COMPOUND AND CASCADING DISASTER RISK (CCDR) IN NEPAL

A GUIDEBOOK FOR LOCAL LEVEL DISASTER PLANNING

FEBRUARY 2023

MINISITRY OF THE ENVIRONMENT JAPAN (MOEJ)

環境省 Ministry of the Environment

AP-PLAT

IGES Institute for Global Environmental Strategies

CWRS

Practical ACTION

CREEW

COMPOUND AND CASCADING DISASTER RISK (CCDR) IN NEPAL: A GUIDEBOOK FOR LOCAL LEVEL DISASTER PLANNING

This guidebook has been developed as a part of Asia Pacific Climate Change Adaptation Information Platform (AP-PLAT) adaptation literacy on Compound and Cascading Disaster Risk. This is the translated version of the original guidebook in Nepali language also available in the AP-PLAT website. Acknowledgements are due to all experts, individual, organizations and government agencies, media, and local communities who provided their valuable inputs to the development of guidebook at different occasions. Special appreciation goes to National Disaster Risk Reduction Management Authority (NDRRMA), Melamchi Municipality, local governments in the upstream, local communities participating and contributing in the field visit and workshop, and Radio Sindhu for their support and sharing valuable feedback to the guidebook.

The core team of the guidebook development are:

Lead, conceptualize and coordinate: Binaya Raj Shivakoti, IGES
Co-lead including information on Nepal and Melamchi Case study: Vishnu Prasad Pandey, IoE-TU
Chapter 2 and review: Sabin Dangol, IoE-TU
Contribution to chapter 5 and feedback to other chapters: Suman Chapagain, Practical Action
Contribution on Japan case study: Nagisa Shiiba, IGES
Contributor: Rabin Malla, CREEW

Suggested citation: Shivakoti, B.R., Pandey, V.P., Dangol, S., Chapagain, S., Shiiba, N., Malla, R. 2023. Compound and Cascading Disaster Risk (CCDR) In Nepal: A Guidebook for Local Level Disaster Planning. Ministry of the Environment, Japan

Table of Contents

List of Tables, Figures, and Boxes

List of Abbreviations and Acronyms

ADPC	Asian Disaster Preparedness Center
AP-PLAT	Asia Pacific Climate Change Adaptation Information Platform
AR6 WGII	6th Assessment Report Working Group Two
BBB	build-back-better
CBOs	community-based organizations
CCA	climate change adaptation
CCDR	compound and cascading disaster risk
CCDRM	compound and cascading disaster risk management
CREEW	Center of Research for Environment, Energy and Water
DHM	Department of Hydrology and Meteorology
DRM	disaster risk management
DRR	disaster risk reduction
DRRM	disaster risk reduction and management
GDP	gross domestic product
GLOF	glacial lake outburst flood
I/NGOs	international/non-governmental organizations
IGES	Institute for Global Environmental Strategies
IoE-TU	Institute of Engineering, Tribhuvan University
IPCC	Intergovernmental Panel on Climate Change
LAPA	National Adaptation Plan of Action
LDOF	landslide dam outburst flood
LISA	Local Government Institutional Capacity Self-Assessment (LISA)
MCM	million cubic meters
MOEJ	Ministry of the Environment Japan
MoHA	Ministry of the Home Affairs
MWSDP	Melamchi Water Supply Diversion Project
NAPA	National Adaptation Programme of Action
NCRA	Natural Calamities Relief Act
NDC	Nationally Determined Contribution in the context of the Paris Agreement on Climate Change
NDRRMA	National Disaster Risk Reduction Management Authority
NPR	Nepalese rupee
NSDRM	National Strategy on Disaster Risk Management
SFDRR	Sendai Framework for Disaster Risk Reduction
Terai	Southern flat plains in Nepal
UNDP	United Nations Development Programme
UNESCO	The United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USGCRP	U.S. Global Change Research Program
VDC	village development committee
WASH	water, sanitation and hygiene

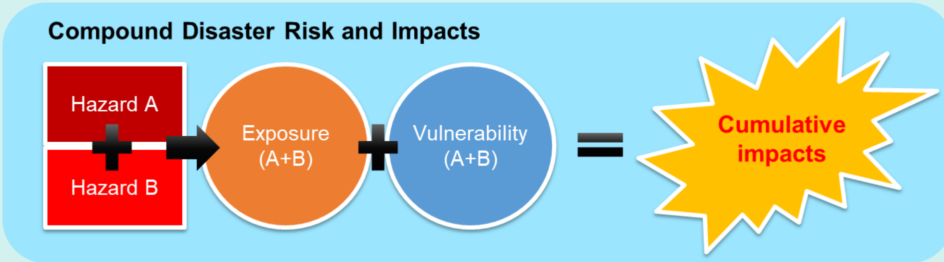
1. INTRODUCTION

Compound and cascading disasters pose a unique set of challenges for communities and governments, as they involve multiple disasters that interact and amplify each other's impact. Interaction of multiple shocks related to climate change (such as, floods, landslides, droughts, forest fires, hurricanes), geological hazards (such as, earthquakes, tsunamis, volcanic eruptions, and landslides) and/or non-climatic factors (such as, COVID-19 pandemic, population growth, social norms and culture, unplanned settlements, geopolitical, food-energy-water security, economic crisis) are increasingly responsible for intense, frequent and complex risk situation (Bowen et al., 2022; UNDRR, 2022). Evolving nature of extreme disaster events are often found to be compound and cascading in nature. The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework), which outlines seven global targets to be achieved between 2015 and 2030, also aims to guide decision making in inclusive and risk-informed manner while managing multi-hazard disaster risk in development at all levels as well as within and across all sectors (UNISDR, 2015). The framework targets to substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030. Recent resurgence in interests on compound and cascading disaster risks (CCDR) is due to their huge potential to spread beyond the point of primary impacts, increase in frequency of such low-probability and high-impact events, and lack of clarity on how to identify and assess resulting risks (Cutter, 2018). Depending on the scale of impacts, compound and cascading disaster could potentially propagate into systemic risks both in time and scale as a result of interactions of climate change and natural hazards, with the complex, interdependent and interconnected networks of social, environmental, and economic systems (see Box 1 for definitions/concepts). CCDR initially may be triggered by natural causes but subsequent spreading of the impacts could be triggered by social and economic factors such as population, urbanization, migration, and long-term response and recovery policies.

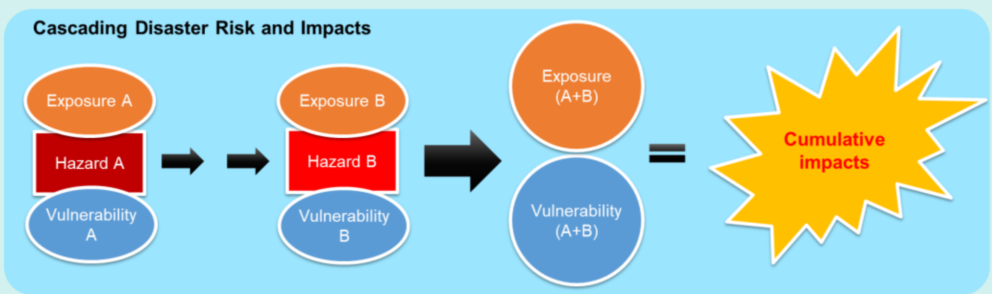
COVID-19 pandemic is the latest instance of how a local scale viral infection in a part of China propagated quickly to become a global health problem affecting all sections of life, political, and economic systems, including complexities and challenges to DRR response and recovery during the pandemic. Rising instances of CCDR imply that we are moving to a new normal where traditional hazard-by-hazard risk assessments approaches are of limited use. Current DRR approaches require a shift to multi-hazard approach in order to catch-up with the new challenges and accordingly enhance an understanding of the degree of magnitude of failure across these systems that could exceed the coping capacity of the society. We need careful assessment and understanding of the risks in all its dimensions of hazards, exposure and vulnerability both spatially and temporally. CCDR can interact in several ways such as by increasing the damage potential of multi-hazards, expanding exposure area,

Box 1 Concepts and definitions of CCDR

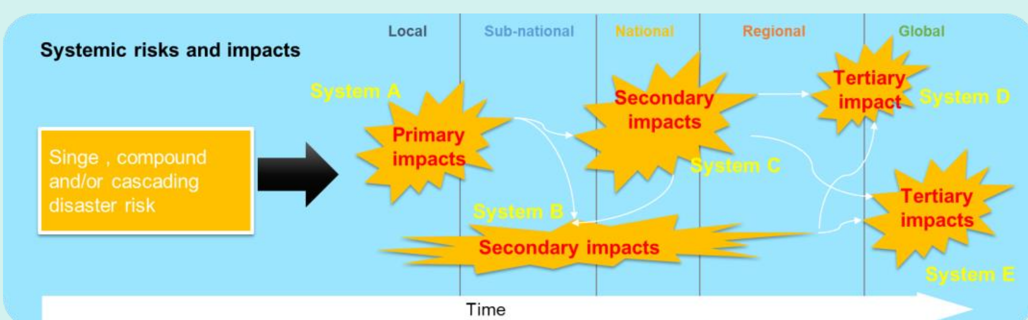
- Compound disaster risk occurs when multiple (and also independent) hazards or events interact and amplify each other's effects simultaneously or successively. For example, co-occurrence of flood and earthquake at a location can compound the scale of the damages.



- Cascading disaster risk refers to the potential for one or more hazards/events to trigger a chain of other events, each of which creates additional hazards and risks, that are distinct from the original trigger. Cascades could lead to the amplification of impacts over time ranging from hours to years. For example, an earthquake in dry season can trigger a landslide or weaken the slope stability. Heavy rainfall in the monsoon season can further destabilize the slope intensifying landslides. The landslides in turn could potentially block flooded river to form a landslide dam, which will eventually breach. Each of the event (earthquake, landslide, debris flow from the dam breaching) could be associated with specific damages/impacts.



- Systemic disaster risk refers to the potential to cause widespread disruption across multiple sectors and systems due to single, compound or cascading disaster risks. One or more disaster impacts could act as triggers for systemic disturbances. For example, damage to major lifeline infrastructures (e.g., transport, health, power, communication) and other critical systems could have severe consequences for the economy and society as a whole. Over time, the local impacts could spread to sub-national, national or even further to regional and global level as secondary or tertiary impacts affecting multiple systems (A, B, C, D, E…). Systemic impacts are often complex, and hard to understand without proper analysis over time.



infrastructure and population, or by worsening existing vulnerability situation. It requires identifying the key signatures of CCDR that differentiates them from recurring and historical disasters.

CCDR demands preparedness based on mapping of combination and successions of multi-hazards scenarios and the resulting interlinkages and inter-dependencies of the exposure elements and resultant expansion of the impact leading to systemic failures. CCDR considers combination of multi-hazards as well as the capacity of whole societal layers to govern the risk in a systematic manner. Disaster governance at different levels has to be reequipped considering the future requirements and by considering the key capacity gaps. Of particular concern is how climate change could amplify CCDR over a larger population and areas. According to IPCC AR6 WGII report, multiple climate hazards will occur simultaneously, and multiple climatic and non-climatic risks will interact, resulting in compounding overall risk and its cascading across sectors and regions (IPCC, 2022). Identification and attribution of climate change impacts that increase CCDR is a new area for further research and investigation on effective DRR and climate change adaptation (CCA) integration. Technical core capacities alone are insufficient for preparedness and resilience but integrated DRR and CCA measures should also prioritize good governance, transparency, inclusiveness, and accountability (Phillips et al., 2020).

1.1. CCDR at the local level

Global Target E of the Sendai Framework highlights the role of local authorities and the local level in achieving DRR. Since disaster risk is context specific and experienced in ways that shape local patterns of exposure, vulnerability, adaptive capacities and resilience in particular locality and times. It is crucial that local actors, such as local governments (politicians and civil servants), the private sector, non-governmental organizations (NGOs), community-based organizations (CBOs) and representatives of vulnerable groups, take part in DRR processes and consolidate development pathways that include DRR. Localizing DRR is of immense importance due to factors such as (UNDRR, 2019):

- Impacts of disasters are the most immediately and intensely felt at the local level
- Local actors are the first responders to disaster events. In particular, local governments are the "first port of call" for citizen concerns on risk and vulnerability and therefore can act more swiftly.
- Many of the most effective tools to reduce exposure to hazards are at the local level.
- Governments and communities can best engage with each other and work together. Local governments bear the ultimate responsibility for the safety of their citizens and communities.
- Basic environmental management and regulatory governance functions for effective DRR are concentrated at the local level.
- Local governments are in charge of promoting local development and therefore offer a real option for linking DRR with climate change adaptation and local development.
- DRR requires relatively consolidated and sustainable organizational and institutional structures.

Since CCDR brings entirely new set of challenges, people and communities at the local level need tools, ability, and knowledge beyond existing DRR to absorb, accommodate, recover, transform, and thrive in response to the effects of shocks and stresses. In this respect, local level needs to think the risks from two angles. First, the CCDR evolving near to the site such as occurrence of multi-hazards simultaneously or in sequence that could bring extensive damages. Such as occurrences earthquake, glacial lake outburst flood (GLOF), and heavy rainfall triggering massive floods and landslides at once or in succession. Second, the CCDR that evolved outside of the locality but over time impacts cascades to the local area. Such as the flood or landslide damaging critical infrastructure somewhere else disrupting the flow/functioning of essential services such as food supply, trade, movement, access to health, electricity, communication facilities. Similarly, drought in a major food producing country or region could create an imbalance in global food supply chain that could eventually cascade into a local market through inflation of food prices. A total understanding of various risk factors (natural, climate change, socio-economic, pandemic, geopolitical, human-made hazards) is crucial to plan against CCDR such as:

- Combination of hazard types that should be considered
- Resultant exposure of new areas, facilities, and population group that were not covered under existing DRR and management plans
- Nature of vulnerabilities as a result of change in the scope of exposure
- Evaluation of preparedness, resources, and local capabilities to address elevated levels of risk
- Additional actions in the short, medium and long-term for building local resilience
- Strategy for effective risk communication, including, when to trigger early warning for CCDR
- Inclusive participation of local stakeholders and leadership development through citizen-science approaches as well as prioritization of local knowledge systems and local DRR innovations
- Revisions of institutional and governance setup

Box 2 About AP-PLAT's CCDR e-learning course

Asia Pacific Climate Change Adaptation Information Platform (AP-PLAT) is a web-based information platform for national and local policymakers, researchers, businesses, and individuals seeking practical, up-to-date information on climate change adaptation and relevant science. The goal of AP-PLAT is to contribute to the sustainability and resilience of the Asia-Pacific region by informing decisions and supporting adaptation actions. Under the capacity building pillar of AP-PLAT, this e-learning course on CCDR targets local/national government officers and will help them develop the capacity to implement specific measures to build resilience against compound and cascading disasters. This course teaches measures that resilient communities can successfully apply to prepare, respond and recover when hazards involving CCDR strikes simultaneously or successively This course has been designed based on recent studies, taking note of voices from leading experts at local, national and international levels as well as lessons from recent disasters involving CCDR.

About the course: *https://ap-plat.nies.go.jp/adaptation_literacy/resources/e_learning/drr/index.html*

1.2. Background and purpose of the guidebook

This guidebook is an extension of e-learning course on CCDR of AP-PLAT's adaptation literacy and capacity building pillar (see Box 2 about AP-PLAT's e-learning course on CCDR). The e-learning course introduces key concepts and approach for building resilience against CCDR at the local level. This guidebook supplements the e-learning course by incorporating specific local context of CCDR situation in Nepal which is one of the most disaster-prone regions due to its fragile mountainous topography and related difficulty for response and recovery due to remoteness and lack of accessibility. Poverty, limited resources and inadequate institutional capacity are some of key challenges for formulating a robust DRR plans at the local level in Nepal.

The main purpose of the guidebook[1] is to enhance CCDR literacy at the local level so that the local government, communities and relevant stakeholders can improvise their existing DRR plan and practices to deal with extreme and multi-hazard situation involving CCDR impacts. The guidebook advises local governments on developing and implementing a holistic and integrated local CDRR strategy that contributes to building resilience at the local level. It outlines what a local CDRR and resilience strategy should look like and what is needed to create and implement one. Local strategies are generally more specific as they reflect the local context and hazard profile and tend to concentrate on the planning and implementation phases, and clearly assigning roles and responsibilities. Specifically, the guidebook aims to:

- Introduce the evolving nature of CCDR situation in Nepal including climate change impacts
- Introduce participatory assessment of CCDR at the local level
- Show the process of developing CCDR scenarios and identifying risks reductions measures
- Explain the process of adaptive planning and preparing implantation framework

1.3. Process and inputs for the development of the guidebook

The guidebook has been developed in a consultative and participatory manner. It includes interactions with leading DRR experts from academic and research, government, practitioners, and I/NGOs in Nepal. The interactions with experts mainly targeted understanding of pre-existing or planned CCDR initiatives such as policy, plans and guidelines. Experts also shared their insights for the value addition, in particular education and awareness on CCDR, to the already practiced community based DRR and management, as well as strategies for the wider dissemination and use of the guideline. Based on the suggestions, the drafting team reviewed relevant documents and literature on DDR, policy documents, DRR guidelines and cases.

An exposure visit followed by capacity building and learning workshop was organized in the Melamchi Municipality, which was severely affected by flood in 2021 involving CCDR. The purpose of the exposure visit was to assess the scale of damage situation and impacts. Evidences from the exposure visit was then used as a reference for discussion during the workshop to design this guidebook. The workshop was designed as a part of capacity building to the stakeholders in Melamchi with an aim to understand the level of awareness on CCDR, gain deep insights on needs and capacity gaps, and receive feedback on the uses of the guidebook. The workshop was a good platform for learning and interacting with the stakeholders and impacted communities. The direct feedback received from affected communities (farmers, fish farms, residents, businesses, women, elderly) and the municipalities were quite valuable and helped to shape the content of the guidebook significantly.

[1] Please refer to the Nepali version of this guidebook

1.4. Audience and Scope

The guidebook is intended for local level, especially, the local government (authorities, planners and managers at sub-municipalities or municipalities and other relevant line agencies) in Nepal who has the primary responsibility to ensure local development, manage disaster, and adapt to the climate change impacts. Here the local level refers to the lowest political-administrative jurisdiction having mandate and responsibilities for DRR. Besides local government, the guidebook is also relevant to other stakeholders who are actively contributing to DRR and resilience building in collaboration with the local government. The local levels are heterogenous with a country and no single DDR framework could be prescribed. For instance, DRR measure in hilly topography can be entirely different from that in *Terai*. Even DRR measures in one hilly area could be different from another hilly areas. In fact, DRR measures tend to change with time and evolving risk profiles.

The guidebook is intended to serve as a reference to identify entry points for understanding and planning CCDR with reference to pre-existing disaster risk management (DRM) practices, including at the national level such as authorities like National Disaster Risk Reduction Management Authority (NDRRMA). The guidebook could be used for participatory assessment and planning of CCDR at the local level either by government or non-government agencies. The guidebook could be best used in combination with the pre-existing DRR guidelines so that the CCDR could be integrated into the existing DRR practices in a seamless manner. While it is hoped that the guidebook could be used for organizing capacity building or resource for project design and implementation at the local level.

1.5. Structure of the guidebook

The guidebook is divided into six chapters (including this introduction chapter and a chapter on conclusion and recommendations). The guidebook includes two concrete examples of CCDR from Nepal and Japan. Below is the brief outline of each chapter:

- Chapter 2 introduces the context of CCDR in Nepal. It provides a good snapshot of how CCDR are becoming more noticeable and linked with climate change impacts. It explains about the vulnerability, complexities, resources and capacity gaps, and associated challenges for disaster risk management both in the present and future. Further, the chapter also touches on the current state of intervention and initiatives by government, researchers, and other non-government organization to address CCDR phenomenon in Nepal. The chapter concludes by highlighting the needs to capacitate local level against future CCDR in Nepal.
- Chapter 3 focuses on the participatory assessment of CCDR at the local level. It guides on familiarizing and contextualizing the nature of CCDR based on the experience and risk perception. The key focus on the chapter is on how to understand CCDR correctly in all

dimensions, such as multi-hazard context, exposure, vulnerability, and capacity, so that the communities can comprehend the likely scale of the impacts. The chapter ends by explaining the process of risk mapping and ranking as a part of participatory risk assessment.

- Chapter 4 advances the concept of CCDR by engaging relevant local stakeholders to formulate likely scenario of hazard combination and impacts so that appropriate preparedness and mitigation measures could be identified. The chapter helps to formulate risk reduction and resilience enhancement measures targeting preparedness (pre-disaster), response (during disaster) and recovery (post-disaster) elements of disaster management cycle.
- Chapter 5 builds on the outcomes of previous chapter to improvise (or newly build) disaster management system into an adaptive planning with robust implementation framework. The chapter starts with assessment of resource and capacity gaps in order to implement the identified measures of risk reduction and resilience enhancement. Following the adaptive approach of learning and gradual improvement, the chapter provides the templates of disaster planning and implementation.
- The chapter on conclusion and recommendations will suggest necessary steps to be taken at the different levels to enhance the literacy and awareness on CCDR at the local level including through development of programs and project for pilot and upscaling.
- In addition, the guidebook supplements two case studies from Nepal and Japan. The cases introduce the causes, impacts and damages, and lessons from recent CCDRs. The case in Nepal is about the 2021 Melamchi Flood. From Japan, it shows a compilation of lessons from multiple disaster events. These two cases will help the readers to understand the nature of CCDR not only in Nepal but also compare and contrast the situation in Japan, where repeated occurrences of extreme hazard events involving CCDR is emerging as a big concern at the local level despite a well-established DDR system. This way, the target readers of the guidebook can develop a solid understanding on the possibilities, challenges and limits when it comes to deal with CCDR.

2. COMPUND AND CASDACING DISASTER RISKS (CCDR) IN NEPAL

Nepal is highly vulnerable to compound and cascading disaster risks due to its location in a seismically active region with presence of numerous active faults and thrusts (Chitrakar et al., 2007) and high vulnerability to the impacts of climate change. Also, the country’s steep and rugged terrain as well as young and fragile geology, when coupled with extremely intense rainfall patterns contributes to high risk of multi hazards (Guragain & Doneys, 2022). Occurrences and distribution of different hazard types are also specific to physiographic region that consists of plain, hills, mountains, high mountains, and Himalayas (GoN/MOFE 2021). Disaster events such as earthquakes, landslides, floods, fire, thunderbolts have caused major damages in the past and have weakened the delicate balance of the nation’s ecosystem (DRR Portal, 2023). Nepal has been ranked within top 20 countries with high risk of multiple hazards and its susceptibility has been ranked as 4th in terms of climate change, 11th for earthquake, and 30th in floods (Dangal, 2011; Gautam, 2017). Hydro-climatic extremes such as flood, drought and heat waves exacerbate other forms of disasters such as landslides and pose serious threats to different sectors including agriculture, biodiversity, ecosystem, and specially river systems that support the life of numerous species, including human-beings (Shrestha et al., 2017). Economic vulnerability analysis reveals that Nepal experiences the greatest losses due to its large exposure to risks and high level of hazards (DRR Portal, 2023). As shown by the global reports, for the period from 1971 to 2015 Nepal was placed in 23rd position globally in case of death toll from natural hazards; 7th position in terms of deaths by floods, landslides and avalanches combined; and 8th rank for flood-related deaths alone (Gaire et al., 2015). With nearly a quarter (i.e., 23.74%) of the population of Nepal is under an annual threat to flood which ranks Nepal in the 11th position in terms of disaster vulnerability in the world (Guragain & Doneys, 2022). Each year, thousands of people are affected by floods, which result in massive death and loss of property, land, assets, and livestock. As different disasters have potential for CCDRs, the damage and losses would be exacerbated.

2.1. CCDR in Nepal

CCDR is evolving in response to a changing global environment. More recently, Himalayan and mountainous region in Nepal are increasingly experiencing rather complex situation due to co-occurrences of multi-hazards, such as heavy rain, landslide, floods and debris flow, avalanches, GLOF, that involves compound and cascading impacts. It is highly likely that climate change will lead to an upsurge in compound and cascading hazards more frequently. Increase of CCDR and associated impacts may likely lead to increased loss of human lives, destruction of assets, disruption of economic sectors, mental health effects, and loss of and damage to plants, animals, and ecosystem services. Such impacts could become systemic spread wider to different parts of the country and persist over time. While it is already challenging for developing country like Nepal to allocate adequate resources to strengthen disaster risk reduction and management (DRRM) activities, now it is experiencing an entirely different and complex situation of DRRM. Cultivating an understanding of the links between climate change, complex types of disasters and development is increasingly becoming more and more important. Nepal needs a more holistic approach in hazard assessment and risk management. The country has to redesign and transform its DRRM approaches from multi-hazard perspective by enhancing risk knowledge, strengthening disaster governance, developing necessary infrastructure, risk sharing and transfer, developing an effective preparedness and response system with the use of information and communication technology and early warning systems. It is essential that systems for collecting climate-related disaster data at different spatial scales are established for a comprehensive analysis of hazards, vulnerabilities, and risks at different administrative levels. Climate trends and scenarios also need to be identified at the municipality level or community levels. A comprehensive disaster, climate, and socio-economic database at the local level will be necessary to understand compound and cascading hazards and plan DRRM accordingly.

Many disaster scenarios in Nepal are the result of complex interactions between multiple systems, such as the environment, global interconnectivity, human activities and socio-economic factors. The increasing interconnectedness of global systems, such as transportation networks, is creating new pathways for disasters to spread and compound. For example, COVID-19, an acute respiratory coronavirus 2 (SARS-CoV-2) was first identified at the end of 2019 in Wuhan City, Hubei Province of China (Zhu et al., 2020), is the result of global connectivity through transportation networks. Due to rising cases of COVID-19 in Nepal, Government of Nepal decided to implement countrywide lockdown from 24th March 2020. The lockdown had a negative impact on small business owners and individuals with limited sources of income, however, the most vulnerable groups such as the poor, marginalized populations, and day laborers are at an even higher risk (Poudel & Subedi, 2020). Every sector of the Nepalese economy such as tourism, international trade, supply and health, aviation and hospitality, agriculture and small businesses, and remittance inflow has been seriously affected by the pandemic. As a result, Nepal government's revenue collection was reduced by 7.45% (Joshi et al., 2021). The COVID-19 pandemic had caused a financial crisis that have escalate economic instability, widen health disparities, and heighten social inequalities in Nepal, leading to a significant increase in poverty (Poudel & Subedi, 2020).

Human activities can also contribute to CCDRs. For example, human activities have led to the degradation of ecosystems and natural resources, reducing their capacity to provide protection and resilience against disasters. O'Keefe et al., (1976) stated that hazards become disasters as a result of human policies and actions in the pursuit of development. Population growth, land-use/cover changes, urbanization, and other forms of human development have increased the vulnerability of communities to disasters. Urbanization in flood-prone areas has increased the risk of flood damage, and deforestation and wrong approach to development has increased the risk of landslides. In Nepal, the plan of local governments to connect each and every house in their jurisdictions to the road network has resulted in haphazard road construction without proper drainage management, which is leading to frequent landslides every monsoon (Sharma, 2020). The haphazard mining of construction materials, without proper knowledge of geo-hazard, in Chure and hilly regions have reduced the resistance of land thus increasing the landslide events (Sharma, 2020). These are few examples of inadequate planning and poor management of infrastructure which has increased the risk of cascading failures during disasters, exacerbating the impacts on communities and the environment.

Socio-economic factors such as poverty, inequality, poor governance and lack of access to services, also plays an important role in increasing the vulnerability of communities to disasters and making them more susceptible to cascade and compounding effects. The population growth has led to an increase in the number of poor people residing in informal settlements near rivers, making them susceptible to natural disasters (Dhungana et al., 2016). One example of this is the squatter settlement in Butwal, where 17 homes were completely destroyed in just an hour during a flood caused by the Tinau River in 2011 (Dhungana et al., 2016). Communities with low levels of education and limited access to information and technology may be less able to get prepared for and respond to disasters. In addition, limited access to healthcare, shelter, and basic services can exacerbate the impacts of disasters on vulnerable populations. Moreover, the absence of a strong legal framework, governance, and institutions can further increase vulnerability, as communities may lack the resources and necessary support to prepare for and recover from disasters. Communities living in areas with high levels of poverty, limited access to resources, and poor infrastructure are often more vulnerable to the impacts of climate change, making them more susceptible to multiple hazards and CCDRs.

It is important to note that CCDRs are not limited to a single event, they can be a chain reaction of multiple events, and the impact of one event can trigger a chain of other events and vice versa. These complex interactions are creating cascading and compound affects that are difficult to predict and manage.

2.2.1. Selected cases of disasters

Selected five cases reflecting different types of disaster events in Nepal are described briefly in this section to highlight how those disasters can be considered as compounding and cascading risks. A summary is provided in Table 2.1 and a brief description is provided after the table.

Table 2.1 Compounding and cascading nature of five selected disaster events in Nepal

	Name of disaster	Location	Date	Impacts	Aftermaths
1	Koshi Flood	Sunsari district of Nepal and Bihar, India	18th August, 2008	Affected 3.1 million peoples in India and Nepal; turned 4648 hectares of fertile land of Nepal into desert-like	An estimated 3 to 7 ft of sand deposited by flood in fertile land, which affected agricultural activities till date making it a deserted land.
2	Jure Landslide	Jure village, 70km N-E of Kathmandu	2nd August, 2014	Rainfall-induced massive landslide of typical slope failure resulted death of 156 people; rising of water level of over 100m in river with an estimated 6 million cubic meters (MCM) of debris; blocked Sunkoshi river completely by forming a lake (3km long, 300-350m wide) with 8 MCM water storage	Economic loss due to blockage of roads and disturbances to livelihoods, cut off of electricity power supply and economic activities downstream
3	Gorkha Earthquake	Epicenter at Gorkha, 76km N-W of Kathmandu; 31 districts affected	25th April, 2015	7.6 Magnitude earthquake and over 450 aftershocks of over 4.0 magnitude impacted over 1/3rd of population of Nepal; ~ 9,000 deaths, ~ 22,000 injury; destroy/ damage of over 0.8 million houses and heritages.	Series of powerful aftershocks, triggered numerous landslides and rock/boulder falls in mountainous regions causing roadblocks and hindering rescue and recovery activities.
4	2017 Flood	35 districts of were affected of which 18 were severely affected	August 2017	134 peoples died. 41,626 houses were destroyed and 150,510 houses were partially damaged, around 1.7 million peoples affected and rendering many homeless.	Shortage of food, water and non-food items. Infection from contaminated water. Housing, health, education, agriculture, live-stock, irrigation, transport, water and sanitation, and energy sector were severely affected in 18 districts.

5	Melamchi Debris Flow	Melamchi watershed, 30km N-W of Kathmandu	15th June, 2021	525 HHs displaced; 337 houses damaged; 25 people killed; xx trout farms washed away; damaged headwork of Melamchi water supply project	Localized heavy rainfall (unformed); snow/glacier melting; heavy erosion at glacial lake and it gets washed-away; high-energy of flowing water scoured significantly along with steep-slope downstream and caused landslides and subsequent LDOFs

a) 2008 Koshi Flood: The Koshi River flood on 18th August 2008 at 12.55 pm was a devastating natural disaster that affected millions of people in Nepal and India, which was caused by natural diversion of the river to its 100-year-old course towards the eastern side by destroying its embankment (Kafle et al., 2017). The flood caused significant damage to three Village Development Committees (then local government units) and partial damage to two others (Kafle et al., 2017). The flood deposited silt and sand in about 4648 hectares of fertile land turning it into desert like and hampering the agricultural activities for many years to come (Shrestha et al., 2010). The flood displaced 45,000 peoples from three severely affected villages (Haripur, Shreepur and Paschim Kusaha) of the Sunsari district of Nepal and about 3.065 million residents from 1,704 villages in north Bihar (Shrestha et al., 2010).

b) The 2014 Jure Landslide: The 2014 Jure Landslide was induced by heavy rainfall leading to slope failure with massive rock fragments, sand and soil on 2nd August 2014 (02:30 AM)(Acharya et al., 2016). The landslide occurred along Sunkoshi River valley on Araniko Highway which connects Kathmandu with Tibet. The landslide blocked Sunkoshi River, creating an artificial dam of approximately 50 m high and an approximately 3 km long which stored an estimated water volume of 8 MCM (Acharya et al., 2016). Massive flood after partial breach of the dam damaged the barrage structures of the Sunkoshi Hydropower Project which is located about one kilometer downstream from the slide area (Panthi, 2021). The reservoir took more than two months to drain off (Panthi, 2021). The lake affected five Village Development Committees (Kalika, Kadambas, Yamuna Dada, Pulchodanda and Thumpakhar VDC) including highway, school, health post, postal service, police station, VDC office and temple upstream (Acharya et al., 2016). 156 people were killed by the landslide, which savaged 120 houses and partially damaged 37 houses (Panthi, 2021). Besides the direct loss of lives and infrastructure, the cascading effect of this landslide is the economic loss caused by the blockage of roads and disturbances to livelihoods, cut off of electricity power supply and economic activities downstream (Gaire et al., 2015).

c) The 2015 Gorkha Earthquake: On 25 April 2015 (local time 11:56 a.m.), an earthquake of moment magnitude 7.8 with its epicenter located in the Gorkha region (about 80 km north–west of Kathmandu) struck Central Nepal (Goda et al., 2015). Over 9000 people were killed, more than 22,000 people were injured, 199 people were missing, further 2 million people were displaced and 498,852 residential buildings were destroyed by the 2015 earthquake (Davis et al., 2020; Goda et al., 2015; Hall et al., 2017). The earthquake can also be categorized as a cultural catastrophe, as this ruined 691 historic buildings across Nepal, among which 403 were within Kathmandu's UNESCO World Heritage Property (Davis et al., 2020). As cascading effect of this earthquake, series of powerful aftershocks were felt among which the major aftershock of 12 May 2015 (moment magnitude of 7.3 in the Kodari region, north–east of Kathmandu) caused more deaths/missing of 163 people (Davis et al., 2020; Goda et al., 2015). In the mountainous areas, the earthquake triggered numerous landslides and rock/boulder falls causing road blocks which hindered rescue and recovery activities (Goda et al., 2015).

d) 2017 Flood: The 2017 flood spanned over the entire width of the country affecting 35 districts of which 18 were extremely affected. The flood killed 134 peoples from 18 affected districts, destroyed 41,626 houses and partially damaged 150,510 houses; around 1.7 million peoples were affected and rendered many homeless (National Planning Commission, 2017). The disaster damaged household assets and food grains, causing a shortage of food, water, and non-food items, and resulting in infections from contaminated water sources (National Planning Commission, 2017). The flood severely affected nine sectors which includes housing, health, education, agriculture, live-stocks, irrigation, transportation, water and sanitation, and energy causing a total loss of NPR 60,716.6 million which is about 3% of Nepal's GDP (National Planning Commission, 2017).

2.2.2. Trends in disaster risk in Nepal

Disaster statistics from BIPAD Portal (2023) reveals that there is an increase in occurrence of natural disaster in recent past which may further continue for next several years due to climate change, rapid urbanization, unplanned development, population growth, environmental degradation and poor enforcement of land-use policy (MoHA, 2017). The country is highly vulnerable to various types of natural disasters such as earthquakes, floods, landslides, and glacial lake outburst floods (GLOFs) due to its unique geophysical and climatic conditions. The increasing frequency and intensity of natural disasters have resulted in significant loss of life, damage to infrastructure, and disruption of the country's socio-economic development. In terms of loss of lives, flood/landslide holds second position accounting 35.6% after epidemic (which accounts 47.5%) (DWIDM, 2015 as cited in Nepal et al., 2018).

a) Earthquakes: Nepal is prone to earthquakes, as the country is located on the boundary between the Indian and Eurasian tectonic plates. The history of earthquakes in Nepal shows that the country has experienced significant losses in terms of lives, properties, and infrastructure, which have hindered its pace of development (Chitrakar et al., 2007). A major earthquake can trigger a cascade of events, such as landslides, rock-falls, power outages and infrastructure damages. These events can lead to further impacts, such as food and water shortages, and public health crises. In Nepal, recorded history of earthquakes dates back to 1255 A.D (Chaulagain et al., 2018). The Bihar-Nepal earthquake of 1934 is considered as great devastating earthquakes of modern times have caused wide spread losses of lives and damages of numerous physical infrastructures (Chaulagain et al., 2018). As the cascading effects, landslides and floods due to blockade in river course aggravated the damage and the problem of soil liquefaction/lateral spreading was experienced by the central part of Kathmandu valley and central and eastern plains of Nepal (Chaulagain et al., 2018). Two moderate earthquakes that occurred on July 29, 1980 and August 21, 1988, have also hit Nepal in the Far Western Region and Eastern Region, respectively (Chitrakar et al., 2007). These earthquakes triggered in numerous landslides in the hilly areas and caused significant loss of life, with 178 people losing their lives in the 1980 earthquake and 721 people losing their lives in the 1988 earthquake (Chitrakar et al., 2007). In Nepal the recorded incidents earthquake have caused 8969 deaths, 773110 infrastructures destroyed and a total estimated loss of 6 million, from year 2011 to 2022 A.D, (BIPAD Portal, 2023).

b) Floods and landslides: Nepal is prone to seasonal flooding; every monsoon the occurrence of floods and landslides cause widespread damage to crops, homes, lives and infrastructure. Specially, southern plains of the country (i.e., *Terai*) are vulnerable to flood hazard/risk due to unusual and intense precipitation patterns (Guragain & Doneys, 2022). Mid-hills are vulnerable to geo-hazards such as landslides and debris flow, due to its young and fragile geology and steep and rugged topography

(Guragain & Doneys, 2022). The landslides and debris flows caused by high-intensity rainstorm during 1993 has hit Nepal affecting 44 districts and taken lives of 1259 people and damaging various physical infrastructures causing a total loss of more than 47194 Million NPR (Chitrakar et al., 2007; Thapa & Dhital, 2000). In 1996, a deadly debris flow occurred in Larcha, Nepal, along the Arniko Highway in the Bhotekoshi Valley, caused by intense rainfall, runoff from cliffs faces and stream, leading to a failure of bedrock (Adhikari & Koshimizu, 2005). The landslide debris dammed the channel, which eventually burst and overwhelmed the village of Larcha which resulted in the death of 54 people and the destruction of 16 out of 22 houses in the village (Adhikari & Koshimizu, 2005). In June 16 2013, six districts of Nepal's Far-Western Development Region, especially Darchula, was highly affected by the flash floods and landslides triggered by intensive rainfall killing nine peoples, sweeping away 158 homes and displacing more than 200 families Darchula alone (Gaire et al., 2015). The flood also damaged bridges, highways, and hydro-power facilities (Gaire et al., 2015). In Nepal the recorded incidents of floods and landslides counts to 4212 from year 2011 to 2022 A.D, which have caused 2240 deaths, 14755 infrastructures destroyed, 5803 livestock destroyed and a total estimated loss of 19 billion (BIPAD Portal, 2023).

c) Glacial Lake Outburst Floods (GLOFs): In Nepal, there are 2,315 identified glacial lakes located in high altitude areas near the foot of mountains, which are formed by damming from moraines (DRR Portal, 2023). Melting glaciers in the Himalayas are increasing the risk of GLOF, while changing rainfall patterns are increasing the risk of both floods and droughts. Between 1935 and 1991, 14 GLOFs were recorded in Nepal, and currently, 15 glacial lakes are considered highly dangerous (DRR Portal, 2023). The Bhote Koshi River in central Nepal was hit by a GLOF on the 5th of July, 2016 (Cook et al., 2017). The cascading effect of the outburst flood on the river can be clearly seen as the flood undermined and weakened river banks and hillslopes in various locations, leading to collapses, slumps, and landslides (Cook et al., 2017).

The combination or succession of hazard types refers to the way in which different types of hazards can interact and amplify each other, leading to more severe and widespread impacts. As the effects of climate change become more pronounced, the future is expected to bring greater challenges in dealing with compound and cascading natural hazards (Lamichhane et al., 2021). These hazards and their cascading impacts will pose increasing difficulties for communities. Some possible examples of hazard combinations or cascading events in the future may be:

- GLOFs triggered by heavy rainfall during the rainy season, which could lead to flash floods, landslides, and other secondary hazards such as debris flows.
- Earthquakes causing structural damage and fires, which can lead to further damage from subsequent hazards such as aftershocks and landslides.
- Heavy rainfall leading to flash floods and landslides, which can also increase the risk of disease outbreaks, displacement, and other social and economic impacts.
- Forest fires igniting in areas prone to drought, which can lead to soil erosion and water quality problems, as well as increased risk of further fires.
- Heatwaves and droughts affect agricultural production and water resources, which can also increase the risk of wildfires and food insecurity.

2.2. CCDR related vulnerabilities and capacity gaps at the local level

Vulnerabilities at local level are related to various aspects as elaborated in following sub-chapters. Similarly, capacity gaps could be in the areas of technical capacity, adequate number of human resources, financial resources, and institutional set-up and strength.

2.2.1. Vulnerabilities at local level

Vulnerability refers to the degree to which a system, community, or individual is susceptible to harm or damage from various hazards, such as natural disasters, technological failures, or health epidemics (Adger & Kelly, 1999). Nepal is characterised by high levels of local vulnerability, which are further accentuated by the effects of CCDR. Some of the factors that can influence vulnerability include geography, demographics, economic and social conditions, governance, and policy (Brooks, 2003). According to Gautam (2017), 46 districts of Nepal are at moderate to high social vulnerability levels. Landslides and floods are more common in Nepal during monsoon season, which generally causes collapse of road network, impacting transportation and access to essential services. The interconnectedness of these events can result in complex and long-lasting impacts, particularly in communities that are already vulnerable due to poverty, lack of infrastructure, or limited access to resources. If the situation remains unchecked, the local level vulnerability is likely to increase, potentially resulting in more widespread destruction and loss of life and property. For example, the destruction of buildings and business institutions, bridges and roads (which were previously designed taking in consideration the various aspects of engineering design such as geology and high flood level) may lead communities to isolation, which may decline the economic activity and increase poverty. This, in turn, could exacerbate the impact of future disasters and make communities even more vulnerable to CCDR. It is therefore imperative that action is taken to reduce local level vulnerability and to increase resilience to CCDR impacts.

Some of the common CCDR related vulnerabilities are:

- ***Physical infrastructure***: Physical infrastructure, such as roads, bridges, and buildings, is often vulnerable to multiple hazards, including earthquakes, wind/rain storms, landslides and floods (Aksha et al., 2019). When these critical infrastructure systems are damaged or destroyed, it can disrupt essential services, impede response and recovery efforts, and exacerbate the impact of disasters. The 2015 Gorkha earthquake serves as a testament to the catastrophic impact of these hazards on the country which caused widespread damage, killing nearly 9000 people and damaging or destroying over 750,000 buildings, particularly in rural areas (Aksha et al., 2019). This is largely due to the widespread use of low-quality, traditional masonry construction methods in these regions, which proved to be highly vulnerable to earthquake damage (Aksha et al., 2019).

- ***Economic system***: Economic systems, such as markets, supply chains, and financial systems are also vulnerable to multiple hazards as the disaster can cause significant economic losses, disrupt economic activities and affect the livelihoods of people, particularly those in low-income communities. The impacts of CCDR on the economic system can be both direct and indirect. Direct impacts can include physical damage to infrastructure, businesses, and assets, as well as disruptions to supply chains, trade, and commerce. These impacts can result in short-term losses and reductions in economic activity, which can have long-term effects on a community's economic development. Indirect impacts can include changes in consumer behaviour, reductions in investment and foreign direct investment, and declining economic growth. The indirect impacts of CCDR can also have long-term effects on the economy, including a decrease in productivity and competitiveness, as well as a reduction in the overall standard of living. In addition, CCDR can exacerbate existing inequalities and vulnerability within the economic system. For example, low-income communities and vulnerable groups, such as women and children, may face disproportionate economic impacts, such as reduced access to markets, loss of livelihoods, and declining health and educational outcomes. In Nepal, the tourism industry was severely hit by the 2015 Gorkha earthquake, economic cycle of the tourism entrepreneurs and tourism products were halted affecting the country's national economy (Ghimire, 2016).

- ***Social systems***: In Nepal marginalised communities and households living in poverty and disaster-prone zones are often more vulnerable to CCDR due to their limited resources and access to services. The local population is typically lacking in knowledge, training, expertise, and resources to effectively handle small-scale disasters in their area (Aryal, 2014). Also, the community that is already struggling with poverty and inequality may be further impacted by a disaster, exacerbating existing social and economic problems. This highlights the crucial need for investing in and strengthening the capacities of local communities to enhance their local disaster risk management systems (Aryal, 2014). Providing education and resources to local people will help them better prepare for and respond to any potential disasters in their community. There is a huge need to invest in and build capacity at a local level to improve local disaster risk management systems. Building local capacities will result in a more resilient community that is better equipped to deal with compounding and cascading disasters. Aryal, (2014) and Aksha et al., (2019) in their paper, have elaborated different type of case studies related to vulnerability of social systems.

- ***Environmental system:*** An environmental system which includes water resources, ecosystems, and biodiversity are also vulnerable to CCDR. The increase in various natural hazards is due to the negligence of ecological sensitivities in development policies and activities (Pokhrel, 2020). For example, a flood that contaminates drinking water sources can have cascading impacts on public health, agriculture, and local economies. The cascading effect of 2015 Gorkha earthquake can be seen clearly on Sindhupalchowk district as the landmass has weakened, triggering continuous landslides at different locations of the district during monsoon season as per geologists and disaster management experts (Shrestha, 2022).

- ***Political systems:*** The country has gone through significant social and political upheaval in recent years, which have further compounded the risk and impacts of these hazards (Aksha et al., 2019). Poor governance and lack of decision-making ability has further exposed the people of Nepal, especially those living in rural and remote areas to the vulnerable situation that may be induced by CCDR. Political instability and corruption have impeded effective disaster response and recovery efforts, increasing the impact of disasters. The shortcomings in disaster risk management system are often seen as the result of inadequate governance and insufficient political commitment (Williams, 2011; Jones et al., 2015 as cited in Nepal et al., 2018). Despite the efforts made by the government of Nepal to establish various laws and policies aimed at promoting disaster risk management, there has been no substantial reduction in the impact of disasters on the country (Nepal et al., 2018). According to the local people, the Lidi landslide of 2020 in Sindhupalchowk district was a result of the development program which was planned and designed under political interests and mostly ignoring the ecological sensitivity (Pokhrel, 2020).

2.2.2. Capacity gaps

Capacity gap is the difference between the necessary administrative, financial and technical capacity that the local community needs to effectively manage and build resilience against the CCDR and actual available administrative, financial and technical capacity (UNISDR, 2017). Some of the CCDR-related capacity gaps that the local levels are facing in Nepal include:

- ***Human resources capacity*:** Human resources capacity refers to the type and technical experts that are required for pre and post-disaster risk management (UNISDR, 2017). Most ministries, departments, provincial and local governments have very limited information about their exposure to CCDR. The government institutions are limited by technical and human resources capacity required for comprehensive climate risk and multi-hazards risks in terms of systemic monitoring and assessment and producing hazard, risk and vulnerability maps. There is limited application of latest techniques, such as modelling and assessment, especially at the local level. Information on hazards is mostly lacking, particularly in remote areas. While Department of Hydrology and Meteorology (DHM) is rehabilitating the hydrometric monitoring network in Nepal, they are still inadequate and do not cover different hazard types. Relevant stakeholders and practitioners neither have detailed climate risk information nor they have adequate capacity to understand available information. There is a huge capacity gaps in the assessment of climate risks, vulnerability assessments, and damage and loss. River-basin level multi-hazard risk reduction efforts are limited, especially, those connecting high altitude processes such as avalanches, GLOF or landslide dam outburst flood (LDOF) with the vulnerability of downstream communities. Likewise, the linkages between upstream risk reduction approaches and downstream impacts are hardly assessed. Detailed basin characterization, risk modelling, and downstream hazard mapping has not been conducted to determine priority areas of response for multi-hazard situation involving compound and cascading impacts. Studies incorporating climate change scenarios suiting the local context are almost absent resulting in limited knowledge for planning risk reduction techniques that would be suitable to local conditions. Gaps in technology and knowledge prevent systematic efforts of risk reduction at the basin level that would consider how CCDR evolves, their interactions, and impacts at upstream and downstream.
- ***Social capacity***: Disasters impact each population group differently and it requires all-of-society engagement and partnership. While community engagement in disaster risk reduction are encouraging and successful there are not applied widely. There is further need to empower local authorities and local communities to reduce CCDR, including thorough resources, incentives and decision-making responsibilities. Coverage of modern (sirens, telephones, megaphones, high frequency radios) and indigenous (drums, house-house visits, observing clouds, rainfall, animal behaviour) means of disaster risk communication at the community level is limited to either to communities covered by limited project and mostly out of the reach vulnerable communities. Proper communication channels at the local level need to be in place to make timely decisions to warn affected people, who must then understand, accept and act appropriately to the early warning. The early warning providers, such as DHM, use technical terms that users of different age, gender and understanding levels cannot understand, while their feedback system for communities to share their experiences, suggestions or requests are mostly absent. Local people, therefore, cannot take decisions on response actions. Further, information from DHM is generated for the national scale that tends to be generic and less useful in promoting local community-level preparedness and response (Shrestha et al. 2021). There is

a need to transform forecasts or warnings into an understandable message by considering the local context. More efforts are needed to ensure an inclusive participation of all concerned stakeholders, especially poorest people who are disproportionately affected by disasters and also considering gender, age, disability and cultural perspective. For instance, women and marginalized have less access to early warning and climate information, and generally, lack the skills to survive extreme events. Cultural and social restrictions curtail mobility of women and their ability to avoid disasters. As a result, the vulnerable population group or communities are at higher risk from climate related hazards due to lack of gender-responsive hazard, risk, and early warning information available with sufficient lead time.

- ***Institutional capacity***: Institutional capacity refers to the legal and institutional frameworks within the local government and their inclusiveness to address CCDRM (UNISDR, 2017). The central government in the country has introduced the Employees Adjustment Act (2017) to improve the technical and administrative capacity of local governments, as they have been given significant powers and responsibilities under The Constitution of Nepal (2015) but face institutional gaps in terms of knowledge, skills, and power structures between central and local government staff (Acharya, 2018). As local communities and governments lacks the capacity to identify, assess, and manage risk effectively, leading to an increased likelihood of disaster, this act aims to strengthen local governments and address the imbalance in resources between central and local government staff (Acharya, 2018). Also the overlapping roles and responsibilities among various acts such as the Water Resource Act (1992) and Building Act (1998) with the Local Government Operation Act (2017) have resulted in the need for strengthened policy formulation and institutional competence to effectively implement disaster risk management policies (Nepal et al., 2018). Furthermore, the lack of effective disaster risk management systems, policies, and institutions can limit a community's ability to prepare for and respond to CCDR. This can include a lack of clear lines of responsibility, inadequate resources, and limited capacity to coordinate with other organizations.

- ***Financial capacity***: Financial capacity refers to the availability of the fund for disaster risk preparedness (UNISDR, 2017). There is a lack of investment to address climate induced CCDR when we consider the need to cover major basins and hundreds of sub-basins in the most geographically challenging and remote landscapes of Nepal. Even though most of the local governments have established and allocated the 'Emergency Funds', in absence of rules and procedures they are unable to spend them (Bhandari et al., 2020). Lack of comprehensive dataset on hazards, climate risks and vulnerability data (including damages and losses) and cost-benefit will continue to limit the government's ability to systematically identify and prioritize limited financial resources for implementing risk reduction measures. The combined challenges of limited public fund for climate change adaptation and resilience investment, inadequate climate risk information, and higher needs for finance and investment can hamper implementation of multi-hazard risk reduction measures which is critical for creating a sustainable and disaster resilient society and communities.

- ***Infrastructure capacity***: Poor infrastructure and limited access to basic services such as healthcare, water, and sanitation can increase the impact of disasters on communities and make it difficult for them to recover. Communities may lack the early warning systems and information needed to prepare for and respond to disasters effectively. Most local governments do not have their own municipal relief supply warehouses whereas some have limited access to regional warehouses managed by the provincial and federal government (Bhandari et al., 2020). There is a lack of concrete plans or formal agreements to make resources available to the local governments during a crisis, such as first aid supplies, health supplies, nutrition support, water sanitation and hygiene (WASH), emergency shelter, camp coordination, emergency communications, early recovery systems, and logistics facilities (Bhandari et al., 2020).

2.2.3. Potential ways of addressing local vulnerabilities and capacity gaps

It is important to address these vulnerabilities and capacity gaps in an integrated and comprehensive manner in order to reduce CCDR, build resilience in community and reduce the impact of disasters. Vulnerability measurement and assessment has been recognized as the important step in reducing the impact of disasters and promoting resilience to such events (Birkmann 2006b; Cutter and Finch 2008; Montz and Tobin 2011). This may involve community engagement and participation, risk reduction measures, capacity building initiatives and investment in resilient infrastructure and systems. Some of the potential ways for addressing local vulnerabilities and capacity gaps are as follows:

- *Strengthening disaster risk management policies and plans at the local level*: This can be achieved by incorporating disaster risk reduction (DRR) principles into development plans and promoting the integration of DRR into local government activities. Disaster risk considerations should be incorporated into all aspects of development planning and decision-making, from infrastructure design and construction to land-use planning and development. For example, the risk of earthquake can be reduced by implementing building code and land use planning effectively (Nepal et al., 2018).

- *Building the capacity of local communities and local governments*: This can be achieved through the provision of training, technical support and financial resources to help them better prepare for, respond to and recover from disasters. Also, the communities can be empowered to take ownership of their own disaster risk reduction and resilience-building initiatives.

- *Improving early warning systems and risk communication*: Effective early warning systems and risk communication can help to reduce the impact of disasters by providing timely and relevant information to communities and local governments.

- *Fostering partnerships and collaboration*: By working with various stakeholders, including government agencies, civil society organizations, the private sector and international organizations, it is possible to create synergies and coordinate efforts to reduce disaster risk and build resilience at the local level.

2.3. Policy contexts and initiatives to address CCDR

The Constitution of Nepal (2015) has provision for three levels of government: national, provincial, and local. There are 753 local governments in Nepal, whose responsibility is to ensure democratic governance, providing efficient and effective public services, and promoting activities that improve the social and economic well-being of local communities; to enhance the quality of life for those they serve. (Acharya, 2016; Kelly, 2016; Pandeya, 2015 as cited in Acharya, 2018). On policy front, the constitution has provided an opportunity for advancing DRRM governance in Nepal. The constitution's Part 4, Article 51, Sub-article (g) has provisioned the multi-purpose use of natural resources and ensuring reliable access to resources even by eliminating water-induced disasters, mitigating possible environmental risks or adverse impacts, and advancing in all phases of DRR in order to mitigate overall risks. The constitution has made every level of government more accountable for hazard mitigation and disaster risk reduction. Schedule 7, 8, and 9 in the constitution has listed out the concurrent powers of federation, state and local level governments, which had specifically listed disaster risk management as one of the major responsibilities of each level of government. These schedules have provided every government with a unique power to take an innovative approach in hazard mitigation and risk reduction.

Following the 2015 Earthquake, there has been a significant improvement in assessing risk and in investing for risk reduction in the affected area including at the national level. The government has shifted its focus towards a proactive disaster risk reduction approach. The National Disaster Risk Reduction and Management Act was formulated in 2017 and its regulation commenced from 2018. This act can be considered as a major step forward in improving disaster management in the country. This act replaces the outdated Natural Calamity (Relief) Act (1982) and places emphasis on a comprehensive approach to disaster management, covering all stages of the disaster cycle including preparedness, response, rehabilitation and mitigation (Nepal et al., 2018). After the adoption of Disaster Risk Reduction and Management Act in 2017, the Government of Nepal established the National Disaster Risk Reduction and Management Authority (NDRRMA) in December 2019 with a mandate to effectively carryout disaster risk reduction management including post-disaster recovery and reconstruction activities. Disaster Management Committees have been formed at Provincial, District and Local levels. The federal and provincial level councils have more responsibility towards formulation of policies, plans, and strategies, while the committees at the local levels are the implementer of contextualized national policies, plans, and strategies. However, depending upon the extent and impacts of a disaster, the roles and responsibilities of each government is further extended. Under the act, the NDRRMA has been provided technical authorities and responsibilities for implementing policies and plans, working as central resources for DRRM, conducting research and providing technical assistance, coordinating with all relevant stakeholders, and conducting capacity building activities to all relevant government stakeholders. In this process, NDRRMA can adopt modern information technology, systems, and promote technological innovations.

The National Policy for DRR 2018 and National DRR Strategic Action Plan 2018 – 2030 guides risk reduction and management considering multiple hazard (GoN, 2018). The Disaster Risk Reduction National Strategic Plan of Action 2018-2030 aims to reduce disaster mortality and the number of affected people substantially, and to mitigate the disaster risk and losses in livelihoods, health, assets, businesses, and communities (MoHA/GoN 2018a). It has identified four priority areas and 18 priority actions. The four priority areas are: i) understanding disaster risk; ii) strengthening disaster risk governance at federal, provincial, and local levels; iii) promoting comprehensive risk-informed private and public investments in disaster risk reduction for resilience; and iv) enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction. The implementation of the action plan will be guided by principles and priority actions such as disaster risk reduction requires a multi-hazard approach and inclusive risk-informed decision-making based on the open exchange and dissemination of disaggregated data, including by sex, age and disability, as well as on easily accessible, up-to-date, comprehensible, science-based, non-sensitive risk information, complemented by traditional knowledge. The disaster risk reduction and management should work in participation and cooperation of its Federal, Provincial and Local level authorities, stakeholder organizations and communities, private sectors and international organizations and pursued with an all-of-society engagement and partnership, paying special attention to people disproportionately affected by disasters, especially the poorest. The ultimate objectives of each of these acts, policies, and strategies are to support the implementation of the national act.

Addressing the risks of hydro-meteorological hazards is one of the top adaptation priorities in the policies, strategies, programs and international commitments. The adaptation measures for reducing climate-related disaster risks, including for multi-hazards and early warning, can be found in major policy documents such as National Climate Change Policy 2019, Enhanced Nationally Determined Contributions (NDCs), National Policy for Disaster Risk Reduction, 2018, Disaster Risk Reduction National Strategic Plan of Action 2018-2030, National Adaptation Programme of Action (NAPA) 2010. As per the National Climate Change Policy 2076, Nepal's enhanced Second Nationally Determined Contributions (NDCs) has set adaptation priorities and actions to cover climate sensitive sectors by adopting an integrated approach exemplifying the inter-sectoral nature of the response (GoN 2020). NDC adaptation priorities cover eight thematic and four cross-cutting areas including Disaster Risk Reduction and Management. Nepal will accelerate adaptation by implementing the National Environment Policy (2019), National Climate Change Policy (2076), National Adaptation Program of Action (NAPA) (2010), Framework on Local Adaptation Plans of Action (LAPA) (2011), Disaster Risk Reduction National Strategic Plan of Action 2018 – 2030. Following are the relevant policy priorities outlined in the Second NDC:

- By 2030, a multi-hazard monitoring and early warning system covering all the provinces will be established.
- By 2030, all 753 local governments will prepare and implement climate-resilient and gender-responsive adaptation plans. The plans will address climate change and disaster vulnerability and risks and prioritize adaptation and disaster risk reduction and management measures focusing on women, differently-abled, children, senior citizens, youth, Indigenous Peoples, economically deprived communities and people residing in climate-vulnerable geographical areas.
- By 2025, a national strategy and action plan on Loss and Damage associated with climate change impacts will be devised.

At the local levels, Local Government Operation Act 2017 has given authority to local governments to operate as self-responsible governments for local planning and development, aligning with the national plans, policies, guidelines, and strategies. The local government can seek support from provincial and federal governments whenever required. The federal government has also developed and provided all local governments with a self-assessment tool - Local Government Institutional Capacity Self-Assessment (LISA) Guideline (2019). A guideline helps local governments to evaluate their progress in several aspects of institutional strengthening. Based on the targets provided and target achieved, the local governments get a score which will be evaluated to provide an amount in a heading of provisional development budgets to be provided by the federal government to local governments.

Each of these acts, policies and plans, strategies and guidelines has opened a pathway for modernization of DRRM in Nepal. The milestones achieved in disaster risk management in Nepal are shown in Table 2-2 below. Each of these has given a priority to the integration of innovative tools and technologies in DRRM for enhancing disaster resilience in Nepal.

Table 2.2 Milestones in disaster risk management in Nepal (Gaire et al., 2015; Pokhrel, 2020)

Year	Initiatives/activities
1982	NCRA promulgated the first legal initiative
1984	UNDP study about the threats of disaster and the need for foreign assistance conducted
1987	Disaster unit under the MoHA established
1989	NCRA 1982 amended (first amendment)
1990	Strategy for training on disaster management prepared
1990	National committee to celebrate the decade of the 1990s as the decade of international disaster reduction
1991	Comprehensive disaster management plan prepared
1992	Second amendment of NCRA 1982 ratified
1993	Training of government officials in collaboration with UNDP organized
1993/ 1994	Training on disaster management conducted by USAID and ADPC, Bangkok, organized as per request of MoHA
1994	Action plan prepared with the help of UNDP
1996	UNDP's disaster management capacity-building program begun
2001	Department of Narcotics Control and Disaster Management under MoHA established
2002	National Development Plan (2002–2007), emphasizing irrigation and water-induced disaster preparedness and natural disaster management
2003	Disaster impact assessments of development projects made mandatory in the Tenth National Plan
2005	National Water Plan development, and Nepal participated in the Hyogo Conference
2006	Approval of water-induced disaster management policy
2007	Drafts on acts, policies, and strategies on disaster management in Nepal prepared
2008	NSDRM prepared
2009	NSDRM approved by Government of Nepal
2011	Five-year Disaster Risk Reduction strategic framework developed by USAID and Nepal Disaster Risk Reduction Office
2014	Disaster Risk Management Policy developed
2015	The Constitution of Nepal with advanced provision for DRRM governance
2017	Disaster Risk Reduction & Management Act
2017	Local Government Operation Act
2018	National Disaster Risk Reduction Policy
2018-2030	Strategic National Action Plan, consistent with SFDRR

Notes: The table shows the milestones in disaster risk management in Nepal from the first disaster act to a recent policy framework that has been taken into consideration. It shows that Nepal is actively participating in disaster management activities.

Abbreviations: ADPC, Asian Disaster Preparedness Center; MoHA, Ministry of Home Affairs; NCRA, Natural Calamity Relief Act; NSDRM, National Strategy for Disaster Risk Management; SFDRR, Sendai Framework for Disaster Risk Reduction; UNDP, United Nations Development Project; USAID, United States Agency for International Development.

As mandated by the national act, the National Disaster Risk Reduction and Management Council chaired by the Prime Minister is the top-most authority for developing and issuing the national policies, strategies, and plans related to DRR. As a forwarding committee, the act has mandated a National

Disaster Risk Reduction and Management Executive Committee chaired by the Home Minister under which NDRRMA acts as an implementing authority. During the implementation process, the authority is responsible for coordinating with different line ministries, provincial committees, district committees, local committees, bilateral and multilateral organizations, development partners, non-government organizations, community-based organizations, civil society organizations, private sectors, academia, etc. Several clusters have been formed by the government for effective preparedness and response to disasters. The line ministries are assigned as the lead and relevant development agencies are assigned as the co-lead for different clusters. At local level, local acts have provided an authority to form disaster risk reduction and management committees at municipal and wards, and if required, community level task force can also be formed. The institutional framework for disaster reduction in Nepal is shown in Figure 2.1.

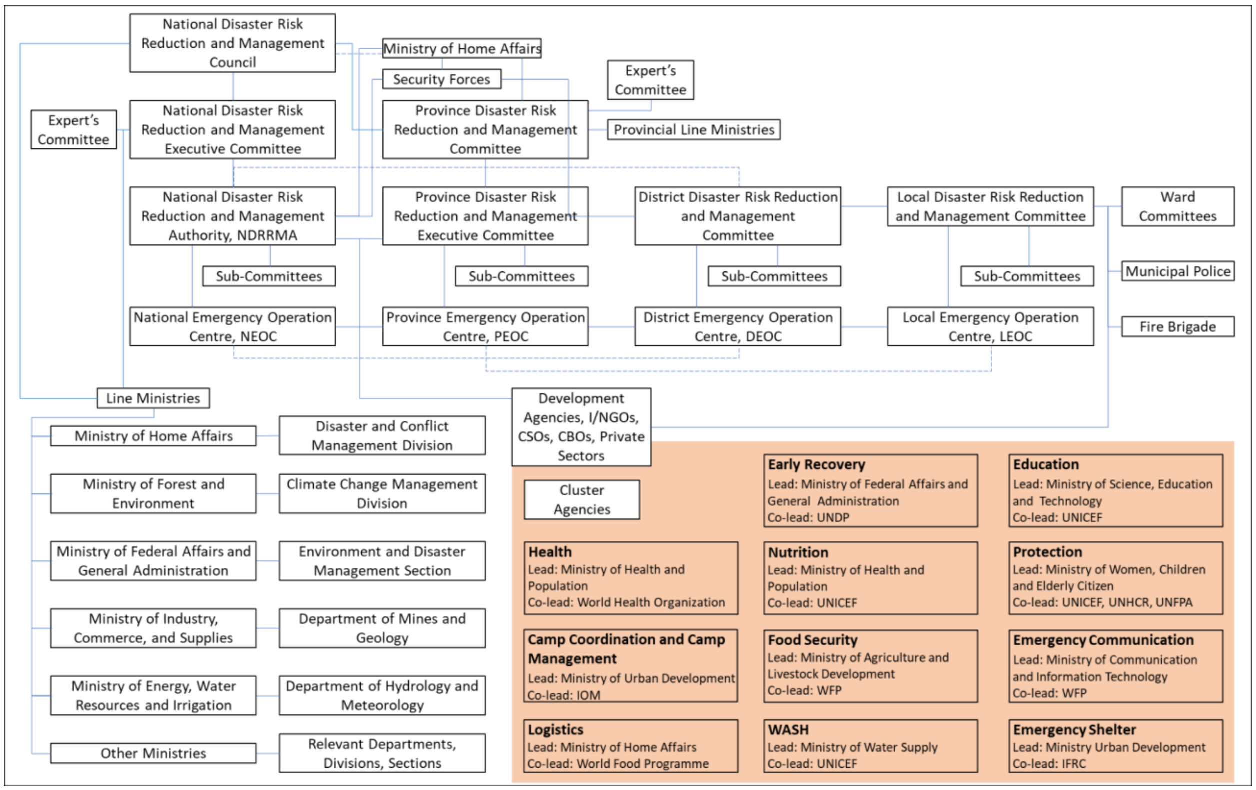


Figure 2.1 Institutional arrangements for disaster risk reduction in Nepal.

2.4. Measures to be taken to address future CCDR at the local level

It is crucial for the government to invest in improving the technical and functional capacities of disaster risk reduction institutions in order to effectively prepare and respond to different types of natural disasters. To achieve this goal, it is necessary to establish a well-equipped National DRM Training Institute and Resource Centre that will be responsible for strengthening capacities at all levels (MoHA, 2017). The disaster policies in Nepal mostly concentrate on responding to and providing relief during disasters, with limited attention paid to preparation and risk mitigation (Nepal et al., 2018). CCDR is a relatively new area for disaster risk management and as such the country does not yet have an effective multi-hazard early warning system which will be critical to deal with increasing number of extreme hazards in future. Effective implementation of disaster risk management faces a number of barriers despite encouraging progress in terms of formulating plans, policies, action plans and institutional setup for disaster risk management and climate change adaptation. The measures taken for DRR should aim to reduce vulnerabilities and capacity gaps, build resilience, ensure effective risk management and respond to future CCDR events. In order to mitigate the impacts of CCDR, the government of Nepal should take several measures such as developing early warning systems, improving disaster risk management policies and practices, and strengthening the capacity of communities to prepare and respond to disasters. An effective institutional setup from the central to local level is crucial for the success of disaster management efforts, and the well-structured set-up provided by National Disaster Risk Reduction and Management Act, (2017) has the potential to yield positive outcomes in this regard. To address future CCDR at the local level, a variety of measures can be taken, which includes:

- *Improving governance and institutional capacity*: An effective response to future CCDR events can be ensured by strengthening disaster risk management governance with clear lines of responsibility and ensuring effective coordination between different organizations. The Constitution of Nepal, (2015) and Local Government Operation Act, (2017) have given local governments the authority to regulate local affairs, development planning and disaster management functions including the management of DRRM fund, formulation of policies, rescue and relief operations (Bhandari et al., 2020). However, it does not address the procedures for the local government to seek assistance from higher levels of government, such as the provincial and federal levels, for disaster management (Bhandari et al., 2020). Therefore, to address CCDR effectively, it is important for the local government to seek support from higher levels of government, such as the provincial and federal levels, when necessary. This can include seeking financial and technical support for disaster risk reduction and management initiatives, as well as cooperation and coordination in the development and implementation of disaster management policies and plans.

  Local governments are responsible for building their minimum capacity for disaster management, including human resources, technical and professional skills, governance tools, and disaster relief supplies. However, the capacity required for different local governments may vary based on their location and exposure to specific hazards like floods, disease outbreaks, or windstorms. It is important to note that local governments have different levels of vulnerability, and their institutional capacity must be tailored to their specific needs (Bhandari et al., 2020). In addition, the local government should also collaborate with other stakeholders, such as non-government organizations, the private sector, local communities and international organizations, to enhance their capacity to manage CCDR and build resilience. The timing and scope of such support and collaboration will depend on the specific needs and circumstances of each community and should be regularly assessed and adjusted as necessary.

- *Risk assessment and early warning systems*: Conducting regular risk assessments can help to identify potential CCDR and respond quickly to reduce the impact. Land-use planning and zoning policies can also be implemented to categorize the vulnerable zones and safe zones, to the potential impacts of CCDR. The local governments, or Palikas, in Nepal have access to weather forecasts and flood risk predictions from the Department of Hydrology and Meteorology (DHM) through various media sources like radio, TV, online news portals, and social media. DHM provides real-time forecasts for at least 12 rivers in the Terai region. The Palikas play a crucial role in utilizing the available information and organizing efficient response actions as part of the end-to-end early warning system but the Palikas do not possess adequate institutional structures or trained staff to effectively respond to disaster risk information available through early warning system (Bhandari et al., 2020). Therefore, investing in early warning systems, along with adequate structures and trained staffs, disaster response capacities, and disaster risk information systems will be helpful to ensure effective and timely response to future CCDR events.

- *Infrastructure development and disaster risk financing*: Investing in infrastructure that is resilient to CCDR can help to reduce risk and improve the ability to respond to disasters. Bilateral agreement between local governments among themselves can help to avoid discussion of disaster response measures during time of crisis, sharing of fire engines can be taken as example in this scenario (Bhandari et al., 2020). Establishing disaster risk financing mechanisms can provide resources for responding to CCDR and help to reduce the impact of disasters. The central government should amend proper rules and procedures for the local governments to spend the allocated emergency funds during time of crisis and for mitigation process. In order to ensure the long-term sustainability of CCDRM efforts, central government should provide a regular budget based on actual needs identified through risk assessments which will ensure that the necessary resources are available to manage and mitigate the impacts of different types of natural disasters effectively (MoHA, 2017).
- *Integrated risk management and building resilience*: Implementing integrated risk management approaches that address the interlinked nature of CCDR can help to reduce risk and improve resilience. Building resilience at the community level through activities such as capacity-building, social mobilization, and enhancing the capacity of local organizations can help reduce the vulnerabilities associated with CCDR. By promoting sustainable development and reducing greenhouse gas emissions, the country can help reduce the risk of future CCDR events caused by the climate change. Further implementing risk measures such as improving building code and promoting community-based disaster risk management can help reduce the impact of future CCDR events. Also encouraging the adoption of climate-resilient agriculture practices can help to reduce the impact of CCDR on food security and the livelihoods of communities.
- *Research and knowledge management*: Conducting research and sharing knowledge on CCDR, including the development of effective monitoring and evaluation systems, awareness and understanding of disaster risks and mitigation measures, can help improve the understanding of CCDR and support the informed decision-making. In absence of the knowledge and capacity within the local government, they can access technical and resource capacity from other government, non- government, I/NGOs and private agencies (Bhandari et al., 2020). For example, local governments can acquire capacity to understanding the information from DHM such as, for flood forecasting, early warning, hazard and risk mapping, and use the information for their territory. The existing disaster information management system BIPAD Portal, (2023) managed by MoHA should be upgraded for reliable and consistent information along with automatic updates, capacity to generate early warning system and sharing risk information on time.

These measures, when implemented in a coordinated and comprehensive manner, can help to address the challenges posed by CCDR and reduce the impact of future disasters. It is important to note that these measures must be tailored to local context and be implemented in a participatory and inclusive manner, involving communities, local organizations, and relevant stakeholders during the planning and implementation process.

3. PARTICIPATORY ASSESSMENT OF CCDR AT THE LOCAL LEVEL

Differentiating the risk of CCDR from recurring disasters due to single-hazard at the local level is the core aspect of participatory assessment. The assessment should be viewed as a continuous process since it requires a comprehensive understanding of the different hazards and resultant exposure and vulnerability of the local population, infrastructure, and services. There are no hard-and-fast guides on assessing CCDR but several steps could be taken in this regard. As an initial guide, Figure 3.1 outlines the basic suggested steps which could be customized to fit the local context.

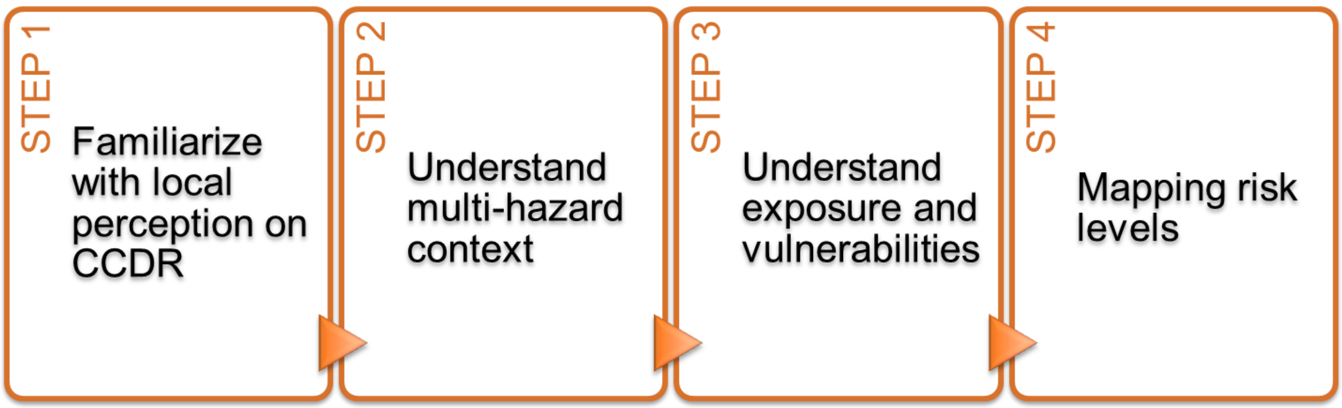


Figure 3.1 Basic steps for assessing CCDR at the local level

These steps are meant to progressively advance the understanding of CCDR in a participatory manner. It will help understand and identify exposure elements as well as evaluate key vulnerabilities that were either considered safe or remained hidden. For instance, during the capacity development workshop on this guideline development in Melamchi, the participants share their surprise how the trout farms located high above the Melamchi river line were severely damaged by the flood. Another surprise was the devastating nature of hazard which was the combination of debris (sediments, boulders) and flood water that was completely different from earlier floods. The infrastructure, including the intake point of newly constructed Melamchi Water Supply, bridges, houses, that we considered safe were severely damaged. In that sense assessment of CCDR often involves wider imagination of unforeseen but potential hazard combinations (natural, man-made, climate change, or other types of disruptions). Below sections will elaborate each step highlighting key actions to be considered.

3.1. Familiarize with local perception on CCDR

Disaster is a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts (UNDRR, 2020). Disaster risk is the combination of hazard, vulnerability, exposure and capacity. However, in the local context understanding of these elements of risk is not well differentiated and often interpreted as observed or anticipated disaster impacts in terms of negative effects to economic, human and environment, and may include death, injuries, disease and other negative effects on human physical, mental (e.g., trauma) and social well-being (e.g., economic losses). It could also be remembered through positive changes as a part of recovery, reconstruction, and disaster preparedness. The risk perception could vary from one person to another depending on their observation, past experience, and capacity to cope with disaster impacts. Before starting the process of risk assessment, it is important to clarify the local perception on the likely scale of disaster impacts.

In this step, local communities and key stakeholders start by discussing the historical context of various disaster events as well as the recent ones. They can further locate those events through participatory mapping exercise. They can prepare the list of those disaster events, including the historical ones from the memory of the elderly, and summarize the impacts and damages. Through this exercise, the communities can identify the nature of recurring hazards types, exposure areas, and key vulnerabilities.

Based on the outcome of the exercise, the community will be ready for discussing CCDR. It will start by explaining the key concepts behind CCDR, why we need to be serious about CCDR, and when relevant referencing the examples of CCDR. Followed by that community will share their perception about CCDR whether they see it as imminent problem, whether observed impacts of climate change such as heavy rainfall, drought, GLOF are responsible for elevating CCDR risks, or even the human actions (unplanned construction, industrialization, settlement and farming in risky locations, deforestation) are contributing to increased vulnerability. Following are the key outcomes that is expected out of this exercise:

1. Level of understanding of disaster risks in general
2. Clarity on the concept of CCDR (what aspects are clear and what aspects are not)
3. How CCDR differs from past disasters
4. General trend of CCDR, whether they are likely to increase or not
5. Shared perception on CCDR

The very objective of this step is to set a common ground for initiating deeper discussion on CCDR. In that respect, the intent here is not about how well communities could understand and interpret CCDR. Instead, it is more about the understanding the level of perception so that further steps could be planned accordingly to address the capacity gaps.

3.2. Understand multi-hazard context

Hazard is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation(UNDRR, 2020). Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity or magnitude, frequency and probability. Studies to understand hazard patterns are still evolving and are difficult to classify. In this respect, preparing a list of hazard clusters, as shown in Table 3.1, that are relevant to the given local context based on past, recent or likely future occurrences could be a good start.

Table 3.1 Hazard clusters based on UNDRR definitions (UNDRR, 2020).

Hazard types	Description	Examples
Meteorological and hydrological hazards	They are of atmospheric, hydrological or oceanographic origin. Hydrometeorological conditions may also be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics and in the transport and dispersal of toxic substances and volcanic eruption material. These hazards are observed, monitored, and forecasted by the national meteorological and hydrological services of each country.	Tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; drought; heatwaves and cold spells; and coastal storm surges.
Extraterrestrial hazards	Extraterrestrial hazards are rare events originating outside the Earth.	Asteroid and meteorite impacts or solar flares. Solar flares have the potential to cause widespread disruption and damage to communications satellites and to electric power transmission, resulting in large economic losses.
Geological or geophysical hazards or geohazards	They originate from internal earth processes. Hydrometeorological factors are important contributors to some of these processes. Tsunamis are difficult to categorize: although they are triggered by undersea earthquakes and other geological events, they essentially become an oceanic process that is manifested as a coastal water-related hazard.	Earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapses, debris or mud flows, and subsidence or ground rupture, GLOF.
Environmental hazards	They may include chemical, natural and biological hazards. They can be created by environmental degradation or physical or chemical pollution in the air, water and soil. However, many of the processes and phenomena that fall into this category may be termed drivers of hazard and risk rather than hazards in themselves.	Soil degradation, deforestation, loss of biodiversity, land/groundwater salinization and sea-level rise, pollution, sand/rocks mining in rivers.
Chemical hazards	Short- or long-term exposure to chemicals both of natural and human origin in the environmental, technological, industry, agriculture and transport.	Toxic chemical spills, industrial accidents, run-off of agro-chemicals

Biological hazards	They are organic origin or conveyed by biological vectors, including pathogenic microorganisms, toxins and bioactive substances. Biological hazards are also defined by their infectiousness or toxicity, or other characteristics of the pathogen such as dose-response, incubation period, case fatality rate and estimation of the pathogen for transmission.	Bacteria, viruses or parasites, as well as venomous wildlife and insects, poisonous plants and mosquitoes carrying disease-causing agents.
Technological hazards	They originate from technological or industrial conditions, dangerous procedures, infrastructure failures or specific human activities. Technological hazards also may arise directly as a result of the impacts of a natural hazard event.	Industrial pollution, nuclear radiation, toxic wastes, dam failures, transport accidents, factory explosions, fires and chemical spills.

After listing potential hazard types, we will focus on visualizing the combination or succession of multi-hazard situation over a given period as shown in Figure 3.2.

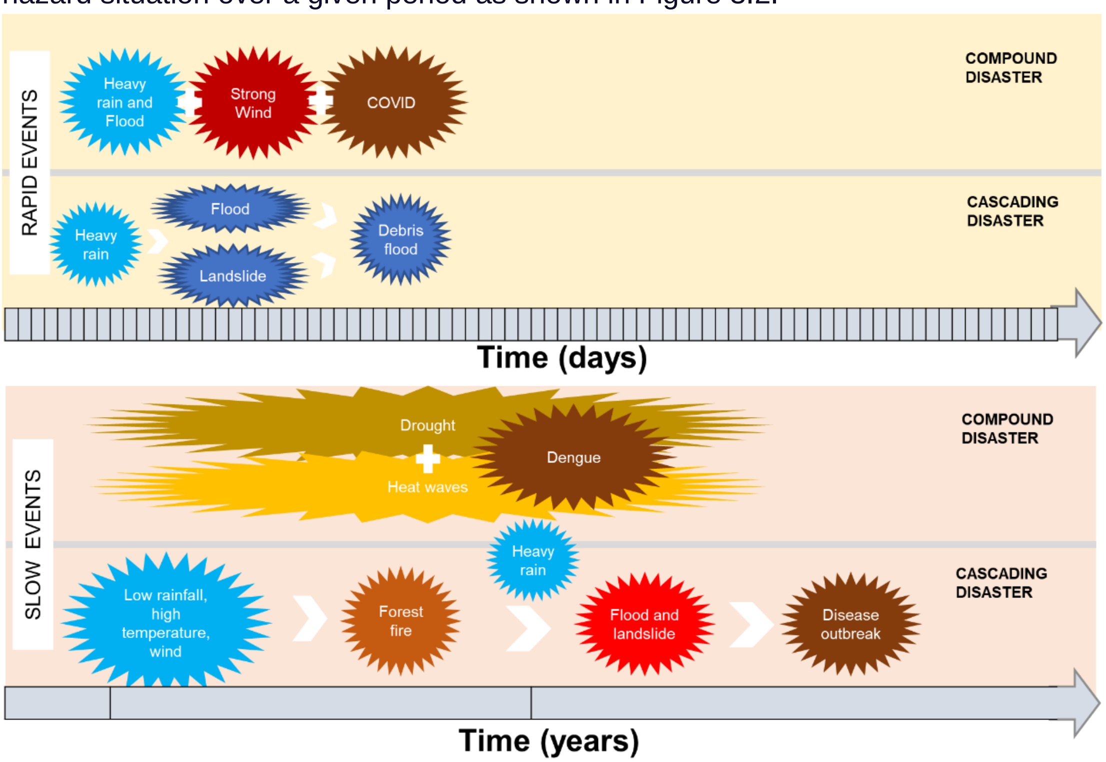


Figure 3.2 CCDR for slow and rapid onset hazard combinations

Here, multi-hazard means (1) the selection of multiple major hazards that the locality could face, and (2) the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects (UNDRR, 2020). One or more criteria could be used to characterize multi-hazard situation and resultant CCDR as shown in Table 3.2.

Table 3.2 Criteria for characterizing CCDR

Criteria	Description
Triggers or causes (what?)	Triggers are the main causes behind initiation of a hazard. The examples include heavy and continuous rainfall, heavy wind, hot and dry conditions etc. A hazard itself could also act as a trigger. For instance, an earthquake can shake the ground and lead to landslides. It is important to understand how different combination of primary or secondary triggers results into compound or cascading impacts. The triggers could be of local origin, external or combination of both.
Occurrences (when?)	This refers to the likely timing or patterns for the hazards to occur. For instance, likely timing for floods and landslides are in the wet/monsoon season where as forest fire occur during the dry season. Timing and patterns of occurrences helps in understanding the likely combination or succession of hazards. For instance, if a heavy rainfall occurs after a prolonged dry period, it could result in massive landslides and floods.
Frequency (how often)	It entails how often a particular hazard will occur within a given time period such as number of flood event or disease outbreak in the past 10 years
Scale (where)	It refers to the exposure area of the hazard. The scale could be further sub-divided based on primary, secondary or tertiary impacts in terms of how the impacts could spread such as from local origin to sub-national to national and to regional and vice-versa
Impacts/ damages (how much/how big/how long?)	Impacts or damage entails the extent of exposure areas that experience disaster impacts and damages in terms of deaths and injury, damages to property and infrastructure, or disruption of services. The impacts or damages could be minor, medium or major. It could be also related in terms of the duration that the disaster impact persisted. The impacts could also spread to primary, secondary, tertiary levels creating dominos or chain reactions. In the worst case the impacts could result in failure of whole system. Often, the news and mis-information could act as threat multiplier
Response	In case of CCDR, the response tends to be ad hoc and uncoordinated due to the limited understanding of underlying cause and impacts and individual response from different sectors. Lack of information and coordination gaps might create confusion and ineffective response and recovery. So, pre-evaluation of response choices will help to understand likely complexities involved when faced with CCDR. Systemic responses are necessary for a sustained recovery.

The result of this exercise could be a multi-layered hazard map overlaying different hazards based on their occurrences and extent of the exposure area or population. The participants involved in this exercise will prepare a list of hazard combination that could result in compound or cascading impacts. It will help the local communities to better understand:

- What multi-hazard combination are likely to occur in future
- When and how frequently they are likely to occur
- What will be the intensity and scale of such hazards when compared to the past disasters?
- Primary, secondary and tertiary nature of impacts over time

One crucial point here is the consideration of the impact of climate change in hazard assessment. Because of the climate change, it has become hard to predict the timing of hazards, especially, hydro-metrological types as communities cannot simply rely on historical patterns. Uses of climate impact assessment or decision support tools like Impact Viewer and Climo Cast, which are freely available on the AP-PLAT website, become quite helpful in this regard. It is strongly advisable to infuse assessment of climate change impacts, including local inputs and observations, during the assessment of CCDR.

3.3. Understand exposure, vulnerability, and capacity

Exposure, vulnerability and capacity defines the likelihood of one or more hazards to become a disaster. While hazards are natural or man-made, but the disaster is a human construct that is determined by the level of exposure, vulnerability and capacity to one or more hazards in question.

Here, exposure is the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. Measures of exposure can include the number of people or types of assets in an area.

Vulnerability is the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

Capacity is the combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience. Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.

While vulnerability and exposure indicate the negative dimensions of disaster, capacities are the positive factors that increase the ability of people to cope with hazards. Vulnerability and capacity are usually determined through socio-economic and damage assessment.

Exposure when combined with the specific vulnerability and capacity of the exposed elements to any particular hazard will allows an estimation of the disaster risks in the area of interest.

In the case of CCDR, evaluation of exposure, vulnerability and capacity dimensions requires obvious broadening of the scope when compared to traditional single or hazard-by-hazard approach. It involves identifying new areas of exposure, vulnerability or capacity that were not obvious or remained hidden in the past as shown in Figure 3.3. Compared to the past, the areas or elements under exposure is likely to increase. For instance, areas such as evacuation centers, critical infrastructure, and services that are normally located in safer zone could fall under high exposure area under CCDR. It could create a new set of challenges for redefining the hazard map of an area.

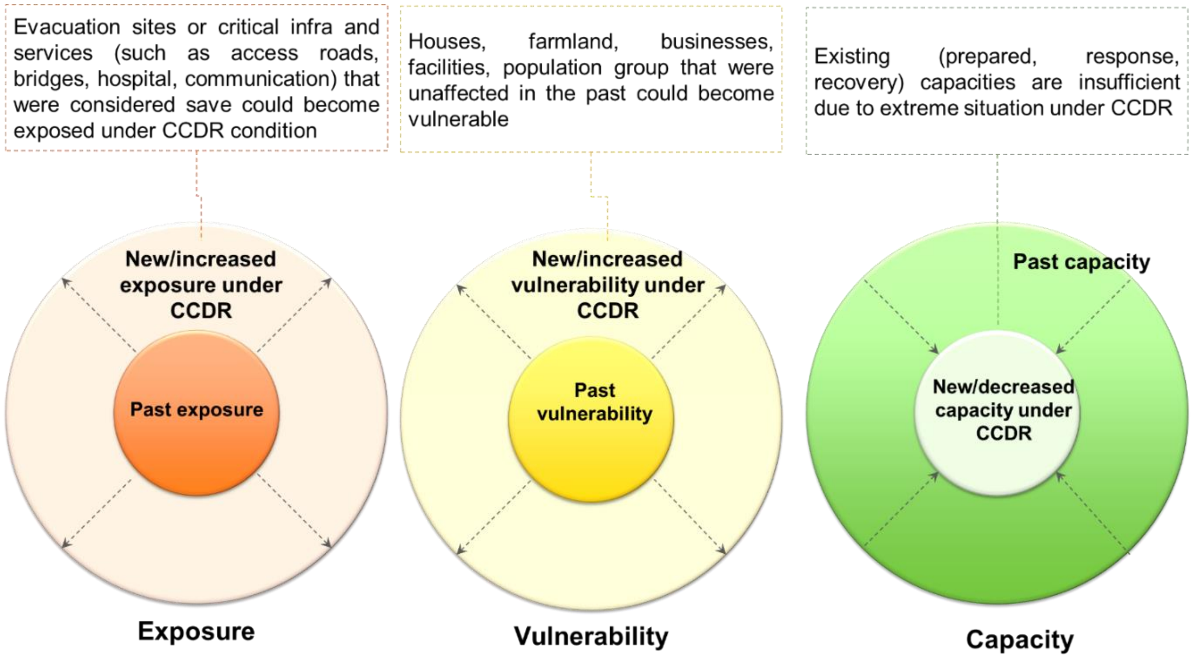


Figure 3.3 Increase in exposure and vulnerability and decrease in the capacity under CCDR condition

Similarly, due to the increase in exposure it is obvious that assets, infrastructure or people that were not affected in the past and perceived to be safe could become vulnerable. The situation will increase the scope and profile of vulnerable elements which then require a new set of measures to cope with the risk. However, there will be likely shortfall in capacity due to the excessive level of the hazard and exposure to deal with. Existing capacity could come under sever strain or might not work at all due to the surprise element beyond the normal ability of people, organizations and systems, using available skills and resources to respond to the impacts. Under CCDR, the coping capacity could soon reach its limit and cease to function. A new level of awareness, resources and governance is essential to enhance the coping capacity and adapt to the situation.

As a part of participatory exercise, communities and stakeholders will prepare a summary of exposure, vulnerability and capacity elements to be considered for each prioritized hazard combination as shown in Table 3.3. The table could be further elaborated by disaggregating exposure in terms of potential for primary, secondary or tertiary impacts. Primary exposure are the areas the areas in the frontline facing the hazards. Whereas secondary or tertiary exposure are resulting from chain of connected events. For each primary, secondary or tertiary impacts, vulnerability and capacity could be assessed accordingly. This will help to prioritize preparedness in terms of timing and scale of likely impacts.

Vulnerability assessment is usually done based on the likely loss and damage in differential manner by considering age, ethnicity, religion, gender, labour conditions, access to resources/services, land ownership, economic status, disabilities (physical, psychological and cognitive), etc. The process often requires time, resources and expertise and could be complex when considering CCDR. As an alternative, a simplified approached could be adopted as a part of participatory assessment. Instead of quantitative estimation, communities could us a simplified approach for categorical ranking of potential damage such as high, medium or low. Similarly, in the case of capacity the focus will be on assessing whether the communities have resources and capability to minimize the level of potential damage. Accordingly, for each damage condition the capacity could be ranked into high, medium, and low.

Table 2.3 Exposure, vulnerability and capacity for identified multi-hazard combinations

Risk components	Multi-hazard combination A (*e.g., flood+ landslide*)	Multi-hazard combination B (*e.g., dry weather→drought→forest fire; crop failure*)	Hazard combination C
EXPOSURE			
Exposure under the current understanding			
Newly identified exposure areas under CCDR			
VULNERABILITY			
Already identified vulnerabilities			
Newly identified vulnerabilities under CCDR			
CAPACITY			
Existing coping capacity (resources, infrastructure, assets, people)			
Newly identified shortfalls in coping capacity under CCDR			

Important outcome of this exercise is the understanding of new areas of exposure, identification of vulnerable infrastructure, assets, services and population groups, and re-evaluation of capacity gaps resulting from the identified/prioritized multi-hazard combination. As a result of this exercise the communities will be able to understand:

- Overall exposure under the CCDR, including identification of new exposure areas/sectors that were not known before
- Increase or decrease in the number of vulnerable elements/sectors/population group based on assessment of the potential damage level. Estimation of damage require significant effort and expertise and could involve significant complexities, the communities can adopt a simplified approach of using categorical scale such as high, medium, or low. The evaluation could be in terms of tangible (lives, injury, economic loss, recovery cost etc) and intangible damages (loss of jobs, trauma, disruption of services etc).
- Capacity gaps or deficiencies to deal with CCDR

3.4. Ranking and mapping of risk levels

Combining the information on multi-hazard combination, exposure, vulnerability and capacity will result in an understanding of the involved risks. As shown in Figure 3.4, exposure and vulnerability positively contribute to the risk while capacity and risk are negatively related. So, the combination of increased exposure, high vulnerability and low capacity results in higher risk. While the opposite condition will result into lowering of the risk.

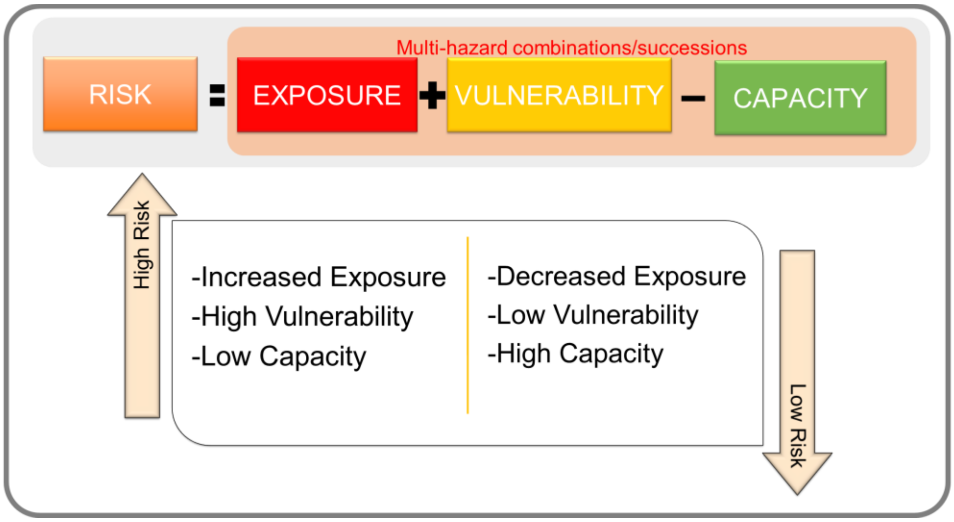


Figure 3.4 Conditions determining the level of risks

This step involves ranking of the risk level through evaluation of exposure, vulnerability and capacity for each multi-hazard combination. Table 3.4 shows the template for ranking risk level. In this process, communities will assign the ranks or weightage or ratings to each risk element based on the relative importance under identified multi-hazard condition. The scale could be either numerical (1-10), categorical (low, medium, high) or any locally used system such that the combination of ratings could be presented as a single score. The total risk score is calculated by summing exposure and vulnerability and subtracting the capacity. Based on the final score or ratings, the communities will then create a priority list of most potential or risky multi-hazard condition.

Table 3.3 Template for ranking risk level

Multi-hazard combination	**Level of exposure** *(1-10 or high, medium, low)*	**State of vulnerability based on damage potential** *(1-10 or high, medium, low)*	**State of capacity** *(1-10 or high, medium, low)*	**Total risk score** (*exposure+vulnerability-capacity*)	**Overall risk priority**
Multi-hazard combination A (*e.g., flood+ landslide***)**	5	6	3	5+6-3 = 8	2
Multi-hazard combination B (*e.g., dry weather→drought→forest fire; crop failure***)**	6	8	2	6+8-2=12	1
Hazard combination C	3	3	5	3+3-5=1	3
Hazard combination D					
Hazard combination E					

After prioritizing the risk level for identified multi-hazard combination, communities will overlay the total risk score in the local map. The mapping exercise allows the community to grasp a total understanding of the relative risks at different location. The result of mapping could then be used for disaster resilient land-use planning in the subsequent steps.

4. CCDR SCENARIO DEVELOPMENT

In Nepal and in the Hindu Kush Himalaya region, compounding and cascading hazards are becoming more frequent due to which a better and reliable approach is required for hazard assessment and risk management (Maharjan et al., 2021). Compound and cascading disasters follow complex patterns in space and time and lead to massive impacts as compared to single hazards (AghaKouchak et al. 2018). The more we are able to recognize the patterns of these disasters, the more we will be able to manage and respond to these disasters.

Scenario development is an extension of the risk assessment that is useful for planning DDR measures and strengthen risk-governance mechanisms at appropriate scales. It gives a clear vision of how, where and why disasters could occur to decision-makers (Martin-Vegue, 2021). Scenario development is a vital step that differentiates CCDR from conventional approaches of disaster risk assessment where approaches of scenario development are not comprehensive. There is a need to broaden the focus of scenario building beyond the mere mapping of direct effects from the potential hazards and use evidence-based methods to map both the direct and indirect nature of cascading effects that can be caused both at a temporal scale (immediate, short term, medium, and long term) and also at a geo-political scale (local, national, transboundary and global) (UNDRR, 2022).

Scenario is a plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships (IPCC, 2018). Scenario describes future events and draws likely outcomes based on assumptions about key factors and their causal relationships. However, scenarios are neither predictions nor forecasts, but are used to provide a view of the implications from CCDR.

The main purpose of scenario development is to help local communities understand how compound and cascading disasters can affect their livelihood and the surrounding environment. The other function of scenario development is to set up a risk analysis process and ways to deal with the damage due to disaster. Scenarios set up risk analysis by clearly defining and decomposing the factors contributing to the frequency and the magnitude of adverse events (Martin-Vegue, 2021).

There are varieties of methodologies to develop risk scenarios for different levels of stakeholders. Different kinds of scenarios ranging from simplistic to complex models, qualitative to quantitative methodologies, as well as expert versus non-expert oriented approaches can be created using numerous methods (Birkmann et al., 2015). A mechanism which describes the future course or conditions for a certain point of time, without the known degree of uncertainty about the future can be represented as scenarios (Kok et al. 2011). Scenario development process helps to develop trust-building and strengthen mutual learning (Wiek et al. 2006). Scenarios help us to generate a clear picture about the consequences that may arise as the consequences of our decision making and management strategies (Birkmann et al., 2015).

Scenario development generally helps us to:

- make the future(s) more realistic and understandable for decision makers and force new thinking;
- shared understanding on the significance of uncertainties, including future climate impacts;

- illustrate different potential development pathways, underscoring possible and undesirable or desirable development directions;
- help to identify policies and measures that are appropriate and beneficial in specific scenarios and, hopefully, across a range of possible scenarios.

Risk scenarios should be developed to identify the most likely and most severe disaster scenarios that could occur in the local area by considering the results of the risk assessments and all potential factors that might interact. Vulnerabilities and CCDR could be best addressed through approaches involving community-based and participatory scenario planning which encourages meaningful participation of the most vulnerable and marginalized groups, co-learning and capacity building. Consideration of inclusiveness, context specific inequities and differentiated vulnerabilities, such as based on gender, ethnicity, disability, age, location and income, can result it the development of realistic scenarios.

For future planning, communities can develop one or more scenarios through interactions with local level government and participation of key stakeholders (prioritizing the vulnerable groups or sectors). The developed scenarios then can serve as an effective source of information for communicating CCDR to all stakeholders including media, farmers, government agencies, businesses, service sectors, etc. Further the developed scenarios can guide the relevant stakeholders on how to respond when new information and knowledge on CCDR becomes available.

To summarize, the overall process to be followed in the scenario development could be done following four steps as shown in Figure 4.1.

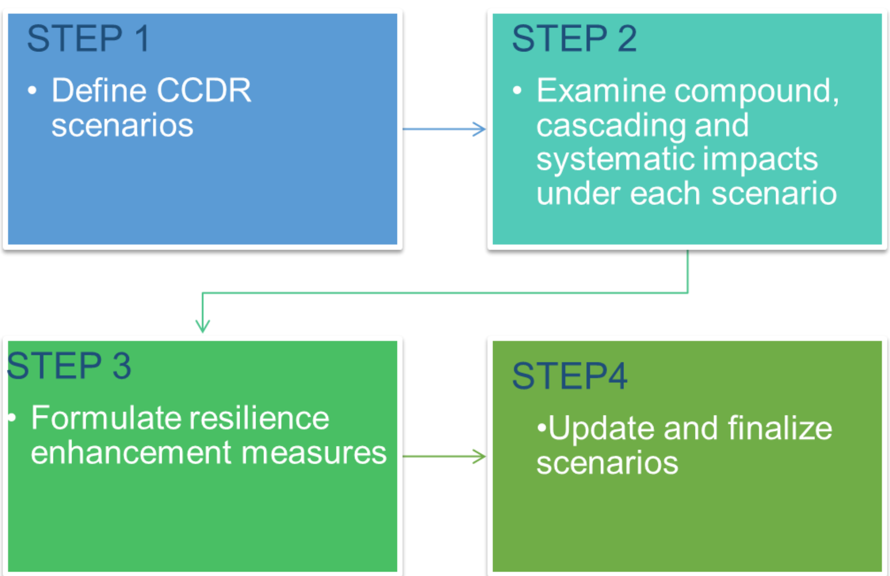


Figure 4.1 Process of scenario development leading to formulation of resilience enhancement measures

After defining of the scenarios, next step involves examining impacts specific to each scenario. The outcome of formulating scenario and examining impacts will pave a way for identifying resilience enhancement measures for each dimension of disaster management cycle. Resilience enhancement measures against CCDR will consider the prevention and minimization of damages as well as preparation for "better reconstruction" to ensure adaptive recovery. In the case of CCDR, additional consideration is also to break the series of cascades and prevent them from happening next time. Followed by that, the last step is about updating and finalizing the scenarios which will be then used as a basis for building an adaptive strategy and planning.

4.1. Define CCDR scenarios

Understanding and managing compound, cascading and systemic risks and their potential effects upon social, economic and environmental systems can be improved via evidence-based scenario building at a spatio-temporal level. In order to build a scenario informed of all types of risks, corresponding effects on the communities and the systems, as well as the corresponding probabilities of effects need to be modelled using a large variety of heterogeneous data and scientific evidence gathered from various sources. The new and emerging technologies can play an instrumental role in doing so. In addition, these scenarios can be modelled for projecting future effects through a time-based analysis.

However, at the community level, it may be challenging to follow a scientifically rigorous, data-intensive, and comprehensive approach of scenario development due to the potential lack of resources and expertise. Instead, the realistic approach would be to follow a simplified approach that could be accomplished locally and gradually improvised over time. In fact, scenarios can be best built using less sophisticated approach than the latest and complex processes that are time-consuming and require special capabilities (human and technical) that are usually out of the reach of the local communities. What is usually necessary for developing a realistic scenario is the current understanding of the local factors contributing to overall risk that are only known to the communities. In the process, the communities can indicate areas where further data collections or assessments are necessary, including those requiring external supports.

Before starting the scenario development, it is beneficial to identify the stakeholders who should be involved in the process of developing risk scenarios in addition to those who were already involved in the participatory CCDR assessment. Consultation sessions with those stakeholders will be conducted to clarify the purpose of scenario development and gather their input and feedback. During the consultation, it is important to update the information on prioritized multi-hazard condition that was developed through participatory CCDR assessment. This can include maps, reports, and other relevant information.

After the preparatory consultations, scenario development can start by establishing a baseline condition based on current situation for a shared understanding of the risk and by elaborating the conditions of multi-hazard situation based on the information gathered during the participatory CCDR assessment. Community will develop a narrative about each scenario in a simple and easily understandable manner. Scenarios could be best explained in the form of a story and if possible using maps and pictures. **Box 3** shows a hypothetical example of scenario with reference to Melamchi condition. The description of scenario has to be very convincing so that all stakeholders are motivated to plan and prepare against potential CCDR situations in the future.

Box 3 Hypothetical description of CCDR scenario with reference to Melamchi

Melamchi Municipality is located at the confluence of Melamchi and Indrawati Rivers which emerge from Himalaya. Heavy rainfall, floods, and landslides are frequent hazards here. However, after 2015 Earhquake, community has noticed the high vulnerability of this area to geo-hazards such as slope failures. Other types of hazards include forest fire and dry landslides. Additional health impacts such as COVID, spread of dengue, and pest attack to crops is also becoming frequent. Due to climate change, the community is increasingly faced with high, intense, and/or untimely rainfall and prolonged dry period.

Compound or cascading hazards due to combination of heavy rainfall, landslides, GLOF and floods are likely to increase in the future. In the meantime, past earthquake and heavy deposition of loose sediments in the upstream are potential dangers which could act as trigger for future hazards.

As a result of these extreme condition, the whole community are vulnerable and unable to cope with the situation without any preparedness and mitigation. Such events are likely to result in deaths, loss of critical infrastructure and services for an extended period, and it could push back the development by at least three decades. Stakeholder and communities, therefore, agree to upgrade their disaster management system, boost internal capacity and prepare a long-term strategy to deal with CCDR.

4.2. Examine compound, cascading and systematic impacts under each scenario

After the description of the scenario, communities can then prioritize a list of exposure elements that are subject to disaster impacts over an extended period. It helps to estimate the extent of impacts that that will persist and spread over time. Disaster impact is the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being. The process will start by discussing the existing as well as newly identified exposure areas, key vulnerabilities and capacity gaps found during the participatory CCDR assessment. Here the focus will be understanding the chain of events and interlinkages, likely surprises, speed of change, spread of impact over areas and systems, and persistence of impacts over area and time. Figure 4.2 shows an image of chain of events and interlinkages of all impacts under a given scenario.

Communities can draw similar chain of events and impact that might unfold under a given CCDR scenario. The diagnosis should cover a broad assessment of the environmental, socio-cultural, and economic context and linkages with respect to key exposure, vulnerabilities and capacity gaps. Table 4.1 shows an example of key impacts identified by community over space and time. In this case, primary impacts are those which are immediately visible and felt by the communities. The secondary and tertiary impacts are the chain of events that will unfold with time and over locations. Further down, communities could look into system wide impacts that will be detrimental for the sustainability development of the community. Through the analysis of various level of impacts, the community could prepare a score card of potential impacts in order to assist prioritization of DRR measures. Table 4.2 shows an example of score card that communities can prepare for each identified impact.

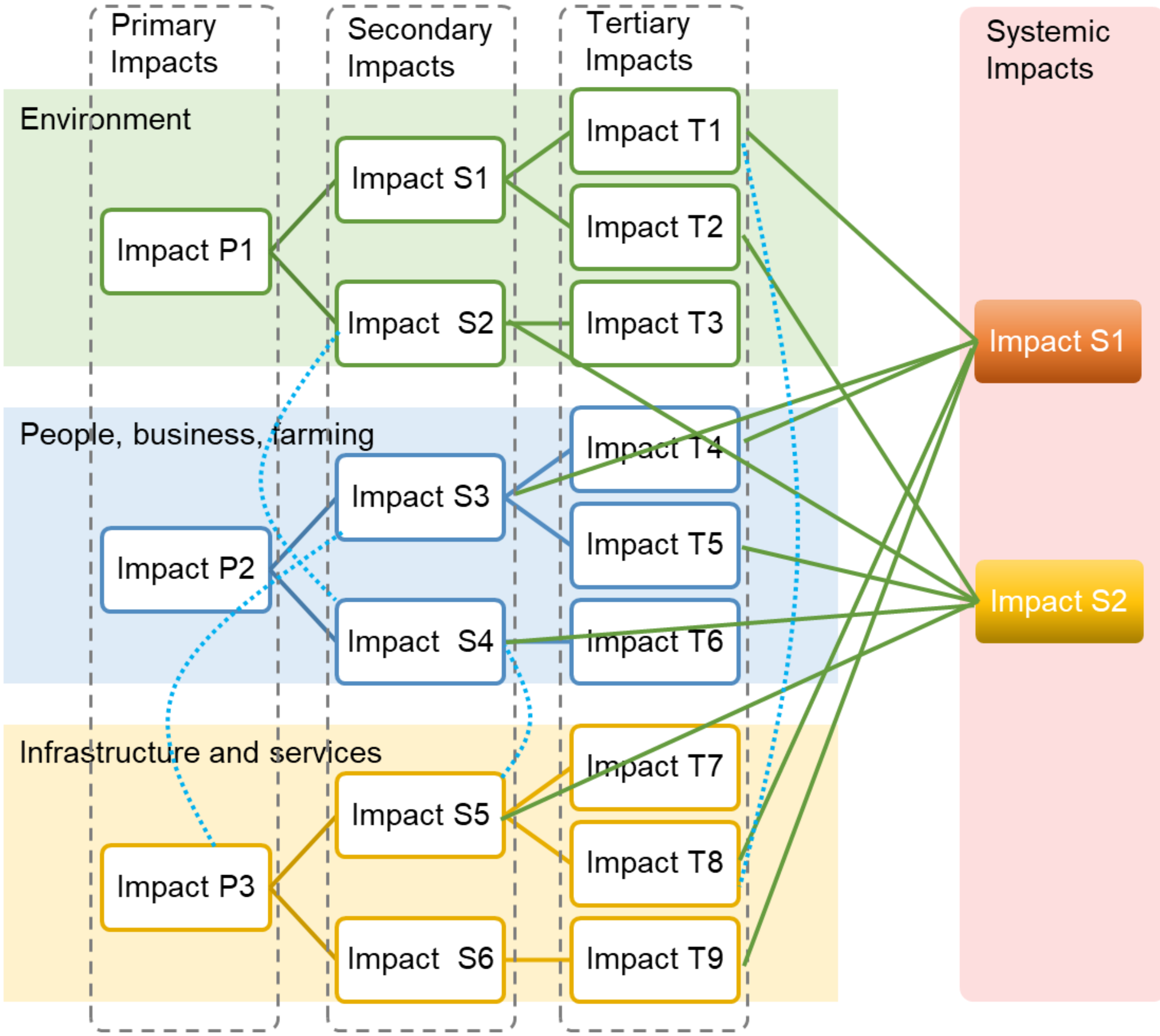


Figure 4.2 Chain of events and interlinkages of all impacts for a given CCDR scenario

Table 4.1 Level of impacts under a given multi-hazard scenario

Level of impacts			
Primary	**Secondary**	**Tertiary**	**Systemic**
-**Injury/deaths to population group** -**Damage to critical infrastructure and services (transport, emergency facilities, electricity, water, etc.)** -**Damage to farmland and business**	-Loss of income -Loss of job opportunities -Decreased food production -Economic impact due to damage to the roads Increased deforestation due to new settlements and farming - Loss of water sources, pollution and wastes	-Migration and loss of culture/tradition -Increased food prices -Permanent closure of business, farms	-Depopulation and loss of culture -Low economic growth -Lack of budget for development

Table 4.2 Scoring of key impacts for future DRR planning

Impacts	Level of impacts	Score	Remarks
Impact A	*Primary, Secondary, Tertiary, Systemic*	*1-10 (1 for least importance, 10 for highest importance)*	*Reasons for score* *Factors contributing exposure, vulnerability and capacity gaps*
Impact B			
Impact C			

4.3. Formulate resilience enhancement measures

After the identification of mostly likely hazards, exposure patterns, vulnerabilities, capacity and impacts, the next step of scenario analysis is the formulation of resilience enhancement measures. The resilience enhancement could be viewed as both combination of DRR and adaptation that will result in improved capacity to not only face the disaster but also recover back to normalcy as quickly as possible. Resilience enhancement stresses on 'build-back-better (BBB)'. The BBB stresses on the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment. Here, resilience is "the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a potentially hazardous event in a timely and efficient manner, including ensuring the preservation, restoration, or improvement of its essential basic structures and functions" (IPCC, 2012). Resilience is "a capability to prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment." (USGCRP Glossary).

Resilience enhancement measures against compound and cascading disasters will consider the prevention and minimization of damages as well as preparation for "better reconstruction" to ensure adaptive recovery. They will build on the existing disaster risk management framework progressively. In other words, there should be additional approaches to conventional DRR measures. Identified options will be multi-functional, generate multi-outcomes, and be flexible enough to be utilized under various circumstances. Ultimately, the identified resilience enhancement measures will form the building blocks of a systemic disaster response mechanism. Resilience enhancement measures could be divided into three dimensions of disaster management cycle as shown in Figure 4.3:

1. Comprehensive Preparedness
2. Preventive Response
3. Adaptive Recovery

Preparedness refers to the knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters. It aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response to sustained recovery. Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, the stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. Beyond this, comprehensive preparedness recognizes a system wide consideration when planning actions before the actual realization of CCDR scenario. Unlike response and recovery, a significant amount of time could be devoted for preparedness and involves a thorough assessment of resources and capacity needed in the future. So, preparedness under CCDR establishes arrangements in advance to enable timely, effective and appropriate responses to a range of multi-hazard scenarios that might threaten wider society and system mechanism.

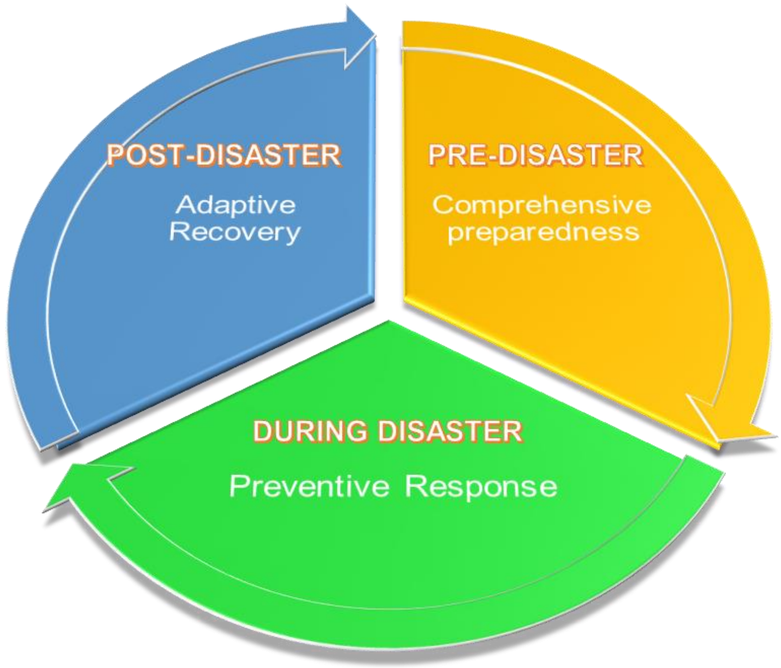


Figure 4.3 Three dimensions of disaster risk reduction cycle for identifying

Responses are actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Effective, efficient and timely response relies on disaster risk-informed preparedness measures, including the development of the response capacities of individuals, communities, organizations, countries and the international community. Preventive response has two goals. First, disaster response is predominantly focused on immediate and short-term needs and is sometimes called disaster relief, similar to conventional DRR system. Second, the preventive part focus on breaking the chain of impact that could unfold over time and space. The second goal requires reconsideration of whole institutional elements of response, including emergency services, assistance by public, private, and community, and volunteer participation. Here the scope is response will be to minimize the spread of impacts to other regions so that the response mechanisms are not overwhelmed before they reach their limit.

Recovery is the process of restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society. In the long-run, recovery aims for sustainable development and “build back better” so as to avoid or reduce future disaster risk. Adaptive recovery on the other hand recognizes not only the need for reconstruction and reaching the state of normalcy, it stresses on the overall building of resilience. It also relies on adaptive strategy and consideration on the resources and capacity. It balances both hard and soft measures including the nature-based solutions and uses of local knowledge that are cost-effective and managed locally. The measures encourage the approach of living with hazards based on the correct understanding of the risks. To provide people with a safety net for large shocks, social protection measures are necessary. Such “adaptive social protection” measures require flexibility and a well-targeted delivery to transfer resources to disaster victims in a timely fashion. Compound disasters may cause people to face multiple challenges and difficulties for an extended period of time. Local governments need to provide additional social protection for such victims. In the long run, designing a seamless recovery process and preparedness should be considered comprehensively and systematically.

Various kind of structural and technical approaches and soft measures could be adopted for this purpose. Hard infrastructure, nature-based solutions, multi-hazard early warning, use of ICT and innovation, community-science approach of hazard monitoring, risk communication, risk insurance, etc., could be promoted depending on the local context and needs.

The ultimate outcome of the resilience enhancement measures is to identify set of actions for preparedness, response and recovery that are critical to deal with situation identified under each CCDR scenario. In the process, communities need to keep in mind whether existing disaster preparedness, response and recovery mechanism are fit to deal with CCDR scenarios. They also need to identify the measures according to short (months to a year), intermediate (less than 5 years), and long (over 5 years) term priorities. Communities could summarize all the necessary resilience enhancement measures that are already available and those to be newly considered as shown in Table 4.3. Using the compiled information, communities are then best positioned to identify additional approaches that are multi-functional, generate multi-outcomes, and be flexible enough to be utilized under various circumstances. Ultimately, the identified resilience enhancement measures will form the building blocks of a systemic disaster response mechanism.

Table 4.3 Summary of resilience enhancement measures for a given CCDR scenario

Measures	Preparedness (*how to prevent before disaster*)	Response (*Minimize the damage/impacts and break the chain during or just before/after the disaster*)	Recovery (*build-back-better after the disaster*)
Structural, natural, and technical measures	*Measure name:* *Scale of application:* *Time required to implement:* *Pre-existing or new:* *Priority:*		
Social measures	*Measure name:* *Scale of application:* *Time required to implement:* *Pre-existing or new:* *Priority:*		
Institutional measures	*Measure name:* *Scale of application:* *Time required to implement:* *Pre-existing or new:* *Priority:*		
Economic measures			
Other measures			

4.1. Update and finalize scenarios

In this final step, communities will revisit the story-line of the scenario developed in the beginning based on the additional information identified during the examination of impacts and formulation of resilience enhancement measures. The scenarios should be based on a comprehensive understanding of the hazards, vulnerabilities, and exposure factors in the local area, and should be relevant and realistic for the local context. Stakeholders will be asked to provide feedback and their own insights and perspectives on the development of risk scenarios. The feedback then will be used to refine and improve the risk scenarios. This may involve adjusting the scenarios to better reflect local conditions, or incorporating new priorities that were not initially identified. Once the feedback has been incorporated, the scenarios will be finalized. Since the hazard contexts, risks, and socio-economic conditions keeps on changing, this final step has to be conducted periodically. The focus here is on the process itself and its ability to ensure continued and complete updating of scenarios. A regular updating exercise should be conducted that captures all changes for the preceding period, or by means of an incremental update process that reliably captures changes as they occur.

5. ADAPTIVE STRATEGY, PLANNING, AND IMPLEMENTATION FRAMEWORK

This is the final and most important section that will incorporate all the outcomes from the risk assessment and scenario development into a strategy, planning and implementation framework that contributes to adaptive governance. A strategy is an integrated set of choices that provides a common vision, includes certain guiding principles and priorities, and defines general goals and objectives across different timescales, considering the short- and mid-term while simultaneously embracing a long-term perspective. It aims to prevent the creation of (new) risks, reduce existing risks, recover from realized risks and strengthen economic, social, health and environmental resilience. Adaptive strategies for compound and cascading disasters involve taking a flexible, iterative approach to disaster risk management and response. Core of the adaptive strategies involve continuously monitoring and evaluating the situation, and adapting according to changing conditions. An adaptive strategy involves collaboration and communication between all stakeholders involved in disaster risk management and response, including government agencies, community organizations, and emergency responders. This collaboration can help to ensure that everyone is on the same page and that decisions are made based on the best available information. By taking a flexible, iterative approach to disaster risk management and response, communities can better prepare for and respond to CCDR events, which can be complex and unpredictable, and reduce the risk of long-term impacts on the community. The alignment of local DRR strategies to their national DRR counterparts (whenever they are available) is considered imperative.

A local disaster plan provides operational guidance for implementing the adaptive strategy in a flexible manner based on new information and changing conditions. The development of the plan is a multi-stage, multi-stakeholders, and participatory process. This can involve adjusting plans and procedures in real-time, based on emerging risks and changing circumstances. The plan sets out the specific goals and objectives for reducing disaster risks, together with related actions to accomplish them based on the identified risk scenarios.

An implementation framework is a structured approach that provides a roadmap for putting strategies and plans into action, and for managing the ongoing monitoring and evaluation process. It ensures that strategies and plans are successfully implemented and that progress is being made towards achieving the desired outcomes. It can also help to ensure that plans and procedures remain relevant and effective in the face of changing conditions and emerging risks. The implementation framework goes into more detail by specifying timeframes, resources, indicators and mechanisms for monitoring and evaluation process, communication, capacity building, and clear roles and responsibilities, including government agencies, community organizations, and emergency responders. For instance, clear roles and responsibilities ensure that everyone knows what is expected of them and that there is clear accountability for achieving objectives. defining responsibilities, and the sources of funding.

Governance affects the distribution of exposure and vulnerability, and therefore of disaster risk, among different groups of people. Adaptive governance of CCDR requires a coordinated, systemic and transformative thinking through multi-level and multi-sectoral collaboration, collective decision making, and continuous learning for building knowledge for addressing system-wide impacts. For instance, collective decision making implies that decisions do not happen in isolation but rather involve those who are part of or affected by their decisions. This can help to ensure that decisions are informed by a broad range of expertise and experience, and that stakeholders have a sense of ownership and investment in the process. Good governance needs to promote participation and recognition to address the underlying risk drivers that result in differentiated disaster impacts according to age, ethnicity, religion, gender, labour conditions, land ownership, economic status and disabilities (physical, psychological and cognitive). Good governance also entails improving accountability, transparency and meaningful participation throughout the procedures and practices. In places where there is a proactive, responsive and accountable local government that works with local actors, the possibilities of resilience are much higher.

Learning from past experiences and upgrading the legal and institutional policies and plans from time to time for the risk governance of the evolving risk-scape has become pertinent. Adaptive and integrative risk governance can help address the key gaps and challenges associated with the understanding and management of compound, cascading and systemic risks, namely, inadequate knowledge base, underlying complexities and associated ambiguities. The adaptive and integrative risk governance is aligned with the whole-of-society approach as it provides a conducive environment and mechanism for bringing together multiple stakeholders for collaborating to systematically co-create and co-implement appropriate risk-management solutions. These stakeholders include government organizations, non-governmental organizations, private-sector players, academics, community and community-based organizations.

Within the scope of this guidebook, a three-step iterative process of resource and capacity mapping, formulate adaptive strategy and action plan and implementation framework for establishing an adaptive and integrative risk governance system is proposed as shown in Figure 5.1.

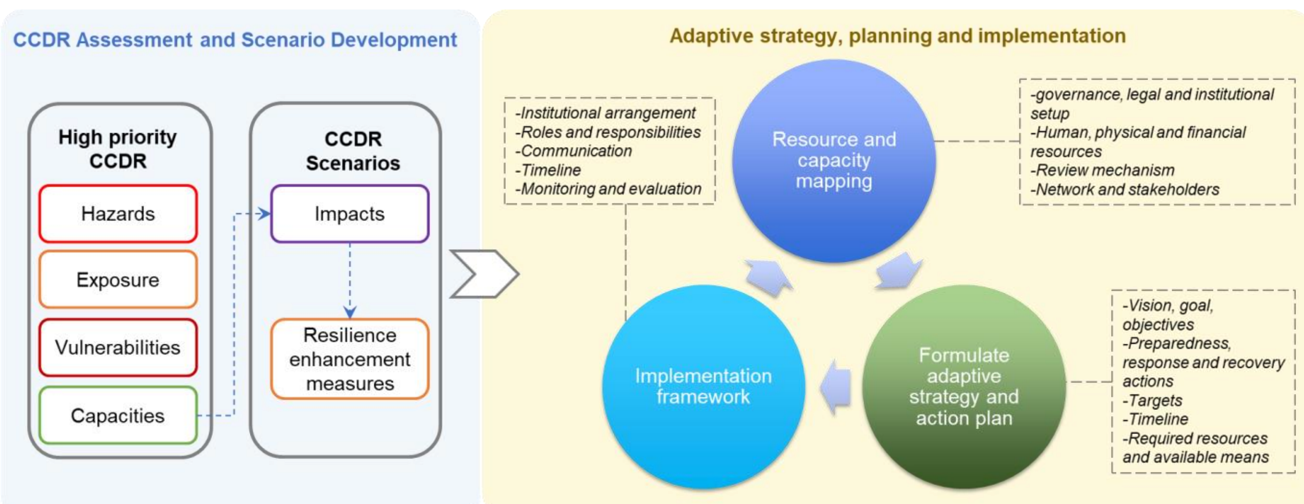


Figure 5.1 Iterative process of resource and capacity mapping, formulate adaptive strategy and action plan and implementation framework

The outcomes of CCDR risk assessment and scenario development will serve as the key inputs. Resource and capacity mapping outline the necessary requirement for developing a realistic strategy, action plan and implementation framework. It is mainly meant for stocktaking of resources and capacity that are available, their state of the use, and adequacy for planning. The process helps in the preparation with respect to what is available and accessible and those which should be additionally prepared.

Strategy and plan outlines visions, goal, directions, and priority actions to be taken. It will be followed by development of an implementation framework that could be put into action in a step-wise manner.

5.1. Resource and capacity mapping

Resource and capacity mapping can be very broad in scope covering policy, legal and institutional arrangements, budgetary allocation, infrastructure and human resources, social capital, networks, media and so forth. The Constitution of Nepal has provisioned several role and concurrent jurisdictions of three tiers of government as listed in Schedules 5, 6, 7, 8, and 9. Schedule 8 has listed jurisdictions of local levels which have clearly mentioned that the local levels have jurisdictions over the utilization, management, conservation, and preservation of locally available resources. The constitution has prevailed local levels with more authority for local planning and development. The bottom-up approach in planning process was found more effective thereafter. Current seven step planning process of all tier governments starts with the income-expense projection, resource and budget thresholding, project selection from community and ward levels, and discussions and approval from municipal committees and assembly (Figure 5.2). The planning process for succeeding fiscal year lasts for seven months in a preceding fiscal year. Resource and capacity mapping start from the very first step in the annual planning process and ends in the final step. Resource mapping and assessment for coping to compound and cascading disasters needs to be done in the first step. Evaluation of past year's actions are done based on resources consumed and resources desired for coping to such disasters. In this step, the basic resources required at local levels are listed for further discussions in upper committees. The project identification and prioritization are done based on the surplus or the deficit of resources available in the municipality, wards, and community levels at the moment. In the third and fourth steps, hazards that are of compounding and/or cascading nature are identified through participatory mapping at the community level. Based on the likelihood and potential impacts of hazards, priorities need to be set at the source. Thus, projects related either to mitigate hazards, or reduce risk, or cope with disasters need to be designed, selected, and sent to the budgeting committee to include them in annual programs of the local level. In the current structure, the most common resource local levels have is the fund for disaster risk reduction and management, which are allocated through local planning. However, such funds are being utilized only for responding to disasters occurring annually and providing relief to the affected. Since, none of the acts and regulations have differentiated compound and cascading hazards from other common hazards, there are very little realizations of such hazards. After conducting trainings on Disaster Risk Management Localization Manual in all 753 local levels by the government, local elected representatives and government officials are more aware on their authority and responsibilities. Local levels have an authority to update their acts, plans, and policies based on the local context and desired innovation at the local level. This has

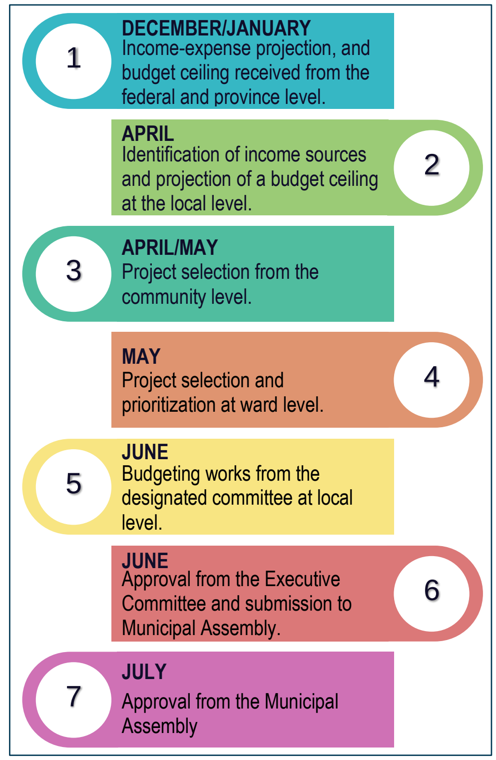


Figure 5.2 Seven-step planning process for the local levels in

created an opportunity for assessing and allocating resources for addressing issues of compound and cascading disasters.

Aligning with the current seven step planning process at the local level, the resource and capacity mapping can be done accordingly as shown in Figure 5.3.

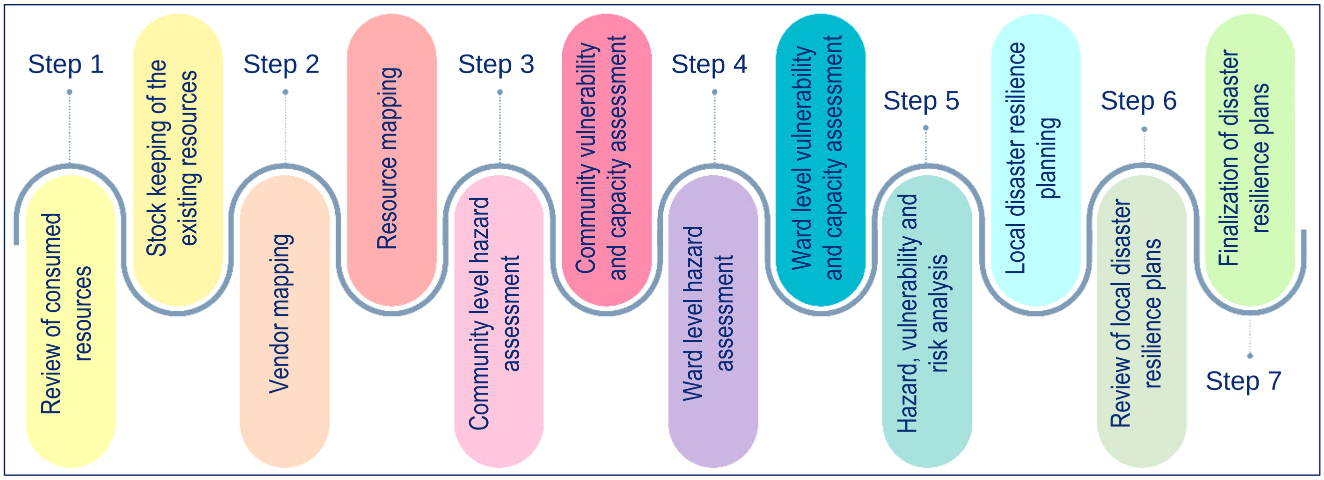


Figure 5.3 Resource and capacity mapping in current seven steps planning process at the local level

A baseline information is required for identifying resources and capacities required for effective implementation of the CCDRR and mitigation strategies. Such a baseline information can be documented through several assessments and surveys. Similarly, different types of resources and capacities are required for adaptive planning for CCDRR. Each of these resources are dependent in nature to one another. The comprehensive categories of resources and capacities required are as follows:

I. **Governance framework-** The government's understanding, priorities, and strategies should be clear on disasters having compounding and cascading risk and impacts. There need to be a national level framework for such understanding, priorities, and strategies. Local governments already have a jurisdiction over prioritizing and developing strategies based on local needs. Thus, the local level can develop a framework for CCDRR aligning it with the DRR National Policy. In the context of cascading and compound disasters, governance system has to be proactive and realistic to the changing risk profile of potential natural as well as man-made disasters

II. **Legal and institutional setup-** It provides instructions on roles, responsibility, and mandates for mobilizing different resources and capabilities during different stages of disaster management local government can form a separate committee providing them roles and responsibilities for implementing adaptive CCDRR activities, however, aligning roles and responsibilities listed within the local disaster risk reduction and management act of the respective local governments. A separate desk can be established within the disaster risk reduction division in local governments.

III. **Human resource-** Local governments already have a pre-configured operation and management structure. This structure consists of locally elected representatives and employees of the government. Such human resources have several responsibilities and might lack understanding of disaster risk reduction. However, under the jurisdiction in the local acts, local governments can recruit the technical experts when needed. Further, the implementation of the CCDRR related activities can be done aligning with the provision of community volunteers in the DRRM act. The integration of adaptive planning for CCDRR requires additional technical trainings and guidance to local planners and representatives of planning division in local governments.

IV. **Physical assets-** The office related assets fall under the institutional setup. The items and equipment for preparing and responding to disasters fall under these assets. NDRRMA has provided a list of minimum search and rescue items required at ward level in each municipality (Table 5.1)

Table 5.1 List of minimum search and rescue items at wards suggested by NDRRMA

SN	Items	Qty	Remarks
1	Stretcher	1	
2	Bucket	5	
3	Rope	200	Meters, Strong
4	Safety Helmet	5	Standard
5	Axe	2	
6	Sickle	2	
7	Crow bar	2	
8	Shovel	2	
9	Splint for legs and hands	2	
10	Hand saw	2	
11	Lever	2	
12	Digging bar	2	
13	Torch light/ head light	4	
14	Whistle	Few	
15	First aid kit	-	
16	Miscellaneous	-	As required

Source: NDRRMA, 2021[2].

V. **Financial provision-** Adaptive planning for CCDRR and mitigation requires annual budgetary provision. Local governments need to integrate activities and plans for adapting to CCD during the annual planning process (i.e., seven-steps planning process discussed above) to allocate budget for adapting to CCD locally.

VI. **Review mechanism-** A review of activities implemented in the ongoing year needs to be done during the start of a planning process. The hazardous incidents and their potential to transform into the CCD need to be reviewed. The resource consumption of past hazards and deficit resources needs to be documented and submit to the planning committee for upcoming years. In doing so, the resource planning should be sufficient to cover the forecasted scenarios.

VII. **Networks and external stakeholders-** Networks and external stakeholders are also the resources and capacities to local governments. International non-government organizations, bilateral and multilateral organizations, national non-government organizations, community-based organizations, media, and local youth, women and children groups can play a role during the implementation of CCDRR framework. Different organizations have technical and financial capacities on different clusters- 11 (Health; Water, Sanitation and Hygiene; Shelter; Food Security; Logistics; Camp Coordination and Camp Management; Education; Protection; Telecommunication;

[2] List of search and rescue items at ward level. http://bipad.gov.np/np/publications/detail/106

Nutrition; and Early Recovery Network) clusters listed in a National Disaster Response Framework, 2013[3,4].

At the end of the resource and capacity mapping, communities can summaries the state of resources and capacity to clarify what is working well, where there are gaps, and what are additionally required. Table 5.2 suggests a template for summarizing such information:

Table 5.2 Template for summarizing resources and capacity needed for CCDR planning and implementation

Resources and capacity	Current state (What)	Strengths /Functionality (how well)	Weakness (gaps or new requirements)	Actions to fill the gaps or new requirements (What is next)
Governance Framework				
Legal and Institutional setup				
Human resources				
Physical assets				
Financial provisions				
Review mechanism				
Networks and external stakeholders				

5.2. Formulate an adaptive strategy and action plan

As an output of a review mechanism in the previous section requires to develop an adaptive strategy and action plan on CCDR preparedness, response, and recovery. Communities and stakeholders need to review past interventions, identified scenarios, and make suggestion for necessary actions that can be undertaken immediately or in a short, medium, and long-term period.

The development of a strategy requires the commitment and involvement of political leadership across levels of government and sectors in a multi-hazard approach. The process starts by defining a shared

[3] National Disaster Response Framework- Structure file:///C:/Users/Dell/Downloads/Nepal%20National%20Disaster%20Response%20Framework%2027%20Jun%202015%202019-04-08%2004-50-15.pdf

[4] National Disaster Response Framework. http://drrportal.gov.np/uploads/document/113.pdf

vision and goal on the CCDR. Then the communities can list one of more objectives in order to realize the goal. A local strategy to address CCDR scenarios should have (UNDRR, 2019):

- A shared vision with targets, indicators and time frames aimed at understanding of DRR, preventing the creation of risk, reducing existing risk, and strengthening economic, social, health and environmental resilience;
- A designated focal point with a core team, with capacity to work with different actors, leading and coordinating the strategy-making process and ensuring its implementation;
- Resources and dedicated budget allocation budget for core team activities as well as with other resources/funds allocated from different offices and departments, but clearly earmarked as contributing to the strategy;
- A timeframe to fulfil the elaboration of the strategy and its implementation through an action plan. Activities might include: working meetings with various actors, preparation of a baseline document, outline of roles and responsibilities of different actors involved in the process, presentation and follow up of the strategy and elaboration of a DRR action plan.
- Have mechanisms to follow-up, periodically assess and publicly report on progress.
- Alignment with national strategies and priorities as well as international frameworks such as the Sendai Framework for Disaster Risk Reduction 2015-2030

The strategy will then serve as a basis for planning. A sample of a framework for adaptive action planning for one of the sample incidents shown in Figure 5.4

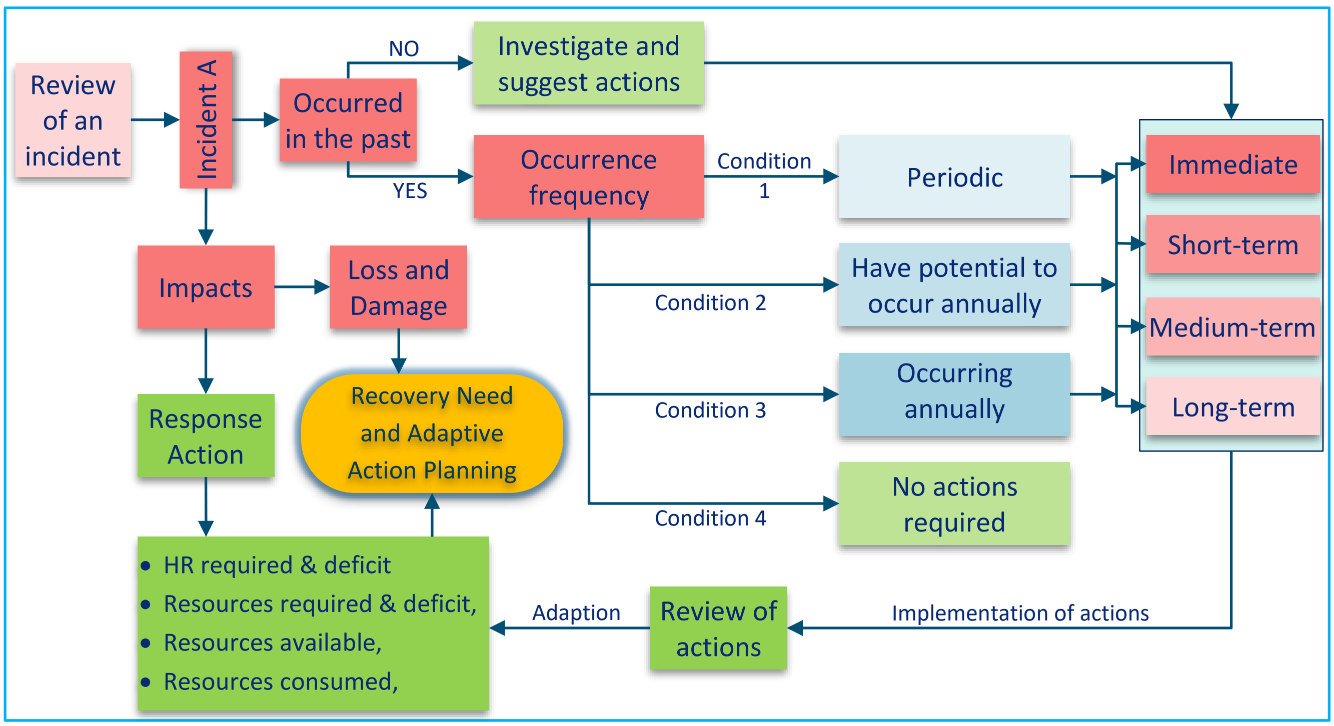


Figure 5.4 A sample of a framework for adaptive action planning for one of the sample incidents

Adaptive planning requires periodic reviews of past activities on preparedness, response, and recovery. In addition, periodic reviews are required also for action plans to ensure that the actions are per the current situation and needs, available access to resources, available technologies, etc.

The following list of activities can be useful in periodic review for adaptive planning:

I. Pre-season and post-season review[5] meetings,
II. Review and update of a hazard/disaster calendar,
III. Review and update of local resources,
IV. Sensitization through simulations (drills at municipal and community level, table-top simulation with stakeholders, etc.).

Table 5.3 shows an example for summarizing the adaptive strategy and action plans. Here vision states the aspiration for the future. Goals are the overall aims in order to reach the achievable state of outcomes and realize the vision. After the goal, communities will set specific objectives. For instance, communities could set an object to establish CCDR early warning and response system by specifying the criteria for declaring CCDR early warning or release of special emergency funds and resources for swift response. For each specific objective, communities will determine the set of targets and actions under preparedness, response and recovery. Each action should be provided with timeline (short, medium, long term), required resources, and available means in order to develop a realistic plan of action. For instance, if there is huge gap between required resources and available means the community may priorities such action for future or try to explore options to overcome such gaps, depending on the importance of the action to be achieved in the near term or long-term.

Table 5.3 Template for preparing strategy and action plan

Vision and goals	**Vision:** *a resilient community to CCDR and climate change impacts* **Goals:** *reduce the loss and damage from CCDR and climate change scenarios and build resilience through improved adaptive disaster risk governance*				
Objectives	Objective A: Improved understanding of CCDR Objective B: Limit the expansion of exposure and vulnerability Objective C: Implement resilience enhancement measures including nature-based solution Objective D: Establish CCDR early warning system and response system				
	Targets	**Actions**	**Timeline**	**Required resources**	**Available means**
Objective A					
Preparedness					
Response					
Recovery					
Objective B					
Preparedness					
Response					
Recovery					

5.3. Implementation framework

Implementation framework ensures that strategies and plans are successfully implemented by specifying timeframes, resources, indicators and mechanisms for monitoring and evaluation process, communication, capacity building, and clear roles and responsibilities, including government agencies,

[5] Here, season should be understood as disaster season as per the disaster/hazards calendar (for example, pre-monsoon, post-monsoon, pre-winter, post-winter, pre-flooding season, post-flooding season, etc.).

community organizations, and emergency responders. Implementation of CCDR should be a multilevel collaboration between each level of governments. The local governments are the ground level stakeholders who need to be the lead implementer. However, the concept of CCDR being more technical and local governments might lack the technical expertise within themselves, the implementation of CCDR needs to be supervised by the line authority (e.g., NDRRMA) in collaboration with the line ministry for DRR (e.g., MoHA), and the line ministry for the local governments (e.g., Ministry of Federal Affairs and General Administration (MoFAGA)).

At the local level, local governments can form a special compound and cascading disaster committee that will come under action under a set specific condition such as before the monsoon and for any annually recurring hazards. The committee could be also assigned additional responsibility to the local DRM committees for identifying localized CCD. A committee could be chaired by the chairman of the municipality and DRR focal person be a member secretary. However, for the sustainability of the CCDR approach, a separate secretariat could to be institutionalized. Such a secretariat needs to provide technical guidance to the implementer, conduct monitoring and evaluation jointly with the NDRRMA, prepare and publish reports, tracking of progress, and disseminating knowledge periodically through reports, papers, brochures, and documentaries. The characteristics of disasters being occurred in Nepal are of complex and interlinked, the coordination between all level governments is desired for the mitigation, preparedness, and response to CCD and recovery from its impacts. The current institutional structure has provided an opportunity for coordinated implementation of disaster risk reduction activities. The current institutional structure for disaster risk reduction, preparedness, response, and recovery is shown in Figure 5.5.

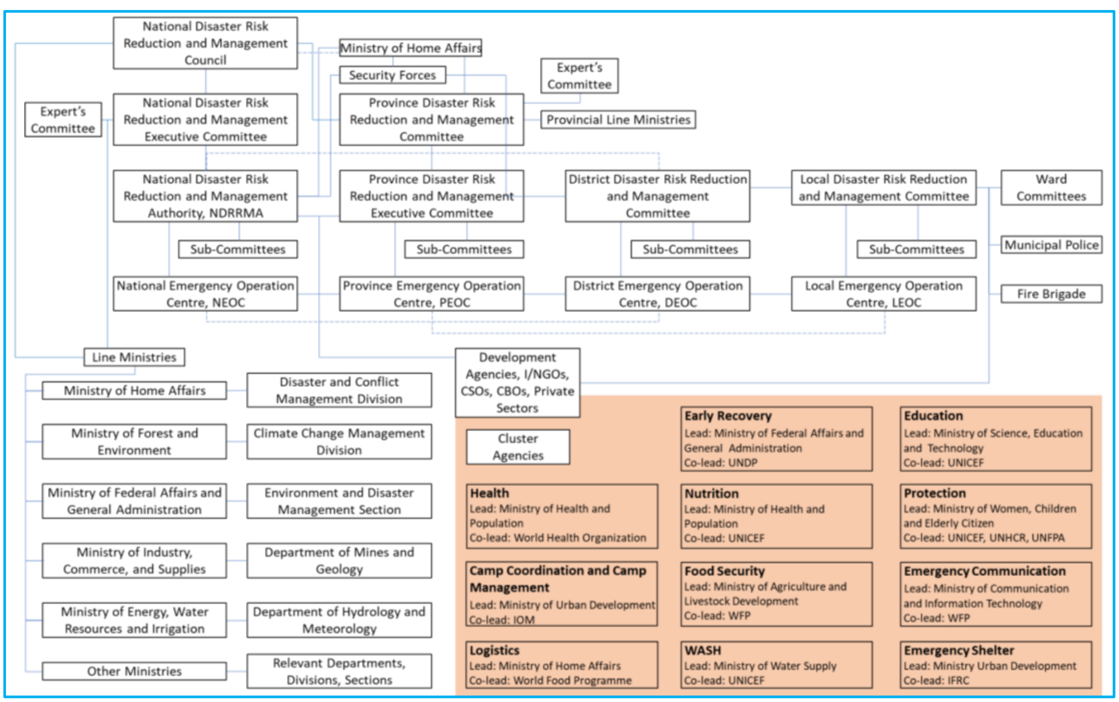


Figure 5.5 Institutional arrangement from national to local level for disaster preparedness, response, and recovery.

The study and implementation require specific level of expertise in relevant fields. The expertise in the current structures might not be sufficient for addressing issues related to CCDR. Thus, a separate framework for CCDRR implementation is desired within the current structure. The structure would be something as shown in Figure 5.6.

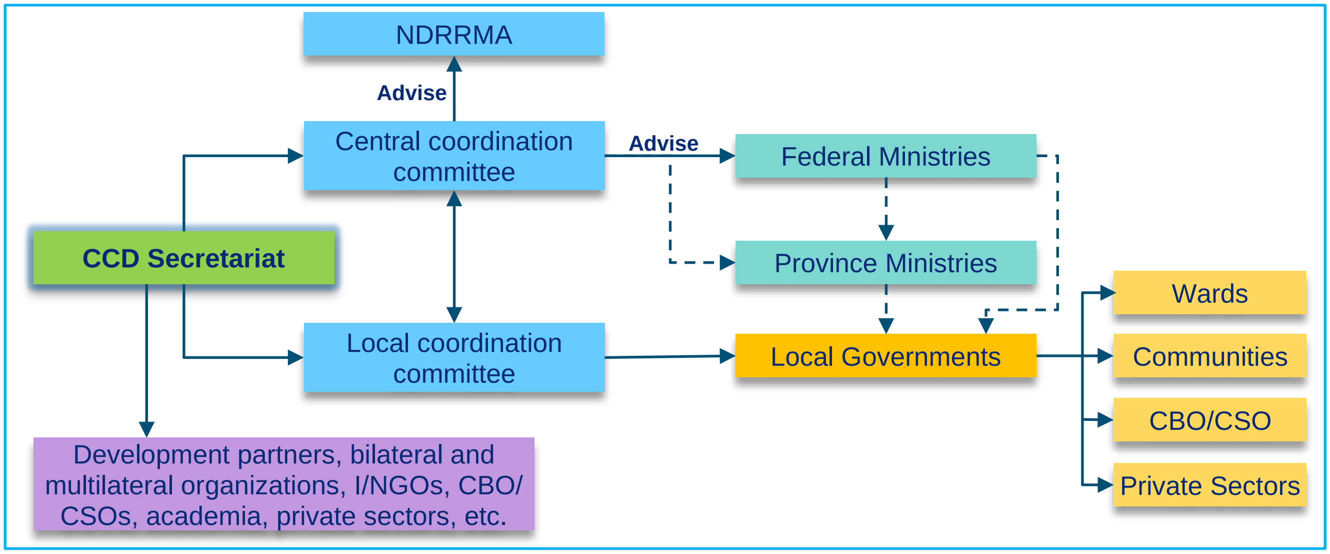


Figure 5. 6 Desired structural framework for the implementation of adaptive planning for CCDR

Monitoring and evaluation are at the heart of effective implementation as well as for adaptive disaster management and decision making. Monitoring and evaluation are critical to understand the risk landscape, which are always changing and evolving in the case of CCDR. The strategy of monitoring and evaluation should be such that the new information and knowledge gained during the period of time can be feedback to the strategy in order to face the future disasters. A well-functioning monitoring and evaluation allows an iterative process of self-learning and evaluating the progress, identify gaps, and suggest mitigation strategies in a timely manner. It helps detect processes and factors behind CCDR as communities could not understand such cause and effects in the absence of the right information. The monitoring and evaluation should be objective, result oriented and based on performance benchmarks and indicators. Since monitoring and evaluation are often resources intensive, they should be designed as a part of learning cycle, continuous, innovative, appropriate, and when possible encouraging self-monitoring, reporting and automated utilising information and communication technologies.

Monitoring and evaluation should be supported by indicators for each target and the methods used so that the identified state of progress and major gaps are clear and transparent. Table 5.4 suggests a template for monitoring and evaluation.

Table 5.4 Template for monitoring and evaluation

Targets	Indicators	Method of monitoring	State of progress	Identified gaps	Feedback for improvement or revision of action plan
Obj A, Target 1					
Obj A, Target 2					
Obj B, Target 1					
Obj B, Target 2					
Obj C, Target 1					
Obj C, Target 2					

6. CONCLUSION AND RECOMMENDATIONS

Compounding and cascading disaster risks (CCD) are the present reality in Nepal as individuals, families, and communities are struggling to cope with disasters hitting one after another before they could fully recover and reach normalcy. Rise in CCDR cases depicts the complex nature of risk that could breach limits unless it is addressed through a systems approach. Climate change and other non-climatic stressors are likely to be the key triggers for amplifying CCDR cases in the fragile landscape and weak socio-economic condition of local governments and vulnerable people living across the country.

The pertinent question before us is whether we continue to follow conventional approach of DRR or move forward to enhance community resilience against scenarios of multi-hazards. Clearly, urgent attention and action is required to address CCDR at the local levels across the whole nation. This understanding of various risk scenarios calls for a holistic and multi-dimensional assessment of risk. This guidebook is an attempt to enhance the literacy and awareness on CCDR at the local level, who are at the forefront to face impacts and also first to respond. The guidebook was prepared building on the inputs from experts, stakeholders, government agencies and local stakeholders in Melamchi, where a catastrophic disaster involving CCDR hit in 2021 causing massive scale damage. The guidebook serves as a valuable supplement to pre-existing efforts on DRR planning and implementation at the local level as well as relevant policies at the national level.

The guidebook proposes a step-wise approach for enhancing CCDR awareness and decision-making capacity at the local level. It starts with clarifying the key concepts as well as state of CCDR in Nepal. The target audience, such as local government, stakeholders, and communities can use the guidebook to learn CCDR assessment in a participatory manner, understand the potential multi-hazard combination, and develop scenarios. The guidebook helps to identify resilience enhancement measures and needed capacity and resources to implement the measures. The guidebook also introduces the strategic planning and implementation to establish an adaptive disaster governance. The adaptive governance of CCDR requires a coordinated, systemic and transformative thinking through multi-level and multi-sectoral collaboration, collective decision making, and continuous learning for building knowledge for addressing system-wide impacts.

Following highlight the key recommendations for further promoting this guidebook across the local levels in Nepal and formulating concrete programs and actions to address CCDRs:

1. There is a huge gap or lack of understanding on CCDR, especially, at the local level. There are no specific guidelines or support systems to differentiate CCDR from recurring single hazard phenomena. More efforts are needed to identify key signals of CCDR, vulnerability and capacity gaps by comparing the past disasters as well as newly evolving ones. Particular attention is needed to integrate CCDR with climate change impacts and adaptation measures.
2. Institutional and financial mechanisms as well as capacity to cope with CCDR is severely constrained. It requires a thorough re-evaluation of limits and gaps.
3. Significant shift in the mindset and approach of risk assessment is needed to identify new areas of exposure, hidden vulnerabilities, capacity gaps, and innovative measures to enhance the resilience of communities.

4. Focus on multi-hazard approach of scenario development through the involvement of communities and disaster experts as well as by the uses of latest technology and risk communication systems. Engage media (newspapers, radio, TV and, increasingly, social media) as a vehicle for risk communication and an important stakeholder to mediate knowledge production and action. Also prioritize local language and methods of risk communication when possible through integration of latest technologies.
5. Promoting locally appropriate and sustainable long-term disaster mitigation and adaptation measures. Where feasible use local knowledge and nature-based solutions that could be designed and implemented at the local level and effective too.
6. Coordinate with national government and available stakeholders to establish a CCDR support committee or unit to provide knowledge services, establish multi-hazard early warning, declaring CCDR emergency and so forth.
7. Adopt a holistic approach of capacity building targeting resilience building, strengthen institutional setup and enhance collective decision-making capacity at the local level. Strengthening of community-centric DRR planning and implementation. Also, capacitate the cadre of trained and skilled personnel with a sound strategy and incentives to retain and mobilize them.

Projects and programs for piloting and upscaling of CCDRR implementation framework

A CCDRR framework for localization requires a development of a set of tools, which involves processes from identifying hazard to analyzing its compounding and cascading potential and developing adaptation strategies and its reviews. Since the local levels are diverse, socio-economic parameters contribute to their development, adaptive capacities, exposure, and vulnerabilities while the geographical parameters contribute to the risk of hazards and disasters. Thus, such tools need to be appropriate for diverse contexts in Nepal. Thus, the development of appropriate tools requires a series of hit-and-trial method for the development, piloting, review, and localization (Figure 6.1).

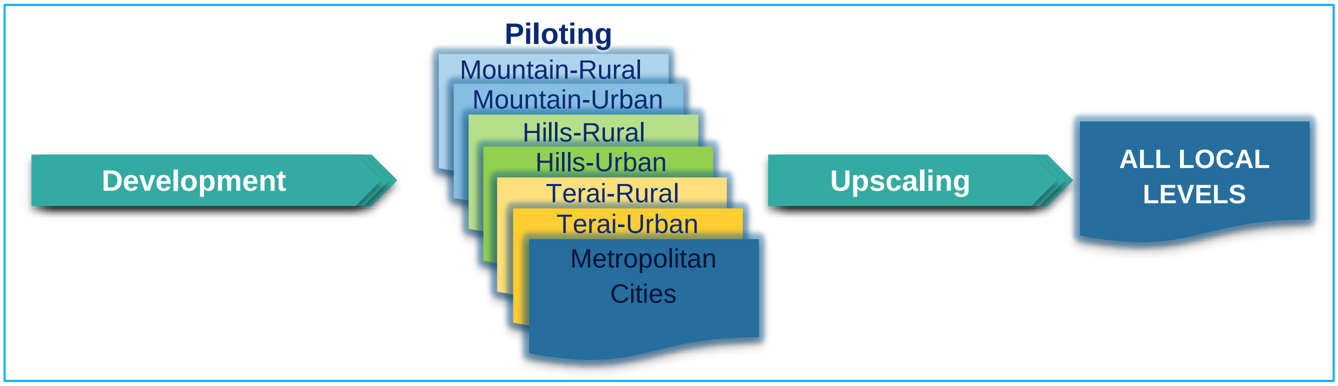


Figure 6.1 Development, piloting, and upscaling of CCD tools for local levels in Nepal.

Development of appropriate tools is possible by developing tools in real scenario with direct engagement in the diverse local context. Such tools can then be tested in similar context in other local levels. After satisfying results from using the tools, such tools then can be upscaled across all local levels. An online platform for CCDR analysis would further result in the sustainability of the CCDRR tool by aiding implementers. To enable the piloting and upscaling, this guidebook suggests the need for developing programs and projects ideas that could be funded by sources from national, international or climate change funds. At best, such projects or programs could be designed to supplement the national plans and policies on disaster management, climate change adaptation, and sustainable development.

CASE STUDY 1. LESSONS FROM 2021 MELAMCHI DISASTER

C1.1. Description of the disaster event

The floods and debris flow intensified by the heavy rainfall, a sharp temperature rise (in June 2021) and glacial lake outburst in June and August 2021 resulted catastrophic damages in the Melamchi watershed located at about 30 km North-West of Kathmandu, the capital city of Nepal. The Melamchi disaster events are well documented in reports from International Center for Integrated Mountain Development (ICIMOD, 2021), MWSDB/Eptisa (2021), Nepal Engineer's Association (Pandey et al., 2021), Department of Mines and Geology (DMG and NDRRMA, 2021) and NDRRMA and the World Bank. The disaster was a result of various of cascading event, and with one event triggering another created a case of cascading and compounding disaster. The first event was experienced on June 15, 2021 and the second event equally severe as the first one was observed on August 1, 2021. On 15th June 2021, the first flood and debris flood occurred after rainfall and glacial lake outburst in the higher reaches of the Melamchi catchment. On 1st August 2021, a major flood and debris flow events re-occurred after rainfall and LDOF. The rainfall during the extreme flood days (15 June and 1 August 2021) was high but apparently not extreme. The flooding was mainly caused by outburst of lakes formed behind natural dams (glacier dam and/or landslide dam) and not rainfall runoff only. A graphical summary of triggering and cascading events is displayed in **Figure C.1.1**.

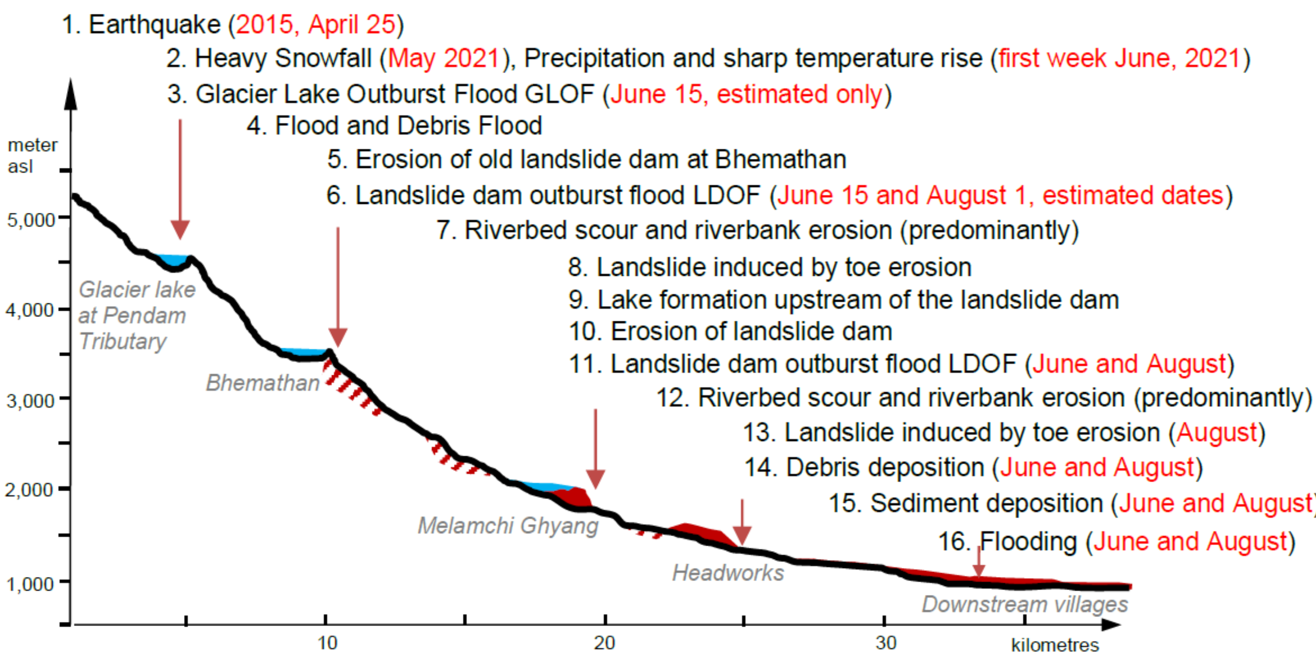


Figure C.1.1 A summary of hazard events of 2021 Melamchi disaster (Source: ADB/GoN, 2022)

The triggering factors leading to the 2021 events in the Melamchi watershed appear to be linked to the 2015 Gorkha Earthquake which evidently triggered many landslides and, more importantly, increased its susceptibility to slope instabilities. As elaborated in ADB/GoN (2022), following precipitation and sharp temperature rise in June 2021, a glacial lake outburst triggered a debris flow in the upper reaches of the catchment. This in turn triggered the collapse of a knickpoint at *Bhemathan*, a large pre-existing sediment deposit in the river channel about 16 km upstream of the headworks of Melamchi Water Supply Diversion Project (MWSDP). Toe erosion caused by the flows from Bhemathan, along with prolonged rainfall in the catchment, generated a major landslide further downstream below Melamchi Ghyang which dammed the river. Breaching of this natural dam caused another outburst flood from the lake that developed behind it. Cumulatively, these outbursts eroded riverbanks along the river between Bhemathan and the headworks area, and the eroded material deposited in the headworks areas of MWSDP and further downstream. The floods and debris floods changed the river cross-sections and generated more debris by cutting river banks and beds, which ultimately impacted to downstream areas and communities in the Melamchi watershed.

The river experienced another large flood and debris flood a few weeks later. Aerial surveys of the catchment area showed the presence of a large sediment deposit at Bhemathan near the Melamchi headwaters, possibly formed by an ancient landslide dam and sediment from upstream fluvio-glacial flows. The downstream parts of the deposit appeared to be eroding rapidly under successive river run-offs and rainstorm events. Photos from Bhemathan before, during and after the 2021 flood events, support these assumptions (**Figure C.1.2**).

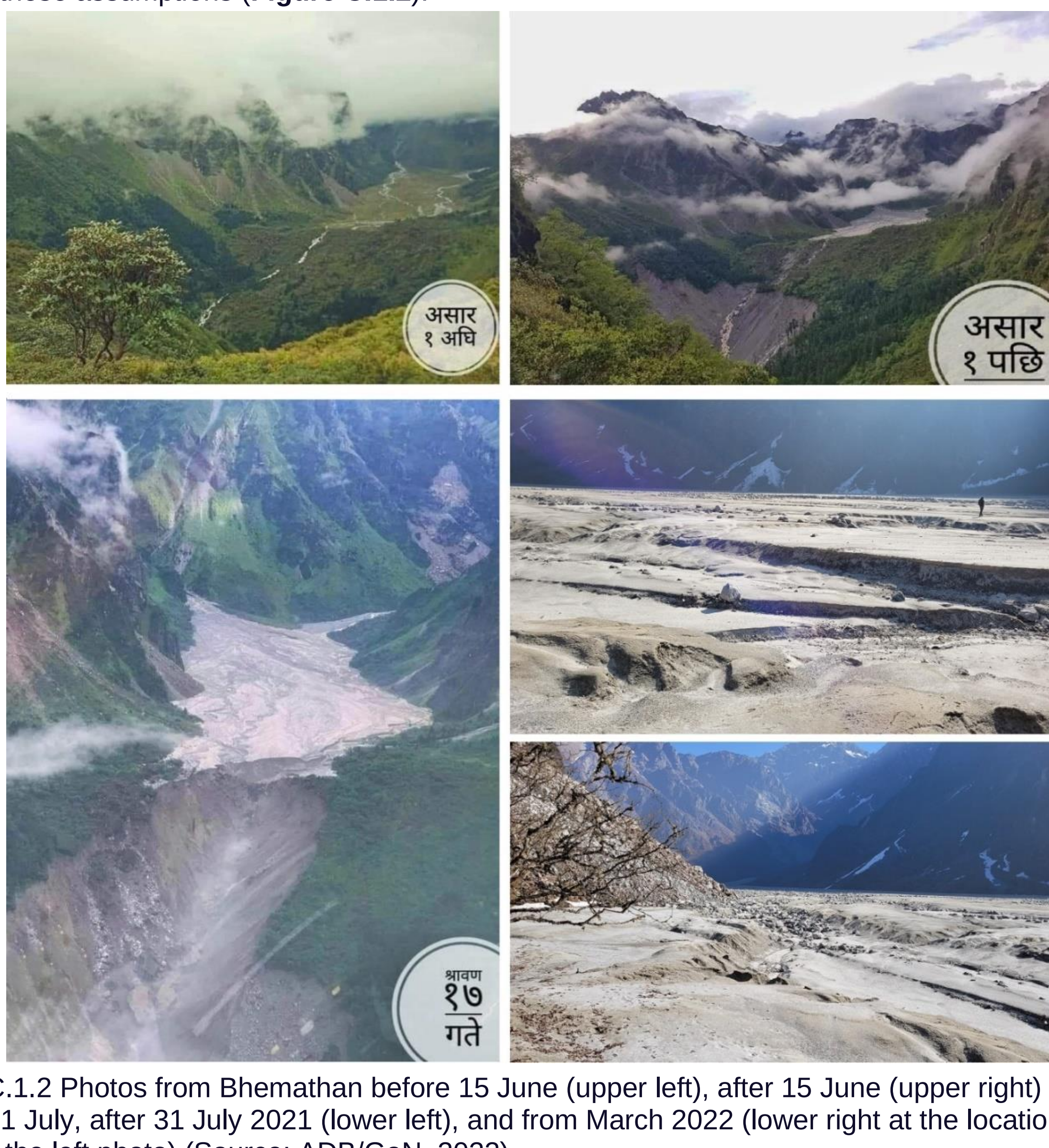


Figure C.1.2 Photos from Bhemathan before 15 June (upper left), after 15 June (upper right) but before 31 July, after 31 July 2021 (lower left), and from March 2022 (lower right at the location of the arrow in the left photo) (Source: ADB/GoN, 2022)

Photographs also indicated heavy erosion along the river channel and extensive collapse of the V-shape valley walls. The collapse of the large Bhemathan sediment deposit near the headwaters, natural damming of the river and the subsequent flood flows following breach of the dam(s) have substantially impacted the river morphology locally. Prior to their breaching, the natural dam(s) would have also caused deposition of sand, gravel and boulders on their upstream. The large volume and high velocity flows in the river following the dam breach have eroded or accreted the riverbed and banks and resulted in significant sediment depositions in reaches where the flows slowed down, for instance in the vicinity of the headworks of MWSDP and in the river valley further downstream.

An assessment of flood marks and consultations with local communities indicate that the magnitudes of both the 15th June and 1st August floods were of the same order. Results from river modelling and flood marks at different locations indicate that the maximum river discharge in 2021 was an estimated 2,700 m^3/s at the headworks of MWSDP due to GLOF and LDOF flow spikes on top of rainfall-runoff (ADB/GoN, 2022).

C1.2. Impacts and damages

Identified new exposure and vulnerabilities

New exposure and vulnerabilities are related to landslides, sediment deposits in Bhemathan area, and glacier lakes and glaciers. At least fifteen critical landslides with the potential of causing river damming are identified in the Melamchi watershed, of which two landslides, i.e., the landslide along the left bank of the headworks and at Melamchi Ghyang, are critical for the headwork infrastructures of MWSDP (ADB/GoN, 2022). The susceptibility to future landslides is very high. Natural damming and subsequent outburst floods from breaching landslide dams (i.e., LDOF) may pose risks to the downstream. Similarly, the Bhemathan deposit has an estimated sediment volume of approximately 21 million m^3 mostly deposited over a long period of time (decades or hundreds of years) and further supplemented by sediment from recent upstream glacial outburst flows (4 million m^3 out of the 21) (ADB/GoN, 2022). Although some of the deposit in the downstream part has been eroded in the 2021 floods, a substantial amount of sediment still remains at Bhemathan, and it will continue to erode and be a source of sediment flows in the river for many years, decades or centuries as a natural geomorphological process with inherent uncertainties. Furthermore, around ten glacial lakes and at least two glaciers exist in the upper part of the Melamchi watershed. Considering the rapid climate change witnessed in the region, some of these glacial lakes have a potential for outburst and therefore pose a threat of GLOF to water infrastructures (e.g., the MWSDP headworks), farm lands, economic activities, and communities in the downstream areas.

Main impacts/damages

The disaster that was initiated by extreme precipitation in the upstream areas triggered the cascading hazards along the river banks, which caused the loss of life and damages to the settlements, roads, bridges, local livelihoods, economic activities, and water infrastructures (Maharjan et al., 2021). A glimpse of the impacts and damages are shown in **Figure C.1.3**. The Melamchi disaster resulted death of 5 persons, disappearance of 20 persons, and displacement of 525 families. Also, it swept away 13 suspension bridges, seven motor bridges and numerous stretches of road cutting off access to several villages. Furthermore, it destroyed 337 houses, 259 enterprises, and thousands of hectares of agricultural farms in the watershed. In the headworks of MWSDP, it inundated the headworks area and buried the headworks structures, including the diversion tunnel and an adit further downstream, under a 15-25 m thick deposit of sand, gravel, boulders and debris. Fortunately, the inlet gate of the water tunnel was closed a few hours before the event to dewater the tunnel, and this has saved the tunnel from more damages. Exposed parts of the headworks structures showed severe damage to their concrete and reinforcing bars. The conditions of the civil structures, hydromechanical installations and instrumentation at the headworks that were submerged under the deposits are also expected to get impacted, however could not be ascertained as they are still buried under the debris.

Figure C.1.3 Some glimpse of the impacts and damages by Melamchi disaster of 2021

C1.3. Lessons

Preparedness: The Melamchi watershed has a steep (the bed slope varies from 1:6 to 1:13 (from 8 to 17%) between Bhemathan knickpoint at 3,500 m elevation and the headworks at 1430 m some 16 km downstream) and is characterized by the presence of glacial lakes, fragile geology and natural and human-induced (settlements, road constructions etc.) disturbances, making it susceptible to landslides, natural river damming, dam breaches and subsequent sediment morphological issues (deposition and erosion). This is representative of many mountainous watersheds in Nepal. There is inherently a probability that such events may reoccur. The risk may now be exacerbated due to the large amount of mobile sediment present in the river which will eventually be transported further downstream. In this context we need to focus on preparedness with plan-B in hand. A warning system was not in place. However, information sharing from affected communities in the upstream to the downstream communities via mobile phone helped to minimize the causalities. We may need to consider implementing a blending of formal and informal warning systems as a part of preparedness activity.

Response: Though government agencies including NDRRMA were mobilized immediately after the event with a team of experts, it was slow and inadequate primarily due to remoteness, extreme topography, and lack of easy access. Many non-government agencies and communities joined hand in an effort for accelerating the response, which was appreciable. Local communication services (e.g., media) played a critical role for disseminating information and alerting communities on reducing exposure to risk.

Recovery: Given a huge-scale of impacts and damages, recovery process is slow as expected. The role of NDRRMA in this process was appreciable in terms of mobilizing financial resources, experts for various studies including inventory of damages and losses, and bringing it to the attention of higher political level. Furthermore, community's initiatives for clearing debris in the Melamchi bazar area and bringing it back to normal was also an appreciable and notable efforts as a part of recovery process.

CASE STUDY 2. LESSONS FROM JAPAN

C2.1. COVID-19 and Heavy Rainfall – Kumamoto, Japan (2020)[6]

C2.1.1. Description of the Disaster Events and Impacts and Damages


Social distancing at an evacuation center due to COVID-19

The torrential rains that occurred between July 3 and July 31, 2020, caused damage in several parts of Japan, particularly in the southern Kyushu region. Kumamoto Prefecture was the hardest hit by the heavy rainfall, with and 64 victims and more than 1.3 million evacuees. The Kuma River system, which flows through Kumamoto, overflowed or collapsed in 13 places, inundating about 1,060 hectares. In some areas, the depth of flooding is believed to have reached up to 9 meters. The impact of COVID-19 has completely changed how people evacuate in response to a disaster. Affected areas faced many challenges, such as caring for people who refrained from evacuating to public facilities and stayed in their homes for fear of being infected, the ongoing mental strain caused by the loss of human interactions in evacuation centers, and the shortage of volunteers and other manpower for post-disaster reconstruction.

C2.1.2. Lesson Learnt

Pre-disaster preparedness

In April 2020 the Cabinet Office published reference materials on how to deal with COVID-19 in evacuation centers and notified local governments that, as a measure to avoid overcrowding and prevent the spread of the COVID-19 virus, as many evacuation centers as possible should be opened, accommodation facilities should be utilized, and dispersing evacuees to relatives' homes should be considered. After the disaster, a noticeable number of people chose to evacuate at home rather than to shelters due to concerns about COVID-19, and they were scattered throughout the prefecture. However, it was difficult to confirm their safety, raising concerns that relief supplies and information may not have reached them.

Response during the disaster

[6] Cabinet Office, Government of Japan. Case studies of measures against COVID-19 in evacuation centers. (May 2020) available at http://www.bousai.go.jp/taisaku/hinanjo/pdf/coronajirei.pdf
Cabinet Office. Guidelines for training in the establishment and operation of evacuation centers in consideration of countermeasures against COVID-19 (2nd edition). (September 2020) available at http://www.bousai.go.jp/pdf/korona_0908.pdf
Hitoyoshi Public Health Center, Kumamoto Prefecture. Record of verification of the response to the July 2020 torrential rain disaster. (March 2021) available at https://www.pref.kumamoto.jp/uploaded/life/90333_127164_misc.pdf
National Research Institute of Land and Infrastructure. Survey Report on the Heavy Rainfall in July 2020. (August 18th, 2020) available at http://www.jice.or.jp/cms/kokudo/pdf/reports/disaster/15/2020_gouu_01.pdf

People had their temperature checked when entering evacuation centers and separate spaces and flow lines were designated for people with fevers. To avoid crowding of evacuees, it was recommended to keep 2 meters between people and to set up partitions made of cardboard or other materials to prevent droplet infection. The capacity of evacuation centers was reduced to prevent the risk of infection and in some cases evacuees were encouraged to move to other evacuation centers to maintain social distance. In the evacuation shelter, beds made of cardboard were neatly lined up and partitions were made for each household to secure a private space. At the entrance to shelters, public health nurses took the evacuees' temperatures, interviewed them about their health conditions, and carefully checked their physical condition. Although Kumamoto experienced mass evacuation on an unexpected scale, the region also succeeded in limiting the spread of COVID-19. This was due to a rapid inspection system in evacuation centers, thorough quarantine, and minimizing human interactions.

Post-disaster recovery

Kumamoto’s experience can be seen as a pioneering case to address pandemic after a disaster and also was reflected to the disaster management at the national level. The Cabinet Office updated its reference materials on how to deal with COVID-19 infections in evacuation centers in September 2020 and released a collection of case studies on measures to deal with COVID-19 infections in evacuation centers in May 2021.

C2.1. Earthquake and heavy snowfall – Niigata, Japan (2004)[7]

C2.2.1. Description of the Disaster Events and Impacts and Damages

Great Earthquake that hit Niigata prefecture in October 2004 severely damaged areas that usually experience heavy snowfall and various infrastructure such as roads, houses, and agricultural facilities were damaged. Snow began to fall in December, while the disaster recovery process was still underway, and nearly twice the normal amount of snow accumulated. Due to the earthquake and landslides caused by heavy rains the previous summer, the slopes of some hillsides collapsed, drastically changing the vegetation and topography, and destroying the physical avalanche prevention measures. In addition, snowmelt caused rivers that were blocked by sediment from the landslides to overflow, resulting in flooding and erosion of farmlands and residential areas. Although some equipment to control snow was repaired after the earthquake, the work was incomplete, meaning these measures did not work properly. Roads were covered with snow and traffic was affected, which in turn affected the economy. In addition, houses that collapsed due to the earthquake were not repaired in time. The heavy snowfall then caused secondary damage and even resulted in deaths.

C2.2.2. Lesson Learnt

Pre-disaster preparedness

In the case of the Niigata earthquake, researchers surveyed residents about the impact of heavy snow damage on the areas that had just been affected by the earthquake. They then informed the local communities by mapping out the hazards and risks in the region. The event showed that having a connected and prepared community (fostered in response to past heavy snowfall disasters) is beneficial for dealing with disasters, including compound risks. The local community cooperated to perform patrols for hazards and remove snow from roads and rooves. This volunteer work contributed greatly to mitigating the damage caused by snowfall in the affected areas.

Response during the disaster

Despite the heavy snowfall there were no large-scale disasters in the areas where restoration work and emergency measures were completed before the snow season. So, it is important to respond to

[7] Kawashima, K., Izumi, K., & Iyobe, T. (2005). Combined Disasters Caused by the Chuetsu Earthquake and Heavy Snowfall. In: Niigata Prefecture Continuous Disaster Verification and Perspectives on Reconstruction - 2004. 7. 13 Comprehensive Verification of the Flood and Chuetsu Earthquakes -, 164-170.[Japanese]
Kawashima, K., Izumi, K, Iyobe. T.,Matsumoto, T, & Urabe, A. (2019). A review of combined earthquake and heavy snow disasters in the Heisei Era: From the 2004 Niigata Chuetsu Earthquake to the 2018 Hokkaido Bold East Japan Earthquake. In Proceedings of the Snow and Ice Research Conference, Snow and Ice Research Conference (2019, Yamagata) (p. 56). The Glaciological Society of Japan/Japan Association of Snow and Ice Engineering. .[Japanese]

disasters and complete recovery work as early as possible to help prevent the occurrence of compound disasters, especially in higher risk regions like those receiving heavy snowfall in winter. During winter in heavy snowfall areas it may be difficult to live in evacuation shelters until temporary housing is built, but in Niigata, construction of temporary housing was completed before the snowfall.

Post-disaster recovery

During recovery in heavy snowfall areas, securing the transportation network is of high importance. Clearing roads is critical for recovery because snow can delay aid and isolate villages. In Niigata, there were problems, such as limited capacity and increased time for snow removal, due to insufficient recovery from the earthquake. Some roads were blocked due to avalanches and landslides. In addition, a flexible approach is required to provide assistance for compound disasters. In Niigata, financial aid was provided before the government determined the thresholds for compensation because it was clear the situation was different to previous years and could not be explained by snow alone. This was an exceptional measure which allowed the fast provision of aid money to victims.

C2.2. Heavy Rain and Mudslide – Hiroshima, Japan (2018)[8]

C2.3.1. Description of the Disaster Events and Impacts and Damages

On 20 August 2014, a major landslide occurred in the northern part of Hiroshima City, Hiroshima Prefecture, Japan. The torrential rainfall, which occurred from the night of 19 August to dawn on 20 August, had a "much lower probability than once in several hundred years". A linear precipitation zone developed, with three-hour precipitation exceeding 200 mm, and simultaneous large-scale mudslides occurred. This disaster can be described as an 'urban mudslide', characterised by three factors: 1) the occurrence of record torrential rainfall, 2) the fact that it occurred during the late night hours when it is difficult to respond, and 3) the fact that it occurred in the mountains behind residential areas with dense human habitation such as new residential areas. The search for victims lasted a month and the death toll from the disaster rose to 74.

C2.3.2 Lesson Learnt

Pre-disaster

The municipality had set the red zones (Areas with a risk of significant damage to buildings and harm to the residents.) and yellow zone (Landslide-prone areas) to inform residents of the degree of landslide or mudslide risks. After the heavy rain occurred, most of the serious damage occurred within the yellow zone, but significant damage to buildings occurred well beyond the red zone. This was because mudslides exceeded the precipitated amounts, and got out of the assumed direction and reached out the adjacent areas. In order to properly identify endangered areas, it is necessary to avoid such underestimation and to take into account that the direction of the debris flow may not always be in a straight line, but may deviate significantly due to topographical factors, or that the debris flow may break up in the middle due to multiple occurrences.

Response during the disaster

Some of people failed to escape as evacuation order was behind. The municipality operates a regional disaster management plan that stipulated the numerical criteria for determining evacuation order and other early actions to be taken by the municipality and residents. In the case of landslides, evacuation order was to be issued from the time of the announcement of a heavy rainfall warning, when the evacuation standard rainfall for each area was reached. On the other hand, it was possible to recognize

[8] Verification results related to evacuation measures in the case of Torrential rain disaster of 20 August 2014 (2015) available at https://www.city.hiroshima.lg.jp/shobou/bousai/260820/01honpen.pdf
Tsuchida, T., Moriwaki, T., Kumamoto, N., Ichii, K., Kano, S., & Nakai, S. (2016). Investigation of debris flow and damaged areas of 2014 Hiroshima landslide disaster. Japanese Geotechnical Journal, 11(1), 33-52.
Ushiyama, M., Honma, M., Yokomaku, S., & Sugimura, K. (2019). Characteristics of victims caused by heavy rainfall disaster in July, 2018. Journal of Japan society for Natural disaster Science, 38(1), 29-54.

the situation of the need for an evacuation order by making full use of various weather information without the procedures in line with the regional disaster management plan. However, at the time, it was difficult to issue an evacuation order given the established perception that "people would move to evacuation centers once an evacuation order was issued", and in view of the danger of evacuation routes due to weather conditions near the affected area and the time of day. It will be necessary to inform the public in advance about how to respond to avoid being affected during evacuation action and to make decisions on the 'next best course of action' (e.g. evacuation to the second floor or higher of a building).

Post-disaster recovery

After the disaster, experts from local universities and voluntary disaster response organisations in the affected areas set up an Evacuation Measures Verification Subcommittee to conduct detailed studies on the evacuation arrangements in place at the time. They made recommendations on, for example, what evacuation measures should be implemented in the future to cope with the similar cases. These include reducing the time intervals for information collection and analysis, establishing a reliable system for collecting critical information, and clarifying the procedures for determining the level of danger and who decides on recommendations, thereby contributing to improved regional disaster management planning in the future.

REFERENCES

Acharya, K. K. (2018). The capacity of local governments in Nepal: from government to governance and governability? *Asia Pacific Journal of Public Administration*, *40*(3), 186–197. https://doi.org/10.1080/23276665.2018.1525842

Acharya, T. D., Mainali, S. C., Yang, I. T., & Lee, D. H. (2016). Analysis of jure landslide dam, Sindhupalchowk using GIS and Remote Sensing. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *41*(July), 201–203. https://doi.org/10.5194/isprsarchives-XLI-B6-201-2016

Adger, W. N., & Kelly, P. M. (1999). Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change*, *4*(3–4), 253–266. https://doi.org/10.1023/A:1009601904210/METRICS

Adhikari, D. P., & Koshimizu, S. (2005). Debris flow disaster at Larcha, upper Bhotekoshi Valley, central Nepal. *Island Arc*, *14*(4), 410–423. https://doi.org/10.1111/j.1440-1738.2005.00495.x

AghaKouchak, A., Huning, L. S., Mazdiyasni, O., Mallakpour, I., Chiang, F., Sadegh, M., Vahedifard, F., & Moftakhari, H. (2018). How do natural hazards cascade to cause disasters? *Nature*, *561*(7724), 458–460. https://doi.org/10.1038/d41586-018-06783-6

Aksha, S. K., Juran, L., Resler, L. M., & Zhang, Y. (2019). An Analysis of Social Vulnerability to Natural Hazards in Nepal Using a Modified Social Vulnerability Index. *International Journal of Disaster Risk Science*, *10*(1), 103–116. https://doi.org/10.1007/s13753-018-0192-7

Aryal, K. R. (2014). Disaster vulnerability in Nepal. *International Journal of Disaster Risk Reduction*, *9*, 137–146. https://doi.org/10.1016/j.ijdrr.2014.05.009

Bhandari, D., Neupane, S., Hayes, P., Regmi, B., & Marker, P. (2020). Disaster risk reduction and management in Nepal : Delineation of roles and responsibilities. *Oxford Policy Management*, *May*, 29. https://www.preventionweb.net/files/72985_delineationofresponsibilityfordisas[1].pdf

BIPAD Portal. (2023). *Incident*. https://bipadportal.gov.np/incidents/

Birkmann, J., Cutter, S. L., Rothman, D. S., Welle, T., Garschagen, M., van Ruijven, B., O'Neill, B., Preston, B. L., Kienberger, S., Cardona, O. D., Siagian, T., Hidayati, D., Setiadi, N., Binder, C. R., Hughes, B., & Pulwarty, R. (2015). Scenarios for vulnerability: opportunities and constraints in the context of climate change and disaster risk. *Climatic Change*, *133*(1), 53–68. https://doi.org/10.1007/s10584-013-0913-2

Bowen, K. J., Patwardhan, A., Wang, Y., & Bialobrzeski, E. (2022). *The risk of cascading climate change shocks and stressors* (Science for Adaptation Policy Brief 5).

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for Climate Change Research. *Tyndall Centre for Climate Change Research*, *February*, 1–20.

Chaulagain, H., Gautam, D., & Rodrigues, H. (2018). Revisiting major historical earthquakes in Nepal: Overview of 1833, 1934, 1980, 1988, 2011, and 2015 seismic events. In *Impacts and Insights of the Gorkha Earthquake*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-812808-4.00001-8

Chitrakar, G., Piya, B., Nepali, D., & Manandhar, S. (2007). Some notable disasters in Nepal and their mitigation. *Journal of Nepal Geological Society*, *36*, 23–23. https://www.nepjol.info/index.php/JNGS/article/view/781

Constitution. (2015). The Constitution of Nepal. *Nepal Gazette*, 1–226. https://lawcommission.gov.np/en/?s=constitutional+of+Nepal

Cook, K., Andermann, C., Gimbert, F., Hovius, N., Adhikari, B., Cook, K., Andermann, C., Gimbert, F., Hovius, N., & Adhikari, B. (2017). Impacts of the 2016 outburst flood on the Bhote Koshi River valley, central Nepal. *EGUGA*, *19*, 10570. https://ui.adsabs.harvard.edu/abs/2017EGUGA..1910570C/abstract

Cutter, S. L. (2018). Compound, Cascading, or Complex Disasters: What's in a Name? *Environment: Science and Policy for Sustainable Development*, *60*(6), 16–25. https://doi.org/10.1080/00139157.2018.1517518

Dangal, R. (2011). *Country Profile : Nepal 1*. 1–17.

Davis, C., Coningham, R., Acharya, K. P., Kunwar, R. B., Forlin, P., Weise, K., Maskey, P. N., Joshi, A., Simpson, I., Toll, D., Wilkinson, S., Hughes, P., Sarhosis, V., Kumar, A., & Schmidt, A. (2020). Identifying archaeological evidence of past earthquakes in a contemporary disaster scenario: case studies of damage, resilience and risk reduction from the 2015 Gorkha Earthquake and past seismic events within the Kathmandu Valley UNESCO World Heritage Pr. *Journal of Seismology*, *24*(4), 729–751. https://doi.org/10.1007/s10950-019-09890-7

Dhungana, H., Pain, A., & Dhungana, S. P. (2016). *Disaster Risk Management and Meso-Level Institutions in Nepal: A Case Study of Floods in Tinau River in Western Terai*. 56.

DRR Portal. (2023). *Nepal Disaster Risk Reduction Portal*. http://drrportal.gov.np/risk-profile-of-nepal

Gaire, S., Delgado, R. C., & González, P. A. (2015). Disaster risk profile and existing legal framework of Nepal: Floods and landslides. *Risk Management and Healthcare Policy*, *8*, 139–149. https://doi.org/10.2147/RMHP.S90238

Gautam, D. (2017). Assessment of social vulnerability to natural hazards in Nepal. *Natural Hazards and Earth System Sciences*, *17*(12), 2313–2320. https://doi.org/10.5194/nhess-17-2313-2017

Ghimire, H. L. (2016). Disaster Management and Post-quake Impact on Tourism in Nepal. *The Gaze: Journal of Tourism and Hospitality*, *7*, 37–57. https://doi.org/10.3126/gaze.v7i0.15119

Goda, K., Kiyota, T., Pokhrel, R. M., Chiaro, G., Katagiri, T., Sharma, K., & Wilkinson, S. (2015). The 2015 Gorkha Nepal earthquake: Insights from earthquake damage survey. *Frontiers in Built Environment*, *1*(June), 1–15. https://doi.org/10.3389/fbuil.2015.00008

Guragain, U. P., & Doneys, P. (2022). Social, Economic, Environmental, and Physical Vulnerability Assessment: An Index-Based Gender Analysis of Flood Prone Areas of Koshi River Basin in Nepal. *Sustainability (Switzerland)*, *14*(16). https://doi.org/10.3390/su141610423

Hall, M. L., Lee, A. C. K., Cartwright, C., Maharatta, S., Karki, J., & Simkhada, P. (2017). The 2015 Nepal earthquake disaster: lessons learned one year on. *Public Health*, *145*, 39–44. https://doi.org/10.1016/j.puhe.2016.12.031

IPCC. (2018). Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,*. World Meteorological Organization.

IPCC. (2022). Summary for Policymakers. In *Climate Change 2022: Impacts, Adaptation and Vulnerability* (IPCC Sixth). Intergovernmental Panel on Climate Change (IPCC). https://doi.org/10.1017/9781009325844.001

Joshi, T., Mainali, R. P., Marasini, S., Acharya, K. P., & Adhikari, S. (2021). Nepal at the edge of sword with two edges: The COVID-19 pandemics and sustainable development goals. *Journal of Agriculture and Food Research*, *4*, 100138. https://doi.org/10.1016/J.JAFR.2021.100138

Kafle, K. R., Khanal, S. N., & Dahal, R. K. (2017). Consequences of Koshi flood 2008 in terms of sedimentation characteristics and agricultural practices. *Geoenvironmental Disasters*, *4*(1). https://doi.org/10.1186/s40677-017-0069-x

Kok, K., van Vliet Mathijs, M., Bärlund Ilona, I., Dubel, A., & Sendzimir, J. (2011). Combining participative backcasting and exploratory scenario development: Experiences from the SCENES project. *Technological Forecasting and Social Change*, *78*(5), 835–851. https://doi.org/10.1016/J.TECHFORE.2011.01.004

Lamichhane, S., Aryal, K. R., Talchabhadel, R., Thapa, B. R., Adhikari, R., Khanal, A., Pandey, V. P., & Gautam, D. (2021). Assessing the prospects of transboundary multihazard dynamics: The case of bhotekoshi—sunkoshi watershed in sino—nepal border region. *Sustainability (Switzerland)*, *13*(7), 1–32. https://doi.org/10.3390/su13073670

Local Government Institutional Capacity Self-Assessment (LISA) Guideline. (2019). 0–62.

Local Government Operation Act. (2017). Local Government Operation Act, 2017. *Nepal Gazette*, *1*, 1–119.

Maharjan, S. B., Steiner, J. F., Shrestha, A. B., Maharjan, A., Nepal, S., Shrestha, M. S., Bajracharya, B., Rasul, G., Shrestha, M., Jackson, M., & Gupta, N. (2021). *The Melamchi flood disaster: Cascading hazard and the need for multihazard risk management - ICIMOD*. https://www.icimod.org/article/the-melamchi-flood-disaster/

Martin-Vegue, T. (2021). *How to Write Strong Risk Scenarios and Statements*. https://www.isaca.org/resources/news-and-trends/newsletters/atisaca/2021/volume-31/how-to-write-strong-risk-scenarios-and-statements

MoHA. (2017). Nepal Disaster Report 2017: The Road to Sendai. In *Nepal Disaster Report 2017: The Road to Sendai* (Issue December). http://drrportal.gov.np/uploads/document/1321.pdf

National Disaster Risk Reduction and Management Act. (2017). *National Disaster Risk Reduction and Management Act*. १.

National Planning Commission. (2017). Nepal Flood 2017: Post Flood Recovery Needs Assessment. *Government of Nepal*. https://www.npc.gov.np/images/category/PFRNA_Report_Final.pdf

Nepal, P., Khanal, N. R., & Pangali Sharma, B. P. (2018). Policies and Institutions for Disaster Risk Management in Nepal: A Review. *Geographical Journal of Nepal*, *11*(1998), 1–24. https://doi.org/10.3126/gjn.v11i0.19546

O'Keefe, P., Westgate, K., & Wisner, B. (1976). Taking the naturalness out of natural disasters. *Nature*, *260*(5552), 566–567. https://doi.org/10.1038/260566a0

Panthi, K. K. (2021). Assessment on the 2014 Jure Landslide in Nepal - A disaster of extreme tragedy. *IOP Conference Series: Earth and Environmental Science*, *833*(1). https://doi.org/10.1088/1755-1315/833/1/012179

Phillips, C. A., Caldas, A., Cleetus, R., Dahl, K. A., Declet-Barreto, J., Licker, R., Merner, L. D., Ortiz-Partida, J. P., Phelan, A. L., Spanger-Siegfried, E., Talati, S., Trisos, C. H., & Carlson, C. J. (2020). Compound climate risks in the COVID-19 pandemic. *Nature Climate Change*, *10*(7), 586–588. https://doi.org/10.1038/s41558-020-0804-2

Pokhrel, K. P. (2020). Disaster management in Nepalese context: An ecological perspective. *Research in Ecology*, *2*(3), 1–9. https://doi.org/10.30564/re.v2i3.2332

Poudel, K., & Subedi, P. (2020). Impact of COVID-19 pandemic on socioeconomic and mental health aspects in Nepal. *International Journal of Social Psychiatry*, *66*(8), 748–755. https://doi.org/10.1177/0020764020942247

Sharma, R. (2020). *Hazards are natural, but disasters are always results of human action - OnlineKhabar English News*. https://english.onlinekhabar.com/hazards-are-natural-but-disasters-are-always-results-of-human-action.html

Shrestha, M. (2022). *Effects of Landslide on the Livelihood of People at Ghumthang, Sindhupalchok*. 93–108.

Shrestha, R. K., Ahlers, R., Bakker, M., & Gupta, J. (2010). Institutional dysfunction and challenges in flood control: A case study of the Kosi flood 2008. *Economic and Political Weekly*, *45*(2), 45–53.

Thapa, P. B., & Dhital, M. R. (2000). Landslides and debris flows of 19-21 July 1993 in the Agra Khola watershed of Central Nepal. *Journal of Nepal Geological Society*, *21*, 5–20–25–20. https://doi.org/10.3126/JNGS.V21I0.32143

UNDRR. (2019). *Local Disaster Risk Reduction And Resilience Strategies: Words into Action*. United Nations Office for Disaster Risk Reduction (UNDRR).

UNDRR. (2020). *Hazard Definition and Classification Review* (Technical Report).

UNDRR. (2022). *Scoping Study On Compound, Cascading And Systemic Risks*. The Asia Pacific, United Nations Office for Disaster Risk Reduction (UNDRR).

UNISDR. (2017). *National Disaster Risk Assessment*.

UNISDR. (2015). Sendai framework for disaster risk reduction 2015–2030. *Proceedings of the 3rd United Nations World Conference on DRR, Sendai, Japan*, 14–18.

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R., Niu, P., Zhan, F., Ma, X., Wang, D., Xu, W., Wu, G., Gao, G. F., & Tan, W. (2020). A Novel Coronavirus from Patients with Pneumonia in China, 2019. *New England Journal of Medicine*, *382*(8), 727–733. https://doi.org/10.1056/nejmoa2001017