.

9.9. Concluding remarks

This research suggests that an effective transboundary EWS needs an understanding of the situated context of people at risk. A thorough examination of cultural, institutional, governance, and geopolitical factors must be done to understand their compounding effects on the vulnerability of people at risk. The flooding and meandering are the nature of the Kosi River and are inevitable in the Kosi River basin; however, with transboundary EWS, that involves contextually informed intervention and knowledge co-production—the lives and livelihoods of most people living in the flood plains (especially vulnerable and marginalised ones) could be saved. The suggested further research was on understanding the transboundary EWS in the Kosi River basin on risk monitoring and disaster response components of EWS, as well as on hazard interaction in the Kosi River basin, cultural dynamics, inclusion of local knowledge in transboundary EWS, and scaling up of this research on basin-wide study. Furthermore, future research on alternative ways of flood risk management in the Kosi River basin was also suggested.

References

- Acharya, A. and Poddar, P., 2016. The river itself warns us: Local knowledge of flood forecasting in the Gandaki River Basin, West Champaran, India.
- Acharya, A. and Prakash, A., 2019. When the river talks to its people: Local knowledge-based flood forecasting in Gandak River basin, India. *Environmental Development*, 31, pp.55-67.
- Acharya, S. and Hori, T., 2019. Revisiting flood management process in Transboundary Koshi River in Nepal and India. *Disaster Prevention Research Institute Annuals. B*, 62(B), pp.640-649.
- Acharya, T.D., Mainali, S.C., Yang, I.T. and Lee, D.H., 2016. Analysis of Jure landslide dam, Sindhupalchowk using GIS and remote sensing. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 41, p.201.
- Adams, W.C., 2015. Conducting semi-structured interviews. *Handbook of practical program evaluation*, pp.492-505.
- Adhikari, J., 2019. Devastating Himalayan Floods are Made Worse by International Blame Game. *The Conversation*, <https://theconversation.com/devastating-himalayan-floods-are-made-worse-by-an-international-blame-game-83103>.
- Adhikari, K.P. and Goldey, P., 2010. Social capital and its “downside”: the impact on sustainability of induced community-based organisations in Nepal. *World Development*, 38(2), pp.184-194.
- Agarwal, A. and Narain, S., 1996. *Floods, Floodplains and Environmental Myths. State of India's Environment: A Citizen Report*, Centre for Science and Environment, New Delhi.
- Agrawal, A., 1995. Dismantling the divide between indigenous and scientific knowledge. *Development and change*, 26(3), pp.413-439.
- Ali, S.H. and Zia, A., 2017. Transboundary Data Sharing and Resilience Scenarios: Harnessing the Role of Regional Organisations for Environmental Security. In *Imagining Hindustan* (pp. 121-139). Springer, Cham.

- Allan, T., 2012. The Middle East water question: Hydropolitics and the global economy. Bloomsbury Publishing.
- Alli, P.S. and Bhatt, B.V., 2013. Dynamics of river, impact, and assessment: case Study of Kosi River. *Nat. Hazards Earth Syst. Sci*, 13, pp.795-808.
- Amaratunga, D., Baldry, D., Sarshar, M. and Newton, R., 2002. Quantitative and qualitative research in the built environment: application of “mixed” research approach. Work study.
- Amaratunga, D., Haigh, R., Premalal, S., Siriwardana, C. and Liyanaarachchige, C., 2020. Report on exercise Indian ocean wave 2020: an Indian ocean-wide tsunami warning and communications exercise.
- Amaratunga, D., Malalgoda, C., Haigh, R., Panda, A. and Rahayu, H., 2018. Sound practices of disaster risk reduction at local level. *Procedia engineering*, 212, pp.1163-1170.
- Anderson, W.A., 1969. Disaster warning and communication processes in two communities. *Journal of Communication*, 19(2), pp.92-104.
- Ansell, C. and Boin, A., 2019. Taming deep uncertainty: The potential of pragmatist principles for understanding and improving strategic crisis management. *Administration & Society*, 51(7), pp.1079-1112.
- Ansell, C., Boin, A. and Keller, A., 2010. Managing transboundary crises: Identifying the building blocks of an effective response system. *Journal of Contingencies and Crisis Management*, 18(4), pp.195-207.
- Armitage, D., de Loe, R.C., Morris, M., Edwards, T.W., Gerlak, A.K., Hall, R.I., Huitema, D., Ison, R., Livingstone, D., MacDonald, G. and Mirumachi, N., 2015. Science–policy processes for transboundary water governance. *Ambio*, 44(5), pp.353-366.
- Armitage, D., Marschke, M. and Plummer, R., 2008. Adaptive co-management and the paradox of learning. *Global environmental change*, 18(1), pp.86-98.
- Arnott, J.C. and Lemos, M.C., 2021. Understanding knowledge use for sustainability. *Environmental Science & Policy*, 120, pp.222-230.
- Arvai, J. and Rivers, L. eds., 2014. Effective risk communication (p. 3). London, UK: Routledge.

- Audia, C., Berkhout, F., Owusu, G., Quayyum, Z. and Agyei-Mensah, S., 2021. Loops and building blocks: a knowledge co-production framework for equitable urban health. *Journal of Urban Health*, 98(3), pp.394-403.
- Avouac, J.P., Meng, L., Wei, S., Wang, T. and Ampuero, J.P., 2015. Lower edge of locked Main Himalayan Thrust unzipped by the 2015 Gorkha earthquake. *Nature Geoscience*, 8(9), pp.708-711.
- Bagale, D.R., 2020. Nepal–India water cooperation: consequences of mutuality or hegemony? *Water Policy*, 22(6), pp.1098-1108.
- Baghel, R., 2014. Governmentality of River Embankment. In *River Control in India* (pp. 93-120). Springer, Cham.
- Baird, A., 1975. Towards an explanation and reduction of disaster proneness. University of Bradford.
- Bajracharya, S.R. and Mool, P., 2009. Glaciers, glacial lakes and glacial lake outburst floods in the Mount Everest region, Nepal. *Annals of Glaciology*, 50(53), pp.81-86.
- Bajracharya, S.R., Khanal, N.R., Nepal, P., Rai, S.K., Ghimire, P.K. and Pradhan, N.S., 2021. Community assessment of flood risks and early warning system in ratu watershed, Koshi basin, Nepal. *Sustainability*, 13(6), p.3577.
- Bakker, M.H., 2009. Transboundary river floods and institutional capacity 1. *JAWRA Journal of the American Water Resources Association*, 45(3), pp.553-566.
- Balibar, E., 2015. *From Extreme Violence to the Problem of Civility: A Selection from Violence and Civility: On the Limits of Political Philosophy*. Columbia University Press.
- Bandyopadhyay, J., 2016. New institutional structure for water security in India. *Economic and Political Weekly*, pp.15-17.
- Barua, A., Vij, S. and Zulfiqur Rahman, M., 2018. Powering or sharing water in the Brahmaputra River basin. *International Journal of Water Resources Development*, 34(5), pp.829-843.

- Basher, R., 2006. Global early warning systems for natural hazards: systematic and people centred. *Philosophical transactions of the royal society a: mathematical, physical, and engineering sciences*, 364(1845), pp.2167-2182.
- Basu, J., 2022. Dynamics of Transboundary River Conflicts vis-à-vis Nature Based Negotiated Approach (NBNA) Solution: Case Study River Teesta. In *Riverine Systems* (pp. 291-305). Springer, Cham.
- Bauer, H. and Brighi, E., 2009. Introducing pragmatism to international relations. In *Pragmatism in international relations* (pp. 17-24). Routledge.
- Bazeley, P. and Jackson, K., 2007. *Qualitative analysis with NVivo*. London, UK: Sage Publications.
- Chiesa, V., & Frattini, F.(2011). Commercializing technological innovation: Learning from failures in high-tech markets. *Journal of Product Innovation Management*, 28(4), pp.437-454.
- Beck, B.E., 1969. Colour and heat in South Indian ritual. *Man*, pp.553-572.
- Beck, U., 1992. *Risk society: Towards a New Modernity*, London: Sage.
- Beck, U., 1996. World risk society as cosmopolitan society? Ecological questions in a framework of manufactured uncertainties. *Theory, culture & society*, 13(4), pp.1-32.
- Beck, U., Giddens, A. and Lash, S., 1994. *Reflexive modernisation: Politics, tradition, and aesthetics in the modern social order*. Stanford University Press.
- Beckert, J., 2003. Economic sociology and embeddedness: how shall we conceptualize economic action. *Journal of economic issues*, 37(3), pp.769-787.
- Belcher, O., Martin, L. and Tazzioli, M., 2015. Editorial: Border struggles: Epistemologies, ontologies, and politics. *Darkmatter: In the Ruins of Imperial Culture*, 12(4), pp.1-7.
- Bell, H.M., and Tobin, G.A., 2007. Efficient and effective? The 100-year flood in the communication and perception of flood risk. *Environmental Hazards*, 7(4), pp.302-311.
- Bhandari, D., Neupane, S., Hayes, P., Regmi, B. and Marker, P., 2020. *Disaster risk reduction and management in Nepal: Delineation of roles and responsibilities*. Kathmandu: Oxford Policy Management.

- Bharati, L., Bhattarai, U., Khadka, A., Gurung, P., Neumann, L.E., Penton, D.J., Dhaubanjari, S. and Nepal, S., 2019. From the mountains to the plains: impact of climate change on water resources in the Koshi River Basin (Vol. 187). International Water Management Institute (IWMI).
- Bharati, L., Gurung, P., Maharjan, L. and Bhattarai, U., 2016. Past and future variability in the hydrological regime of the Koshi Basin, Nepal. *Hydrological Sciences Journal*, 61(1), pp.79-93.
- Bhattarai, D., 2009. Multi-purpose projects. In *The Nepal–India Water Relationship: Challenges* (pp. 69-98). Springer, Dordrecht.
- Bickerstaff, K., 2004. Risk perception research: socio-cultural perspectives on the public experience of air pollution. *Environment international*, 30(6), pp.827-840.
- Bilham, R., 1995. Location and magnitude of the 1833 Nepal earthquake and its relation to the rupture zones of contiguous great Himalayan earthquakes. *Current Science*, 69(2), pp.101-128.
- Bilham, R., Bodin, P. and Jackson, M., 1995. Entertaining a great earthquake in Western Nepal: historic inactivity and geodetic test for the development of strain. *Journal of Nepal Geological Society*, 11, pp.73-88.
- Biswas, A.K., 2011. Cooperation or conflict in transboundary water management: case study of South Asia. *Hydrological Sciences Journal*, 56(4), pp.662-670.
- Bobbette, A. and Donovan, A., 2019. Political geology: An introduction. In *Political Geology* (pp. 1-34). Palgrave Macmillan, Cham.
- Boholm, A. and Corvellec, H., 2011. A relational theory of risk. *Journal of risk research*, 14(2), pp.175-190.
- Boholm, A., 1998. Comparative studies of risk perception: a review of twenty years of research. *Journal of risk research*, 1(2), pp.135-163.
- Boholm, Å., 2008. New perspectives on risk communication: uncertainty in a complex society. *Journal of risk research*, 11(1-2), pp.1-3.

- Boin, A., Stern, E. and Sundelius, B., 2016. The politics of crisis management: Public leadership under pressure. Cambridge University Press.
- Boisvert, R.D., 1998. John Dewey: rethinking our time. SUNY Press.
- Botterill, L. and Mazur, N., 2004. Risk and risk perception: A literature review. Kingstrom, ACT: Australian Government Rural Industries Research and Development Corporation.
- Boyce, J.K., 1990. Birth of a megaproject: political economy of flood control in Bangladesh. *Environmental Management*, 14(4), pp.419-428.
- Bradbury, J.A., 1989. The policy implications of differing concepts of risk. *Science, Technology, & Human Values*, 14(4), pp.380-399.
- Brambilla, C. and Jones, R., 2020. Rethinking borders, violence, and conflict: From sovereign power to borderscapes as sites of struggles. *Environment and Planning D: Society and Space*, 38(2), pp.287-305.
- Bremer, S. and Meisch, S., 2017. Co-production in climate change research: reviewing different perspectives. *Wiley Interdisciplinary Reviews: Climate Change*, 8(6), p.e482.
- Bréthaut, C. and Pflieger, G., 2015. The shifting territorialities of the Rhone River's transboundary governance: a historical analysis of the evolution of the functions, uses and spatiality of river basin governance. *Regional Environmental Change*, 15, pp.549-558.
- Brewer, J., 2000. *Ethnography*. McGraw-Hill Education (UK).
- Bromley, D.W., 2008. Volitional pragmatism. *Ecological Economics*, 68(1-2), pp.1-13.
- Brown, S., Budimir, M., Lovell, E., Wilkinson, E. and Meechaiya, C., 2019. The governance of Nepal's flood early warning system: opportunities under federalism.
- Brown, S., Budimir, M., Sneddon, A., Lau, D., Shakya, P., Upadhyay, S. 2019. Gender transformative early warning systems: experiences from Nepal and Peru, Practical Action, Rugby, UK.
- Budimir, M., Donovan, A., Brown, S., Shakya, P., Gautam, D., Uprety, M., Cranston, M., Sneddon, A., Smith, P. and Dugar, S., 2020. Communicating complex forecasts: an analysis of

the approach in Nepal's flood early warning system. *Geoscience Communication*, 3(1), pp.49-70.

Burele, S.A., Sharma, N. and Gupta, Z.A.I., 2015, December. Mathematical model to study channelisation by lowering the riverbed through excavation. In *Proceedings of HYDRO 2015 International Conference* (pp. 17-19).

Burns, D. and Heywood, F., 2004. *Making community participation meaningful: a handbook for development and assessment*. Policy Press.

Callon, M., 1999. The role of lay people in the production and dissemination of scientific knowledge. *Science, Technology and Society*, 4(1), pp.81-94.

Cannon, T., 1994. Vulnerability analysis and the explanation of 'natural' disasters. *Disasters, development, and environment*, 1, pp.13-30.

Cannon, T., 2002. Gender and climate hazards in Bangladesh. *Gender & Development*, 10(2), pp.45-50.

Carter, S., Steynor, A., Vincent, K., Visman, E., and Waagsaether, K., 2020. *Co-production of African weather and climate services*, Second edition.

Chakraborty, T., Kar, R., Ghosh, P. and Basu, S., 2010. Kosi mega fan: Historical records, geomorphology, and the recent avulsion of the Kosi River. *Quaternary International*, 227(2), pp.143-160.

Chambers, J.M., Wyborn, C., Ryan, M.E., Reid, R.S., Riechers, M., Serban, A., Bennett, N.J., Cvitanovic, C., Fernández-Giménez, M.E., Galvin, K.A. and Goldstein, B.E., 2021. Six modes of co-production for sustainability. *Nature Sustainability*, 4(11), pp.983-996.

Chambers, R., 1983 *Rural development: Putting the last first*. Oxford: Routledge.

Chen, N.S., Hu, G.S., Deng, W., Khanal, N., Zhu, Y.H. and Han, D., 2013. On the water hazards in the trans-boundary Kosi River basin. *Natural Hazards and Earth System Sciences*, 13(3), pp.795-808.

Chenoweth, J.L. and Feitelson, E., 2001. Analysis of factors influencing data and information exchange in international river basins: can such exchanges be used to build confidence in cooperative management?. *Water international*, 26(4), pp.499-512.

- Chintan, G.S., 2012. Trans-boundary river basins in south Asia: Options for conflict resolution (No. id: 4953).
- Choudhury, E., 2021. Negotiated resolution of transboundary water disputes: A function of facts, frames and fairness. In *Water Conflicts and Resistance* (pp. 25-55). Routledge India.
- Cianfarani, M., 2012. Integrating diversity into disaster risk reduction (DRR): A literature review. *International Association of Emergency Managers Bulletin*, 29, pp.26-27.
- Clark, W.C., Van Kerkhoff, L., Lebel, L. and Gallopin, G.C., 2016. Crafting usable knowledge for sustainable development. *Proceedings of the National Academy of Sciences*, 113(17), pp.4570-4578.
- Clarke, L., 1999. *Mission improbable: Using fantasy documents to tame disaster*. University of Chicago Press.
- Cleaver, F., Boelens, R. and Swatuk, L., 2016. Reductionist and integrative research approaches to complex water security policy challenges. *Global Environmental Change*, 39, pp.143-154.
- Clegg, G., Haigh, R., Amaratunga, D. and Rahayu, H., 2021. Transboundary River Governance Practices for Flood Risk Reduction in Europe: A Review. *Multi-Hazard Early Warning and Disaster Risks*, pp.291-302.
- Clifford, N., Cope, M., Gillespie, T. and French, S. eds., 2016. *Key methods in geography*. Sage.
- Conway, D. and Vincent, K., 2021. *Climate risk in Africa: adaptation and resilience* (p. 168). Springer Nature.
- Cosens, B., 2010. Transboundary river governance in the face of uncertainty: resilience theory and the Columbia River Treaty. *J. Land Resources & Envtl. L.*, 30, p.229.
- Covarrubias, M., 2019. The nexus between water, energy, and food in cities: towards conceptualizing socio-material interconnections. *Sustainability Science*, 14(2), pp.277-287.
- Covello, V. and Sandman, P.M., 2001. Risk communication: evolution and revolution. *Solutions to an Environment in Peril*, 164, p.178.

- Covello, V.T., 1983. The perception of technological risks: A literature review. *Technological forecasting and social change*, 23(4), pp.285-297.
- Cramer, L., Förch, W., Mutie, I. and Thornton, P.K., 2016. Connecting women, connecting men: how communities and organisations interact to strengthen adaptive capacity and food security in the face of climate change. *Gender, Technology and Development*, 20(2), pp.169-199.
- Creswell, J.W. and Clark, V.L.P., 2011. *Designing and conducting mixed methods research*. Sage publications.
- Creswell, J.W. and Creswell, J.D., 2017. *Research design: Qualitative, quantitative, and mixed methods approach*. Sage publications.
- Creswell, J.W., 2009. Mapping the field of mixed methods research. *Journal of mixed methods research*, 3(2), pp.95-108.
- Créton-Cazanave, L., 2014. Understanding the Warning Process Through the Lens of Practice: Emancipation as a Condition of Action—Some Lessons from France. In *Reducing Disaster: Early Warning Systems for Climate Change* (pp. 223-248). Springer, Dordrecht.
- Daly, M. and Dilling, L., 2019. The politics of “usable” knowledge: examining the development of climate services in Tanzania. *Climatic Change*, 157(1), pp.61-80.
- Das, P., 2012. Disaster management in India: policy review and institutional structure. *Asiapac Journal of Socical Sciences*, 4, pp.37-52.
- Davies, T., Beaven, S., Conradson, D., Densmore, A., Gaillard, J.C., Johnston, D., Milledge, D., Oven, K., Petley, D., Rigg, J. and Robinson, T., 2015. Towards disaster resilience: A scenario-based approach to co-producing and integrating hazard and risk knowledge. *International journal of disaster risk reduction*, 13, pp.242-247.
- Davis, I., Haghebeart, B. and Peppiatt, D., 2004. *Social vulnerability and capacity analysis*. Geneva: Provention Consortium.
- Dazé, A. and Dekens, J., 2017. A framework for gender-responsive National Adaptation Plan (NAP) processes. NAP Global Network. At [https://www. weadapt. org/sites/weadapt](https://www.weadapt.org/sites/weadapt).

- org/files/2017/august/napgn-en-2017-gender-considerations-adaptation-planning1. pdf [Accessed on 13 December 2018] .
- De Stefano, L., Duncan, J., Dinar, S., Stahl, K., Strzepek, K.M. and Wolf, A.T., 2012. Climate change and the institutional resilience of international river basins. *Journal of Peace Research*, 49(1), pp.193-209.
- Demeritt, D. and Nobert, S., 2011. Responding to early flood warnings in the European Union. In *Forecasting, warning, and responding to transnational risks* (pp. 127-147). Palgrave Macmillan, London.
- Demeritt, D. and Nobert, S., 2014. Models of best practice in flood risk communication and management. *Environmental Hazards*, 13(4), pp.313-328.
- Demeritt, D., Cloke, H., Pappenberger, F., Thielen, J., Bartholmes, J. and Ramos, M.H., 2007. Ensemble predictions and perceptions of risk, uncertainty, and error in flood forecasting. *Environmental Hazards*, 7(2), pp.115-127.
- Devkota, K.C., Regmi, A.D., Pourghasemi, H.R., Yoshida, K., Pradhan, B., Ryu, I.C., Dhital, M.R. and Althuwaynee, O.F., 2013. Landslide susceptibility mapping using certainty factor, index of entropy and logistic regression models in GIS and their comparison at Mugling–Narayanghat road section in Nepal Himalaya. *Natural hazards*, 65(1), pp.135-165.
- Devkota, L., Crosato, A. and Giri, S., 2012. Effect of the barrage and embankments on flooding and channel avulsion case study Koshi River, Nepal. *Rural Infrastructure* 3 (3), 124-132. (2012).
- Devkota, L., Giri, S., Crosato, A. and Baral, B., 2018, March. Impact of the Koshi barrage and embankments on river morphology and dynamics. In *Seventh International Conference and Exhibition on Water Resource and Renewable Energy Development in Asia* (pp. 13-15).
- Dewals, B. and Fournier, M. eds., 2013. *Transboundary water management in a changing climate*. CRC Press.
- Dewey, J., 1896. The reflex arc concept in psychology. *Psychological review*, 3(4), p.357.
- Dewey, J., 1930. The quest for certainty: A study of the relation of knowledge and action. *The Journal of Philosophy*, 27(1), pp.14-25.

- Dhungel, D.N. and Pun, S.B., 2008. Impact of the Interlinking of Rivers on Nepal: A Critical Analysis. *Interlinking of Rivers in India: Issues and Concerns*, p.91.
- Dieleman, S., 2017. Pragmatist tools for public administration. *Administration & Society*, 49(2), pp.275-295.
- Dixit, A., 2009. Kosi embankment breach in Nepal: Need for a paradigm shift in responding to floods. *Economic and political weekly*, pp.70-78.
- Dixit, A., Shukla, A., Wajih, S.A. and Singh, B., 2022. Transcending boundaries for sustainability in the Koshi Basin: Contestations and cooperation. In *Water Conflicts and Resistance* (pp. 102-128). Routledge India.
- Dixit, K., 2020, The ill-conceived push for a high dam to curb Kosi flooding is a litmus test for democracy in India, available at: <https://scroll.in/article/976756/the-ill-conceived-push-for-a-high-dam-to-curb-kosi-flooding-is-a-litmus-test-for-democracy-in-india>, accessed on 16/8/2021
- Dominey-Howes, D., Gorman-Murray, A. and McKinnon, S., 2014. Queering disasters: On the need to account for LGBTI experiences in natural disaster contexts. *Gender, Place & Culture*, 21(7), pp.905-918.
- Donovan, A. and Oppenheimer, C., 2014. Science, policy, and place in volcanic disasters: insights from Montserrat. *Environmental Science & Policy*, 39, pp.150-161.
- Donovan, A. and Oppenheimer, C., 2016. Imagining the unimaginable: communicating extreme volcanic risk. In *Observing the Volcano World* (pp. 149-163). Springer, Cham.
- Donovan, A., 2017. Geopower: Reflections on the critical geography of disasters. *Progress in Human Geography*, 41(1), pp.44-67.
- Donovan, A., 2020. When the vertical becomes horizontal: experiencing exploding mountains in borderlands. *Annals of the American Association of Geographers*, 110(4), pp.1040-1058.
- Donovan, A., Eiser, J.R. and Sparks, R.S.J., 2014. Scientists' views about lay perceptions of volcanic hazard and risk. *Journal of Applied Volcanology*, 3(1), p.15.

- Donovan, A.R., Borie, M.A.H. and Blackburn, S.E., 2019. Changing the paradigm for risk communication: integrating sciences to understand cultures. In *Global Assessment Report on Disaster Risk Reduction (GAR 2019)*. United Nations Office for Disaster Risk Reduction (UNDRR).
- Douglas, M. and Wildavsky, A., 1983. *Risk and culture: An essay on the selection of technological and environmental dangers*. Univ of California Press.
- Douglas, M., 1986. *Risk Acceptability According to the Social Sciences*.
- Douglas, M., 1992. *Risk and Blame: Essays in Cultural Theory*. Routledge.
- Douglas, M., 1996. *Thought styles: critical essays on good taste*. Sage.
- Dutta, V. ed., 2022. *Water Conflicts and Resistance: Issues and Challenges in South Asia*.
- Duvall, M.J., Waldron, J.W., Godin, L. and Najman, Y., 2020. Active strike-slip faults and an outer frontal thrust in the Himalayan foreland basin. *Proceedings of the National Academy of Sciences*, 117(30), pp.17615-17621.
- Duymedjian, R. and Rüling, C.C., 2010. Towards a foundation of bricolage in organisation and management theory. *Organisation Studies*, 31(2), pp.133-151.
- Earle, A. and Neal, M.J., 2017. Inclusive transboundary water governance. *Freshwater governance for the 21st century*, pp.145-158.
- Earle, A. and Wouters, P., 2015. Implementing transboundary water cooperation through effective institutional mechanisms: exploring the legal and institutional design dimensions of selected African joint water institutions—creating lessons for global problems. *Journal of Water Law*, 24, pp.100-114.
- Earle, A. and Wouters, P., 2015. Implementing Transboundary Water Cooperation Through Effective Institutional Mechanisms. *Journal of Water Law*, volume 24.
- Earle, A. ed., 2013. *Transboundary water management: Principles and practice*. Earthscan.
- Eisenman, D.P., Cordasco, K.M., Asch, S., Golden, J.F. and Glik, D., 2007. Disaster planning and risk communication with vulnerable communities: lessons from Hurricane Katrina. *American journal of public health*, 97(Supplement_1), pp.S109-S115.

- Eiser, J.R., Bostrom, A., Burton, I., Johnston, D.M., McClure, J., Paton, D., Van Der Pligt, J. and White, M.P., 2012. Risk interpretation and action: A conceptual framework for responses to natural hazards. *International journal of disaster risk reduction*, 1, pp.5-16.
- Elkjaer, B. and Simpson, B., 2011. Pragmatism: A lived and living philosophy. What can it offer to contemporary organisation theory? In *Philosophy and organisation theory*. Emerald Group Publishing Limited.
- Etinay, N., Egbu, C. and Murray, V., 2018. Building urban resilience for disaster risk management and disaster risk reduction. *Procedia Engineering*, 212, pp.575-582.
- Evans, K.G., 2000. Reclaiming John Dewey: Democracy, inquiry, pragmatism, and public management. *Administration & Society*, 32(3), pp.308-328.
- Ewald, F., 1991. Insurance and risk. *The Foucault effect: Studies in governmentality*, pp.197-210.
- Fang, Y.P., Zhu, R., Zhang, C.J., Rasul, G. and Neupane, N., 2020. Cascading adaptation of rural livelihood to changing environment: Conceptual framework and experiment from the Koshi River basin. *Advances in Climate Change Research*, 11(2), pp.141-157.
- Farjoun, M., Ansell, C. and Boin, A., 2015. PERSPECTIVE—Pragmatism in organisation studies: Meeting the challenges of a dynamic and complex world. *Organisation Science*, 26(6), pp.1787-1804.
- Festenstein, M., 2002. Pragmatism's boundaries. *Millennium*, 31(3), pp.549-571.
- Filipe, A., Renedo, A. and Marston, C., 2017. The co-production of what? Knowledge, values, and social relations in health care. *PLoS biology*, 15(5), p.e2001403.
- Finlay, C.C. and Hearn Morrow, B., 1998. The gendered terrain of disaster: Through women's eyes. In *The gendered terrain of disaster: Through women's eyes* (pp. 143-9). International Hurricane Center. Laboratory for Social and Behavioral Research.
- Fischer, F., 2003. *Reframing public policy: Discursive politics and deliberative practices*. Oxford University Press.
- Fischhoff, B., Bostrom, A. and Quadrel, M.J., 1993. Risk perception and communication. *Annual review of public health*, 14(1), pp.183-203.

- Fischhoff, B., Watson, S.R. and Hope, C., 1984. Defining risk. *Policy sciences*, 17(2), pp.123-139.
- Flint, C., 2021. *Introduction to geopolitics*. Routledge.
- Flügel, W.A., Nepal, S. and Shrestha, A.B., 2018. Framework for Upstream-Downstream Linkages of Land and Water Management in the Hindu Kush Himalaya (HKH) Region. HI-AWARE Working Paper, 15, p.2018.
- Foster, H.D., 1980. *Disaster planning: the preservation of life and property* Springer. New York.
- Foucault, M., 1991. *The Foucault effect: Studies in governmentality*. University of Chicago Press.
- Frankel-Pratt, S., 2016. Pragmatism as ontology, not (just) epistemology: Exploring the full horizon of pragmatism as an approach to IR theory. *International Studies Review*, 18(3), pp.508-527.
- Frantzeskaki, N. and Rok, A., 2018. Co-producing urban sustainability transitions knowledge with community, policy and science. *Environmental Innovation and Societal Transitions*, 29, pp.47-51.
- Fundel, V.J., Fleischhut, N., Herzog, S.M., Göber, M. and Hagedorn, R., 2019. Promoting the use of probabilistic weather forecasts through a dialogue between scientists, developers and end-users. *Quarterly Journal of the Royal Meteorological Society*, 145, pp.210-231.
- Gade, R., 2020. Shifting gender priorities in transboundary communities of India and Nepal in the context of disasters. *Loyola Journal of Social Sciences*, 34(2).
- Gade, R., Gyawali, N., and Sharafudeen, M.I., 2020. Transboundary disaster governance between India and Nepal-A perspective study on Kosi basin about risk governance dealing policies and communities. *Disaster Advances*, 13 (4), pp.32-39.
- Gaillard, J.C. and Mercer, J., 2013. From knowledge to action: Bridging gaps in disaster risk reduction. *Progress in human geography*, 37(1), pp.93-114.

- Gaillard, J.C., 2010. Vulnerability, capacity and resilience: Perspectives for climate and development policy. *Journal of International Development: The Journal of the Development Studies Association*, 22(2), pp.218-232.
- Garcia, C. and Fearnley, C.J., 2012. Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards*, 11(2), pp.123-137.
- Gentle, P. and Maraseni, T.N., 2012. Climate change, poverty, and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental science & policy*, 21, pp.24-34.
- Georgaka, D., Mparmparousi, M. and Vitos, M., 2012. Early warning systems. *Hospital Chronicles*, 7(1 Sup), pp.37-43.
- George, A.M. and Kwansah-Aidoo, K. eds., 2017. *Culture and crisis communication: transboundary cases from non-western perspectives*. John Wiley & Sons.
- Giddens, A., 1985. *The nation-state and violence* (Vol. 2). Univ of California Press.
- Gill, J.C. and Malamud, B.D., 2016. Hazard interactions and interaction networks (cascades) within multi-hazard methodologies. *Earth System Dynamics*, 7(3), pp.659-679.
- Gladfelter, S., 2018. The politics of participation in community-based early warning systems: building resilience or precarity through local roles in disseminating disaster information? *International journal of disaster risk reduction*, 30, pp.120-131.
- Glantz, M.H., 2004, February. Usable science 8: early warning systems: do's and don'ts. In Workshop report). Diane Publishing Company.
- Goldkuhl, G., 2012. Pragmatism vs interpretivism in qualitative information systems research. *European journal of information systems*, 21(2), pp.135-146.
- Gole, C.V. and Chitale, S.V., 1966. Inland delta building activity of Kosi River. *Journal of the Hydraulics Division*, 92(2), pp.111-126.
- Goles, T. and Hirschheim, R., 2000. The paradigm is dead, the paradigm is dead... long live the paradigm: the legacy of Burrell and Morgan. *Omega*, 28(3), pp.249-268.

- Gordon, E., Dilling, L., McNie, E., Ray, A.J., Parris, A.S., Garfin, G.M., Dow, K., Meyer, R. and Close, S.L., 2016. Navigating scales of knowledge and decision-making in the Intermountain West: implications for science policy. *Climate in Context: Science and Society Partnering for Adaptation*, John Wiley & Sons, Ltd, Chichester, UK, pp.235-254.
- Goyal, N., 2019. Disaster governance and community resilience: The law and the role of SDMAAs. *International Journal of Disaster Risk Management*, 1(2), pp.61-75.
- Grasso, V.F. and Singh, A., 2011. Early warning systems: State-of-art analysis and future directions. Draft report, UNEP, 1.
- Gupta, A.K., 2018. Disaster governance and legal systems in India. In *Disaster Risk Governance in India and Cross Cutting Issues* (pp. 39-60). Springer, Singapore.
- Gupta, N., Dahal, S., Kumar, A., Kumar, C., Kumar, M., Maharjan, A., Mishra, D., Mohanty, A., Navaraj, A., Pandey, S. and Prakash, A., 2021. Rich water, poor people: Potential for transboundary flood management between Nepal and India. *Current Research in Environmental Sustainability*, 3, p.100031.
- Gustafsd, P.E., 1998. Gender Differences in risk perception: Theoretical and methodological perspectives. *Risk analysis*, 18(6), pp.805-811.
- Hagemeier-Klose, M. and Wagner, K.J.N.H., 2009. Evaluation of flood hazard maps in print and web mapping services as information tools in flood risk communication. *Natural hazards and earth system sciences*, 9(2), pp.563-574.
- Hall, T.E. and Slothower, M., 2009. Cognitive factors affecting homeowners' reactions to defensible space in the Oregon Coast Range. *Society and Natural Resources*, 22(2), pp.95-110.
- Halpern-Felsher, B.L., Millstein, S.G., Ellen, J.M., Adler, N.E., Tschann, J.M. and Biehl, M., 2001. The role of behavioral experience in judging risks. *Health Psychology*, 20(2), p.120.
- Hamza, M. and Mansson, P., 2019. The human dimension of early warning—a viewpoint. *International journal of disaster resilience in the built environment*.
- Hanasz, P., 2017. Transboundary water governance and international actors in South Asia: the Ganges-Brahmaputra-Meghna Basin. Routledge.

- Handapangoda, W.S. and Kumara, A.S., 2013. The world at her fingertips?: Examining the empowerment potential of mobile phones among poor housewives in Sri Lanka. *Gender, Technology and Development*, 17(3), pp.361-385.
- Handl, G., Zekoll, J. and Zumbansen, P. eds., 2012. *Beyond territoriality: transnational legal authority in an age of globalisation*. Martinus Nijhoff Publishers.
- Haque, C.E. and Blair, D., 1992. Vulnerability to tropical cyclones: evidence from the April 1991 cyclone in coastal Bangladesh. *Disasters*, 16(3), pp.217-229.
- Heijmans, A., 2001. 'Vulnerability': A Matter of Perception.
- Heimer, C.A., 1988. Social structure, psychology, and the estimation of risk. *Annual review of sociology*, pp.491-519.
- Heitz, C., Spaeter, S., Auzet, A.V. and Glatron, S., 2009. Local stakeholders' perception of muddy flood risk and implications for management approaches: A case study in Alsace (France). *Land Use Policy*, 26(2), pp.443-451.
- Hennink, M.M., 2013. *Focus group discussions*. Oxford University Press.
- Hewitt, K., 2014. *Regions of risk: A geographical introduction to disasters*. Routledge.
- Hilal, A.H. and Alabri, S.S., 2013. Using NVivo for data analysis in qualitative research. *International interdisciplinary journal of education*, 2(2), pp.181-186.
- Ho, S., 2016. 'Big brother, little brothers': comparing China's and India's Transboundary River Policies. *Water Policy*, 18(S1), pp.32-49.
- Hofstede, G., 1980. Culture and organisations. *International Studies of Management & Organisation*, 10(4), pp.15-41.
- Houlton, J., 1949. *Bihar, the heart of India*. Orient Longman, Bombay.
- Hu, J., Yao, X., Duan, H., Zhang, Y., Wang, Y. and Wu, T., 2022. Temporal and Spatial Changes and GLOF Susceptibility Assessment of Glacial Lakes in Nepal from 2000 to 2020. *Remote Sensing*, 14(19), p.5034.
- Hufschmidt, G., 2011. A comparative analysis of several vulnerability concepts. *Natural hazards*, 58(2), pp.621-643.

- Imperiale, A.J. and Vanclay, F., 2019. Command-and-control, emergency powers, and the failure to observe United Nations disaster management principles following the 2009 L'Aquila earthquake. *International journal of disaster risk reduction*, 36, p.101099.
- Imperiale, A.J. and Vanclay, F., 2019. Command-and-control, emergency powers, and the failure to observe United Nations disaster management principles following the 2009 L'Aquila earthquake. *International journal of disaster risk reduction*, 36, p.101099.
- Imperiale, A.J. and Vanclay, F., 2020. The mechanism of disaster capitalism and the failure to build community resilience in post-disaster situations: Learning from the L'Aquila earthquake. *Disasters*, pp.1-26.
- Imperiale, A.J. and Vanclay, F., 2021. Conceptualizing community resilience and the social dimensions of risk to overcome barriers to disaster risk reduction and sustainable development. *Sustainable Development*.
- Islam, S. and Choudhury, E., 2018. Complexity and contingency: Understanding transboundary water issues. *Complexity of transboundary water conflicts: Enabling conditions for negotiating contingent resolutions*, pp.3-25.
- Islam, S. and Susskind, L., 2013. *Water diplomacy: A negotiated approach to managing complex water networks*. Routledge.
- Jagannathan, K., Arnott, J.C., Wyborn, C., Klenk, N., Mach, K.J., Moss, R.H. and Sjostrom, K.D., 2020. Great expectations? Reconciling the aspiration, outcome, and possibility of co-production. *Current Opinion in Environmental Sustainability*, 42, pp.22-29.
- Jägerskog, A., 2002. Contributions of regime theory in understanding interstate water cooperation: lessons learned in the Jordan River Basin.
- Jain, S.K., Agarwal, P.K. and Singh, V.P., 2007. *Hydrology and water resources of India (Vol. 57)*. Springer Science & Business Media.
- Jain, V., Kumar, R., Kaushal, R.K., Gautam, T. and Singh, S.K., 2018. The dynamic Kosi River and its tributaries. In *The Indian Rivers* (pp. 221-237). Springer, Singapore.
- Jasanoff, S. ed., 2004. *States of knowledge: the co-production of science and the social order*. Routledge.

- Jayasekara, R.U., Jayathilaka, G.S., Siriwardana, C., Amaratunga, D., Haigh, R., Bandara, C. and Dissanayake, R., 2021. Identifying gaps in early warning mechanisms and evacuation procedures for tsunamis in Sri Lanka, with a special focus on the use of social media. *International Journal of Disaster Resilience in the Built Environment*.
- Jha, D.K. and Tripathi, V.K., 2013. Kosi Flood Hazard and Disaster Management: A case Study of Supaul District.
- Jha, R.K. and Gundimeda, H., 2019. An integrated assessment of vulnerability to floods using composite index—A district level analysis for Bihar, India. *International Journal of Disaster Risk Reduction*, 35, p.101074.
- Johnson, B.B. and White, M.P., 2010. The importance of multiple performance criteria for understanding trust in risk managers. *Risk analysis*, 30(7), pp.1099-1115.
- Jones, R., 2016. *Violent borders: Refugees and the right to move*. Verso Books.
- Jones, S., Aryal, K. and Collins, A., 2013. Local-level governance of risk and resilience in Nepal. *Disasters*, 37(3), pp.442-467.
- Jones, S., Oven, K.J. and Wisner, B., 2016. A comparison of the governance landscape of earthquake risk reduction in Nepal and the Indian State of Bihar. *International Journal of Disaster Risk Reduction*, 15, pp.29-42.
- Jones, S., Oven, K.J., Manyena, B. and Aryal, K., 2014. Governance struggles and policy processes in disaster risk reduction: A case study from Nepal. *Geoforum*, 57, pp.78-90.
- Kaini, S., Nepal, S., Pradhananga, S., Gardner, T. and Sharma, A.K., 2021. Impacts of climate change on the flow of the transboundary Koshi River, with implications for local irrigation. *International Journal of Water Resources Development*, 37(6), pp.929-954.
- Kale, V.S., 2008. Himalayan catastrophe that engulfed north Bihar. *Journal Geological Society of India*, 72, pp.713-719.
- Kaphle, K., 2016. 12 injured in clash over levee row - The Kathmandu post, available at: <https://kathmandupost.com/national/2016/07/29/12-injured-in-clash-over-levee-row>, accessed on: 16/8/2021

- Karanci, A.N., Aksit, B. and Dirik, G., 2005. Impact of a community disaster awareness training program in Turkey: Does it influence hazard-related cognitions and preparedness behaviors. *Social Behavior and Personality: an international journal*, 33(3), pp.243-258.
- Karki, K.K. and Hari, K.C., 2020. Nepal-India relations: beyond realist and liberal theoretical prisms. *Journal of International Affairs*, 3(1), pp.84-102.
- Kasperson, J.X., Kasperson, R.E., Pidgeon, N. and Slovic, P., 2003. The social amplification of risk: assessing fifteen years of research and theory. *The social amplification of risk*, 1, pp.13-46.
- Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X. and Ratick, S., 1988. The social amplification of risk: A conceptual framework. *Risk analysis*, 8(2), pp.177-187.
- Kaushik, V. and Walsh, C.A., 2019. Pragmatism as a research paradigm and its implications for social work research. *Social sciences*, 8(9), p.255.
- Kellens, W., Terpstra, T. and De Maeyer, P., 2013. Perception and communication of flood risks: A systematic review of empirical research. *Risk Analysis: An International Journal*, 33(1), pp.24-49.
- Kelman, I. and Glantz, M.H., 2014. Early warning systems defined. In *Reducing disaster: Early warning systems for climate change* (pp. 89-108). Springer, Dordrecht.
- Kelman, I., 2018. Lost for words amongst disaster risk science vocabulary? *International Journal of Disaster Risk Science*, 9(3), pp.281-291.
- Keoduangsiang, S. and Goodwin, R., 2012. An appropriate flood warning system in the context of developing countries. *International Journal of Innovation, Management and Technology*, 3(3), p.213.
- Khadka, M., Rasul, G., Bennett, L., Wahid, S. and Gerlitz, J.Y., 2014. Gender and social equity in climate change adaptation in the Koshi basin: An analysis for action. *Handbook of climate change adaptation*. Berlin Heidelberg: Springer-Verlag. DOI, 10, pp.978-3.

- Kim, B.J., Jeong, S. and Chung, J.B., 2021. Research trends in vulnerability studies from 2000 to 2019: Findings from a bibliometric analysis. *International Journal of Disaster Risk Reduction*, 56, p.102141.
- Klinke, A. and Renn, O., 2012. Adaptive and integrative governance on risk and uncertainty. *Journal of Risk Research*, 15(3), pp.273-292.
- Koirala, S., Bhattarai, P. and Barma, S., 2020. Multi-stakeholder hydropower disputes and its resolutions in Nepal. In *Water Issues in Himalayan South Asia* (pp. 125-152). Palgrave Macmillan, Singapore.
- Koirala, S., Bhattarai, P. and Barma, S., 2020. Multi-stakeholder hydropower disputes and its resolutions in Nepal. In *Water Issues in Himalayan South Asia* (pp. 125-152). Palgrave Macmillan, Singapore.
- Kramarae, C. ed., 2004. *Technology and women's voices: Keeping in touch*. Routledge.
- Kruger, F., Bankoff, G., Cannon, T., Orlowski, B. and Schipper, E.L.F. eds., 2015. *Cultures and disasters: understanding cultural framings in disaster risk reduction*. Routledge.
- Kuban, R. and MacKenzie-Carey, H., 2001. *Community-wide vulnerability and capacity assessment (CVCA)*. Office of Critical Infrastructure protection and preparedness.
- Kuller, M., Schoenholzer, K. and Lienert, J., 2021. Creating effective flood warnings: A framework from a critical review. *Journal of Hydrology*, 602, p.126708.
- Kumar, A. and Singh, A.K., 2018. Flood-induced Migration and its socio-economic impact on women-A Case Study of Kosi Flood in North-Bihar. *International Journal of Research in Social Sciences*, 8(9), pp.486-501.
- Kumar, R., Jain, V., Babu, G.P. and Sinha, R., 2014. Connectivity structure of the Kosi megafan and role of rail-road transport network. *Geomorphology*, 227, pp.73-86.
- Kumar, S., Jain, S.K. and Gurrapu, S., 2020. Challenges and recent developments in flood forecasting in india. *Roorkee Water Conclave*.
- Lahiri-Dutt, K., 2003. People, power and rivers: experiences from the Damodar River, India. *Water Nepal, Journal of Water Resources Development*, 9(10), pp.251-67.

- Landstrom, C., Whatmore, S.J., Lane, S.N., Odoni, N.A., Ward, N. and Bradley, S., 2011. Coproducing flood risk knowledge: redistributing expertise in critical 'participatory modelling'. *Environment and Planning A*, 43(7), pp.1617-1633.
- Lane, S.N., Odoni, N., Landström, C., Whatmore, S.J., Ward, N. and Bradley, S., 2011. Doing flood risk science differently: an experiment in radical scientific method. *Transactions of the Institute of British Geographers*, 36(1), pp.15-36.
- LaPorte, T.R., 2007. Critical infrastructure in the face of a predatory future: preparing for untoward surprise. *Journal of Contingencies and Crisis Management*, 15(1), pp.60-64.
- Latour, B., 2004. Why has critique run out of steam? From matters of fact to matters of concern. *Critical inquiry*, 30(2), pp.225-248.
- Latrubesse, E.M., Stevaux, J.C. and Sinha, R., 2005. Tropical rivers. *Geomorphology*, 70(3-4), pp.187-206.
- Lee, A.C.K., 2016. Barriers to evidence-based disaster management in Nepal: a qualitative study. *Public health*, 133, pp.99-106.
- Legard, R., Keegan, J. and Ward, K., 2003. In-depth interviews. *Qualitative research practice: A guide for social science students and researchers*, 6(1), pp.138-169.
- Lejano, R.P. and Ingram, H., 2009. Collaborative networks and new ways of knowing. *Environmental Science & Policy*, 12(6), pp.653-662.
- Lemos, M.C. and Morehouse, B.J., 2005. The co-production of science and policy in integrated climate assessments. *Global environmental change*, 15(1), pp.57-68.
- Lemos, M.C., Kirchhoff, C.J. and Ramprasad, V., 2012. Narrowing the climate information usability gap. *Nature climate change*, 2(11), pp.789-794.
- Levin, K., B. Cashore, S. Bernstein, and G. Auld. 2012. Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences* 45: 123–152.
- Lewis, J. and Kelman, I., 2010. Places, people, and perpetuity: Community capacities in ecologies of catastrophe. *ACME: An International Journal for Critical Geographies*, 9(2), pp.191-220.

- Lewis, J., 1999. Development in disaster-prone places: Studies of vulnerability. ITDG Publishing.
- Lewis, J., 2012. The good, the bad and the ugly: disaster risk reduction (DRR) versus disaster risk creation (DRC). *PLoS currents*, 4.
- Lidskog, R., Soneryd, L. and Ugglå, Y., 2009. Transboundary risk governance. Routledge.
- Lidskog, R., Ugglå, Y. and Soneryd, L., 2011. Making transboundary risks governable: Reducing complexity, constructing spatial identity, and ascribing capabilities. *Ambio*, 40(2), pp.111-120.
- Lin, S., Shaw, D. and Ho, M.C., 2008. Why are flood and landslide victims less willing to take mitigation measures than the public? *Natural Hazards*, 44(2), pp.305-314.
- Lincoln, Y.S., Lynham, S.A. and Guba, E.G., 2011. Paradigmatic controversies, contradictions, and emerging confluences, revisited. *The Sage handbook of qualitative research*, 4(2), pp.97-128.
- Lindell, M.K. and Perry, R.W., 2003. Communicating environmental risk in multi-ethnic communities.
- Lindell, M.K. and Perry, R.W., 2012. The protective action decision model: theoretical modifications and additional evidence. *Risk Analysis*, 32(4), pp.616-632.
- Lindell, M.K., Huang, S.K. and Prater, C.S., 2017. Predicting residents' responses to the May 1–4, 2010, Boston water contamination incident. *International Journal of Mass Emergencies and Disasters*, 35(1), pp.84-114.
- Linkha, T.R., 2020. The Saptakoshi high dam project and its bio-physical consequences in the Arun River basin: A geographical perspective. *Geographical Journal of Nepal*, 13, pp.167-184.
- Lorino, P., 2018. Pragmatism and organization studies. Oxford University Press.
- Loster, T., 2012. From the last mile to the first: risk awareness is the key. In *Climate Change, Justice, and Sustainability* (pp. 239-246). Springer, Dordrecht.

- Lowi, M.R., 1993. Bridging the divide: transboundary resource disputes and the case of West Bank water. *International Security*, 18(1), pp.113-138.
- Luo, T., Maddocks, A., Iceland, C., Ward, P. and Winsemius, H., 2015. World's 15 countries with the most people exposed to river floods. Washington, DC: World Resources Institute.
- Lupton, D. and Tulloch, J., 2002. 'Life would be pretty dull without risk': Voluntary risk-taking and its pleasures. *Health, risk & society*, 4(2), pp.113-124.
- Lupton, D. ed., 1999. *Risk and sociocultural theory: new directions and perspectives*. Cambridge University Press.
- Lupton, D., 1999. *Risk*. Psychology Press.
- Macherera, M. and Chimbari, M.J., 2016. A review of studies on community based early warning systems. *Jàmbá: journal of disaster risk studies*, 8(1).
- Maharjan, K., 2018. *Political Ecology of Water Governance in South Asia: A Case Study of the Koshi River Communities*.
- Mahmud, S., Shah, N.M. and Becker, S., 2012. Measurement of women's empowerment in rural Bangladesh. *World development*, 40(3), pp.610-619.
- Mansuri, G. and Rao, V., 2012. Localizing development: Does participation work?
- Mansuri, G. and Rao, V., 2013. Can participation be induced? Some evidence from developing countries. *Critical Review of International Social and Political Philosophy*, 16(2), pp.284-304.
- Marsalek, J., Stancalie, G. and Balint, G. eds., 2006. *Transboundary floods: reducing risks through flood management (Vol. 72)*. Springer Science & Business Media.
- Marshall, C. and Rossman, G.B., 2014. *Designing qualitative research*. Sage publications.
- Marston, C., Hinton, R., Kean, S., Baral, S., Ahuja, A., Costello, A. and Portela, A., 2016. Community participation for transformative action on women's, children's, and adolescents' health. *Bulletin of the World Health Organisation*, 94(5), p.376.
- Martin, J., 2007. Educating communal agents: Building on the perspectivism of GH Mead. *Educational Theory*, 57(4), pp.435-452.

- Maxcy, S.J., 2003. Pragmatic threads in mixed methods research in the social sciences: The search for multiple modes of inquiry and the end of the philosophy of formalism. *Handbook of mixed methods in social and behavioral research*, (51-89).
- McCaffrey, S.C., 2003. The need for flexibility in freshwater treaty regimes. In *Natural resources forum* (Vol. 27, No. 2, pp. 156-162). Oxford, UK: Blackwell Publishing Ltd.
- McCaffrey, S.C., 2019. *The law of international watercourses*. Oxford University Press.
- McClure, J., White, J. and Sibley, C.G., 2009. Framing effects on preparation intentions: distinguishing actions and outcomes. *Disaster Prevention and Management: An International Journal*, 18(2), pp.187-199.
- McDonald, M., 2008. Securitisation and the Construction of Security. *European journal of international relations*, 14(4), pp.563-587.
- McGowran, P. and Donovan, A., 2021. Assemblage theory and disaster risk management. *Progress in Human Geography*, 45(6), pp.1601-1624.
- McLindin, M., 2019. The challenges of flood warning systems in the developing world. In *Flood Risk Management* (pp. 115-130). Routledge.
- McOmber, C., Panikowski, A., McKune, S., Bartels, W. and Russo, S., 2013. Investigating climate information services through a gendered lens. CCAFS Working Paper.
- Meechaiya, C., Wilkinson, E., Lovell, E., Brown, S. and Budimir, M., 2019. The governance of Nepal's flood early warning system: opportunities under federalism-working paper. BRACED.
- Meena, M., Singh, S. and Bhattacharyya, R., 2014. After the Kosi avulsion, August 2008, North Bihar, India: notes on the socio-economic impact. *Asian Profile*, 42(3).
- Mehta, M., 2007. *Gender matters: Lessons for disaster risk reduction in South Asia*. The International Centre for Integrated Mountain Development (ICIMOD).
- Mercer, J., Gaillard, J.C., Crowley, K., Shannon, R., Alexander, B., Day, S. and Becker, J., 2012. Culture and disaster risk reduction: lessons and opportunities. *Environmental Hazards*, 11(2), pp.74-95.

- Mercer, J., Kelman, I., Taranis, L. and Suchet-Pearson, S., 2010. Framework for integrating indigenous and scientific knowledge for disaster risk reduction. *Disasters*, 34(1), pp.214-239.
- Meriläinen, E. and Fougère, M., 2022. The nature–human dichotomy within disaster governance. In *Transformative Action for Sustainable Outcomes* (pp. 113-119). Routledge.
- Miceli, R., Sotgiu, I. and Settanni, M., 2008. Disaster preparedness and perception of flood risk: A study in an alpine valley in Italy. *Journal of environmental psychology*, 28(2), pp.164-173.
- Miles, M.B. and Huberman, A.M., 1994. *Qualitative data analysis: An expanded sourcebook*. sage.
- Mileti, D., Nathe, S., Gori, P., Greene, M. and Lemersal, E., 2004. *Public hazards communication and education: the state of the art*. University of Colorado: Natural Hazards Center.
- Mileti, D.S. and O'Brien, P., 1993. Public response to aftershock warnings. *US geological survey professional paper*, 1553, pp.31-42.
- Mileti, D.S. and Peek, L., 2000. The social psychology of public response to warnings of a nuclear power plant accident. *Journal of hazardous materials*, 75(2-3), pp.181-194.
- Mileti, D.S. and Sorensen, J.H., 1990. Communication of emergency public warnings. *Landslides*, 1(6), pp.52-70.
- Mileti, D.S., Peek, L. and Stern, P., 2002. Understanding individual and social characteristics in the promotion of household disaster preparedness. *New tools for environmental protection: Education, information, and voluntary measures*, pp.127-132.
- Miller, C.A. and Wyborn, C., 2020. Co-production in global sustainability: Histories and theories. *Environmental Science & Policy*, 113, pp.88-95.
- Mirumachi, N. and Allan, J.A., 2007, November. Revisiting transboundary water governance: Power, conflict cooperation and the political economy. In *Proceedings from CAIWA international conference on adaptive and integrated water management: Coping with scarcity*. Basel, Switzerland (Vol. 1215).

- Mirumachi, N. and Chan, K., 2014. Anthropocentric hydro politics? Key developments in the analysis of international transboundary water politics and some suggestions for moving forward. *Aquatic Procedia*, 2, pp.9-15.
- Mirumachi, N., 2013. Securitising shared waters: an analysis of the hydropolitical context of the Tanakpur Barrage project between Nepal and India. *The Geographical Journal*, 179(4), pp.309-319.
- Mirumachi, N., 2015. *Transboundary Water Politics in the Developing World*, Routledge, London. Available from: ProQuest Ebook Central.
- Mirumachi, N., 2016. Rivers and river basin management. *International Encyclopedia of Geography: People, the Earth, Environment and Technology: People, the Earth, Environment and Technology*, pp.1-9.
- Mishra, D.K., 2008. *Serpent tied around the neck: Kosi embankment* (Hindi Language). Patna, India, Freedom from Floods Campaign.
- Mishra, D.K., 2008. The Kosi and the embankment story. *Economic and Political Weekly*, pp.47-52.
- Mishra, D.K., 2008. *Trapped! between the devil and deep waters*. Peoples' Science Institute.
- Mishra, K. and Sinha, R., 2020. Flood risk assessment in the Kosi mega fan using multi-criteria decision analysis: A hydro-geomorphic approach. *Geomorphology*, 350, p.106861.
- MoEWRI. 2022. Ministry of Energy, Water Resource and Irrigation, Revised Agreement between His Majesty's Government of Nepal and The Government of India on The Kosi Project 1966, available at: <https://www.moewri.gov.np/storage/listies/May2020/revised-agreement-on-nepal-and-india-koshi-river-1966.pdf>, accessed on: June 2022.
- MoHA. 2009. Ministry of Home Affairs, Government of Nepal, Nepal Disaster Report. The Hazardscape and vulnerability, 2009, 58. <http://www.moha.gov.np>
- Molden, D., Sharma, E., Shrestha, A.B., Chettri, N., Pradhan, N.S. and Kotru, R., 2017. Advancing regional and transboundary cooperation in the conflict-prone Hindu Kush–Himalaya. *Mountain Research and Development*, 37(4), pp.502-508.

- Monin, N. and Bathurst, R., 2008. Mary Follett on the leadership of 'Everyman'. *Ephemera-theory & politics in organisation*, 8(4), pp.447-46.
- Morgan, D.L., 2014. Integrating qualitative and quantitative methods: A pragmatic approach. Sage publications.
- Morgan, M.G., Fischhoff, B., Bostrom, A. and Atman, C.J., 2002. Risk communication: A mental model approach. Cambridge University Press.
- Morss, R.E., Mulder, K.J., Lazo, J.K. and Demuth, J.L., 2016. How do people perceive, understand, and anticipate responding to flash flood risks and warnings? Results from a public survey in Boulder, Colorado, USA. *Journal of hydrology*, 541, pp.649-664.
- Mukherji, A., Ganapati, N.E. and Manandhar, B., 2021. Panacea or problem: New governance structures for disaster recovery. *International Journal of Disaster Risk Reduction*, 52, p.101960.
- Munro, A., Kovats, R.S., Rubin, G.J., Waite, T.D., Bone, A., Armstrong, B., Beck, C.R., Amlôt, R., Leonardi, G. and Oliver, I., 2017. Effect of evacuation and displacement on the association between flooding and mental health outcomes: a cross-sectional analysis of UK survey data. *The Lancet Planetary Health*, 1(4), pp. e134-e141.
- Mustafa, D., Gioli, G., Qazi, S., Waraich, R., Rehman, A. and Zahoor, R., 2015. Gendering flood early warning systems: the case of Pakistan. *Environmental Hazards*, 14(4), pp.312-328.
- Mwangi, E. and Visman, E., 2020. Technical Brief. ForPac project Technical Paper: Drought Risk Management: The Towards Forecast-based Preparedness Action Approach.
- Mwangi, E. and Visman, E., 2020. Technical Brief. ForPac project Technical Paper: Drought Risk Management: The Towards Forecast-based Preparedness Action Approach.
- Najmuddin, O., Rasul, G., Hussain, A., Molden, D., Wahid, S. and Debnath, B., 2018. Low water productivity for Rice in Bihar, India—a critical analysis. *Water*, 10(8), p.1082.
- Nakamizo, K., 2021. Climate Change and Democracy: Floods and Their Political Implications in Bihar, India Kyoto University.

- Nanditha, J.S. and Mishra, V., 2021. On the need of ensemble flood forecast in India. *Water Security*, 12, p.100086.
- Nath, S., 2019. A sociological perspective on “institutional coordination” for disaster risk reduction in India. In *Disaster Risk Reduction* (pp. 157-172). Palgrave Macmillan, Singapore.
- Nations, U., 2009. UNISDR terminology on disaster risk reduction. United Nations Office for Disaster Risk Reduction, Report.
- Neisser, F. and Müller-Mahn, D., 2018. Urban riskscape—social and spatial dimensions of risk in urban infrastructure settings. In *Urban Disaster Resilience and Security* (pp. 347-359). Springer, Cham.
- Nepal, A.K. and Neupane, N., 2022. Living in the flood plain: can financial inclusion, productive assets and coping mechanism help reduce food insecurity? *Environmental Challenges*, p.100437.
- Nepal, P., Khanal, N.R. and Sharma, B.P.P., 2018. Policies and institutions for disaster risk management in Nepal: A review. *Geographical Journal of Nepal*, 11, pp.1-24.
- Nepal, S., 2012. Evaluating upstream downstream linkages of Hydrological Dynamics in the Himalayan Region.
- Nepal, S., Flügel, W.A. and Shrestha, A.B., 2014. Upstream-downstream linkages of hydrological processes in the Himalayan region. *Ecological Processes*, 3(1), pp.1-16.
- Noolkar-Oak, G., 2022. From lukewarm to meaningful: Understanding and transforming transboundary water cooperation in the Indian subcontinent. In *Water Conflicts and Resistance* (pp. 56-82). Routledge India.
- Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A. and Campbell, B.M., 2020. Principles for knowledge co-production in sustainability research. *Nature sustainability*, 3(3), pp.182-190.
- Nyong, A., Adesina, F. and Osman Elasha, B., 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation strategies for global Change*, 12, pp.787-797.

- O’Keefe, P., Westgate, K., Wisner, B., 1976. Taking the naturalness out of natural disasters. *Nature* 260(5552): 566–567.
- O’Neill, E., Brereton, F., Shahumyan, H. and Clinch, J.P., 2016. The impact of perceived flood exposure on flood-risk perception: The role of distance. *Risk Analysis*, 36(11), pp.2158-2186.
- O’Sullivan, J.J., Bradford, R.A., Bonaiuto, M., De Dominicis, S., Rotko, P., Aaltonen, J., Waylen, K. and Langan, S.J., 2012. Enhancing flood resilience through improved risk communications. *Natural Hazards and Earth System Sciences*, 12(7), pp.2271-2282.
- Ogra, A., Donovan, A., Adamson, G., Viswanathan, K.R. and Budimir, M., 2021. Exploring the gap between policy and action in Disaster Risk Reduction: A case study from India. *International Journal of Disaster Risk Reduction*, 63, p.102428.
- Okamura, M., Bhandary, N.P., Mori, S., Marasini, N. and Hazarika, H., 2015. Report on a reconnaissance survey of damage in Kathmandu caused by the 2015 Gorkha Nepal earthquake. *Soils and Foundations*, 55(5), pp.1015-1029.
- Pahl-Wostl, C., 2007. The implications of complexity for integrated resources management. *Environmental modelling & software*, 22(5), pp.561-569.
- Pahl-Wostl, C., 2007. The implications of complexity for integrated resources management. *Environmental Modelling & Software*, 22(5), pp.561-569.
- Pahl-Wostl, C., 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global environmental change*, 19(3), pp.354-365.
- Pandey, A.C., Singh, S.K. and Nathawat, M.S., 2010. Waterlogging and flood hazards vulnerability and risk assessment in Indo Gangetic plain. *Natural hazards*, 55(2), pp.273-289.
- Pandey, C.L., Joseph, J., Deshar, R. and Niraula, P., 2023. Transboundary Flood Resilience: Insights from Narayani and Mahakali Basins *International Journal of Disaster Risk Reduction*, 86, p.103535.
- Pandey, C.L., Joseph, J., Deshar, R. and Niraula, P., 2023. Transboundary Flood Resilience: Insights from Narayani and Mahakali Basins. *International Journal of Disaster Risk Reduction*, 86, p.103535.

- Pandey, D., Lal, C., Jacquleen, D., Deshar, D. and Niraula, M., 2022. Transboundary Flood Resilience: Insights from Narayani and Mahakali Basins.
- Pandey, S., 2013. The politics of foreign aid. *The Nepali Times*, (620), p.31.
- Pansiri, J., 2005. Pragmatism: A methodological approach to researching strategic alliances in tourism. *Tourism and Hospitality Planning & Development*, 2(3), pp.191-206.
- Panthi, K.K., 2021, August. Assessment on the 2014 Jure Landslide in Nepal—a disaster of extreme tragedy. In *IOP Conference Series: Earth and Environmental Science* (Vol. 833, No. 1, p. 012179). IOP Publishing.
- Parker, D.J., 2017. Flood warning systems and their performance. In *Oxford Research Encyclopedia of Natural Hazard Science*.
- Paton, D. and Tang, C.S., 2009. Adaptive and growth outcomes following tsunami: The experience of Thai communities following the 2004 Indian Ocean tsunami.
- Paton, D., 2008. Risk communication and natural hazard mitigation: how trust influences its effectiveness. *International Journal of Global Environmental Issues*, 8(1-2), pp.2-16.
- Paul, J.D., Buytaert, W., Allen, S., Ballesteros-Cánovas, J.A., Bhusal, J., Cieslik, K., Clark, J., Dugar, S., Hannah, D.M., Stoffel, M. and Dewulf, A., 2018. Citizen science for hydrological risk reduction and resilience building. *Wiley Interdisciplinary Reviews: Water*, 5(1), p.e1262.
- Payne, M., 2015. *Modern social work theory*. Oxford University Press.
- Perera, D., Agnihotri, J., Seidou, O. and Djalante, R., 2020. Identifying societal challenges in flood early warning systems. *International Journal of Disaster Risk Reduction*, 51, p.101794.
- Petersen-Perlman, J.D., Veilleux, J.C. and Wolf, A.T., 2017. International water conflict and cooperation: challenges and opportunities. *Water International*, 42(2), pp.105-120.
- Petley, D.N., Hearn, G.J., Hart, A., Rosser, N.J., Dunning, S.A., Owen, K. and Mitchell, W.A., 2007. Trends in landslide occurrence in Nepal. *Natural hazards*, 43(1), pp.23-44.
- Prasad, R., 2021. Impact of Physical Factors on Transboundary Water Management and Governance in the Kosi Basin. In *Resource Management, Sustainable Development and Governance* (pp. 225-247). Springer, Cham.

- Prasai, S. and Surie, M.D., 2015. Water and climate data in the Ganges basin: Assessing access to information regimes and implications for cooperation on transboundary rivers. *Water Alternatives*, 8(2).
- Pritchard, B. and Thielemans, R., 2014. 'Rising Waters Don't Lift All Boats': a sustainable livelihood analysis of recursive cycles of vulnerability and maladaptation to flood risk in rural Bihar, India. *Australian Geographer*, 45(3), pp.325-339.
- R. and Richard, R., 1989. *Contingency, irony, and solidarity*. Cambridge University Press.
- Raadgever, G.T., Mostert, E., Kranz, N., Interwies, E. and Timmerman, J.G., 2008. Assessing management regimes in transboundary river basins: do they support adaptive management? *Ecology and society*, 13(1).
- Rahayu, H.P., Comfort, L.K., Haigh, R., Amaratunga, D. and Khoirunnisa, D., 2020. A study of people-centered early warning system in the face of near-field tsunami risk for Indonesian coastal cities. *International journal of disaster resilience in the built environment*, 11(2), pp.241-262.
- Rahman, M., Ghimire, G.P. and Gurung, G.B., 2018. *Trans-border Flood Early Warning System in South Asia: Practices, Challenges and Prospects*.
- Rai, D.K., and Linkha, T.R., 2020. The Saptakoshi high dam project and its bio-physical consequences in the Arun River basin: A geographical perspective. *Geographical Journal of Nepal*, 13, pp.167-184.
- Rai, P. and Khawas, V., 2019. Traditional knowledge system in disaster risk reduction: Exploration, acknowledgement, and proposition. *Jàmbá: Journal of Disaster Risk Studies*, 11(1), pp.1-7.
- Rai, S.P., Wolf, A.T. and Sharma, N., 2017. Hydro politics and hydro political dynamics between India and Nepal: an event-based study. *Water Policy*, 19(5), pp.791-819.
- Ramos, M.H., Mathevet, T., Thielen, J. and Pappenberger, F., 2010. Communicating uncertainty in hydro-meteorological forecasts: mission impossible? *Meteorological Applications*, 17(2), pp.223-235.

- Ranjan, A. ed., 2019. Water Issues in Himalayan South Asia: Internal Challenges, Disputes and Transboundary Tensions. Springer Nature.
- Räsänen, A., Lein, H., Bird, D. and Setten, G., 2020. Conceptualizing community in disaster risk management. *International journal of disaster risk reduction*, 45, p.101485.
- Ravetz, I.R., 1999. What is post-normal science. *Futures-the Journal of Forecasting Planning and Policy*, 31(7), pp.647-654.
- Ray P.K Champati and Chatteraj, S.L., 2014. Sunkoshi landslide in Nepal and its possible impact in India: A remote sensing-based appraisal. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40(8), p.1345.
- Ray, P.A., Yang, Y.C.E., Wi, S., Khalil, A., Chatikavanij, V. and Brown, C., 2015. Room for improvement: Hydroclimatic challenges to poverty-reducing development of the Brahmaputra River basin. *Environmental Science & Policy*, 54, pp.64-80.
- Ray-Bennett, N.S., 2009. The influence of caste, class and gender in surviving multiple disasters: A case study from Orissa, India. *Environmental Hazards*, 8(1), pp.5-22.
- Reddy, D.V., Kumar, D., Saha, D., and Mandal, M.K., 2008. The 18 August 2008 Kosi River breach: an evaluation. *Current Science*, 95(12), pp.1668-1669.
- Renn, O. and Swaton, E., 1984. Psychological and sociological approaches to study risk perception. *Environment International*, 10(5-6), pp.557-575.
- Renn, O., 1998. The role of risk perception for risk management. *Reliability Engineering & System Safety*, 59(1), pp.49-62.
- Renn, O., 1998. Three decades of risk research: accomplishments and new challenges. *Journal of risk research*, 1(1), pp.49-71.
- Renn, O., 2008. *Risk Governance-Coping with Uncertainty in a Complex World* Routledge.
- Renn, O., 2009. White Paper on risk governance: Towards and integrative approach. International Risk Governance Council (IRGC).
- Renn, O., 2017. *Risk governance: coping with uncertainty in a complex world*. Routledge.

- Reynolds, J.M., 1999. Glacial hazards in the Himalayas: an overview. *Journal of Nepal Geological Society*, 20, p.255.
- Reynolds, J.M., 2019. On the need for transboundary management of geohazards. In *HYDRO 2019, Conference Proceedings*, Porto, Portugal, 14th–16th October.
- Richardson, S.D., and Reynolds, J.M., 2000. An overview of glacial hazards in the Himalayas. *Quaternary International*, 65, pp.31-47.
- Ritchie, A., McOmber, C., Pelling, M., Audia, C., Crowley, F. and Visman, E., 2017. Building resilience by challenging social norms: Towards a gender transformative approach in BRACED.
- Rollason, E., Bracken, L.J., Hardy, R.J. and Large, A.R.G., 2018. Rethinking flood risk communication. *Natural hazards*, 92(3), pp.1665-1686.
- Rorty, R. and Richard, R., 1989. *Contingency, irony, and solidarity*. Cambridge University Press.
- Rorty, R., 2009. *Philosophy and the Mirror of Nature* (Vol. 81). Princeton university press.
- Ruin, I., Gaillard, J.C. and Lutoff, C., 2007. How to get there? Assessing motorists' flash flood risk perception on daily itineraries. *Environmental hazards*, 7(3), pp.235-244.
- Russell, C., Clark, J., Hannah, D. and Sugden, F., 2021. Towards a collaborative governance regime for disaster risk reduction: Exploring scalar narratives of institutional change in Nepal. *Applied Geography*, 134, p.102516.
- Sadoff, C., Harshadeep, N.R., Blackmore, D., Wu, X., O'Donnell, A., Jeuland, M., Lee, S. and Whittington, D., 2013. Ten fundamental questions for water resources development in the Ganges: myths and realities. *Water Policy*, 15(S1), pp.147-164.
- Sahu, A.K., 2019. Referent object, securitising actors, and the audience: The climate change threat and the securitisation of development in India. *Cambridge Review of International Affairs*, pp.1-24.
- Sai, F., Cumiskey, L., Weerts, A., Bhattacharya, B. and Haque Khan, R., 2018. Towards impact-based flood forecasting and warning in Bangladesh: A case study at the local level in Sirajganj district. *Natural Hazards and Earth System Sciences Discussions*, pp.1-20.

- Sapkota, S.N., Bollinger, L. and Perrier, F., 2016. Fatality rates of the M_w 8.2, 1934, Bihar–Nepal earthquake and comparison with the April 2015 Gorkha earthquake. *Earth, Planets and Space*, 68(1), pp.1-9.
- Schipper, E.L., Ayers, J., Reid, H., Huq, S. and Rahman, A., 2014. *Community-based adaptation to climate change: Scaling it up*. Routledge.
- Schmeidl, S. and Piza-Lopez, E., 2002. *Gender and conflict early warning: A framework for action*. London: International Alert.
- Schmeier, S., 2013. *Governing international watercourses: river basin organisations and the sustainable governance of internationally shared rivers and lakes*. Routledge.
- Schmeier, S., Gerlak, A.K. and Blumstein, S., 2016. Clearing the muddy waters of shared watercourses governance: conceptualizing international River Basin Organisations. *International Environmental Agreements: Politics, Law, and Economics*, 16(4), pp.597-619.
- Scolobig, A., De Marchi, B. and Borga, M., 2012. The missing link between flood risk awareness and preparedness: findings from case studies in an Alpine Region. *Natural Hazards*, 63(2), pp.499-520.
- Scolobig, A., Weyrich, P., Bresch, D.N. and Patt, A., 2018. Effects of impact-based warnings and behavioral recommendations for extreme weather events. *Weather, climate, and society*, 10(4), pp.781-796.
- Seager, J., 2014. Disasters are gendered: What’s new? In *Reducing disaster: Early warning systems for climate change* (pp. 265-281). Springer, Dordrecht.
- Seal, D.W., Bogart, L.M. and Ehrhardt, A.A., 1998. Small group dynamics: The utility of focus group discussions as a research method. *Group Dynamics: Theory, Research, and Practice*, 2(4), p.253.
- Sebastian, J., 2009. *Understanding Public System Management in Bihar: The Case of Kosi Floods*.

- Shah, A.A., Ullah, A., Khan, N.A., Pal, I., Alotaibi, B.A. and Traore, A., 2022. Gender Perspective of Flood Early Warning Systems: People-Centered Approach. *Water*, 14(14), p.2261.
- Shah, A.J., 2011. An overview of disaster management in India. *WIT Transactions on The Built Environment*, 119, pp.73-83.
- Shanahan, E.A., Reinhold, A.M., Raile, E.D., Poole, G.C., Ready, R.C., Izurieta, C., McEvoy, J., Bergmann, N.T. and King, H., 2019. Characters matter: How narratives shape affective responses to risk communication. *PloS one*, 14(12), p.e0225968.
- Shepherd, A., Mitchell, T., Lewis, K., Lenhardt, A., Jones, L., Scott, L. and Muir-Wood, R., 2013. *The geography of poverty, disasters, and climate extremes in 2030*. London: ODI.
- Shields, P.M., 2008. Rediscovering the taproot: Is classical pragmatism the route to renew public administration. *Public Administration Review*, 68(2), pp.205-221.
- Shree, R., 2020. Mapping the water disputes in India: Nature, issues, and emerging trends. In *Water Issues in Himalayan South Asia* (pp. 103-123). Palgrave Macmillan, Singapore.
- Shrestha, A.B., Bajracharya, S.R., Sharma, A.R., Duo, C. and Kulkarni, A., 2017. Observed trends and changes in daily temperature and precipitation extremes over the Koshi river basin 1975–2010. *International Journal of Climatology*, 37(2), pp.1066-1083.
- Shrestha, B.B. and Nakagawa, H., 2016. Hazard assessment of the formation and failure of the Sunkoshi landslide dam in Nepal. *Natural Hazards*, 82(3), pp.2029-2049.
- Shrestha, M., Goodrich, C., Udas, P., Rai, D., Gurung, M. and Khadgi, V., 2016. Flood early warning systems in Bhutan: a gendered perspective. *International Centre for Integrated Mountain Development (ICIMOD)*.
- Shrestha, M.S., Gurung, M.B., Khadgi, V.R., Wagle, N., Banarjee, S., Sherchan, U., Parajuli, B. and Mishra, A., 2021. The last mile: flood risk communication for better preparedness in Nepal. *International journal of disaster risk reduction*, 56, p.102118.
- Shrestha, N., 2017. *Reaching the Most Vulnerable Across the Border: Community-Based Flood Early Warning Systems*. ICIMOD, Kathmandu.
- Shrestha, R., 2015. *Kosi River Basin Inventory*, Nepal.

- Shrestha, R.K., Ahlers, R., Bakker, M. and Gupta, J., 2010. Institutional dysfunction and challenges in flood control: a case study of the Kosi flood 2008. *Economic and Political Weekly*, pp.45-53.
- Shreve, C., Begg, C., Fordham, M. and Müller, A., 2016. Operationalizing risk perception and preparedness behavior research for a multi-hazard context. *Environmental hazards*, 15(3), pp.227-245.
- Siddiqui, S., 2022. Environmental justice for the victims of the Koshi River Project: The context and elements of transboundary legal response. In *Water Conflicts and Resistance* (pp. 129-149). Routledge India.
- Siegrist, M. and Gutscher, H., 2008. Natural hazards and motivation for mitigation behavior: People cannot predict the affect evoked by a severe flood. *Risk Analysis*, 28(3), pp.771-778.
- Sil, R. and Katzenstein, P.J., 2010. *Beyond paradigms: Analytic eclecticism in the study of world politics*. Bloomsbury Publishing.
- Simpson, B. and Hond, F., 2022. The contemporary resonances of classical pragmatism for studying organisation and organizing. *Organisation Studies*, 43(1), pp.127-146.
- Simpson, B., 2009. Pragmatism, Mead and the practice turn. *Organisation studies*, 30(12), pp.1329-1347.
- Singh, D.S., 2018. Concept of Rivers: An Introduction for Scientific and Socioeconomic Aspects. In *The Indian Rivers* (pp. 1-23). Springer, Singapore.
- Singh, R.P., 2010. GEO-POLITICAL POSITION OF NEPAL AND ITS IMPACT ON INDIAN SECURITY. *The Indian Journal of Political Science*, pp.1281-1292.
- Sinha, R. 2009. The Great avulsion of Kosi on 18 August 2008, *Current Science*, 97, 3 10 August 2009
- Sinha, R., 2008. Kosi: rising waters, dynamic channels and human disasters. *Economic and Political Weekly*, pp.42-46.
- Sinha, R., Bapalu, G.V., Singh, L.K. and Rath, B., 2008. Flood risk analysis in the Kosi River basin, north Bihar using multi-parametric approach of analytical hierarchy process (AHP). *Journal of the Indian Society of Remote Sensing*, 36(4), pp.335-349.

- Sinha, R., Burton, M. and Tiwari, G., 2012. Strengthening the institutional framework for flood and water resources management in Bihar: Developing a strategy for reform (Phase I). International Growth Centre Working Paper. London: London School of Economics.
- Sinha, R., Cherry, B. and Densmore, A., 2014 a. Living with the Floods: Sustainable Management of the Kosi River. Policy Brief, Institute of Hazard, Risk and Resilience, Durham University.
- Sinha, R., Gupta, A., Mishra, K., Tripathi, S., Nepal, S., Wahid, S.M. and Swarnkar, S., 2019. Basin-scale hydrology and sediment dynamics of the Kosi River in the Himalayan foreland. *Journal of Hydrology*, 570, pp.156-166.
- Sinha, R., Nepal, S. and Uddin, K., 2018. Understanding Sediment Management. ICIMOD, Kathmandu.
- Sinha, R., Sripriyanka, K., Jain, V. and Mukul, M., 2014 b. Avulsion threshold and planform dynamics of the Kosi River in north Bihar (India) and Nepal: A GIS framework. *Geomorphology*, 216, pp.157-170.
- SIWI, 2018. Stockholm International Water Institute Annual Report, SIWI.
- Slovic, P. and Peters, E., 2006. Risk perception and affect. *Current directions in psychological science*, 15(6), pp.322-325.
- Slovic, P., 1987. Perception of risk. *Science*, 236(4799), pp.280-285.
- Slovic, P., 1993. Perceived risk, trust, and democracy. *Risk analysis*, 13(6), pp.675-682.
- Slovic, P., 1999. Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. *Risk analysis*, 19(4), pp.689-701.
- Smith, D. and Fischbacher, M., 2009. The changing nature of risk and risk management: The challenge of borders, uncertainty, and resilience. *Risk management*, 11(1), pp.1-12.
- Smith, K. and Petley D.N., 2009. Environmental hazards: assessing risk and reducing disaster. Routledge.
- Smith, K., 2013. Environmental Hazards: Assessing Risk and Reducing Disaster. Routledge.

- Smith, P.J., Brown, S. and Dugar, S., 2017. Community-based early warning systems for flood risk mitigation in Nepal. *Natural Hazards and Earth System Sciences*, 17(3), pp.423-437.
- Somanathan, E., 2013. Are embankments a good flood control strategy? A case study on the Kosi River. *Water policy*, 15(S1), pp.75-88.
- SOPFF (Standard Operating Procedure for Flood Forecasting), 2019. Department of Water Resources, River Development & Ganga Rejuvenation, Central Water Commission, Ministry of Jal Shakti, Government of India.
- Spiegelhalter, D.J. and Riesch, H., 2011. Don't know, can't know: embracing deeper uncertainties when analysing risks. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369(1956), pp.4730-4750.
- Stengers, I., 2005. The cosmopolitical proposal. *Making things public: Atmospheres of democracy*, 994, p.994.
- Stern, Paul C., and Harvey V. Fineberg, 1996. *Understanding risk: Informing decisions in a democratic society*. National Academies Press.
- Sternberg, T., 2014. Transboundary hazard risk: the Gobi Desert paradigm. *Natural hazards*, 72(2), pp.533-548.
- Subramanian, A., Brown, B. and Wolf, A., 2012. *Reaching across the waters: Facing the risks of cooperation in international waters*. World Bank Publications.
- Sufri, S., Dwirahmadi, F., Phung, D. and Rutherford, S., 2020. A systematic review of community engagement (CE) in disaster early warning systems (EWSs). *Progress in Disaster Science*, 5, p.100058.
- Sukhwani, V., Gyamfi, B.A., Zhang, R., AlHinai, A.M. and Shaw, R., 2019. Understanding the barriers restraining effective operation of flood early warning systems. *International Journal of Disaster Risk Management*, 1(2), pp.1-19.
- Sultana, F., 2007. Reflexivity, positionality, and participatory ethics: Negotiating fieldwork dilemmas in international research. *ACME: An international journal for critical geographies*, 6(3), pp.374-385.

- Sultana, F., 2010. Living in hazardous waterscapes: Gendered vulnerabilities and experiences of floods and disasters. *Environmental Hazards*, 9(1), pp.43-53
- Surie, M.D., 2015. Strengthening transparency and access to information on transboundary rivers in South Asia. Asia Foundation.
- Sutton, J., Spiro, E.S., Johnson, B., Fitzhugh, S., Gibson, B. and Butts, C.T., 2014. Warning tweets: Serial transmission of messages during the warning phase of a disaster event. *Information, Communication & Society*, 17(6), pp.765-787.
- Syal, R., van Wessel, M. and Sahoo, S., 2021. Collaboration, Co-Optation or Navigation? The Role of Civil Society in Disaster Governance in India. *VOLUNTAS: International Journal of Voluntary and Nonprofit Organisations*, 32(4), pp.795-808.
- Tandan, P., 2021. Challenging hydro-hegemony of India: resistance of Nepal in the Upper Karnali and Saptakoshi dam project. *Sustainable Water Resources Management*, 7(6), pp.1-19.
- Tandon, S.K. and Sinha, R., 2022. Geology of large river systems. *Large Rivers: Geomorphology and Management*, Second Edition, pp.7-41.
- Tashakkori, A. and Teddlie, C., 2003. The past and future of mixed methods research: From data triangulation to mixed model designs. *Handbook of mixed methods in social and behavioural research*, 671, p.701.
- Tashakkori, A., Teddlie, C. and Teddlie, C.B., 1998. *Mixed methodology: Combining qualitative and quantitative approaches* (Vol. 46). sage.
- Tasnimuddaulah, M., 2019. Scheduled Caste Population in Kosi Plain, Causes and Effects of External Migration: A Geographical Analysis. *Think India Journal*, 22(35), pp.1130-1136.
- Terpstra, T., 2011. Emotions, trust, and perceived risk: Affective and cognitive routes to flood preparedness behavior. *Risk Analysis: An International Journal*, 31(10), pp.1658-1675.
- Terpstra, T., Lindell, M.K. and Gutteling, J.M., 2009. Does communicating (flood) risk affect (flood) risk perceptions? Results of a quasi-experimental study. *Risk Analysis: An International Journal*, 29(8), pp.1141-1155.

- Terry, L.D., 2015. Leadership of public bureaucracies: The administrator as conservator: The Administrator as Conservator. Routledge.
- Thévenot, L., 2006, July. Institutions and agency: Differentiating regimes of engagement. In Conference on Economy and Society.
- Timalsina, S.K., 2019. Nepal India Relations: People to People Contact. *International Journal of Innovative Science and Research Technology*, 4(3), pp.444-450.
- Titz, A., Cannon, T. and Krüger, F., 2018. Uncovering 'community': Challenging an elusive concept in development and disaster related work. *Societies*, 8(3), p.71.
- Trogrlić, R.Š., Duncan, M., Wright, G., van den Homberg, M., Adeloje, A., Mwale, F. and McQuistan, C., 2021. External stakeholders' attitudes towards and engagement with local knowledge in disaster risk reduction: are we only paying lip service? *International Journal of Disaster Risk Reduction*, 58, p.102196.
- Turner, G., Said, F., Afzal, U. and Campbell, K., 2014. The effect of early flood warnings on mitigation and recovery during the 2010 Pakistan floods. In *Reducing disaster: Early warning systems for climate change* (pp. 249-264). Springer, Dordrecht.
- Turton, A. and Henwood, R. eds., 2002. *Hydropolitics in the developing world: A Southern African perspective*. IWMI.
- Twigg, J., 2003. The human factor in early warnings: risk perception and appropriate communications. In *Early warning systems for natural disaster reduction* (pp. 19-26). Springer, Berlin, Heidelberg.
- UN Water, 2008. *Transboundary waters: sharing benefits, sharing responsibilities*. Thematic Paper, p.20.
- UN Water, 2015. *Good Practices in Transboundary Water Cooperation*, p.20. UN, available at: <<https://www.unwater.org/activities/thematic-priority-areas/transboundary-waters/en/>>, accessed on 13/08/2022
- UN, 2006. *Global Survey of Early Warning Systems- Final version*, The United Nations, accessed on 6 June 2018, https://www.unisdr.org/files/3612_GlobalSurveyofEarlyWarningSystems.pdf.

UN, 2015. Transforming our world: the 2030 Agenda for Sustainable Development United Nations.

UNEP, 2012. Early warning systems: a state-of-the-art analysis and future directions. United Nations Environment Programme (UNEP).

UNESCAP, 2017. Strengthening regional mechanisms for strengthening the early warning systems, United Nations Economic and Social Commission for Asia and the Pacific, Bangkok, Thailand.

UNFCCC (United Nations Framework Convention on Climate Change), 2015. Paris agreement.

UNFCCC, 2014. Community Based Early Warning Systems, United Nations Framework Convention on Climate Change, Available at: <http://unfccc.int/mfc2014/lighthouse-activities/ict-solutions/community-based-flood-early-warning-system/>, last accessed 20/03/2019

UNISDR, 2006. Early Warning – From Concept to Action: The Conclusions of the Third International Conference on Early Warning (EWC III), Bonn, Germany, 27 – 29

UNISDR, 2006. Early Warning – From Concept to Action: The Conclusions of the Third International Conference on Early Warning (EWC III), Bonn, Germany, 27 – 29

UNISDR, 2009. Reducing Disaster Risks through Science: Issues and Actions. Report of the ISDR Scientific and Technical Committee. Global Platform for Disaster Risk Reduction, Geneva, 6 – 19

UNISDR, 2009. Reducing Disaster Risks through Science: Issues and Actions. Report of the ISDR Scientific and Technical Committee. Global Platform for Disaster Risk Reduction, Geneva, 6 – 19

UNISDR, 2018. UNISDR Annual Report 2017 United Nations Office for Disaster Risk Reduction. Geneva, Switzerland. Retrieved from <<https://www.undrr.org/publication/unisdr-annual-report-2017>>.

UN-OCHA, 2009. Kosi Flood disaster 2008. United Nations Office for the Coordination of Humanitarian Affairs, Nepal.

- Upadhyay, S.N. and Gaudel, P., 2018. Water resources development in Nepal: myths and realities. *Hydro Nepal: Journal of Water, Energy and Environment*, 23, pp.22-29.
- Upadhyay, S.N., 2012. *International Watercourses Law and a Perspective on Nepal-India Cooperation*, Ekta Books, Kathmandu, Nepal
- Upreti, K., and Salman, S.M., 2011. Legal aspects of sharing and management of transboundary waters in South Asia: preventing conflicts and promoting cooperation. *Hydrological Sciences Journal*, 56(4), pp.641-661.
- Van der Geest, K., 2018. Landslide loss and damage in Sindhupalchok District, Nepal: comparing income groups with implications for compensation and relief. *International Journal of Disaster Risk Science*, 9(2), pp.157-166.
- Van Kerkhoff, L.E. and Lebel, L., 2015. Coproductive capacities: rethinking science-governance relations in a diverse world. *Ecology and Society*, 20(1).
- Vij, S., Russell, C., Clark, J., Parajuli, B.P., Shakya, P. and Dewulf, A., 2020a. Evolving disaster governance paradigms in Nepal. *International Journal of Disaster Risk Reduction*, 50, p.101911.
- Vij, S., Warner, J.F., Biesbroek, R. and Groot, A., 2020b. Non-decisions are also decisions: Power interplay between Bangladesh and India over the Brahmaputra River. *Water International*, 45(4), pp.254-274.
- Vila Seoane, M.F., 2021. Data securitisation: the challenges of data sovereignty in India. *Third World Quarterly*, pp.1-18.
- Villagrán de Leon, J.C. 2014. People centred early warning, in Lopez-Carresi, A. F.M., Wisner, B., Kelman, I. and Gaillard, J.C. (Eds), *Disaster Management: International Lessons in Risk Reduction, Response and Recovery*, Routledge, New York, NY, pp. 64-81.
- Vincent, K., 2022. Development geography I: Co-production. *Progress in Human Geography*, 46(3), pp.890-897. Vincent et al. (2018)
- Vincent, K., Steynor, A., McClure, A., Visman, E., Waagsaether, K.L., Carter, S. and Mittal, N., 2021. Co-production: learning from contexts. *Climate Risk in Africa: Adaptation and Resilience*, pp.37-56.

- Visman, E., Audia, C., Crowley, F., Pelling, M., Seigneret, A. and Bogosyan, T., 2018. Underpinning principles and ways of working that enable co-production: reviewing the role of research. *BRACED Learning Paper*, 7, pp.1-8.
- Visman, E., Vincent, K., Steynor, A., Karani, I. and Mwangi, E., 2022. Defining metrics for monitoring and evaluating the impact of co-production in climate services. *Climate Services*, 26, p.100297.
- Wachinger, G., Renn, O., Begg, C. and Kuhlicke, C., 2013. The risk perception paradox—implications for governance and communication of natural hazards. *Risk analysis*, 33(6), pp.1049-1065.
- Wahid, S.M., Kilroy, G., Shrestha, A.B., Bajracharya, S.R. and Hunzai, K., 2017. Opportunities and challenges in the trans-boundary Koshi River basin. In *River System Analysis and Management* (pp. 341-352). Springer, Singapore.
- Walmsley, D.J., 2000. Community, place, and cyberspace. *Australian Geographer*, 31(1), pp.5-19.
- Warner, J. and Zawahri, N., 2012. Hegemony and asymmetry: Multiple-chessboard games on transboundary rivers. *International Environmental Agreements: Politics, Law and Economics*, 12, pp.215-229.
- Warner, J., Mirumachi, N., Farnum, R.L., Grandi, M., Menga, F. and Zeitoun, M., 2017. Transboundary 'hydro-hegemony': 10 years later. *Wiley Interdisciplinary Reviews: Water*, 4(6), p.e1242.
- Warner, J., Mirumachi, N., Farnum, R.L., Grandi, M., Menga, F. and Zeitoun, M., 2017. Transboundary 'hydro-hegemony': 10 years later. *Wiley Interdisciplinary Reviews: Water*, 4(6), p.e1242.
- Waylen, K.A., Fischer, A., McGowan, P.J. and Milner-Gulland, E.J., 2013. Deconstructing community for conservation: why simple assumptions are not sufficient. *Human Ecology*, 41(4), pp.575-585.

- WB, 2012. Disaster Risk Management in South Asia: Regional Overview, The World Bank, Disaster Risk Management and Climate Change Unit, South Asian Region, Washington DC, WB
- Webster, P.J., Jian, J., Hopson, T.M., Hoyos, C.D., Agudelo, P.A., Chang, H.R., Curry, J.A., Grossman, R.L., Palmer, T.N. and Subbiah, A.R., 2010. Extended-range probabilistic forecasts of Ganges and Brahmaputra floods in Bangladesh. *Bulletin of the American Meteorological Society*, 91(11), pp.1493-1514.
- Weichselgartner, J. and Pigeon, P., 2015. The role of knowledge in disaster risk reduction. *International Journal of Disaster Risk Science*, 6(2), pp.107-116.
- Weick, K.E., Sutcliffe, K.M. and Obstfeld, D., 2005. Organizing and the process of sensemaking. *Organisation science*, 16(4), pp.409-421.
- Weyrich, P., Scolobig, A., Bresch, D.N. and Patt, A., 2018. Effects of impact-based warnings and behavioral recommendations for extreme weather events. *Weather, climate, and society*, 10(4), pp.781-796.
- Whatmore, S. J., 2009. Mapping knowledge controversies: science, democracy and the redistribution of expertise. *Progress in Human Geography*, 33, 587–98.
- Wilkinson, I., 2001. Social theories of risk perception: At once indispensable and insufficient. *Current sociology*, 49(1), pp.1-22.
- Williams, C., 2007. Research methods. *Journal of Business & Economics Research (JBER)*, 5(3).
- Wingqvist, G. and Nilsson, A., 2015. Effectiveness of River Basin Organisations—an institutional review of three African RBOs. Sida's Helpdesk for Environment and Climate Change.
- Wisner, B., 1995. Bridging “expert” and “local” knowledge for counter-disaster planning in urban South Africa. *Geo Journal*, 37(3), pp.335-348.
- Wisner, B., Blaikie, P., Cannon, T. and Davis, I., 2014. At risk: natural hazards, people's vulnerability, and disasters. Routledge.
- Wisner, B., O'Keefe, P. and Westgate, K., 1977. Global systems and local disasters: the untapped power of peoples 'science. *Disasters*, 1(1), pp.47-57.

- Wouters, P., 2013. International law—facilitating transboundary water cooperation. Published by the Global Water Partnership, TEC Background Papers, (17).
- Wuetherick, B., 2010. Basics of qualitative research: Techniques and procedures for developing grounded theory. *Canadian Journal of University Continuing Education*, 36(2).
- Wynne, B., 1992. Uncertainty and environmental learning: reconceiving science and policy in the preventive paradigm. *Global Environmental Change*, 2, 111–27.
- Yaari, E., Neal Patrick, M. and Shubber, Z., 2015. Governance structures for transboundary water management in the Jordan Basin. Stockholm: Stockholm International Water Institute.
- Yadav, V. and Ibrar, Z., 2022. Relationship of Water Stress and Flood Damage for Sustainable Development. *Water Resources Management*, pp.1-16.
- Yongjian, D. and Jingshi, L., 1992. Glacier lake outburst flood disasters in China. *Annals of Glaciology*, 16, pp.180-184.
- Zeitoun, M. and Warner, J., 2006. Hydro-hegemony—a framework for analysis of transboundary water conflicts. *Water policy*, 8(5), pp.435-460.
- Zeitoun, M., Goulden, M. and Tickner, D., 2013. Current and future challenges facing transboundary river basin management. *Wiley Interdisciplinary Reviews: Climate Change*, 4(5), pp.331-349.
- Zeitoun, M., Lankford, B., Krueger, T., Forsyth, T., Carter, R., Hoekstra, A.Y., Taylor, R., Varis, O., Sneddon, C. and Fox, C., 2006. Rethinking transboundary waters: A critical hydropolitics of the Mekong basin. *Political geography*, 25(2), pp.181-202.
- Zeitoun, M., Mirumachi, N. and Warner, J., 2011. Transboundary water interaction II: The influence of ‘soft’ power. *International Environmental Agreements: Politics, Law, and Economics*, 11(2), pp.159-178.
- Zeitoun, M., Mirumachi, N. and Warner, J., 2020. *Water conflicts: Analysis for transformation*. Oxford University Press.
- Zeitoun, M., Mirumachi, N., Warner, J., Kirkegaard, M. and Cascão, A., 2020. Analysis for water conflict transformation. *Water International*, 45(4), pp.365-384.

- Zhang, J.Q., Liu, R.K., Deng, W., Khanal, N.R., Gurung, D.R., Murthy, M.S.R. and Wahid, S., 2016. Characteristics of landslide in Koshi River basin, central Himalaya. *Journal of Mountain Science*, 13(10), pp.1711-1722.
- Zhang, Y., Prater, C.S. and Lindell, M.K., 2004. Risk area accuracy and evacuation from Hurricane Bret. *Natural Hazards Review*, 5(3), pp.115-120.
- Zinn, J.O., 2020. *Understanding risk-taking*. Cham: Palgrave Macmillan.
- Zommers, Z. and Singh, A. eds., 2014. *Reducing disaster: early warning systems for climate change*. Springer Science+ Business Media.
- Zschau, J. and Küppers, A.N. eds., 2013. *Early warning systems for natural disaster reduction*. Springer Science & Business Media.

Appendices

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07/02/2019

Gaurab Dawadi

Dear Gaurab

Understanding transboundary impacts of multi-hazard early warning systems and their cultural context

Thank you for submitting your Research Ethics Minimal Risk Registration Form. This letter acknowledges confirmation of your registration; your registration confirmation reference number is MRS-18/19-10491

Please note: For projects involving the use of an Information Sheet and Consent Form for recruitment purposes, please ensure that you use the KCL GDPR compliant [Information Sheet & Consent Form Templates](#)

Be sure to keep a record your registration number and include it in any materials associated with this research. Registration is valid for **one year** from today's date. Please note it is the responsibility of the researcher to ensure that any other permissions or approvals (i.e. R&D, gatekeepers, etc.) relevant to their research are in place, prior to conducting the research.

Record Keeping:

In addition, you are expected to keep records of your process of informed consent and the dates and relevant details of research covered by this application. For example, depending on the type of research that you are doing, you might keep:

- A record of the relevant details for public talks that you attend, the websites that visit, the interviews that you conduct
- The 'script' that you use to inform possible participants about what your research involves. This may include written information sheets, or the generic information you include in the emails you write to possible participants, or what you say to people when you approach them on the street for a survey, or the introductory material stated at the top of your on-line survey.
- Where appropriate, records of consent, e.g. copies of signed consent forms or emails where participants agree to be interviewed.

Audit:

You may be selected for an audit, to see how researchers are implementing this process. If audited, you will be expected to explain how your research abides by the general principles of ethical research. In particular, you will be expected to provide a general summary of your review of the possible risks involved in your research, as well as to provide basic research records (as above in Record Keeping) and to describe the process by which participants agreed to participate in your research.

Remember that if you have any questions about the ethical conduct of your research at any point, you should contact your supervisor (where applicable) or the Research Ethics office.

Feedback:

If you wish to provide any feedback on the process you may do so by emailing rec@kcl.ac.uk.

We wish you every success with this work.

With best wishes

Ms Laura Stackpoole

Research Ethics Office

INFORMATION SHEET FOR PARTICIPANTS



Ethical Clearance Reference Number: MRS-18/19-10491

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Title of study

Understanding transboundary impacts of multi-hazard early warning systems and their cultural context

Invitation Paragraph

I would like to invite you to participate in this research project which forms part of my Ph.D. research. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask me if there is anything that is not clear or if you would like more information.

What is the purpose of the study?

The purpose of this study is to improve the understanding of transboundary early warning systems and their cultural contexts, specifically in the Kosi River basin. I will do this by exploring the cultural, institutional and governance contexts and identifying the factors that act as barriers to the establishment of effective transboundary early warning systems and suggesting how these constraints may be overcome.

Why have I been invited to take part?

You are being invited to participate in this study because your work directly or indirectly relates to the DRR interventions in the Kosi River basin. The selection criteria for participants in this research includes local government authorities, scientists, DRR experts, local communities and the representatives of the central government of Nepal and India.

What will happen if I take part?

If you choose to take part in the study, you will be asked to participate in a discussion or take part in an open-ended interview. Participation will take place in a safe environment, and will likely last 30-60 minutes, where you will be asked to provide your experience or views regarding early warning system in the Kosi River basin. If you wish to stop, postpone or extend the interview at any point, please just let me know. With your consent, the interview will be audio-recorded on my password protected audio device. This is necessary for me to draw on what you say when I analyse my data. I will transcribe the audio into written format before

analysis. Any personal data which identifies you or others will be anonymised in the transcription process.

Do I have to take part?

Participation is completely voluntary. You should only take part if you want to and choosing not to take part will not disadvantage you in any way. Once you have read the information sheet, please contact us if you have any questions that will help you make a decision about taking part. If you decide to take part, we will ask you to sign a consent form, and you will be given a copy of this consent form to keep.

Data handling and confidentiality

Your data will be processed in accordance with the General Data Protection Regulation 2016 (GDPR).

- You will remain anonymous, and all the information collected will be confidential
- The information you have given will be held for 4 years and after which the data will be destroyed.
- Confirm that data will only be shared within the research team or if it will not be shared with any third parties, without participants' consent.

Data Protection Statement

The data controller for this project will be King's College London (KCL). The University will process your personal data for the purpose of the research outlined above. The legal basis for processing your personal data for research purposes under GDPR is a 'task in the public interest' You can provide your consent for the use of your personal data in this study by completing the consent form that has been provided to you.

You have the right to access information held about you. Your right of access can be exercised in accordance with the General Data Protection Regulation. You also have other rights including rights of correction, erasure, objection, and data portability. Questions, comments and requests about your personal data can also be sent to the King's College London Data Protection Officer Mr Albert Chan info-compliance@kcl.ac.uk. If you wish to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk.

What if I change my mind about taking part?

You are free to withdraw at any point of the study, without having to give a reason. Withdrawing from the study will not affect you in any way. You are able to withdraw your data from the study up until 2019, December, after which withdrawal of your data will no longer be possible due to anonymisation and being committed to the final report. If you choose to withdraw from the study, we will not retain the information you have given thus far.

How is the project being funded?

This study is being funded by the Science for Humanitarian Emergencies and Resilience (SHEAR) research programme, which is jointly funded by the UK's Department for International Development (DFID) and the Natural Environmental Research Council (NERC). (<http://shear.org.uk/>).

What will happen to the results of the study?

The results of the study will be summarised in my PhD Thesis, publications in academic journals or conference presentations. The research findings from my PhD thesis will be published in journals and research papers, which can be obtained from the researcher.

Who should I contact for further information?

If you have any questions or require more information about this study, please contact me using the following contact details: Gaurab Sagar Dawadi – gaurab.dawadi@kcl.ac.uk

What if I have further questions, or if something goes wrong?

If this study has harmed, you in any way or if you wish to make a complaint about the conduct of the study you can contact King's College London using the details below for further advice and information: Dr George Adamson (PhD Supervisor) – george.adamson@kcl.ac.uk

Thank you for reading this information sheet and for considering taking part in this research.

CONSENT FORM FOR PARTICIPANTS IN RESEARCH STUDIES

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: Understanding transboundary impacts of multi-hazard
early warning systems and their cultural context

King's College Research Ethics Committee Ref: MRS-18/19-10491



Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part. If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

I confirm that I understand that by ticking/initialling each box I am consenting to this element of the study. I understand that it will be assumed that unticked/initialled boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element I may be deemed ineligible for the study.

Please tick or initial

☐

1. I confirm that I have read and understood the information sheet dated [20/05/19-001] for the above study. I have had the opportunity to consider the information and asked questions which have been answered to my satisfaction.
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason, up until December 2019.
3. I consent to the processing of my personal information for the purposes explained to me in the Information Sheet. I understand that such information will be handled in accordance with the terms of the General Data Protection Regulation.
4. I understand that my information may be subject to review by responsible individuals from the College for monitoring and audit purposes.
5. I understand that confidentiality and anonymity will be maintained, and it will not be possible to identify me in any research outputs.
6. I consent to my interview being audio/video recorded.

Please tick or initial

☐
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Name of Participant

Date

Signature

Name of Researcher

Date

Signature

interviews at the community level, the open-ended semi-structured questions will be as follows:

1. What do you understand about the flood risk?
2. Please explain about the past flood early warning information you have received from local institutions and your comprehension of it, was it useful?
3. In what language is the flood early warning communicated? Do you understand it?
4. How timely do you receive the warning information regarding floods?
5. how do you act after receiving the early warning messages?
6. Please explain about your understanding and interpretation of the hazard maps.
7. How do local government and other institutions support you for flood preparedness and early warning system?
8. Did you receive training or orientation on what do during, and after flood event?
9. Who participates in the meetings for designing the early warning information? What are discussed in those meetings?
10. Do you take part in the training and orientations on the flood early warning system?
11. Have you identified a safe shelter for the flood in the community?
12. What should be done to improve the early warning system?

The Interview Questions for focus group discussion with community members:

1. How do you interpret the flood risk?
2. How many flood events did you face in the past? What loss did your community suffer due to the flood?
3. Did you receive early warning messages in the past floods?
4. What role did community and local government play during the flood event?
5. Are community members involved in designing early warning messages? If yes, At what stage and how?
6. What should be done to make early warning system effective?
7. What is your preferred way for receiving early warning messages?
8. What do you discuss with your family and community when you receive early warning information?
9. What resources and capacity do you have at the community level for flood response?

The open-ended Interview Questions for the local government representatives:

1. How is risk information generated for the flood early warning system and by whom?
What are the processes involved in it? What information feeds into this process?
2. How do you disseminate the early warning information? Please explain the detail process of dissemination and communication of early warning information to vulnerable communities.
3. What mode of communication is used for the flood early warning system? What language is used in risk communication?
4. How you disseminate the information to communities requiring special needs (disabled, children, elderly)
5. How effective do you think is the current mode of risk communication? Why? What needs to be changed? How?
6. What is the current institutional capacity for risk information generation and dissemination of warning messages?
7. At what stage is community involved in the EWS process?
8. Do you conduct awareness raising activities, mock drills and simulation in the region? Who participates in these activities?
9. What are the issues around the governance of early warning systems? How can these be overcome?
10. In your view how can early warning system be made effective?
11. What is your opinion on transboundary early warning system between Nepal and India? What needs to be done to make it happen? What are the constraints for transboundary EWS at implementation level?

The interview questions for the central level government representatives:

1. Please give details about the infrastructural plans for flood protection in the Kosi River.
2. Please explain how is risk information generated and how does the risk information flow across the border for transboundary early warning system in the Kosi River basin?
3. Which institutions are involved in it?
4. In your opinion how useful are the current operational models of the early warning system? What are the constraints in it?
5. How inclusive are the current early warning system?
6. In your opinion, is it necessary to have transboundary early warning system? Why?
7. What are the policy constraints for the establishment of transboundary early warning system? Such as issues around the bilateral treaties.
8. What are the broader geopolitical challenges related to the implementation of EWS?
9. In your opinion what are the challenges to establish transboundary early warning system between Nepal and India?

The Key informants' interview (KII) questions for scientists, experts from government and I/NGOs:

1. How have the patterns of disaster changed over time in the study area?
2. Has the flood risk increased in the region? How?
3. How much lead time does the current system give to the vulnerable community? In your opinion what could be done to improve the lead time of warning?
4. How is risk information generated in the current EWS?
5. What are the steps involved in the dissemination of EWS to the local people at risk?
6. How inclusive are the currently operational models of EWS for risk knowledge generation and for disseminating of early warning messages?
7. In your opinion, do you think it is important to involve community from the design process of an EWS?
8. In what ways could the communities be involved in the generation of risk knowledge and dissemination of early warning messages?
9. What are the drawbacks within the existing EWS? What needs to be improved?
10. What is the possibility of integrating the EWS systems in Nepal and India and making a transboundary EWS between Nepal and India? How?
11. What changes are required in the current system to integrate the EWS between two countries to make Transboundary EWS?
12. In your opinion, what are the challenges in establishing transboundary early warning system between Nepal and India?

Anonymised list of experts interviewed in this thesis

S.no	Interviewee Code	Sector and Coverage	Affiliation
1	E1	Central government-Nepal	National Emergency Operation Centre - Nepal
2	E2	Central government -Nepal	Ministry of Energy, Water Resource, and Irrigation
3	E3	Central government -Nepal	Ministry of Home Affairs, Disaster Risk Management Department
4	E4	INGO-Transboundary	ICIMOD- Community based EWS project
5	E5	Government-Nepal	Expert working as a consultant in government of Nepal, Flood Monitoring and Forecasting Expert
6	E6	Central government-Nepal	DHM- Flood Modeler
7	E7	Local Government-Nepal	Local Government Official Nepal
8	E8	Central government-Nepal	DHM- Flood Forecast
9	E9	UN Agency-Nepal	United Nations Development Programme
10	E10	Activist-Nepal	Senior advocate and activist for Kosi flood victims
11	E11	Central government-Nepal	Department of Water Induced Disaster Prevention Nepal
12	E12	INGO-Nepal	Oxfam-Nepal
13	E13	NGO-Nepal	Nepal Red Cross Society
14	E14	Central government-Nepal	DHM Flood Forecaster
15	E15	Donor Agency in Nepal	USAID- Donor Agency
16	E16	Scholar in Water Resource- Nepal	Former minister of Water Resource in Nepal, Water Resource Expert, Scholar.
17	E17	INGO-Transboundary	Lutheran World Relief
18	E18	INGO-Transboundary	ICIMOD- Transboundary Kosi Project
19	E19	INGO-Transboundary	Transboundary Rivers of South Asia project
20	E20	Government-Nepal	National Disaster Risk Reduction and Management Authority Nepal
21	E21	NGO-Transboundary	Kosi Victims Society- NGO
22	E22	Donor Agency Nepal	Foreign and Commonwealth Development Office (FCDO) in Nepal
23	E23	INGO-Transboundary	Practical Action in Nepal
24	E24	INGO-Nepal	Red Cross and Red Crescent Climate Centre
25	E25	Policy Institute-Transboundary	Oxford Policy Management Limited
26	E26	Former local government officer, Activist, and scholar in Kosi River from India	Local Government Department, Bihar- District level, Activist, Scholar
27	E27	Local Government- India	Local Government India, Bihar-District level
28	E28	Activist-India	Local Activist, Author on Kosi River in Bihar, India
29	E29	NGO-India	NGO worker-Bihar, India
30	E30	Local Government- India	Water Resource Expert, Author, Activist in Bihar India
31	E31	Local Government - Municipality-Nepal	Local Government Officer – Hanumannagar Municipality, Nepal
32	E32	Local Government - Ward- Nepal	Local government officer in Nepal - Ward level- Hanumannagar-Kankalini
33	E33	Local Government - Ward- Nepal	Local Government officer in Nepal - Ward level- Tilathi Koiladi
34	E34	Local Government-District- India	Local Government officer in India- Supaul District, Bihar

Anonymised list of Community level interviewees

Community level interview Code	Gender	Country	Location
C1	Female	India	Kunauli
C2	Male	India	Kunauli
C3	Male	India	Kunauli
C4	Male	Nepal	Tilathi
C5	Female	Nepal	Tilathi
C6	Female	Nepal	Tilathi
C7	Female	Nepal	Tilathi
C8	Male	Nepal	Tilathi
C9	Female	Nepal	Shankarapura
C10	Female	Nepal	Shankarapura
C11	Female	Nepal	Koiladi
C12	Male	Nepal	Shankarapura
C13	Male	Nepal	Shankarapura
C14	Female	Nepal	Koiladi
C15	Male	Nepal	Shankarapura
C16	Male	Nepal	Koiladi
C17	Male	Nepal	Koiladi
C18	Female	Nepal	Rampura-Malhaniya
C19	Female	Nepal	Rampura-Malhaniya
C20	Female	Nepal	Hanumannagar
C21	Male	Nepal	Rampura-Malhaniya
C22	Male	India	Kunauli
C23	Male	Nepal	Rampura-Malhaniya
C24	Male	India	Bathnaha
C25	Male	Nepal	Rampura-Malhaniya
C26	Female	Nepal	Hanumannagar
C27	Male	India	Bathnaha
C28	Male	Nepal	Hanumannagar
C29	Female	India	Bathnaha
C30	Male	India	Bathnaha
C31	Male	India	Haripur
C32	Female	India	Bathnaha
C33	Male	India	Haripur
C34	Male	Nepal	Hanumannagar
C35	Male	India	Haripur
C36	Male	India	Haripur
C37	Male	Nepal	Hanumannagar
C38	Male	India	Kamalpur
C39	Male	India	Kamalpur
C40	Female	Nepal	Hanumannagar
C41	Female	India	Haripur
C42	Female	India	Kamalpur
C43	Male	India	Kamalpur
C44	Male	India	Kamalpur

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