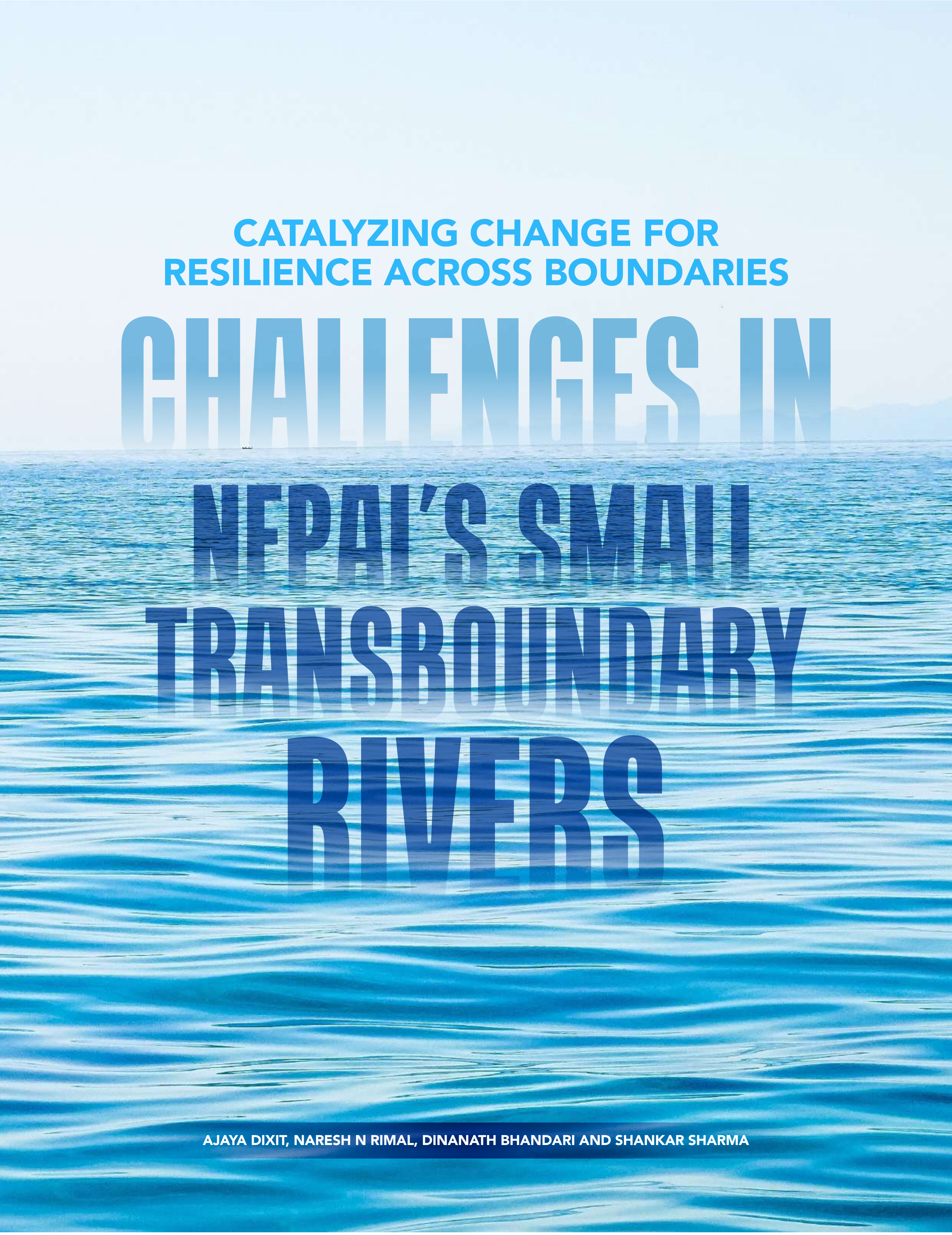

CATALYZING CHANGE FOR RESILIENCE ACROSS BOUNDARIES

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AJAYA DIXIT, NARESH N RIMAL, DINANATH BHANDARI AND SHANKAR SHARMA

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Executive Summary

The analysis of environmental, social, and economic problems at the local, regional, and global levels requires a transdisciplinary approach to understanding and addressing them. This study highlights how structural interventions and dysfunctional policies that neglect and free-ride the terrestrial and freshwater biodiversity of Chure Basin (CB) districts in Nepal have cascade impacts on the well-being of humans and nature. CB rivers, dependent on the monsoon and the Chure range, which is hydro-morphologically diverse, behave uniquely and respond differently from climate and landuse/landcover changes, and other human interventions.

Operating on the local to regional scales, the issue of inundation along certain border areas of Nepal transcends political and disciplinary boundaries. It is part of the processes of change in the socio-ecological landscape with limited historical data that limits our understanding of the increasing exposure to climate hazards as well as local, border-side inundation challenges enmeshed in sometimes sticky Nepal-India bilateral relations. Increased flood damage impacts the poor, marginalized, and women. In addition, ecosystem services are poorly valued despite the wealth of promising policies.

The CB districts face chaotic urbanization and degradation of aquatic, and terrestrial ecosystems and socio-economy linked to poor environmental governance of the region's, unique socio-economy, demography culture, and development. The haphazard disposal of untreated solid and liquid wastes, in the region degrades riverine environments and water quality, including that of underground aquifers. Such practices harm both the aquatic ecologies of receiving bodies and the livelihoods of those who depend on river ecosystems.

Similarly, haphazard sand extraction alters landscapes and riverine morphologies, exacerbating flooding, erosion, and siltation as well as damage to infrastructure and local assets hurting communities on the socio-economic fringe, and economies at multiple levels. The practice is part of a well-established supply-and-demand ecosystem with a nexus of contractor-politician-mafia members operating in a regime of poor governance.

Systematic data on river discharge, sediment flow and geomorphology of CB rivers, rainfall, temperature, soil moisture, groundwater dynamics, natural vegetation, flora, and fauna that help establish a direct link between extreme rainfall events and flood damage is limited. Although the measurement of river discharges and water levels in Nepal started in the 1960s, rivers flowing through CB districts are not systematically or regularly monitored, and the lack of data makes forecasting flood discharges of different magnitudes and estimating needs for water management difficult.

The other major obstacle to the effective design and management of flood mitigation measures is a dearth of systematic documentation of the current state of the changes in CB districts. The lack of historical data limits our ability to make climate-friendly strategies. Without grounded evidence, local authorities will face challenges in moving towards resilience-building and adaptive management. To be able to design effective strategies for minimizing weather-related disaster risks including floods, the links between impacts and extreme events need to be established with contextualized assessments of loss and damage.

In theory, challenges imposed by changing precipitation patterns and other events in the high-mountain and mid-hill regions should not affect CBs as they are not linked directly to snow or glaciers or the mid-mountain region. However, in practice, CBs will have to bear the downstream impacts of changes in the hydrology and socio-economy of upper regions via migration and changes in flow regimes. For instance, irrigation barrages built-in snow- or glacier-fed and mid-mountain rivers serve areas of CBs and the people in their command areas. Overall, along with its inherent challenges, the CB region will also face risks transferred to users via existing water infrastructures and institutions but have not been assessed. Within such complexity, vulnerabilities become nested, and impacts cascade from one location to another, often in an unimaginable way.[1]

Flooding has been on the agenda of Nepal-India bilateral discussions for the last half a century (1970 to date) although limited in scope. The minutes of meetings between the water sector agencies of the two countries provide details about the inundation of areas along the border. The participants in these meetings accorded consideration to the structural measures and did not include watershed conversation, multiple uses of water and institutions that manage their different uses, or the need to reduce vulnerability to climate change impacts that cascade from one location to another. Nor do they provide input to inform policies that include insights from studies of changing exposure to climate hazards, flow responses, and local natural resource management practices. Emerging insights are not streamlined into water education to any appreciable degree.

The emerging socio-environmental challenges common across the CB region are appropriate entry points for India and Nepal to address environmental and climate change challenges. Both need to focus on achieving balanced socio-economic development through climate-smart technological practices which consider environmental and social considerations and rely on and use robust information for policymaking and implementation. Small rivers in the CB region are important candidates for beginning the process of joint stewardship beginning with flood disaster risk mitigation.

While in Nepal the role of local governments in disaster risk reduction is clear, responses are guided by the objective of providing immediate rescue and relief. Efforts to engage with counterpart areas in India for strategic solutions are limited. On both sides of the border in the CB region, in Nepal and India, the absence of alternative livelihoods is another major challenge. Nepal's eighteen CB districts, which have the highest rates of out-migration of the country's seventy-seven districts, manifest these challenges. Despite easy accessibility, fertile land, and other opportunities, the CB region has several pockets of poverty and many highly marginalized communities.

The agreements on the Koshi, Gandaki, and Mahakali (Sarada) rivers and the existing instruments shared by Nepal and India to manage transboundary rivers need to be reviewed to determine the risks they face. The ethos of turning to reductionist engineering as solutions to flood control, irrigation, and hydropower development guided the design of these agreements. The agreement on the Mahalaki (Sarada) River was first signed more than 100 years ago in 1920 (Sarada Treaty). It was revised in the Memorandum of Understanding in 1991. Nepal and India signed the updated Mahakali Treaty in 1996. The agreements on the Koshi, and Gandaki rivers were signed in 1954 and 1959. The treaties' provisions do not cover sustainable water management, promote participation, or recognize emerging risks, and are also limited in their ability to harness opportunities to support the building of resilience. The power asymmetry between Nepal and India and the feeling in Nepal of having gotten unfair deals in these treaties makes future pathways unclear.

Interactions between Nepal and India take place among various actors and sectors, including trade, customs, security, border patrol, religion, medical treatment, people's day-to-day dealings across the border, and travel to places of faith and pilgrimages in both countries. The role of these engagements as plural diplomatic avenues contributing to positive Nepal-India relations for meeting larger environmental needs must be realized. Discussions between the two countries on development, security, and economic cooperation have not recognized the fact that environmental risks are increasing. Bilateral interactions on the flood, do not include discussions on the challenges of degrading natural ecosystems either.

CB districts also face fast-paced changes as a result of the conceptualization, design, construction, usability, and maintenance of physical infrastructure such as roads and proposed railway lines linked to the riverscape. In Nepal's CB districts, all rivers flow from north to south and all major highways with bridges and culverts run perpendicular to them. Highways with bridges need to provide uninterrupted service to guarantee the connectivity of rural and urban communities so floods that disrupt them bring challenges. Building flood-adapted infrastructure requires moving away from the siloed approach and toward systemic learning and the application of that learning.

Compartmentalized water education insulated from critical questioning, lived realities, ongoing challenges, and change processes is a limitation that must change. Within a singular disciplinary boundary, water education promotes a supply-driven approach to water development and management that focuses largely on engineering and structural solutions that preclude gender and social inclusion. Instruments such as environmental and strategic impact assessments offered for environmental governance and stewardship are used ritualistically with poor compliance. Mitigating measures are not effectively implemented. Poor implementation of policies, acts, and regulations and lack of coordination among agencies in the practices of natural ecosystem conservation and infrastructure developments further adds to the challenges.

Decision-makers' insufficient understanding of the roles and importance of small rivers in contextualizing flood disasters is synonymous with the disconnect between reality and interventions. Locally rooted efforts related to the reduction of social vulnerability, water management, and adaptive actions that provide useful lessons are scattered and await amalgamation into a coherent whole. Systemic analysis and responses based on insights from grounded practices implemented through good governance can lead to resilient outcomes. The limited learning, often from civil society and community efforts on the part of government agencies debilitates transformative changes.

We make the following broad recommendations to help meet the challenges of Nepal as a whole as well as in the CB region in particular, in a rapidly changing climate scenario.

1. Establish a systematically integrated data collection mechanism and repository platform informed by the economic, ecological, and social contexts that support the national development agenda. The available but fragmented data and information need to be coherently linked to this platform so that policy designs and interventions can be made easily following further analysis and research to be used at the ward, municipality, district, provincial, and national levels. The National Planning Commission (NPC) must lead this process with support from the Central Bureau of Statistics (CBS), concerned sectoral agencies, and the National Disaster Risk Reduction and Management Authority (NDRRMA) providing support in managing data on disaster losses and damages.
2. Local governments must systematically develop inventories of small seasonal rivers, wetlands, and other ecosystems of CBs with the objectives of rejuvenating small rivers, mitigating pollution, and reducing flood disaster risk and addressing overlapping jurisdiction. In this exercise, help of related stakeholders across the border must be sought.
3. Increase investments in expanding knowledge in science, particularly in more granular data on rainfall, temperature, humidity, river discharge, sediment flow, groundwater and water quality, and soil moisture content, and their relation with social systems as important step in developing integrated knowledge (a synthesis and assimilation of natural science, social science, and local and traditional insights) for environmental governance.
4. Take measures in the urbanization process to maintain green spaces and water bodies for aesthetic, healthy living, and equitable future through an improved understanding of how institutions and organizations operate as well as the relationships among the state, citizens, communities, and the private sector to identify points of entry for catalyzing the change process required to secure such a future.
5. Ensure sustainable livelihoods opportunities to people as key to help establish resilient communities by creating opportunities for them to be independent and address ecological, social, and livelihood challenges faced by the poor in the region.

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[1] Friend et al. (2015)

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Opinions expressed in this report are those of the authors, not the organization supporting the research and individuals who found time to discuss and share their thoughts with us.

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List of Acronym

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
AR6	Assessment Report 6
CAMC	Conservation Area Management Committee
CBDRM	Community-Based Disaster Risk Management
CDAFN	Community Development and Advocacy Forum Nepal,
CDM	Clean Development Mechanism.
CFUG	Community Forest Users Group
CRF	Climate Resilience Framework
CTML	Chure Tarai Madesh Landscape
DFO	District Forest Officer
DHM	Department of Hydrology and Meteorology
DOEC	District Emergency Operation Centre,
DoI	Department of Irrigation
DoR	Department of Road
DoWRI	Department of Water Resources and Irrigation
DPTC	Disaster Prevention Training Center
DRR	Disaster Risk Reduction
DRRM	Disaster Risk Reduction And Management
DPTC	Disaster Prevention Traning Centre
DSCWM	Department of Soil Conservation and Watershed Management
DTW	Deep Tubewell
DWIDP	Department of Water-Induced Disaster Prevention
EGR	Eastern Ganga Region
EIA	Environment Impact Assessment
EWS	Flood Early Warning System
FMIS	Farmer-Managed Irrigation Systems"
GBM	Ganga-Brahamaputra-Meghna
GEAG	Gorakhpur Environment Action Group
GESI	Gender and Social Inclusion
GLOF	Glacier Lake Outburst Flood
GoI	Government of India
GoN	Government of Nepal
HKH	Hindu Kush Himalaya
ICIMOD	International Centre for Mountain Development
IDNDR	International Decade for Natural Disaster Reduction
IEE	Initial Environment Evaluation
IPCC	Intergovernmental Panel on Climate Change
ITDG	Intermediate Technology Development Group

LEOC	Local Emergency Operation Centre.
LPG	Liquified Petroleum Gas
MC	Mercy Corps
MoHA	Ministry of Home Affairs
MPA	Megh Payeen Abhiyan
MOU	Memorandum of Understanding
MCC	Millennial Challenge Compact
NDRRMA	National Disaster Risk Reduction and Management Authority
NEOC	National Emergency Operation Center
NGO	Non Government Organization
NGR	Nepal Government Railway
NJJR	Nepal Jainagar Janakpur Railway
NPC	National Planning Commission
NTFP	Non-Timber Forest Product
NWP	National Water Plan
NWRS:	National Water Resource Strategy
PEOC	Provincial Emergency Operation Centre,
RSDC	Rural Self-Reliance Development Centre
SAM	South Asian Monsoon
SDG	Sustainable Development Goal
SEA	Strategic Environmental Assessment
SSK	Sahbhagi Sikshan Kendra
STW	Shallow Tubewell
UP	Uttar Pradesh
USAID	United States Agency for International Development
USGS	United States Geological Survey
WPPF	Water Resources Project Preparatory Facility
WUA	Water Users' Association

Notes on Terminology

This study uses the following terms

Hindu Kush Himalaya (HKH): Ten major rivers of Asia originate here.

Ganga-Brahamaputra-Meghna (GBM): Three major rivers of HKH that flow through parts of China, India, Nepal, Bhutan and Bangladesh.

Eastern Ganga Region (EGR): The region encompassing Bangladesh, Nepal, West Bengal, Bihar and Uttar Pradesh.

Chure Tarai Madesh Landscape (CTML): The geographic unit encompassing all of Chure region and Tarai/Madesh within which CB districts exist.

Chure Basin (CB): The region through which the seasonal rivers that originate in Nepal's Chure range flow through Tarai/Madesh of Nepal and into India.

Tarai/Madesh: Tarai is southern plain region of Nepal while Madhesh identifies the identity and ethnic composition of the population.

BACKGROUND

Background

01

1.1 CONTEXT

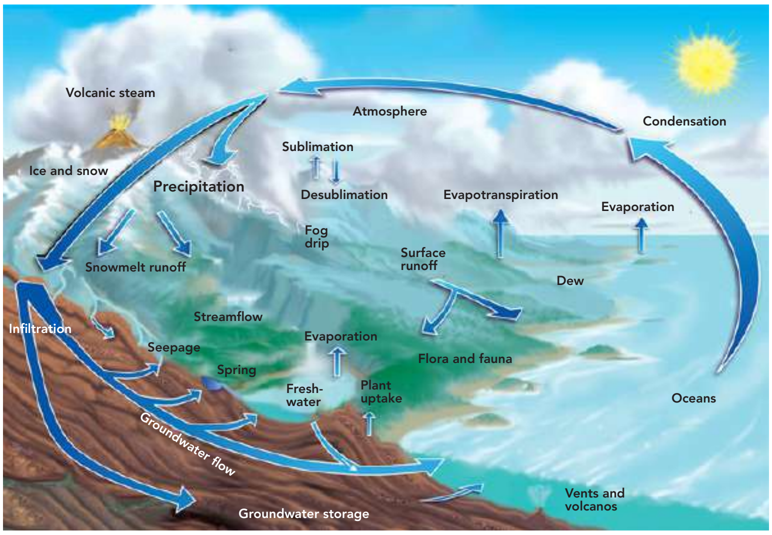
In 2022, the United States Geological Survey (USGS) published an image (Figure 1.1) of the water cycle modified by human actions. In this image, the USGS brings, humans into the picture and presents the water cycle “as a complex interplay of small, interconnected cycles that people interact with and influence, rather than one big circle”. The earlier images showed only the way water moved naturally within the cycle and did not depict its movement through various human-built structures, storage, and uses. In the last 100 years, the construction of dams, barrages, canals, embankments, settlements, roads, railway lines, laying of pipes, groundwater pumps, and pollution have substantially changed the way water moves within the hydrological cycle and its quality[1]. In addition, human actions such as the conversion of agricultural land into real estate, paving of green and open spaces with concrete and other impervious materials, and encroachment on wetlands have further altered regional hydrologies.

In all river basins across the world, including the Ganga and its tributary sub-basins, the natural hydrological cycle is no more the same as that of 100 years ago. Presently, water moves through multiple ecosystems – including, dry basin, wet basin and agricultural basin, coastal plain and urban regions, dams and barrages, inter basin transfers, modification by embankments, pumps and industries – connected across watersheds and at continental scales[2]. Climate change spawned weather events add a new complex layer on the altered landscape and communities[3]. The increasing magnitude of the peak discharges and resulting damages and losses due to flood disasters is one of the major impacts of these ongoing change processes.

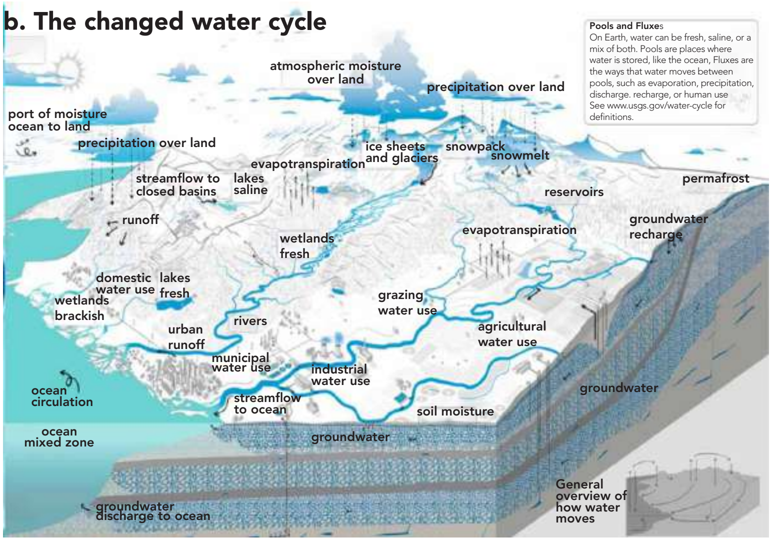
Both changes in climate and in terrestrial ecosystem pose challenges in adapting to “too little water”, “too much water”, and “too dirty water”. While the first two can be considered the natural outcomes of South Asia and Ganga basin’s water regime (Figure 1.2), the third has been brought about by human folly. In this region, the monsoon brings high rains for about four months and then in the remaining months, rainfall is lower, and too little water is available. Too much water in the monsoon months can lead to flood disasters whose effective management generally, and particularly in South Asia, has remained, and remains elusive as damages keep rising. While

FIGURE 1.1: THE IMAGES OF NATURAL AND CHANGED HYDROLOGICAL CYCLE

a. The natural water cycle



b. The changed water cycle



Source: USGS (2022)

rainfall is the main trigger of floods, the naturally diverse, changed terrestrial landscape of CBs brought about by human interventions have made different types of flood impacts widespread: inundation, sand casting, and bank cutting. Researchers have suggested considering other types such as flash floods along the Chure (Siwalik) range, flooding of settlements between two embankments of a river, the region between embankments built on two adjoining rivers, flooding of non-embanked lower plains, and the regions outside of an embanked river[4].

Among these topologies is the unique problem of inundation along the border between Nepal and India, the starting point of this study. During the monsoon months this unique problem surfaces in Nepal's Tarai region close to the country's border with Bihar and Uttar Pradesh, the states of India mostly along Nepal's rain-fed small seasonal rivers[5]. Called rivers of the Chure basins (CBs) in this study, they originate in Nepal's Chure range, flow through the districts of Nepal's Tarai/Madhesh and flow across into the northern parts of the two Indian states. The construction of embankments, dykes or levees on India's side of the border has given rise to inundation problems in the parts of lower CBs in Nepal while media reports suggest that interventions in a few river locations in Nepal also inundate a few border areas in India[6]. In the transboundary setting, the embankments on rivers constrict the flow submerging upstream areas with negative impacts on local communities. The problem is an irritant issue that affects the cordial relationship between Nepal and India.

During the monsoon months, these rain-fed rivers cause large-scale inundation in the CBs in Nepal and the effects of this flooding can also extend across the areas of the two border states. The Eastern Ganga Region (EGR) that covers present-day Bangladesh, West Bengal, Bihar, eastern Uttar Pradesh and lower CB districts in Nepal, have a low land slope which makes them naturally susceptible to flooding (Figure1.2). Even a slight increase in river water levels can submerge land and the water is not immediately drained[7]. In such a landscape, embankments along a river further narrow its natural flow width, prevent tributary river to empty in the embanked river, with water stagnating for a longer period of time. The stagnant water lowers crop productivity, affects human assets and thus adversely affects local economies and community well-being.

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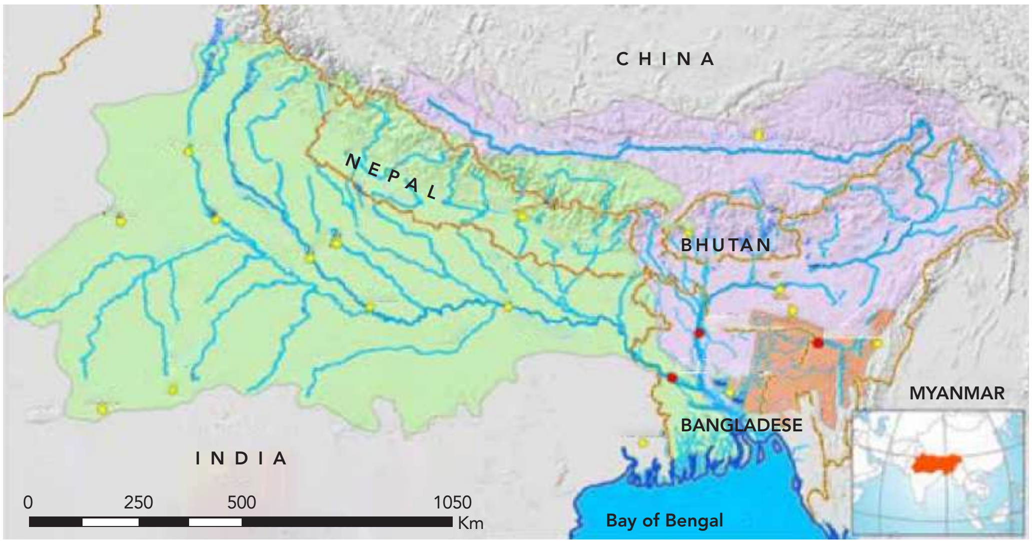
FIGURE 1.2: GANGA RIVER AND ITS TRIBUTARIES



Source: Palash, et al (2018)

Historically, rainfall events in CBs have triggered floods and their impacts have cascaded across boundaries. Some of the recent major flood events, such as those of 1987, 1998, 2007, 2008, and 2014 affected various parts of the CBs in Nepal, Bihar and Uttar Pradesh. From 11 to 17 of July in 2017, Nepal's CB region from east to west received very heavy rainfall. Some rainfall stations in Nepal recorded as high as 450 mm in 24 hours (discussed in Chapter 3) that resulted in widespread flood disaster in the CB region[8] as well as the two southern Indian states[9]. The same weather system led to high rainfall caused widespread flooding in Bangladesh too. Few years later, in October 2021 untimely heavy rainfall led to floods that affected various parts of Nepal, including the CB regions damaging infrastructure and almost-ready-to-be-harvested paddy in most districts[10].

A number of scientific studies in the plains of Nepal and India and the lived experiences of the region's communities validate the rising trend of recurring erratic extreme rainfall, secondary flood hazards, droughts, more frequent high winds, rising temperature and humidity, and foggy cold conditions[11]. The emerging climate regime is also altering the moisture dynamics of the landscape, the flow responses of watersheds, and groundwater recharge that can translate into higher magnitudes of, as mentioned above, various typologies of floods in the CBs and impact freshwater ecosystems. While the upper regions of CBs face flash floods, the middle and lower CBs face sheet and riverine floods which will continue to make the problem of inundation along the border more serious if left unanswered.

In Nepal–India joint committees on water resources, inundation and flood management, officials of Nepal and India have been discussing the challenges of border inundation since the early 1970s. The suggestions these bilateral committees prepared for addressing the problem consist mostly of structural measures such as embankments[12]. This singular focus of the committees' efforts is indicative of a deficit in their consideration of the changing and the stressed eco-hydrology of the CBs. Their approach is also illustrative of the fact that, in South Asia, structural measures continue to remain the dominant component of the prevailing approach to flood disaster mitigation.

From the perspectives of the water sector agencies of Nepal and India, this structural approach as a preferred method of food management provides immediate respite from floods, despite its technical limitations in the region's dynamic rivers. Flowing through the region normally with high rainfalls and higher groundwater tables, and carrying a high sediment load, rivers become rather violent in the monsoon months, and, they regularly shift courses, a fact that presents major challenges in controlling them using embankments. In addition, embankments have long-term adverse consequences on the landscape and people living there as already evidenced in Northern Bihar and Bangladesh[13]. In recent times, parts of Nepal CBs are beginning to face similar impacts but as yet remains inadequately studied.

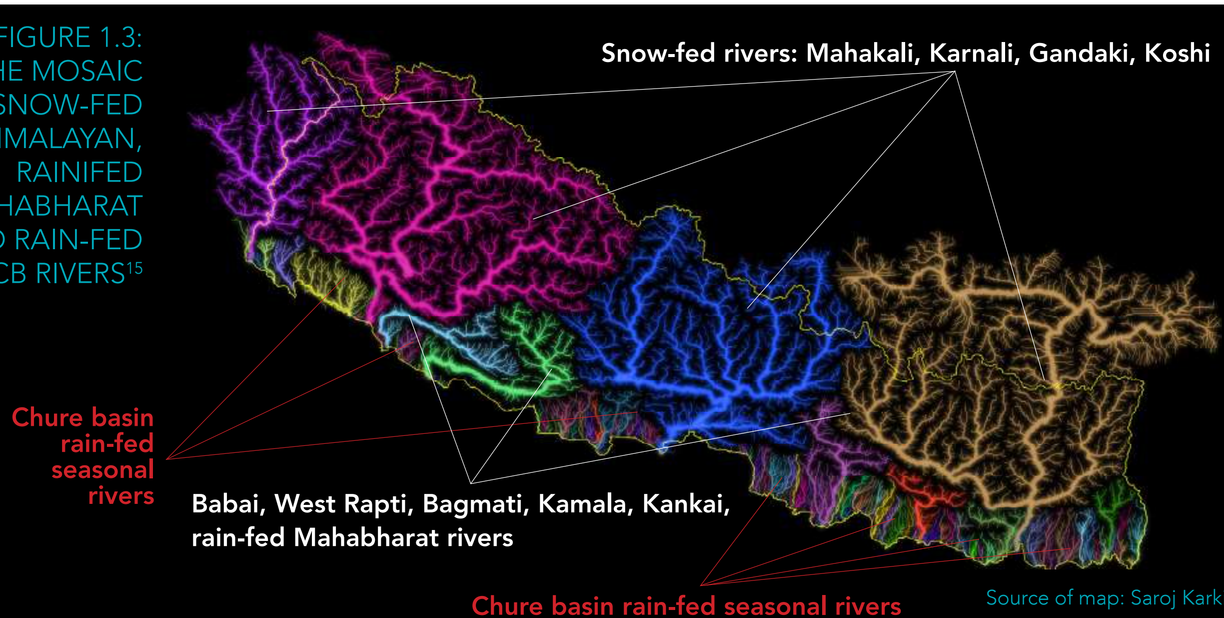
Regardless, the approach is already embedded in the region's political economy, and institutional culture of water sector agencies', and as a result it would be hard to immediately switch to alternatives by discarding embankments. Yet, it is important to expand the scope of the flood risk management approach that is sensitive to the region's changing ecology, and consider a suite of methods such as flood warning and forecasting, preparedness, livelihood enhancement and social support to communities in the frontline facing the impact of floods. This study has aimed for studying the flood challenge in Nepal's eighteen CB districts from a systemic perspective and proposes a pathway for a more flood-resilient future.

1.2 STUDY AREA AND PROBLEM STATEMENT

These eighteen CB districts are under the jurisdiction of Nepal's four provinces (Province Number 1 as well as the Madhesh, Lumbini, and Sudur Pachhim provinces) (see Table 3.1). The rivers flowing through Nepal's CBs (Figure 1.3) into Bihar, and Uttar Pradesh are eco-hydrologically linked. These seasonal rivers and their ecosystems are extensively used in Nepal's CBs and contiguous areas across the border for irrigation and local economies. These ecosystem services are sources of livelihoods of one of the most marginalised population of the region[14]. They also support recharge of the region's contiguous groundwater aquifers; which people tap with pumps and wells for both drinking, other domestic usages and irrigation purpose. Moreover, industries and businesses in both countries also use the CB rivers; water and underground water. In addition, disposal of untreated effluents from industries and settlements are polluting these rivers. See page, inundation, rising river water temperatures, and waterlogging further degrade water quality. Maintaining the ecosystem health of the rivers is critical for the people of the Nepal's CB region and across the border.

Local communities, particularly those in social and economic margins, living in these regions are coping with the impacts, using the available yet depleting eco-services such as water flow and competing for natural resources with communities in adjoining regions. These emerging dynamics are often not included in Nepal-India bilateral discussions, policy development, diplomatic engagements or water management plans[16]. Despite challenges inundation, water pollution, and seasonal water scarcity pose, the two governments focus mostly on engineering interventions for economic gains through harnessing of the large snow-fed transboundary rivers and fail to consider the emerging challenges posed by climate change and environmental degradations.

FIGURE 1.3: THE MOSAIC OF SNOW-FED HIMALAYAN, RAINIFED MAHABHARAT AND RAIN-FED CB RIVERS[15]



Source of map: Saroj Karki

Thus, as we began the study, we realized that it has to be located in the framing of ongoing change processes based on grounded theory.

1.3 OBJECTIVES

This study aims to identify strategies to be pursued for building resilience across boundaries, taking CBs as the case in the context of climate change emerging as a new source of stress. This approach would open avenues for bottom-up water dialogue in the various scales of the transboundary setting of the rivers of the Ganga Basin. The following are the objectives of the study".

- Understand the process of inundation as it fits within the CB's social and ecological dynamics;
- Assess the ongoing change processes associated with development interventions in CBs;
- Analyze the minutes of meetings between Nepal and India on water resources for lessons on inundation;
- Purposively identify local initiatives regarding floods risk reduction and water management;
- Draw insights on the change processes including identify gaps and opportunities;
- Identify elements that will help in taking actions to build resilience across boundaries considering climate change and environmental degradations; and
- Explore avenues for pluralized diplomatic efforts for meeting the objectives of resilience building.

1.4 RESEARCH QUESTIONS

The initial effort was to understand the border inundation. However, during the study phase it was realized that a broader approach of understanding of the dynamics of CBs, transboundary flood water management, and the response by the state agencies was needed. The following key research questions guided the study:

- How long has inundation along the Indo-Nepal border been a problem and what is the characteristics of that problem?
- How is the problem linked to the historical context of responses to floods in the region?
- How have bilateral discussions of transboundary water approached the problems of inundation and flooding?
- What were the outcomes of these dialogues and what gaps remain?
- What systemic challenges does the problem of inundation suggest?
- What are some recommendations for concerned stakeholders about how to respond to flooding, inundation, and other transboundary water challenges?

1.5 DATA SOURCES AND METHODOLOGY

In order to meet the objectives, the study is based on review of published and unpublished reports. The data sources were as follows.

Literature: A literature review is the standard method for thematic analysis in grounded theory. Relevant literature was carefully screened for analysis.
Key informants: Meetings with key participants were centered on open-ended questions designed to elicit information for analysis. The participants were from relevant agencies in Nepal and India, persons in both countries who have been working on water resource management and disaster risk reduction, and few local members of local communities experiencing and witnessing changes in the CBs
Nepal-India meeting minutes on water resources: The minutes of meetings on water resources held between Nepal and India between1970 and 2020 were reviewed

as one of the key data sources. This helped understand the context within which water sector agencies in Nepal and India functioned and approached the problems of flooding.

Quantitative data: Secondary quantitative data were used as a descriptive statistic and to support the qualitative information obtained via interviews.

Policies reviews: Policies related to climate exposure, natural ecosystem, infrastructure, and users were collected, reviewed and synthesized.

In understanding the direction towards a more flood-resilient future, the study also used lessons from past research on flood disaster management in the EGR, relevant regional studies on the implications of climate change in South Asia as well as literature on ecological degradations. The reviews, the study of literature and the discussions with key stakeholders during this study helped understand the perspective of state level agencies about the challenges flood risks, climate change and environmental degradations[17].

For analyzing temperature and rainfall trends in the CBs, we used the available data set on daily rainfall, mean (T_{mean}) maximum (T_{max}) and minimum temperature (T_{min}) from 1980–2020) of 220 manually operated rain gauges stations maintained by Nepal's Department of Hydrology and Meteorology (DHM). To examine time-series data of these parameters we delineated the analysis area of the CB region below the contour line (1500 m) of Chure range (Figure 1.4). Thus, we selected forty two stations shown by red triangles (Figure 1.4) for analysis.

1.6 IMPLICATIONS OF THE STUDY

The study will be useful to seek ways to help achieve a tangible reduction in flood risks by improving drainage, giving rivers space and addressing social vulnerabilities that exacerbates the impacts of flood events. The recommendations broadly apply to local and national governments, non-government organizations and other stakeholders who wish to creatively respond

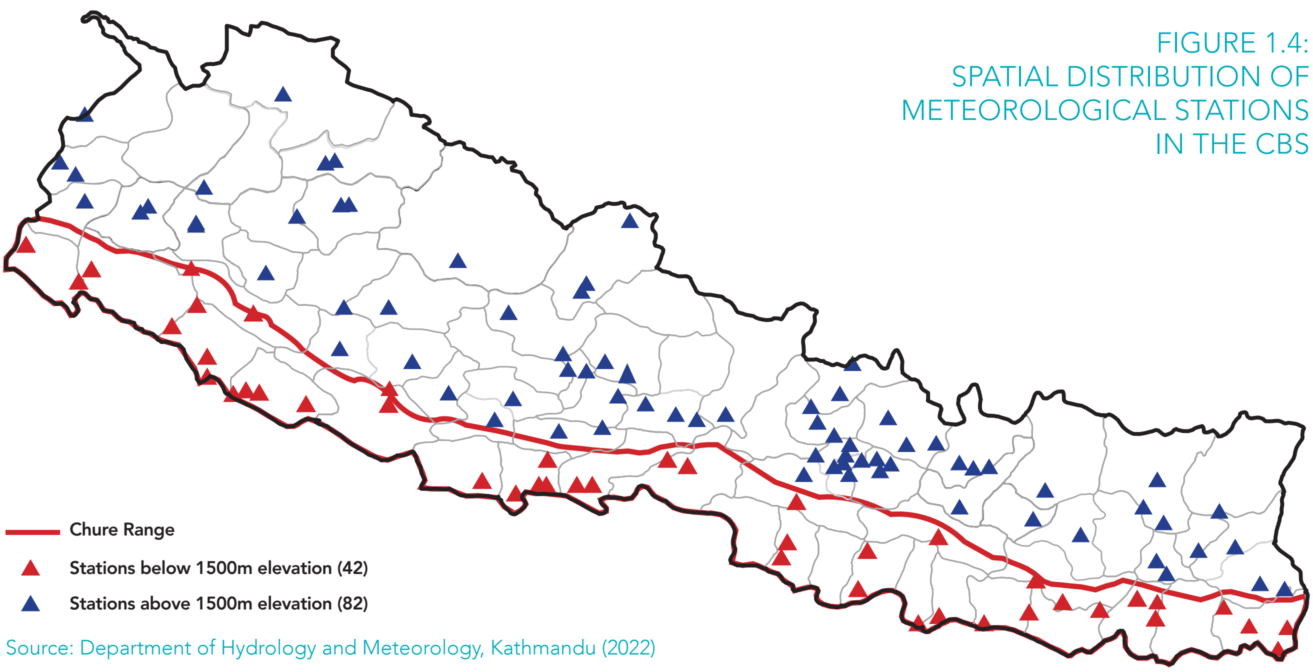


FIGURE 1.4: SPATIAL DISTRIBUTION OF METEOROLOGICAL STATIONS IN THE CBS

Source: Department of Hydrology and Meteorology, Kathmandu (2022) to inundation and other transboundary challenges. In addition, the findings will help inform ways to engage and organize cross-border dialogues at the local, state, and national levels to sensitize authorities, stakeholders, and general participants about bottom-up diplomacy in amicably addressing the localized problem of inundation as well as lowering flood risks. This way the study will help to (1) employ engagement strategies for embedding contextualized knowledge within affected and outside communities, (2) identify cross-boundary strategies appropriate at various scales for pursuing adaptive actions designed to minimize adverse impacts, and (3) use bottom-up dialogue as an element of diplomacy to highlight the benefits of collaborative strategies for building resilience across boundaries. The insights can also apply to other seasonal transboundary rivers of the Ganga and other basins.

1.7 LIMITATIONS OF THE STUDY

Despite the combined heuristic capability of the researchers' more than 80 years of accumulated experience in water resource management, disaster risk reduction, resilience, and climate change adaptation, the complexity embedded in the inundation challenges that demanded nuanced information for analysis was not available at the scale of the CB region. The reviews of existing materials suggested the need to undertake a more in-depth analysis of the change dynamics of the CBs, and decision-making processes at the national government, state and local levels and their interactions. Unfortunately, the researchers were unable to do so in this study as the examination of these aspects would require more time and activities than envisioned. This also limited the scope of the study and covers only rivers that flow through CB districts in Nepal. It presents a holistic perspective that can set a stage later to include CB-dependent areas in Bihar and Uttar Pradesh. The lack of systematic availability of data on the five pillars of resilience (explained in next chapter 2) specific to the CBs as well as the other published materials was insufficient to glean lessons on the impacts and social vulnerability.

The other limitation was the lack of readily available high-resolution maps of the CB basins that showed the number of these small rivers that extend across the border. Similarly, information on migration, livelihood diversification, as well as the role of social networks that play key roles in resilience building, is limited. The deeper analysis of urbanization, population exposure, industrial processes and poverty alleviation, and social vulnerabilities, some of the elements of the going change processes, particularly through extensive local-level interactions was beyond the scope of this study. Thus, it does not offer prescriptive public policy suggestions to address the specific problem of inundation or other emerging challenges. Our review suggests that the multi-dimensional nature of the challenges of inundation and other environmental problems in the CB river systems and other dynamics requires more detailed analysis and interpretations for designing and implementing policies. The delicate geopolitical relationship between Nepal and India, the emerging complexities as well as the lack of a grounded ecological narrative of the CB region, also limited the making of prescriptive suggestions.

1.11 ROAD MAP FOR THE REPORT

The report is organized as follows. Chapter 1 presents background of of the study Chapter 2 discusses the nature of cascading disaster, the conceptual framework for building resilience across borders. Chapter 3 presents the natural ecosystem of the

CBs while Chapter 4 and Chapter 5 respectively introduce human-built systems the social context in CBs. Chapter 6 presents the history of flood control measures and the cooperative efforts by the Government of Nepal (GoN) and Government of India (GoI) in addressing inundation along the border in specific areas including the issue of flood warning and forecasting. Chapter 7 discusses the impacts of the interventions and uses in the CBs. In the next Chapter 8 a broad examination of public policies as well as their implementation and gaps are presented. Chapter 9 draws insights from the earlier discussions and Chapter 10 makes recommendations. The final Chapter 11 recapitulates key aspects of the study and lays out implications regarding emerging risks in the CBs and suggests ways to achieve effective resilience across boundaries.

NOTES

1. See USGS (2022).
2. Ibid USGS (2022)
3. Mirza & Dixit (2021) highlights South Asia as a climate change hot spot.
4. Researchers are also looking at typologies of flood and their impacts for more effective responses, see Gupta, et al. (2020).
5. Discussions on border inundation problems are found in Dixit, et al. (2004), and Dhungel et al. (2009).
6. Nepali broadsheet Kantipur highlights the recurring nature of the inundation problem along the border, see https://ekantipur.com/news/2022/06/09/165473738204072873.html.
7. As early as 1927, Mahalanobis (1927) recognized the relation between low slope of the EGR land river stages
8. NPC (2017) provides details of scale of the disaster and recovery plan.
9. For further information visit https://www.unicef.org/press-releases/16-million-children-affected-massive-flooding-south-asia-millions-more-risk; https://www.bbc.com/news/world-asia-40975232; https://www.independent.co.uk/news/world/asia/india-floods-bangladesh-nepal-millions-affected-says-un-a7920721.html (Accessed February 6, 2023).
10. Bhandari & Dixit (2022) presents an assessment of the impact of the 2021 disaster in Nepal.
11. See Mirza & Dixit (2021). For a discussion on the foggy condition see https://www.himalmag.com/the-dark-white-shroud/ and Dixit & Bhandari (2023).
12. Minutes of the fourteenth meeting of Nepal-India joint committee on inundation and flood management (January10-14-2011).
13. The 2023 report by People's Commissions on Koshi made public in Patna highlights the larger challenges of flood management in Koshi River in the plains as a representation of the challenges of flood management in EGR. In Bangladesh, the mostly deltaic country floods lead to human suffering and impoverishment of the poor, loss of property, crops, cattle, adversely affecting food security and poverty, and cause major damages to infrastructure, see Syadur et al (2017). See NPC (2017) for impacts of 2017 flood in Nepal CBs. The 2022 August flood in Pakistan showed major limitation of conventional ways of flood management. According to the World Weather Attribution group "devastating impacts were also driven by the proximity of human settlements, infrastructure (homes, buildings, bridges), and agricultural land to flood plains, inadequate infrastructure, limited ex-ante risk reduction capacity, an outdated river management system, underlying vulnerabilities driven by high poverty rates and socioeconomic factors (e.g. gender, age, income, and education), and ongoing political and economic instability.". https://www.worldweatherattribution.org/wp-content/uploads/Pakistan-floods-scientific-report.pdf
14. Grill et al (2020) highlights the importance of the CB rivers in meeting local livelihood needs.
15. The classification is based on Zollinger (1979) and in Chapter 3 we provide further classification of the rivers after Grill et al (2020).
16. Unni et al (2021) have noted that small rivers are neglected and that they face governance challenges (Unpublished).
17. In EGR both rivers and groundwater face increasing degradation. MacDonald et al (2015) broadly highlights arsenic contamination of the region's groundwater while Grill et al (2020) using integrated water quality pressure index (WQPI) consisting of a) nitrate prediction, b) phosphorous balance, c) sediment erosion, d) population density and c) urban areas found that all CB rivers are in moderate to very poor-quality range. Also see Chapter 7 for discussions on river water quality in CBs. Given that Uttar Pradesh and Bihar have more population and urban areas the quality of CB rivers there would be similar. Climate change adds a new stress layer on these challenges (Mirza & Dixit, 2021)

CONCEPTUAL APPROACH

CONCEPTUAL APPROACH

02

2.1 INTRODUCTION

The EGR is characterized by diverse climatic zones from the snowcapped Himalayas, mid-mountains, the plains, and the coasts of the Bay of Bengal. The region frequently faces extreme weather events such as heavy precipitation, floods, cyclonic storms, coastal inundation, heat waves, droughts, and forest fires. These events result in heavy losses of life and livelihoods of the vulnerable population, ecosystems, and economies[1]. In the last few decades, global climate change has made these events more frequent and extreme and leading to increased disaster damages. The 2022 heat waves in South Asia, and GLOFs, riverine and other floods in the Indus River (Pakistan), and droughts and floods in parts of the EGR are examples. The rise in the population living in flood and landslide risk areas in the region as well as the development of infrastructure are increasing their exposure to extreme climatic hazards. At the same time, erosive economic development and fragmentation of arable lands including natural ecosystems are further adding to the pressure. The change processes and impacts point to the need to take a deeper examination of the natural and social dimensions of climate-induced disasters and take efforts in minimizing the cascading impacts[2].

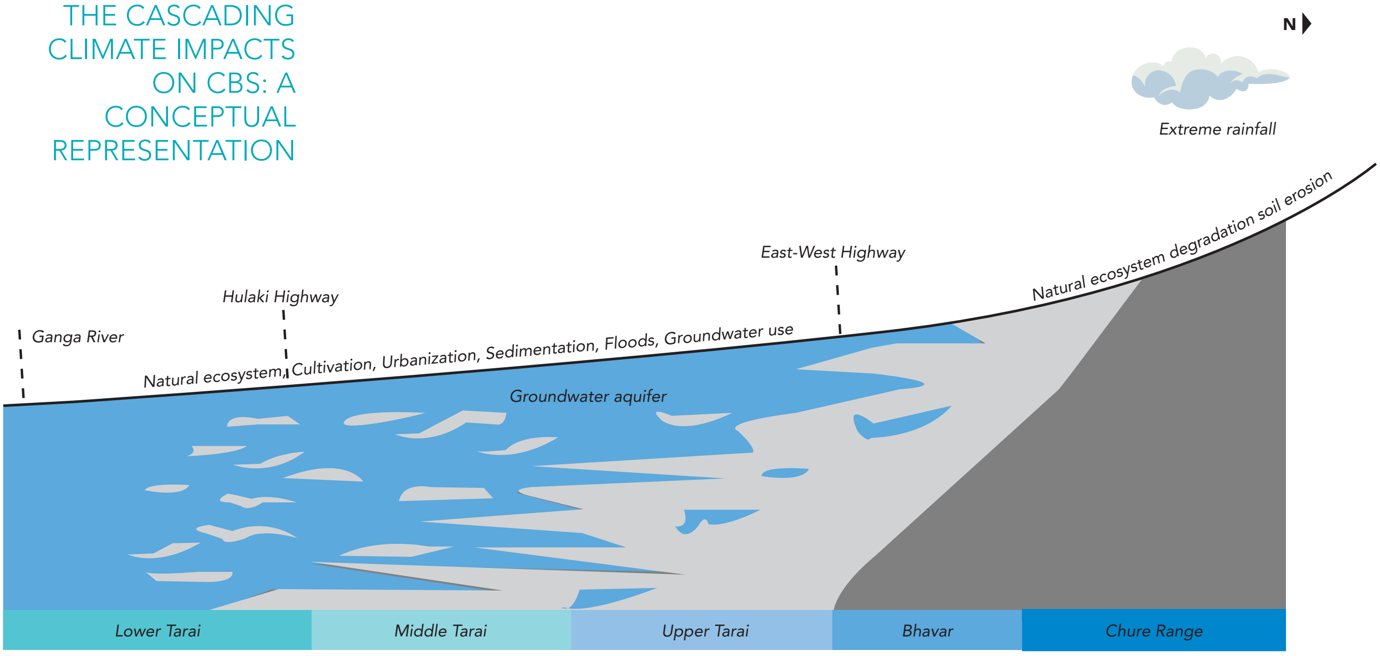
2.2 CASCADING DISASTERS

Extreme weather event such as rapid on-set rainfall lead to secondary hazards such as floods and landslides that can cause disasters cascading across boundaries. In the EGR, such flood disasters affect Nepal's CB districts and large parts of northern Uttar Pradesh and Bihar. As is true elsewhere, in this region too, floods are outcomes of precipitation and landscape dynamics, both of which are undergoing changes. At a broader scale, the ongoing changes in the upper Himalaya region's glaciers, snow, and ice reserves have implications locally, on the CB regions and further downstream and the communities there. Simultaneously, climate change will influence dynamics in the spring-fed rivers of the mid-hills and the CB rivers, causing cascading impacts. Though these dynamics in the mid-hills and CB region and rivers are equally important, they are less evident than the changes in snow, ice, and glacier environment. The CB rivers are vulnerable to disruptions from human-led interventions and climate change-induced extreme events.

Because of CB rivers seasonal nature, exposure of people and infrastructure, impacts are high. At the same time, both in Nepal and across the border in India, CB regions face a decline in the integrity of natural ecosystems leading to a decline in the quantity and quality of the region's freshwater base. In the last few years, increasing risks of upstream changes on downstream regions has been highlighted, but not many on-the-ground studies exist that specifically assess the changing dynamics of the river flow, and of the impacts on existing water infrastructure generally of lower quality, and people affected by the disruptions of ecosystem services. The degradation of quality and services of natural ecosystems of the CB region further adds to the challenges of management and flood risk reduction efforts (Figure 2.1).

Thus, the CBs face both direct and indirect threats of climate change influencing precipitation patterns in the Himalaya, mid hills and the region itself. The scale of impacts in the mountainous region as well as in the CBs given their proximity to the higher mountains, however, have an element of uncertainty, particularly, regarding climatological parameters studied by global climate models. The uncertainty has implications on the dynamics of climate induced disasters on communities, natural ecosystem and infrastructure, their critical

FIGURE 2.1: THE CASCADING CLIMATE IMPACTS ON CBS: A CONCEPTUAL REPRESENTATION



Adapted from GCF (2019) and Pandey et al (2021)

services, and the role of governance in addressing these impacts. Given the fluidity of governance in the region and the uncertainties associated with climate change-induced impacts on precipitation, generally and in Nepal, resilience is a useful approach to minimize climate induced risks[3].

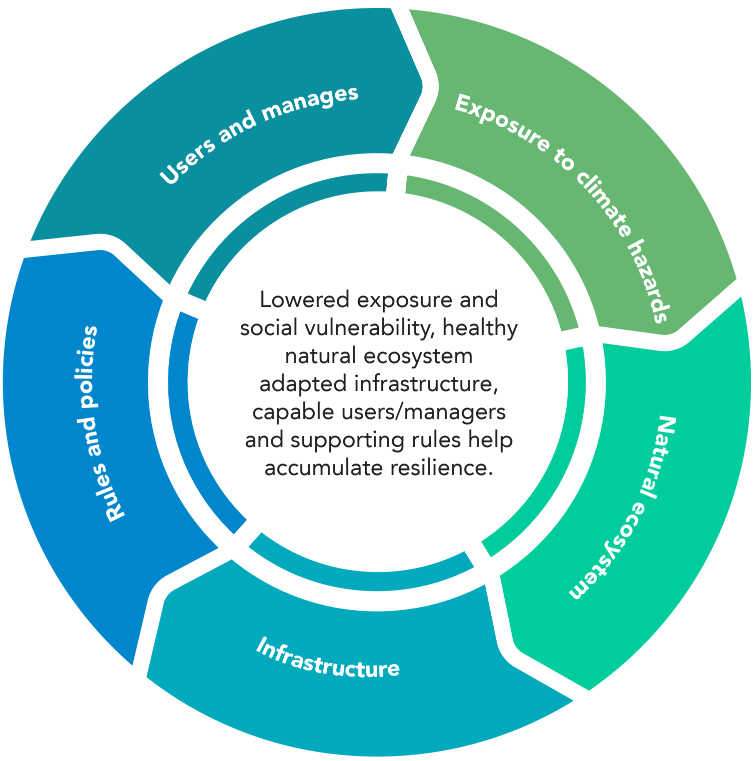
2.3 RESILIENCE DEFINITION

With climate change recognized to be real and unavoidable, resilience is becoming one of the most discussed term in contemporary environmental literature[4]. Two schools of thoughts coming out of natural science and social science present broader understanding of resilience. According to the Resilience Alliance, it is the "ability to absorb disturbances, to be changed and then to re-organize and still have the same identity while retaining the same basic structure and ways of functioning". The Institute of Social Anthropology, University of Basel, defines resilience as "reactive capabilities of people to cope with, recover from and adjust to various risks and adversities and their proactive capacity to create options and anticipate responses to health risks and adversities."[5] Broadly thus, the concept of resilience suggests "a different complementary effort to mitigation; to design our institution, embolden our communities, encourage innovation and experimentation and support our people in ways that will help them be prepared and cope with surprises and disruption even as we work to fend them off."[6] Resilience, however, means different things to different people, and the meaning can be even different in diverse socio-ecological contexts. Hence we can recognise resilience to be internal human strength, the capacity to do well even when faced with external shocks and adversities. Since these elements vary across regions, context and individuals, it can be argued that achieving resilience is a journey and does not have a clear-cut objective or a goal post[7].

2.4 PILLARS OF RESILIENCE

In order to understand and broadly explain the complexities of inundation in the CBs, the study has proposed five pillars of resilience adapted from the climate resilience framework (CRF)[8]. The CRF is based on research in South Asia using insights from livelihood framework, applied insights, and an understanding of the dynamic interactions among human behavior, institutions, natural ecosystems, and infrastructure. Adapted forms of CRF have been used in Nepal in the contexts of adaptation to floods and droughts, food security,[9] local resilience,[10] and irrigation management[11]. The interactions among the elements of the pillars (Figure 2.2) are conceived as a heuristic tool for accumulating resilience, linking analysis of human vulnerability, institutions, and systems dynamics with practical examples for planning and identifying solutions, thereby enabling researchers to identify points of entry for implementing measures for building resilience across boundaries.

FIGURE 2.2: THE PILLARS OF RESILIENCE



Building on the CRF, the study has proposed the following five components key to building resilience: 1) lowered exposure to biophysical hazards 2) the availability of and access to good-quality natural ecosystems and services, 3) adapted infrastructure and services, and 4) the capacity of users to manage ecosystem, infrastructure and services and 5) the provisioning of equitable benefits supported by rules and policies. The benefits can be conceived in terms of tangible incomes and revenues and intangibles like knowledge and capacity built. We chose this conceptual approach because it best matches the ecological, economic, and political landscape of the CB rivers. In these applications both nature and infrastructure consist of components, entities, factors, and parts that are interrelated and interdependent directly and indirectly. Each of these components plays a key role in enabling people to adjust as exposure changes and helps build resilience[12].

The following sections explain these components in the context of CBs.

Exposure to climate hazards: In the CBs, the typical natural climate exposure drivers are temperature rise, humidity, extreme rainfall and other forms of precipitation, evapotranspiration, heavy winds, hailstorms, and droughts. Increasing population. physical interventions and haphazard expansion of settlements in the region expose them to changing climate hazards whose impacts on socially vulnerable people make their condition worse[13].

Natural ecosystem. In the CBs the four types of natural ecosystems available are agricultural, grassland ecosystem, forest, and freshwater (rivers, wetlands, and ponds)[14]. The resilience of these ecosystems and their service interrelated and interdependent directly and indirectly, support the well-being of most people living in CB-dependent regions of Nepal and India.

Infrastructure: Drinking water supply, roads, energy generation, electric power lines, food storage, health, education, and finance, and their services help the functioning of human society with their interrelated components.

Users and managers: While each individual have a different internal strength to deal with shocks, those in social and economic margins generally with the lowest levels of access to services produced by natural ecosystems and infrastructure are among the first affected when hazards disrupt the services[15]. Their political, economic, and technical inability to engage the management regime further leads to vulnerability and limited access to services and lowers resilience.

Rules and policies. Rules and policies can either create opportunities or introduce constraints concerning the above-mentioned four pillars. Rules and policies play an important role in reducing vulnerability by mediating access to services and therefore need to be at the center of the resilience-building task. Supportive rules and policies allow access to services from natural ecosystems and infrastructures and can help secure livelihoods. In many cases, historical factors such as caste and ethnic-based exclusion, lack of employment, and food insecurity debilitate well-being and resilience.

An understanding of how the individual components and the combined whole of the dynamically interlinked pillars behave and respond when hit by climate hazards is needed for resilience-building. By considering the pillars, both, individually and by examining the linkages, it will be possible to identify the barriers to be overcome to resilience-building. Since many of the underlying vulnerabilities are structural and systemic[16], any efforts at reducing vulnerability or building resilience must take a holistic approach that considers various types of flows across boundaries.

2.5 RESILIENCE ACROSS BOUNDARIES

The idea of resilience across boundaries is useful in studying transboundary socio-ecological challenges in South Asia. Transboundary treaties on rivers are major examples of flow across boundaries. Other transboundary flows are trade, human migration, wildlife movements, and air pollution. Climate change is a major global transboundary challenge that can lead to cascading impacts and in South Asia, necessitates responses across boundaries. Governments and other parties recognize these changing dynamics and draw on global climate funds, knowledge, and a wealth of experiences of multi-country cooperation on other socio-ecological challenges with the aim of understanding and responding to stresses across boundaries[17].

The signing of treaties by governments to develop projects in transboundary rivers and allocate the resources among the signing countries as well as other instruments of cooperation are examples of such responses. With climate change exerting increased pressures on water resources, it is necessary to conduct review of these initiatives and seek effective multi-country cooperation in managing emerging socio-ecological challenges. The idea of resilience across boundaries thus will help explore the interdependencies among the five elements – hazard exposure, natural ecosystems, infrastructure, users and managers, and rules and policies at the local to regional scale, across sectors within a country, as well as across political boundaries. The insights can help countries take proactive measures for building resilience.

NOTES

1. Climate change in the future might account for up to 13% of the Gross Domestic Product (GDP) of South Asian countries by 2050. See Mirza & Dixit (2021).
2. Mountains face multiple hazards that can have cascading impacts. For discussions, see https://adaptationataltitude.org/knowledge-base/adaptation-in-mountains/leave-no-mountain-behind
3. Dixit et al (2018) use resilience as a conceptual approach to examine responses to the rebuilding of the damages caused by the 2015 Gorkha earthquake in Nepal.
4. For more discussions, see Folke (2006), Adger (2016) and Koliou et al (2018)
5. For framing of Climate Resilience Framework (CRF) see Tyler & Moench (2012)
6. The stress associated with exposure can be both direct and indirect. An infrastructure that is not exposed to a potential source of disruption cannot be vulnerable to it. For example, except those living along the Chure range the majority of the settlements and people in the CBs are not exposed to landslides but to floods and inundation.
7. Zolli & Healy (2012) presents in depth examination of resilience.
8. The CRF also uses the thinking of global thinkers such as Holling (1978), Ostrom (1990) and Sen (1999).
9. Dixit, et al. (2014) used the CRF on assessing cross scale implications of climate change in Nepal's Gandak Basin.
10. GoN's strategy for building local resilience is also based in CRF See Dixit et al. (2016).
11. Mott MacDonald & CDKN (2017) uses system-agent institutions, the elements of CRF in analyzing challenges of irrigation management in Nepal.
12. Tyler & Moench (2012) explain the use of the framework in the building of urban resilience
13. Ibid.
14. TISC (2002)
15. Man (2019) while analyzing climate change impacts on Nepal's food security writes, "people are affluent or poor, influential or marginalized, educated or not educated, and so on. Their occupations are equally diverse: there are farmers, traders, government officials, business persons, industrial workers, and many other occupations".
16. See Friend & Moench (2013) for further discussions on use the concept of resilience and addressing vulnerability in urban regions.
17. Countries have negotiated and agreed on numerous regional cooperation frameworks, treaties, and protocols, ranging from cooperation on shared freshwater resources to agreements on marine resources. See Adaptation Fund (2022).

CHURE BASINS

Chure Basins

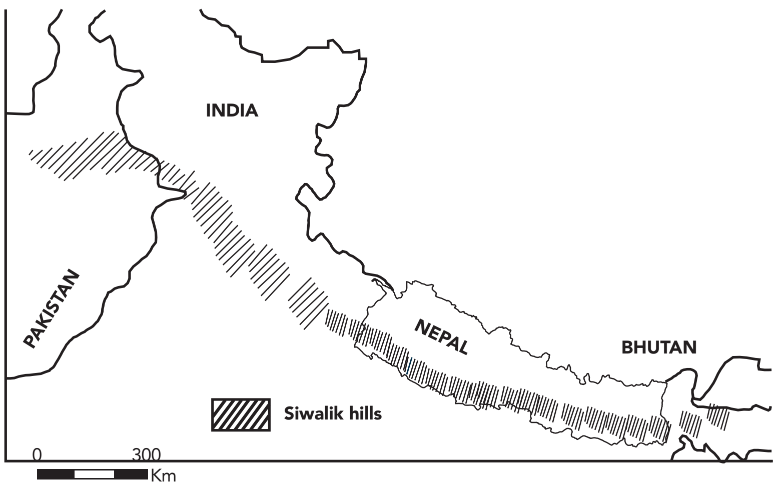
03

3.1 CHURE BASINS AND HINDU KUSH HIMALAYA

Fifty million years ago, the present-day South Asian landmass separated from Gondwanaland, moved northwards, and subducted under the larger Eurasian Plate, pushing the Eurasian plate upward and beginning to form the Hindu Kush Himalaya (HKH) region[1]. The Indian plate continues to push against the larger Eurasian Plate, generating seismic tremors in the region. These tremors have caused major earthquake disasters until recent times. The HKH region includes the planet's highest and one of its longest mountain chains as well as the Indus and Ganga plains, where ten major rivers including the Ganga and Indus begin. The rivers support the lives, livelihoods, and well-being of millions in the basin countries.

The elevation in the eastern parts of the HKH region is less than a hundred meters above sea level, but no more than 150–200 km northward as the crow flies lie snowcapped Himalayan mountain peaks over 8,000 m high. The about 3,500 km long HKH mountain range begins in present-day Myanmar and extends up to Afghanistan via eastern India, Nepal, western India, and Pakistan. This young and fragile geological formation incorporates a diverse environmental and socio-culture milieu. The Himalaya system is the youngest chain on earth and within this system the Chure (Siwalik) is the geologically youngest range [2], [3]. The Chure range is the source of the headwaters of the CB rivers. East to west, the Chure range extends almost parallel to the northern ranges (Figure 3.1). In Nepal, the watersheds of CB rivers lie between northwest Uttar Pradesh in the west, the Darjeeling hills in the east, and the Chure range in the north. To the south are the major tributaries of the Ganga River into which the small seasonal rivers of the CB flow.

FIGURE 3.1: CHURE RANGE IN NEPAL AND NORTHERN SOUTH ASIA



The interaction between HKH region, Tibetan Plateau, Bay of Bengal, and the Arabian Sea led to the beginning of the monsoon rainfall regime about fifteen to twenty million years ago, The rain and snowfall from the monsoon, including that brought by westerly winds from the Mediterranean are the main sources of water in the region. These as well as the mountains and plains and the geology have all given rise to the numerous rivers and streams of the HKH region.

Water from snowmelt, rainfall, and the rain-fed springs of the mid-hills regularly augment these rivers. Rainfall feeds small seasonal rivers which after flowing through Nepal's CB districts, cross into the Indian states of Bihar and Uttar Pradesh, thereby acquiring a transboundary character. Via other tributaries, these rivers merge with spring-fed Mahabharat and snow and glacier-melt-fed rivers in Nepal's lower CB region as well as in Bihar and Uttar Pradesh and eventually join the Ganga. The fluvial, biological, and hillslope processes of the Chure range and the southern region determine the environments, livelihoods, and economies of CB districts, factors within which the region's present-day administration and management function.

3.2 GENERAL CHARACTERISTICS

Unlike Nepal's snow and glacier-melt-fed rivers and the rainfed rivers that drain the mid-hill (Mahabharat) catchments, CB rivers are seasonal. In their upper reaches, CB rivers flow only as long as rain lasts. In addition to rainfall, the slope, elevation, relief, and vegetation cover of a given CB catchment also determine the flow of its rivers. When they reach the Bhabar zone, CB rivers become braided and may even be invisible for a certain distance. As they flow south from the Bhabar region, the rivers receive inflows from the banks and begin to meander. Thus, in the lower reaches, even during the dry seasons, these rivers may have some discharge. The velocity of their flow is low, however, because of the gentle slope of the landscape. The natural ecosystems (grassland, forests, and freshwater bodies) of the CB feed these rivers, providing provisioning, regulating, supporting, and cultural ecosystem services for the people of the Nepal CB, North Uttar Pradesh, and North Bihar. The eighteen CB districts in Nepal occupy 18.10 percent of the country's total land area and are home to about 45 percent of the population according to the census of 2021.

3.3 ADMINISTRATIVE ARRANGEMENT

The CB region covers 18 Tarai/Madesh districts of Nepal in Koshi Province, Madesh Pradesh, Lumbini Pradesh, and Sudur Paschim Pradesh. The region borders the State of Uttar Pradesh in the west and Bihar in the east (Figure 3.2). Out of Nepal's six metropolitan cities, 11 sub-metropolitan cities, 276 municipalities, and 460 rural municipalities, the CB region has 2 Metropolitan cities, 8 sub-metropolitan cities, 125 municipalities, and 117 rural municipalities . As mentioned earlier, this study does not consider Chitwan, East Nawalparasi, and Dang districts to be part of the CB region, even though Chure region touches them. In Nepal's Chitwan, East Nawalparasi and Dang districts, the Chure range borders India, Nepal has no

TABLE 3.1: CBS, PROVINCES AND DISTRICTS IN NEPAL AND CB STATES AND DISTRICTS IN INDIA

Nepal				India			
Province	District	Area km²	Population	State	District	Area km²	Population
Koshi Pradesh	Jhapa, Morang Sunsari	4,774.26	3,075,737	Bihar	Purba Champaran, Sitamarhi, Madhubani. Supaul, Araria, Kishanganj	22,130	19,741,369
Madhesh Pradesh	Saptari, Siraha, Dhanusha, Mahottari, Sarlani, Rautahat, Bara, Parsa	9,596.72	6,578,623				
Lumbini-Pradesh	West Nawalparasi, Rupandehi, Kapilwastu	7315.03		Uttar Pradesh	Pilibhit. Kheri, Bahraich. Shrawasti Balrampur, Siddhartha Nagar, Kushinagar, Maharajganj. Paschim Champaran	30,344	25,549,593
	Banke, Bardia		3255453				
Sudur Pachhim Pradesh	Kailali, Kanchanpur	4,890.54	14,28800				
	Total	26,576.55	14338613		Total	52,474	45290962

Source: Various maps and secondary sources.

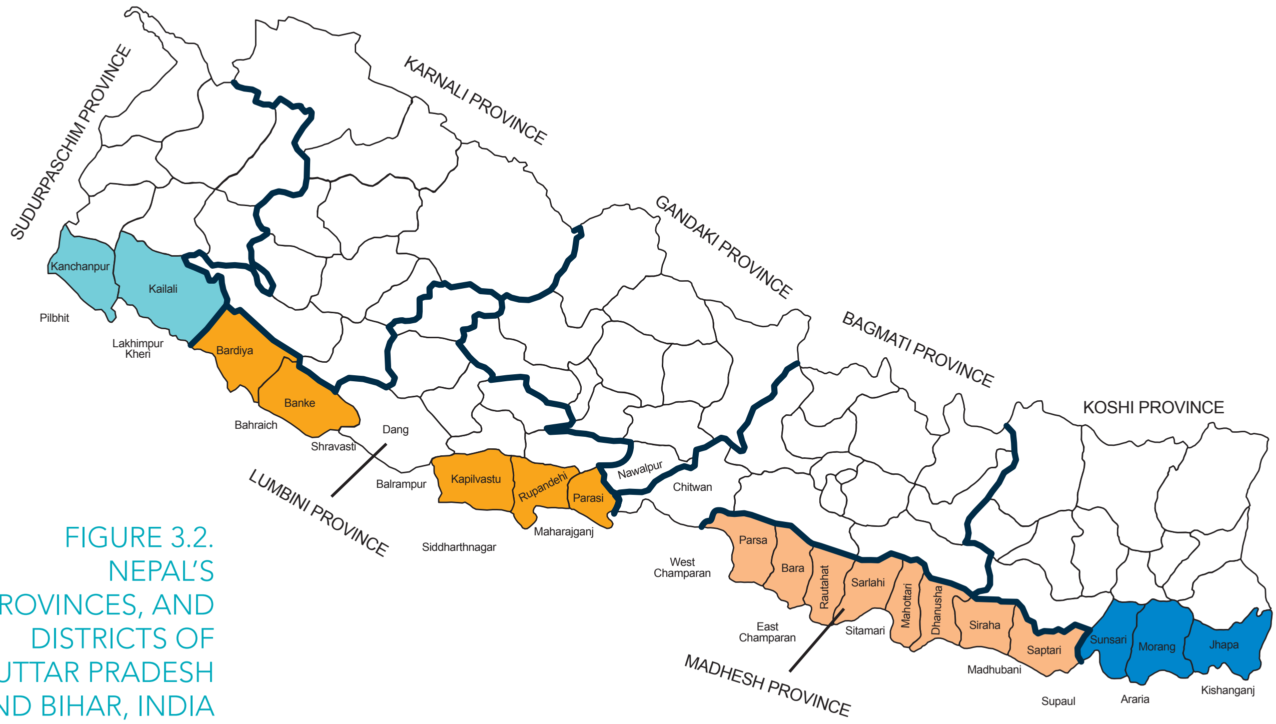


FIGURE 3.2. NEPAL'S PROVINCES, AND DISTRICTS OF UTTAR PRADESH AND BIHAR, INDIA

Tarai plains south of these districts as the hills transit directly into the plains of Uttar Pradesh and Bihar. For this reason, these were excluded from the analysis.

3.4 TOPOGRAPHY

The CB region is divided into the northern, central, and southern zones:

3.4.1 Northern zone

The northern zone is mainly the Chure Mountain range (Figure 3.3) and generally, the Chure range's ridge is the northern boundary of the CB watershed. With a width of 8-10 km the elevation of the range varies between 150 m and 1,600 m. The Chure range is higher and wider in the west compared to east in Nepal. East of the Koshi River, the Chure range is subdued, while in the west, beyond the Karnali River, it stands as a separate range whose elevation is higher than that in the east. In some of the stretches in the west, the Chure hills rise sharply, at slopes of more than 50 degrees. In general, the Chure's southern slopes are steeper than its northern slopes. To the north, lie the doon valleys, separating the Chure from the Mahabharat range.

While the Chure range constitutes the northern boundary of the CB districts, the range itself is the southernmost mountain range of the HKH region[4]. The Chure range comprises soft, loose, unconsolidated rocks and easily erodible sediments like sandstone, siltstone, mudstone, and conglomerate[5]. In the monsoon months, when saturated with water, the soil layers of the range can break down into smaller parts[6]. The Chure range does have very little cultivable topsoil, found largely in its low terraces and alluvial fans as well as in a thin layer of sandy soil cover in the north and fan deposits in the northern doon valleys. The Bhabar zone is dominated by gravel while the southern plains have thick soil deposits underlain by groundwater aquifers.

Extending from east to west, at the southern foot of the Chure range and north of Nepal's East-West Highway, lies the Bhabar zone. The northern edge of this zone is prone to flash floods and landslides This zone, with lower slope, consists of permeable strata of with high water infiltration capacities that aid the groundwater recharge of the regional aquifers. The quality of the land in this zone, however, is poor and agricultural productivity is less here than it is in the southern plains. Despite this shortcoming, families belonging to different ethnic groups have migrated from the hills to the Bhabar zone too in search of livelihoods. Because of the zone's proximity to the East-West Highway, its settlements of expanding gradually.

3.4.2 Central zone

This zone, which is located between the East-West Highway and the Postal Highway (Hulaki), includes settlements, farmlands, wetlands, forests, national parks and wet lands. National parks, are located in Bara, Parsa, sections of East Nawalparasi, Banke, Bardia, Kailali, and Kanchanpur, and Saptari. The forest ecosystem of this zone straddles both Nepal and India recognized critical to biodiversity conservation in Nepal and India[7]. This region has major groundwater aquifers that are used as a basic source of water for meeting drinking, other household usage, industrial and irrigation needs. Local and many public surface irrigation canals serve parts of the region's agricultural lands. The region is prone to flooding.

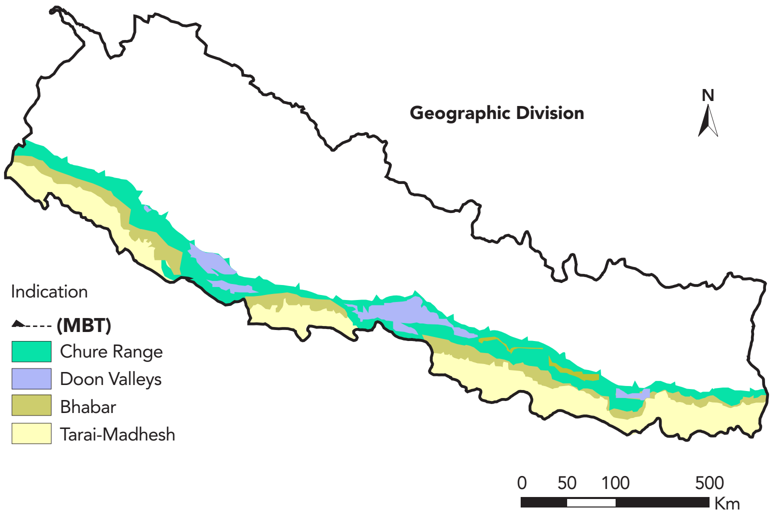
3.4.3 Southern zone

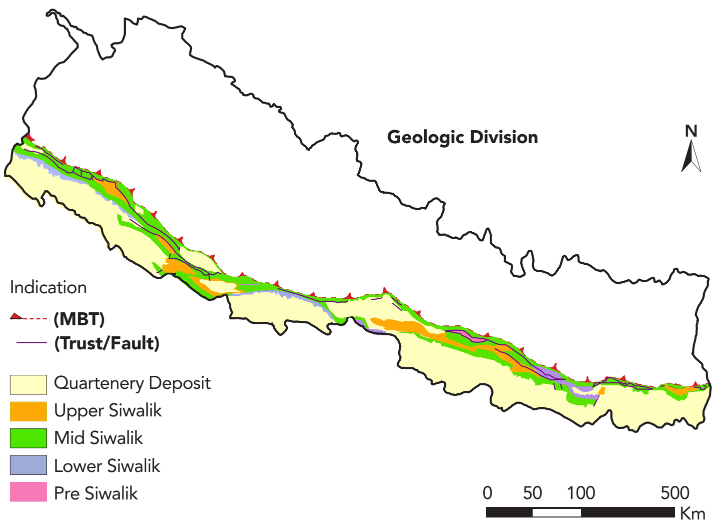
This zone covers the area between the Hulaki Road and Nepal's border with Bihar, and Uttar Pradesh. Agricultural lands in this zone are largely rain-fed and served by public surface irrigation facilities and groundwater pumping. CB rivers that begin in the upper region cross into Bihar and Uttar Pradesh from this zone and are prone to flooding. Border inundation problems exist in this zone. The major cities along the border such as Biratnagar, Malangawa, Gaur, Birganj, Bhairahawa, Krishnagar, Nepalganj, Dhanagadhi and Mahendranagar. Indian part is also densely populated with some important border cities like Jogbani, Jayanagar, Sitamadi, Bairgania, Raxaul, Nautnwa and Nanpara.

3.5 GEOMORPHOLOGY AND LANDUSE

The young geological formation of the Chure range gives rise to

FIGURE 3.3. GEOLOGICAL AND GEOGRAPHIC DIVISION OF CHURE RANGE AND CB REGION





Source: PCTMCDB. (2074/2018):

geomorphological processes in the CB region and, in a short timeframe, influences the landscape via biological, hill-slope, and fluvial processes. In addition, human interventions are changing the terrestrial and freshwater ecosystems of CB districts. Changes in land use began in 1769 CE when the then government encouraged people to migrate from India and the hills to the Tarai to cultivate land with the objective of augmenting state revenue to meet its growing financing needs for funding campaigns of territorial expansion. Commercial exploitation of the forests began in 1900s to meet the needs for the development of railway tracks in north India and other commercial purposes. Subsequently, the eradication of malaria in the early 1950s and the then government's promoting the conversion of forest land into agricultural land in the CB region led to further changes[8]. Two decades later, in 1970, the Master Plan of Irrigation envisioned the development of public irrigation systems in the Tarai to augment agricultural production[9]. With the completion of Nepal's East-West Highway, the pace of change increased. Gradually, new settlements have developed along both sides of the highway, continuing to accelerate changes at multiple levels of the ecological and social landscape of the CB region. The upgrading of the Hulaki road is leading to further social, economic, and environmental changes.

3.6 CLIMATE

The climate of the CB region is subtropical and humid in the summer months. Along the ridges of the Chure, the summer climate is a little bit cooler than it is on the plains. The Chure range is dry despite its being covered by forest and having, in gullies, humid and wet microclimates that support various plant and animal species. After the monsoon ends, the relative humidity remains high on the north-facing slopes of the range. This face experiences more radiation than south-facing slopes. Because of the combination of radiation impacts and altitude differences, moisture regimes differ between close sub-watersheds and also from year to year. The CB districts have unique hydrologies that need to be recognized to establish appropriate water and natural resource management strategies.

3.6.1 Temperature

Figure 3.4 shows the spatial distribution of seasonal and annual mean temperatures in CB districts between 1980 and 2020 based on data collected by DHM. Western CB districts seem hotter than central and eastern parts though some parts of the CB region are hot throughout the pre-monsoon season months (Figure 3.4a) when mean temperature ranges between 19 ^{0}C and 23 ^{0}C (Figure 3.4a). In the western, central, and eastern regions, mean temperatures range between 27 ^{0}C and 29 ^{0}C in the monsoon months. The post-monsoon

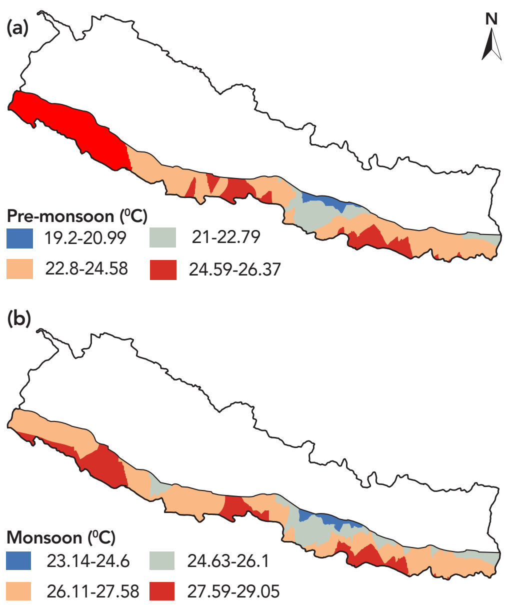
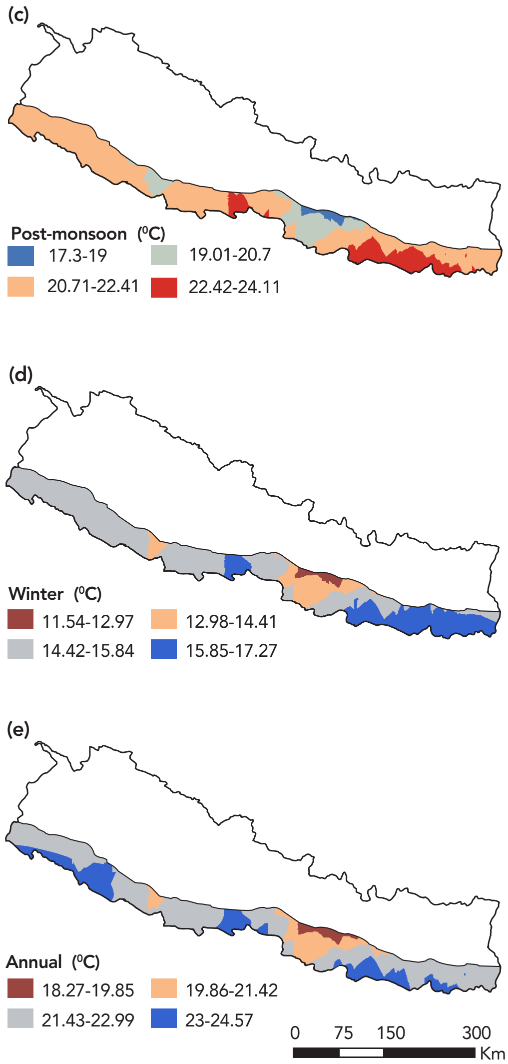


FIGURE 3.4. DISTRIBUTION OF MEAN TEMPERATURES OVER CB DISTRICTS (a) PRE-MONSOON, (b) MONSOON, (c) POST-MONSOON, (d) WINTER, (e) ANNUAL.



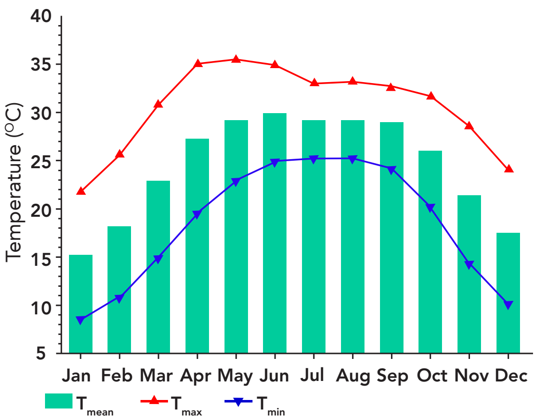
Data Source: DHM

and winter seasons are relatively dry and cold. The lowest mean temperatures in the winter are observed in eastern CB districts (~11.5 ºC). The annual average temperature in CB districts varies between 18 ºC and 24.5 ºC (Figure 3.4e). Needless to say, the monsoon season is humid and hot. The combination of humidity and high temperature is likely to be more elevated in the days to come and may constitute a serious threat.

The annual cycle of maximum, minimum, and mean temperature (T_{max}, T_{min}, and T_{mean}) (Figure 3.5) shows that the highest temperatures fall between April and October. In April, the mean maximum temperature is 35 ºC and 20 ºC is the minimum. In July, the maximum temperature reached 35 ºC while the average minimum is 25 ºC . Across the CB districts, hot days (above 25 ºC) start in April and last till October. The coldest days fall in December and January (Figure 3.5).

Across the CB districts, from 1980 to 2020, the annual mean temperature fluctuated between 23 ºC and 25 ºC (Figure 3.6). The interannual variation in mean maximum ranged between 29 ºC and 32 ºC while the minimum for the year (Figure 3.5) ranged between 16 ºC and 19 ºC .

FIGURE 3.5. ANNUAL CYCLE OF TEMPERATURES (T_{mean}, T_{max}, T_{min})



Data Source DHM

Figure 3.7 shows the seasonal and annual variations of the mean maximum temperatures in CB districts between 1980 and 2020. Temperatures in the pre-monsoon, monsoon, and post-monsoon seasons are increasing, but the increment was significant only in the monsoon season. The rate at which the maximum temperature in the pre-monsoon season increased was 0.009 ºC /year (Figure 3.6a); in the monsoon season, 0.02 ºC /

FIGURE 3.6. ANNUAL TEMPERATURES (T_{mean}, T_{max}, T_{min})

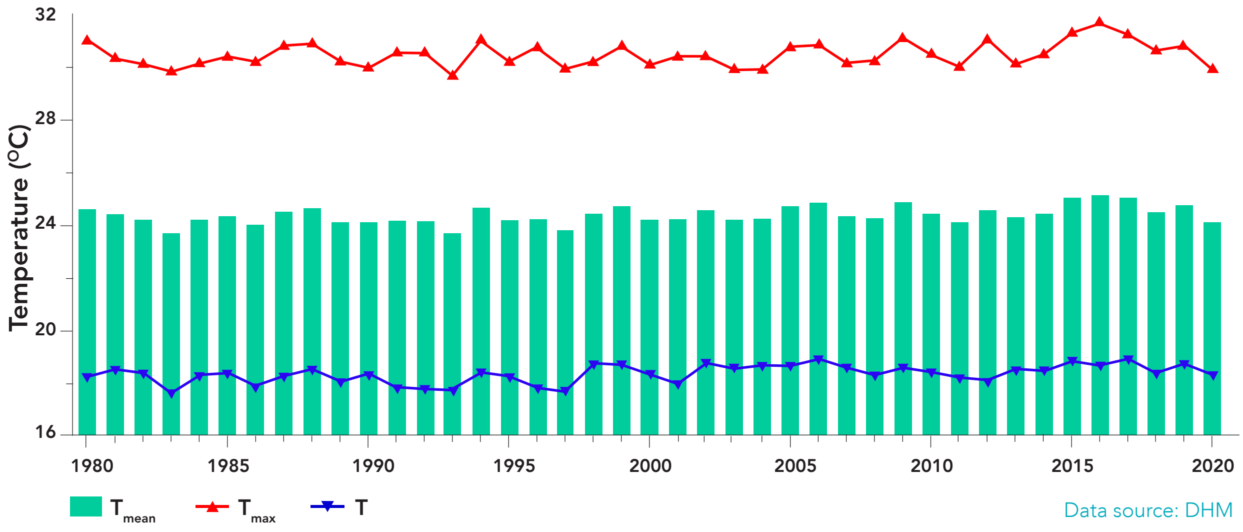
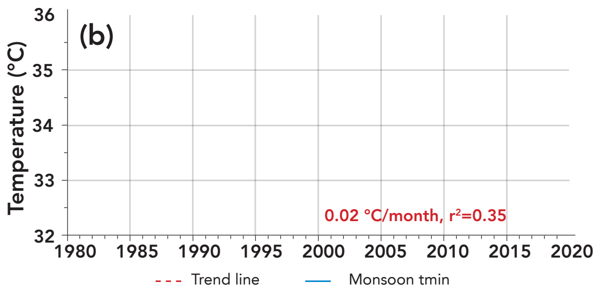


FIGURE 3.7. SEASONAL AND ANNUAL VARIATIONS OF MEAN MAXIMUMS AND TRENDS (⁰C)



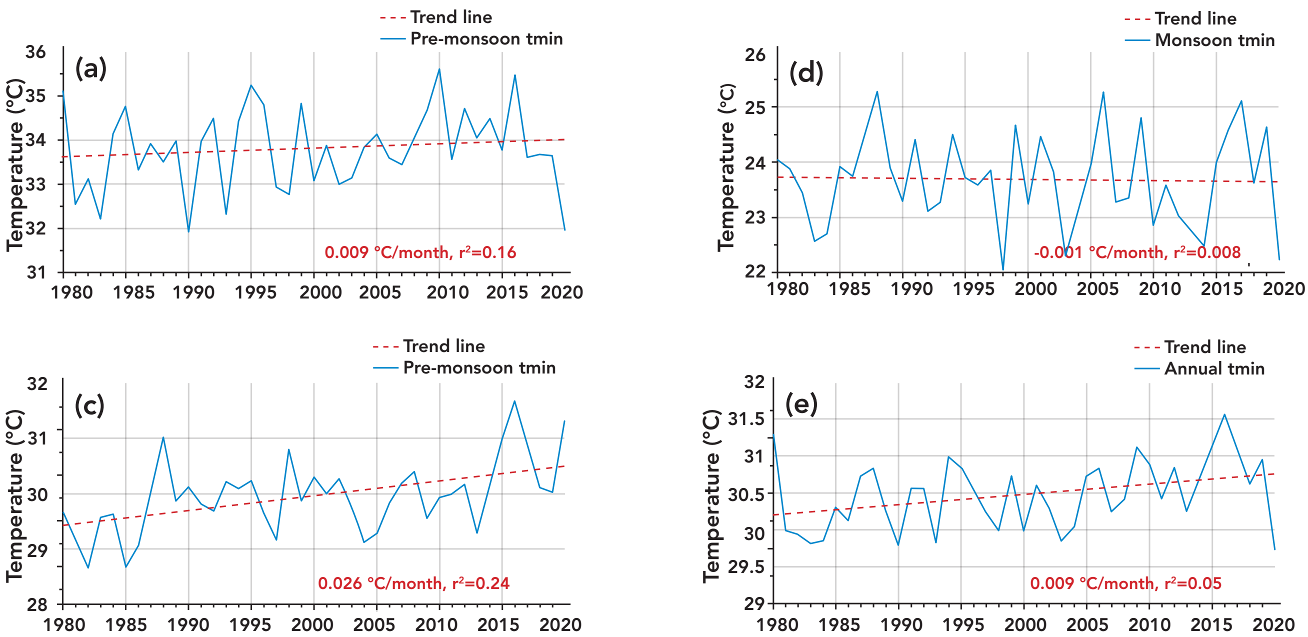
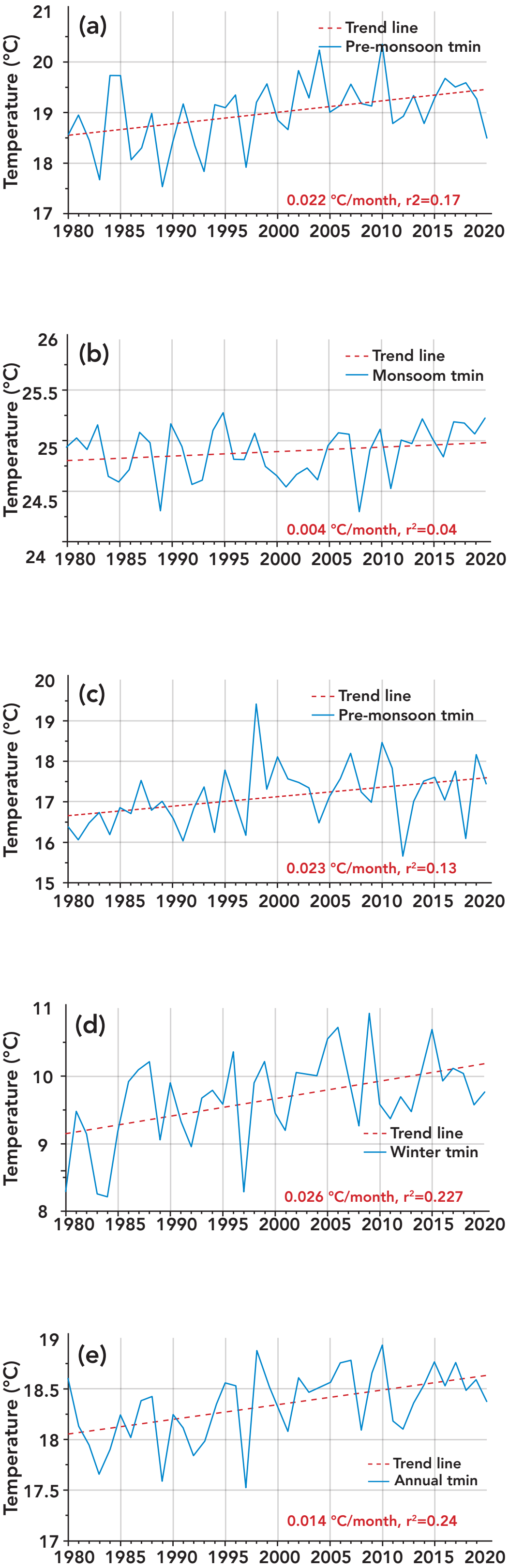


FIGURE 3.8. SEASONAL AND ANNUAL VARIATIONS IN MINIMUM TEMPERATURES (T_{MIN}) AND THEIR TREND (^{0}C)



Data source: DHM

year (Figure 3.7b); and in the post-monsoon season, 0.026 ^{0}C /year (Figure 3.7c). No trend was observed for the winter season (Figure 3.7d).

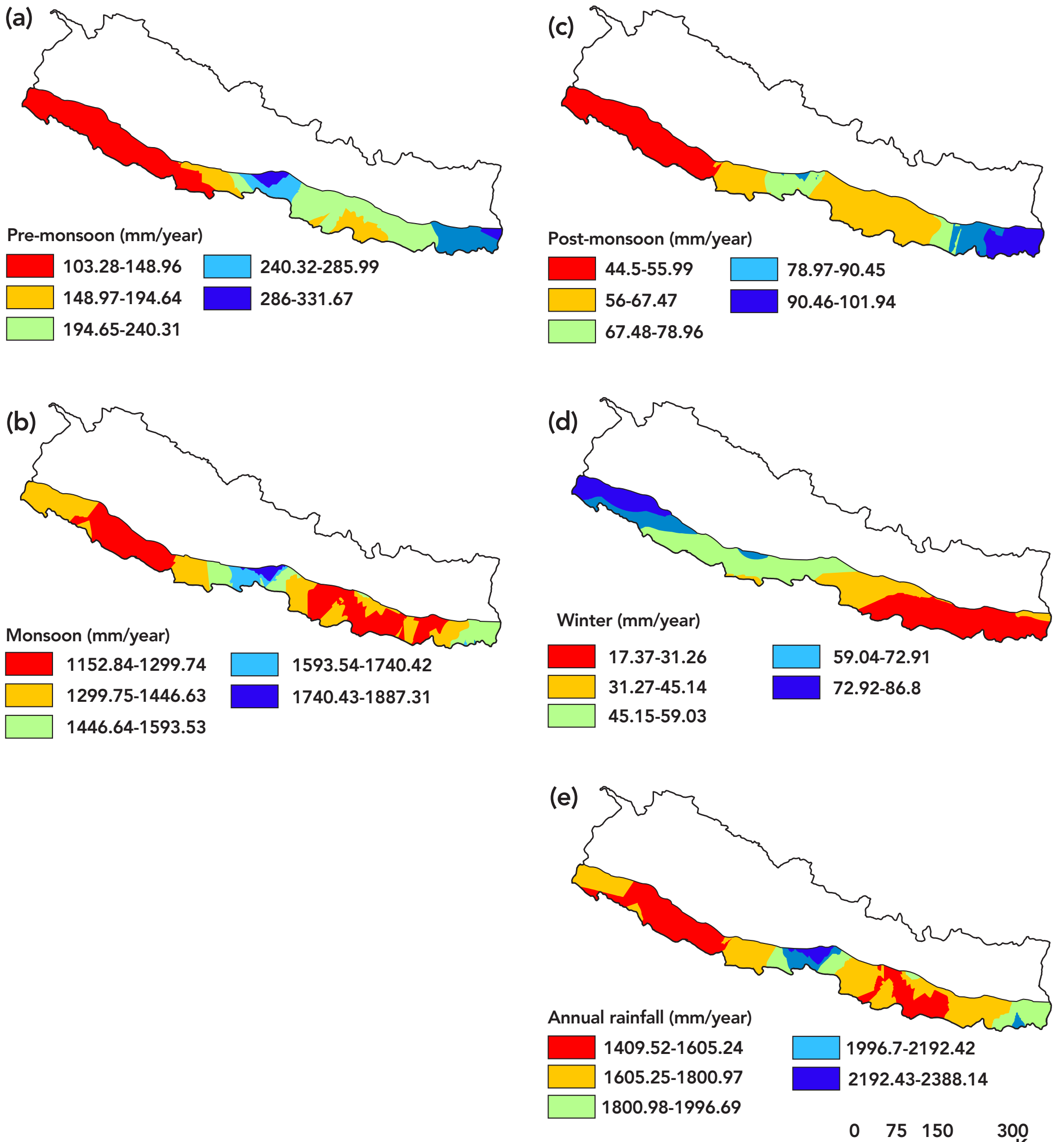
Figure 3.8 shows the seasonal and annual variations of minimum temperatures and their trends across the CB districts between 1980 and 2020. In all seasons, the trend is upward. The increment of that increment, however, was significant only for the pre-monsoon and winter seasons. The rate of increment for the pre-monsoon season was 0.022 ^{0}C/year (Figure 3.8a); for the monsoon season, 0.004 ^{0}C/year (Figure 3.8b); and for the post-monsoon season, 0.023 ^{0}C/year (Figure 3.8c). In the winter season, temperatures increased at the rate of 0.026 ^{0}C/year (Figure 3.8 d). The overall minimum temperature increased at the rate of 0.014 ^{0}C/year (Figure 3.8e).

3.6.2 Rainfall

Rain-laden winds from the Arabian Sea and the Bay of Bengal bring rainfall to CB districts in the monsoon season, which begins in June. In contrast, westerly winds bring winter rains to the region. Monsoon rain nurtures the landscape with moisture and plays a role in maintaining ecosystem services within the contiguous landmass of CB districts in Nepal and India. These rains fill the storage capacities of vegetation and land, augment rivers, recharge groundwater aquifers, and provide food and forage. Water, following its natural rhythms, has always traversed and continues to traverse this landscape, crossing geographical, historical, environmental, social, and political boundaries and serving as both a boon and bane.

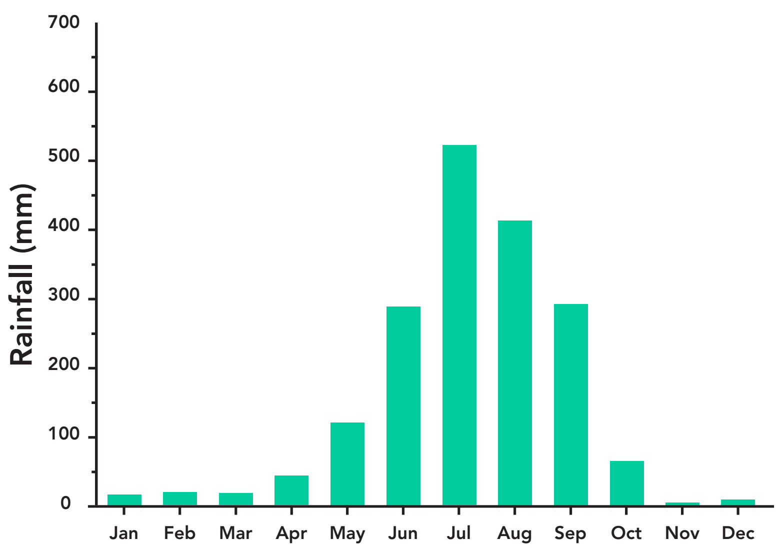
Figure 3.9 shows the spatial distribution of seasonal and annual rainfall over the CB districts. Total rainfall ranges between 100 mm/year and 300 mm/year, with the highest rainfall concentrated in the central, and eastern parts of the country and the lowest,

FIGURE 3.9. SPATIAL DISTRIBUTION OF RAINFALL IN THE (a) PRE-MONSOON, (b) MONSOON, (c) POST-MONSOON, AND (d) WINTER SEASONS, AND (e) ANNUALLY.



Data Source: DHM

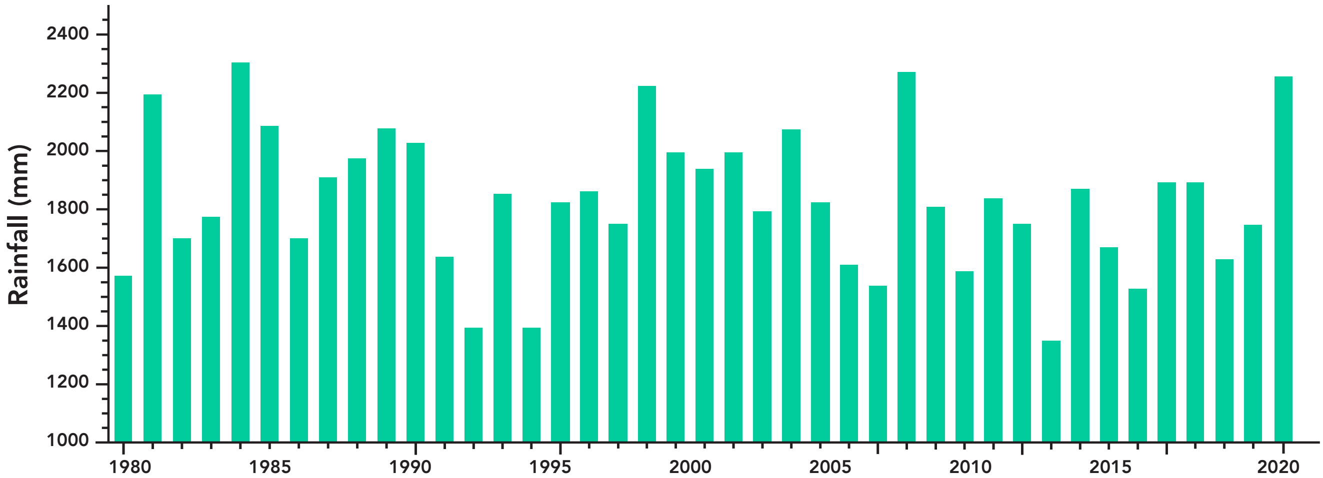
FIGURE 3.10. MONTHLY RAINFALL



Data Soure: DHM

west of Dang (Figure 3.9). Monsoon rains contribute the majority of the annual rainfall and are the season when floods and landslides occur. There is considerable variation in the amount of monsoon rainfall across the CB districts, from ~1,000 mm to ~1,800 mm. The highest rainfall, above 1700 mm, is observed over Chitwan, and the lowest, less than 1300 mm, over the western and eastern parts of the country. High rainfall may lead to flash and sheet floods in the CB region (3.9b). Annual

FIGURE 3.11. THE PATTERN OF ANNUAL RAINFALL OVER THE CB DISTRICTS



Data Soure: DHM

rainfall varies between ~1400 mm and ~2400 mm (Figure 3.9e) though the post-monsoon and winter seasons are comparatively dry.

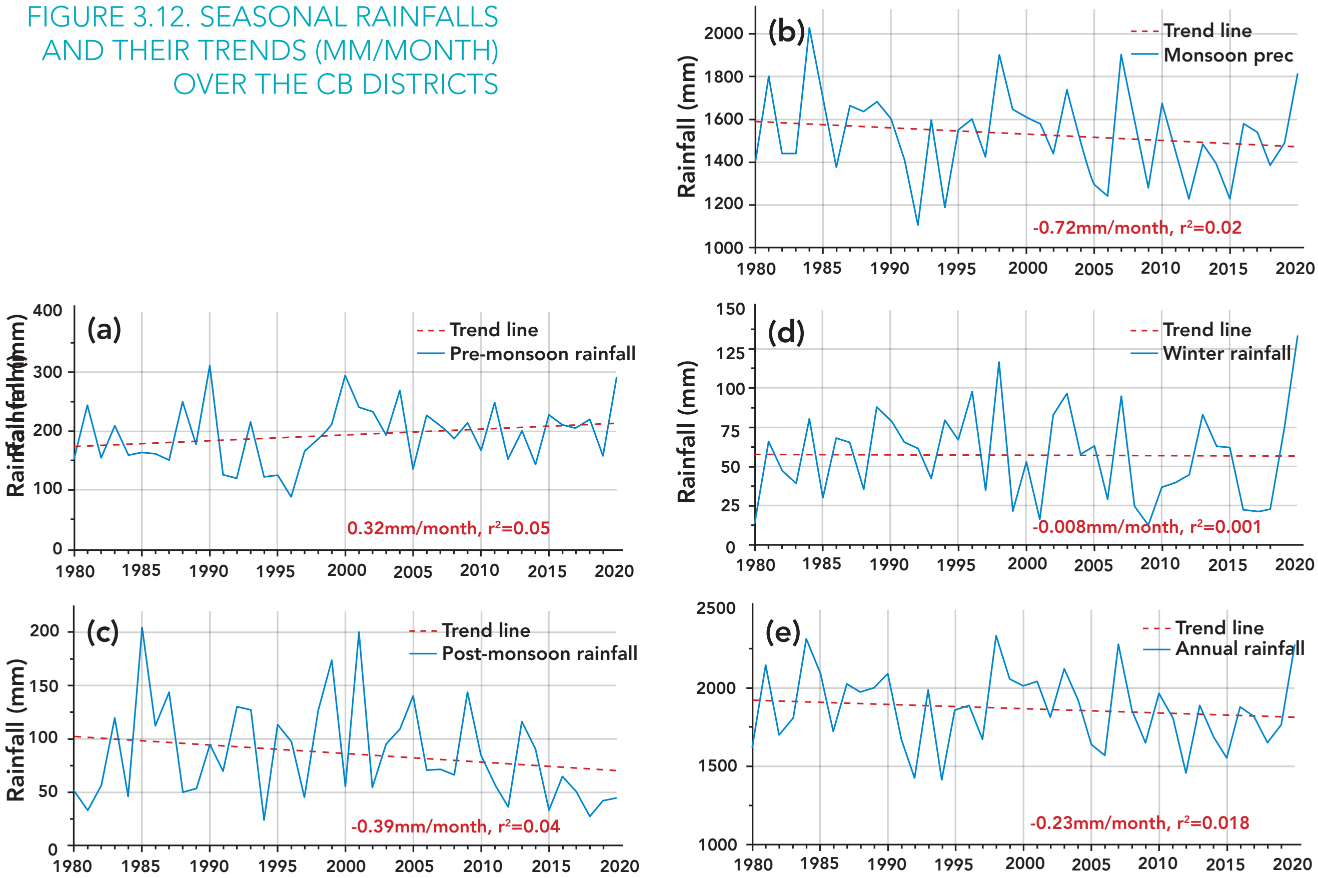
Figure 3.10 shows that the annual distribution of rainfall with higher amount from June to September. During this season, rainfall starts to increase in June, peaking in July, and decreasing in August and September. The highest mean monthly rainfall, 520 mm, is recorded in July, while the lowest, about 20 mm, is recorded in November.

The interannual variation shows that the highest rainfall (above 2,200 mm) fell in the years 1984, 1998, 2007, and 2020 (Figure 3.11). The lowest rainfall (below 1,400 mm) was observed in the years 1992, 1994, 2012, and 2017. Generally, high rainfall years are related to flood disasters. The nature of that flooding, however, is interdependent on a complex set of factors in tandem. For example, though 2017 was a low rainfall year, it faced major floods due to high rainfall in August. Flooding in the lower parts of CB districts also depends on the area's interactions with flood responses in rivers that originate in the Mahabharat ranges, interactions affected by the exposure of people and their assets and infrastructures.

3.6.3 Seasonal and annual trends:

Figure 3.12 shows seasonal and annual rainfall and various trends over the CB districts between 1980 and 2020. Pre-monsoon rainfall over CB districts varies between 100 mm and 300 mm. In this season, the highest rainfall (about 300 mm) fell in 1990, 2000, and 2020 (Figure 3.12a). The monsoon season contributes about 80% of the annual rainfall in the country. In the CB districts, its contribution ranges between 1,200 mm and 2,000 mm (Figure 3.12b), with the highest and lowest amounts having fallen in the years 1984 and 1993, respectively. Post-monsoon rainfall ranges between 40 mm and 200 mm (Figure 3.12 c), whereas winter rainfall varies between 20 mm and 125 mm (Figure 3.12 d). An insignificant increasing trend in rainfall (0.32 mm/month) was recorded in the pre-monsoon season while decreasing trend was recorded in the monsoon (0.72mm/month) and post-monsoon (0.39 mm/month) seasons. No trend was evident

FIGURE 3.12. SEASONAL RAINFALLS AND THEIR TRENDS (MM/MONTH) OVER THE CB DISTRICTS



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in the winter season. Overall, on an annual timescale, a declining trend of 0.23mm/month was recorded, but that rate was insignificant.

3.6.4 Extreme rainfall events:

High-intensity rainfall events trigger landslides in upper reaches and, in consequence, flood hazards that lead to disasters in CB districts. The following section analyzes the temporal distribution of rainfall days and heavy and extreme rainfall events over CB districts during the study period. CCI/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) has suggested extreme rainfall indices[10]. Based on the indices used in earlier studies are applied [11].

Rainfall days are classified as follows:

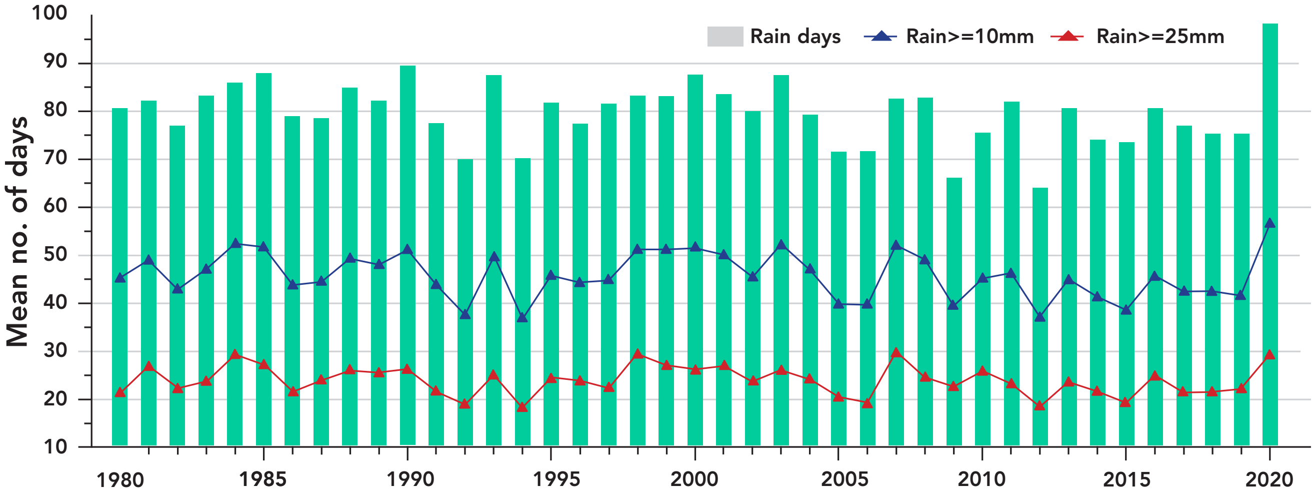
Normal: Days when rainfall is equal to or greater than 1mm/day but less than 10 mm/day

Heavy: Days when rainfall is equal to or greater than 10 mm/day and less than 25 mm/day

Extreme: Days when rainfall is equal to or greater than 25 mm/day.

Figure 3.13 shows that, during the study period, the number of rain days in a year varied between 60 days and 90 days. By this measure, the year 2020 was the wettest (rainfall for ~100 days), and in 2012, the driest (rainfall for ~65 days). The variation in the number of heavy and extreme events is also stark: the greatest number of heavy

FIGURE 3.13. AVERAGE NUMBERS OF RAIN DAYS, HEAVY RAIN DAYS, AND EXTREME RAINFALL



Data Soure: DHM

and extreme events, 30, was observed in 2020, and the least, 17, in 1994. Most of these events occurred during the monsoon season and represent the extreme over the CB districts. In 2020 several flood and landslide events, and a larger-than-usual number of extreme events were reported in Nepal.

Table 3.2 presents the average numbers of rain days, heavy rain days, and extreme rainfall as classified above. Over the data analysed period in the selected stations the average normal, heavy and extreme rainfall are 21 percent, 12 percent, 6 percent respectively,

It is worth mentioning that the floods in CB districts are caused by extreme events. In a few cases, the flows of the first and second-oder rivers with larger catchment areas and flow respones than those of CB rivers and each with its unique hydrology intermingle in the Tarai plains. When the flood peaks of these rivers synchronize, the scale of devastation is amplified. Table 3.3 presents the highest one-day rainfall at each station for the period from 1980 to 2020 The highest 24-hour rainfall amounts vary between 210 mm (Mahottari) and 516 mm (Makawanpur of CB region) (Figure 3.14)[12].

3.7 CLIMATE CHANGE

Global climate change is already becoming a lived reality in South Asia. South Asia's diverse geography: the Himalayas, the Mid hills, the CBs Indo-Gangetic plains, and the diverse climatic regime is highly vulnerable to climate change. The low economic development and institutional capacity of south Asian countries add to further vulnerability. The CBs face changes in climate regime that imposes new norms on urban poor, smallholder farmers challenges across the region and its inhabitant's urban poor, smallholder farmers, artisans, and women who lose out on water security.

The Intergovernmental Panel on Climate Change (IPCC) AR6 suggests that the average annual temperature in Nepal will increase faster than the global average. Changes in rainfall in Nepal, too, are likely to be less predictable than precipitation changes globally. Recent climate projections suggest that the mean annual

TABLE 3.2 RAINFALL DAYS IN CB DISTRICTS

District	Rainfall days			% of rain days		
	Rainy (>1 mm/ day and <10 mm/day)	Heavy (>10 mm/day and <25 mm/day)	Extreme (>25mm/day)	Rainy (>1 mm/day and <10 mm/day)	Heavy (>10 mm/day and <25 mm/day)	Extreme (>25mm/day)
Banke	3768	1918	875	26	13	6
Banke	2484	1334	670	17	9	5
Banke	2202	1363	665	15	9	5
Bara	2712	1896	1037	19	13	7
Bara	3952	2066	1014	27	14	7
Bardiya	3500	2111	1139	24	14	8
Bardiya	2415	1395	673	17	10	5
Bardiya	2096	1213	672	14	8	5
Chitawan	2533	1451	775	17	10	5
Dang	2656	1639	847	18	11	6
Dhanusa	3218	1703	915	22	12	6
Jhapa	4259	2334	1161	29	16	8
Jhapa	3872	2140	1097	27	15	8
Kailali	2591	1488	882	18	10	6
Kailali	3104	1654	847	21	11	6
Kailali	3096	1742	974	21	12	7
Kailali	3778	1989	1019	26	14	7
Kailali	3574	2219	1214	24	15	8
Kailali	3331	2308	1300	23	16	9
Kanchanpur	3504	1886	960	24	13	7
Kapilbastu	3013	1659	866	21	11	6
Makwanpur	1951	1323	708	13	9	5
Morang	2673	1422	744	18	10	5
Nawalparasi	3158	2075	1203	22	14	8
Nawalparasi	3801	2399	1286	26	16	9
Nawalparasi	3026	1703	889	21	12	6
Rupandehi	1823	919	443	12	6	3
Rupandehi	2821	1420	655	19	10	4
Rupandehi	2995	1578	829	21	11	6
Saptari	2591	1464	796	18	10	5
Saptari	3264	1732	825	22	12	6
Sarlahi	2791	1561	819	19	11	6
Sarlahi	4218	2438	1232	29	17	8
Sindhuli	4577	2451	1210	31	17	8
Siraha	2701	1569	845	19	11	6
Siraha	1243	910	453	9	6	3
Sunsari	3560	2038	1006	24	14	7
Sunsari	2458	1459	708	17	10	5
Sunsari	3005	1663	839	21	11	6
Surkhet	3228	2136	1271	22	15	9
Surkhet	4018	2181	1242	28	15	9
Udayapur	2375	1377	700	16	9	5
	Average	893	315	21	12	6

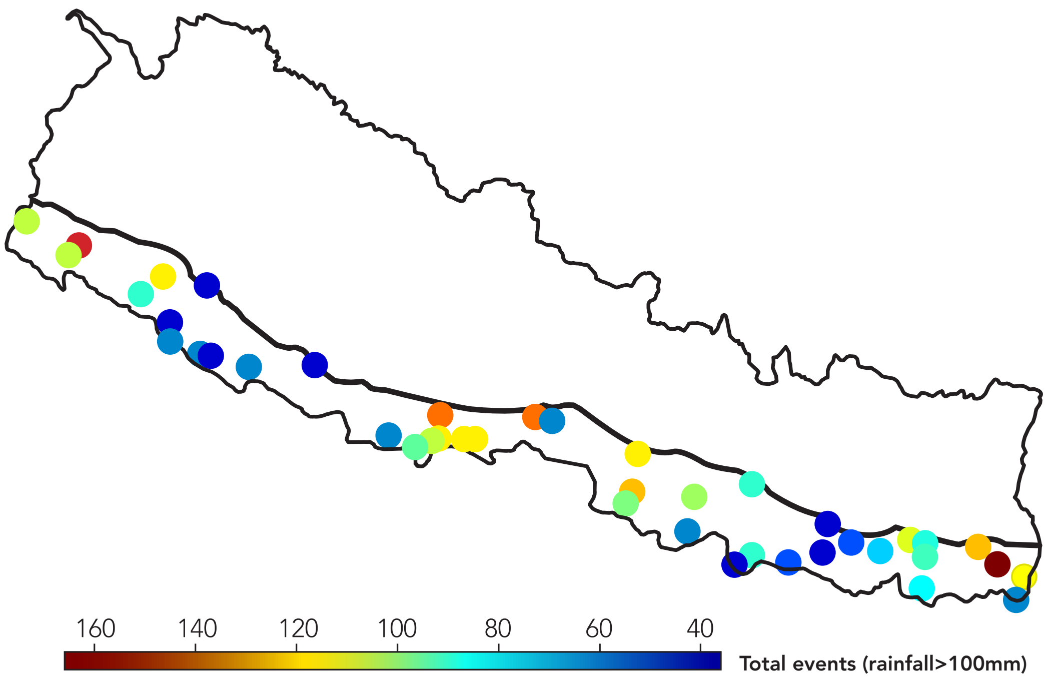
Total number of days in 40 years, 14600, Leap year not considered . More than one station in the same district.

TABLE 3.3. THE HIGHEST-EVER 24-HOUR RAINFALL RECORDED AT EACH STATION IN CB REGION BETWEEN 1980 AND 2020

District	Recorded highest 24 hours rainfall (mm)
Banke	280.2
Banke	336.9
Banke	420
Bara	300.3
Bara	320
Bardiya	325
Bardiya	335.5
Bardiya	499.8
Chitawan	405.4
Dang	298.4
Dhanusa	339.5
Jhapa	330
Jhapa	381
Jhapa	437
Jhapa	452
Kailali	296
Kailali	324
Kaliali	290.9
Kanchanpur	309.5
Kapilbastu	298.5
Mahottari	210
Makwanpur	516.2
Morang	223.5
Nawalparasi	324.5
Nawalparasi	355
Nawalparasi	400.7
Rupandehi	266.5
Rupandehi	267.4
Rupandehi	332.2
Rupandehi	378.6
Saptari	245.4
Saptari	270
Sarlahi	325.4
Sarlahi	432
Sindhuli	403.2
Siraha	228
Siraha	274.6
Sunsari	286.4
Sunsari	352
Sunsari	377.6
Surkhet	423.1
Udayapur	444.4

* Note : To indicate the nature of extreme values we have also included rainfall in Dang, Chitwan and Nawalparasi (East and West). More than one station in the same district.

FIGURE 3.14. NUMBER OF PEAK RAINFALL EVENTS HIGHER THAN 100 MM/DAY IN CB REGION



temperature in Nepal as a whole and in the Tarai, in particular, will increase by 1.4°C and 1.5°C respectively by 2030.

The increase in mean annual temperature is slated to be higher in western than central Nepal. An increase of 15–20% in monsoon rainfall and more variability in its incidence is also projected[13].

The CB region already experiences extreme weather events and frequent secondary hazards, primarily floods. More intense rainfall, especially if it falls on the degraded watersheds of the Chure range, is likely to result in greater damage than is currently caused. It does not help that the excessive extraction of sand, gravel, and boulders from the rivers of the CB region is changing the dynamics and flow regimes of those rivers. The major roads of the region are mostly aligned east-west and cross CB rivers almost at right angles. Since the drainage openings of those roads are inadequate, river flow is constrained in many places. In addition, sedimentation in CB rivers causes them to shift channels, a movement that induces flood impacts on downstream communities, ecosystems, and infrastructures.

Climate change is likely to make rainfall patterns in the CB region more unpredictable. It might also lead to an increase in the frequency and intensity of the sort of climate-related hazards that disrupt socioeconomic systems. In October 2021, rains and consequential floods damaged crops that were ready to harvest as well as roads, bridges, irrigation canals and hydropower plants, resulting in high economic, social, and livelihood losses. During the monsoon season of the following year, in contrast, the same region faced droughts. Though it is hard to attribute any one weather event to climate change, the influence of climate change is clear in the unpredictability of events from year to year. In addition,a more disturbed landscape due to human intervention than in the past and social contexts play a part in making people more vulnerable. Repeated disruptions will further impinge upon social systems which people are already emigrating from in search of new sources of livelihood.

The CB region is one of the fastest-urbanizing regions of Nepal. In India, the CB-dependent region is already densely populated .Climate change exacerbates the region's multi-hazard risks. Steady increases in temperature and erratic rainfall are likely to affect the functioning and integrity of the region's natural ecosystems and infrastructure with higher risks of frequent, longer, and more intense heat waves, flooding, air pollution, forest fires, and dry spells. The change in climatic events toward more extremity will manifest itself in the water cycle and their responses to the livelihood of the people. In the CB districts in Nepal, as is this case in the northern Ganga plains, any increase in temperature is associated with a rise in moisture content. Their combined impact in turn increases the heat index that cause excruciating summer condition.

An increase in the temperature and humidity combine will have a direct impact on people, the food system, and vegetation. Increased heat and weather changes will make environmental conditions different from those of the past, and the new regime may be unsuitable for some of the existing species of vegetation. Older species may be forced to shift to cooler or wetter regions found at higher altitudes or in sheltered pockets. The continuation of this change may result in alterations of vegetative structures and the acceleration of the encroachment of invasive alien plant species. Under such conditions, some species may adapt to survive, while others may simply die. Present-day climate scenarios do not capture some of these granular impacts on ecosystems even though they can have serious social and environmental consequences. The implications of the combined rises in temperature and moisture content that add to heat challenges on the social-environmental contexts of CB districts in Nepal, and human comfort have not yet been systematically studied.

3.8 CHURE BASIN RIVERS

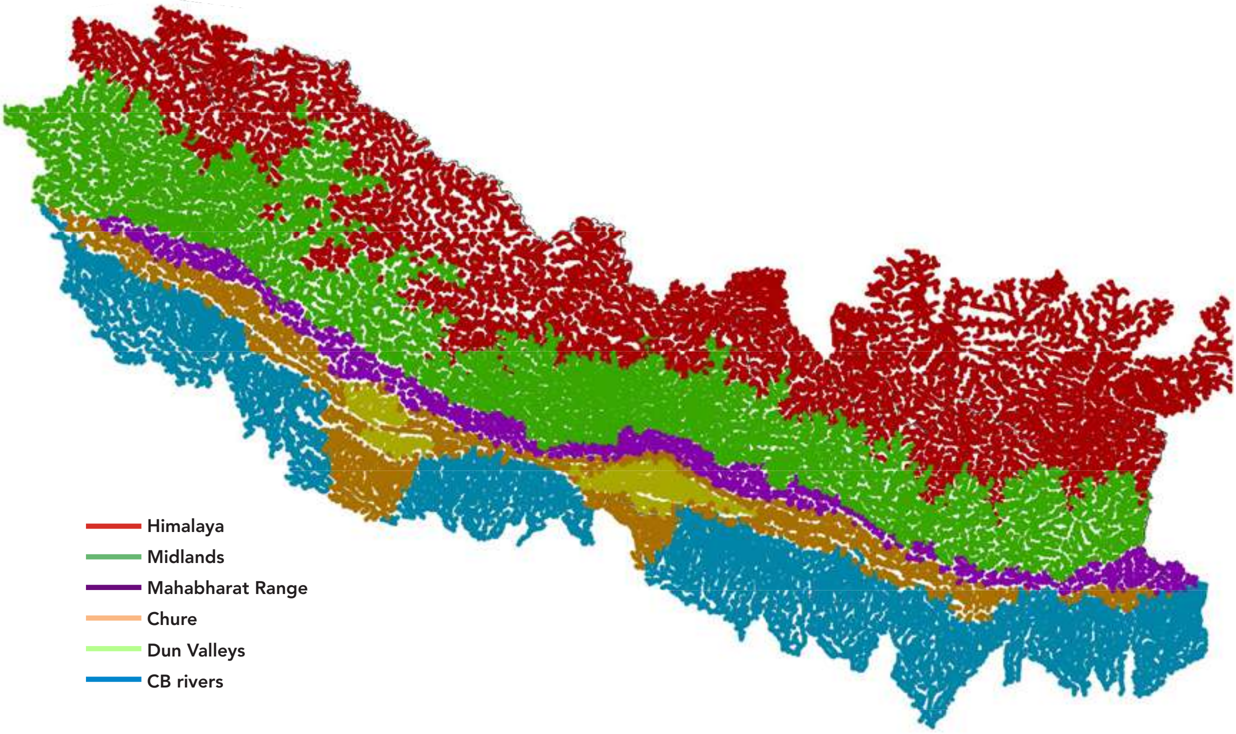
The seasonal rivers of CBs in Nepal have their headwaters in the Chure range. Some of their smaller tributaries also originate in Bhabar, central and southern Tarai. The rivers first flow onto the plains of southern Nepal and then cross into the contiguous landscape of Northern Bihar and Uttar Pradesh. The general direction of the flow of CB rivers in Nepal changes from west to east. In Nepal, most CB rivers flow in a north-south direction until they reach their receiving rivers across the border. The exception is the Mohana River, which begins in the Chure range of Nepal's Sudur Pachhim Province. After receiving flow from its tributaries, the Mohana flows in a west-east direction along the Nepal-India border and joins the Karnali in Uttar Pradesh. In the west, Nepal's CB rivers flow into the Mahakali (Sarada) and Karnali (Ghaghara), Babai (Sarayu), West Rapti, Gandak, and Burhi Gandak rivers in Uttar Pradesh and Bihar, all of which generally flow in the east-south direction towards the Ganga River. The Bagmati River flows southward in the Tarai and after flowing into Bihar generally flows south-eastward until it meets the Koshi. The Koshi then flows southward in its inland delta before turning eastward in the lower reaches to join the Ganga. (See Figure 1.2) while the Mahananda flowing southward joins the Ganga. In Chapter 1 we mentioned about Nepal's three major river system as snow-fed, spring fed and rain-fed rivers. In 2020, this classification has been further expanded to incorporate the diversity contained the country. The classification is based on physiography size (Strahler stream order system) and water source as shown below (Figure 3.15 a,b,c)

The CB basins in Nepal are situated between the courses of Nepal's snow-fed and Mahabharat rivers as they flow across the Tarai with the Chure range as their northern and the Nepal-India border as their southern boundary. Thus, in Nepal, CB rivers can be grouped into eight watershed units, as shown in Table 3.4 and figure 3.16. The catchments of these rivers in Nepal is small each is typically less than 350 km^2) and has lower surface water yields than spring- and snow-fed rivers. The catchment of a few CB rivers, including the Tinau and the Banaganga rivers, also extends to the southern slopes of the Mahabharat range in northern Nepal. Collectively the rivers drain an area of around 26,576.55 km^2 of CBs. In many places, embankments have created a boundary between river courses and their flood plains. For example, the Koshi is contained within embankments from a few kilometers north of the Koshi barrage in Nepal to a few kilometers upstream of its confluence with the Ganga River. As rivers flow within such embankments, they may erode and cut the banks on which embankments lie.

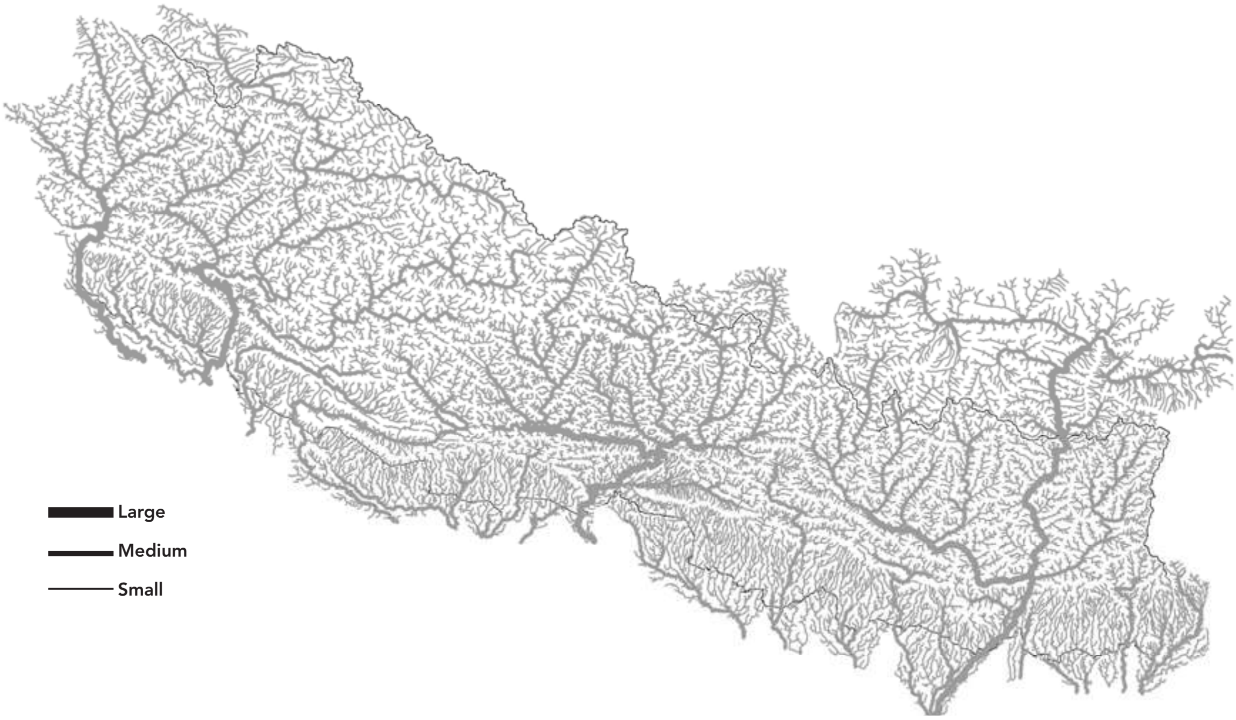
The upper elevations of the CB districts which are the southern face of the Chure range, have large numbers of streams and as they flow south, they merge and their number decreases (Figure 3.17). Some rivers merge with each other before they cross Nepal-India border. The Lal Bakaiya and Dhansar in Rautahat and Bara districts merge with each other about 12 km south of the East-West Highway. The merged course flows as Bakaiya. Likewise, some CB rivers like Kamal, Banani and Arjun khola merges with Kankai, the Mahabharat river in Jhapa District. This presented accounting for their number difficult and not straightforward as a river

FIGURE 3.15: CB RIVERS AS PART OF RIVERS IN NEPAL ACCORDING TO PHYSIOGRAPHY, SIZE AND WATER SOURCES

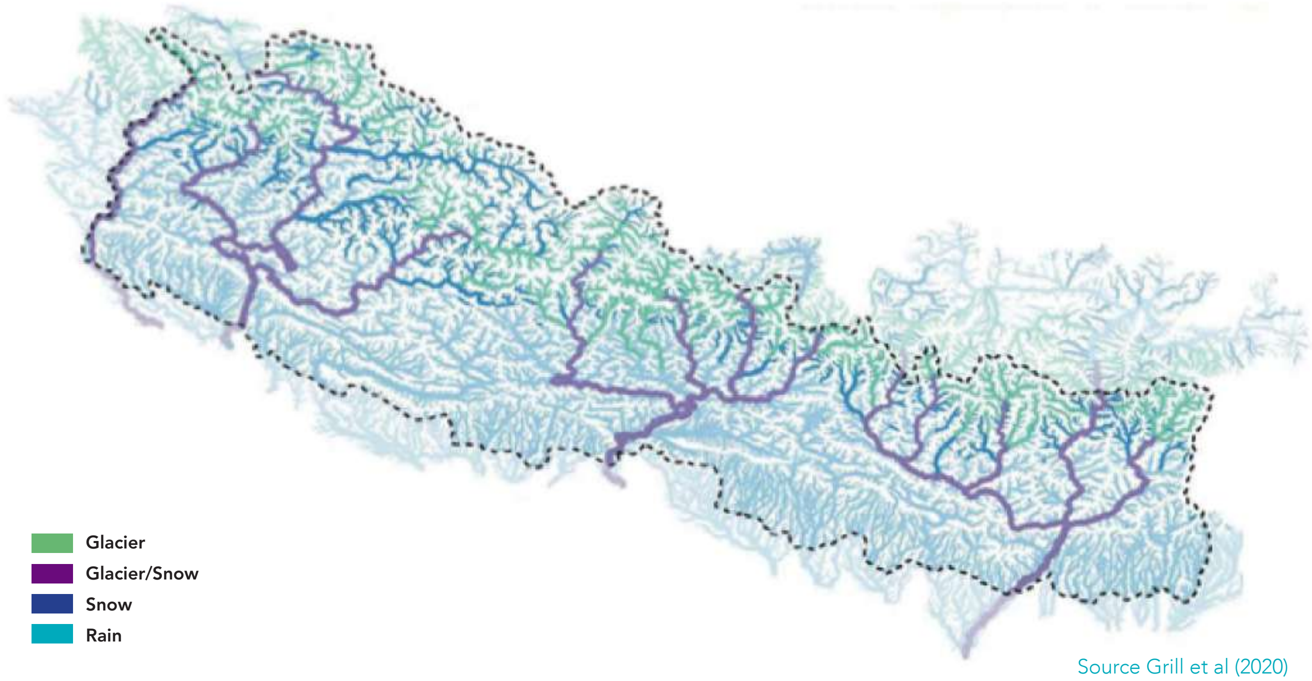
a. Rivers of Nepal according to physiography



b. Rivers of Nepal according to catchment size



c. Rivers of Nepal according to source of water



Source Grill et al (2020)

in the mountain with defined watershed boundary. The rivers begin to meander and move between banks, which, over time, the rivers may erode. Many times, when the larger snow-fed and Mahabharat rivers flood during the monsoon season, the excess river flow mixes with CB rivers and can bring widespread inundation. In the plains in both Nepal and India, the catchment boundaries of CB rivers overlap making estimate of the watershed and number difficult (Figure 3.17)[14].

We used bridges built or required to be built in the highways to broadly estimate the number of CB rivers. The East-West Highway mostly aligned along Bhabar zone, and along the Hulaki Highway which lies about 30 km south of the East-West highway running along Southern Tarai zone closer to the Nepal-India border. We assumed that the number of bridges constructed and proposed over rivers that cross both highways corresponds to the number of river courses. The Department of Road maintains database of the bridge[15]. This database puts the number of bridges along the East-West highway at 516[16], which we propose corresponds to the number of rivers in the upper part of the larger Tarai region including Chitwan, Nawalparasi, and Dang districts. In these three districts the total number of bridges is 90, and since this study does not include these as CBs, we deducted 90 from 516 to get 426 bridges (and correspondingly 426 rivers) in the 18 CB districts.

As the rivers flow south, they merge into each other; thus, by the time the rivers reach the Nepal-India border, there are less than 426. Indeed, the DoR's database of the bridges on the Hulaki Highway has fewer bridges. According to the database, this southern highway has 192 bridges, 28 of which are in Chitwan, Nawalparasi East, or Dang districts again not considered part of the CB region. Thus, deducting 28 from 192 yields a total of 164 bridges suggesting that the same number of seasonal transboundary CB rivers cross the Nepal-India border. It must, however,

TABLE 3.4 CB RIVERS IN NEPAL

Sub watersheds	Boundary	Rivers
1	Between the Mahakali River on the west, the Karnali River on the east	Mohana, Khutiya, Dhuraha, Choudhar, Brahmni, Siyali, Donda, Kanari, Kaitaya, Kanera, Kaha, Patharaiya
2	Between Babai River on the west and the West Rapti on the east	Man khola, Dundawa khola.
3	Between the West Rapti River on the west to northwest, and the Gandaki/Narayani River on the east.	Banganga, Kothi, Kanchan, Tinau, Rohini, Dano, Jamuar, Marthi, Mahau, Jharahi, Dhanuwa, Satabudri.
4	Between Narayani/Gandaki River on the west and the Bagmati River on the east	Tilawe, Uria, Sikta, Bhaluyahi, Sirsia, Bagari (Dudhora), Pashaha river, Thalahi, Tiar river, Jamuni, Arawa (Aruwa) river, Lal Bakeya, Jhanj, Chandi.
5	Between the Bagmati river on the west and the Kamala on the east	Manusmara, Lakhendehi, Hardi, Hardinath, Jamuni, Marha, Rato, Aurahi.
6	Between the Kamala River on the west, and the Koshi River on the east.	Bhatibalan, Khando, Gurmi, Mainawati, Gagan, Kalayandehi, Bihul, Kharag, Ghoradah, Mahuli, Sundari, Gangajali.
7	Between the Koshi River on the west, the Kankai River to the east	Lohandra, Sunsari, Singhiyahi, Chisang, Bakra, Dansa, Ratuwa, Goriya, Kisani, Budhi.
8	Between the Kankai and the Mechi rivers	Biring Khola, Dewan Khola. Joshi et al (2008)

FIGURE 3.16: SCHEMATIC OF CB RIVERS

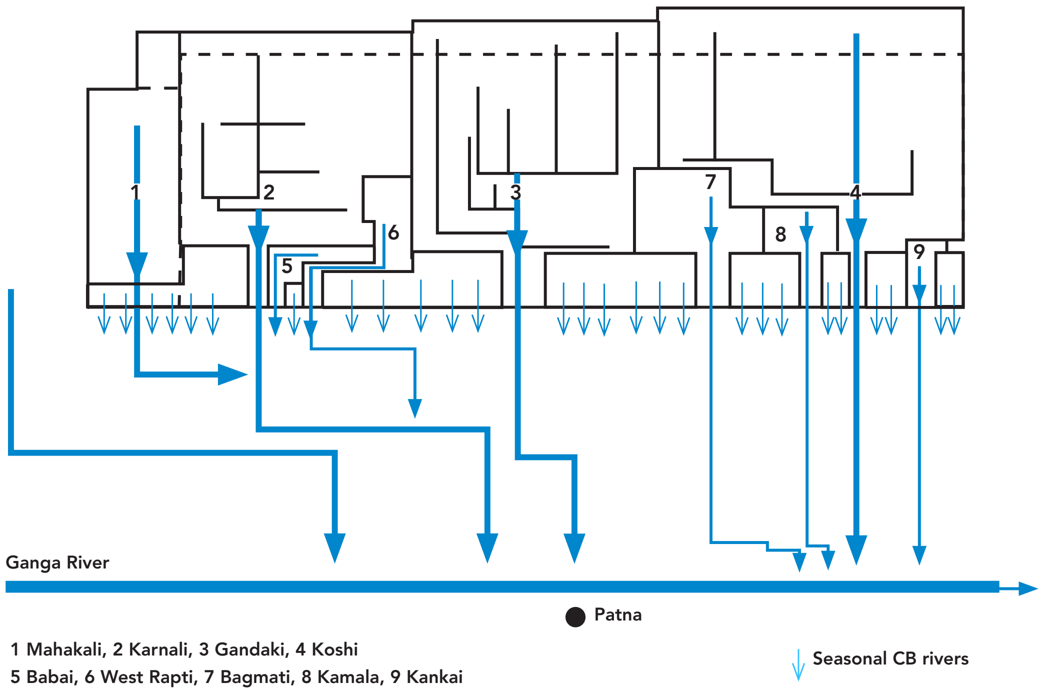


FIGURE 3.17: SCHEMATIC OF SEASONAL RIVERS IN UPPER AND LOWER REGIONS OF CBs

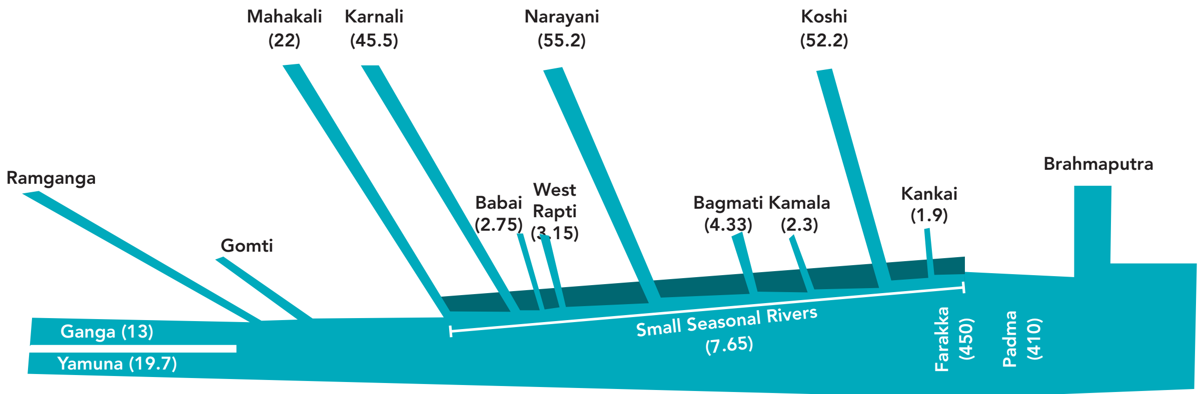
be recognized, as mentioned earlier, that given the flat landscape of the Nepal Tarai, sheet and rill flows as well as many smaller rivulets flow through this southern region into India.

The hydrology of CB rivers is governed by rainfall during the monsoon months. In the dry season, their flows become much lower than they are during the monsoon months. Except during the monsoon, most CB rivers appear dry in the upper regions, and their channels, which are braided with the flow, occur underneath their riverbeds. In the last few decades, human interventions such as transportation networks and barrages, the expansion of settlements, sand, and aggregate mining, pollution, and groundwater pumping have altered the geomorphology of CB rivers. During the monsoon months, CB rivers overflow and spill onto the floodplains which line their banks, inundating agricultural land and settlement, destroying assets, and adversely affecting people. As mentioned above, CB rivers maintain some flow, even during the dry season, in the low-elevation and southern parts of CB districts.

The discharges of only a very few CB rivers are routinely measured[17] and indirect methods are used to do estmate annual runoff from these rivers. These estimates suggest that the combined annual run-off from these basins in Nepal is 1,113 m^3/s and more than 90% of their annual runoff occurs during the monsoon months[18] with flashy peaks following upland rainfall. The share of discharge that CB rivers contribute to Ganga's annual flow at Farrakka is 7.65%. In contrast, snow-fed and Mahabharat rivers from Nepal contribute 38.13% and 3.17% of Ganga's total discharge at Farrakka, respectively[19] (Figure 3.18). Nonetheless, these small rivers flow through a region with high population density and form a crucial part of local ecosystems and play a key role in meeting people's needs. In addition, the health of these small rivers eventually determines the health and integrity of the Ganga River. At the same time, CB rivers also lead to flood disasters.

CB rivers are different from snow-fed rivers and the spring-fed Mahabharat rivers. the snow- and spring-fed rivers cover a much larger area in the hills than in the Tarai plains. In contrast, CB rivers flow over larger areas in the plains than in the Chure hills. Each CB river also has its own unique

FIGURE 3.18:
SCHEMATIC OF THE GANGA RIVER AND ITS NORTHER SNOW-FED, MAHABHARAT AND SESONAL FLOW AND THEIR AVERAGE ANNUAL DISCHARGE



Flow in billion m^3

Ganga flow data Adapted from MacDonald et al (2015)

Note: The flow of the CB rivers add to the Ganga via the tribiraries e the Sharada, the Ghagahara, the Narayani, Koshi and Mahandanda. The numbers may not add. The flow of Padma is lower than that at Farakka due to diversion of Ganaga flow to Hoogly River


Bishazari Taal in Chitwan

Source: Deep Narayan Shah

morphological, hydrological, and sediment transport characteristics, which in part determine the changes they experience in form, plans and the elevation of their beds. In the plains, these rivers move laterally, form oxbow lakes, and sometimes link with wetlands, thereby becoming part of the natural mosaic of terrestrial and freshwater ecosystems. In many places, embankments have created a boundary between river courses and their flood plains. For example, the Koshi is contained within embankments from a few kilometers north of the Koshi barrage in Nepal to a few kilometers upstream of its confluence with the Ganga River. As rivers flow within such embankments, they may erode and cut the banks and on which embankments are built.

3.9 SEDIMENTATION PROCESS

CB rivers carry sediment load derived from upstream land surface erosion, including that from the beds and banks of the rivers. High-intensity rains erode land surfaces, releasing fine sand, clay, and silt from rills, sheet, and gully erosion. These particles are then transported downstream as natural sources. Landslides contribute larger particles of sediment. In addition to these natural factors, human activities also trigger landslides in many places of the CB districts, particularly in the Chure range. In April and May, forest fires in the range burn the vegetation and expose


Gharial Gohi at Babai River ©Bed Bahadur Khadka/ WWF Nepal

the landscape to high rainfall impacts. Such exposed land, then, often generates a greater than usual sediment load into CB rivers. Some of this sediment load is deposited in the Bhabar region.

Generally, the sediment discharge of the CB rivers is not monitored and indirect estimates can only provide an approximate yield. The Burhi Gandak, a CB river that constitutes a small portion of the watershed area in Nepal's Bara District and Bihar's East Champaran and joins the Ganga. With an area of 8,510 km^2, it has an average annual sediment load of 4,450 tonnes. Its specific yield of 523.5 tons/km^2 [20] can be judiciously used to estimate the sediment yields of other CB rivers after appropriately accounting for the influence of the Chure range and other landscape specificities. More than 90% of the sediment load of CB rivers is transported in the four monsoon months.

3.10 GROUNDWATER AQUIFERS

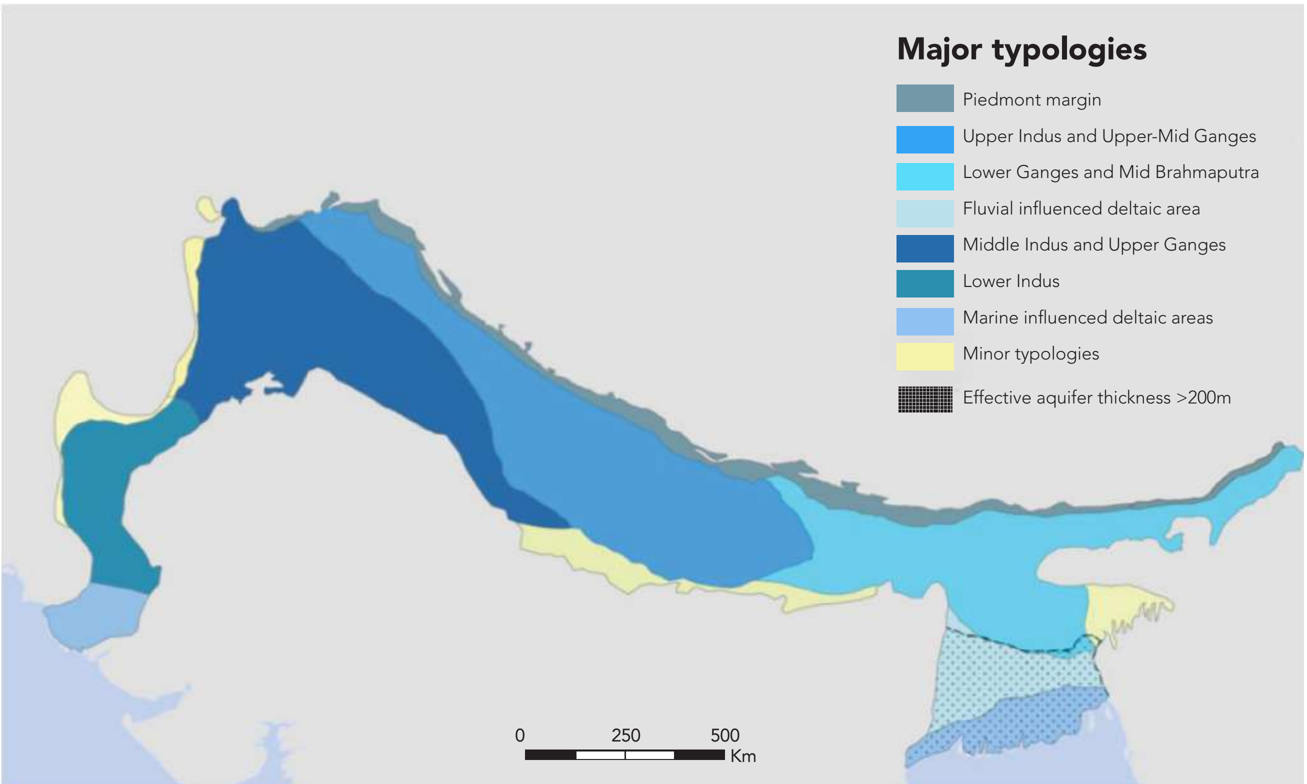
The plains of the CB districts are part of the larger Ganga aquifers (Figure 3.19) that extend to the Bhabar region at the foothills of the Chure range. Broadly, three interconnected aquifers—the Bhabar, seepage zone, and plains zones—exist along the north-south transect up to the Nepal-India border, including the plains in Bihar, and Uttar Pradesh. In the Chure range, groundwater is available only in very few limited pockets of the rock strata. The underground aquifers along the Bhabar zone are deep, about 60 m to 100 m below the surface. Further south on the plains of CB districts, two types of


Trijuga River flows into Koshi River

Source: Narayan Gyawali, Lutheran World Relief aquifers exist shallow (0–46 m depth) and deep (>46 m deep)[21]. The surface flow of rivers flowing from the southern face of the Chure, in-situ rainfall, and part of the river discharge flowing through the Bhabar together recharge these aquifers. In addition, monsoon floods, seepage from irrigation canals, and irrigation water from farmers' fields also replenish aquifers in the plains and add to the amounts of aquifer storage. At a basin scale, across the aquifer, significant spatial differences in groundwater recharge, permeability, storage, and water chemistry (Quality)exist.[22]

Various estimates of groundwater storage, extraction and recharge in Nepal's CB plains are available[23]. One estimate is that the recharge is 8.8 x10^9 m^3/year, extraction, 1.9x10^9 m^3/year; and the reserve, +6.9 x10^9 m^3/year. Another study mentions a net renewable reserve of 1.4x10^9 m^3, while a more recent estimate puts the net groundwater recharge in the CB districts at 11.928x10^9 m^3/year. The Bhabar zone accounts for a recharge of 5.41x10^9 m^3/year; the seepage zone, 2.118x10^9 m^3/year and the plain zone, 4.399x10^9 m^3/year; . These figures indicate that there is more net groundwater recharge in the Bhabar than in other zones. The district-wise details about groundwater in Table 3.5 show that Rupandehi District has the highest net total groundwater recharge at 997x10^6 m^3/year followed by an 864 x 10^6 m^3/year recharge in Kailali District. The groundwater recharge rates of the seepage and Tarai zones are highest in Rupandehi District, at 256x10^6 m^3/year and 478x10^6 m^3/year, respectively. Among the CB districts, the Bhabar zone in Kailali has the highest recharge rate, 522x10^6 m^3/year. These macro picture of

FIGURE 3.18. THE MAIN GROUNDWATER TYPOLOGIES OF THE INDO-GANGETIC BASIN.



Source: MacDonald, et al (2015).

TABLE 3.5: RENEWABLE GROUNDWATER RESOURCES

District	Net total groundwater recharge ($10^6 m^3/yr$)			
	Bhabar zone	Seepage zone	Tarai zone	Total
Jhapa	434	155	258	847
Morang	418	100	345	863
Sunsari	264	100	357	721
Saptari	342	197	250	789
Siraha	247	112	213	572
Dhanusha	176	65	219	460
Mahotari	234	49	200	483
Sarlahi	261	124	162	547
Rautahat	220	88	135	443
Bara	361	41	195	597
Parsa	470	37	154	661
Nawalparasi West	68	59	85	212
Rupandehi	263	256	478	997
Kapilbastu	280	175	237	692
Bardiya	211	185	363	759
Banke	320	167	145	632
Kailali	522	73	269	864
Kanchanpur	320	135	334	789
Total	5,411	2,118	4,399	11,928

* Half of the cultivable area is served by groundwater
Source: Irrigation Master Plan (2019)

the groundwater dynamics also need to heed to excessive extraction and deepning of the level that limit peoples' access to frest water for meeting various needs . These later dynamics are not systematically maintained .

3.11 FOREST RESOURCES

In CB districts, the areas of forest contiguous to the plains in the south and the Chure range in the north vary from east to west. To estimate the area of forest in the CB region, this study uses the lower composite designated as the Chure Tarai Madesh Landscape (CTML), the larger geographic unit within which CB districts exist (Figure 3.20). This composite, which includes northern areas of the Chure range, covers an area of 39,252 km^2, about 26.67 percent of the country's total land area. The CB districts alone occupy a smaller area, just 18 percent of the total. The CTML encompasses five physiographic units; the Chure hills (34.4 percent); Chure narrow gorges (2.2 percent); Doon valley (8.4 percent); Bhabar region (14.9 percent); and Tarai Madhesh (40 percent)[24]. Along with forest, land use in the CB region consists of agriculture, water bodies, and built-up areas as shown in Table 3.6 below.

About 47.16 percent of the CTML is under either forest, shrubland, or grassland. The CTML is home to nine out of Nepal's total 55 forest types[25] and includes tropical and subtropical species such as riverine grassland, *Shorea robusta, Terminalia tomentosa, Anogeissus latifolia, Dalbergia sissoo, Acacia nilotica, Acacia Arabica, Bombax ceiba* dominant forests, and in the upper reaches in Chure *Schima wallichii, Castanopsis indica and Pinus roxburghi* dominant forests are distributed in the CTML.

The CTML is home to seven of Nepal's twenty protected areas, including national parks, wildlife reserves, and conservation areas. They are Chitwan National Park, Shuklaphanta National Park, Bardia National Park, Banke National Park, Parsa Wildlife Reserve, Koshi Tappu Wildlife Reserve, and Blackbuck Conservation Area. These protected areas and their buffer zones cover 5,886 km^2 or about 4% of the country's total area.

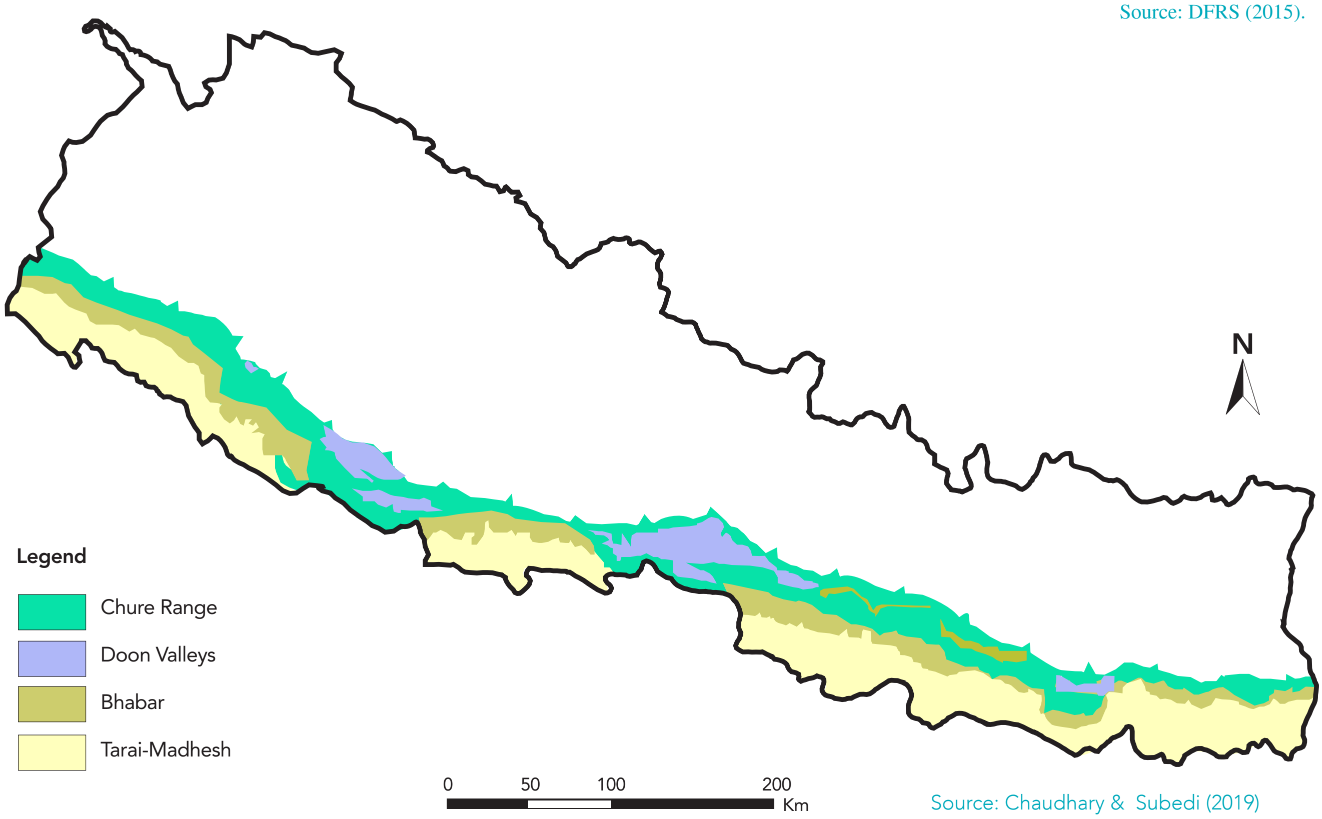
These national parks and reserves are home to the country's charismatic wildlife species, including the wild Asian elephant, Royal Bengal tiger, and one-horned rhinoceros *(Rhinoceros unicornis)*[26], and house more than 500 bird species, including the endangered giant hornbill.

TABLE 3.6. LAND USE IN THE CBs

Districts	Total area	Forest coverage		Agricultural land		Others (River, Bank, Rocks)	
	Ha	Ha	%	Ha	%	Ha	%
Kanchanpur	161,741	50,464	41.55	5,932	3.7	14,009	8.66
Kailai	327,313	197,309	60.28	34,645	10.58	34,629	35.69
Bardiya	202,500	31,729	28.83	75,000	37	14,900	7.35
Banke	225,836	115,776	61.78	12,068	10.74	20,473	9.00
Kapilvastu	173,800	60,448	36.71	83,000	47.75	30,352	17.46
Rupandehi	129,367	24,976	19.30	94,832	73.30	9,559	7.38
Parsa	140,661	17,224	22.01	55,383	39	9,976	7.09
Bara	127,306	45,257	35.55	69,655	54.71	12,394	9.74
Rauthatat	103,854	24,825	23.90	66,494	64.03	12,535	12.07
Sarlahi	126,384	23,460	18.56	87,341	69.11	15,583	12.33
Mahottari	100,149	19,044	19.02	68,548	68.45	12,557	12.54
Dhanusha	118,933	25,640	21.56	76,194	64.06	16,378	13.77
Siraha	114,040	14,951	13.11	81,431	71.41	17,658	15.48
Saptari	128,345	18,808	14.65	79,241	61.74	30,295	23.60
Sunsari	127,734	21,304	16.67	91,799	71.87	13,123	10
Morang	185,500	55,500	29.90	105,270	56.70	24,730	33.2
Jhapa	164,192	13,239	9.54	141,795	86.35	9,158	6.16
Nawalparasi_W		21,859	30.15	NA	NA	NA	NA
Total	1,438,731	781,813	27.95	1,123,358	52	298,309	14.22

Source: DFRS (2015).

FIGURE 3.20: CHURE TARAI MADESH LANDSCAPE



Source: Chaudhary & Subedi (2019)


Fresh water Dolphin in Mohana River
Source: Padam Bista


Royal Bengal Tiger
Source: Muna Thapa


Rhinoceros needs wetlands
Source: Stuwart Chapmas WWF

TABLE 3.7 PROTECTED AREAS OF THE CTML

S.N.	Protected area	Area (sq km)			Remarks
		Core area	Buffer zone	Total	
1.	Chitwan National Park	952.63	729.37	1,682.00	
2.	Bardiya National Park	968.00	327.00	1,295.00	
3.	Banke National Park	550.00	343.00	893.00	
4.	Shuklaphanta National Park	305.00	243.50	548.50	
5.	Parsa National Park	637.39	285.30	912.69	
6.	Koshi Tappu Wildlife Reserve	176.00	173.00	349.5	
7.	Blackbuck Conservation Area	16.95	NA	16.95	
Total		3595.97	2101.17	5886.12	4% (approx.)

Source: DNPWC Portal

TABLE 3.8: RAMSAR SITES IN CBs

S.N.	Name	Area (ha)	Districts
1.	Koshi Tappu	17,500	Sunsari, Saptari and Udayapur
2.	Bishazari Lake and Associated lake	3,200	Chitwan (outside CBs)
3.	Jagadishpur Lake	225	Kapilwastu
4.	Ghodaghodi Lake Area	2,563	Kailai Source: GoN-RCTM (2017)

Source: Chaudhary & Subedi (2019)

The forests are also the habitat of snakes, including the common and king cobras, common and banded karets, pythons, and a variety of other reptiles. A total of three hundred and seventy different species of flora and fauna were found to be used as NTFPs in the region[27].

3.12 WETLANDS

Rivers, riverbeds, and wetlands (the official count of the wetlands is 438 and occupy 4.65 percent of the CTLM[28]. The wetlands of the composite which are designated as Ramsar sites comprise 39 percent of the total area of Nepal's ten Ramsar sites. As is true in other wetlands, these water bodies are among the most diverse and productive of ecosystems that serve as the habitat of birds and aquatic flora and fauna. The wetland ecosystem services support diverse biodiversity and irrigated agriculture through surface and groundwater uses and their conservation is part of nature-based solutions to the emerging risks of climate change.

Within the CTML, CB districts have many local ponds and small water bodies though, as highlighted in the next chapter, increasing urbanization is threatening to encroach upon them. In addition, CB rivers like the Mohana and Pathariya, the tributaries of the Karnali River in the west, are the habitat of freshwater dolphins *(Platanista gangetica)* and when the river water level is high, these aquatic animals move upstream on the rivers and from the lower reaches in Uttar Pradesh. This river region is estimated to house about 100 freshwater dolphins. The GoI has recognized the freshwater river dolphin as the country's national aquatic animal, and in Nepal also efforts are being made for their conservation.

NOTES

1. USGS, The Himalayas: Two continents collide, at https://pubs.usgs.gov/gip/dynamic/himalaya.html. (Accessed on February 7, 2023)
2. See Roy & Purohit (2018).
3. See Roy (2014).
4. Geologically, the HKH is bordered by the Main Boundary Thrust (MBT) in the north and the Main Frontal Thrust (MFT) in the south. The HKH's age dates to between the Neogene and Quaternary periods, which means it is between 14 million and 1 million years old.
5. The details are from CIDS (2020).
6. Ibid.
7. The connected forest also called the "Tarai Arc Landscape" See Thapa et al (2015) and Thapa &Tuladhar (2021).
8. Also see Chapter 5.
9. Leibrand (2022) mentions of the 1972 irrigation master plan of the Tarai.
10. Zhang et al (2011)
11. See Sharma et al (2020a) and Sharma et al(2020b)
12. In this case we also consider Makawanpur immediate north of central CB districts.
13. Based on MoE (2010).
14. While maps prepared in Nepal show the coursesof the CB rivers till India's northern border, maps prepared by analyst in India show the courses of these rivers only till Nepal's border. Basin level maps do not clearl show the details course of these seasonal rivers.
15. See http://bms.softavi.com/dashboard/guest_report_bi/0
16. According CIDS(2020) 48 river systems originating from the Chure region and flowing during the rainy season and 13 river system originating from the Tarai Madhesh region. According to Prasad E (2022), 110 small transboundary rivers flow from Nepal into Bihar's districts of Pashchim Champaran, Purbi Champaran, Sitamarhi, Madhubani, Supaul, Araria and Kishanganj. A systematic study supported by ground-truthing needs to take inventory of the seasonal CB rivers. Carrying out this endeavor in partnership with local entities in Nepal and across the border can yield a better result than having academics alone do it.
17. Only limited data on the discharges of the Tinau and Banaganga rivers exist. In recent times, few other CB rivers have been studied and their discharges estimated. The existing data needs to be collated and synthesized. It is however, not easy to measure their discharge due to their seasonal nature, flat slope, low depth and ill definded channel without stable banks.
18. The percentage of monsoon months flow is calculated based on Joshi et al (2008)
19. The share of flow of rivers of Nepal to that of the Ganga at Farakka is based on data available in Bhattarai (2009).
20. The details are from the Government of India (2015).
21. See GDC (1994).
22. MacDonald et.al (2015) describes seven groundwater typologies of the aquifer each having different resilience to abstraction and climate change and a unique set of challenges and opportunities for groundwater development. The seven typologies are: a) The piedmont margin; b) The Upper Indus and Upper-Mid Ganga; c) The lower Ganga and Mid Brahmaputra d) the fluvial influenced deltaic area of the Bengal Basin; e) The Middle Indus and Upper Ganga; f) The Lower Indus; and g) The Marine influenced deltaic areas. The aquifers face localised water quality degradation depletion and as climate change leads to new rainfall dynamics the infiltrates rates is likely to change exacerbating the problems of arsenic contamination, limit groundwater recharge and base flow of CB rivers. This understanding of the linkage between surface and groundwater system witin the regional hydrology of the CB rivers is limited (Gyawali & Dixit 1999).
23. See Nepal et al (2021).
24. The condition of forest in the CB region called Char Kose Jhadi once considered inexhaustible resource began to change around the time of Nepal's unification in 1784 CE. Changes bagn with providing of grants of land and forests and gradually converting of the forests into agricultural land. The expansion of railways in Bihar, West Bengal and Uttar Pradesh created a new demand for the hard wood (to be used as sleepers for railway tracks) available in these forests. For the then Rana government the selling of the forest was a source of revenue. The practice of cutting trees continued in the post-1950s period too. See Chaudhary & Subedi (2019) for details.
25. Miehe et al (2015).
26. The forests are home to sloth bears, leopards, blue bulls, sambars, chitals, hog deer, barking deer, langurs, rhesus macaques, striped hyenas, jungle cats, and palm civets.
27. See DFRS (2014).
28. See Chaudhary & Subedi (2017).

HUMAN BUILT-SYSTEMS

HUMAN BUILT-SYSTEMS

04

The natural ecosystem, together with services from infrastructure (Human built system) particularly water services, plays a key function in supporting the people of the CB region. Ensuring the sustainability of that ecosystem and those services will be key to building resilience. This chapter provides an overview of the different infrastructures in the CBs which have been producing different services for the people as conditions change.

4.1. SURFACE IRRIGATION CANALS

The CB districts in Nepal once had many large and small earthen irrigation canals built and managed by farmers. Farmers themselves would build a temporary diversion in a suitable section of a river and divert its water to both a main canal and its distributaries for use in irrigation. They operated and managed these diversions and canals as well as a system of water distribution. These "farmer-managed irrigation systems" (FMIS) were prevalent until the modern system began to get built in the 1950s. At present, however, many such locally built small systems no longer function; they have been damaged and/or abandoned. A few have been "modernized": their temporary diversions have been replaced with concrete structures, stretches of their canals lined with concrete, and water control structures built in the canals.

Both farmers and government agencies participate in the operation and management of these upgraded systems. According to the 2019 draft of the irrigation master plan of the DoWRI, "over the past thirty years, Nepal has invested more than NPR 67 billion [approx. USD 800 million] on twelve major irrigation development projects" that include both agency-built and farmer managed irrigation systems. The majority of the large-scale agency-built systems lie in CB districts and together the net area served is about 341,285 ha. The gross and net command areas of the public systems are shown in Figure 4.1 and Table 4.1 below.

Past investments were directed at replacing and rehabilitating diversion headworks and canals as well as providing support to the development of command areas and management of completed systems. In addition, several projects that will divert water from snow-fed rivers into existing irrigation projects in the CBs are being built. The aim of these project is to bring additional areas under irrigation coverage. These projects are shown in Table 4.2 below.

Headworks of Nepal's first engineered irrigation system Chandra Canal in Trijuga River

Source: Sanjeeb Wagle

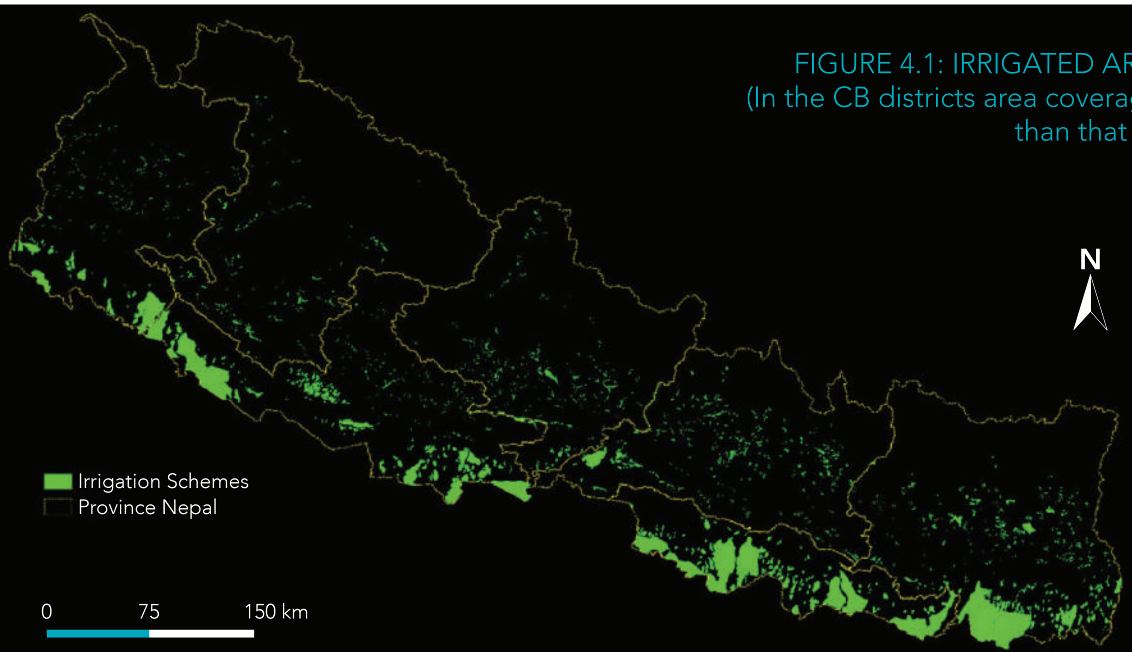


FIGURE 4.1: IRRIGATED AREA NEPAL
(In the CB districts area coverage is larger than that in the hills)

Map source: Based on Irrigation Master Plan 2019 developed by Saroj Karki

TABLE 4.1. SURFACE IRRIGATION SYSTEMS IN CB DISTRICTS

SN.	District	River Name	Gross Command Area	Net Command Area	Type
1.	Bara	Narayani	16,650	12,238	Type
2.	Bardiya	Babai	35,421	29,500	
3.	Bardiya	Rajapur	17,140	13,000	Upgraded FMIS
5.	Dhanusha	Kamala	12,500	12,500	Agency-built
6.	Jhapa	Kankai	10,216	8,000	
7.	Kailali	Ranijamara	11,300	11,300	Upgraded FMIS
8.	Kanchanpur	Mahakali Phase	5,520	4,800	Agency-built
9.	Kanchanpur	Mahakali Phase	8,500	6,800	
10.	Kapilbastu	Banganga	10,734	6,200	
11.	Morang	Sunsari-Morang	28,000	23,800	
12.	Nawalparasi_W	Nepal Gandak	14,112	10,300	
13.	Parsa	Narayani	20,761	16,462	
14.	Rautahat	Bagmati	29,035	23,000	
15.	Rupandehi	Marchwar Lift	3,500	3,500	
16.	Saptari	Chandra Canal	13,593	10,500	
17.	Saptari	Koshi West Canal	14,298	11,000	
18.	Sarlahi	Bagmati	28,403	2,2600	
19.	Sarlahi	Manusmara	2,828	2,200	
20.	Sarlahi	Manusmara 2nd	3,912	3,000	
21.	Siraha	Kamala	12,500	12,500	
22.	Sunsari	Chanda Mohana	2,362	1,800	
23.	Sunsari	Sunsari-Morang p-3	40,000	34,000	
Total			341,285	279,000	

Source: Adapted from Irrigation Master Plan (2019)

TABLE 4.2. INTER-BASIN WATER TRANSFER PROJECTS: ONGOING AND PROPOSED

Diverted Basin	Source River	Tunnel (km)	Water Diversion (m3/s)	Hydropower Output	Irrigated Area (ha.)	Status /Comment
Bheri-Babai	Bheri	12.3	40	46MW	45100	Tunnel is completed
Karnali-Tarai	Karnali	19	59	80MW	46000	
West Rapti-Kapilvastu	Rapti	23		100MW	40849	
Kaligandaki-Rupandehi District	Kaligandaki	25	66		42000	Transfer tunnel & addition of Andhi Khola storage dam
Sunkoshi-Marin and Kamala	Sunkoshi				352000	Tunnel is being built
Sunkoshi to Marin River		14	77	41MW	55000	Command area includes the existing irrigation systems of the Narayani and Bagmati rivers.
Sunkoshi Kamala diversion		17	72		129000	Command area includes the existing irrigation systems of Kamala river.
Tamor to Chisang River	Tamor	31		732MW	45000	
				90MW	114000	

Source: Irrigation Master Plan (2019)

4.2 GROUNDWATER USES

In the CBs, water from both shallow and deep groundwater aquifers is pumped to the surface to meet irrigation and drinking water and some industrial needs. Both shallow tubewells (STWs) and deep tubewells (DTWs) are used. The number of STWs and DTWs each in CB district is shown below in Table 4.3.

There are 141,596 STWs in CB districts. Together they irrigate 415,753 ha of land. Bara District has the greatest number-10,876 STWs serving 32,280 ha- while Kapilbastu District has the fewest, just 2,997 STWs serving 8,456 ha of land. The 1,179 DTWs in CB districts serve a land area of 46,949 ha. Rupandehi District has the most DTW, 24 serving 22,104 ha, while Sunsari District has the fewest, just 16 serving 444 ha. The GoN subsidizes farmers who wish to install STWs but is itself the main installer of DTWs. STWs and DTWs operate for, on average, 720 and 1,000 hours respectively in a year. DTWs also pump water from deep aquifers and store it in overhead tanks to supply settlements to meet their drinking water needs. Industries install DTWs but no systematic database or their installation is available.

4.3 TRANSPORTATION SYSTEMS

(a) Roads and highways

In CB districts both in Nepal and across the border in India, the development of transportation infrastructure such as railways and roads began in different periods. Indeed, there was almost a

TABLE 4.3: SHALLOW AND DEEP TUBEWELLS IN CB DISTRICTS (2017/2018) [1]

District	Number	Ha
Jhapa	22	690
Morang	16	532
Sunsari	16	444
Saptari	30	800
Siraha	59.9	1,443
Dhanusa	108	3,194
Mahottari	90	1,548
Sarlahi	41	866
Rautahat	18	160
Bara	42	1,160
Parsa	27	463
Nawalparasi	85	2,305
Rupandehi	243	22,104
Kapilbastu	118	2,245
Banke	84	2,645
Bardiya	38	1,295
Kailali	80	2,475
Kanchanpur	62	2,580
Total	1179	46,949

District	Number	Ha
Jhapa	10,040	32,172
Morang	9,841	32,052
Sunsari	9,084	30,521.5
Saptari	6,779	20,888
Siraha	7,477	24,357.5
Dhanusa	7,476	20,533
Mahottari	5,712	15,997
Sarlahi	8,076	22,893.5
Rautahat	7,924	23,263
Bara	10,876	32,280
Parsa	4,998	13,958.5
Nawalparasi	6,913	18,586.5
Rupandehi	9,235	27,416.5
Kapilvastu	2,997	8,456
Banke	6,503	17,665
Bardiya	8,819	23,540
Kailali	10,805	29,119
Kanchanpur	8,041	22,053.5
Total	141,596	415,753

Source: Groundwater Development Board

Section of East-West Highway being expanded.

Source: Sanjaya Wagle

century-long gap as the development of transportation infrastructure in Bihar and Uttar Pradesh began in the 1850s, while that in the CB districts of Nepal began only in the 1950s. Until the 1950s, Nepal had only 376 km of roads and the entire length was in the capital city of Kathmandu. Elsewhere, people walked, sometimes for days, to reach their destinations. In 1956 Nepal's Tribhuban Highway, which connects Kathmandu with Bhaise in Makawanpur District, was completed. Then, via Bhainse, the highway that ultimately reach the southern Indian border town of Raxaul of Bihar was built. After the completion of this highway, the building of motorable all-weather roads across the country began. Today Nepal has thousands of kilometers of roads on which more than 2.5 million motor vehicles ply. The construction of road infrastructure is at present the country's major focus and development endeavor.

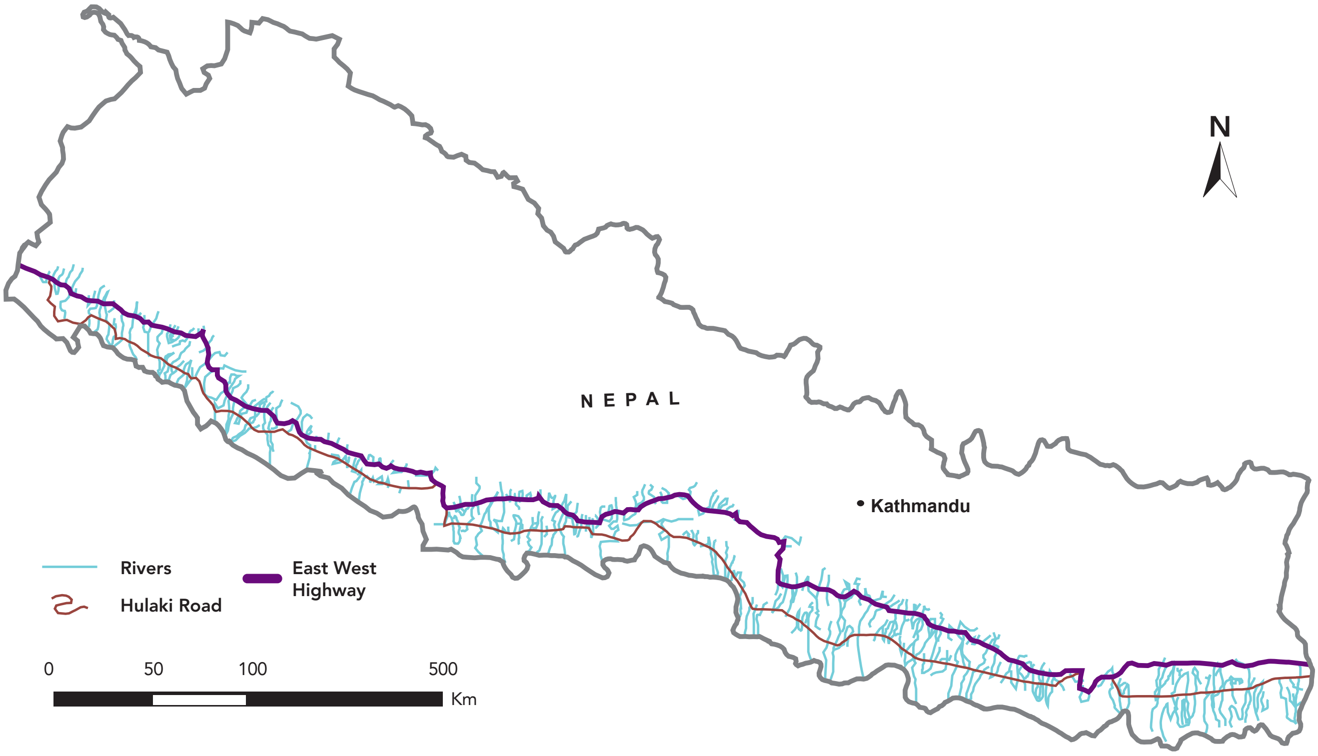
The Tribhuban Highway, which connects the capital with Raxaul, goes through a CB district: Parsa. In 1950, with support from USAID, the stretch of that highway from Bhaise to Birganj was upgraded. In this stretch, Pathalaiya became the junction where the road to Dhalkebar, that section of the East-West Highway that initially runs through forests in Bara District, would begin. Today, the East-West Highway connects Nepal's eastern border town of Kakarvitta to the country's western town of Mahendranagar. The 1,027 km-long highway, built between the early 1970s and late 1980s[2], is aligned along the southern edge of the Bhabar zone, the northern parts of all CB districts. In the late 1950s, the road connecting Hetauda to Bharatpur was built as a part of a malaria eradication and agriculture development program in Chitwan Valley.

From Amlekhganj to Bardaghat in present day West Nawalparasi and from Seoraj in Kapilwastu to Lamahi in Dang, sections of the East-West Highway are aligned along the Chure, along Doon Valley, and again along the Chure, respectively. The East-West highway passes through Nepal's national parks in Chitwan, Banke, and Bardiya districts. The East-West highway is being upgraded to a six-lane artery that is part of the Asian Highway[3]. Some sections of the highway are being expanded with loans from the World Bank and the Asian Development Bank, while another section is being upgraded with material, technical, and financial support from the Millennial Challenge Compact (MCC) of the U.S.

About 30 km south of the East-West Highway, another highway referred to as Hulaki (Postal) Highway is being upgraded. This 1,700 km-long highway linking the east and west of Nepal passes through towns along the country's southern Tarai. The operation of this road, when it was still just a dirt road, began during the reign of Prime Minister Bhimsen Thapa (1806-1837). Since it was used for delivering mail[4] it was called a "postal road." It remained a dirt road for a long time, throughout the Rana era (1846–1951). Even though it was unpaved and rudimentary, jeeps would ply on it, thereby providing some connectivity between towns in the CBs during non-monsoon months[5]. In 1991, Prime Minister Chandrashekhar of India agreed to provide support to upgrade Hulaki Highway and, in 2005, 14 years after he made that promise, Nepal and India signed a formal agreement to that end. At present, only certain sections of the highway are in operation and just 64.84 kilometers have been blacktopped[6]. The two highways are shown in Figure 4.2.

In addition to hosting these two major east-west highways, the CB districts have lower-order roads built in the north-south and other directions. These link cities, towns, and settlements. They cross more than one district and many local

FIGURE 4.2: EAST-WEST AND HULAKI HIGHWAYS



streams. In addition, municipalities and user organizations have also built local roads and upgraded village tracks with cement-concrete pavement. The Hetauda-Birganj Highway is the country's oldest north-south road. The other major north-south roads of the CBs are the Dharan-Rani, Butwal-Behaliya and Attariya-Dhangadi, Kohalpur-Nelgunj, Dhaljkebar-Janakpur, and Gorusinghe-Taulihawa roads. The overall length of the roads in the CB districts is 6,576.62 km and, according to the Department of Roads (DoR), the road density is 14.16 km per 100 sq km.

(b) Bridges and culverts

All highways and roads in the CB districts interface with all three types of rivers of Nepal: the snow-fed, Mahabharat, and seasonal CB rivers. In CB districts, all the rivers flow north-south while all the main highways are aligned east-west. Thus, the highway and rivers cross each other at almost right angles. Bridges and culverts built on them offer uninterrupted commuting through monsoon flood events and have often washed away bridges. According to DoR's database (also see Chapter 3) the total number of bridges along the East-West Highway in the CB districts is 426. Hulaki Highway, in contrast, has just 164 bridges in those districts. The Hulaki Highway has fewer bridges because as rivers flow south, they merge and their number decreases by the time they reach Hulaki Highway. The number of bridges along the Hulaki Highway broadly corresponds to the number of seasonal streams that cross from CB districts in Nepal to India[7]. Given the nature of the border region, however, the waterscape exists as a mosaic of rivers, wetlands, and oxbow lakes, as well as sheet and rill flows in the monsoon months.

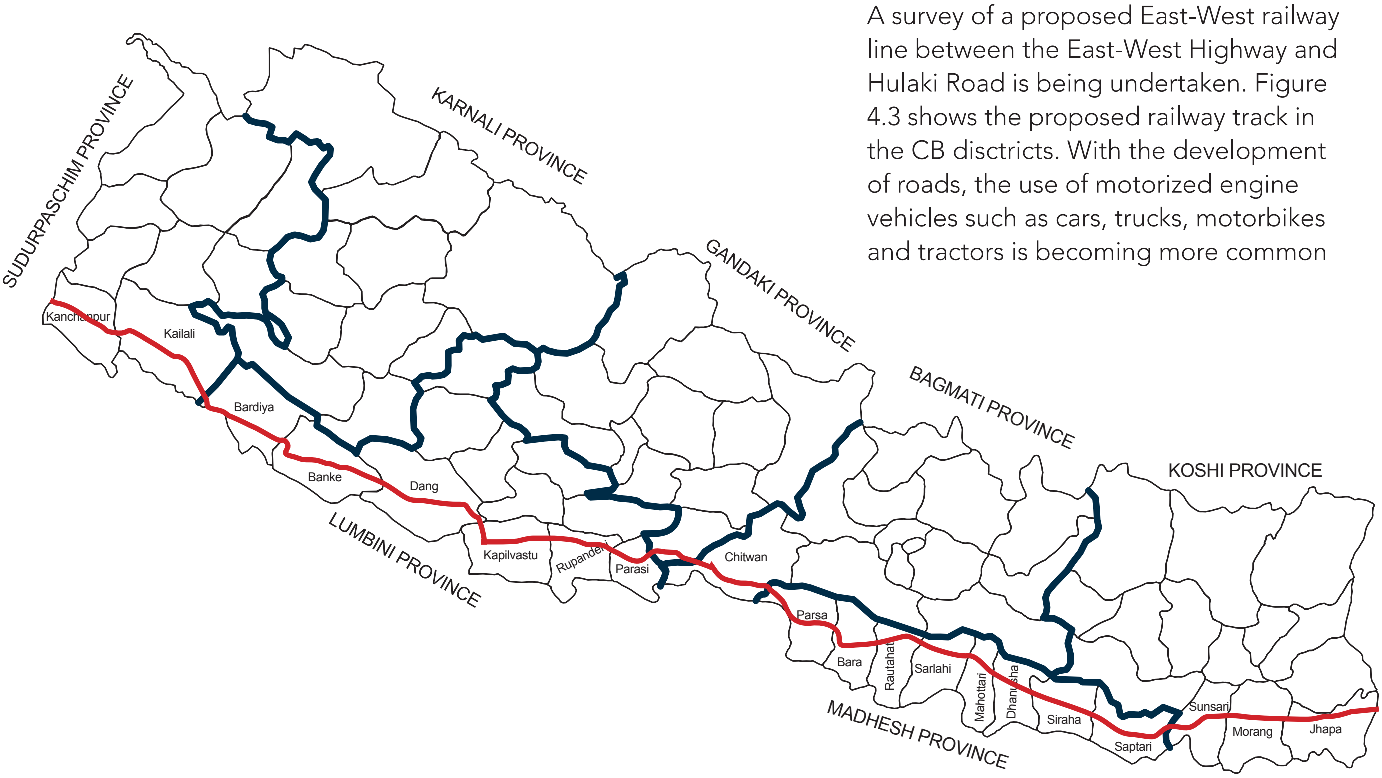
TABLE 4.4
BRIDGES AND CULVERTS

Highway	River Type	Number of Bridges in CBs
East West	Snow-fed (Koshi, Gandaki, Karnali)	4
	Originating in Mahabharat Range (Kankai, Kamala, Bagmati, Tinau/ Danau Banganga, West Rapti and Babai)	10
	Chure	426
Hulaki Road	Snow-fed	2
	Mahabharat	3
	Chure	164

Source: DoR Database

(c) Railways
In Nepal, two short-distance narrow-gauge passenger railway tracks were built in 1927 and 1936 respectively. They were Nepal Government Railway (NGR) and Jainagar Janakpur Nepal Railways (JJNR) . The slow-moving NGR laid in 1927 during the tenure of Prime Minister Chandra Sumsher connected Amlekhganj with Birgunj. Those traveling from Kathmandu to India would board the train at Amlekhganj and arrive at Birgunj, where they would cross the border to the town of Raxaul, from where they would take another train to their final destinations. This narrow-gauge track was aligned along the Amlekhganj to Birgunj road but is no longer functional. With help from India, the narrow-gauge JJNR was upgraded to a broad-gauge track. It now connects Jainagar with Kurtha near Bardibas but is not yet fully operational. A survey of a proposed East-West railway line between the East-West Highway and Hulaki Road is being undertaken. Figure 4.3 shows the proposed railway track in the CB disctricts. With the development of roads, the use of motorized engine vehicles such as cars, trucks, motorbikes and tractors is becoming more common

FIGURE 4.3: PROPOSED EAST-WEST RAILWAY LINE



Note: The railway line is indicative only.

Source: Chitrakar

and gradually replacing the animal-driven modes of transportation once prevalent in the CB districts.

4.4 AIRPORTS

The major towns of CB districts, inlcuding Bhadrapur, Biratnagar, Rajbiraj, Janakpur, Simara, Bhairahawa, Nepalgunj, and Dhangadi, all have all-weather airports. While the airport at Bhairahawa has been upgraded to international status, challenges to its regular operation have not yet been effectively addressed[8]. The proposed Nijgadh international airport in the CB district of Bara is being contested on multiple fronts, including environmental and economic. Though Nepal's Supreme Court issued a decision staying the building of the proposed airport, the country's political leadership continues to advocate for its development. Almost all of the airports located in CB districts have faced floods affecting their operation. Indeed, some of these airports were inundated following heavy rains, a phenomenon reflecting the interrelationship of flow the landscape and for them to reman flood free uninterrupted space is need for river to flow to downstream reaches.

4.5 EMBANKMENTS

In 2009, embankments began to be built in Nepal and in CB rivers as a matter of public policy. The country's first embankment along river was perhaps built in 1880 as part of the Mahali Sagar and later as guide bunds in the Sharada barrage in 1920. In 1959, embankments were built along the Koshi River in Sunsari and Saptari districts and then, in the early 1960s, along the Gandak barrage project area. In the late 1970s, Nepal and India began discussing the flood problems created by building embankments along a few seasonal rivers along the border (See Chapter 6). In the early 1970s Nepal's erstwhile Department of Soil Conservation and Watershed Management (DSCWM) had begun to pilot the construction of check in the watershed of the Likhu Khola, a tributary of the Trishuli River in Central Nepal. Also in the 1970s, Nepal implemented a number of watershed management projects in the mid-mountains to minimise soil erosion flood problems.

In 1991, the Government of Japan helped establish the Disaster Prevention Training Center (DPTC) to work on disaster mitigation measures, including the alleviation of flooding-related problems in Nepal[9]. Its subsequent incarnation, the Department of Water-Induced Disaster Prevention (DWIDP), brought the river-training division of the then Department of Irrigation (DoI) under its wing in 2000. It focused on building check dams and embankments designed to mitigate floods and landslides in the country, and, to that end, in 2009 launched the People's Embankment Program. Nepal adopted a federal governance system in 2015. Then, after the 2017 election, the DWIDP was dissolved and its activities brought under the Department of Water Resources and Irrigation (DoWRI). The DoWRI today looks after river and watershed management and the development of technology for flood control.

Experts at the district offices of the DWIDP would hold discussions with local communities to select embankment sites. Their choice, then, rested on an analysis of the area's vulnerability and the demands of local people. The top surface of a completed embankment would serve as a road to nearby villages and it was suggested that local communities could use reclaimed plots of land on the sides of river embankments for farming, for recreational sites like playgrounds and parks, and for real estate development[10].

In the meantime, embankments have been built in the Narayani, Kankai, Ratu, Lakhandehi, Rapti, Mahakali, and Tinau rivers[11]. Before it was dissolved, the DWIDP had identified 102 rivers, including those in CB districts, as vulnerable to flood threats. Subsequently, the GoN, with a loan from the Asian Development Bank (ADB), established the Water Resources Project Preparatory Facility (WRPPF) to study 25 specific river basins for further action with DoWRI as the executing agency. In January 2013, WRPPF prioritized the following six basins for implementing the Flood Risk Management Project (FRMP) aimed at improving the performances of irrigation facilities and water-induced disaster prevention activities.

TABLE 4.5 SPECIFIC RIVERS FOR FLOOD RISK MANAGEMENT PROJECT

1.	Aurahi/Bighi	13.	Jhim
2.	Bakraha	14.	Kamal Biniyani
3.	Balan	15.	Kandra
4.	Banganga	16.	Kankai
5.	Biring	17.	Karnali
6.	Budhi	18.	Khado
7.	Chaudhar	19.	Khutiya
8.	Chisang	20.	Lakhandehi
9.	Dodha	21.	Lalbakeya
10.	East Rapti	22.	Mawa Ratuwa
11.	Gagan	23.	Mohana
12.	Jalad	24.	Narayani
		25.	West Rapti

Source ADB (2019)

TABLE 4.6: PRIORITISED FLOOD RISK MANAGEMENT PROJECT

CB	Non-CB
Mawa Ratuwa	West Rapti
Lakhandei	East Rapti
Mohana Khutiya	
Bakraha	

Covering an area of 293.56 km^2, the FRMPs are expected to serve 70,428 people at risk from a 1-in-50-years-probability flood in the identified river basins. The project involves the following activities: Hydrological and hydrodynamic modeling; Flood forecasting and early warning systems; Embankments with provision for avoiding overtopping, erosion, and inner slopes; Putting gabions on top of existing structure to prevent failure; Community-based disaster risk management (CBDRM) with social and environmental safeguards; and Use of low-cost solutions such as bamboo for flood mitigation. The dynamics of these interventions need to be analysed from the perspective of both the benefits they provide and their costs with respect to building system resilience in CB districts.

4.6 SETTLEMENTS, URBANIZATION AND SERVICES

(a) Urban centers and towns

A systematic accounting of the trend toward urbanization and the development of various types of houses in CB districts is not available. Once a malaria-prone region, the CB districts had few urban settlements before 1950s and rural houses were built mostly of bamboo and mud with straw roofs[12]. Affluent households, however, built their houses of bricks with mud mortar with tiled roofs. After malaria was eradicated in the 1950s, the region began to draw immigrants from the less agriculturally productive hill and mountain regions, the government promoted the development of the CB region for irrigated farming[13]. as well as migration of people across the border working for projects in Nepal. Thus, the CB region gradually began to urbanize. Today, it is home to about 45 percent of the country's population.

In recent times, the region has seen the expansion of markets and towns at the intersections of major north-south roads and the East-West Highway. In 2011, just a few of the urban growth centers in the CB districts close to the Indian border housed 44 percent of the region's entire urban population. Biratnagar, Birgunj, Butwal, Nepalgunj, Janakpur, and Dhangadhi are all emerging as the principal urban centers of the CB region[14]. Over the last many years, Dhangadhi, Butwal and Bharatpur have consistently experienced annual growth rates higher than 4 percent[15]. Damak and Itahari in Jhapa and Morang districts respectively are the fastest-growing cities with populations below 100,000; their rates of growth exceed 4 percent, too[16] and with the GoN proposing to build ten new cities along Hulaki Highway this trend would increase further [17]. The increase in urban areas has occured at the cost of agricultural land whose dynamic are highlighted in Chapter 5. Figure 4.4 a and b illustrate the changes in land use from 1989 to 2016 and the increase in built up area of six CBs cities from 2000 to 2022.

(b) Industrial corridors

Industrial establishments have developed at the intersections of the east-west and the following north-south roads of the CB region: Attariya-Dhangadhi; Butwal-Belhiya; Pathaliya-Birgunj and Itahari-Biratnagar. These establishments produce pharmaceuticals, textiles, vegetable ghee, plastic, steel, cigarettes and tobacco, aluminum, cement, sugar, rice, and other processed grains. The industrial units also house breweries and distilleries; produce cement, animal feed, iron and steel, rosin and turpentine, soap and chemical solvents, jute, paper and pulp, and sugar, and engage in leather tanning. Activities in these corridors create further impetus for the expansion of settlements in the CB region.

(c) Urban drains

At the local level, a few CB municipalities engage in activities that aim to improve natural and stormwater drainage in order to minimize flooding during the monsoon season[18]. The activities aim to eliminate cross-sewer connections, rehabilitate (line, widen, etc.) and desilt existing drains, develop links that are missing from existing drains and provide new drains to improve urban health.

(d) Digital communication and infra-strucutre

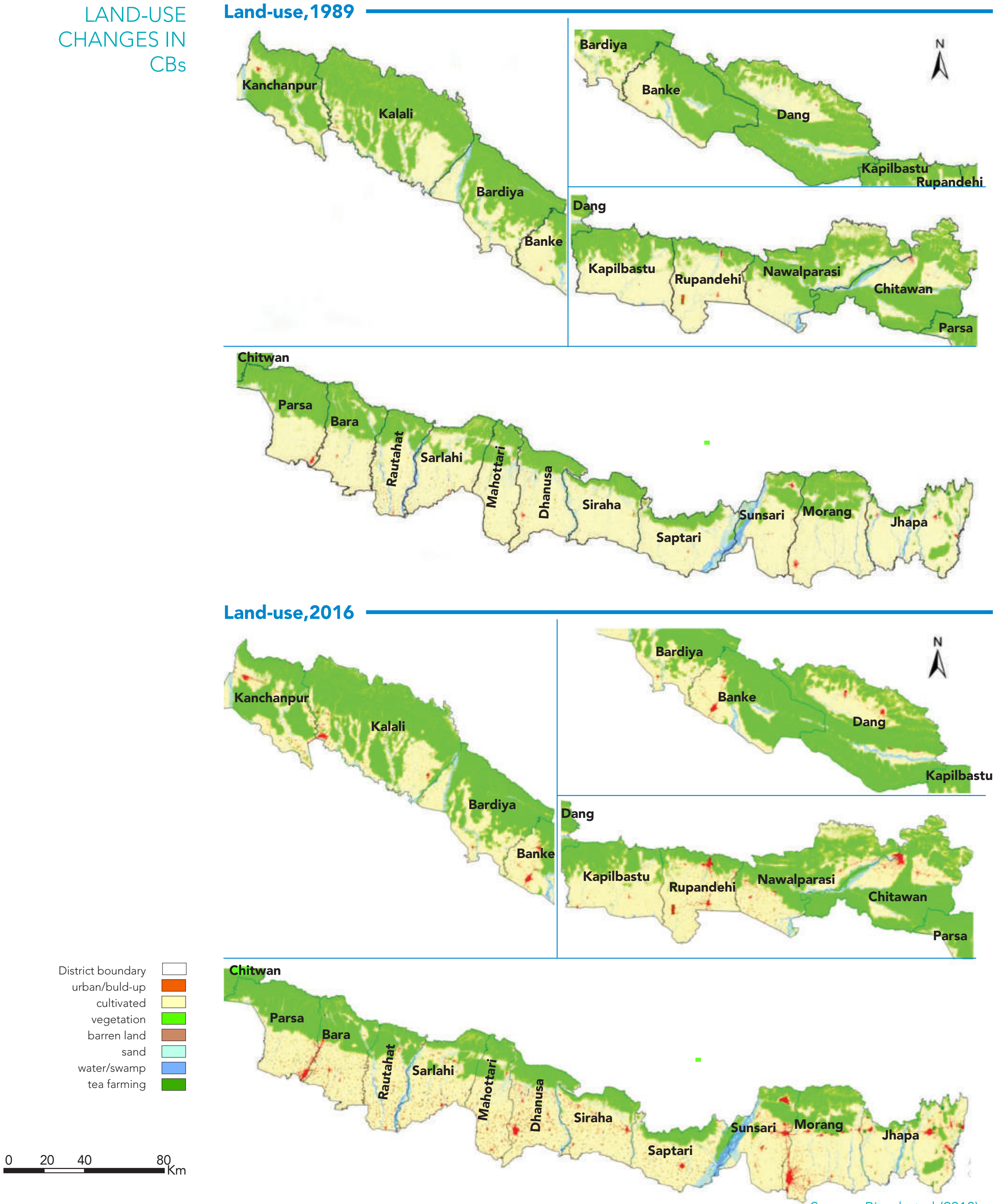
Digital communication and infrastructure are emerging elements in CB districts that provide mobile services and communication services that connect people. By using 2G, 3G, or 4G telecommunication towers, many service providers make mobile connectivity available in the districts. Expanding of access to and uptake of digital technologies, however, are limited[19]. The GoN has launched digital marketplaces called Krishi Bazaar and e-Haat Bazaar with aims to connect farmers directly to the regional and central agricultural marketplace whose penetration and usage are limited as is evident by the low number of downloads of these apps[20] including by farmers in CB region. Digital infrastructure and access can offer new livelihood and employment opportunities as the distinction between the rural and the urban blurs and people seek job opportunities outside of agriculture.

4.7 CULTURE, HERITAGE AND TOURISM

The districts in the CB region (also CTML) are home to many sites of attraction with appeal to domestic and international tourists. As mentioned in Chapter 2, the CB region includes six protected areas, including national parks and wildlife reserves as well lakes, ponds, and wetlands that have the potential for tourism in addition to the ecosystem services they provide. The Koshi Tappu wetland, which encompasses parts of Sunsari, Saptari, and Udayapur districts, is a major wildlife reserve and bird sanctuary. The other wetlands are Bishazari Lake in Chitwan District, Jagadishpur Lake in Kapilwastu

FIGURE 4.4: LAND-USE CHANGES IN CBs

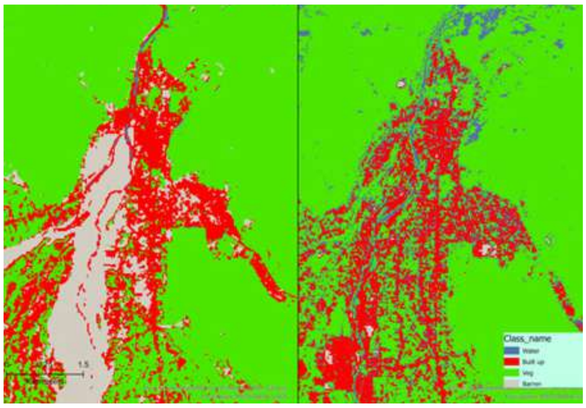
a. Changes in landuse (1989-2016)



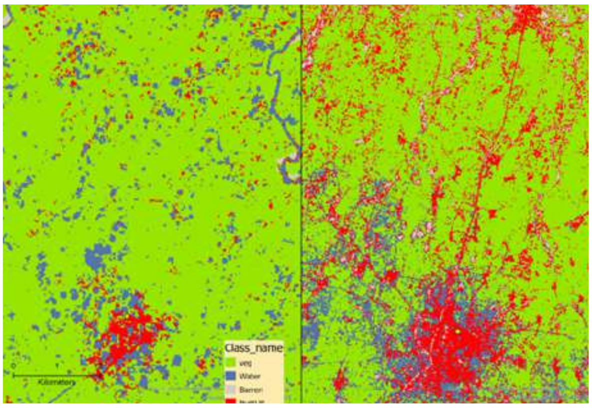
Source: Rimal et al (2018)

b. Increase in built-up areas of six CB cities (2000-2022)

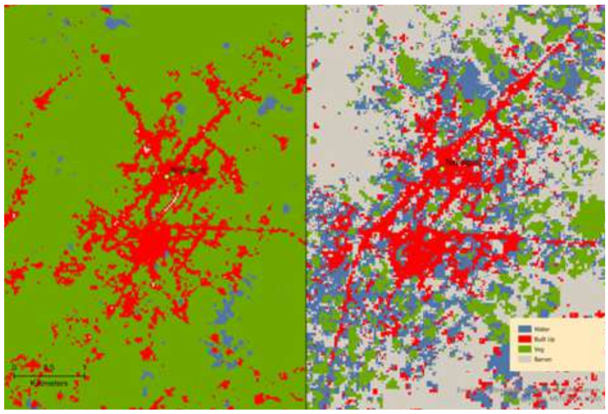
2000 Built up area - Biratnagar 2022



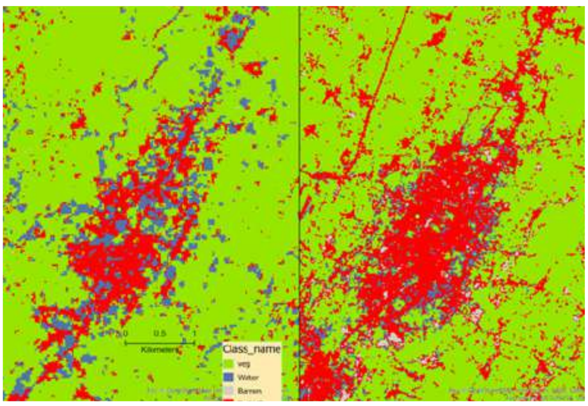
2000 Built up area - Butwal 2022



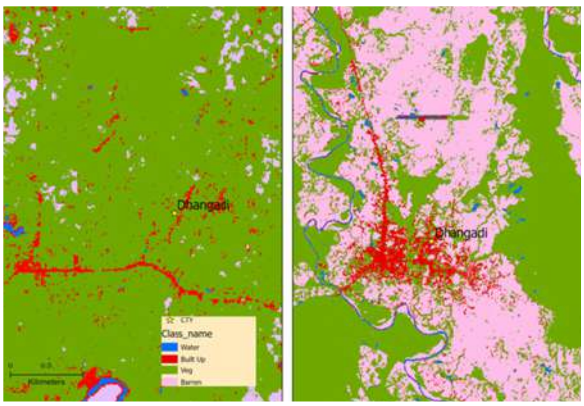
2000 Built up area - Janakpur 2022



2000 Built up area - Nepalgunj 2022



2000 Built up area - Birgunj 2022



2000 Built up area - Dhangadi 2022

Source: This study

Lumbini

Janaki Mandir

Source: Internet

District, and Ghodaghodi Lake in Kailali District, all listed as Ramsar sites and Halkhoria Daha in Bara District. While crucial for the preservation of the region's biodiversity and flora, these landmarks also attract international and domestic tourists.

From east to west, the CB region is rich in culture, art, music, folklore, food, and tradition. The ancient cultures of Mithila, Braj, Vaishali, Awadh, and Koch each offer a rich selection of diverse practices. Mithila art is popular in Jankpur and in the tourist hub of Chitwan National Park, traditional Tharu dance is popular. Janakpur and Lumbini are major cultural landmarks in the CB region. The marriage of the goddess Sita with Lord Ram is said to have taken place in Janakpur, while Lumbini is the birthplace of Lord Buddha. Today Lumbini is part of the Buddhist circuit ,with links to Bodh Gaya, Saranatath and Kushinagar in India, and Janakpur is linked to the villages in Bihar and Ayodhya as part of the Ramayan Circuit. Other religious and cultural landmarks of importance in the CB districts are Gadi Mai, Bara District; Chhinamasta, Saptari District; Jaleswar Mahdev and Matihani, Mahotari District; Dhanus Dham, Dhanusha District; Bageswari, Banke, District; Balmiki Nagar, East Nawalparasi District; Chhinamasta, Saptari District; Mai Khola and Kichak Badha, Jhapa District; Barakhchetra, Sunsari District; and Sahalesh Mandir, Siraha District. These destinations of faith attract both domestic and international tourists. The CB districts of Jhapa, Bhairahawa and Saptari are recognized centers for eye treatment that cater both to Nepali patients and patients from across the border.

NOTES

1. The STWs are machines that extract water from shallow groundwater aquifers. Between1980 and 2000 agencies in Nepal such as ADB/N, Agricultural Development Project, Janakpur, and the as well as different donors under the DOI installed these pumps. Private farmer also install STWs. The DOI, Agricultural Development Project groundwater development projects also installed DTWs between 1973 and 1992. Surendra Raj Shrestha provided the data. Following the promulgation of 2015 Constitution the admistrative boundaries have been changed and disaggregated data is not available. An example is Nawlaparasi divided into two districts.
2. Different donors provided support to build the road. In 1974, with grant assistance from the then United Socialist Soviet Republic (USSR), the 109 km-long Pathalaiya-Dhalkebar section was completed. The British Government aided in building the Narayanghat-Butwal section of the highway in 1972. The Government of India provided support to build the Dhalkebaar-Kakarbhita, Butwal-Kohalpur, and Kohalpur-Banabasaa sections of the highway, which were completed in late 1970s early 1980s, and the late 1980s respectively. For a discussion the East West Highway, see Himal (1990).
3. For the design and construction of their respective sections of the East-West highway, the implementors used their own standards. The Soviet engineers used mechanized technology and boulders and gravel from nearby rivers while the British engineers also used mechanized technology but also introduced the use of gabion boxes packed with stones as retaining structures to protect roads and bridges from floods. For their part, Indian engineers used labor-intensive techniques to lay the road on top of an earthen embankment. Ibid Himal (1990). This highway is being upgraded as part of the Asian Highway Project. Also see https://www.unescap.org/sites/default/files/Nepal_3.pdf
4. See Lal (2015) for discussions on its history.
5. In 1969 the lead researcher of this study travelled from Kathmandu to Kapilwastu in a jeep by road. From Raxaul the route went to Betia and then Bhaisalotan in India. After crossing the Gandak River ,the jeep took a dirt road through the southern part of Nawalparasi to Kapilwastu (Taulihawa) via Bhairahawa along the unpaved Hulaki road.
6. https://karma1549.rssing.com/chan-65532450/article14.html
7. The Koshi barrage has a motorable bridge. Gammon India built the bridge over the Narayani River in the 1970s. The World Bank supported building of the 500-meter "single tower cable-stayed" bridge over the Karnali at Chisapani constructed by Kawasaki Company of Japan in the 1980s. Recently, a motorable road connecting the town of Mahendra Nagar in Bhim Dutta municipality with Chandani Dhodhara by a bridge over the Mahakali River has been built. Bridges have been built on most of the Mahabharat rivers, including the Kankai, Kamala, Bagmati, West Rapti, and Babai as well as many large and small bridges on the Chure rivers.
8. https://kathmandupost.com/money/2022/10/31/aviation-regulator-pressuring-airlines-to-link-bhairahawa
9. This was a joint undertaking by the Ministry of Water Resources, the Ministry of Forestry, and the Ministry of Works and Transpory. The DPTC was expected to work in partnership with the Ministry of Home Affairs (MoHA) and the National Planning Commission (NPC).
10. https://kathmandupost.com/national/2017/07/02/peoples-embankement-programme-faces-funds-crunch
11. According to Sheetalbabu Regmi, Joint Secretary at the Ministry of Irrigation, the government earmarked NPR 1 billion for this program to be implemented in seven places. Mr. Regmi said that NPR 200 million had been allocated for the program to be implemented in Chitwan and Nawalparasi districts alone. See https://thehimalayantimes.com/ampArticle/90762
12. See Lal (2019).
13. See Leibrand (2021).
14. See Muzzini & Apericio, 2013, pp. 34–35
15. Ibid.
16. See https://gsdrc.org/wp-content/uploads/2015/11/HDQ1294.pdf
17. They are proposed at Gaurigunj, Jhapa, Rangeli, Morang, Shambhunath, Saptari, Mahagadhimai Bara, Ishwarpur, Sarlahi, Balwa, and Sarpallo in Mahottari; Bardaghat in Nawalparasi; Rajapur in Bardiya; and Bhajani Trishakti in Kailali District Belauri in Kanchanpur. https://myrepublica.nagariknetwork.com/amp/ten-new-cities-coming-up-along-hulaki-highway/news.html.twig
18. The ADB approved USD 130 million for urban water and sanitation activities in Nepal (2018-2023). See The Himalayan Times https://thehimalayantimes.com/business/adb-approves-130m-for-urban-water-and-sanitation-in-nepal. The stormwater collected will be disposed of in rivulets. The town involved is Siddharthanagar Municipality. Drain pipes in Tikapur Bazar and Shaktinagar areas will be repaired.
19. By 2020, mobile broadband penetration in Nepal was estimated at 35.4 percent, and fixed broadband at 2.8 percent while ome sources (based on data from Nepal Telecommunications Authority) claim much higher broadband penetration rates of around 72 percent. See DECA (2022).
20. https://nepaleconomicforum.org/digital-landscape-in-nepals-agriculture-sector/#:~:text=To%20solve%20this%20problem%20the,regional%20and%20central%20agricultural%20marketplace

SOCIOECONOMIC CONTEXT

SOCIOECONOMIC CONTEXT

05

Five interrelated processes began accelerating the changes in Nepal CB's region. First, it began with the clearing of the region's forests more than 150 years ago[1]. Second, the increasing pace of urbanization and the construction of roads, irrigation canals, and flood control embankments over the last four decades. It changed land-use practices in the region and constrained drainage, and, as a result, exacerbated the impacts of flooding. Third, the agriculture-based livelihoods of the majority of the people living in CB districts are changing as the youths seek employment overseas and in neighboring India based on socio-economic factors and the domino effect of 10 years old (1996-2006) Maoist insurgency, subsequent conflicts and lack of employment opportunities. Fourth, the promulgation of the 2015 Constitution and the adoption of a federal political system have given rise to new political and economic dynamics in the region. Finally, the impacts of climate change have added new layers to the ability of CB residents to adapt to the regular occurrence of floods and droughts, and other challenges to their livelihoods. The following sections discuss the character of the population and some of the services they obtain from both the natural ecosystem and human-built systems.

5.1 DEMOGRAPHY AND POPULATION

The CB districts covered in this study are home to 14,310,613 people, 45 percent of Nepal's total population (29,192,480).[2] Of them, 7,265,837 are males and 7,044,776 are females, giving the region an average sex ratio of 96.64. The CB districts have 2,490,831 households with an average size of 4.78 members and an annual population growth rate of 2.08 percent. The average population density of the CB districts at 532 person/km^2 is higher than Nepal's overall population density of 198 person/km^2. Rupandehi District has the highest density: 823/km^2. The population densities of the Indian districts of Uttar Pradesh and Bihar bordering the CB in Nepal are 829/km^2 and 1,106/ km^2 respectively[3], making them the most densely populated states in India. Table 4.1 below provides data on the population structure in CB districts.

The increased population in conjunction with other change dynamics in the region is likely to increase the overall exposure of CB districts to climate-induced hazards. Extreme climatic hazards, particularly heavy rainfall, are the primary triggers of secondary hazards such as floods and landslides. These factors interacting with ecosystems, infrastructure, and local communities and societies have led to the worsening of impacts. To understand people's vulnerability, it is necessary to know socioeconomic characteristics, demography, livelihood strategies, occupations, and access to services in the CBs. People with access to basic services from infrastructure and services from ecosystems will be able to successfully deal with external shocks, including the adverse impacts of climate change.

Out of the 18 CB districts, Sarlahi District with nearly 3 percent is the highest annual population growth rate of all 77 districts in the country. The Bardiya District with 0.74 percent is the lowest annual population growth rate in the CB region. If the trend of population growth continues in-migration to the CB district is likely to increase with the higher population living there.

The composition of the population of the CB region is mixed. In-migration to parts of the CB region, particularly along the southern Chure and Bhabar zones, suggests the potential for an increase in the rates of deforestation, water stress, and extraction of the construction-grade river

TABLE 5.1 POPULATION DISTRIBUTION

District	Household	Male	Female	Total	Sex Ratio	HH size	Population density	Annual Growth rate
Kanchanpur	103,372	243,598	274,047	517,645	88.89	4.63	322	1.32
Kailali	183,707	429,792	471,363	911,155	93.30	4.54	282	1.54
Bardiya	98,936	217,850	242,981	460,831	89.66	4.33	228	0.74
Banke	110,135	295,112	308,281	603,393	95.73	4.57	258	1.97
Kapilbastu	103,765	337,604	349,135	686,739	96.70	5.30	395	1.76
Rupandehi	195,103	547,545	571,430	1,118,975	95.82	4.63	823	2.3
Parsa	93,724	334,919	314,478	649,397	106.50	5.63	480	2.27
Bara	112,329	380,192	363,783	743,975	104.51	5.54	625	2.6
Rautahat	111,613	415,864	409,759	825,623	101.49	5.92	733	2.59
Sarlahi	138,427	433,382	423,978	857,360	102.22	5.09	681	2.91
Mahhottari	117,494	354,952	360,088	715,040	98.57	4.90	714	2.37
Dhanusa	146,476	873,274	434,335	130,7609	98.95	4.83	630	2.85
Siraha	123,536	369,049	379,367	748,416	97.28	4.84	630	2.41
Saptari	124,328	355,530	357,673	713,203	99.40	4.71	523	2.41
Sunsari	181,787	454,075	480,386	934,461	94.52	4.31	743	1.94
Morang	241,415	557,527	589,659	1,147,186	94.55	4.18	618	1.66
Jhapa	219,989	477,496	516,594	994,090	92.43	4.04	619	1.93
Nawalparasi_W	84,695	188,076	197439	385515	88.98	4	267	1.93
Total	2,490,831	7,265837	7,044,776	14,310,613	Av 96.64	Av 4.78	Av 532	Av 2.08

Source: Central Bureau of Statistics (2021), Madesh Province Profile (various dates)

and other natural materials[4]. Such practices change land-use patterns thereby impacting local natural ecosystems, resource utilization practices, and socioeconomic dynamics[5]. Increasing populations, new farming practices, road and infrastructure development, conversion of forests into farmland, and real estate development both change land use and increase exposure to climate hazards. Table 5.2 shows human development index of the 18 CB districts. The human development index of the CB district varies with some of the districts of Madhesh Pradesh with value lower than than national average, This presents a major challenge to transit toward resilience.

5.2 EDUCATION AND LANGUAGE

In the CB districts, education has improved in recent decades but the literacy rate, at 60 percent for men and less than 45 percent for women, is still less than the national average. Among women, education rates also fall short of the national average. The poor quality of education in the CB region, too, helps account for women's lack of leadership skills and opportunities and their limited roles in decision-making platforms. Being less educated than men limits women's access to opportunities and is a barrier to adopting successful adaptive actions in response to climate change impacts. It is noteworthy that the ratio of boys and girls in school has improved and that efforts are being made to increase the literacy rates of girls in CB districts. In particular, the Madesh Pradesh government began the Beti Padao Beti Bachao program targeting the education of girls in 2018. In the CB districts, the people speak Maithili, Bhojpuri, Awadhi,

TABLE 5.2: HDI INDEX OF CB DISTRICTS

District	HDI
Kanchanpur	0.475
Kailali	0.46
Bardiya	0.466
Banke	0.475
Kapilbastu	0.432
Rupandehi	0.498
Parsa	0.464
Bara	0.457
Rauthat	0.386
Sarlahi	0.402
Mahhottari	0.388
Dhanusa	0.431
Siraha	0.408
Saptari	0.437
Sunsari	0.496
Morang	0.513
Jhapa	0.518
Nawalparasit_W	0.493

National Average: 0.49

Source: Nepal Human Development Report (2014)

and Tharu languages in addition to speaking other dialects and languages. The communities speaking Maithili, Bhojpuri, and Awadhi in Nepal's CB regions share cultural and linguistic links with people in Uttar Pradesh and Bihar, India.

5.3 AGRICULTURE

Water, air, land, and forest are interdependent ecosystems whose services support agriculture and food production in the CB region. Secure access to food, as well as water, basic clean energy, and livelihoods, is critical for people's well-being. Services providing such resources are foundational during and after a disaster and for adaptation to the impacts of climate change. Household food security is dependent on agriculture as one of its key elements and mediated by other factors such as social structure, markets, and public policies and support. The CB districts occupy 18.02 percent of the country's area (14,718,000 ha). About 1,028,526 ha, or 52.40 percent of the total CB area, is used for agriculture. Agriculture practices in CB districts vary, but two broad cropping patterns exist[6], irrigated and rain-fed. On irrigated land, cropping patterns include rice-wheat, rice-rice-wheat, rice-rice/legumes, rice-maize, rice-vegetables, and rice-wheat, rice-maize, and rice-vegetables. On rain-fed land, cropping patterns include rice legumes, maize-finger, millet-wheat, and rice-fallow.

The main crops grown in the irrigated areas of CB districts are paddy, wheat, and mustard though maize, millet, mustard, and other crops are also grown extensively. Paddy cultivation during the monsoon season is often followed by mustard cultivation during the dry season. Farmers also plant black gram and soybeans on bunds along the boundaries of their farms. These and other such legumes stabilize the bunds, supply nitrogen to the soil, and supplement the diets of farmers. A few farmers cultivate pulses and vegetables. The traditional system of seed exchange, reuse, and storage, though still common, is gradually changing[7]. The products cultivated are consumed by individual households and sold both within and outside the country.

5.4 LANDHOLDINGS

Dividing the total agricultural area of the CB region by the total population of that region gives a per capita landholding of 0.11 ha/person. This figure, however, distorts what is a complex reality. In particular, it conceals a marked disparity: average per capita landholding varies from 0.01 ha/person in Kanchanpur District to 0.42 ha/person in Dhanusha District. Table 5.3 provides an overview of the landholding situation in CB districts. Like the rest of Nepal, the ownership structure and spatial distribution of land in CBs is highly skewed

TABLE 5.3: POPULATION ENGAGED IN AGRICULTURE AND PER CAPITA LAND HOLDING

District	Population	Agricultural land		Per Capita land (Ha)
		Ha	%	
Kanchanpur	517,645	5,932	3.66	0.01
Kailali	911,155	34,645	10.58	0.04
Bardiya	460,831	75,000	37.03	0.16
Banke	603,393	12,068	10.74	0.02
Kapilbastu	686,739	83,000	47.75	0.12
Rupandehi	1,118,975	94,832	73.30	0.08
Parsa	649,397	55,383	39.37	0.09
Bara	743,975	69,655	54.71	0.09
Rautahat	825,623	66,494	64.03	0.08
Sarlahi	857,360	87,341	69.11	0.10
Mahhottari	715,040	68,548	68.45	0.10
Dhanusa	180,832	76,194	64.06	0.42
Siraha	748,416	81,431	71.41	0.11
Saptari	713,203	79,241	61.74	0.11
Sunsari	934,461	91,799	71.87	0.10
Morang	1,147,186	105,270	56.70	0.09
Jhapa	994,090	141,795	86.36	0.14
Nawalparasit_W	381,105	NA	NA	NA
Total	13,189,426	1,028,526	Average 52.40	0.11

Source: Open Data Nepal (Portal), Nepal Stuff (Portal), Madhesh province profile, (2077)

by several factors, including caste, class, gender, ethnicity, language and cultural patterns, and spatial exclusion[8].

In 2011, Nepal had 5,423,297 households, 74 percent of which were involved in farming. Of them, 53 percent (2,127,017) owned less than 0.5 ha of land[9]. Ten years later, in 2021, the total population had reached 29,192,480, a 10.18 percent rise. The average household size had decreased to 4.32 members from 4.88 members in 2011. If this reduced household size is taken, a total of 6,757,518 households would exist and of this number, 66 percent (4,459,961) are engaged in farming. On this basis, 2,363,779 households engaged in agriculture have less than 0.5 ha of land. Given that CB districts house 45 percent of the country's population, this figure means that 1,063,700 families in the CB region have less than 0.5 ha of land. This macro picture is likely to more nuanced at the level of the municipality. Small farm holders dominate agriculture in Nepal, meaning that agriculture is a low-production enterprise. Almost 25 percent of the population of farmers do not own enough land to produce adequate crops to feed their households for an entire year.

Within Nepal's social power structures, land has always been perceived as a political issue with implications for equitable distribution, inclusion, equality, social justice, and livelihoods[10], and, by extension, for adaptation to climate change impacts. The low throughput of natural resources use, the limited local employment opportunities, and the lack of regular stable incomes have resulted in high rates of migration from Nepal as a whole and the CB region in particular. The remittance that migrants send home has helped improve food intake; send children, particularly girls, to schools; and improve hygiene and health support, including that for the aged and the ill, all the while maintaining some savings for emergencies[11]. This reliance on remittance, however, has created a new risk: the possibility that opportunities for jobs abroad will dry up, leaving migrants jobless and families in debt and without a source of income. In contrast, local-level employment and secure livelihoods are key to creating a base that helps families successfully respond to floods and other shocks. A detailed examination of this local economic dynamic in CB districts, however, is beyond the scope of this study.

Two ongoing processes highlight worrying trends in agriculture and dependent livelihoods in CBs and are likely to increase vulnerability. The first trend is a loss of land under agriculture. In 1989 urban areas occupied just 221.1 km^2 of the Tarai region; twenty-seven years later, in 2016, the urban area had more than quadrupled to 930.22 km^2. This 320 percent increase was associated primarily with the loss of cultivated lands. Indeed, it is estimated that 93 percent of the land absorbed by cities was formerly cultivated. Urban growth and the attendant loss of agricultural land did not seem to be directly related to population growth[12]. Rather, this loss was attributed to poor urban planning, poor implementation of conservation policies, and encroachment on cultivated lands by expanding peri-urban areas, a process expected to continue in the future[13]. The second disquieting trend is that agricultural land is increasingly being left fallow. A recent study found that 15 percent of the cultivated land in Jhapa and Banke districts and 10 percent in the Sarlahi District are left fallow and that these rates are lower than that in the hills[14] Both trends, the loss of agricultural land and deciding not to cultivate what is available, will intertwine with multiple shocks, including climate change, to increase inundation and exacerbate social vulnerability.

5.5 SOURCES OF LIVELIHOOD

Men and women in the CB region are dependent on natural resources and agriculture as the main sources of their livelihoods with almost 70 percent of the population identifies agriculture as its main occupation[15]. Other sources of livelihood are livestock rearing and the collection of natural products. In addition, in the last few years, Tarai districts have faced a high rate of in- as well as out-migration. In 2021/2022 the total number of migrants from Nepal was 2,169,478 (7.43 percent), with 1,065,969 (49.13 percent) from the Tarai. The majority of the migrants, 906,767 (41.79 percent), were male; women migrants numbered just 159,202 (7.33 percent). Unless more secure employment opportunities emerge and the other dynamics mentioned above change, the CB region is likely to see more residents go abroad in search of jobs.

5.6 DRINKING WATER AND SANITATION

Access to drinking water and sanitation is the foundation of both well-being and the ability to deal with climate hazard-induced shocks. As mentioned earlier, groundwater is the major source of drinking water in CB districts. People in rural CBs use tube wells, mostly STWs, to bring water to the surface to meet various drinking water needs. In addition, cities and towns have installed DTWs in my deep aquifers. The water thus pumped is stored in overhead tanks and supplied via pipelines to homes with private connections. Even households that have pipeline supplies install tubewells because supplies from municipal sources are not always reliable and families keep redundant options such as welll or tube wells. In addition, other types of water sources are also used for drinking.

About 79 percent of the population uses tubewells and another 14 percent, piped water. About 2 percent of the population


Household tubwell in Itahari and overhead tank in Banke

Source: Ajaya Dixit and Dinesh Bajracharya

TABLE 5.4. TYPES OF AVAILABILITY OF DRINKING WATER AND USERS

District	Total HH	Percentage using drinking water sources					
		Tap	Tubewell	Covered well	Uncovered well	Spout water	River
Jhapa	1,84,384	18.9	72.8	1.1	2.7	0.2	0.1
Morang	2,13,870	18.9	78.0	0.3	0.7	0.5	0.3
Sunsari	1,62,279	28.8	67.6	0.4	0.7	0.5	0.2
Saptari	121,064	1.7	94.4	0.3	1.1	0.1	0.1
Siraha	117,929	5.5	84.3	0.3	6.9	0.1	0.6
Kanchanpur	138,225	9.6	87.1	0.2	0.1	0.5	0.4
Kailali	111,298	12.9	81.0	0.2	1.1	1.8	1.3
Bardiya	132,803	7.4	90.4	0.2	0.3	0.3	0.1
Banke	106,652	14.6	80.5	0.9	1.3	0.3	0.1
Kapilbastu	108,600	10.2	85.0	0.4	1.3	0.6	0.2
Rupendehi	95,516	38.4	59.1	0.2	0.1	0.3	0.0
Parsa	82,134	14.4	81.0	0.3	0.5	1.3	0.1
Bara	142,413	17.2	78.9	0.3	1.1	0.2	0.2
Rautahat	83,147	7.0	88.2	0.4	1.2	0.1	0.1
Sarlahi	94,693	11.8	77.2	1.0	6.3	0.2	0.5
Mahhotrai	91,264	14.1	76.3	0.2	5.8	1.2	0.3
Dhanusa	163,835	13.0	75.1	0.9	7.5	0.2	0.2
Total	2,150,106	14.4	79.8	0.4	2.3	0.5	0.3

Source: CBS (2011)

uses far fewer safe uncovered wells, but this proportion varied from district to district. In many other cases, wells are covered. Though the percentage of the population using uncovered wells, open spouts, and rivers is small, the use of such poor-quality sources at all is a reflection of the marginalization of certain sections of the population. In the Bhabar region, people use modified deep hand pumps to get water to the surface from deep aquifers, and, in some cases, people manually draw water from deep open wells. It is suggested that the water table has declined over the years and that, as a result, hand pumps fail to deliver water[16]. This decline in groundwater levels is not monitored systematically, however. Table 5.5 summarizes the sources of drinking water used by populations in CB districts.

According to the CBS database, more than half of the households in CBs lack toilet facilities, while about 25 percent have a flush toilet with a septic tank and 15 percent have an ordinary toilet. In Saptari, 79 percent of the households lack toilet facilities, and in Jhapa 30 percent have ordinary toilets.

5.7 HEALTH SERVICES

While access to basic drinking water has improved over the years the access to safely managed drinking water supply at just 19.1 percent and the faecal contamination of household drinking water one of the criteria of safely managed drinking water supply at 85.1 percent shows scale of the health challenges in Nepal and CBs as major determinants of basic health resilience[17]. Overall, health and access to health facilities and services are poor and need improvement. The reliability of drinking water[18], another important criteria of

TABLE 5.5: SANITATION COVERAGE

District	Total HH	HHs without toilet facility	Flush Toilet (Public sewerage) HHs	Flush toilet HHs (septic tank)	Ordinary toilet
Jhapa	1,84,384	25.8	1.6	42.5	29.7
Morang	2,13,870	36.2	1.4	39.6	22.4
Sunsari	1,62,279	36.1	1.7	40.9	20.7
Saptari	121,064	79.3	1.7	11.1	6.5
Siraha	117,929	78.7	1.3	12.0	7.1
Dhanusha	138,225	64.9	1.7	16.2	15.5
Mohattari	111,298	72.5	1.0	14.4	11.5
Sarlahi	132,803	73.6	1.2	16.3	7.9
Rautahat	106,652	75.5	0.9	10.0	12.1
Bara	108,600	72.4	1.0	16.1	9.5
Parsa	95,516	65.0	1.2	24.3	8.4
Kanchanpur	82,134	44.8	1.1	33.3	20.1
Kailali	142,413	50.8	1.3	30.8	16.6
Bardiya	83,147	51.3	1.2	18.6	28.7
Banke	94,693	51.7	1.7	30.4	15.6
Kapilbastu	91,264	68.4	0.8	22.9	7.0
Rupendehi	163,835	41.5	1.1	42.9	13.7
Total	2150106	58.1	1.3	24.8	14.9

Note: Nawalparasi West is NA. Source: CBS (2011) safely managed drinking water is also an issue in Nepal's drinking water sector including CBs that need indepth look.

5.8 ENERGY USE

Energy is a primary input to the well-being of a society and the development of a country. Concentrated energy is needed for communication, the service sector, manufacturing, commuting, accessing markets, social networks, and finance and institutional arrangements. In many rural parts of CB districts, families still use bio-mas (forest fuelwood, agriculture residue, and cow dung) for cooking. Along the Chure belt, for example, each person on average consumes twice as much fuel wood as the national average, which is 750 kg/person[19]. Clean energy platforms will be the foundation for meeting the demands of most human activities in the CB region as climate change threats become more and more real. Table 5.6 provides the percentage of different energy sources used for lighting and cooking.

In CB districts, the dynamics of energy use have to be examined at both the national and the local levels. In 2019, Nepal consumed 13.996 million tons of oil-equivalent energy, 69 percent of which came from biomass and 24.5 percent from petroleum products and coal. Electricity

TABLE 5.6: ENERGY USED FOR COOKING & LIGHTENING

District	Lighting			Cooking				
	Electricity	Kerosene	Others	LPG	Firewood	Biogas	Others	Source
Kanchanpur	69.9	26.9	3.2	4.3	86.6	7.3	1.8	Local level profile, 2074
Kailali	70.5	14.1	15.4	6.8	85.9	5.8	1.5	Local level profile, 2074
Bardiya	62.6	22.7	14.7	4.4	87.6	6.2	1.8	Rural Municipality & Municipality Profile, 2075
Banke	68.8	22.2	9.0	20.6	71.4	2.2	5.8	Rural Municipality & Municipality Profile, 2074
Kapilbastu	54.9	29.8	2.1	5.5	48.0	3.0	30.7	Rural Municipality & Municipality Profile, 2073
Rupandehi	80.6	18.0	1.4	34.2	34.3	3.2	62.5	CBS, 2068
W_ Nawalparasi	NA	NA	NA	NA	NA	NA	NA	NA
Parsa	75.4	24.0	3.7	15.7	65.8	0.4	18.2	District profile, 2074
Bara	68.3	29.4	2.3	4.7	67.2	1.9	26.2	CBS, 2068
Rautahat	46.6	50.5	2.9	2.1	54.3	0.7	42.9	CBS, 2068
Sarlahi	46.6	49.4	4.0	4.0	64.5	1.8	28.6	Distict profile, 2072
Mahottari	63.2	34.8	2.0	3.0	56.4	0.6	39.5	District profile, 2071
Dhanusa	73.2	23.5	3.2	10.1	42.5	0.3	47.1	CBS, 2068
Siraha	67.3	30.2	2.5	3.5	36.6	0.2	59.3	CBS, 2068
Saptari	41.9	55.3	2.8	4.2	34.0	0.3	61.5	Local level profile, 2075
Sunsari	81.7	16.6	1.6	29.0	35.7	1.8	33.5	District profile, 2074
Morang	75.8	22.1	2.1	23.3	44.9	4.0	27.9	District profile, 2074
Jhapa	82.1	16.2	1.7	22.7	58.9	8.8	9.6	Local level profile, 2075
Total	66.4	28.6	4.4	11.7	57.3	2.8	29.3	

and renewable sources such as solar and micro-hydro accounted for 4.5 percent and 2.0 percent respectively of the total energy consumed. In 2000, in contrast, biomass accounted for 86.11 percent of the total energy mix, and electricity use was just 1.28 percent. Petroleum products and coal comprised 9.14 percent of the total while coal comprised 13.31 percent. The total energy use, 7.869 x 10^6 tons of oil equivalent, was slightly more than half of what it is today. Currently, 85 percent of the petrol and diesel Nepal imports are used in the transport sector[20].

In the CB districts, traditional biomass, including the cow dung used for cooking, accounts for about 57 percent of the total energy use, while about 11 percent use LPG, 3 percent biogas, and 29 percent kerosene. Dried cow dung is used for cooking by about 10 percent of households[21]. The use of electricity for cooking is limited to a few households in urban areas. For lightning, about 66 percent of the population uses electricity, followed by 29 percent who rely on kerosene, and 5 percent who rely on biogas or solar panels. People also use these sources simultaneously. For example, in Jhapa District, for lightning, 82 percent use electricity, and 55 percent use kerosene. Similarly, people use multiple energy sources for cooking: in Rupandehi District 34 percent of the household use LPG, in Bardiya District 88 percent use biomass, and in Morang District 4percent use biogas for cooking.

In the CB districts, a major task is helping families shift to cleaner sources of energy including electricity from the grid for household uses and other cleaner energy sources for cooking. The other task is promoting the use of electricity in the operation of STWs used for irrigation and switching away from the diesel-based engines currently used. On a larger scale, the required transformative actions include creating opportunities for increasing the use of in-country electricity in the public transportation sector. Making this shift will depend, in parts, on establishing charging stations built across the CB districts.

NOTES

1. Ojha (1983) provides discussions of the earlier social history of Tarai. For later discussion, See Himal (1990)
2. CBC (2021)
3. https://www.indiacensus.net/states/uttar-pradesh/density and https://www.indiacensus.net/states/bihar/density accessed on 28 January, 2023.
4. See Ghimire (2016).
5. See LRMP (2010).
6. MoFSC (2014).
7. Ghimire (2016).
8. See Roka (2017).
9. Ibid.
10. See Adhikari (2008).
11. https://kathmandupost.com/columns/2022/12/06/repercussions-of-remittance-economy
12. Rimal et al (2018).
13. Ibid.
14. In Nepal's mid-hill districts of western Rukum, Gorkha, Khotang and Ramechap, 40 percent of the total land area was left fallow, while in the Trans-Himalaya District of Dolpa that percentage was 90 percent . See Roka et al. (2022).
15. GCF (2019).
16. Dr. Ram Baran Yadav, Nepal's first president and a man from Dhanusha District, has consistently made public statements about the declining groundwater table in his district. It was under his tenure that the government began the President Chure Tarai Madhesh Conservation Program. According to Parikshit Shrestha, engineer consultant for the Urban Water Supply and Sanitation Project, 15 years ago groundwater was available at 30 feet below the surface, today in 2023 the drilling depth has increased to at least 80 to 120 feet deep and even that doesn't guarantee that water will be available." See https://kathmandupost.com/sudurpaschim-province/2023/03/16/groundwater-depletion- affecting-many-settlements-in-western-tarai. A more systematic asseemsment is needed.
17. Bajracharya (2023)
18. According to JMP (2019), "Water is counted as 'available when needed' if households report having 'sufficient' water or water is available 'most of the time' that is, continuously or for at least 12 hours per day or four days per week)". https://washdata.org/sites/default/files/2022-01/jmp-2021-wash-households-highlights.pdf
19. See NPC (2010).
20. Nepal's present energy system has three undesirable dimensions that need transformations: the emission of greenhouse gases, the pollution of outdoor and indoor air, and the especially adverse impacts of indoor pollution on the health of women, and the drain on the country's budget due to the import of petroleum products. According to the Customs Department, in the fiscal year, 2078/79 Nepal imported petroleum worth NPR 320 billion https://gdpnepal.com/archives/25036
21. CBS (2068 BS).

Evolution of Flood Risk Management Approach in Eastern Ganga Region

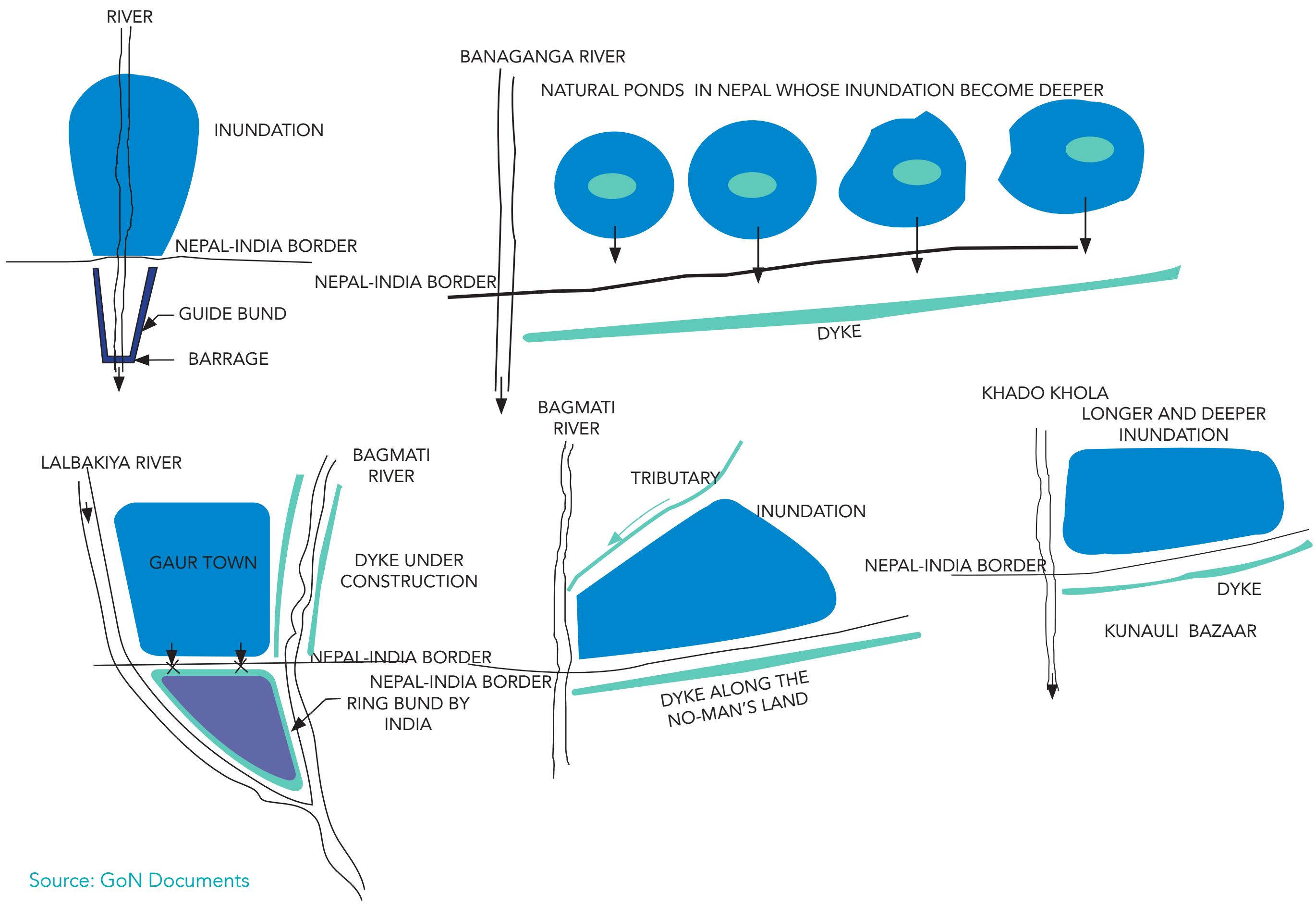
EVOLUTION OF FLOOD RISK MANAGEMENT APPROACH IN EASTERN GANGA REGION

06

6.1 INTRODUCTION

This chapter discusses flood dynamics and interventions made to address flood inundation in the EGR including CBs and along Nepal-India border areas. Inundation can be a seasonal or permanent natural or human induced phenomenon in a landscape. Wetlands, ponds, and lakes are natural permanent inundations while a dam-created reservoir is a man-made yet still permanent type. Heavy and widespread rainfall in an upper catchment can flood a river and its water can submerge land and the vegetation on it as well as settlements along the riverbanks. Floods often lead to human deaths and cause damages and losses to social and economic sectors including disruption of essential services. During a seasonal flood, rivers carry silt, whose deposit on agricultural land can improve the land's productivity as a natural source of nutrients, as a beneficial impact. Rivers also transport sediments larger than silt, such as sand, whose deposition on farmland affects productivity through the loss of land and crops. Once rainfall ceases, inflow to the river declines, and the accumulated water begins to drain from the land. Constriction of the natural flow of a river can cause the permanent inundation of upstream areas not usually submerged. As mentioned above, the inundation problem in Nepal's border areas of CB districts is human-induced, one that has been around for years (Figure 6.1).

FIGURE 6.1: SCHEMATIC OF EMBANKMENTS ALONG RIVERS CONSTRICTING FLOW



Source: GoN Documents

6.2 RESPONSE TO FLOODS EVENTS

An understanding of the inundation phenomena in the CBs requires a contextualized analysis of the dynamics of the South Asian Monsoon (SAM), its interaction with the landscape and societies, surface flow responses such as floods, and the water regimes of watersheds. Broadly, it requires understanding the historical evolution of approaches to respond to floods in the Ganga plain. Particularly, the inquiry needs to look at the emergence and domination of structural methods such as embankments in the plains of two Indian states bordering Nepal, Bihar, and Uttar Pradesh.

Rainfall in the districts of CB varies according to space, time, and elevation in the north. Though not as dramatic as the microclimatic conditions in the hills, the CBs also have such conditions, as well as variations stemming from differences in soil, gradients, and land use. During the monsoon, when about 80% of Nepal's total annual rainfall occurs, rivers swell as a natural consequence of the regional hydrological cycle. Human interventions on the land surface over the last 100 years have changed the surface and the interflow subprocess of this cycle. In the last several decades, climate change has emerged as another driver of inundation by making precipitation more extreme

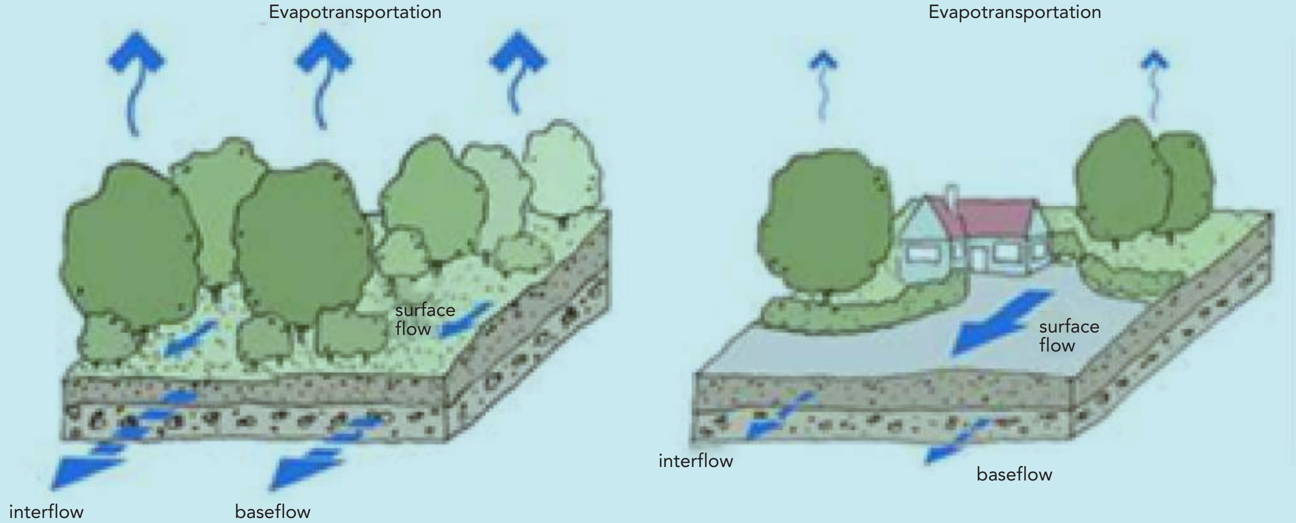
Inundation Tikapur Nepal Source: Naresh Rimal and more erratic. Areas affected by the SAM experience four major rainfall seasons: monsoon, post-monsoon, winter, and pre-monsoon. As mentioned earlier, knowledge about the specific impact of climate change on rainfall has elements of uncertainty that make it difficult to anticipate what each season will bring.

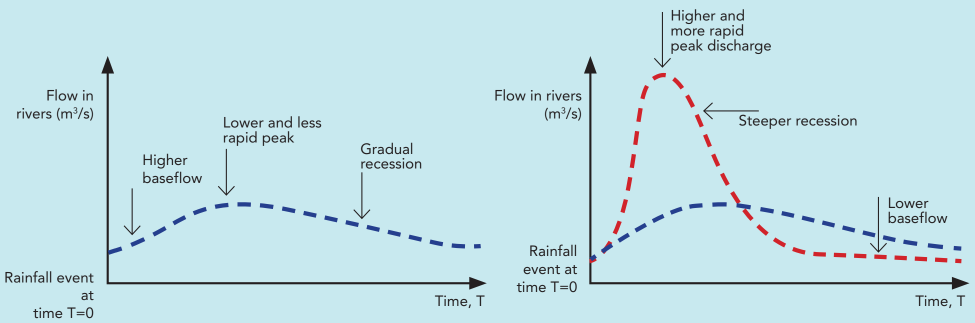
For communities in the EGR, monsoon floods are a regular feature. Since antiquity, the monsoon has brought both advantages and disadvantages as a living reality. The summer monsoon rainfall begins to fill the moisture deficit of vegetation and the soil of the terrestrial ecosystems and rivers get additional flow.

Nurtured by rain, the terrestrial ecosystems produce services that support the livelihood opportunities of millions in the region. The availability of rainwater enables the planting of paddy, a staple upon which millions of South Asians depend. A normal monsoon is the lifeline for people, animals and vegetation that supports the region's agriculture-based economy.

Once the land saturates, water moves as surface flow to downstream regions and tributaries. With even more rainfall, the rivers become flooded, overflowing their banks. In recent years, as more surface area in watersheds is paved, land use and land cover changed, the amount of water

BOX 1 IMPACTS OF DEPLETION OF VEGETATION AND INCREASE IN IMPERVIOUS SURFACE ON PEAK FLOWS





Impermeable surfaces, gullies, pipes, sewers and channels and removal of vegetation and compacted grounds alters natural drainage and replaced free draining ground with increase the total volume and flow of runoff. The Interventions make areas more susceptible to flooding locally and also exacerbate river flooding.

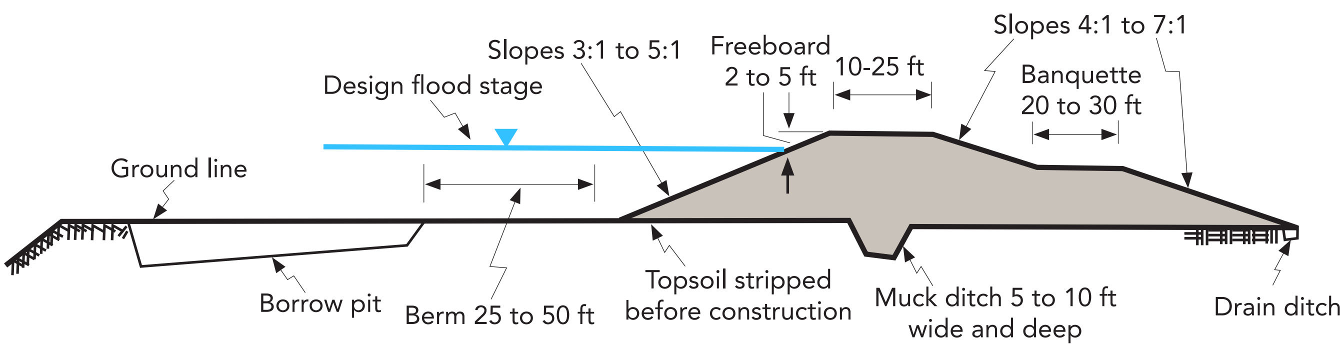
https://www.susdrain.org/delivering-suds/using-suds/benefits-of-suds/flood-risk-management.html that can infiltrate has declined and almost all of the rainfall has become surface flow. Moreover, physical infrastructure like roads, irrigation canals , embankments, barrages and dams and railways have altered the natural drainage. When heavy rainfall occurs, surface runoff is immediate and in downstream river sections, the volume of flow is higher, and the time to peak is faster than it would have been if fewer areas were paved. Thus, in regions with many paved surfaces, climate change-spawned extreme rainfall will lead to high overland flow and potentially flash and peak floods. All types of floods erode banks, inundate fields, and damage crops and assets. They even take human lives. Rainfall variability, land-use changes, infrastructure development, and socio-political aspects of communities along floodplains determine the intensity of flood disasters.

In the CBs, rainfall acts as one of the main triggers of surface soil erosion. The watershed's flow response interacts with processes such as deforestation, construction, and agricultural activities, generating more eroded sediment mass into rivers for transporting downstream. In the hills, rainfall also triggers landslides, which serve as a point source of sediment of different size[1]. As a river's flow velocity decreases, smaller and smaller sediment particles accumulate in riverbeds, on riverbanks, and flood plains. Very fine materials such as silt remain suspended in a river and are transported to the Bay of Bengal, where they are permanently deposited to form a delta. High concentrations of sediment in monsoon-swollen rivers are natural consequences of water flow within the hydrological cycle. Fine-sized sediment and vegetation in flood water have nutrient-rich content useful for agriculture. The conventional approach to flood control does not, however, account for this value. This contextualization is useful for recognizing the limitations of, challenges, and opportunities for structural approaches to responding to flood hazards.

6.3 ENGINEERING APPROACH

Historically, communities in the deltaic region of Bengal (e.g.EGR) built raised mounds on which they would move temporarily during storm-caused high flows in rivers[2]. Then, under the Mugal rule in India, certain forms of embankments were also built for dealing with floods. With the advent of colonial rule, the state began building embankments to develop railway lines, roads, and irrigation canals, and to prevent river floods (Figure 6.2). Meeting this later objective of

FIGURE 6.2: IDEALIZED EMBANKMENT CROSS SECTION



Adapted from: Linsley et al (1992).

preventing flood was no straightforward proposition, however. Engineers debated the role embankments play in controlling floods as well as their ill effects. Revenue collection departments argued that embankments flood the land and submerge it, thereby lowering revenue.

Gradually, the engineering of embankments was consolidated and a structural approach to flood control became standard procedure. In the EGR, the building of embankments for laying railway lines began in the 1830s. To ensure the uninterrupted operation of services during the monsoon, railway tracks had to be placed higher than the highest level of river water in the season. Thus, to avoid inundation, tracks were laid on top of mounds of broadly trapezoidal-shaped compacted earth. These were termed embankments, levees, or dikes (Figure 6.2). Hardwood sleepers were laid across such levee, and steel tracks were fixed so locomotives could move.

This development of railways in Bihar and Uttar Pradesh had ecological, social, and political impacts on the CBs in Nepal. Sal trees *(Shorea robusta)* provided hardwood sleepers, and the trees available in parts of CB forests became a convenient source.[3] This demand for railway sleepers across the border thus led to the widespread cutting of trees from forests in the CBs, and their export become a source of revenue for the then Nepali state. Subsequent interventions in the form of malaria eradication, state-sponsored resettlements in some parts of the CBs, and the development of highways began to change the region's land use. Thus deforestation, the development of settlements and agriculture farming changed the landscape with resulting new socioeconomic, environmental, and political outcomes.

Building embankments for railways faced challenges. First, the railway lines had to cross rivers, and bridges and culverts were built. Indeed, in the monsoon months, in EGR's Bihar and Bengal, rivers became like inland seas requiring viaducts, bridges, culverts, and flood openings to cross them.[4] The smaller the span of a bridge or culvert or the waterway underneath it, the lower the cost of its development. Thus, in some places, openings under bridges were built too small to safely negotiate the high river flow of the monsoon. Even if waterways of the bridges, culverts were sufficient when they were built, erratic precipitation and the land use change as well as changes in drainage pattern combined have caused river stage to rise than in the past. As a result, the waterways below these infrastructures are too narrow to pass peak flood discharges.

Having too small a waterway under a bridging structure is akin to a constriction that can result in backwater effects on upstream reaches. In such circumstances, a river may also cut a road/railway embankment, outflanking and/or damaging the concerned bridge. Rivers can scour piers and, if the depth of water is inadequate, a bridge structure could collapse. Thus, not only a bridge but also its pier and abutments have to be properly designed and built and adequately protected from floods. In many cases, the waterways of existing bridges and culverts have become inadequate to safely cope with high flood events. This is especially so as climate change has made rainfall more extreme, and flood peak magnitudes and sediment loads greater. Since safe bridges provide uninterrupted service to roads and railway lines, having small waterways constricting flow can heighten the risk of such infrastructure getting damaged and their services disrupted.

The roads in CBs have hundreds of bridges and culverts built on them. The roads here are aligned east-west, crossing north-south-flowing rivers almost at right


The waterway below the aquaduc is almost blocked

Source: A Pokhrel, See Dixit et al (2007)

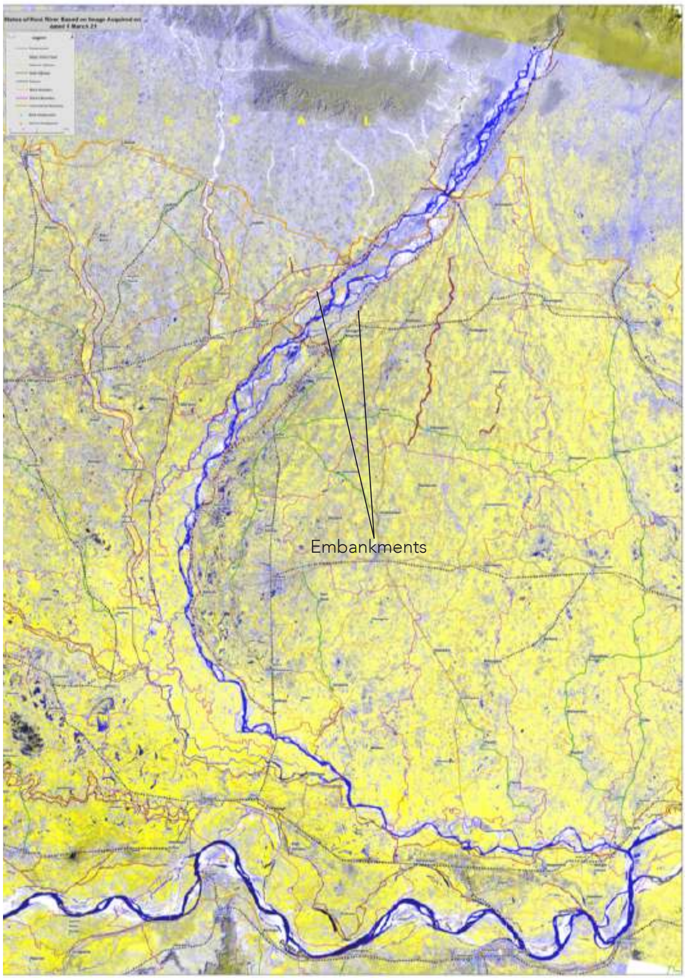
angles, having such small waterways that they constrict river flow under bridges can be issues of concern. Building resilience to climate change requires assessing new flood scenarios and revisiting the old design assumptions, codes, and standard operating practices of the development of transportation infrastructures such as roads, highways, and bridges as well as other water infrastructure. We will cover these aspects later in the insights and recommendations sections.

Embankments built of compacted soil are not waterproof as they leak. While the riverside of an embankment faces the threat of erosion by river flow, seepage could erode the lower end on the opposite side. Embankments also prevent tributaries from flowing into the main river, thereby causing water to accumulate outside them and leading to permanent inundation. While British engineers did recognize these limitations, embankments nevertheless became elements of the colonial state's development agenda. The British East India Company began using embankments to address floods in eastern rivers, such as the Mahanadi in Odissa, the Damodar River in West Bengal, within the Indian state and the Koshi in Bihar.[5] For colonial engineers, the Koshi was not only a unique case eco-hydrologically but was also transboundary. While they did mention the role of the upper catchment, in the ongoing discourse, it remained as a black box.

6.4 EMBANKING OF THE KOSHI RIVER

The Koshi is one of the largest tributaries of the Ganga River. Three of the Koshi's tributaries, the Bhote Koshi, Tama Koshi, and Arun rivers, begin in Tibet, while four others, the Tamor, Likhu, Indrawati, and Dudh Koshi rivers, emerge within Nepal and flow into the Sun Koshi. The Arun, Tamor, and Sun Koshi rivers meet at the village of Tribeni in Nepal's Dhankuta District. The conjoined river, called the Sapta Koshi, flows south, cutting through

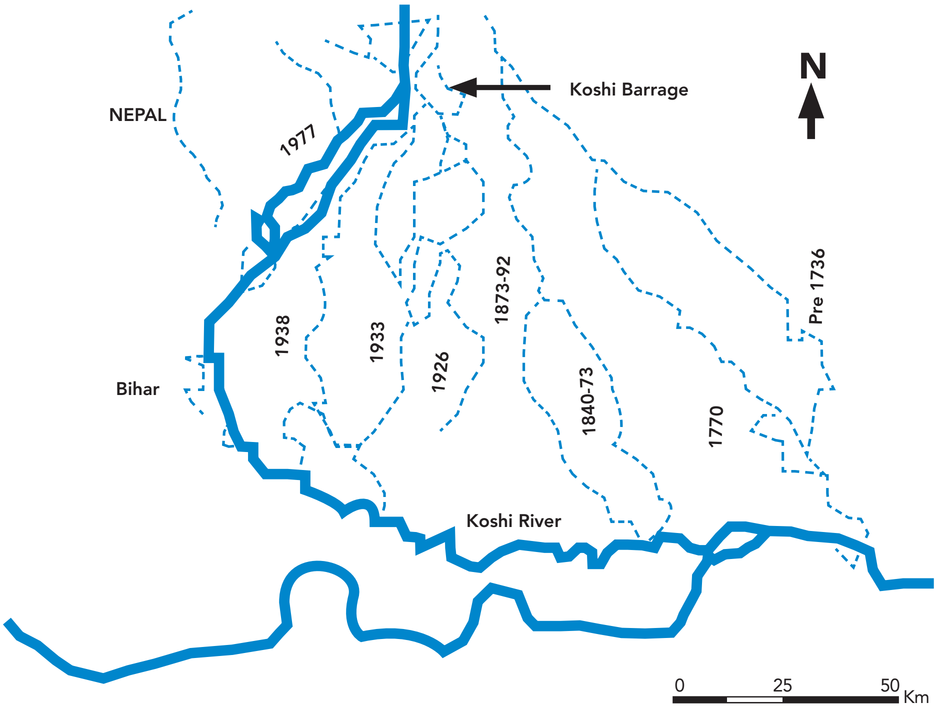
FIGURE 6.3: THE KOSHI BARAGE AND EMBANKMENTS ALONG THE RIVER BANKS



Source: Sanjaya Wagle

about 15 km of the Mahabharat range until it arrives at Chatara in northern Sunsari District. The river then flows through Nepal, crosses into Bihar and joins the Ganga in Bihar. Housing six of the eight highest peaks in the world, the Koshi basin also has one of the highest natural sediment yields in the world. At Chatara, as the river's gradient decreases, it no longer has sufficient energy to push the massive volume of sediment downstream. Until 1959 it deposited that sediment load on the region between Chatara and its confluence with the Ganga, forming one of the largest inland fans in the world. Though the river continues to bring the sediment load, it is no longer deposited on the fan but instead within embankments built along the banks in 1959 (Figure 6.3).

FIGURE 6.4: SHIFTING KOSHI RIVER BEFORE THE EMBANKMENT WERE BUILT



Source : Gole and Chitale (1966)

A map of the Koshi fan and the stages of migration of the river prepared in 1962 shows that the Koshi River has consistently moved westward on the fan. In the last 250 years, it has migrated 150 km west of Saharsha (Figure 6.4). This distance is less when measured from Nepal's Biratnagar[6]. The Koshi's shifting and its flooding used to hit local communities in Nepal's lower Udaypur, Saptari, and Sunsari districts of the CBs, and Bihar, which were and still are among the poorest regions of South Asia. Most of them are the poorest. The flooding did bring ills, as a 1953 paper indicates: "Hundreds of houses which have collapsed will have to be rebuilt. Damaged roads, railways, etc., will have to be repaired. Moreover, floods bring hunger, disease, and misery in their wake, and the people affected have to face stark misery after the flood is over[7]."

Indeed, the deluges triggered disasters that hit local communities hard. The extant social vulnerability and extractive socio-economic order further exacerbated people's suffering due to floods. Those hit by floods coped with the impacts and were further pushed into vulnerability. The approach for flood mitigation that the engineers proposed was not holistic in that it did not combine both reductions in hazard exposure and social upliftment. High river flows were considered the source of all ills, and engineers sought structural measures to keep water away from communities on riverbanks and flood plains. This approach also suited the strategy of the then-political order, which was to extract revenue from land, and maintain political control. Within this social-political realm, British engineers labeled the Koshi River "The Sorrow of Bihar" and the Damodar, "The Sorrow of Bengal[8]."

The communities hit by Koshi or other flood were, and even today are, not homogenous: they comprise peasants and zamindars, men and women, traders and officials, and so on. Each group of individuals, even each person was and is impacted differently and their responses to the floods were, and are, different. However, a top-down blanket solution designed to prevent river water from overflowing its banks and spreading across the flood plains on the banks was proposed. This decision failed to consider the socio-economic context of local communities, other ways of understanding floods, and how local people dealt with floods. Indeed, rainfall in the catchment did lead to flooding in the Koshi, but the nature of that flooding varied according to the month and the nature of the rainfall, and the people along the Koshi had their ways of understanding the river's behavior and coping.[9] This local knowledge was disregarded in the decision-making about how to address floods.

The two proposals considered were constructing a high dam in Nepal's Barahkchetra gorge and/or building embankments along both riverbanks. Eventually, in the early 1950s, embankments were chosen. Up until the 1940s, however, there were debates about their suitability to control floods. British engineers argued that embankments constrain flow and should not be built in the eastern rivers of the Ganga basin. At the 1937 Patna conference, Chief Engineer G. H. Hall highlighted the three main limitations of embanking a river: a) it increases the amount of damage caused by floods, b) it shifts the problem from one place to another, and c) it creates a false sense of security. However, embankments were already the basis of the engineering-guided approach to the development of public irrigation, railways, and highways. The jacketing of rivers by embankments also received impetus from a similar flood-control approach practiced in the US and China.[10]

6.5 CONSOLIDATION OF STRUCTURAL FLOOD MANAGEMENT PARADIGM

After independence from British rule, the structural approach to flood control began to get more policy priority in India and Pakistan (both West Pakistan and East Pakistan, which is now Bangladesh). A series of very heavy rainfall events led floods in large parts of the north Bihar in 1952, 1953, and 1954, promoting the GoI to develop a flood control strategy.[11] In 1954, the GoI formed the National Programme of Flood Management, which included the structural approach as a main constituent. It was during this policy shift that the stage for building embankments on the Koshi and the signing of the 1954 Koshi Treaty was also set. After this point, successive governments of India, both central and state, included the building of embankments as a strategy to control floods[12], and, in subsequent decades, made major investments in the building of such structures in Bihar, Uttar Pradesh, and West Bengal[13].

The state of Bihar was one major beneficiary of this policy. In the 1950s the total length of embankments in Bihar was 160 km; by 2003, 2,952 km had been added. Officially, this approach has protected 2.9 million hectares of land—2.7 million hectares in North Bihar and the remainder in South Bihar—against floods.[14] This achievement, however, is contested. It is argued that a large swath of land in north Bihar is permanently flooded, and that annual flooding is a regular feature. With the impacts of climate change, the scenario that the region will suffer both floods is plausible.

In Nepal, the use of embankments to control floods formally was adopted as a state policy in 2009. The country was not part of either this evolving phenomenon of flood control methods or the debates. The 1954 Koshi Treaty was questioned

TABLE 6.1: SUMMARY OF FLOOD DISASTERS FROM 1987 TO 2021 IN CHURE BASINS

Date	Rainfall (mm/24hrs)	Impact Area	Death-missing-affected	Damages
08/1987	200	East Tarai District (Jhapa, Morang, Sunsari, Saptari and Udayapur. Caused damages in Bihar, India	1,399 died and nearly 29x106 affected	At many locations in E-W Hwy. Inundated farms nearby the highway and 5302 animals lost
1993	540 Tistung in Khulekhani catchment	An unprecedented number of landslides and floods in South-Central Nepal	1,460 dead 73,606 families affected	39,043 houses were damaged, and 43,330 hectares of cultivated land were washed away/covered with debris. 367 kilometers of roads, 213 large and small bridges destroyed 38 small and large irrigation schemes 452 school buildings, hospitals, and government offices.
06-08/1998	3,200mm in 07/98	Ramgram Municipality, Nawalparasi	273 dead, 80 injured, 33,549 families (279 families, Nawalparasi)	Washed away about 24 hectares of land. Property damage worth NPR 680,000. 33,549 families were affected, 13,990 houses fully damaged. 45,000 hectares of agriculture were inundated 982 cattle died (Yogacharya, 2008). Estimated damage NRP 2 billion.
07/2002	Heavy rainfall	Affected 49 districts	445 died, 300,000 people affected	12,800 families are homeless (Yogacharya, 2008).
2006	Heavy rains	Heavy monsoon rain and swollen rivers caused flooding in Mahottari, Parsa, Bara, Rauthat, Banke, Nawalparasi, Bardia	12 died, 17,106 people affected	Estimated damage NRs 20,10,87,027.
18/08, 2008	Breached embankment	Kusaha VDC of Sunsari and Bihar.	3 died, 12 missing 65,000 in Nepal, 3.5 million in Bihar/India	
19-21/09 2008	205mm Nepalgunj	Banke, Bardia, Kailali, and Kanchanpur	30,733 people Dekhatbhuli and Shankarpur VDCs and Mahendranagar Municipality 18 VDCs and Dhangadi Municipality	2,152 houses completely damaged, 12,962 houses were partially damaged 5,647 households lost stored grains, 12,552 households lost some stored grains
August 17, 014	200-500mm in eight stations in mid-west	Kailali, Badia, Surkhet, Dang	222 died, 6,859 people, 84 injured	5,167 houses fully damaged and 14,913 partially damaged, displaced households, 117,580 Livestock embankments, dwellings, and agricultural land roads and bridges. Many culverts were washed out.
2017	11/08-16/08/2017, 36 CB stations heavy rain, 45 events >100mm, Jhapa-the highest rain of 452mm	Districts of CB	134 died, affected 1.7 million people 22 injured	>190,000 houses destroyed and some partially damaged, thousands of people displaced, and many homeless. Loss of nearly NPR 60,716.6 (USD 584.7million)
11-14/07/ 2019	Rainfall	Rautahat, Sarlahi, Mahottari, Dhanusha, Siraha and Saptari	117 died, 38 missing, and 80 injured.	19.994 houses complete damage, 41,343 partial damage, 6,096 moderate damage
2020	Continuous rainfall	58 Districts	297 died 674 missing and 223 injured	51 NRP Million
2021	Rainfall ranged 502.20 mm to 211.40 mm at 28 stations	Kanchanpur, Kailai Bardiya, Banke, Dang	120 died 28 missing	Standing and cut paddy 31.49% loss in paddy production and affected local roads

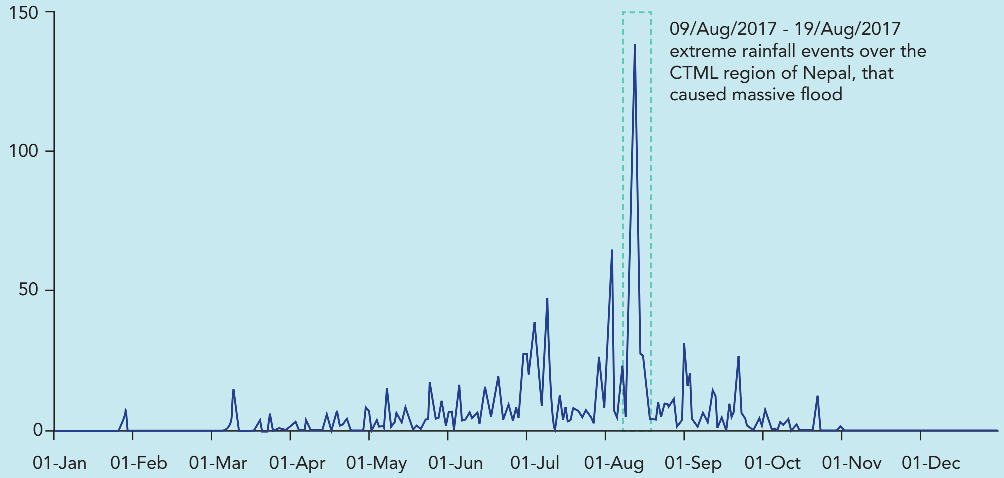
Source: NCVST (2009) MOEST(2021) RISK NEXUS (2014)

BOX 2: WEATHER EVENT THAT LED TO FLOOD IN NEPAL'S CHURE AAD CB REGION IN 2017

District	10-Aug-17	11-Aug-17	12-Aug-17	13-Aug-17	14-Aug-17	15-Aug-17	16-Aug-17
Kanchanpur	42.5	2.5	1.5	41.5	28.5	36.4	0
Kailali	35.2	10.4	100.3	275.4	68.2	69.2	25.2
Kailali	16.3	4.9	13.3	27.1	16.2	156	35
Kailali	16	0	137	31	5	142	33.4
Surkhet	3.8	3.2	20.5	30.8	39.1	43.2	3.5
Bardiya	0	3	35.8	53.5	32.8	93.1	28.5
Banke	0	5.5	119.2	51.5	14.4	78.4	43
Bardiya	2	6.4	88.2	242.5	36.1	46.2	20
Banke	7.8	4.2	420	118	169.6	52.4	43
Banke	5.8	1.2	169.7	62.5	14.2	98.8	42.6
Dang	1	1.2	157.2	48.4	72.4	17.8	3
Rupandehi	8.4	12.7	378.6	49.8	161.6	65.6	150.6
Rupandehi	9.8	85.2	35.8	25.1	222.2	6.3	27
Nawalparasi	0	19	64	224	45.4	10	19
Rupandehi	2	109	42	31	262	4	35
Nawalparasi	0	85	85	165	21	0	185
Kapilbastu	24.6	36.3	35.8	49.9	130.3	2.2	14.1
Nawalparasi	7	103	77	161	305	0	193
Chitawan	0.2	28	57.5	210	57.3	1.9	24.5
Makwanpur	0	45.8	128.9	516.2	20.2	0.7	1.2
Bara	6.4	89.4	226.6	191.8	30	10.2	2
Bara	5	37.5	132	139	11	30	21.5
Sindhuli	1.2	50.5	54.5	70.1	3.5	0	2.9
Dhanusa	72.2	117.6	137.6	192.4	7.8	0.6	0
Sarlahi	0	172	183	80	0	0	0
Sarlahi	10.4	51	149	320	1	0.6	0.8
Saptari	47	15	115.4	135	128	0	5
Udayapur	26.6	39.6	50.6	27.6	53	0	3.4
Siraha	19.2	39	12.4	66.5	107	35	7
Siraha	32.8	39.5	113.4	116.6	67.5	4.6	0
Saptari	53.6	43.5	146.5	207.5	89.2	0.5	0
Sunsari	28	30.3	292.9	122.6	10.1	0	13.4
Sunsari	41.5	41.1	0	40.7	0	0	13.4
Morang	26	56.7	0	0	0	0	0
Sunsari	111.8	19.4	255	261	26	0	0
Jhapa	106	107.2	376.5	279	7.7	0	0
Jhapa	58.6	79.7	274	452	19.7	0	0

Source: DHM

The data from 42 meteorological stations over the CTML region shows the high rainfall from 09/Aug/2017–19/Aug/2017. Average total rainfall of about 397 mm over the Chure range was observed in 3 days from 11, August to 15 August/(2017) which led to massive flooding.



Source: DHM

due to its allocation of river resources, its use and political context. There was no public discourse on the choice of method or science in relation to the use of the control mehod proposed. In the early 1950s, (1952-1954) floods in Nepal's lower Bagmati region damaged the embankment of the railway line built south of the border forming perhaps one of the earlier incidents of anthropogenic inundation outside of the Koshi, Gandak, and Sarada barrage project areas. A few years after the Koshi Treaty was signed, embankments built in Bihar's Barganiya close to Nepal's southern created inundation in Nepali territory.

6.6 FLOOD DISASTERS IN CB REGION

The CBs in Nepal, particularly those in the central-southern parts, face regular flood disasters. Even today, people remember the impacts of the floods of 1953 and 1954. In 1953 heavy rainfall in eastern Nepal and Bihar flooded parts of the central and eastern Tarai of Nepal, including areas across the border. This flood is commonly referred to as an event that forced people to live in trees, saw Prime Minister Nehru visit the area, and feel distressed enough to decide to do something immediately to alleviate the suffering. A year later the Koshi Treaty was signed. A few months after the signing of the treaty, in July of 1954, the upper catchments of the Koshi faced very heavy rainfall that led to high floods in the river. At Chatara a flood of 25,000 m^3/s magnitude, the second-highest flood ever in the river, was recorded.

The heavy rainfall of July 1954 not only led to landslides and floods in the hills but also caused widespread damage to the plains of the Bara, Parsa, Rautahat, Sarlahi, and

TABLE 6.2: FLOOD EVENTS AND THEIR TOTAL IMPACTS IN THE 18 CB DISTRICTS FROM 2011 AND 2022.

District	Events	Deaths	Missing People	Affected Family	Injuries	Private House Full Damage	Private House Partial Damage	Livestock Loss	Animal-shed Damage	Financial Loss (NPR) In Millions
Banke	27	30	11	11145	2	2771	7999	0	1	482.73
Bara	34	17	1	425	1	13	370	110	0	2.73
Bardiya	47	48	28	18294	4	3877	14068	0	0	3781.19
Dhanusha	32	10	0	320	1	65	258	0	1	3.05
Jhapa	103	38	17	3687	0	55	2389	0	2	6.34
Kailali	42	14	14	2875	3	12	2632	0	0	0.05
Kanchanpur	19	5	6	543	0	117	274	0	9	1.75
Kapilbastu	19	19	4	3022	0	125	1	0	0	0.05
Mahottari	42	21	4	85	0	597	417	6	0	498.72
Morang	107	40	17	5899	2	597	4679	116	224	44.18
Parsa	24	15	1	313	4	4	250	1	0	0.99
Rautahat	57	37	13	423	3	47	118	1582	0	1.23
Rupandehi	37	15	11	377	1	52	312	0	0	3.72
Saptari	50	19	1	2958	1	82	2426	0	4	21.01
Sarlahi	41	33	5	36	1	12	12	0	2	1.32
Siraha	22	10	6	26	0	15	56	0	1	1.83
Sun sari	74	27	18	1460	9	23	288	3	10	3.23
Nawalparasi	5	0	0	141	0	2	134	0	5	0.15
Total	782	398	157	52029	32	8,466	36,683	1,818	259	4854.27

Source: DRR PORTAL

TABLE 6.3: OVERVIEW OF FLOOD DISASTER LOSSES AND DAMAGES IN CB DISTRICTS (2011-2022)

Year	Total Death	Missing Persons	Directly Affected Family	Injured	Private House Fully Damaged	Private House Partially Damaged	Livestock Loss	Animal Shed Damaged	Estimated damage (NPR) iIn Millions
2011	64	24	75	5	681	443	0	0	506
2012	5	3	107	1	107	278	0	0	163
2013	53	54	429	1	67	5	0	0	124
2014	58	23	28,627	4	1677	2151	831	2133	14,255
2015	0	0	7	0	6	0	0	7	23
2016	38	9	6152	3	352	14	110	8	43
2017	114	20	362,705	21	144	11,732	1,597	7	60,716
2018	3	0	712	2	4	278	1	0	13.58
2019	42	10	2851	3	425	1871	0	224	176
2020	6	3	125	0	11	37	0	6	376
2021	16	4	65	0	24	5	0	3	8,540
2022	3	0	15	2	1	2	0	2	1780
Total	402	150	401,870	42	3,499	16,816	2,539	2,309	86,552.58

Sources: DRR Portal, IFRC (2014), NPC (2017), MOHA (2017), MOHA (2019) MOHA (2022), Bhandari & Dixit (2022), available respective DDMC records and Nepal's position paper presented to APMCDRR in 2022 and various media reports.

Note: Data except on death, missing and injured is very scanty. The amount of crop damage and livestock death are included in the estimated loss where available from reliable sources. This scenario reveals poor quality of documentation and need for urgent improvement for systematic accounting and documentation of disaster damages and losses. Besides other hazards like fire, windstorms, drought, heat and cold wave in the region bring significant damages annually, but not included in this table.

Mahottari districts in the CBs. Almost 200,000 people in the Tarai were affected and more than 300 people died. About 2,000 domestic animals were washed away, the land was completely covered by sand and 10,000 people were rendered landless. In addition, 50 hectares of cropland were damaged in Jhapa and 200 villages in the eastern Tarai were washed away[15] and the damage was estimated at NPR 10-15 million then . Since then, there have been more floods and more damage and losses. Table 6.1 summarizes the rainfall events that led to flood disasters in Nepal CBs since 1987 and the impact areas including the damages and losses.

The data in Table 6.1 was compiled from various sources and lacks some coherence. More systematic records are available since 2011 in the http://drrportal.gov.np, which is maintained by Ministry of Home Affairs of the GoN. Table 6.2 presents flood events and their impacts in the 18 CB districts from 2011 and 2022.

During the 16 years between 2006 and 2022, 782 flood events hit CB districts. The hazards caused 398 people to die, 157 people go missing and 32 get injured. The flood disasters affected 52,029 families and damaged 8,466 houses fully and 36,683 partially. About 1,818 livestock were lost and 259 cattle sheds were damaged. The total economic damage was estimated at NPR. 48,532,397,700. The number of deaths was higher in western CB districts such as Bardiya, while the number of flood events was greater in eastern CBs. In Bardiya District, 48 died, 28 went missing, 18,294 families were affected, 3,877 and 4,068 houses were fully or partially damaged. The number of flood events in Jhapa was very high at 200 but fewer people died than in Bardia. Morang alone had 103 flood events during the period 2011-2022 but lesser casualties. It must be, however, recognized that many smaller events are unrecorded.

6.7 OFFICIAL DIALOGUE AND NEGOTIATIONS: INUNDATION IN THE BORDER AREA

Inundation along the Nepal-India border in the CBs is also the outcome of the events highlighted above, including the hazard itself, the history of flood-control approaches, the signing of water treaties by Nepal and India, and subsequent dialogue that has been guided by a flood-control approach disregard the constriction of the natural flow of rivers.

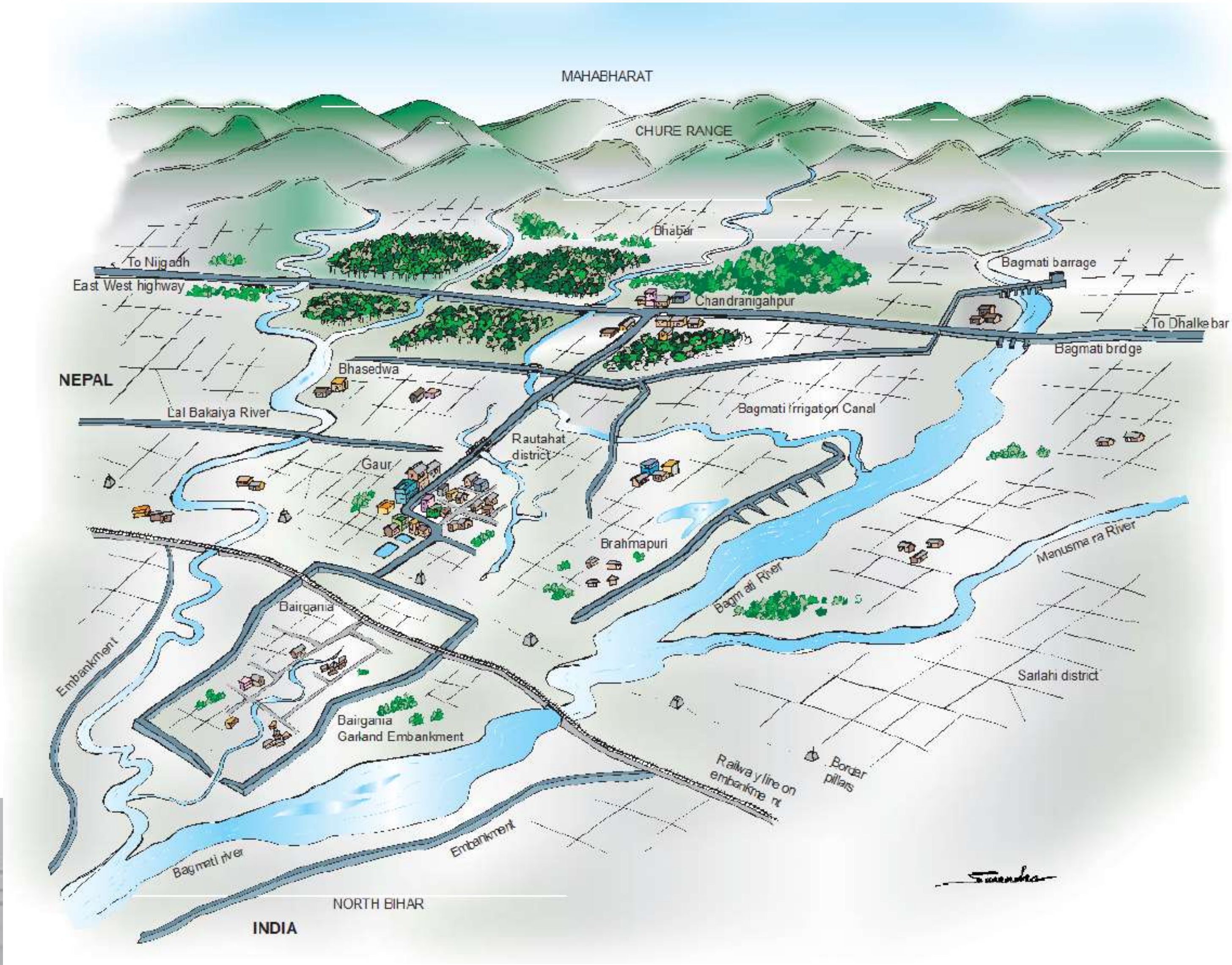
The formal water dialogue between the two governments goes back to the late 19th century, in the colonial era. In 1874 a member of the colonial administration raised concern about the water discharge (sill) level of the Bajah, Marathi, and Siswa **sagars** (human-built reservoirs) built in Nepal's Kapilbastu District. The Commissioner of Gorakhpur, Dr. W. Racy, referred to a 'boundary dispute' between Nepal and United Province concerning the above lakes and to the later resolution of that dispute.[16]

During this period, the Rana Durbar in Nepal and the United Province Government in Awadh had begun exchanging letters regarding a proposed barrage project in the lower reaches of the Mahakali River (called Sharada in India). A few years later, in 1910, the two governments signed an agreement on the Sharada project. The project, which was to provide irrigation water to the interfluve between the Sharada and Ghagara rivers in Awadh, was completed in 1928. To direct the river flow to the barrage, a few guide bunds were built.

In subsequent periods, there seems to have been little exchange regarding rivers and water management between the two governments. One milestone during this period was the Nepal government's hiring of two British engineers engaged in the Sharada negotiations for developing the Chandra Canal. The project on the Trijuga River, a lower tributary of the Koshi River, was built in 1928. In the meantime, in India, the colonial government seemed to focus on the eastern rivers, including the problem of flooding in the Koshi, and, to a limited extent, on developing a barrage in the Gandak River.

The main objective of the Koshi treaty was to control the flooding of the river. Irrigation and hydropower generation were secondary and tertiary benefits. These three benefits would be achieved by the construction of embankments and a barrage in the river as well as two canal systems extending from the barrage to the east and west and a canal drop hydropower plant in the eastern main canal. The treaty on the Gandak River, which was signed in 1959, set the stage for building the Gandak barrage, which was designed primarily to obtain irrigation benefits with flood control a minor objective of the package. The Gandak project also involved building a hydropower plant in the western main canal to supply energy solely to Nepal. Today, however, neither plant functions as designed.[17]

The provisions of both treaties were questioned in Nepal and subsequently revised. The Gandak treaty was revised in 1964 and two years later in 1966, the Koshi treaty was revised. It is fair to assume that from 1954 to 1966, the two governments met on different occasions and discussed certain dimensions of the implementation



Schematic of lower Bagmati region Dixit et al (2007)
Section of Gaur-Chandranigahpur highway and section of inundated Gaur town in 2017 flood.

Source: Dipendra Thakur

Railway embankment in Bargainiya, Bihar Source: Purushottam Jha
Section of inundated Gaur town in 2017 flood.
Source: Dipendra Thakur

of the two projects, potential revisions, and other issues related to water development. It is equally fair to assume that the Indian government focused on the implementation of the projects and sought concurrence from Nepali government authorities on the logistical aspects of implementing the two large-scale barrage projects. Some of the issues discussed, too, were related to compensation for the land acquired for the projects, the supply of construction materials, and so on. This study does not cover these aspects.

TABLE 6.4 a: THE DETAILS OF BORDER AREAS INUNDATED

District	Details
Rautahat	Gaur and the surrounding area
Sarlahi	Tribhuban Nagar
Dhanusha	Phulbariya Village Panchayat and Mukhiya Patti and Musariya
Siraha	Language Village
Saptari	Chhinnamastta Village, Tilathi Village
Kanchanpur	Jimuwa Village
Bardia	Rajapur, Kothiya Ghat
Kapilbastu	Bajha Sagar, Sisuma Sagar, Mahali Sagar, Malle Sagar
Morang	
Jhapa	
Nawalparasi	
Banke	Ramanagar, Shri Nagar, Kamdi, Bhagwanpur, Fattepur, Narayanpur, Laxmanpur
Rupandehi	
Dang	
Sunsari	

Source: Minute of the meeting in 1982

6.8 MINUTES ON BORDER INUNDATION

This study reviewed the minutes of meetings related to water held between officials of GoN and GoI between 1971 and 2022. The meetings, which were held at various levels of the two governments, broadly discussed proposed large dam projects, flood problems, energy exchange, inundation along the border, and flood forecasting. In the early period, the 1970s, discussions seem to recognize the challenges of floods in the lower Bagmati region. As mentioned earlier, the 1954 rainfall-triggered floods had impacts on the lower reaches of the Bagmati and Lalbakaiya rivers in Nepal's Rautahat and Sarlahi districts. Both rivers enter Bihar's Madhubani District near the town of Barganiya south of Nepal's border.

The floods impacted the village of Brahmapuri in, Sarlahi District, Nepal, close to the Nepal-India border. The 1954 floods resulted in sediment being deposited on land in Brahmapuri, an effect that destroyed the entire paddy crop. The river also brought tree trunks and deposited them in fields. Some people collected the timber, sold it, and earned some income. Other people built resting places on stilts (**machan**) and lived and cooked food there for many days**.** Some families stacked one bed on top of another to stay dry. Many fields looked like sand banks and could not be farmed for many years. As a result, many families faced food shortages. Well-off households bought food from local and regional markets while many poor households migrated to India."[18]

These conditions lasted for six years. Then, in 1960, the residents of Brahmapuri took the initiative to construct a canal from the Bagmati River to irrigate the land

TABLE 6.4 b: THE DETAILS OF BORDER AREAS INUNDATED

SN	Locations	Code figure 6.5	Rivers	The area affected (km^2)	Causes
1	Gaur Bazar	1	Bagmati/ Lalbakaya	32.25	Bunds in Bihar
2	Raghunathpur and Hathiyol villages of Sarlahi District and Southern part of Mahottari District.	2	Marha Manusmara	28	Embankment and spurs within no-man's-land.
3	Phulbari village and the area surrounding of Dhanusha District	3	Kamala	8	Guide bund on the eastern side along the Kamala River and extending parallel to the border
4	Lagadi village and surroundings in Siraha District	4	Gagan	25.5	Guide-bund on the eastern side and extending parallel to the border
5	Govindapur, Lalpatt village, Tilathi village, and surrounding area in the border side in Saptari District	5, 6	Khando	8	Embankment along the border disturbs the Khando River flow (the problem in Nepal is serious)
6	Saheganjanj customs area and its surrounding in Sunsari District, Majhore village and its surrounding in Morang District	7, 8	Burhi, Kaisali, and Lohindra	15.5	Bund disturbs the flow of the Burhi and Baisali rivers (the problem was dropped in the third SCIP meeting)
7	Bahundangi and Jamir village and its surrounding area. South part of Kakarvita in Jhapa District	9 & 20	Mechi	16.5	Embankment and spur on the eastern bank of Mechi River (this item was dropped in the 5th meeting)
8	Susta region in Nawalparasi_W District	10	Narayani	10	Construction of protective work on Narayani River (this problem began in 1984)
9	Siswa Sagar, Bajha Sagar, Marthi Sagar, and Mahali Sagar and surrounding areas in Kapilbastu District	11	Siswa, Marthi, Bajaha and Mahali Sagar	9.5	Lakes (increasing height of embankment year by year and situation of inundation area increases. Nepali land is inundated)
10	Koilabash area in Dang District	12	Gurongena	9	Dam over Gurangere River by GOI (the item was dropped in 3rd meeting)
11	Submergence of the South-Eastern area of Nepalgunj in Banke District	13	West Rapti	7.5	Canal crossing over West Rapti at Saryu Feeder canal
12	Darchula district headquarter in Darchula District	14	Mahakali	12	Spur and embankment on Mahakali River. (Dropped in 2nd meeting)
13	Inaruwa and its surrounding area across the order of Parsa District	15	Uriaiya	7.5	Canalization and straightening work of the Uriaiya River, (Dropped in 4th meeting)
14	Jamuni area of Dhanusha District	16	Jamuni	62	Construction of pump lift irrigation pump.
15	Balan River and its nearby border area in Saptari and Siraha District	17	Balan	55	Construction of embankments on both banks of the Balan River up to the Nepal border
16	No man's land area between border pillars No. 41 and 42 of Parsa District	18		27.5	Embankment
17	Bairawa village in the Saptari District	19	Drainage congestion by Koshi Canal	32.5	Koshi barrage
18	Kauraulia, Hevadawa, Singhahawa, Semari, Itahawa villages and areas of Suthaula and Rajahwa village in Kapilbastu District	21	Banganga	12	Closer of gates on the Banganga barrage in India, construction of guide bunds on both banks
19	Pakhlihawa village near Bhairawa	22	Danda	50	Diversion structure on the Danda River

20	Village near the border pillar No. 27 of Rupandehi District	23	Ghagra	6	Temporary bund across the Ghagra River
21	Border pillars. 22 and 23 near Barthahewa and Pajarbati villages in the Rupandehi District	24	Rohini	At least 30 villages	Temporary bund
22	Bhujehawa, Sankharpur, and Kurtharal villages in Nawalparasi District	25	Jharai	121.86	Settlement in the old course
23	Chauguvdi village and border areas of Dhansing village of Kailali District	26	Karnali		Girijapur barrage on Karnali Ghagharaa) River (Dropped in 5th meeting)
24	Rajapur and Gulariya villages area in Bardia District	27 & 29	Karnali and Saryu		Barrages in Ghagara and Saryu rivers
25	Nearby areas of Surajpura Powerhouse in Nawalparasi District	28			Gandak Main Western Canal
26	Raghunathpur village area in Mohattari District	30	Marha		Embankment along the banks of MMaraRiver
27	Jogbura in Kanchanpur District	31	Escape channel of Sharada Canal		Operation of escape channel (Dropped in 3rd meeting)
28	Betahani, Holiya, Fattehpur, Gangapur, Matehiya, Narainpur, Kalakot, Laxmanpur and Katuinya VDCs of Banke District				13.6-kilometers embankment in Laxmanpur Barrage by GoI
29	Amchaura and Pancheswar VDCs of Baitadi District, Lali VDC of Darchula and Rupal, Shirsha and Alital VDCs of Dadeldhura District				Proposed Pancheswar and auxiliary dams

Source: DHM(1991).

where sand had been deposited and rejuvenate farming. The canal irrigated land lying east of the village. A year later, in 1961, the Bagmati River began flowing in two channels along the east and west of Brahmapuri village. The westward channel accommodated most of the river's flow, while the eastward portion resembled a small canal. The westward river channel began to flow along the railway embankment in Bihar, threatening it. In 1966, to protect the embankment, the Indian Railway diverted the flow of the Bagmati from the western channel to the eastern channel by driving wooden piles on the upstream ground close to the embankment to prevent flood water from damaging it. Since the diversion began to adversely affect land on Nepal's side, the railways agreed to compensate Nepali farmers who had land adjacent to the eastern channel. Initially, the farmers did not agree to the amount offered, but later, as the river gradually started to move toward the eastern channel across the border, they did.[19]

A few years later, in 1970, local officials in Bihar requested the GoI to build a ring bund around the town of Barganiya and make it safer from floods. The ring bund, however, constrained the flow of the Bagmati and Lalbakaiya rivers, causing backwater effects that extended to Nepal's Gaur Bazaar. Subsequently, the GoN brought this impact to the attention of the GoI. In one early meeting in 1970, the minutes mention the avulsion of the Bagmati and Manusmara rivers. In a later meeting in 1980, the officials discussed problems related to flood control and water utilization of "smaller" seasonal rivers.[20] They also discussed specific flood problems in the lower Bagmati basin, problems that were already more than 10 years old.

By the mid-1970s, the inundation of land and other sites in Nepal along the border had emerged. The minutes of the February 12, 1982 meeting between Nepali Secretary of Water Resources P.P. Shah and the Indian Irrigation Secretary C.C. Patel mention submergence along several areas of Nepal,[21] as shown in Table 6.4 a.

Subsequent documents list the following areas of inundation and also indicated in Figure 6.5.

Another account of the areas of inundation[22] is shown in Table 6.3 c.

6.9 THE DHAKA MEETING AND SCIP

Despite these meetings the problem persisted and eventually led to discussions between Nepal's late King Birendra and India's late prime minister Rajiv Gandhi when they met at the 1985 South Asian Association for Regional Cooperation (SAARC) Summit in Dhaka. Following this discussion, a year later, in 1986, the GoI and GoN agreed to form a Standing Committee on Inundation Problems (SCIP). The SCIP had the following objectives.

- Identify the problem areas
- Itemize the actions to be taken and
- Suggest solutions

The first SCIP meeting was held in July 1986 in Kathmandu and covered 33 areas of concern due to inundation. Nepal raised 29 issues and India, just four[24]. SCIP continued to exist until 2001, and subsequently, Joint Committee on Inundation and Flood Mnagement (JCIFM) replaced SCIP.

6.10 OUTCOMES OF DISCUSSIONS

The regular meeting between government officials of Nepal and India on water resources, flood, energy exchange, and

FIGURE 6.5: AREAS OF INUNDATION

TABLE 6.4 c: THE DETAILS OF BORDER AREAS INUNDATED[23]

SN	Name of structure	District	Details	The tentative Area inundated in monsoon sq km	The tentative area inundated in winter	Date BS inundation began sq km
1	Laxmanpur Barrage	Banke	14 gates	22.45	14	2042 (1986)
2	Mahali Sagar Barrage	Kapilbastu	15 gates	5.05	1.15	1957 (1901) five gates· 2066 (2010), 15 gates
3	Rasiyawal-Khurdalotan Jyortibandh	Rupandehi	3 km complete, 17 km left gates	14	0.35	Begun in 2056 (2000), 2003), stopped
4	Kailashpur Barrage	Bardia_kailali	35 gates	10.10	0.66	2040 (1984)
5	Koilabass Bandh	Dang	4 gates	0.20	0.07	2061 (2005)
6	Danda Farena Embankment	Rupandehi	3 gates	0.67	0.06	2063 (2007)
7	Gandak Barrage	Nawalparasi¬_W	36 gates	0.67	–	2021 (1965)
8	Lalbakaya Embankment	Rautaha	8 km	0.50	–	2060 (2004)
9	Bargainya Ring Bund	Rautaha	16 gates	0.15	–	2039 (1983)
10	Bagmati Embankment	Sarlahi	8 km	0.10	–	2042 (1986)
11	Kamala Embankment	Siraha-Dhanusha	30 km	0.27	–	2066 (2010)
12	Siraha Embankment	Siraha	4 km	0.47	–	2063 (2007)
13	Khando Kunauli-Embankment (jal bandhan)	Saptari	310 m	7.10	0.07	Khando, 2054 (1998) Kunauli, 2042 (1986)
14	Kosi Barrage	Sunsari- Saptari	56 gates	0.70	–	2048 (1992)
15	Luna Bakraha Embankment (Jalbandhan)	Luna Bakraha Embankment (Jalbandhan)	400 m	8.40	0.14	2060 (2004) since constructed
16	Supporting Highway to no 730 and 27	Supporting Highway to no 730 and 27	1750 km L	11.50	2.30	
Total				82.33	18.8	

Note: A barrage is an engineering structure designed and built in a river section to alter its stock and flow for obtaining largely irrigation benefits. Koshi barrage is built in the snow-fed Koshi River under the Nepal-India treaty while the other two are built in rain-fed West Rapti and snow-fed Kanali rivers respectively in Uttar Pradesh.

TABLE 6.5 TIMELINE OF DISCUSSIONS REGARDING INUNDATION PROBLEMS (1985-2022)

Year	Milestone	Outcomes
07/1986	1st meeting of SCIP, Kathmandu	Submergence of 'Gaur Bazaar' discussed. Nepal raises submergence in Banke District due to the Laxmanpur barrage. India asserts that the design of the barrage was done not to submerge Nepali land.
12/1987	2nd SCIP, Kathmandu	India suggests building storage systems in Kamla, Bagmati, Babai, and Kankai to benefit both countries. India assures that 'no bund will be constructed in the future that will submerge parts of Nepal' and suggests that the issue be discussed in the next meeting.
1988	4th SCIP meeting	Nepali delegation says some villages of Bake District would be submerged by Laxmanpur Barrage and its afflux bund. India claims that "the inundation issue is not associated with the Rapti (Laxmanpur) barrage," and requests Nepal to "consider submergence in Nepal as a different problem."
01/ 1991	6th SCIP meeting	Gaur Bazaar inundation discussed. Indian delegation says inundation is caused 'mainly because of spilling from Bagmati and Lalbakaiya rivers', and that can be prevented by constructing embankments along the two rivers.
1991	PM. GP Koirala visit to India.	Agreement on a joint team of experts to expeditiously finalize schemes for flood protection embankments along the Kamala, Bagmati, Lalbakaiya, and Khando rivers. The committee will focus on cost-effective proposals for immediate implementation, starting work in November 1991 with financial assistance from India.
1992	8th SCIP meeting	India provides Nepal with details of the plane table survey of the Laxmanpur barrage area and its high flood level from the year 1980 to 1991. Nepal wants to verify the data and seeks India's cooperation to conduct that survey.
10/1993	Meeting of Prime Ministers of Nepal and India	Action Plan agreed. GoI to provide comments on the detailed proposal prepared by GoN for the construction of the embankment along Lalbakaiya
1994	9th SCIP meeting,	Nepal and India recorded a minute to conduct more studies to specify the cause of the problem' in Lalbakaiya.
02/1996	Ministry of Water Resources officials of Nepal visit New Delhi	Action plan agreed upon between GoN and GoI during the finalization of alignments, land acquisition, and commencement of works on flood Protection Embankments in Lalbakaiya, Bagmati, Kamala, and Khando rivers.
11/ 1996	Indo-Nepal meeting on Joint Water Resources Development	Implementation of Lalbakaiya embankment and preparation for Kamla Bagmati and Khando rivers.
10/1999	10th SCIP Meeting.	Discusses embankment on Danav River and Danda River which had submerged 21 villages of Nepal's Rupandehi District in the 1999 monsoon. Agreed that the 'contact officers should examine the problem and submit a joint report to the respective member secretaries at the earliest possible .
10/2000	1st Meeting (Nepal-India Joint Committee on Water Resources, Kathmandu)	India suggests that embankments be built along the Rapti River to protect Nepali territory in Banke District.
01/2001	11th SCIP meeting	Nepal hands a proposal to India for the construction of an embankment in the Rapti River.
10/2004	2nd meeting of the India-Nepal Joint Committee on Water Resources, New Delhi	Sub Committee on Embankment Construction (Swas CEC) was formed. Design and construction of the embankments on the Lalbakaiya, Bagmati, Kamla, and Khando rivers.
2009	JCIFM 1st Meeting,	Discussions on the issues of the construction of embankments along the Bagmati, Kamala, and Lalbakaiya rivers

2010	JCIFM 2nd Meeting	Additional embankments in Bagmati, Kamala, Lalbakaiya, and more proposed.
05/2010	JCIFM 3rd Meeting	Addition of embankments in Bagmati, Kamala, Lalbakaiya, and proposal for embankments.
01/2011	JCIFM 4th Meeting (Jan 10-14, 2011)	Addition of embankments along Bagmati, Kamala, and Lalbakaiya, with further addition of embankments. Report on Khando river embankment forwarded.
06/2011	JCIFM 5th Meeting	Addition of embankment in Bagmati, Kamala, Lalbakiaya
01/2012	JCIFM 6th Meeting	Embankment along Khando river. Nepal requests to examine DPR Extension of embankment along Bhutahi Balan River and DPR submitted by Nepal. DPR of embankment along Rapti prepared
03/2013	JCIFM 7th Meeting	Field Visit (Kamala, Bagmati, LalbakeyaKhado, Bhutahi, Lakhandehi, and West Rapti) Proposed embankments and flood protection work along Kamala, Bagmati, and Lalbakaiya
02/2014	JCIFM 8th Meeting	Proposal on Jhanji submitted proposes 33 new work packages; 7 packages for Bagmati, 11 packages for Lalbakeya, and 15 Packages for Kamala rivers.
02/2015	JCIFM 9th Meeting	Inspected proposed work. Discussed the completed survey for the embankment of 52 km in the Mechi River
12/2015	JCIFM 10th Meeting	33 new work packages considered along the respective rivers
04/2017	JCIFM 11th Meeting,	The completed amount released for package work on Bagmati, Kamala, and Lalbakaiya rivers
04/2018	JCIFM 12th Meeting	Emergent work carried out on Bagmati, Kamala, and Lalbakaiya rivers
05/2019	JCIFM 13th Meeting,	Nepal reported construction of embankment was completed on Bagmati, Kamala, and Lalbakaiya rivers
03/2022	JCIFM 13th Meeting,	Accepts DPR for Khando, Banganga, and West Rapti rivers prepared by Nepal. Completes site visits to these rivers

Source: Minutes of meeting

related issues began in 1954. In addition, the governments also exchanged many letters. Based on the publicly available minutes of the meetings, this study has estimated that officials of the two governments met about 150 times between 1971 and 2022. The specific subjects of discussion in these meetings were three high dams projects proposed on the snow-fed rivers Koshi, Karnali, and Mahakali (Pancheswar Dam) as well as other hydropower projects like Naumure,

TABLE 6.6 COUNT OF DISCUSSED SUBJECTS (1970-2022)

Subjects	Count
High dams (Koshi, Karnali, and, Pancheswar)	71
Power exchange	17
Other hydro Projects	151
Flood forecasting and inundation	51
Embankments	240
Total	530

Bagmati, and Kankai dams. The subjects also included power exchange, flood problems caused by seasonal rivers, border inundation, and its solutions, and flood forecasting. By identifying these subjects of discussion counting the number of times the same subject was repeated, the study has attempted to present a mosaic of the key subjects of interest. The types of subjects discussed are shown in Figure 6.6 and the number of times they were discussed is shown in Table 6.6. In total, the five subjects mentioned above were discussed 530 times. The building of embankments to control floods in the southern regions of the CB rivers was discussed 240 times, a little less than 50 percent of the time.

A review of the minutes indicates that officials did discuss the problem of inundation. In their meetings, they covered technical issues such as discharge, slope, sluices, sill levels, scour depth, and details regarding gates.

FIGURE 6.6: MATRIX OF SUBJECTS DISCUSSED (1901- 2022)[25]

1901 Mahali Sagar

1910 Sharada Barrage

1920 Sharada Canal

1928 Construction of Chandra Canal

1954 Koshi Project Agreement

1959 Gandak Project Agreement

1964 Revised Gandak Project Agreement

1966 Revised Koshi Project Agreement

1971
- Gandak project: extension of Nepal Western Canal
- Gandak Project: Western Nepal Canal on Gandak Project issue
- Chatara Canal
- Tinau Project
- Gandak Project: Customs levies
- Koshi Project: Power tariff
- Gandak Project: Surajpura Power House
- Power Exchange
- Trisuli HEP

1975
- Flood Problems
- To study the problems of floods comprehensively
- Coordination to avoid
- Chandra Canal extension
- Werstern Koshi Canal
- Eastern canal Gandak Project

1976
- Gandak project: Surajpura Power House
- Bhalubhang Project
- Devighat HEP
- Power Exchange

1978
07 April
- HMG & GoI
- Renovation and extension of Chandra Canal
- Construction of a pumped canal and distribution system of the Western Koshi Canal

12 April
- HMG & GoI

1979
- Delegates of India and Nepal by Secretary Level Meeting Level
- Chatra Canal operation
- Kothar Project
- Kankai Project
- Kankai Dam
- Mulghat HEP

1980
23 Aug.
- Karnali Dam
- Pancheshwar Dam
- Bhalubhang Project
- Sikta Project
- Chandra Canal
- Bagmati Project
- Kamala Project
- Kankai Project
- Banganga Irrigation
- Power Exchange

06 Oct.

1982
12 Feb.
- Bhalubhang Project
- Bagmati Project
- Kamala Project
- Kankai Project
- Banganga Irrigation
- Lohindra river
- Singali river
- Banganga Irrigation Issue
- Specific problems at Indo-Nepal Boarder
- Flood Forcasting System
- Power Exchange

1983
24 April
- Bhalubhang Project
- Kamala Project
- Babai Project
- Kankai Project
- Mechi Project
- Bagmati Project (Bargania, Gaur Town)
- Lohindra river
- Singhali river
- Banganga Irrigation
- Lalbakaaiya River
- Manusmara River
- Specific problems at Indo-Nepal Border
- Power Exchange
- Flood Forcasting System

1984
23-24 Feb.
- HMG/N &GoI
- Bhalubhang Project

22 April
- Bhalubhang Project

20 Sept.
- Bhalubhang Project
- Bagmati Project
- Kamala Project
- Babai Project
- Kankai Project
- Power Exchange

1986
31 Oct.
- Chissapani
- Kaligandaki
- Trishulganga
- Seti
- Saptakoshi
- Surkhet
- Thapna
- Kamala

1987
22 Dec.
- Chandra Canal
- Flood forcasting and Warning System
- Problem Duty Construction
- Power Exchange
- Kamala Project
- Bagmati Project
- Kankai Project

1988
02 June
- Chandra Canal
- Kamala Project
- Bagmati Project
- Kankai Project
- Power Exchange
- Flood forcasting and Warning System
- Inundation Committee
- Lalbakaiya River
- Khado river

27 Dec.
- Chandra Canal
- Bhalubhang Project
- Power Exchange
- Flood forcasting and Warning System
- Inundation Problems along the border
- Soil conservation and watershed management
- Inland Navigation

LEGENDS
- Secretary Level Meeting
- Koshi Project
- Gandak Project
- Koshi Dam
- Karnali Dam
- Pancheshwar Dam

contd..

1990

23 Jan.
Press note
- Chandra Canal
- Trishuli Project
- Chatara Canal
- Devighat hydro-electric power project

26 May
Office Level
- Koshi Project
- Kamala Project
- Bagmati Project
- Kankai Project
- Mechi Project
- Lalbakaiya River

1991

14 Feb.
Prime Minister
- Karnali Project

27 Feb.
His Majesty's
- Chatra Canal

17 March
JGE

18 April
- Power Exchange
- Bhalubhang Project
- Kamala Project
- Bagmati Project
- Kankai Project
- Babai Project
- Lalbakaiya River
- Khado river
- Inland Navigation
- Soil conservation and watershed management
- Flood forcasting and Warning System

14 Dec.
India-Nepal Joint Team of embankments
- Khando river
- Bagmati river
- Lalbakeya river
- Kamala river

29 Dec.
Prime Minister
- Karnali Dam
- Pancheswar Dam
- Koshi Project
- Koshi Dam
- Burhi Gandaki Project
- Kamala Project
- Bagmati Project
- Flood forcasting and Warning System
- Power Exchange
- Flood Protection Embankment

1992

31 Jan.
India-Nepal Joint Team of embankments
- Khando river
- Bagmati river
- Lalbakeya river
- Kamala river

03 Feb.
JGE

14 Feb.
JGE

29 Feb.
JGE
- Burhi Gandaki Project
- Kamala Project
- Bagmati Project
- Lalbakaiya River
- Khado River

19 Aug.
India-Nepal Joint Team of embankments
- Khando river
- Bagmati river
- Lalbakeya river
- Kamala river

02-03 Sept.
India-Nepal Joint Team of embankments & JGE
- Khando river
- Bagmati river
- Lalbakeya river
- Kamala river

1993

21 Jan.
JGE

26 Feb.
India-Nepal Joint Team of embankments
- Lalbakeya river

24 Dec.
Official level

28 Dec.
Prime Minister
- Burhi Gandaki Project
- Karnali Project
- Flood Protection Embankment
- Flood forcasting and Warning System
- Power Exchange
- Kamala Project
- Bagmati Project

30 Dec.
Statement of the Indian Minister
- Karnali Project
- Flood Protection Embankment
- Flood forcasting and Warning System

1994

25 Jan.
Official level
- Karnali Project
- Seti Project

23 Feb.
Standing Committee on Inundation Problems
- Khando river
- Bagmati river
- Lalbakeya river
- Kamala river
- Siswa Sagar
- Bajha Sagar
- Marthi Sagar
- Maholi Sagar
- Rapti river
- Karaulia
- Haradauna
- Saighorahawa Sumari
- Itawa
- Sunsari River

03 April
Letter of the Nepalese State Minister
- Flood forcasting and Warning System
- Power Exchange
- Gandak Project

1996

12 Feb.
His Majesty's

15 Feb.
- Burhi Gandaki Project
- Kamala Project
- Bagmati Project
- Flood forcasting and Warning System
- Flood Protection Embankment

14 May
India-Nepal Joint Team of embankments
- Khando river
- Bagmati river
- Lalbakeya river
- Kamala river

19-20 Nov.
- Karnali Project
- Burhi Gandki Project
- Kamala Project
- Bagmati Project

1997

07 Jan.
Joint Team of Experts
- Kamala river

15 Jan.

14 Sept.
JGE

1998

23 Jan.

contd..

1999

12 Feb.
India-Nepal Joint Team of embankments
Khando river
Bagmati river
Lalbakaiya river
Kamala river

12 Feb.
JGE

26 April
Technical level

05 Aug.
JGE

12 Feb.
SCIP
Gaur Bazar
Hathiyol, Balara and Madhubani
Phulbari Village
Musharniya and Mukhiyapatti villages
Lagadi Village
Govindpur & Lalpatti Villages
Jogbura Area
Mahali Sagar
Marthi Sagar
Bajha Sagar
Nepalgunj Area
Ugurdi Village
Rajaput Area

12 Feb.
JOP

2000

16 Feb.
JGE

12 June
Technical level

28 July
Press release
Rapti river

03 Oct.
JCWR
Kamala Project
Bagmati Project
Power Exchange
Flood Control and Flood Forecasting System
Inundation Problems
Inundation in border

16 Feb.
JGE

2001

12 Jan.
SCEC
Lalbakaiya river
Bagmati River
Khando River
Kamala River

SCIP
Gaur Bazaar
Hathiyol, Balara and Madhubani
Phulbari Village
Musharniya and Mukhiyapatti villages
Lagadi Village
Govindpur & Lalpatti Villages
Jogbura Area
Mahali Sagar
Marthi Sagar
Bajha Sagar
Nepalgunj Area
Ugurdi Village
Rajaput Area

08 Feb.
Press release
Sarda Barrage

21 Feb.
Technical Level
West Rapti Project
Burhi Gandaki Project

20 March
Technical Level
Sun Koshi Diversion Project

23 March
JGE
Sun Kosi Diversion Project

15 April
India-Nepal Sub-Commitee of embankments
Khando river
Bagmati River
Kamala River

27 April
India-Nepal Committee on Flood Forecasting System
Flood Forcasting System

23 Aug.
JGE

13 Oct.
JGE
Sun Kosi Diversion Project

23 Nov.
JGE

23 Nov.
JCKGP

LEGENDS

- Secretary Level Meeting
- Koshi Project
- Gandak Project
- Koshi Dam
- Karnali Dam
- Pancheshwar Dam

JCIFM	Joint committee on Inundation and Flood Management
JPO	Joint Project Office
SCIP	Standing Committee on Inundation Problems
JCWR	Joint Committee on Water Resources
SCEC	Sub-Committee on Embankments Construction
JCKGP	Joint Committee on the Koshi and Gandak Projects
HLTC	High Level Nepal-India Technical Committee
JGE	Joint Group of Experts

JCIFM: Lalbakaiya River, Bagmati River, Kamala River, Khando River, Flood Inundation

- Flood Forecasting System
- Kalkalwa Bund
- Mahali sagar
- Bairgangiya ring Bund
- Rasiyawal-Khurd-Laton Bund
- Rato river
- West Rapti River
- Lakhandehi river
- Bhutahi Balan river

2022
09-13 Mar.

2019
27-31 May

2018
16-20 Apr.

2017
16-21 Apr.
Mohana River

2002

04 March
- SCIP
- Gaur Bazar
- Hathiyol, Balara and Madhubani
- Phulbari Village
- Musharniya and Mukhiyapatti villages
- Lagadi Village
- Govindpur & Lalpatti Villages
- Jogbura Area
- Maholi Sagar
- Marthi Sagar
- Bajha Sagar
- Nepalgunj Area
- Ugurdi Village
- Rajaput Area

05 March
- India-Nepal Sub-Commitee of embankments
- Khando River
- Bagmati River
- Lalbakeya River
- Kamala River

08 May
- India-Nepal Committee on Flood Forcasting System
- Flood Forcasting System

15 May
- JGE

08 Oct.
- SCIP & India-Nepal Sub-Commitee of embankments
- Gaur Bazar
- Hathiyol, Balara and Madhubani
- Phulbari Village Musharniya and Mukhiyapatti villages
- Lagadi Village
- Govindpur & Lalpatti Villages
- Jogbura Area
- Maholi Sagar
- Marthi Sagar
- Bajha Sagar
- Nepalgunj Area
- Ugurdi Village
- Rajaput Area
- Khando river
- Bagmati river
- Lalbakeya river
- Kamala river

2003

18 March
- Press release
- Mahalisagar

05 April
- India-Nepal Committee on Flood Forcasting System
- Flood Forcasting System

11 May
- India-Nepal Sub-Commitee of embankments
- Khando river
- Bagmati River
- Lalbakeya River
- Kamala River

27 June
- JGE
- Sun Koshi Diversion Project

30 Oct.
- Burhi Gandaki Project

30 Nov.
- India-Nepal Sub-Commitee of Embankments
- Khando river
- Bagmati River
- Lalbakeya River
- Kamala River

2004

15 March
- Mahalisagar

17 June
- India-Nepal Sub-Commitee of Embankments
- Khando river
- Bagmati River
- Lalbakeya River
- Kamala River

06-08 Oct.
- JGE & JCWR
- Power Exchange
- Sun Koshi Diversion
- Kamal Project
- Bagmati Project
- Karnali Project

2009

30 June - 05 July

2010

07-12 Jan.
Laxamanpur Barrage

14-19 May
Laxamanpur Barrage

2011

10-14 Jan.
Geruwa river

18-23 June

2012

16-21 Jan.
Geruwa river

2013

19-24 Mar.

2014

04-08 Feb.

2015

04-08 Feb.
Jeet river

06-10 Dec.
Jeet river

Sources Nepal-India Minutes

The participants in these meetings were civil engineers, most male, working in the irrigation and flood control agencies of Nepal and India[26]. Since the 1970s, the measures suggested for addressing flood problems have been structural, that is, they have homed in on embankments. This preference seems to dominate even today even though today's stakeholders also refer to drainage, gates, and openings, which are artifacts for improving floodwater evacuation and minimizing submergence. In all cases, India was to provide funding for the building of the embankments.

6.11 DEVELOPMENT OF FLOOD WARNING SYSTEM

The focus of South Asian countries on structural flood management meant that little attention was accorded to non-structural flood risk management strategies, including early flood warning mechanisms. In the aftermath of 1954 flood in Bihar flood early warning system was mentioned in Bihar State Assembly[27]. The earliest early flood warning initiative in the Yamuna River in 1958 aimed to establish "a unit in the Central Water Commission (CWC), New Delhi, for the flood forecasting of the river Yamuna at Delhi."[28] This initiative also included the Ganga River and its tributaries, including cooperation extended by Nepal to "set up a network of hydro-meteorological stations to collect data in rivers originating in the country."

In September 1975, during a bilateral meeting on water resources between the secretaries of Nepal and India, flood management was implicitly discussed. The minutes stated the intent: "a study [on floods] had to cover the catchment areas. The groups or committees set up earlier focused on certain engineering aspects and relief and rescue operations. What was required was a more detailed study of the problem keeping in view the needs on both sides of the border." The minutes, however, do not mention whether or not the secretaries specifically discussed further actions on flood forecasting. Two years later, in July 1977, during the visit of Minister of External Affairs of India Mr. Atal B. Vajpayee to Nepal, the issue of flood forecasting emerged. During that visit, Mr. Vajpayee met with Nepal's Minister of Water Resources, Mr. D.P. Adhikari, at the Ministry of Foreign Affairs in Kathmandu[29] and inquired about the status of the hydro-meteorological stations to be installed in central and eastern Nepal for flood forecasting. India was to provide field technicians and wireless communication technology support for developing the forecasting system that would benefit the downstream region of India.

Five years later, on February 12, 1982, flood forecasting was again discussed. The minutes of this meeting mention an earlier draft proposal for a flood forecasting scheme that was forwarded to the GoN (then HMG) of Nepal[30]. At the same time, Nepal enacted the Natural Calamity Relief Act that included provisions for responses and relief to disaster-affected families, including those impacted by floods. In its conception, however, the 19982 Act did not include either preparedness or reconstruction, which came much later in 2017, when the new Disaster Risk Reduction and Management Act was promulgated. Moreover, the nature of the emerging national policy on disaster risk reduction including floods, and the bilateral discussions on these challenges held were two very different worlds.

Flood forecasting was again discussed in April 1983, 1987[31], and June 1988 meetings[32]. The next meeting on December 27, 1988,[33] was more specific. It's minutes mention establishing rainfall and flood-level monitoring stations as follows:

appraisal of 15 hydro met sites for flood forecasting in eastern Nepal for planning the appropriate telecom instruments… India's commitment to supply hydrological and telecommunication equipment for warning systems and also to provide training facilities for Nepalese technicians and professionals and that .. the telecommunication system between base stations of Nepal and India be operated within the frequencies from 2 to 7 Mhz and sought confirmation for formal agreement."

6.12 FLOOD WARNING : POST-1990 PERIOD

In 1990 Nepal ended the party-less panchayat polity and adopted a multiparty democracy with a more open and liberal political space and promulgated a new constitution. In 1991, the country's newly elected Prime Minister Girija Prasad Koirala visited India. During the visit, Prime Minister Koirala and Indian Prime Minister Narasimha Rao signed a Memorandum of Understanding (MoU) on the Tanakpur barrage project on the lower Mahakali River. In a significant change in the level of transparency compared to the pre-1990 period, bilateral agreements signed by the government gradually became open for public scrutiny. Opposition parties in Nepal began questioning the provisions of the MoU, particularly those regarding the allocation of the benefits from a project developed on a boundary river[34].

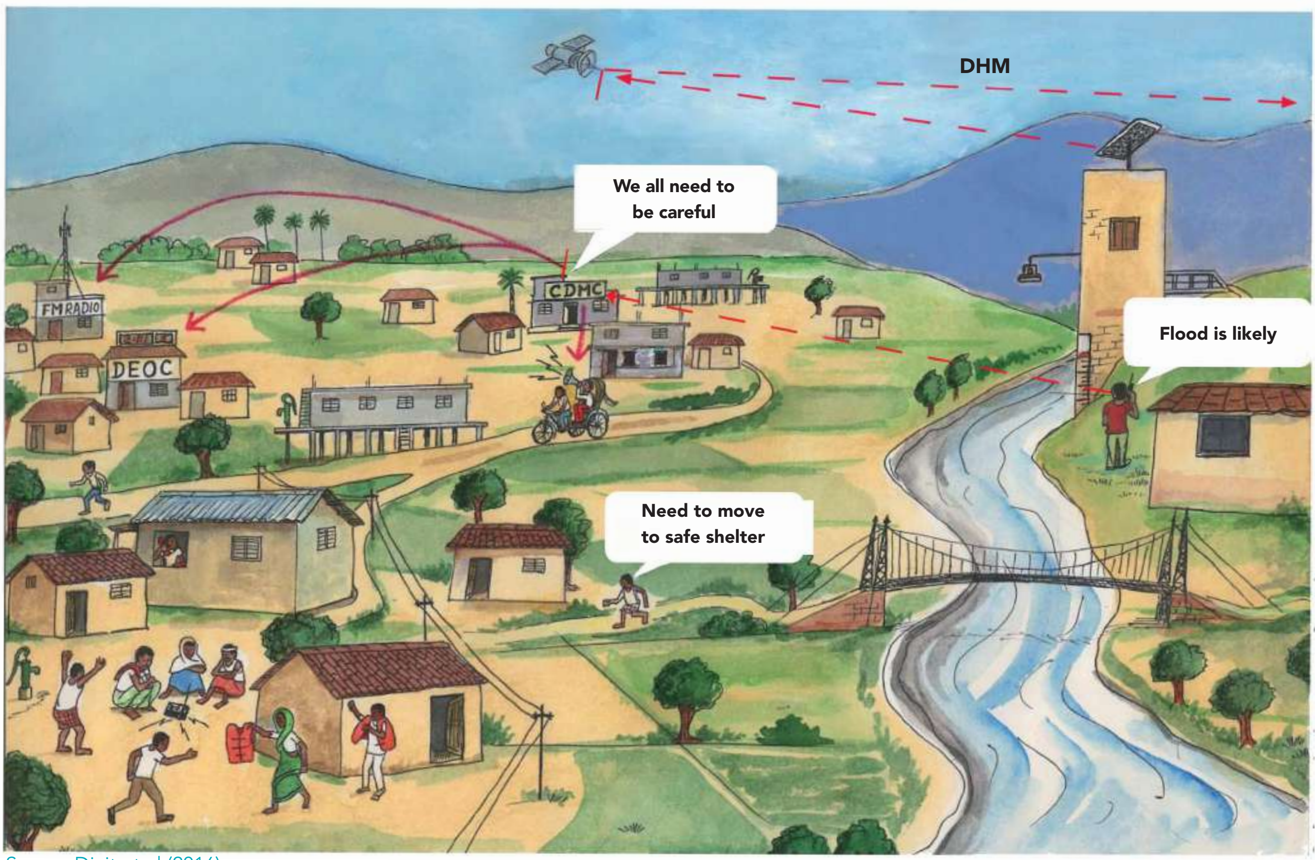
The MoU included a clause on flood forecasting: it said[35] that "every effort needed to make the scheme fully operational from the monsoon season of 1992 will be made. Necessary arrangements will be made for continuous and effective functioning of the system, enabling improved monitoring of the flood situation continuously." The government agencies of the two countries followed up on this decision at the highest political level and in 1995, as agreed in the 1991 MoU, data were dispatched from seven hydro-metric and 16 rainfall stations and, efforts were also made to transmit data from another 45 stations[36]. Agencies of Nepal and India interacted on flood forecasting till the mid-1990s. Subsequently, governmental discussions remained fluid, and, increasingly, non-governmental actors got involved in the arena of early warning systems for floods.

In this period of transition, with support from India, nine hydrology stations were established, one each in Karnali (Chisapani), Babai (Chepang), West Rapti (Kusum), Narayani (Devghat), Bagmati (Sarlahi), Kamalam (Ranibas), Koshi (Chatara), Budhi Gandak (Sunsari), and Kankai (Domukha) and a master control room was established at Sindhulimadi. Through successive meetings, mentioned in the following paragraphs, the stations were equipped, and a mechanism was set up to ensure that information about the flood levels of these stations would come to the master control room in Sindhuli every day. The data would then be relayed to Patna. Some of these stations are still operational. The information did not benefit Nepal, however, since it had no flood response mechanism used this information. As Nepal was able to collect water-level data at the river stations selected and using the new equipment, the understanding of flood hazards generally in the country and particularly in the CBs began to gradually improve.

In a limited way, subsequent bilateral discussions Nepal and India had on flood management did touch upon the notion of preparedness through developing flood forecasting arrangements. However, they only discussed collecting river stage data and sharing that information with the centralized agency with responsibility for flood control and barely touched upon the various elements of the early flood warning and risk reduction mechanism. For example, as we mentioned above, of the 530 subjects discussed in the Nepal-India bilateral meetings from 1971 to 2022, 7 percent were related to flood forecasting. These discussions recognized the need to first operationalize a flood information-sharing arrangement between the state agencies of the two countries. Investment in the establishment of stations, daily river-level measurement, and sharing with India are indications of this recognition of the importance of flood preparedness. But, as mentioned above little effort went into contextualizing the information at the local level.

In fact, neither the localization of information figure in these discussions at all, nor the information on floods shared by the state agencies did reach the communities on the front line of flood risks in the downstream region and thereby was unable to not save lives or assets. The Nepali side seemed somewhat unsure of how to use the information in the downstream region, even though collecting such data and sharing it with the downstream stakeholders was desirable from the humanitarian perspective. At the same time, in these early discussions, it appears that establishing flood early warning mechanisms in Nepal's CBs was not deemed important. The region did face floods historically; these began to be documented better in the 1950s. In Nepal, the role of flood early warning mechanisms as a flood risk reduction strategy began

FIGURE 6.7: A SCHEMATIC OF FLOOD WARNING SYSTEM



Source Dixit et al (2016)

in the mid-1990s and would take more tangible form in the early 2000s.

6.13 FLOOD WARNING AND THE IDNDR INITIATIVE

The 1990s saw a new global beginning in the landscape of Disaster Risk Reduction (DRR). With the UN declaring the decade of 1990-2000 as International Decade for Natural Disaster Reduction (IDNDR), a concerted action had begun to minimize the loss of life, damage to property, and social and economic disruption caused by disasters, especially in developing countries. One of the objectives of IDNDR was "to improve the capacity of each country to mitigate the effects of natural disasters, in the assessment of disaster damage potential and the establishment of early warning systems and disaster-resistant capabilities:" DPTC that the Japanese government helped establish in 1991 was in line with this global initiative[37]. The DPTC aimed to build the capacity of the government to cope with landslides, debris flows, soil erosion, and flooding by developing technology suitable for the country and training personnel working in these fields[38].

The 1994 World Conference on Natural Disaster Reduction in Yokohama was an important milestone in furthering DRR objectives. Nepal adopted the Yokohama Plan of Action in 1996 and prepared the first-ever 10-year national plan for disaster management [39].

In July 1993, three years after IDNDR and two years after the DPTC were established, a widespread cloudburst triggered floods in the Bagmati and the Trishuli rivers and their tributaries, causing major devastation in central Nepal. Altogether 1,460 people died or were reported missing, altogether 73,606 families were seriously affected, 39,043 houses were completely or partially destroyed, and about 43,330 hectares of cultivated land were washed away or covered with debris[40]. Landslides and floods damaged many large and small bridges and destroyed 38 small and large irrigation schemes, 452 school buildings, and dozens of health posts and government offices.

The cloudburst-triggered flood severely damaged the Kulekhani hydropower plant and the Bagmati barrage. At the barrage, equipment, the gate control system, sections of the main canal, and the housing colony for staff were damaged. Both the 60-MW Kulekhani I and the 32-MW Kulekhani II were shut down, a measure that removed almost half of the total installed electricity capacity of the Integrated Nepal Power System and resulted in three months of load-shedding. The cloudburst-triggered erosion in the Kulekhani watershed deposited 4.8 million m^3 of sediment in the reservoir. The floods damaged important roads as well as six concrete bridges on the national highways to the capital, thereby disrupting the supply chain for more than a month.

A year later, in 1994, Intermediate Technology Development Group (ITDG), a charity registered in the UK and working in South Asian countries, convened a meeting of activists and NGO representatives from Bangladesh, Nepal, Pakistan, Sri Lanka, Pakistan and the Bangkok-based Asian Disaster Preparedness Center (ADPC)[41] in Colombo. The meeting agreed to establish Duryog Nivaran, a network that would advocate alternative disaster management philosophy in place of conventional wisdom. The network suggested that a disaster is an "unfinished business of development" and that preparedness is very important to risk reduction because "disasters are part of the normal process of development and should be viewed as opportunities for social transformation and that…

disasters are opportunities to encourage 'good' forms of development rather than continued mal-development"[42]. The network began to support research, training, and advocacy in DRR[43]. It worked at the policy and community levels and supported cross-border dialogue and experience-sharing among organizations in South Asia.

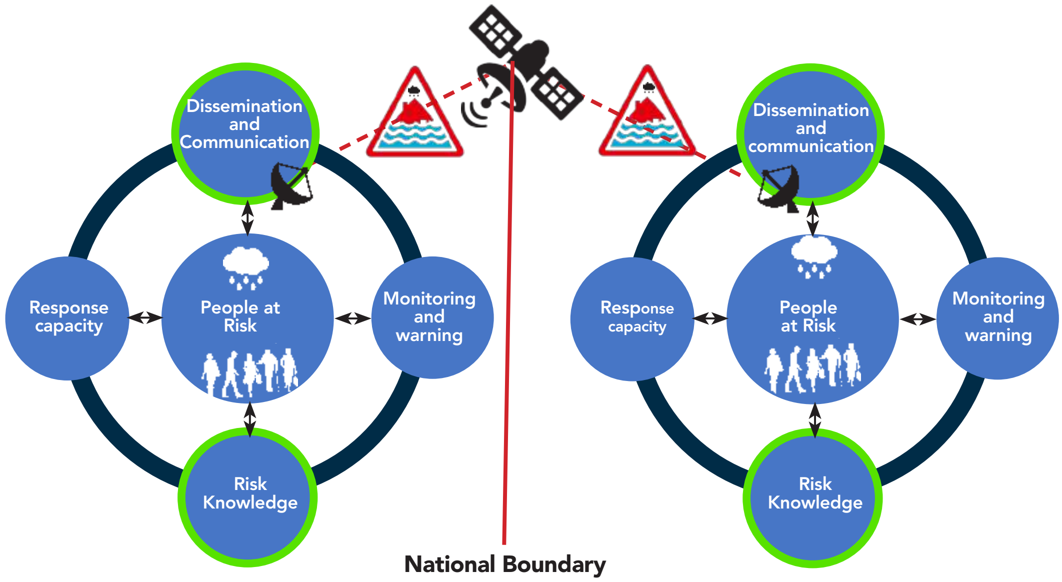
6.14 COMMUNITY BASED FLOOD WARNING SYSTEM: THE BEGINNING

With the political and administrative changes introduced to Nepal in the 1990s, international non-governmental organizations (INGOs) such as ITDG, OXFAM, CARE, and Action Aid began incorporating themes of disaster management, such as vulnerability reduction, into their work[44]. OXFAM was also involved in collaborative flood DRR activities in the Nepal Tarai as well as Uttar Pradesh and Bihar. One initial study in which local NGOs and researchers from Nepal and Uttar Pradesh collaborated involved the transboundary Rohini River, which flows from present-day western Nawalparasi District in Nepal to Maharajgunj in Uttar Pradesh. In early 1998 researchers from Nepal and India, together with NGO representatives, completed a week-long foot march along the Rohini River interacting with flood-affected communities along the banks of the river and its tributaries in Uttar Pradesh and Nawlaparasi, Nepal. This endeavor brought to the fore the limitations of the data on rainfall in the river's catchment and river flows. Later, before the onset of the monsoon rains, the members of the study team installed seven low-cost rain gauges in the upper and lower regions of the Rohini catchment. Earlier, in 1997, low-cost rain gauges had been installed in selected public schools in Kathmandu as a pilot effort to collect rainfall data, make it available to FM stations, and broadcast it as an effort at democratizing practice of science through citizens' participation.

In the upper Rohini basin, too, a similar arrangement was made to transfer the collected rainfall data to local FM stations to be broadcast so that it could inform listeners of a potential flood reaching the downstream region. It was assumed that the communities would listen to such messages and, with the lead time thus made available, be able to escape to safety from the flood[45]. Incidentally, after the stations were installed, in the 1998 monsoon, the Rohini region faced one of the highest rainfalls it had ever had, bringing major floods to Nepal's eastern Nawalparasi, Rupandehi, and Kapilbastu districts and eastern Uttar Pradesh[46]. The experiment of installing rain gauges, however, did not move forward due to a lack of resources to continue the operation of the stations and the inability to build a data management (collection, transmission, broadcast, and reception) ecosystem.

Regardless, the idea of having locally contextualized flood early warning systems (EWS) began to get traction in Nepal. In some parts of the country that had been hit by flood disasters, communities sought respite from floods through early flood warning information. The communities along the East Rapti River in Chitwan District participated in piloting an early warning system in 2002 with support from Practical Action[47]. The East Rapti River faces frequent floods in the monsoon and the 1993 floods seriously affected the communities along its lower bank[48]. This EWS initially used **machan**, elevated platforms built to observe and fend off rhinos, deer, and wild boars from Chitwan National Park crossing the East Rapti River and damaging agricultural fields in the villages of Piple, Bhandara, and Jagatpur, to observe river levels. During the flood season,

FIGURE 6.8: TRANSBOUNDARY FLOOD WARNING MECHANISM



Source Dawadi (2022)

from the machan, a person would watch the river water stages and, when necessary, inform downstream communities of an incoming potential flood and suggest that they move to safer locations[49].

Over the next ten years, community-based early warning systems (CBEWSs) were established in Nepal's Karnali, West Rapti, Babai, East Rapti, Narayani, Bagmati, Kamala, Koshi and Kankai and Koshi river basins. These helped the communities in the CBs region use local resources and capacities to prepare for and respond to flood events[50]. With support from various bilateral donors, organizations such as the International Centre for Mountain Development (ICIMOD) and Mercy Corp were also involved in developing CBEWSs. In 2019 the Asian Development Bank (ADB) began providing support to develop flood warning systems in the six CB basins mentioned in Table 6.6.

Today, some of Nepal's CB basins receive flood warning messages from systems involving DHM, the Ministry of Home Affairs (MOHA), the National Disaster Risk Reduction and Management Authority (NDRRMA), Nepal Telecom Corporation (the national telephone service provider), NCELL, private-sector entity, and local community groups. The DHM sends weather alerts and warning messages via SMSs, to social media platforms and to a flood warning app targeting the users in the communities likely to be affected by an impending flood. The NDRMMA and many other agencies also relay those messages. These arrangements have helped save lives, decrease the amount of damage, and made response and relief part of[51] social and development activities rather than the domain of engineers and technicians[52]. On the ground, however, many challenges exist. Despite early weather and flood warnings, people continue to stay in their homes guarding their properties and assets against what they perceive to be anti-social elements who might steal them if they leave. This behavior, though understandable, can lead to the loss of human lives and needs deeper analysis to improve the effectiveness of responses. The provision

Three aspects of localization of flood warning information: Digital indication and voice amplification through loudspeaker and volunteers.
Source: Narayan Gyawali, Lutheran World Relief

of simultaneous effective social support mechanisms to the likely victims of the flood is key.

These challenges became very clear in October 2021 in Nepal. A year earlier, in the aftermath of the Amphan cyclone, farmers in Bangladesh had faced seen their ready-to-be-harvested paddy devastated. Learning across political boundaries is limited even though climate change is resulting in such impacts across many countries. The 2021 October rainfall is a case in point. On 11 October Nepal's DHM officially declared that the SAM had ended, about 18 days later than usual. Four days after this announcement, on October 15, the DHM reported that a weather system had again become active in Far-Western Nepal. The agency issued alerts that heavy rains were likely in different parts of the country. Indeed, heavy rains did hit India's Uttarakhand and, after entering Nepal on October 17, the rains reached eastern Nepal and Sikkim two days later.

The heavy rains, floods, inundations, and landslides that ensued resulted in human casualties, injuries, widespread damage to property, disruption of services, and negative effects on the livelihoods of the people in the country. Roads, bridges, and electricity and telecommunication lines were damaged. The rainfall and flooding damaged standing and ready-to-be-harvested paddy across the country. Paddy worth NPR 11.87 billion was reported to have been damaged[53]. A recent assessment of the damage by NDRMMA in Nepal's Karnali Province put this damage at NPR 6,279 million[54]. The farmers, however, had no external support to adapt or save their crops [55]. The same extreme event also had an impact on western Uttar Pradesh and Bihar but no details are available.

In Nepal, CBEWSs have saved lives. The scaling up of CBEWSs remains a challenge at both the in-country and transboundary levels. A functional CBEWS is key to reducing risk and must be supported by actions aimed at minimizing flood damage to assets and improving the well-being of households at the social and economic margins. Much more needs to be done to support those households at the social and economic margins, minimize damage to their assets, and improve their well-being.

Raised latrines, boat for rescue and handpump on elevated platforms as local flood risk reduction efforts.
Sources: RSDC and Narayan Gyawali, Lutheran World Relief

6.15 EFFORTS ON FLOOD VULNERABILITY REDUCTION

As mentioned above, in the post-1990 era, with support from INGOs, NGOs also began working to create alternate livelihoods and build capacity to help reduce the vulnerability of flood-affected communities. They provided support in lowering vulnerability and building community resilience. These non-governmental entities remain important actors in innovating and piloting flood risk-reduction management measures in partnership with local communities. The following section provides examples purposively selected from Nepal's CBs, Uttar Pradesh, and Bihar to highlight the nature of their work. They demonstrate both opportunities for and challenges to scaling up resilience-building actions across boundaries.

6.15.1 Cross-border coordinated actions

Rural Self-Reliance Development Centre (RSDC)[56] in Nepal and Sahbhagi Sikshan Kendra (SSK)[57] in Uttar Pradesh worked with vulnerable communities on flood mitigation, preparedness, and responses from 2013 to 2019. Supported by Malteser International, each worked in the Karnali and Koshi river basins, RSDC in Neapl, and SSK in India. In Nepal, the program covered three-flood prone local administrative units (rural and urban municipalities) of Bardiya District along the Karnali River and five gaupalika of Sunsari District along the Koshi River. In Uttar Pradesh, the program covered vulnerable local administrative units in Bahraich and Barabanki districts along the Karnali (Ghagara) River. In Bihar, the program was

Local level nature based flood risk reduction and livelihood support
Source: Narayan Gyawali, Lutheran World Relief

implemented in the three most vulnerable gram panchayats of Mahishi block, Saharsa District, in the Koshi Basin.

The program involved enhancing community preparedness, and better response and developing a suite of community-owned and managed approaches to reduce vulnerability and minimize flood risks. The approach the support organizations took to build the capacity of communities, particularly the women in those communities, was to strengthen the hygiene practices and management of safe drinking water central to adapting to flood disasters while minimizing secondary risks like water-borne diseases. Both organizations provided equipment for evacuation and rescue, constructed a raised platform for a safe evacuation, established rescue shelters, and built capacity. They supported the communities in developing local disaster response capabilities with clear responsibilities and provided first aid kits and basic equipment, including rescue boats. Other support included the construction of raised platforms for tube wells and toilets built above flood levels as well as the installation of rainwater harvesting tanks.

Community members on both sides of the border engaged in exchange visits during which they shared their learning regarding risk reduction strategies. Though they live in areas that have similar ecological and social characteristics, the specifics of their conditions vary. Both organizations, in partnership with the Red Cross, provided capacity-building support on practical aspects of rescue, first aid, and crowd management during floods. By engaging the district administration, local governing institutions, and communities, early warning messages were provided as last-mile efforts to help mainstream disaster response into regular local governance.

6.15.2 Gorakhpur Environment Action Group :

This group works with small-scale flood-affected farmers in Maharajgunj, Uttar Pradesh. It helps farming families pursue innovative agricultural practices that are only minimally harmed by flooding, such as bamboo cultivation. The group also supports poverty alleviation, income generation, skill enhancement, girl-child education, and the conservation of local environments.

6.15.3 Community Development and Advocacy Forum Nepal[58] :
This group Bardibas, Mahottari, which was established in 2006, works to conserve the watersheds of Ratu, a CB river flowing through Nepal's Sindhuli, Mahottari, Dhanusha and Siraha districts and into Bihar. The organization focuses on climate change adaptation, mitigation, disaster risk reduction, and livelihood enhancement. Its work involves introducing new water management techniques through physical and social interventions. Some of these programs involve building flood resilience through the cultivation of river banks and bank protection using biological measures.

6.15.4 Megh Payeen Abhiyan:
A public charitable trust, MPA works on issues of water distress in eastern India. Its focus is on the processes, technologies, and participatory management mechanisms that can provide safe drinking water, sanitation, and hygienic services. It works to build the resilience and adaptability of local rural communities, particularly in regions prone to natural hazard impacts.

6.15.5 Civil society members meet on Bagmati River:
In August 2019, civil society members across the border of Nepal and Bihar discussed challenges related to the Bagmati River. After the dialogue, the representatives issued a 19-point resolution that called for better interactions among stakeholders across the border and for improving scientific understanding of flood. They also called for a better appreciation of changing social and climate dynamics and focusing on the needs of the communities in each country across the border[59].

6.15.6 Civil society dialogue on GBM's biodiversity conservation:
Another initiative involves having civil society groups from India, Nepal, Bhutan, and Bangladesh dialogue about the conservation of freshwater biodiversity in the Ganga-Brahamaputra-Meghna (GBM) basins. The vision of the network is to connect the people of the GBM basins to steward the freshwater ecosystem. It aims to create an enabling environment for enhanced cooperation for the conservation, long-term economic development, livelihood security, and sustainable management of the rivers of GBM[60].

NOTES

1. Carson (1986) highlighting the importance landslides as point source of sediment to rivers.
2. See Roy (2012)
3. In Nepal sal tree dominant forests are also found in doon valleys and the lower belts of mid-mountian regions along major rivers up to about 1200 metre above sea level.
4. See Amrith (2018)
5. For historical account of floods in Odissa see D'Souza (2006)
6. It is suggested that the Koshi River used to swing like a pendulum along the east-west direction though this behavior of the river before 1734 is an element of speculation because scientific evidence is not available. Satellite image and other drawings show old channels spread on the fan since that date.
7. See Ray (1953).
8. See Mishra (2003)
9. In a converstaion with the lead researcher on 12th March 2023 Dr Dinesh Kumar Mishra shared excerpts of his book on Bagmati River in Bihar. Locally food water reaching doors was called 'Boah', a flood coming with an interval of 25 years and reaching the window or submerging cattle half would be called 'Humma', flood coming once or twice in one's lifetime would be 'saha' and next lager one would be 'pralaya". In the modern scheme of things these knowledge system did no find any space.
10. This history, available elsewhere, is relevant to this analysis of inundation challenges in CBs as the region undergoes changes, including those related to the extreme rainfall spawned by climate change.
11. It is suggested that the 1934 CE Nepal-Bihar earthquake exacerbated the magnitude of floods by loosening the affected land surface, making it more prone to sediment erosion than usual. The Burhi Gandak River flowing from the southern watershed of Nepal's Parsa District and north Bihar witnessed many severe floods in the 1950s (Ministry of Water Resources, 2015). A number of other studies also mention flood events and resulting disaster that, affected the region encompassing lower central Tarai of Nepal and north Bihar easten in 1785, 1833, 1871, 1902, 1926 and 1935 and that the 1934, Bihar-Nepal earthquake's shaking of the landscape may have changed the course of the Bagmati River (Adhikari, 2013) and the high rainfall in the region in 1951, 1952, 1953 and 1954 may have influenced flood responses of some of the CB rivers. The occurrences and impacts of these events need further validation, ground-truthing, and triangulation to systematically reconstruct their historicity so that it can be used to improve understanding of flood hazards in the CBs
12. See Sinha and Jain (1998)
13. The knowledge base that evolved under colonial rule also guided building of embankments as major development enterprise in West Pakistan and East Pakistan (today's Bangladesh)..
14. See Singh et al (n.d.).
15. Flood disaster affects those in the margins and relief materials (finance, materials like food, bedding, dishes, etc.) provide initial respite, but they also reproduce vulnerabilities. Following this flood, Rautahat District released Rs 20,000 for immediate distribution as relief and distributing relief continues to be a dominant policy response (Ghimire, 2014).
16. Rai et al (2017) mention of three exchanges between Nepal and the British government in India before 1900. In 1874 an agreement was made to maintain water levels of three reservoirs located on the international border. Twenty-three years later in 1897 it was agreed that existing levels in the three reservoirs as 1874 agreement will be maintained. A year later in 1898 an letter mentioned he issue of three reservoirs as a boundary dispute and maintenance of water levels in the reservoirs. Also see Dhungel and Pun (2009) for details. Many decades later, in 1998, the gated regulator was damaged and two years later on September 4, 2000, the contact officers of India and Nepal decided to construct a new gated escape regulator using the same crest at the same level prior to the damage. This issue continues to remain contentious.
17. There have been many proposals to retrofit the plants but they remain inadequate in operating the plants as designed.
18. See Dixit et al (2007)
19. Ibid.
20. In July 1982 the Indo-Nepal Joint Technical Group (JTG) decided that the sluice gates of the bund could be left completely open to allow up to 200 cusecs to be discharged unhindered. Regardless, the inundation of Gaur Bazaar persisted and was discussed in subsequent meetings. Three gated openings on the ring bund were provided to allow the incoming water flows to drain. This inundation continues even today.
21. See the minutes of the meeting between the Nepali Secretary Water Resources P.P. Shah and the Indian Irrigation Secretary C.C. Patel in New Delhi in February 12, 1982. The minutes mention flood control problems in the following cases: 1. Spills from Bagmati and Lalbakaiya, 2. Flood protection work in the Bagmati, 3. The Parman flood control scheme, 4. Bhutahi Balan and 5. embankments.
22. The numbers in the table refer to those in Figure 6.4b: Inundation spots Source: Progress Report (1) for the study on the National Management Hydro-Metrological Management Project (Annex) Ministry of Water Resources, Department of Hydrology and Meteorology, Kathmandu 1991.
23. https://bordernepal.wordpress.com/2019/09/26/inundation-discussion/
24. See Regmee, (2013). Nepal India and Inundation Problems, PowerPoint presentation
25. As we mention above Rai et al (2017) mention 1874 the year of hydro diplomacy
26. Till 2002, the director general of Nepal's Irrigation Department represented Nepal in the meetings. After the formation of the Department of Water-Induced Disaster Prevention (DWIDP), its director general represented Nepal in the meetings instead. The chairman of the Ganga Flood Control Commission (GFCC) led the Indian team.
27. The Bihar Assembly member Lahatan Chaudhary after the floods had said by having wireless system inform the downstream of the flood event at the foothills coming down will provide a lead time of 3 to 4 days for necessary evacuation. Dr Dinesh Kumar Mishra personnel communications 12th March 2023. This idea took long time to get traction and still need major efforts for scaling up across the board.
28. See INCID (1993).
29. Departmental heads were also invited to attend the meetings and brief the visiting minister on various related issues (Dhungel & Pun (2009)

30. Minutes of the meeting between the Nepali Secretary Water Resources P.P. Shah and the Indian Irrigation Secretary C.C. Patel in New Delhi on February 12, 1982. Item 3 of the minutes says: "Shri Patel stated that a draft proposal for the flood forecasting scheme had been forwarded to His Majesty's Government of Nepal some time back and enquired whether His Majesty's Government of Nepal is now ready to accept the same so that forecasting can be started before this monsoon season. Shri Shah replied that the necessity of such a flood forecasting system is felt in Nepal also. The Nepalese experts are at present working on a comprehensive plan to establish such a flood forecasting system in Nepal. It will be geared to accommodate the requirements of India and incorporate the hydro-metrological stations as suggested by the Indian side earlier. The execution of the program in Nepal will be carried out by Nepalese experts and data will be exchanged on a regular and reciprocal basis. Any cooperation from the Indian side in terms of equipment and/or technical assistance will be welcomed. It was agreed that a meeting of the experts of the two sides will be held before the next meeting to finalize the draft agreement."
31. On flood forecasting, the minutes of the meeting held between the Indian Secretary (Water Resources) Naresh Chandra and the Nepali Secretary (Water Resources) Madhusudan Dhakal in Kathmandu on December 22, 1987, say: "Both India and Nepal agreed to expedite the implementation of facilities to be provided for an efficient flood forecasting system. As agreed before Nepal will implement and maintain the system in its territory. However, at the suggestion of India, Nepal agreed to accept the necessary equipment from India to implement the scheme expeditiously. It was agreed that Nepal will supply data in real-time for flood forecasting (June-October). India will provide similar data on two points downstream of the border of the same river on a reciprocal basis. It was also agreed that a standard format for information gathering and a standard schedule of information exchange should be agreed upon at the technical level. The experts of both countries should have an exchange visit to the sites of each other's countries frequently."
32. "As a first step, it had to be noted that the Expert Level Meeting prepared a report identifying the stations and the data to be collected and transmitted. This meeting had to approve this report. Very shortly, an expert team including those experienced in the installation and transmission of data through wireless would visit the sites from where data would be collected and transmitted. This expert team would identify the equipment required for the implementation of the scheme would be supplied by Govt. of India free of cost and he hoped that these would be installed expeditiously to serve the purpose. Director, IMD, stated that some data from the recently identified seven rainfall stations had started coming in, but he suggested that Nepal might consider sending these rainfall data separately and at 3 hourly intervals (during daytime) instead of the present twice daily method. Director General (hydrology and Meteorology), HMG Nepal, responded by stating that it would be possible to send the data of these selected stations as separate messages at the 3-hourly interval (during daylight hours) through the existing Kathmandu/New Delhi communication circuit." Minutes of discussions between the Indian Secretary (Water Resources) Naresh Chandra and Nepali Secretary (Water Resources) B.K. Pradhan. New Delhi, June 2, 1988.
33. Summary record of the discussions of the First Meeting of the Indo-Nepal Sub-Commission on Water Resources at the Secretary Level. Kathmandu, December 27, 1988
34. For details on MoU and debates on the Tanakpur barrage, see Gyawali and Dixit (1999)
35. Notification in the Nepal Gazette Vol. 41, No. 36 Kathmandu, December 29,1991. His Majesty's Government, Ministry of Water Resources-Information
36. See Dixit (1997).
37. DPTC was a joint undertaking of the Ministry of Water Resources, the Ministry of Forest, and the Ministry of Works and Transport, with the Ministry of Water Resources as the lead agency. The Ministry of Home Affairs (MoHA) and the National Planning Commission (NPC) were expected to work in partnership with the DPTC. It no longer exists. See Dixit et al (2021).
38. See Vij et al (2020).
39. Ibid Vij et al (2020).
40. See Yogacharya & Gautam (2008).
41. ITGD, a United Kingdom-based NGO, worked in Sri Lanka, Bangladesh, Nepal, India and Pakistan. In 2005 its name was changed to Practical Action
42. Moench & Dixit (2003).
43. https://duryognivaran.org
44. Earlier Red Cross Nepal was the only intenational organization explicitly working on disasters, with a focus on post-disaster response and relief (Vij, et al, 2020).
45. See Dixit (2003)
46. The same year high rainfall also occurred in downstream regions, causing flooding. Bangladesh experienced one of the widespread flood disasters in recent history
47. Practical Action (2008)
48. See https://soanas.org/community-centred-flood-early-warning-system-in-nepal/
49. See Bhandari (2021).
50. See Smith et al (2017).
51. See Meechaiya et al (2019).
52. See Shrestha (2014).
53. See Bhandari & Dixit (2022).
54. In its assessment in Humla, Mugu, Kalikot and Jumla districts, the NDRRMA included damages to dridge, micro-hydropower and supply lines, housing and settlements, roads and foot-trail, schools, religious and cultural heritage sites, water supply and sewage systems, irrigation canals, public and government buildings, agricultural and farmlands, hospitals and health posts, and river training works and slope protection. This is a useful step that needs to be replicated for assessing losses and damages across country's other districts and the lessons used in the design of a data collection mechanism and repository platform (See executive summary of the report)
55. This is based on Bhandari & Dixit (2022). Also see Dawadi (2022) for a discussion of flood EWSs at the transboundary level.
56. https://rsdc.org.np/accessed on Feb- 04-2023
57. https://www.sahbhagi.org/accessed on Feb- 04-2023
58. https://cdafn.org.np/ accessed on Feb- 04-2023
59. For details see https://www.onlinekhabar.com/2019/09/793260/accessed on Feb- 04-2023
60. https://www.iucn.org/sites/default/files/content/documents/2017/ final_draft_gbm_cso_vision_rev_6_nov_2017_cso_network.pdf/accessed on Feb- 04-2023

Interventions and Impacts

INTERVENTIONS AND IMPACTS

07

7.1 RIVER POLLUTION

The expansion of settlements, commercialization, and the development of markets around urban areas is leading to the socio-ecological transformation of CBs. Industries, cities, towns, and commercial agriculture produce point and non-point sources of waste that, when unmitigated, cause pollution. In many cases, solid and liquid wastes produced by expanding cities and towns pollute nearby rivers and streams. Pollution is a burden to present and future generations. Polluted rivers degrade human and environmental health and cause net negative impacts on livelihoods. The impacts of pollution on CB rivers are considerable during non-monsoon months when river discharge and consequently the capacity of rivers to dilute wastes are low.

Thus, in non-monsoon months, high concentrations of pollutants in the drains of cities in the CB turn those drains into cesspools. Sites where solid waste is dumped and polluted rivers become home to hazardous pests which directly threaten human health. At the same time, the discharge of agrochemical-enriched return flows from farmland can lead to river eutrophication and algal growth. The persistence of these phenomena causes algal bloom, further diminishing the quality of river water. Eutrophication and algal bloom can be toxic to humans and destructive to biodiversity. Once water quality has declined, the poisoned aquatic environment can permanently damage ecosystems and erode human well-being. Climate change creates favorable conditions for disease vectors like dengue mosquitoes that spread long distances, transmitting diseases and affecting people, adding to already existing health threats.

Waste from domestic, commercial, and industrial units is another major source of pollution. As the number of users goes up, the amount of waste produced also increases. The amount of waste with concentrated pollutants is greater in cities than in rural households. Washing, bathing, cleaning, and kitchen uses of water produce greywater, which is less polluting than black water, which consists of human feces and urine. In CBs, as urbanization spreads, the number of enclosed toilets and septic tanks disposing of human waste is increasing. Gray water is released into drains and dumped into rivers without any treatment. In some cities, rudimentary sewage pipes exit, but no treatment system is available.

In very limited cases, sewer lines exist. They take away grey and black wastewater and stormwater, dumping them all together into rivers. The combined flow, with its load of oxygen-demanding waste, synthetic organic compounds, inorganic chemicals, and minerals, significantly degrades the quality of river water. Industries along the corridors of CBs also produce wastewater, but, except for very few in-house cases, neither the quality nor the quantity of this water is monitored.

TABLE 7.1 SOURCES OF RIVER POLLUTION AND THEIR IMPACTS.

Sources	Impacts
Municipal effluent	Without treatment reduces the quality of surface and groundwater
Industrial effluent	Inorganic and organic chemicals affect aquatic flora and fauna
Agricultural runoff	Affects surface and groundwater
Urban runoff	Increases pollution in runoff water
Solid waste	Pollutes land, rivers, and groundwater
Sediment load	Agricultural land and the built-environment adds to pollution loads

Industrial wastes are discharged untreated. In addition, around cities and, in some cases, even in rural areas, small- and medium-scale enterprises have been built. They, too, generate wastewater whose quality and quantity are unknown. This wastewater is not treated. In some cities, stormwater runoff from houses and streets is discharged into rivers, ponds, and lakes. Both road expansion and haphazard urbanization are adding untreated storm flows to drainage systems.

Agrochemical residue from agricultural land flows as a diffuse source of pollution and reduces the quality of river water. Because such flows are not monitored, little is known about the extent of pollution by agrochemical residue through the use of fertilizers and agricultural chemicals has increased in central and eastern CB districts[1]. Such residue can pass through the food chain and become hazardous to human health. The following are typical examples of polluted rivers in CBs.

A 2020 analysis of rivers of CB using a) nitrate prediction, b) phosphorous balance, c) sediment erosion, d) population density and e) urban areas found that all the rivers of the rivers are in moderate to very poor-quality pressure range[10]. Given that the CB rivers in Uttar Pradesh and Bihar have more urbanized and has higher population the quality can be assumed to be similar range.

TABLE 7.2: SELECTED EXAMPLES OF POLLUTED RIVERS

River	Origin	Flows Through	Source of pollution
Tengra	Chure foothills in Sunsari District,	Itahari City and the region's industrial corrdior and joins Budhi Khola.	Stormwater runoff, solid waste, livestock-processing waste, animal carcasses, and feces dumped directly into the river.
Kamala	Sindhuli and Western Udayapur districts	The CB before entering India[2].	Human and animal feces[3], higher concentrations of coliform[4] and other pollutants[5], runoff from unpaved roads, the soil loss from Chure range and riparian regions, and sand mining in both Nepal and India increase turbidity, lower river health during the pre-monsoon seasons than the monsoon and winter seasons[6].
Sirsiya	Pathalaiya hills, Ramban forests.	Through Nepal's Bara and Parsa districts and after entering Raxaul, flows into the Budhi Gandak River.	Wastes from more than 250 industries in the Bara-Parsa industrial corridor and the solid waste of Birgunj Municipality.
Tinau	Mahabharat Range, Palpa District.	West Rapti River near Gorakhpur, India.	Debris from landslides, gravel mining, waste from squatters, effluent from local slaughterhouses, solid waste, household and industrial waste, and agricultural runoff[7] .
Kailali Nala	Chure Hills, Kailali District	Towards Dhangadhi Sub-Metropolitan municipality.	Garbage dumps, encroachment of rivers, waste from cities, and construction wastes.
Mohana	Chure Hills, Kailali, and Kanchanpur districts	South of Dhanagadhi[8] joins the Karnali River at Nepal-India border.	Agricultural runoff and waste from washing and bathing can cause eutrophication[9].


Polluted Sirsia River 2017

Source: Naresh Rimal

7.2 ARSENIC CONTAMINATION OF GROUNDWATER

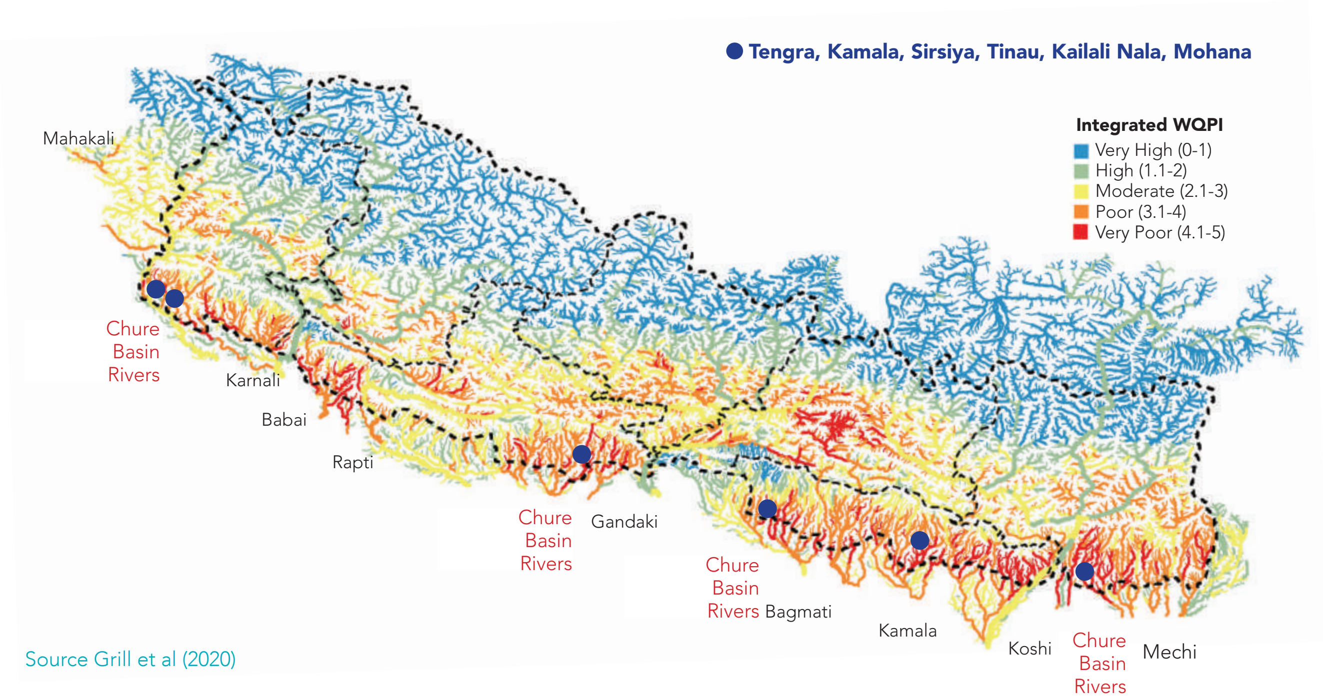
In the plains of the Ganga basin, naturally occurring arsenic is an emerging threat to groundwater use. Rocks rich in arsenic eroded from mountains and highlands thousands of years ago and were deposited, along with sand, gravel, and silt. in low-lying areas of the CBs of Nepal, Uttar Pradesh, Bihar, West Bengal, and Bangladesh. In the rural areas of these countries, tube wells, which pump water from shallow aquifers at a depth of about 20 m–30 m, are widely used and provide safe drinking water to almost 100 percent f the population. The geological and geochemical conditions of the region favour the release of contaminants[11]. These aquifers face arsenic contamination, a possibility that poses a serious risk to the user depending on tubewells for drinking water.

Arsenic contamination can lead to arsenicosis among the poor and create social and economic challenges. In these regions, various types of bio-sand filters and chemical powder are used to remove arsenic and iron from tubewell water. Their effectiveness is yet to be assessed.

TABLE 7.3 INSTANCES OF ARSENIC CONTAMINATION

Country	Details
Bangladesh	In 1993, the Department of Public Health Engineering first reported that there was arsenic poisoning in the groundwater of the district of Chapai Nawabganj and that the central part of Southeast Dhaka was the worst affected region. Out of 64 districts, 61 districts had groundwater containing amounts exceeding the WHO limit of 10 µg/ L for potable water. More than 85 million people are affected.
Bihar, India	Affects 12 districts and an estimated 9 million people that use groundwater from alluvial aquifers are at risk.
Uttar Pradesh, India	First reported in Ballia District. Presently 20 districts are reported to have elevated arsenic concentrations in groundwater in scattered pockets.
West Bengal, India	First detected in 1978. Affects around 16.66 million people (according to the 2001 census) in eight districts. The high-risk areas are North 24 Pargana, Burdwan, Howrah, Hooghly, and Kolkata.
Nepal, CBs	The first report that concentrations exceeded the WHO guideline of 10 µg/L was made in 1998. A study by the Department of Water Supply and Sanitation (DWSS) in 2000 showed that groundwater in 17 CB districts had high arsenic concentrations. Nawalparasi, Parsa, Rautahat, and Bara were the four most affected districts[12]. This contamination is a challenge in the districts of Nawalparasi, Kapilbastu, Siraha, Rautahat, Parsa, Sarlahi, Kanchanpur, and Saptari[13].

FIGURE 7.1: INTEGRATED WATER QUALITY PRESSURE INDEX (WQPI) OF RIVERS OF NEPAL



Source Grill et al (2020)

7.3 FECAL SLUDGE

Chapter 4 discussed the state of sanitation in CB districts. Sanitation involves the safe disposal of waste generated after human use, both in solid and liquid forms. In Nepal, as in many countries, people engage in open defecation, a practice that leads to poor health, deaths due to diarrhea, high child mortality, and stunted child growth. The use of latrine pits and pour-flush and within-house toilets, in contrast, isolates human feces. With the expansion of offices, malls, schools, colleges, hospitals, and security barracks, the number of within-house toilets has increased. Pit and pour-flush toilets deposit solid materials in the soil. It is assumed that the soil will disinfect harmful pathogens. Within-house toilets discharge fecal materials first into septic tanks, then to sewer lines, and ideally, next to a waste treatment plant.

Latrines do bring health and hygiene benefits, but the improper disposal of fecal sludge is an emerging threat. In Nepal wastewater from only 11 percent of houses is transported away by sewer pipes either to a treatment plant or to be discharged untreated in a river or on peri-urban land. Mostly it is neighborhoods in Kathmandu that rely on sewers for sanitation facilities. Elsewhere in the country, on-site sanitation systems are most common. Indeed, as much as 89 percent of the country's population uses on-site sanitation practices, including unlined septic tanks and pit latrines. In Nepal, about 2,925 cubic meters of fecal sludge produced each day is contained in unlined underground pits within households' premises. In limited cases, they are emptied, transported mechanically to nearby rivers and marginal lands, and disposed of without any treatment[14]. With the increasing rise in urban populations and haphazard urban expansion, these challenges are likely to become serious in CB districts. In almost all rural and urban municipalities of the CBs, the provision of sewerage sanitation services and septic tanks is far behind that of piped water networks. These unsafe practices increase the pollution of land as well as surface and groundwater and pose high public health risks.

7.4 RIVER BED MATERIALS EXTRACTION

The use of sand and aggregates in CBs is linked to the expansion of urban areas and infrastructure development. In CB districts, the use of sand-based materials began after it has in the capital Kathmandu. Across the world, sand and gravel, mostly from riverbeds, are extensively used as construction materials for the infrastructure (e.g. residential, educational, commercial, and industrial buildings, dams, barrages, airports, highways, and bridges). The commercial production of cement and the growth of its supply ecosystem have been foundational to this increase. With the pace of construction of the infrastructure increasing, the amount of sand and aggregates extracted from rivers has also seen a steady rise. Though an exact estimate of the amount extracted is not available, it can logically be assumed that collection is increasing in all CB rivers. The extraction of construction-grade materials has social, economic, political, and environmental consequences. In the 1980s, excessive topsoil loss (sedimentation) was recognized as an externality that would lower productivity and increase lowland sedimentation and flooding. At the same time, sand, a contingent of the sediment chain, was considered a non-exhaustive resource.

As Nepal aims for infrastructure-led development, including urbanization, the tension over achieving a balance between the volume of sand and gravel extracted and the amount used is evident[15]. In the 1970s, with increasing urbanization in Kathmandu, cement-and-sand mortar became a common binder for the brick walls of houses. The use of cement-and-sand mortar in the Tarai was limited mostly to a few main cities and became common later. Improved accessibility and rapid urbanization across the country led to growth in the construction of cement-concrete buildings and increasing demand for sand in the early 1980s[16]. After the 1988 earthquake, the number of cement-concrete buildings increased but this increase did not automatically lead to the construction of earthquake safe-buildings[17]. This limitation was evident in the widespread damage the 2015 Gorkha earthquake caused to houses. Since then, the use of cement concrete has become even more widespread and has concurrently increased the use of sand and construction-grade riverbed materials. River beds in the mid-mountains and CB region are major sources of boulders, aggregates, and sand[18] and are also used for exporting across the border.

The increase in the use of sand and river bed materials in CBs is linked to infrastructure development and urbanization, but a systematic account of the trend and shift in the types of houses built is not available[19]. It is assumed that in the towns and cities of CBs, the construction of concrete houses began in the 1960s. Later an increase in average household incomes due to remittance and the preference for houses with flat concrete roofs to gain respite from floods also engendered this shift[20]. In the villages of CBs in Nepal, brick houses began to replace thatched huts in the mid-1990s, attributable largely to remittances from Gulf Cooperation Council countries, and Malaysia[21] and CBs have seen increases in the number of houses built with the cement-concrete mix.


Tractor extracting sand in Tinau River (2017)

Source: Naresh Rimal

With increasing demands for sand and aggregates, the materials available easily in CB rivers are mined haphazardly. Sand mining from rivers in Nepal also serves as a source across the border in India's Bihar and Uttar Pradesh. In Bihar and Uttar Pradesh, sand is also extracted from rivers of the CBs. Till the late 1980s, since the amount of sand extracted from rivers was small, the materials available in rivers that flow close to cities and towns met this need. However, no accurate data on the amount thus extracted is available. For example, sand from the Bagmati and its tributaries in the valley met the construction needs of Kathmandu and Patan till the early 1990s. Today sand is extracted from many sites in rivers across the country that are away from cities, including in CBs, and the materials are transported by trucks and other mechanical means. The Chure Master Plan (2074) identifies 242 locations in 27 districts linked to the Chure mountain range where river materials are mined[22]. It is estimated that 6.5 million cubic meters per year (source) of material is extracted. The following table presents a tentative estimate of the amount mined.

The judicious use and conservation of sand and river materials are central to achieving resilience within a geographical space as well as across its boundaries. A better understanding of the interdependence among the CB region's natural ecosystems, infrastructure, the services used by people, the impacts of uses, and policy applications is basic to this effort.

TABLE 7.4 SAND EXTRACTION

Types	Details	Remarks
Permitted Extraction (MT)	6,502,582	Based on extracted materials former 6 VDCs (municipality) along Tinau[1] and West Rapti[2]
Ad-hoc Extraction (MT)	9,460,800	Based on daily extraction on an ad-hoc basis from Karjanha Siraha[3]/Kamala, Vedkot[4]/Chhela, Bagun and Ghursuwa, Parsagadhi[5]/Singiyahi, Barbardia[6] / Thakurdwara and Babai. The same amount is assumed to be extracted for 6 months/year.
Amount of Tender call in Rs x 106	328.84	The sum amount contracted by the local Government in their respective sites; Kawasoti[7] /Kerunge, Madhyabindu[8], Hoopsekot, Boudikali, Vinayi Triveni/Vinayi Gaindakot, Fatuwa Vijayapur[9] /Lalbakaiya-Botwa Ghat (2021-22), Raptisonari /Rapti, Muguva, Jhijhari, Khairi, and Paruva (2018-19)

Source of information used in the table 7.4: are as follows

1. Dhakal et al (2015)
2. Pandey Jay-ekantipur (Shrawan 1, 2079) https://ekantipur.com/pradesh-5/2022/07/17/165802404358736397.html
3. Yadhav Mithilesh- My Republica Dec 17, 2018). https://myrepublica.nagariknetwork.com/news/illegal-boulder-mining-in-chure-in-collusion-with-local-units/accessed on Feb- 06-2023 .
4. Bhatt Bhavani- ekantipur (Magsir 28, 2077) https://ekantipur.com/news/2020/12/13/160784716692888015.html
5. Bhatt Bhavani- ekantipur (Magsir 28, 2077) https://ekantipur.com/news/2020/12/13/160784716692888015.html
6. Panthi Kamal – ekantipur (Magh 28, 2076) https://ekantipur.com/pradesh-5/2020/02/11/158139502124388759.html
7. Bhattarai Kalpana- Himalkhabar (Baishak 30, 2076) https://www.himalkhabar.com/news/12515)
8. https://ekantipur.com/Pradesh2/2022/03/22/16479201295349626.html
9. CIJ – (Shrawan 2, 2077) https://cijnepal.org.np/78945/

NOTES

1. In Nepal about, 250 different types of pesticide are known to be used (Shukla, et al. (n.d.).
2. See WECS & CSIRO (2020).
3. Ibid
4. Updated Initial Environmental Examination Report (IEE) for Kamalamai Small Towns Water Supply and Sanitation Sector Project, Sindhuli District (2015)
5. See Central Pollution Control Board of India (2022).
6. Tachamo-Shah et al (2019).
7. Dahal et al (2012).
8. See Pandey et al (2021).
9. See Shrestha et al (2019).
10. See Grill et al (2020).
11. Arsenic can easily be solubilized in groundwaters depending on pH, redox conditions, temperature, and solution composition. See Mueller (2016).
12. Nearly a quarter of the wells exceed the WHO standard of 10 mg/litre, and 8 per cent exceed the Nepal interim Standard of 50 mg/litre. It is estimated that tens of thousands of people in Nepal's Tarai may be dependent on arsenic contaminated water. See (Shrestha et al 2003).
13. See Nepal Water Supply, Sanitation and Hygiene Sector Development Plan (2016-2030)..
14. See Adhikary & Sharma (2021).
15. Traditionally, different regions of Nepal use different natural materials for shelters. In the Himalayan region, stones and timber are common, while in the mid-hills, stone with clay as a binding material, bricks, hay and timber are used. Bamboo, mud and thatch and tiles for roofs are common in the Tarai. In both the hills and the Tarai higher income households use clay tiles as roofing materials. With the construction of European-style palaces in Kathmandu, an era of building modernization began. The palaces used bricks with clay as a binder as well as bricks with lime and smashed brick dust mix as a binder. After the Great Earthquake of 1934, corrugated iron sheets began to be used for roofing. Gradually a cement-sand mix as a binder and brick walls became the most prominent of materials (Raj 2016) by the middle of the 20th century, and the number of cement houses significantly increased. This rise in turn led to an increase in the extraction of sand and gravel from rivers in Kathmandu (Baidya, 2003).
16. Rai et al (2019).
17. Raj (2016).
18. The deposits of mudstone, siltstone, shale, and fine-grained sandstone on the foothills of Chure Range are used as construction materials (Upreti, 1999). Also see Kaphle (2020).
19. See Lal (2019).
20. Dixit et al (2003).
21. See Lal https://kathmandupost.com/columns/2022/12/06/repercussions-of-remittance-economy/accessed on Feb-12-2023
22. One tractor load carries 2.5 Mt; a six-tyred tipper; 7 Mt; and 10-tyred tipper, 13 Mt.

POLICIES RELATED TO RESILIENCE PILLARS

Policies Related to Resilience Pillars

08

8.1 INTRODUCTION

This study considered healthy natural ecosystems as one of the pillars of the resilience of communities. The other three pillars of resilience are a decrease in exposure to climatic hazards, the empowerment of users and managers, and climate-adapted infrastructure. Having rules and policies that make services available and enable the most vulnerable to access these services is the fifth pillar. An examination of these interdependent components can help us assess the gaps and risks in CB districts to meet the objectives of enhancing resilience. This chapter broadly reviews Nepal's policy landscape, its implementation, and how it can shape strategies and actions to achieve the objective of flood risk reduction management.

Nepal's Constitution identifies "economic equality, prosperity, and social justice" as the values characterizing an equitable society. Environmental integrity is a major aspect of meeting equity goals. Article 30 states that "every citizen shall have the right to live in a clean and healthy environment"[1] and thus recognizes the value of environmental integrity for a resilient future when ecological sustainability, intergenerational equity, and social justice at all levels of governance become the nation's guiding philosophy. Similarly, Article 51 (g) 1 of the Constitution states: "State shall pursue a policy of conserving the natural resources available in the country by imbibing the norms of inter-generation judicious use of it and for the national interest. The policy shall ensure the fair distribution of the benefits generated by it by giving local people a priority and preferential rights." The Constitution envisions that local, provincial, and federal governments will share responsibility for conserving the country's natural resources and using them equitably and that the cooperation of all is needed to meet the objective of achieving resilience.

8.2 POLICY GAP ANALYSIS

This analysis is based on a systematic review of policies that directly or indirectly influence environmental conservation and water and infrastructure development in Nepal. The review also includes policies on pollution, forests, climate change, disaster risk reduction, settlement, and mining. The policies are broadly grouped into the following four thematic pillars of resilience: reduced exposure to climate hazards, healthy natural ecosystems, adapted infrastructure, and empowered users. The policies related to impacts are categorized according to the four pillars shown in Table 8.1 below.

The policies on the four pillars as shown in Table 8.1 are detailed in Table 8.2

While there is a multitude of public policies (as shown in Table 8.2), their implementation is ad hoc and ineffective. Gaps remain and compliance is poor. Policies are framed and revised without adherence to grounded evidence and the participation of a wide group of stakeholders, particularly those at the margins. The factors shown below in Table 8.3 have resulted in ineffective policy implementation.

In addition, policy implementation is sectoral and siloed, weakly coordinated, and poorly harmonized. For example, while the government requires IEEs and EIAs as key instruments in the design and implementation of infrastructure and development projects, carrying out these evaluations is often just a matter of ritual. In many cases, projects are neither monitored nor evaluated. The result has been such a steady decline in Nepal's overall environmental quality that stemming that fall now poses a major challenge. Needless to say, the quality of the environment in CB districts has also declined, and with the lack of disaggregated detail, intervening to halt that degradation poses a substantial hurdle. Moreover, climate change adds new layers of complexity that overwhelm the

TABLE 8.1 REVIEW APPROACH

Pillar of Resilience	Policy Instruments	Key Categories
Climate hazards	Climate change, ecological alterations, DRR	Acts Policies Rules and Regulations, Guidelines and Manuals Norms and Standards
Natural ecosystems	Forest and vegetation loss, sand and gravel mining, industrial, settlement, pollution	
Infrastructure	Settlements and infrastructure development	
Users	Jobs, skills, gender balance, and social inclusion	

TABLE 8.2 BROAD GAPS IN THE NATURAL ECOSYSTEM, WATER, LAND USE, AND MANAGEMENT POLICIES[2]

Determinant	Details
Approach	The approach is largely dependent on a monocentric and technology-guided path that evolved in the late 19th and early 20th centuries to meet human needs for food, energy, and water in well-off, urban, and industrialized centers that ignores the integrity of natural ecosystems and local communities. It has the following characteristics: • Policies ignore the importance of the nexus between humans and natural ecosystems and their services and functions, reflecting a gap in using enhanced science-based understanding to support a holistic approach to freshwater and its use and management as well as their effectiveness. • Nepal lacks instruments to translate the inherent value of natural ecosystems into significant social benefits by incorporating services crucial for maintaining the biotic integrity of an area. • The formal education stream related to natural and water resources considers that their development, use, and management are neutral from a social and environmental standpoint and accord little recognition to the importance of freshwater research that can promote understanding of evolving socio-ecological dynamics. • The fact that sectoral policies either accord low priority to or exclude the conservation of natural ecosystems while at the same time promoting their extractive use has resulted in the degradation of those ecosystems.
Carrier	No organization is designated for the conservation of freshwater and rivers.
Coordination	The mechanism to coordinate the implementation of policies among various government agencies is inadequate.
Representation	Limited representation of affected people, common users, and those with indigenous knowledge in the policy-making process.

Adapated from Dixit et al (2020)

implementation of policies designed to build resilience and adaptive capacity, and public policies remain inadequate in meeting emerging environmental and social challenges. A 2022 review of aquatic health, for example, suggests that policies focused on the conservation, restoration, and effective and sustainable management of wetlands to promote biodiversity and environment conservation do not address how to achieve the long-term conservation of key riverine indicator species[3]. Another example is that while Nepal's 2001 Hydropower Policy stipulates that all hydropower dams must release 10 percent of the minimum monthly average discharge of the river or the minimum suggested by EIA downstream of the dam, very few projects comply with this policy, and hydropower plants increasingly fragment rivers.

NOTES

1. See the Constitution of Nepal (2015)
2. Adapted from Dixit et al (2021)
3. Analyzing the role of Nepal's policies in protecting riverine animals, Acharya et al (2022) suggest that Nepal's development projects do not follow the provisions of environmental impact studies during their formulation, implementation, or monitoring.

TABLE 8.2 POLICY INSTRUMENTS

PILLARS RESILIENCE

Natural Eco-system

The Fifteenth Plan Fiscal Year 2019/20 – 2023/24 (2020)

- Planning and developing projects making optimal use of resources.
- Protecting, valuing, and mobilizing natural resources and building their resilience.

Nature Conservation: National Strategic Framework for Sustainable Development 2015- 2030 (2015)

- Mainstreaming nature conservation in development.
- Valuing and accounting ecosystem goods and services.
- Harmonizing amongst sectoral strategies.
- Coordinating amongst related agencies.

Water Induced Disaster Management Policy, 2072 (2015)

Helping achieve the objectives of the NWRS and NWP in managing water-induced disaster.

National Water Plan (2005)

Developing SEA in water resource management.

National Biodiversity Strategy and Action Plan (2014-2020)

Proposes strategies and action plan for biodiversity conservation including different types of wetlands and terrestrial ecosystems and species richness.

The Forests Act, 2076 (2019)

- Sustainable management of forests contributing to the economic development
- Allocating benefits from protected forest area.

Forest Sector Strategy 2016-25 (2016)

Incorporating traditional knowledge, indigenous practices, and local involvement for silvicultural system-based forest management for national forests.

National Forest Policy, 2075 (2019)

- Promoting conservation, restoration, and sustainable use of forests, vegetation, wildlife, and biodiversity.
- Restoring degraded forest without reducing the coverage of present forest.

Nepal National REDD+ Strategy (2018)

Improving resource tenure and ensuring fair and equitable sharing of carbon and non-carbon benefits of forests with effective implementation of safeguards measures among rights holders, women, indigenous peoples, Madhesis, Dalits, and forest-dependent local communities.

National Agro-Forestry Policy, 2076 (2019)

- Enhancing the market for agro-forestry-based production.
- Promoting agroforestry and its appropriate models in barren, abandoned, public, and marginal land.

Aquatic Animal Protection Act, 2017 (1960)

- Recognizing the need for the conservation of aquatic life.
- Constructing a fish ladder at the dam site to ensure the movement of fish.

Climate Hazards

Disaster Risk and Management Act Amendment, 2075 (2019)

Envisioning the development of a procedure of prevention, mitigation, preparedness, and response for disaster risk reduction caused by hazards.

Disaster Risk Reduction and Management Regulation, 2076 (2019)

Adopting risk transfer mechanisms such as insurance and social security measures.

National Policy for Disaster Risk Reduction, 2075 (2018)

- Strengthening disaster risk governance for disaster risk reduction and information management for multi-hazard early warning.
- Ensuring "Build Back Better" in recovery, rehabilitation, and reconstruction.
- Achieving SDFDRR (2015-2030) and SDG targets with suggested structures at federal, provincial and local level.

Monsoon preparedness and response plans, 2077 (2021)

- Making NEOC active 24 hours while POEC, DOEC and LOEC activated for preparedness.
- Fostering collaborations of DHM, DoWRI and MoHA to strengthen flood early warning system
- Outlines responsibilities of agencies for monsoon preparedness and response.

Infra-structure

Irrigation Policy, 2070 (2013)

- Minimizing adverse environmental impacts during the construction and operation of irrigation projects.
- Encouraging farmers' participation in the management of irrigation systems.

Environmental Protection Act, 2076 (2019)

Maintaining a balance between environment and development.

The Land Act, 2021 (1964)

Specifying the compensation to registered tenants on land sold by the owner or acquired for development purposes.

Land Acquisition Act, 1977

Empowering the government to acquire land for public purposes, by compensating for private properties.

Public Roads Act, 2031 (1974) amended (2010)

Provision for planting trees on both sides of highways, feeder roads, district roads, and urban roads.

Users

The Fifteenth Plan Fiscal Year 2019/20 – 2023/24 (2020)

Planning and developing projects by making optimal use of local skills and create new employment opportunities.

Water-Induced Disaster Management Policy, 2072 (2015)

Involving communities, cooperatives, and the private sector in disaster mitigation actions

Irrigation Policy, 2070 (2013)

Mitigating diverse environmental effects arising from the implementation of projects

Water Resources Act, 2049 (1992)

Empowering WUAs for the utilization of irrigation use as second priority.

Irrigation Rules, 2056 (2000)

- Formation mobilization of WUAs to manage schemes.
- Granting permission to WUA to function as the CFUG from the respective DFO.

Environmental Protection Rule, 2077 (2020)

- Consulting and informing the stakeholders on the contents of the proposal.
- Enhancing capacity of stakeholders related to the CDM

Hydropower Development Policy, 2058 (2001)

Developing water resources in an integrated manner by adopting a broader perspective on national development by developing and managing hydropower.

National Energy Efficiency Strategy, 2075 (2018)

Establishing policy, legal, and institutional frameworks for ensuring energy efficiency.

Water Resources Strategy (2002)

SEA in water resources management.

Water Resources Policy, 2077 (2020)

- Integrating water resource databases with environmental databases.
- Preparing and implementing floodplain action plans.

Irrigation Policy, 2070 (2013)

- Maintaining flow in the rivers/rivulets.
- Conserving lakes, ponds, wetlands, and springs.
- Integrate all the uses of natural resources within the catchment.

Water Resources Act, 2049 (1992)

- Fixing permissible levels of pollution.
- Minimizing impacts of soil erosion, landslide, flood.

Environmental Protection Rule, 2077 (2020)

Controlling pollution, and conserving national heritage.

Environmental Protection Act, 2076 (2019)

- Recognizing the fundamental right of citizen to live in a clean and healthy environment, compensate the victim by the polluter for any damage resulting from environmental pollution.
- Mitigating adverse environmental impacts on the environment and biodiversity.

National Park and Wildlife Conservation Act, 2029 (1973), Fifth Amendment, 2073 (2017)

- Prohibiting wildlife hunting and damage to flora and fauna, fishing, etc. within the conservation area
- Mammals, birds, and reptiles protected wildlife species .
- Helping local people access forest products from buffer zones.
- Establishing zoos, wildlife rescue centers, and wildlife hospitals
- Enhancing and conserving wildlife crossing.
- Allowing farming of wild animals for commercial purposes

National Environmental Impact Assessment Guidelines (1993)

Guidance to project proponents to integrate mitigation on managing quarries, borrow pits, disposal of spoils, safety, slope stabilization, and management of stone crushing plants.

Mines and Minerals Act, 2042 (1985)

Complying with safe mining operations without adverse impact on the environment.

Mines and Minerals Rules, 2056 (1999)

Mining operations not to harm surface and groundwater; minimize wastes by building ponds, treat the affluent; and cause minimum pollution.

Environmental Safeguards Guidelines for Irrigation and Water-Induced Disaster Prevention Sector (2015)

- Offering guidelines for assessment for water-induced disaster.
- Forming committees that will decide on the location and period of the mining as suggested by IEE.

National Drinking Water Supply Standard, 2062 (2005)

Including standard limits, guidelines for the required frequency for quality monitoring, and the process and schedule for measuring the standards.

Solid Waste Management Rules, 2070 (2013)

Empowering local bodies for the segregation, transportation, and disposal of solid waste as well as involves the private sector in waste management.

Solid Waste Management Act, 2068 (2011)

- Making local government responsible to manage waste except for chemical waste or industrial waste and waste generated from health institutions.
- Reducing the amount of solid waste by making
- Arrangeme for its disposal or reuse
- Making obtaining a license from the local body, to carry manage solid waste obligatory.

Disaster Management Fund Operation Procedure, 2079 (2022)

Utilize fund transparently and efficiently for risk reduction, anticipatory response following an early warning, search, rescue, relief and recovery.

Disaster risk financing strategy, 2078 (2021)

- Making use of financial, actuarial, and catastrophic risk modeling tools to determine gaps for making financial plans and their implementation.
- Common alerting protocol to be made and put into practice.

Disaster Risk Reduction National Strategic Plan of Action 2018 – 2030 (2018)

Increasing the availability of and access to services from multi-hazard early warning systems and disaster risk information and assessments to "Build Back Better" in recovery, rehabilitation, and reconstruction

The Fifteenth Plan Fiscal Year 2019/20 – 2023/24

- Minimizing adverse impacts of climate change-induced disasters on people, property, culture, and economy
- Integrating disaster risk management in development activities.

Water-Induced Disaster Management Policy, 2072 (2015)

- Recognizing climate change as one of the main causes of water-induced disasters and highlights the need to develop sustainable infrastructure
- Making disaster prevention programs climate resilient.

Climate Change Policy, 2076 (2019)

- Formulating standards to develop a culture of safety in disaster for the creation of resilient societies.
- Developing monitoring, forecasting, and early warning systems for disaster preparedness.
- Integrating disaster risk reduction activities with climate change adaptation plans and programs.

Environmental Protection Act, 2076 (2019)

Highlighting measures to face impact of climate change.

National Transport Policy, 2058 (2001)

- Emphasizing environmental sensitive construction, management and improvement of roads and bridges.
- Making provisions for disposal of batteries, waste oil, grease, and other oily substances at designated locations.

Land Acquisition Rehabilitation and Resettlement Policy for Infrastructure Development Project, 2071 (2014)

Facilitating the land acquisition process for the infrastructure projects.

National Water Plan, (2005)

- Monitoring and auditing of programs.
- Avoiding and resolving disputes.

Water Resources Act, 2049 (1992)

Forming Water Resources Committee in each district.

National Building Codes

Insists on disaster resistant (e.g., earthquake) building construction and operation

Building Act (2055, amended in 2074) and bylaw 2075

Mandates ensuring of disaster resistant and environment friendly buildings with open space and safety.

The Land Act, 2021 (1964)

Provisions related to compensation issues

Local Government Operation Act, 2074 (2017)

- Granting the local level units legislative, executive, native, and judicial rights.
- Clarifying the functions, roles, and responsibilities of local government.
- Specifying the roles and responsibilities of the local governments in disposal of wastes, fixation of tariff in partnership with private sector and non-government agencies.

Gender Equity and Social Inclusion in Climate Change: Strategy and Action Plan 2077-2087, 2077 (2021)

- Mainstreaming gender equality and social inclusion in climate change adaptation at all levels of governance.
- Operate climate change financial management to enhance gender equality and social justice.
- GESI strategies implemented across sectors.

Climate Change Policy, 2076 (2019)

- Households at risk of adverse impacts of climate change targeted for climate-resilient livelihood programs.
- Local and indigenous knowledge will be used in formulating adaptation measures.
- Access to climate change-related information and technologies across languages, classes, cultures, ages, and sexes, and for people with disability enhanced.

National Adaptation Plan 2021-2050 (2021)

- Increase research on GESI and climate change and promote GESI responsive and climate resilient indigenous knowledge.
- Establish and strengthen GESI responsive multi-hazard early warning systems, capacitating the frontline service providers and community networks in providing GESI responsive emergency support.
- Develop, implement, and operationalize a GESI-responsive budgetary system at all tiers of government.

Reflections and Insights

REFLECTIONS AND INSIGHTS

09

Climate hazards and human interventions are changing both the terrestrial and freshwater ecosystems of CB districts, bringing with them cascading impacts on the livelihoods of communities . The change processes began prior to 1900 with the provisioning of land grants and commercial felling of *Sal* forests to build railway tracks in India and put the timber to various other uses and were stepped up with the eradication of malaria in the Tarai in the 1950s. These activities triggered the clear-cutting of forests and the subsequent conversion of forestland into farmland and settlements. The completion of Nepal's East-West Highway in the 1980s launched the expansion of ribbon like settlements along the highway and the CB districts saw, on multiple levels, rapid changes in their socio-ecological landscapes, including increased exposure to the impacts of climate hazards. However, the expected level of development in the region remains contested and inadequate. Issues of border inundation and the tangled web of bilateral relations with India are enmeshed in this history. The following sections present some of the insights from the study.

Documentation of border inundation is limited: There has been no systematic documentation of the current or historical state of border inundation though details regarding inundation in various locations are found in the minutes of Nepal-India meetings, secondary literature, and newspaper articles. No systematic monitoring of the impacts of inundation at specific sites is carried out either. In Nepal, the issue comes on the surface on episodic manner, often raised by media after the outcry of affected people when the area is inundated. The inundation events generate political and media attentions. With recession of the flood water, however, the matter cools down and is almost forgotten after the monsoon season ends.

Embankments are proposed as a panacea for flood disaster management: All bilateral meetings between India and Nepal since the 1970s have recognized the problem of inundation, and have proposed embankments as the solution. For solving embankment-induced inundation, more embankments have been proposed. The preference for engineering interventions in flood control is clear and is a reflection of the dominantly engineering-guided ethos of the water-sector agencies in the two countries. In South Asia, a reductionist engineering approach guides water development, including flood management, and is reflected in the preponderance of structural measures and ideology of controlling floods which are, paradoxically, beyond control. In some cases, writing by the agencies of the state questions the idea of total flood control; still, the momentum toward embankment-building continues. Theoretically, all the rivers in Nepal's CBs, Bihar, and Uttar Pradesh could be embanked, yet the region could still get flooded.

The embankment is part of the political economy: In more than 150 years of history, a political-economic nexus of engineers, bureaucrats, contractors, and decision-makers have been established. This nexus also carries over to water engineering education, which itself has barely internalized the negative environmental externalities of development. On the contrary, environmental consequences are considered to be an irritant to the development of structural interventions and their costs have been externalized to the future and unsuspecting societies. The reason behind the choice of structural measures is political economic. Embankments are visible and provide state agencies and political parties opportunity of winning public support by making immediate solution for the people. For the communities, the embankments emerge as an easy measure of respite from floods than the more sustainable ecological practices, which are long term.

People demand embankments for the immediate security they provide from floods: When faced with the immediate threat of a flood or bank erosion, community members request state agencies to act to provide security and respite from the threat. The embankment thus emerges as a straightforward, tested, easy and tangible solution for state agencies to meet the immediate need to mitigate floods. Embankments fulfill the notion of "safety" and are perceived to provide other benefits, too. The tops of embankments are used as roads and the so-called reclaimed land on the outside banks is used for real estate development and/or agriculture. During floods, at many times and in many places, the tops of embankments offer safe places for flood victims. Embankments, which are higher than adjacent flooded areas, remain dry. Here, affected families live and cook food until the flood water recedes. The longer the water takes to recede, the longer the embankment will remain their temporary home. In recent times, in a few areas of CBs development agencies have built flood shelters for community members to evacuate into a safer habitat for the affected community.

Embankments have long-term negative impacts and give a false sense of security: Embankments have negative consequences. They alter the river dynamics along whatever stretch they are constructed along, and, as explained earlier, have negative impacts in the long term. Embankments also constrain drainage, deteriorate local ecologies, increase exposure to flood disasters and breaches, and cause widespread damage to assets, livelihoods, and well-being. Large swaths of the eastern Ganga plains face waterlogging due to embankments. In a few instances, in the bilateral meetings, holistic approaches to the flood problem that will benefit both countries are mentioned. The outcomes of the discussions, however, are almost always purely decisions of structural solutions, perhaps reflecting the rigidity of the water sector agencies in both countries and of the political economy of flood mitigation[1]. Globally, it is recognized that floods are part of the water cycle and can never be fully controlled[2].

The change processes in CB region have been poorly understood: The CB region is ecologically diverse although not as dramatically as the mid and high Himalayas, which owe their diversity to their extreme difference in elevation. Because each CB district has distinctive natural characteristics and is at different stages of change, they are diverse in geography, natural resource availability, forest and soil types, ecosystems, biodiversity, ethnicity, language, cuisine, music, literature, folklore, and social networks. The landscape, which fifty years ago was connected by earthen roads plied by bullock carts, is undergoing social, economic, and environmental changes. Along the main roads in CB districts, the expansion of virtually green shade-less settlements comprising shopping malls and residential complexes simultaneously accelerates the processes of peri-urbanization and aquatic and terrestrial ecosystem degradation. These change dynamics require a contextualized understanding of development strategies to lower the risks extant in Nepal's CB districts and in downstream areas in India's Bihar and Uttar Pradesh, where rivers and other water sources face similar stresses.

As is true elsewhere in the country, the CB region will face ever greater climate change risks. Analysis of those risks and their impacts, however, have received less focus than similar phenomena in the hills and high mountains. Indeed, many studies suggest dire scenarios regarding the depletion of snow and ice storage and the potential for GLOFs in the Himalayan region and extreme rainfall resulting in landslides, flash floods, and siltation in the mid-hills. At the same time, the flow of springs originating in the mid-hills is dwindling due to a decline in recharge rates, changing rainfall patterns, and other landscape-level processes, including the high extraction of water from upstream hill aquifers. Global climate change will also affect the CB region making rainfall and the secondarily induced flood hazards more extreme. In addition, the region also faces droughts, heat and cold waves, and high winds. These change dynamics in the CB region will also occur with impacts in the mid-hills and Himalaya region and collectively impact millions living in both upstream and downstream areas.

There are three limitations to our ability to contextualize the impacts of climate change in the CB region. First, there is a dearth of scientific studies on the ongoing changes in CB districts. This gap also extends to assessments of the consequences of changes in the mid-hills and high mountains, consequences which cascade down onto the CB region via the linked hydrological system. This lack leads in turn to the second limitation. The nuances of the hydrological dynamics of CB rivers have received very limited attention. There are not enough studies that analyze both the long- and short- terms impacts of melting glaciers and other changes in the mid-hills on existing water systems in lower basins which are linked via the interbasin transfer of snow-fed rivers and existing water-use infrastructures such as barrages to CB basins. The third is our limited understanding of the changes of groundwater systems, particularly lowering of the water levels due combined impacts of excessive pumping, erratic rainfall and changing hydrological cycle spawned by climate change, extraction of riverbed materials, degradation of Chure region, haphazard urbanisation and more paved impervious surfaces.

CB region are affected by climate change in the HKH: The CB region is directly exposed to changes in temperature and precipitation, which has direct impact on the hydrology as well as other natural systems. The region faces heat and cold waves, strong windstorms which are getting worse in recent decades due to climate change. The cascading disasters like forest fire during dry seasion and flood during monsoon are also one of the consequences of changing climate systems. The CB basins are not linked directly to snow or glaciers, but their areas do get served by irrigation systems built in snow-fed rivers. Barrages built in the Koshi (including the intake at Chatara), Gandaki, and Mahakali rivers under Nepal-India treaties serve parts of the CB districts of Sunsari, Morang, Saptari, Bara, and Rautahat, West Nawalparasi and Kanchanpur respectively. The Rani Jamara irrigation canal, for instance, uses the water of the Karnali River serving land in the lower Karnali region in Nepal. Similarly, irrigation barrages and weirs in the Kankai, Kamala, Bagmati, West Rapti, and Babai rivers serve command areas in the CB while ongoing and proposed inter-basin transfer projects divert snow-fed rivers into these same Mahabharat rivers, augment their dry season flow and serve land in CB districts via the existing barrages. A few irrigation projects have also been built on small seasonal CB rivers. Thus, along with their inherent challenges, the CB rivers will also face external challenges posed by changing precipitation patterns and extreme weather events in the high-mountain and mid-hill regions. The risks will be transferred to users via existing systems.

The degradation of the interdependent ecosystems of CB districts and large river catchments and the attendant disruption of their services leads to cascading impacts: The Chure range is an important natural constituent of the CB region. Its ecosystems provide various services, including the provision of water which supports both surface and groundwater sources across CB basins. Despite their shared dependence on the monsoon and headwaters in the Chure region, each river of the CB has a unique character and will therefore respond to change differently. The interdependence between surface water flow and groundwater is recognized, yet poorly understood. The ecosystem degradation in the CBs will have impact on the greater Ganga Basin including its acquifers as the ecosystem degradation is primarily resulting to either too much, too little or too dirty water.

The nature of floods and risks in CB districts is changing: As is true in the rest of Nepal, extreme rainfall in CB basins is a major primary event, one that triggers secondary flood hazards in downstream regions. In the CB region floods damages in recent decades have increased due to increasing exposure, but the number of human casualties has decreased due to the implementation of flood-warning mechanisms. In many cases, the data needed to establish a direct link between extreme rainfall and flood damage is not systematically available. The changes in the flooding is due to combined impact of climate hazards and land use conversion including poorly placed physical insfactructure.

There is a lack of systematically collected data on hydrology of CB rivers: The lack of data on river discharge and sediment flow is a major limitation in the design and management of water systems in CBs. Though the measurement of river discharge in Nepal started in the 1960s, the flows in rivers flowing through CB districts are not systematically monitored, thereby making accurate forecasting of flood discharges of different magnitudes and calculating needs for water allocation difficult. However monitoring discharge in these seasonal rivers is not easy. The channels are not well defined as that in the hills where permanent stations can be set up for monitoring flow.

In some cases, water flow data for a short period is used but doing so decreases the accuracy of the parameters obtained and may result in less-than-ideal or even inappropriate designs and management schemes for water infrastructures being adopted. Because flow data is limited, indirect methods based on rainfall data, which is generally available for longer periods, are resorted to. However, as climate change continues to alter the subprocesses of the hydrological cycle such as rainfall, the use of its historical data to determine project designs will be increasingly inadequate.

Data on disaster damage and losses are fragmented: The number of flood-related casualties can be minimized or even eliminated though, of course, even a single human death cannot be accounted for in monetary terms. In contrast, damage like the loss of agricultural harvests and disruption of the functioning of human-built infrastructure can be estimated and its economic value worked out. Since 2006, the MoHA has maintained systematic data disaggregated at the district levels on the number of deaths and cost of economic damage due to floods. Its estimates of damage to agriculture and infrastructure, however, are available only in sectoral sources and not yet systematically included in its platform. Nepal's 2015 Constitution and the Local Governments Operation Act of 2017 specify the responsibilities of local-level entities for disaster risk reduction actions. These responsibilities include accounting of damage and loss. Local authorities, however, are not yet systematically and institutionally involved in this process. Until they are involved and the link between impacts and extreme events is established assessments of losses and damages will be uncertain and limit the effective design of strategies for minimizing flood disaster risks.

Flood early warning systems save lives and help build resilience: In response to flood disaster reduction, three trajectories are evident in CB districts: a structure-based approach, the practice of relief, and the use of flood early warning systems. The structure-based approach has a long history and, despite its long-term negative impacts, which tend to get discounted during decision-making, has become part of the culture of the political economy as the preferred response. The relief-based approach dominant till 1990 is struggling to be more holistic: it now embraces in its purview preparedness, reconstruction, and rehabilitation. Even so, structural options and providing relief continue to remain the political preference. The use of flood early warning mechanisms is more widespread now than it was two decades ago, and the use of community-based early warning mechanisms has saved lives from floods.

This evolution rooted in a history of efforts that began in the 1950s with governments' interests and later by non-government agencies in Nepal provides useful lessons. Though Nepal and India initiated the idea of flood forecasting in 1977, this process was not grounded well. Around 1995, rudimentary pilots began to be implemented to develop localized community-based early warning systems. These systems have evolved through trial and error, resource allocation, and stakeholder partnership, but they are still not systematically aligned with the policies of governments as is necessary to promote ownership and sustainability. The learning from NGO-facilitated cross-border flood EWS projects can help scale up CBEWSs, encouraging them to take action and achieve impacts over a larger area.

Conventional ways of designing water infrastructure are inadequate: With the increase in population and expansion of settlements and cities, CB districts are witnessing fast-paced change and are exposed to elevated climate risks. Access to basic services like drinking water, health services, information, food, and commuting is central to successfully responding in a fashion that can minimize disaster impacts. In CB districts, pipes and hand pumps, irrigation canals, and mechanized pumps provide water services. While roads, bridges, and airports are foundational for connectivity and commuting, access to clean electricity is the gateway to other services and opportunities. The functioning of the pipes, pumps, and canals which provide water-based services depends on the integrity of the water cycle, which however, is no longer the same as it was say 100 years ago. The changes it has undergone are manifested in the cycle's sub-processes, which, because of the alterations, have adversely affected the normal functioning of water-based use systems.

Because the changing climate is further altering the nature of these sub-processes, existing tools, and metrics used to design and develop water-based infrastructure will increasingly be limited in their ability to address flow responses. Officials in Nepal and the CB districts have accorded little attention to the sub-processes of the hydrological cycle, particularly the systematic monitoring of discharge, in their development of infrastructure. Instead, they rely on ad hoc methods, for example, that limit their utility in the designs of bridges. Our review suggests that in Nepal the design and construction of bridges are poorly linked to water flow. This is in part because data on river discharge is limited, and the designs of bridges, roads, and other infrastructure rarely take into consideration their interdependence with the river's regime. In the future, when climate change makes extreme events more frequent and river discharges during the monsoon are thereby likely to increase dramatically, the waterways of bridges may be inadequate for the task of smoothly facilitating commuters.

The quality of an infrastructure's design and management determines the quality of its services: The pace of infrastructure development (e.g., the construction of roads, embankments, bridges, and urbanization) in Nepal's CB districts is increasing. Roads are used for commuting, trade, and receiving goods and services supporting development. In many cases, roads are also used as a place of refuge during floods. The conceptualization, design, construction, usability, and maintenance of roads, however, do not attend to the increasing risks of climate change, particularly those related to the waterscape and temperature extremes.

The designs of bridges and culverts are poorly linked to water flow: In Nepal's CB districts, where all rivers flow from north to south and major highways run perpendicular to the flow regime, bridges and culverts help provide uninterrupted service and ensure the connectivity of rural and urban lives. While modern bridges are structurally robust, their designs have not internalized hydrological externalities. During floods, many bridges have failed, thereby disrupting the continuity of their services. The following factors have led to bridge failure in the past:

- Insufficient linear waterways to accommodate increasing flood peaks and detritus.
- Over-topping, with buoyant forces lifting decks, leads to their failure.
- Debris impacts and drag effects.
- Inadequate scour depth.
- Inappropriate construction practices.
- Designs poorly linked with river flows and road stretches.

Multidisciplinary representation in bilateral flood management efforts is limited: The interactions among officials for policy-making from water sector agencies, particularly those in charge of irrigation, flood control, and disaster risk reduction are limited. In the dialogue, the representation of other departments of the government in the dialogues was limited and there was no representation at all of the faculties at universities, other academic institutions or the communities. Considerations of gender, livelihoods, and environmental concerns, all issues central to flood mitigation, are missing from the dialogue, as is the acknowledgment of the ways with which locals use traditional knowledge to deal with the natural sequence of floods.

Nepal-India bilateral discussions on floods are limited in scope: Our review of the minutes of the meetings between Nepal and India from 1971 to 2020 (50 years) provided useful insight into the dynamics of the negotiations between the two parties, the use of scientific evidence, the institutional conception of flood problems and solutions, and the responses of the agencies of both states to minimize floods. In this preliminary examination we found that each side articulated its position, and sometimes even made contradictory demands, and agreed, despite differences, to maintain the conversation. Participants also discussed the inundation of specific sites along various minor tributaries. Nepali officials tended to present details about the inundation of areas along the border, in doing so demonstrating the presence of a mechanism that makes information available from the local context to the officials in Kathmandu. Similar local-to-central communication seems to exist in India, too.

In the 50 years of minutes surveyed, projects proposed for construction in snow-fed rivers dominated the discussion. During this period (1971-2022), no less than 110 official meetings were held. During them, participants discussed 530 individual subjects, which we researchers grouped broadly into five categories (see Table 6.6). Slightly more than 45% of the discussion subjects were related to large-scale projects proposed for construction in snow-fed rivers such as Koshi, Karnali, and Mahakali. Another 45 percent of the subjects were related to the problems of inundation along both the border and seasonal rivers. Flood forecasting comprised 7 percent of the themes discussed. The minutes reflect limited considerations of the multiple services that water provides to nature and communities. As discussed in Chapter 6, in the 20 years after 1970, Indian and Nepali agencies engaged in flood management efforts did accommodate the ideas of flood warning and forecasting. The agencies of the two states exchanged data to that end.

However, their efforts did not yield fruitful outcomes on the ground benefiting those on the frontline of flood disaster impacts. Despite its limited success, this movement towards preparatory measures is part of a historical layer that led to the beginning of the piloting of flood early warning mechanisms in 2000. This shift was also the outcome of Nepal's political changes in 1990, in whose aftermath, more actors outside of the state realm began to get involved in activities related to the management of flood risks and reduction of vulnerability. Over the past two decades, since early 2000, the flood early warning mechanisms piloted by these actors and facilitated by the state agencies with the participation of private telephone service providers have helped minimize the loss of life.

The engagement between Nepal and India does not include a conversation about the challenges of reducing vulnerability to climate change impacts: Climate change will affect in several ways and the hazards and impacts that cascade across boundaries, the challenges of taking adaptive actions, or the need to develop synergistic responses to these challenges in a region of interconnected eco-hydrology. In addition, very little learning from discussions conducted outside the formal tracks has found salience in the formal processes of the two governments. As a result, policy responses are not informed by emerging insights into the changing nature of climate hazards, flow responses, and increased hazard exposure. Such insights have not found their way into the water education stream to a considerable degree. Bilateral discussions do not seem to provide or internalize lessons in formulating public policies. Each meeting of the representatives seems to justify rather than reflect on the earlier decisions.

Bilateral interactions on floods mitigation do not include natural ecosystems: Interactions between Nepal and India take place among various actors and sectors, including trade, customs, security, religion, medical treatment, and people's travel. That these engagements are examples of plural diplomatic avenues that can contribute to positive Nepal-India relations has not been foundationally realized. Thus, the engagements remain fragmented and their role in the stewarding of the larger environmental context is poorly included in formal diplomatic processes of flood mitigation. Further, discussions on development, security, and economic areas have not adequately recognized the increasing environmental risks the two countries and the people face.

Public policy implementation is ineffective: The preceding chapters, though they focus on flood management, show that Nepal's approach to water development and management continues to be based on the notion of control and falls short of meeting the objectives of including smallholder farmers, marginal groups, and natural ecosystems in a consideration of its benefits. Despite the existence of public policies on gender, equity, and social inclusion (GESI), actions in CB districts that make tangible improvements for people in general and the flood-affected in particular are limited.

Sediments are beneficial but this fact is not recognized in the design or calculus of flood management: The current structurally dominated approach proposes that floods, a natural part of the regional water cycle, are a problem to be avoided entirely. Rather than recognizing that sediment is an inherent constituent of flow, this approach defines it as an externality and, unsuccessfully, seeks a total solution to it i.e. total flood security. The fact that floods are a source of nutrients and recharge groundwater is not considered in the development of management strategies.

Irrigation systems have not yet contributed to improving agriculture in Nepal's CB region: The cost of public irrigation is not commensurate with the benefits that such a large investment has for farmers and the state. Nepal's need to import the majority of agriculture products in large amounts, a need that leads to food insecurity and lowers resilience, is an indicator of this deficiency. The strategic role that investment in irrigation can play in helping Nepal achieve its SDGs has not yet been systematically analyzed.

The water quality of CB rivers is declining: Very few cities in Nepal's CB region have wastewater treatment facilities, and those that do exist do not work. Similarly, solid waste management is very rudimentary. The haphazard disposal of untreated solid and liquid wastes characteristic of all CB districts degrades riverine environments and water quality, affecting the aquatic ecology of those bodies as well as the livelihoods of those who depend on river water ecosystems for survival. While some municipalities have received support for improving drainage and minimizing pollution, in many places stagnant drains emit foul smells and are the source of many water-borne diseases, an unsanitary condition unlikely to change soon. If the abatement of pollution is left unaddressed, there are likely to be cascading impacts. Arsenic contamination, for example, has not only decreased the gains associated with using groundwater from shallow aquifers for drinking but also forces communities, particularly those at the social margins, to return to using polluted surface sources for drinking.

Improper disposal of human waste ultimately threatens wellbeing: The proper disposal of solid and liquid waste has received little attention in the CB region. The surface drainage systems in the cities of that region are inadequate. Waste and stormwater are allowed to discharge into downstream regions and, in many cases, have left downstream communities dissatisfied. With the pace of urban development accelerating, the use of flush and pan toilets in houses is increasing. In some cases, toilet waste is disposed of in soak pits, but in most cases it is allowed to flow into rivers and streams, degrading riverine environments and water quality. The seepage of fecal materials from soak pits has polluted groundwater and begun to seriously affect aquifers below the Bhabar region. The high permeability of the CB region suggests that both groundwater aquifers and those further south may become contaminated. With the expansion of urban areas, the amount of wastewater produced in the major cities of the CB region has increased. Other change processes include new consumption patterns which are also likely to increase the amount of waste produced. Despite the significance of these changes, neither the urban nor rural areas of the CB region keep systematic data on either the total volume of wastewater produced or its type.

Haphazard mining of construction-grade materials from rivers hurts ecosystems, communities, and economies: Sand and aggregate mining are fueled by the increasing pace of urban and infrastructure development. Sand is an essential material for the construction of houses and other edifices. Sand is no longer an infinite resource in many countries, including those in South Asia. Sand is part of a well-established supply and demand ecosystem, with an embedded nexus of contractor-politician-mafia members that survive in a regime of poor governance. Many other countries also face similar challenges; indeed, the scale of sand problems is increasing across the globe[3]. The mining of sand from rivers, as well as terraces and riverbanks, is unregulated and haphazard which has long-lasting negative impacts on the morphology and surrounding landscape of rivers. These impacts cascade downstream, degrading other, connected ecosystems and waterscapes and threatening communities. They lead to the deterioration of beds and banks, changes in watershed responses, and alterations in sedimentation dynamics and riverine ecology. Landscapes altered by sand extraction contribute to flooding and siltation, damage infrastructure and local assets, and can even result in the loss of life[4]. The debris from excavated areas is often deposited on farmland and in settlements, clogging drains and preventing runoff from draining quickly, thereby causing inundation[5]. Haphazard sand extraction can have the following adverse impacts:

Sand extraction impacts groundwater and local water sources: Sand extraction adversely affects groundwater discharge and alters the dynamics of a balanced natural ecosystem. In particular, it changes flow dynamics and may lead to the depletion of local spring sources and the lowering of a groundwater table that already suffers excessive pumping.

Sand extraction hurts livelihoods: The above changes may affect people who depend on services from natural ecosystems. Families at the lower rungs of the economic and social ladder who make a living by mining sand and aggregates from rivers and selling them to local contractors may lose out.

Sand extraction negatively impacts the economy: The haphazard extraction of sand and construction-grade materials can accumulate negative economic impacts. In 2007, the GoN earned NPR 12.37 million from the sale of such materials; those earnings increased to 387 million in 2017. Over the ten years from 2007 to 2017, the GoN earned NPR 960 million in revenue from the extraction of minerals and construction-grade river materials. In the same decade, disasters resulted in economic and financial losses estimated at NPR 38,233 million. The damage was almost 40 times more than the benefits[6].

Sand extraction can heighten social tensions and violence: The unregulated extraction of sand and aggregates in the CB rivers has escalated social tension and violence in both Nepal[7] and India[8].

Water education perpetuates narrow sectoral views: The state agencies that work on water issues seem to constitute an insulated domain that has chosen to keep itself aloof from ongoing changes. One of the reasons for this detachment could be that the representatives in India-Nepal dialogues have generally been engineers and engineering viewpoints have prevailed. These engineers work within an institutional culture that evolved in the pursuit of a particular knowledge stream, once which assumes that stock-and-flow modification is the most rational and appropriate structural approach to water problems. This supply-driven approach focused on engineering and structural solutions have meant that a hierarchical management style and pedagogy have been the hallmarks of the prevailing water resource education. By and large, this approach to education is not only single-disciplinary but also blind to gender and social inclusion. The few efforts to alter this orientation lie in the periphery[9].

Environmental governance is almost absent: In the early 1990s Environment Impact Assessment (EIA) emerged as a tool to identify, predict, and evaluate likely impacts on project-affected people. It was enunciated as the country's working principle. Based on the findings of the assessments before a project is built, the purpose of EIA is to put in place safeguards and measures to minimize the consequences of the intervention on the environment and dependent communities. The idea behind this precautionary principle is that problems are prevented rather than addressed later when irreversible changes may happen. EIAs and IEEs however, are carried out ritualistically and are not used as instruments with which to effectively monitor compliance and stewardship of the environment. The ability of EIAs to engage in a project site-based strategic analysis of the impacts of a given project on water dynamics is limited, and governments ignore the implementation of mitigating measures as well as the strategic impacts.

In addition, compliance with the policy is poor. Though some policies have overlapping jurisdictions, their implementation is sectoral, restricted, for example, to water resource development and management, and falls short of meeting the needs of human and ecological communities. The lack of coherent implementation of policies acts, and regulations and poor coordination among agencies are evident in the practices of natural ecosystem conservation and infrastructure developments. Many policies and acts adopted before the promulgation of the 2015 Constitution are still in use and have yet to be reconciled with federal governance. The prevailing approach leads to ecology, efficiency, and equity crises that deplete resilience. For example, decision-makers have little understanding of the role small rivers can play in contextualizing flood disasters. Participants interviewed during this study did recognize that the small rivers of the Ganga Basin are a climate change hotspot, but their understanding of the challenges in the context of Nepal and India relations was limited.

Transboundary water treaties between Nepal and India fall short of responding to climate change-imposed stresses: The existing instruments between Nepal and India that address transboundary rivers are the agreements on the Koshi, Gandaki, and Mahakali rivers. The ethos of engineering and technology as solutions to flooding, irrigation, and hydropower development guided these treaties. These treaties make provisions for allocating the waters of the rivers for irrigation, flood control using embankments, and generating electricity to the benefit of each country[10]. In all cases, the allocated amount of the resource (water) to be used within the jurisdiction of an individual country is guided by the policies of that country's government. No treaty's provisions cover water management, promote participation, or recognize emerging risks, nor do they call for joint transboundary water management. As a result, these treaties are highly limited in their ability to address the emerging risks associated with climate change and harness opportunities to build resilience and help people adopt adaptive actions. The context of real power asymmetry between the signatory countries when some of these treaties were signed about 70 years ago has widened and it is not clear how synergistic responses between the two countries would emerge.

Despite asymmetrical context Nepal and India's relationship is diverse and yet interdependent: The interests of Nepal and India are diverse, and power disparities and differences in institutional capacities are real. At the same time, both countries are facing common environmental challenges due to the impacts of climate change that have manifested themselves in the CB regions of both countries. Nepal and India, for example, once had very clear differences in economic development, institutional capacity, infrastructure development, and political system. Today, that asymmetry remains, but both countries have advanced. India now aspires to become a five trillion dollar economy, while Nepal aims to graduate to a middle-income country. The common environmental challenge they face also offers opportunities for them to begin constructive engagement to broadly address risks currently emerging in the CB region. A common feature in the CB region on both sides of the border is the fragmentation of the information-and-knowledge base, a condition which limits officials' ability to engage in both effective adaptive policy framing and decision-making about how to steward health of small rivers.

Civil society-based water dialogue is episodic and fragmented: Several local civil society organizations have taken the initiative to respond to flood risk management, minimizing vulnerability, livelihood enhancement, river restoration, and capacity-building. However, there has been limited direct cross-scale learning, particularly on the part of government agencies. These civil society efforts remain anecdotal and have not been scaled up for transformative action. Local efforts related to vulnerability reduction, water management, and adaptation action provide useful lessons but these are scattered and await amalgamation into a coherent whole. Thus, good practices are rarely replicated through policy uptake. In some cases, however, such civil society efforts do also involve state agencies. For example, early flood warning systems in some CB rivers also involve Nepal's DHM and the systems have also benefited downstream communities in Uttar Pradesh and Bihar.

Local governments have a limited role in flood disaster mitigation actions: Nepal's 2015 Constitution spells out the role of local entities in disaster risk reduction, which itself embraces flood disaster management. Like the responses of the central government, local responses are also guided by the objectives of providing immediate rescue and relief. The constitutional and legislative provisions, however, that include preparedness, reconstruction, risk reduction, and resilient development are not effectively addressed.

Alternative employment opportunities are limited: The absence of alternative livelihoods and employment opportunities is a major challenge in the CB region as these districts have some of the highest rates of outmigration out of 77 districts of Nepal. In CB districts, services from both natural ecosystems and infrastructures are inadequate, and opportunities are limited. They do not support individuals to tap into diverse income sources provided by both natural ecosystems and infrastructure. Remittances sent home by a migrant member of a household are an alternative income source, one that does not rely on either agriculture or natural resources. That said, many households are still involved in natural resource-dependent livelihoods such as agriculture, NTFP collection, and fishery. Each of the latter livelihoods is already at risk due to climate change.

Small-holding farmers, tenants and landless are becoming more vulnerable: A few locally knowledgeable people of CBs, we purposively contacted, recognized flooding as the major hazard in their villages along with increasing instances of droughts. Both in the past and the present, these disasters impact small and marginal farmers who face a multitude of problems including degradation of their land worsening their condition. They said that damages are high when congestion of flow inundates their land. The inundation results in submerges of low-lying farmlands and can last the entire monsoon season, damage crops, and while receding, the water drains away some of the topsoil and nutrients.[11] While such conditions repeat every year aggravating risks, farmers have limited meaningful support in mitigating them. Many others in Nepal CBs also mention increasing heat in summer and monsoon is uncomfortable, damages crop and lead to unknown problems which is not yet systematically examined.

NOTES

1. Some years ago, the lead author had a chance to interact with India's ambassador to Nepal. He had asked the ambassador if it would be possible to widen the support which Nepal receives from India for border inundation to include early flood warning systems, local-level interactions, research, and livelihood enhancement. Diplomatically, the ambassador had replied, "That, unfortunately, is not part of my remit."
2. See Fox (2003).
3. See Pedro (2020).
4. Bhattarai et al (2018).
5. See Sada (2013).
6. See Dixit et al (2000).
7. Ramu Sapkota (2021) discusses violence and death of a social activist while opposing rampant extracting river bed materials in the Ratu River in Nepal putting settlements along the river banks at risk. https://www.himalkhabar.com/news/127840
8. The Son River in South Ganga Basin also faces similar problems related to sand. See Khan (2022) for a discussion https://www.thethirdpole.net/en/nature/bihar-illegal-sand-mining-devastates-rivers/.
9. Based on Dixit et al. (2021).
10. The treaty between India and Bangladesh regarding the sharing of the Ganga River's flow at Farakka is going to expire in 2026.
11. See https://www.microsave.net/2023/01/27/impact-of-climate-change-on-smallholder-farmers-and-their-coping-strategies/

Recommendations

RECOMMENDATIONS

10

The study demonstrates that little is known about changes in the CBs region and that ecosystem degradation is on the rise and adverse impacts of climate change impacts makes communities more vulnerable. The impacts of extreme weather events cascade through the water system and lead to adverse social and economic consequences on the CB region and its population. Effective flood management must consider interactions among the five pillars of resilience deploy a mix of systemic socio-economic development interventions, policies and institutions, engineering, and nature-based solutions. Based on the findings, analysis and insights in the preceding chapters, specific recommendations are explained in the following sections.

Systematic documentation of border inundation: The joint maintenance of inventories and an interdisciplinary study of selected rivers that include both local and regional climate, hydrological, flood management, social, and livelihood contexts will provide evidence-based information for dialogues and necessary decision-making on holistic flood risk management approach in CB basins. The process should engage JCIFM in identifying ways to mainstream holistic approach to flood risk reduction and management. Regular on-site monitoring of border inundation could be a starting point for the collaboration of academics in Nepal and across the border in Uttar Pradesh and Bihar. In addition, a systematic study supported by ground-truthing needs to take inventory of the seasonal rivers. Carrying out this endeavor in partnership with local entities in Nepal and across the border can yield a better result from particpation in and ownership of the process and implementation of practical actions for resilience building.

Balanced water cycle promotes resilience: In the changing climate system, where weather extremes and water-related disasters are increasing, albeit with significant level of uncertainty, the business-as-usual approach will not take us to a secure future. The CB region is fragile in itself and faces secondary hazards from the upstream regions. Given that climate change will cause extreme events to become more common, a paradigm shift is required in our approach to flood risk reduction and natural resource management, one that should begin with maintaining interrupted drainage. In the CB districts of Nepal, linear infrastructure such as major roads and the proposed Mechi-Mahakali railway directly crosses the north-south flowing rivers at right angles. The spatial arrangement of natural and manmade structures is similar across the border. New design approaches are needed must consider the relation of linear infrastructures with water flow broadly and be guided by the goal of providing sufficient waterways under bridges and culverts to accommodate extreme rainfall-caused floods and sediment pulses. Similar accommodating measures must also be applied in the case of roads and railways aligned perpendicular to topographical contours. Flood risk reduction should be grounded in the objective of providing space for rivers to flow. This principle is also valid across the border, where the terrain is flatter than it is in Nepal CB districts. The conventional approach has limitations and upstream breaching of embankments has led to inundation across the border in Bihar and Uttar Pradesh India, too.

Design physical infrastructures that take account of the increasing climate risk: We need to develop new design tools that show links among climate change impacts, flow responses, and the assumptions of infrastructure designs. The design, construction, operation, and maintenance of infrastructure must consider the increasing risks posed by climate change and incorporate measures to rebuild disrupted systems and restore the continuity of their services to beneficiaries. Measures are needed to restore infrastructure to a better condition without reproducing the sources of vulnerabilities that led to disruption in the first place. In other words, up-to-date design approaches must ensure that infrastructures can adapt to extreme floods and rising heat an emerging threat in the CBs. Particular attention needs to be focused on incorporating nature-based solution in flood mitigation effort as a cheaper method and build local resilience. The building of infrastructure must be accompanied by mitigation measures and full-cost accounting.

Anticipation of floods greater than those designed for: Particular attention needs to be focused on the design of water structures such as barrages, bridges, and culverts so that they have sufficient under-passage space (linear waterways) for floods. The higher the magnitude of the rainfall in a landscape that has become less permeable with land-use changes and concretization (in a broad sense), the greater the magnitude and the more instantaneous the flood peak of a watershed will become, and infrastructure will need to have sufficient waterway to safely accommodate the peak floods that will come with a mix of water, sediment, and detritus. For this reason, designs need to consider upstream watersheds and river morphology, and, in the case of bridges, links with river banks connected to roads. In addition, methods for calculating scour depth need to be reviewed and updated. To that end, a systematic review of the past failures of bridges and recent floods and their impacts on bridges needs to be conducted.

Systematic collection, maintenance, and use of water flow data and groundwater dynamics: A review of approaches to the design and development of water (barrages, weirs, embankments) and other infrastructures (bridges) is needed. It should examine methods of estimating the return period flood used in those designs and recall the need to consider the economic and social importance of infrastructures in any new design. In the new regime imposed by climate, design flood estimates for water use and water-dependent structures must be based on continuous discharge records, despite limitations that non-stationarity imposes. The duration and other parameters of those records should be decided through consultation among climate scientists, hydrologists, designers, academic and local communities. It is equally important to investigate the status of groundwater stocks, typologies of aquifers, water tables, uses and recharge dynamics for harvesting of the resource base that primarily supports the CB's populations' needs of drinking water, irrigation and other needs.

Replication and scaling up of community-based early flood warning systems in a coordinated fashion: The use of Community based early warning systems (CBEWSs) has prevented the loss of human life in Nepal and, to a certain extent, at the transboundary scale but the measures implemented have not been institutionalized. Much more needs to be done to improve EWSs at the transboundary scale, including increasing the participation and representation of at-risk people. In bilateral interactions, the participation of representatives of the local governments of both countries (district magistrates/municipal mayors) needs to systematically expand in incremental steps. Doing so will lead to win-win outcomes as decisions will be informed by local context and the needs of people at risk. Community-owned and -managed strategies are an appropriate vehicle for building cross-border trust among people as part of decentralized governance which aims to minimize flood risks. While functional CBEWSs are key to reducing risk, actions targeting the minimization of flood damage to assets and the improvement of the well-being of households at the social and economic margins are equally needed.

Minimum fragmentation of natural habitats by infrastructure in the CB region: The highways passing through national parks have fragmented ecosystems and led to the accidental deaths of wild animals. Passages for the movements of animals in such infrastructure are not connected with flood management, however, although their adoption is guided by the desire to maintain ecological continuity and watershed health. Avoiding fragmentation in the design, implementation, and management of infrastructure recognizes that self-healing nature will contribute to the building of the resilience of watersheds. The likely positive outcome will be fewer cascading impacts when extreme events occur. Nepal's Department of Road (DoR) has designed various types of passages for the movements of wild animals; these must be implemented strategically.

Proper consideration of forest fires and forest clearance in the Chure and Bhabar regions: Recurrent forest fire in the CB region degrade land cover and increase soil erosion and eventually lead to higher floods and more siltation of rivers. A conserved forest, in contrast, can provide livelihood opportunities as well as minimize erosion. Law enforcement is necessary to curb forest clearance for agriculture, settlement, and timber, fuelwood.

Incorporation of the sustainable management of wetlands in the CB region: The Chure, Bhabar, and lower CB region have different ecological characteristics. While ponds and oxbow lakes in CB districts are significant from the perspective of livelihoods earned through fishing as well as of supplementary protein in the diets of communities, waterbodies in the Chure and Bhabar support the recharging of aquifers in the lower Tarai and the inflow of water supplies to ponds, oxbow lakes, and wetlands. Management of these water bodies must consider rising temperatures and siltation during heavy flooding with the objectives of minimizing impacts.

Land-use regulations that lead to balanced development: Expanding settlements in CB districts encroach on and pollute rivers and water bodies and this pollution and encroachment adversely affect the lives and livelihoods of CB residents. Local municipalities must begin preparing, designing and implementing risk-sensitive land-use plans, and agriculturists need to apply appropriate technologies like bunding terrace farming, the stall feeding of livestock, and crop diversity to promote adaptive action.

Effective use of existing tools to support environmental stewardship: EIAs and IEEs are instruments that the GoN uses to regulate the extraction of construction-grade materials, mitigate harm, and ensure effective implementation, compliance, and monitoring. Effective enforcement of conservation laws and policies and strict implementation of policies based on landscape-level responses are needed to avoid an environmental downturn and promote effective risk mitigation measures through synergistic interagency cooperation in the planning and implementation of policies. In Nepal, one major endeavor must be to align the policies, laws, and regulations of the federal, provincial, and local governments so that horizontal and vertical synergies can be generated and maintained. Sectors such as roads and railways, irrigation, forestry and agriculture involved have their specific roles and responsibilities, yet need to strive for coordinated efforts for risk reduction and building resilience. Instruments such as the polluters-pay principle, penalties, and taxation can be useful. The effective implementation of policies also requires grounded scientific evidence, the validation of people's representation, and stakeholder engagement.

Regulation of river sand mining: Sand is a key ingredient in achieving development as it is used in large amounts in various construction sub-sectors. Its mining has created opportunities for governments and the private sector to earn higher than existing incomes through its trade. Mining sand also serves as a source of livelihood among some low-income families. It is crucial to effectively regulate mining in the Chure hills and the rivers of CB districts for stone, pebbles, and sand. The ballooning of demand currently makes balancing the volume of materials extracted and the volume naturally replenished an unachievable goal, yet it is nonetheless necessary to move towards a future of balance. To minimize the negative impacts of the extraction of riverbed materials on the environment, the capacity to monitor compliance must be improved. It is essential to embed conservation priorities into all of the political and economic development activities implemented. At the same time, it is necessary to determine the number of people involved in sand mining to earn a living. Local governments must take systematic initiatives to identify sand-mining families and take measures to provide them with secure alternative livelihood sources.

For effectiveness policy synergy and coherent responses: Efforts are needed to achieve coherence among policy implementation and the practices of disaster risk reduction, preparedness, and response. Among the measures to be drawn upon is the use of flood early warning systems in the CB districts. Flood risk management must be made within an approach to water stewardship that promotes the use of adaptive policies and continuous creative engagement among decision-makers at the federal, provincial, and local levels. In doing so, community groups, various service providers in the private sector, and other stakeholders need to come together and play constructive roles. It will also be important for Nepal to harmonize its policies, and to the extent practical, across the border with the policies of India to foster synergy. Both Nepal and India should involve civil society actors and NGOs in risk reduction and resilience building initiatives in the CB watersheds and cross border initiatives. The resultant synergy can open avenues for further contextualizing the idea of building resilience across boundaries. Those with low-paying jobs and without jobs at all need special consideration.

Improvements in water quality: Maintaining water quality should be an overarching priority at all levels in CB districts. Since addressing water quality and reducing pollution are related, the following are important aims to pursue:

i. It is necessary to begin assessing the number of point and non-point sources of pollution at the levels of households, municipalities, commercial/industrial units, agricultural farms, and watersheds.

ii. It would be useful to separate brown, grey, black, and storm water discharges, but a practical way forward to achieve this is far from clear. Using low-volume flushes, waterless urinals, eco-sanitation, and pour-flush devices can incrementally add to the goals of making rivers and other water bodies waste-free. Their use can also help improve the sanitation of households and settlements.

iii. Municipalities must make the removal of arsenic contamination a top priority. People dependent on tubewells that pump water from arsenic-contaminated aquifers must be provided with alternative water sources. Creating a database on arsenic contamination will be a major step towards narrowing the gap and building the information base needed for mitigating the associated risks.

iv. Efforts must be made to ensure that the quality of effluents from industries is kept within the limits set by national standards. Doing so requires building the capacity of local institutions and adopting and enforcing measures to ensure policy compliance. For this purpose, dedicated financial resources will be necessary. Calculating the volume of wastewater produced from the average daily per capita water consumption in these areas can help plan for the treatment of waste at source using appropriate methods and institutional designs with municipalities at the center.

v. Given the diffuse nature of the pollution from agricultural farms and the dependence of agricultural practices on commercial fertilizers, addressing pollution from agricultural runoff will be hard. The way forward requires research, action, experimentation with organic fertilizers, and dialogue with farmers. Simultaneously, awareness must be built.

Empowerment of local communities and agencies: Individuals, families, communities, NGOs, and the government agencies respond, cope and adapt to hazards, including climate change, based on their characteristics. Such responses must be reviewed to glean lessons on resilience-building actions for them. Provincial and local governments must be supported to play the pro-active role of facilitators: While state-level actions are key to maintaining the quality of rivers and other water bodies, independent audits are equally crucial to ensure that the policy space is creatively contested by civic groups required to ensure compliance. Engagement with local municipalities across the border can help in the pursuit of plural diplomacy between India and Nepal and the production of desired outputs that benefit the people of both countries. Active and engaged local governments can keep CB districts balanced, conserved, and able to restore themselves faster following a weather-triggered disruption, thereby helping to bolster the resilience of those districts.

Improved access to climate services: The changing climate warrants better access to climate services such as weather and flood warning information as well as other support services. Nepal and India must collaborate in sharing data and information about extreme weather events and potential flood disasters. While Nepal can provide real-time information on rainfall and flooding in upstream areas, India should provide Nepal with access to its superior weather forecasting capability to develop river basin-focused weather forecasts and flood risk monitoring. In addition, improving access to information about resources, markets, and financial services can significantly help smallholder farmers reap the benefits of ongoing digital innovations.

Reflexive reviews that generate interdisciplinary knowledge: The response to address the emerging water challenges in CBs should be based on a system of integrated knowledge that synthesizes natural sciences, social sciences, indigenous knowledge, and local practices[1]. This synthesis should help build a new social compact on water that incorporates the following values.

- Rivers need sufficient space to flow freely and be clean enough to sustain iconic aquatic systems and human needs while still being able to safely evacuate flood flow.
- Open and green space must be conserved and new sponges in the urban regions developed to promote groundwater recharge.
- Human wastes without treatment should not be dumped in water and land as a principle of ensuring top-quality water in the new ethos.
- New tools and methods must be developed to deal with the increase in the incidence of extreme climate events and to mainstream them in interdisciplinary water education.
- Promoting the concept of houses on stilths and open basins to minimize flooding

Universities, think tanks, research groups, civil society organizations and communities engaged in various aspects of water have already generated insights on their use and management. These insights can help engender a shift towards the holistic management of water, rivers, and river catchments. In addition, reflexive analysis of ongoing programs on water, flood reduction, adaptation, watershed, irrigation, and forest management can generate lessons for principles, policy reviews, and practices. The preparation of reading materials and case studies, the capacity-building of faculties, and access to knowledge products are needed to support this effort, particularly in terms of making resources relevant to education at all levels.

Supporting smallholder farming communities: Building resilience in CBs must look at the challenges of the farming community particularly, smallholders. Despite DHM's timely warning messages, in 2021 October extreme rainfall and flooding severely damaged paddy hurting farmers. A functional mechanism with clarity of how institutions would be involved in supporting them was not clear and not so even today. Access to diversified sources of livelihood is a key aspect of successful adaptation generally as well as in CBs in Nepal and across the border. In Nepal, young men of CB districts out-migrate seeking employment and those employed send remittance home as one of the income sources outside of agriculture. How much of this amount is invested in creating non-farming-based income assets and the type of policy support state agencies provide are important questions. Availability of affordable credits, and seeds including climate-resilient varieties. reliable irrigation and timely weather and agricultural advisories are key ingredients for effective risk reduction efforts.

Alternative sources of secure livelihoods: Increasing the number of ways to diversify livelihoods is central to making individuals and families more resilient to stresses, including those induced by climate change. A secure and diversified livelihood provides an individual with the ability to recognize the emerging stress he/she is likely to face or already face and adopt appropriate strategies to deal with it. A family with varied sources of income is better cushioned against disasters such as floods and droughts than those who have only one source of income. The capacity of individuals to tap into diverse income sources should be enhanced as well as the quality of services provided by both natural ecosystems and infrastructure. It is necessary to safeguard natural resource-dependent livelihoods such as agriculture, NTFP collection, and fishery. The conservation of natural ecosystems should be a priority, as should helping those dependent find employments outside this sector. Nepal's federal, provincial, and local governments need to begin strategies about creating alternative opportunities, especially given that returning migrants are likely to end up in urban areas/cities in the transportation, construction, industry, or service sectors.

Effective social inclusion that addresses social vulnerability: Actions related to infrastructure and other types of development must directly or indirectly create positive benefits for all segments of society. To meet these goals, Nepal needs to make an earnest effort to meet GESI provisions. The key idea is to harness opportunities for enhancing inclusion and building human capital to unlock the potential of securing the well-being of women and disadvantaged groups. Strategic actions are necessary to maintain the ecosystem services of CB rivers, which support millions living in the Nepal Tarai and northern parts of Bihar and Uttar Pradesh. These rivers are essential for basic life requirements such as drinking water, irrigation, and construction materials, as well as cultural and faith-based needs and livelihoods that can lower extant levels of poverty.

Financial inclusion to build resilience: Local financial institutions and cooperatives play important role in providing needed resources and play a supportive role in dealing with external shocks including floods. Suitable and trustworthy insurance products are still not widely available and effort in providing support in restoring the quality of land is limited. There is a need to develop metrics to assess the needs of small farmers for support before, during, and after a disaster. Strategies for strengthening smallholder farmers' resilience against climate change should include an assessment of the cost-effectiveness of the instruments for replication and scaling up as well as financial literacy. This process must link with the organizing of intensive vocational courses that help students in Nepal generally and also those in CBs to learn specific digital tools and skillsets such as code writers, sales associates, account managers, graphic designers, marketing specialists, customer service representatives, financial advisors, and social media managers as a new source of employment[2].

Clean energy sources, both at the household and national scales: The use of clean and renewable energy platforms such as energy from sustainable hydropower, solar plants and other sources must be promoted in CB districts to meet household cooking needs and pump groundwater for agriculture. The use of such energy will reduce exposure to the risks of kitchen smoke, particularly from the burning of dung patties. It will also have environmental benefits, including reductions in the region's dependence on forests and the import of petroleum products. Reliable and clean sources of energy are key to meeting the needs of digital tools and skillsets as sources of new employment.

Deeper analysis of impacts cascading through existing water treaties: Many studies highlight the impacts of climate change on the watersheds of the HKH rivers that will affect millions in the downstream region, and as one of the major rivers of the HKH, the Ganga basin also faces similar challenges. It is necessary to juxtapose insights from the studies on existing institutional arrangements within which structures have been built for using the river water for irrigation and hydropower generation as well as controlling floods by building embankments. These upstream dynamics--prolonged drought and/or systematic recession of dry season flow due to depletion of snow, ice, and glacier reserves--need to be linked to potential changes in discharge at specific sites to examine the implications, for example, on water availability at respective barrages in Koshi, Gandaki, and Sharada (Mahakali) rivers. What do the changes mean for existing transboundary water treaties? The countries need to begin deeper analysis to work out measures for sharing "scarcity". At the least, the governments can commission academic analysts from each country to begin discussing potential scenarios to highlight emerging challenges and worse-case eventualities. The analysis also needs to examine the consequences of the changes in the socio-economic context of the "so-called beneficiaries" of existing projects as well as the legal, ecological, and developmental dimensions of the treaties[3]. Joint research, gleaning lessons, and application must be part of a potential discussion process. In the meantime, existing policy tools must be effectively marshaled to minimize the pollution of water and the degradation of natural ecosystems. Nepal also needs to look at the implications of changes in medium and smaller rivers on which barrages and weirs have been built for irrigation.

Dialogue on regional environmental challenges between India and Nepal: Approaches are needed to promote the development of tools for dealing with future extreme events. Changes in the quality of upstream river stretches, particularly those due to pollution and ecosystem degradation, will have downstream consequences. Creating an appropriate platform to address these challenges will be a major endeavor. Nepal and India need to develop cooperative platforms for stewarding the watersheds of CB rivers to achieve upstream and downstream synergy as climate change rages.
The leaders of Nepal, India, (and also Bangladesh) need to marshal political will for initiatives to systematically address climate and environmental challenges in the EGR. This initiative should bring scientists, bureaucrats, the private sector, communities, and non-profit organizations together to discuss emerging challenges and work towards the common goal of decreasing vulnerability, building adaptive capacity, and minimizing disaster risks. This dialogue must create increased interaction between water, climate change, and international relations professionals to help transcend boundaries. Meeting these goals requires the allocation of financial resources and institutional vehicles to facilitate the process as a matter of discussion and dialogue.

NOTES

1. Bandyopadhyay & Modak (2022) makes a case for integrated knowledge system for developing and managing rivers of the HKH region and averting the water crises.
2. Dixit Ashraya discusses a digital skill section for Nepal highlighting the need for vocational education programs, private sector involvement, and improved access to technology. For details visit https://theannapurnaexpress.com/news/a-digital-skills-action-plan-for-nepal-38711
3. Rai & Neupane (2020) highlights a disconnect between the framing of the discourse on Nepal-India water cooperation and existing realities. One such disconnect is the filtering out of knowledge on the degrading natural ecosystem realm from the discussion in Nepal-India water cooperation. In this context, informal proposal by Siddiqui (2017) of a revised treaty "to preserve the Ecological Integrity of the Aquatic Ecosystem; and to facilitate reasonable, equitable and sustainable use of this resource for present and future generations" can be a matter for discussions in and for a new future.

Final Observations

FINAL OBSERVATIONS

11

The plains region of southern Nepal is home to several small seasonal rivers that begin in the Chure range. After flowing through Nepal's 18 CB districts, these rivers, about 164 in number, cross into the Indian states of Bihar and Uttar Pradesh, thereby acquiring a transboundary character. A number of areas along the international border next to the banks of these rivers experience inundation problems because of various structures built in India which constrain river flow. This problem repeats periodically and, each time it arises, stresses the cordial relations between the two countries. For Nepal, border inundation is a "substantial" problem, while for India, Nepal's large and powerful neighbor, it appears to be a "nominal" problem, one that can and needs to be resolved from systemic perspectives.

The inundation of the CB region is a consequence of erosive human interventions ignoring fragile and critical natural landscape and choosing of only the structural approach to flood management prevalent in the EGR. Both are embedded in policy and practices. Our review of the minutes of the bilateral dialogues Nepal and India held on water resources over the last fifty years (1971-2022) indicates that water agencies of both the countries prefer structural method as tangible measure over appropriate mix of structural and non-structural approaches as the solution to floods. Engagement between the two governments on this problem has not been able to expand the scope of the approach to include flood risk management, conservation, river health, and the rejuvenation of seasonal rivers, or to include vulnerability reduction in the dialogue.

In the CBs, monsoon rainfall makes rivers swell, cutting banks in the upstreams and submerging banks as they flow through central and southern CBs and across the border. While they reach downstream regions, these rivers mix with the high discharges of Nepal's snow- and spring-fed rivers, significantly magnifying flood hazards. Human interventions in the CB region elevate the adverse impacts of such hazards on local socioeconomic conditions and livelihoods, and these impacts cascade across boundaries. Changing climate system is making weather events more extreme and unpredictable than they were in the past. For this reason, the impacts of floods and droughts, high winds, forest fires, winter fog, and hail, are increasing. In addition, rising temperatures and humidity rates in combination pose an emerging risk to the region although they are barely recognized or systematically studied. Collectively, these changes are likely to make it even more challenging to adapt in the future than it is now.

The five pillars of resilience adopted in the study are useful tools for making proactive systemic responses that can minimize flood risks across the CB region. An improved understanding of ongoing climate and socio-ecological change dynamics is one of the bases for making synergistic efforts to minimize climate hazard risks and achieve win-win outcomes. A better understanding of how exposure has changed and how it can be reduced putting communities and natural landscape at the core of interventions with technological flexibility and nature-based solutions can ensure that the response strategy reduces flood and other climate induced risk and strengthen multi-faceted resilience to be more effective. A community-centered, technologically flexible, and nature-based strategy will not only facilitate adaptation and recovery from all disasters, including floods but also help agencies in Nepal and India become action-oriented in addressing risks and thereby be able to build back better. Concepts of resilience show that the ecological approaches can be cost effective in the long run for the reason they provide several tangible and environmental services in addition to providing barrier or buffer to the hazards and their impacts.

The pathway to a more resilient and interdependent future requires recognizing that the climate change and human footprints on the rivers, catchments and aquifers of the CBs are already beginning to expand. These are occurring via alterations like geomorphology, lowered quality and degradation of rivers, high uptake and less recharge of aquifers and increased dependency of local economies to outside the region such as the money workers earn and send as remittance from abroad. The impacts of these changes ultimately spiral outward, impacting the lives of all people in Nepal's CB districts as well as in parts of northern Bihar and northern Uttar Pradesh. The conventional approaches to flood management practiced in the region have not supported effective adaptive actions. In the meantime, the adverse impacts suffered by those in the social and economic margins have only increased. Consequently, vulnerable and marginalized families without alternative livelihood trajectories are being pushed further into vulnerability.

Approaches to flood risk management need to underscore the centrality of uninterrupted drainage and space for rivers. Guided by this foundational philosophy, the package of solutions that comprise effective responses must include several measures, including upscaled transboundary flood early warning systems across all seasonal rivers including timely weather forecasts and agricultural advisories, an improved understanding of climate change science and its impacts in the region, contextualized actions for vulnerability reduction, development of climate-adapted infrastructure, and conservation of natural ecosystems. For efforts in flood risk reduction to be effective, farmers, who constitute the majority of the region's population, should be provided with diversified sources of livelihood, appropriate and effective agricultural technologies and inputs such as extreme climate-tolerant seeds, reliable and affordable irrigation, trustworthy insurance products, affordable credit and finances. Other key measures of support include social safety arrangements, fair pricing, and ready access to local markets for produce.

Successful adaptation requires policy support that enables communities to take contextualized actions. Decision-makers and resource managers in both Nepal and India should adopt collaborative working modalities. They should invite academics, analysts, policymakers, and local communities across the border to study the ongoing change processes and co-create solutions for a more resilient future. This partnership needs to build on the learnings from the many community-based flood risk management programs implemented on both sides of the border in the CB region. Demonstrated commitment to maintaining the quality of all kinds of water and the good health of all rivers, no matter how small or seasonal they are, are other entry points for beginning the journey to a sustainable future in harmony with natural ecosystems. This transition must be supported by a governance framework of accountable role of state agencies that focuses on empowering local communities to develop adaptive capacity. A major focus of this support must be creating opportunities for communities to make appropriate livelihood choices as unanticipated climate and non-climate shocks proliferate.

Learnings from both practices in the field as well as many studies on water, environment, and climate change do offer opportunities for the replication and scaling up of good practices. Creative efforts are needed to include lessons from such practices in bilateral dialogues on water resources. At the same time, such learnings must also serve as elements in national, subnational, local, and civil society-level engagements across the border to achieve a pluralized approach to diplomacy. While it is true that climate change is a global phenomenon with local impacts, it is equally important to recognize that impacts such as floods also move across scales and boundaries, leading ultimately to cascading disasters. Impacts do not only move directly with the hazards but also transfer through linkages of watersheds, markets and peoples' mobility.

In many countries including Nepal and India disaster risk reduction actions still are based on certain ex-post measures like immediate relief, to certain extent rehabilitation support, and little on risk reduction and preparedness. Strategic in-country, as well as collaborative actions that help policy alignment and harmonized actions, will be helpful. The progress of Nepal and India in achieving shared prosperity includes wide variety of in-country efforts as well as efforts made synergistically across boundaries.

When hazards damage natural ecosystems and infrastructure, their services are disrupted and, if the disruptions persist, communities will be deprived of basic services and face additional hardships. They may be pushed further into a vulnerability if these disruptions are unaddressed. It is important to emphasize that the better and more enduring quality of the services, the better-prepared communities can deal with external shocks. On the other hand, losses of and damages to natural ecosystems can aggravate impacts of disasters as the degraded ecosystems can act as hazards, whereas healthy ecosystems provide buffer to communities against environmental shocks and physical hazards. By examining the emerging challenges of the CB region in Nepal through the lens of flood inundation, this study highlights the benefits of a holistic approach to flood risk reduction as a new journey toward well-being.

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