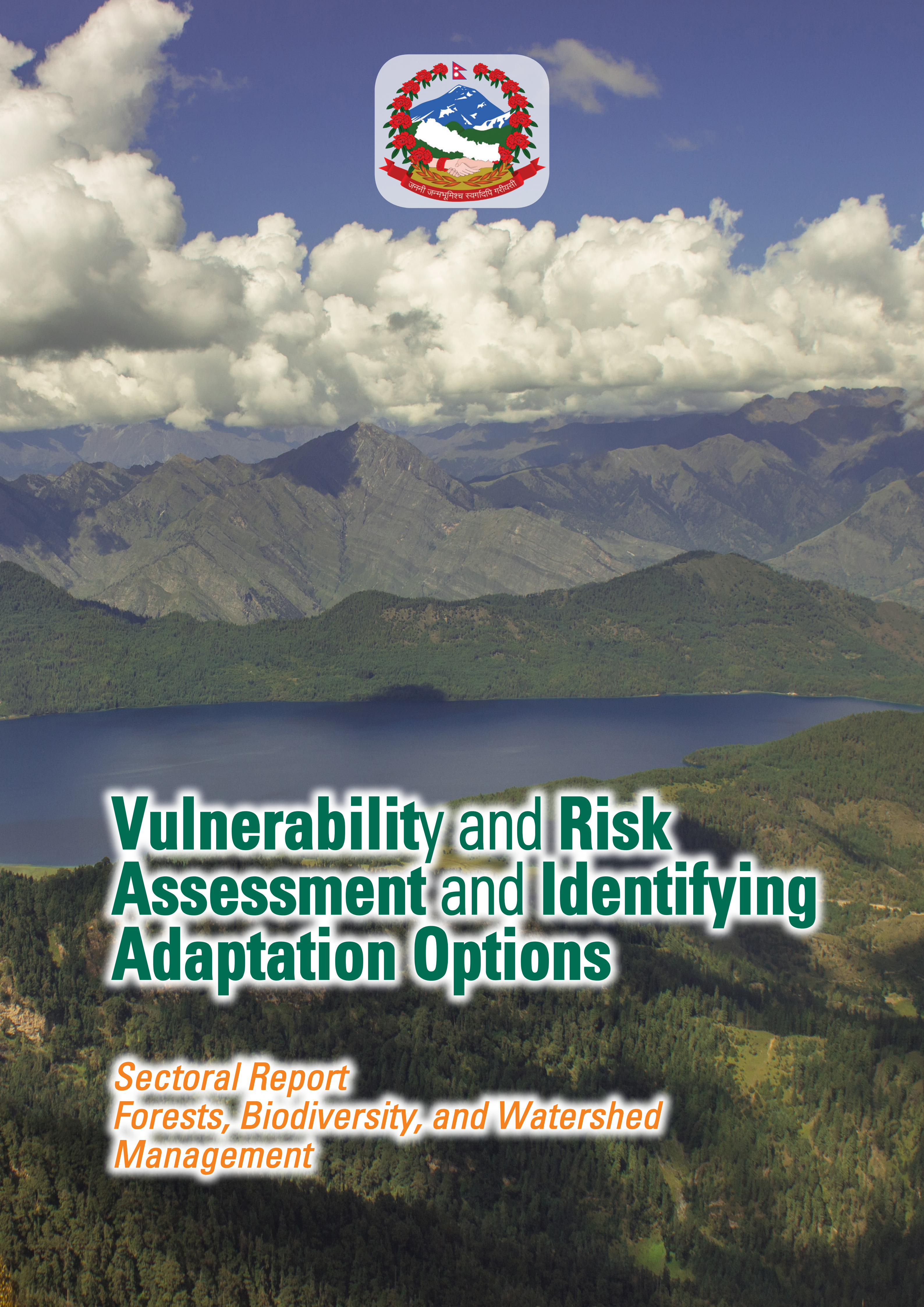

Vulnerability and Risk Assessment and Identifying Adaptation Options

Sectoral Report
Forests, Biodiversity, and Watershed Management

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Foreword

Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. The latest IPCC report confirms that human activities have changed our climate and led to the more frequent heatwaves, floods, droughts, and wildfires that we have seen recently. The evidence is incontrovertible. This highly influential report provides the evidence base and impetus to develop policy strategies and practices that will help people around the world and in Nepal live with and adapt to change.

Nepal has been a pioneer in the development and implementation of effective adaptation policies and practices. Nepal has made a strong commitment to updating a mid-long term National Adaptation Plan (NAP) every ten years, as well as conducting a National level Vulnerability and Risk Assessment every five years to inform climate resource allocation policies. Vulnerability and Risk Assessment (VRA) was initiated to assess vulnerability and risk at the national, physiographic, province, municipal, and sector levels to inform the Government of Nepal's current NAP formulation process.

I am pleased to see that the VRA report on Forest, Biodiversity, and Watershed Management was prepared by identifying sector-specific current vulnerability and future risk based on a solid scientific foundation and information. This report is the result of a thorough consultation process with national and provincial stakeholders and experts. This report, I believe, provides an opportunity for policymakers, decision-makers, and practitioners to make informed decisions about sector-specific vulnerability and risk to build a climate-resilient society and reduce the impacts of climate change at the local, provincial, and federal levels.

On behalf of the Ministry of Forests and Environment, I would like to thank the Chair and all the respected thematic group members who provided technical guidance to finalize this report. In addition, I gratefully acknowledge the assistance provided by the Climate Change Management Division, particularly Dr Radha Wagle and all technical committee members.

I also take this opportunity to acknowledge the funding and technical support of the British Embassy Kathmandu, and Policy and Institutions Facility (PIF) /Oxford Policy Management Limited.

Dr Pem Narayan Kandel
Secretary
Ministry of Forests and Environment (MoFE)

Acknowledgments

The National Climate Change Policy (2019) identifies eight thematic areas and four cross-cutting areas which will be impacted by climate change. As such, there is a pressing need to understand how public and private investments might be impacted. Without adequate information on risks and vulnerability, it will be difficult to translate policy into action. To plan and implement a successful adaptation strategy, it is vital to understand the likely impacts of climate change on different sectors and communities, and, in particular, how these may evolve in the future National Adaptation Plan (NAP) needs to be developed based on a strong scientific foundation and reliable evidence. This includes data and information about how the climate has evolved in the recent past and how it may further change in the future. To realise this, the MoFE has carried out detailed Vulnerability and Risk Assessments (VRAs) of the thematic areas identified by the National Climate Change Policy at the municipal, district, and regional scales. The VRA framework and methodology presented in the report are based on the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and the NAP technical guidelines of the UNFCCC.

This VRA report contributes to the establishment of a strong baseline for climate change impacts, risks, and vulnerabilities in Nepal. In particular, it presents relevant information on social and structural vulnerabilities and risks triggered by the interaction of climate change and socio-economic, governance, political and cultural norms and practices. The report also offers a range of adaptation options for reducing root causes of vulnerability and risk, including enhancing social inclusion and reducing gender disparity

On behalf of the Climate Change Management Division (CCMD), I would like to extend my appreciation to the chair, vice-chair, member secretary, and all the members of the Thematic Working Groups (TWGs) on Forest Biodiversity and Watershed Management (FBWM) for providing guidance and input in the VRA process. Also, I acknowledge the input provided by federal, provincial, and local governments, national and international organizations, community-based organizations, and communities.

Special thank goes to the technical committee members Raju Sapkota, Dr Arun Prakash Bhatta, Srijana Shrestha, Hari Pandey, Dr Indira Kandel, Gyanendra Karki, and Dr Bimal Raj Regmi who supported and facilitated the VRA process. We would also like to thank Dr Eak Rana, Basana Sapkota, Dr Nilhari Neupane, Dr Shiba Banskota, Apar Paudyal, Dr Ram Prasad Lamsal, Dr Pashupati Nepal, Dr Bhogendra Mishra, Regan Sapkota, Pratik Ghimire, Rojy Joshi, Bamshi Acharya, Goma Pandey, and Prashamsa Thapa from the PIF, who provided technical insights and were involved in producing this report.

Besides, I also take this opportunity to acknowledge the funding and technical support of the British Embassy Kathmandu, and Policy and Institutions Facility (PIF) /Oxford Policy Management Limited.

Dr Radha Wagle
Joint Secretary
Climate Change Management Division
Ministry of Forests and Environment (MoFE)

List of Acronyms

AC	Adaptive Capacity
AFFON	Association of Family Forest Owners Nepal
AHP	Analytical Hierarchical Process
AR	Assessment Report
CAPA	Community Adaptation Plan of Action
CbA	Community-based Adaptation
CbFMS	Community-based Forest Management System
CBS	Central Bureau of Statistics
CF	Community Forestry/Forest
CFUG	Community Forest User Groups
CITES	Convention on International Trade in Endangered Species
CSOs	Civil Society Organizations
DFO	Division Forest Office/Divisional Forest Officer
DFRS	Department of Forest Research and Survey
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife Conservation
DoE	Department of Environment
DoF	Department of Forest
DoFSC	Department of Forests and Soil Conservation
DoI	Department of Industry
DPR	Department of Plant Resources
EbA	Ecosystem-based Adaptation
FECOFUN	Federation of Community Forest Users' Nepal
FenFIT	Federation of Forest-based Industry and Trade, Nepal
FNCCI	Federation of Nepalese Chambers of Commerce and Industry
FRTC	Forest Research and Training Centre
GDP	Gross Domestic Product
GESI	Gender Equity and Social Inclusion
GLOFs	Glacial Lake Outburst Floods
GoN	Government of Nepal
HIMAWANTI	Himalayan Grassroots Women's Natural Resource Management Association
IAPS	Invasive Alien Plant Species
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
IPs	Indigenous Peoples
IUCN	International Union for Conservation of Nature
IWM	Integrated Water Management

LAPA	Local Adaptation Plans of Action
LDCs	Least Developed Countries
LEG	LDC Expert Group
MAP	Medicinal and Aromatic Plants
MoFE	Ministry of Forests and Environment
MoFSC	Ministry of Forests and Soil Conservation
MoITFE	Ministry of Industry, Tourism, Forests, and Environment
MoPE	Ministry of Population and Environment
MPFS	Master Plan for the Forestry Sector
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NAST	Nepal Academy of Science and Technology
NBSAP	National Biodiversity Strategy and Action Plan
NCCSP	Nepal Climate Change Support Programme
NDC	Nationally Determined Contribution
NEFIN	National Federation of Indigenous Nationalities
NPC	National Planning Commission
NTNC	National Trust for Nature Conservation
NTFPs	Non-Timber Forest Products
OPML	Oxford Policy Management Limited
PAs	Protected Areas
PIF	Policy and Institutions Facility
RCP	Representative Concentration Pathway
RDN	Rastriya Dalit Network
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation of Forest Carbon, Sustainable Management of Forests, and Carbon Stock Enhancement
REDD IC	REDD Implementation Centre
SMCE	Spatial Multi-Criteria Error
SWC	Social Welfare Council
TAL	Terai Arc Landscape
TWG	Thematic Working Group
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VRA	Vulnerability and Risk Assessment
WFP	World Food Programme
WWF	World Wide Fund for Nature
ZSL	Zoological Society of London

Executive Summary

Nepal's forests, biodiversity, and watershed resources are critical to both local livelihood and environmental conservation. Nepal has an ecologically diverse landscape which is home to many different species of flora and fauna. With as many as thirty-five different vegetation types and 118 ecosystems, it fosters immense genetic diversity. Its forests currently cover around forty-five per cent of the total land. A network of 20 protected areas (PA) covers nearly twenty-four per cent of it and manage over two hundred and forty-three watersheds. The country has been able to build and sustain these practices through participatory natural resource management initiatives such as the Community-based Forest Management System (CBFMS)—initiated in late 1970—as well as traditional resource management practices especially prevalent among communities of Indigenous Peoples (IPs).

In spite of all these efforts, Nepal is faced with a series of challenges in conserving its natural resources, stemming from natural and anthropogenic factors. IPs, local communities, and several studies have found that climate change seems to be aggravating the pre-existing problems in natural resource conservation and jeopardizing the lives of IPs and local communities. Two climatic stressors—increase in temperature and change in precipitation—along with associated hazards like droughts, floods, landslides, and extreme rainfall events have collectively posed threats to forests, biodiversity, and watershed resources. Some observed impacts on this sector include vegetation range shift; phenological change; forest fire incidences; the spread of invasive alien plant species (IAPS); drying of water resources; and watershed degradation.
IPs and local communities are faced with unemployment and indigenous people are unable to sustain their cultural and spiritual practices. Women have seen an increase in their workload due to a decline in forest products.

To tackle the aforementioned challenges, the Government of Nepal (GoN), being a party to the United Nations Framework Convention on Climate Change (UNFCCC), initiated its National Adaptation Plan (NAP) formulation process in 2016. Several preparatory initiatives of the NAP process took place, including the formulation of the Vulnerability and Risk Assessment (VRA). This particular study is the VRA that was carried out as an integral part of Nepal's NAP process across three scales—districts, provinces, and physiographic regions. The overall objective of the study was to assist Nepal's NAP process in assessing climate-related risk and vulnerabilities at the district, provincial, and physiographic region level and identify appropriate adaptation options for forests, biodiversity, and watershed management.

The assessment adopted a step-by-step approach with the participation of and in consultation with IPs, local communities, stakeholders, and relevant experts as guided by the overarching VRA framework. The first step in this process was identifying possible indicators for exposure, sensitivity, and adaptive capacity concerning forests, biodiversity, and watershed management, through an extensive literature review. This was further broken down into two broad sub-sectors: forests and biodiversity, and watershed management. The assessment used both intrinsic (biophysical) attributes and relevant socio-economic-related indicators to characterize the hazard, exposure, sensitivity, and adaptive capacity of these sub-sectors. The assessment also looked into the vulnerability and risk of the sector.

A total of 75 indicators have been selected from the aforementioned sub-sectors: forests and biodiversity (62 indicators) and watershed management (13 indicators), for exposure, sensitivity, and adaptive capacity. These selected indicators were finalized in consultation with members of the technical committee and Thematic Working Group (TWG) represented by various government organizations (DoFSC, FRTC, DoE, DNWPC, REDD IC, DPR, President Chure–Terai Madhesh Development Board), development organizations (WWF, ICIMOD, NTNC, ZSL), civil society including Nepal Federation of Indigenous Nationalities (NEFIN), Federation of Community Forest Users' Nepal (FECOFUN), The Himalayan Grassroots Women's Natural Resource Management Association HIMAWANTI, Rashtriya Dalit Network (RDN), Nepal Foresters' Association (NFA), and private sectors (FenFIT). Data related to the selected indicators was collected from various authenticated sources mostly from published and unpublished reports produced by the government, development organizations, civil society, and peer-reviewed articles.

The collected data were tabulated, filtered, and normalized to transform them into unitless values by using the min-max method. Every normalized data was given weightage and prioritized by using pair-wise comparison as described in the Analytical Hierarchy Process (AHP) model with a 9–point importance scale, its values ranging from equal importance (1) to extreme importance (9). This prioritization was done by the TWG members and other experts through a set of questionnaires. Individual judgments from experts were converted into group judgment by using their geometric average. The aggregated value of each indicator of exposure, sensitivity, and adaptive capacity was calculated by using the weighted linear summation method.

The vulnerability of sub-sector-wise and cumulative of forests and biodiversity and watershed management were determined with the aggregated value of sensitivity and adaptive capacity as defined by IPCC–Assessment Report–5. As indicated by IPCC–AR5, the vulnerability was estimated as a function of sensitivity and adaptive capacity, whereas the risk was estimated as a function of extreme events and hazard intensity, exposure, and vulnerability. The calculated sub-sector and sector-wise cumulative vulnerability indexes of the district, provinces, and physiographic regions were ranked into five classes: Very low, Low, Moderate, High, and Very High.

Climate extreme events as proxy climate hazards indexes were assessed at three temporal scales: baseline period and the years 2030 and 2050 under two Representative Concentration Pathways (RCPs) 4.5 and 8.5. The calculated ranks were presented both in the thematic map and in numerical value to inform the decision-makers in setting the priorities and selection of adaptation interventions and investments at national, provincial, and local government levels. The findings showed that most western high mountain districts exhibit moderate to low levels of climate extreme events. However, the eastern Terai districts generally represented high climate extreme events which can be attributed to the increase in precipitation and its erratic pattern.

Unlike the case of climate extreme events, high mountain districts represent generally high exposure to climate change. Some western Terai districts also appear to have a similar level of exposure to climate change. Increased exposure to climate change for high mountain districts could be due to the distribution of climate-susceptible forest types (e.g., *Abies spectabilis, Betula,* etc.) and climate-sensitive non-timber forest products, distribution of wetlands, and water bodies including glacial lakes and exposed watershed areas.

Generally, the middle and high mountain regions and the districts within these regions appear more vulnerable except for Mustang. On the contrary, Terai districts appeared less vulnerable. Nevertheless, some districts in other regions represent a high vulnerability due to district-specific biophysical characteristics and forests, biodiversity, and watershed management interventions. In the case of risk, mostly eastern high mountain districts have high climate risk and Terai districts have low risk despite high levels of climate extreme events. Risk analysis of future scenarios under two RCPs, 4.5 and 8.5, for 2030 and 2050 indicates a unidirectional shift towards the high risk of climate change across all scales—district, physiographic regions, and provinces. High and middle mountain regions and districts of these regions are expected to experience very high climate risk. Such shifts towards higher levels will also occur in the Siwalik (from moderate to very high) and Hill region (low to moderate).

Unlike highly vulnerable provinces including Karnali, Lumbini, Bagmati, and Gandaki Provinces, Province 2 (or Terai region) seems to be unaffected by low climate vulnerability and risk. However, some districts of this province are expected to become high risk in the future.

Overall findings reveal that there is a variation of vulnerability and risk level across districts, provinces, and physiographic regions owing to the different levels of sensitivity and adaptive capacity, hazard, and exposure, which are attributed to the context-specific biophysical characteristics and socio-economic conditions. Variation also appeared between the two sub-sectors—forests and biodiversity and watershed—for the same district due to the different levels of sensitivity and adaptive capacity.

Considering the uneven pattern of vulnerability and risks and observed impacts across the districts, provinces, and physiographic regions, this analysis provides a broader level of adaptation measures for three time scales: short, medium, and long-term in the face of uncertain climate change and socio-economic scenarios. These options were synthesized from a comprehensive literature review and refined through a series of consultations with IPs, local communities, stakeholders, and experts including the VRA technical team and the TWG. The report outlines adaptation options in terms of plans, actions, strategies, and approaches which broadly include no and low-regret type activities. Ecosystem-based Adaptation (EbA) is recommended as a nature-based solution to address the variation of vulnerability and risk that appeared between forests and biodiversity, and watershed management.

There is a need to maintain a thematic breakdown of data from all social groups, which includes women, IPs, and the Dalit community at different jurisdictional, spatial, and temporal scales by establishing a data cleansing house at the federal level. VRA at the local government level is suggested to identify the site-specific risks and vulnerabilities thereby designing adaption measures. Similarly, species (faunal) level VRA is recommended in the future. A systematic longitudinal ecological study is essential to understand the climate impacts on forests, biodiversity, and watershed resources.

Table of Contents

Foreword **i**
Acknowledgements **ii**
List of Acronyms **iii**
Executive Summary **v**

Chapter 1: Background and Sectoral Context **1**
1.1 Introduction - Forests, Biodiversity, and Watershed Management in Nepal 2
  1.1.1 Forests 2
  1.1.2 Biodiversity 4
  1.1.3 Watershed Management 5
  1.1.4 Challenges in Forests, Biodiversity, and Watershed Management 5

Chapter 2: Objectives and Scope of the Study **7**
2.1 Objectives and Rationale of the Study 7
2.2 Scope and Limitation of Study 7

Chapter 3: Framework, Approach, and Methodology **9**
3.1 Defining assessment framework 11
3.2 Methodology 12
3.3 Data Normalization, Weightage, and Analysis 15
3.4 Calculation of the Vulnerability and Risk Index 19
3.5 Prioritizing and ranking vulnerability and risk 21
3.6 Error minimization 22
3.7 Identification of adaptation options 22

Chapter 4: Observed Climate Change Impacts on Forests, Biodiversity, and Watershed Management **21**
4.1 Observed impacts on forests 23
  4.1.1 Species and vegetation range shift 23
  4.1.2 Phenological change 27
  4.1.3 Forest fire incidences 27
  4.1.4 Distribution of Invasive Alien Plant Species 28
  4.1.5 Forests pests, diseases, and pathogens 29
4.2 Impact on biodiversity 30
  4.2.1 Impact on ecosystem-diversity 30
  4.2.2 Impact on species diversity 30
  4.2.3 Loss and Damage (L&D) due to climate-induced disasters 33
  4.2.4 Impact on floral diversity 34
  4.2.5 Distribution of alien invasive faunas 34
4.3 Potential impact of climate change on Nepal’s protected areas 34
4.4 Impact on watershed management 36
  4.4.1 Disruption of hydrological cycles 36
  4.4.2 Watershed degradation 36

4.4.3 Wetland degradation 37
4.4.4 Shortage of water for domestic use 37
4.5 Impact on forest-dependent populations, infrastructure, and enterprises 38
4.5.1 Impact on forest-dependent populations 38
4.5.2 Impact on forest-related infrastructure and enterprises 39

Chapter 5: Observed and Projected Climate Change Hazards and Exposure **37**
5.1 Climate change stressors/hazards in forests, biodiversity, and watershed management 40
5.1.1 Climate change trends 40
5.1.2 Climatic extreme events trend and scenarios 42
5.2 Climate Change Exposure of Forests, Biodiversity, and Watershed Management 47
5.2.1 Climate change exposure across the districts 47
5.2.2 Climate Change Exposure Across Physiographic Regions and Provinces 50

Chapter 6: Observed Climate Change Vulnerability **49**
6.1 Sensitivity of forests, biodiversity, and watershed management 54
6.1.1 Sensitivity across districts 54
6.1.2 Sensitivity across physiographic regions and provinces 58
6.2 Adaptive capacity of forests, biodiversity, and watershed management 61
6.2.1 Adaptive capacity across districts 62
6.2.2 Adaptive Capacity Across Physiographic Regions and Provinces 67
6.3 Vulnerability of forests, biodiversity, and watershed management 69
6.3.1 Vulnerability across the districts 70
6.3.2 Vulnerability across physiographic regions 73
6.3.3 Vulnerability across provinces 75

Chapter 7: Projected Climate Change Risks **75**
7.1 Climate change risks in forests, biodiversity, and watershed management 79
7.1.1 Risk Across the Districts 80
7.1.2 Risk Scenarios Across the Physiographic Regions 84
7.1.3 Risk scenarios across physiography by provinces 86

Chapter 8: Adaptation Options in the Sector **85**

Chapter 9: Conclusion and Recommendations **95**
9.1 Lessons learned and conclusions 95
9.1 Recommendations: Process, data gaps, and future needs 96

References **99**

Annexes **112**

List of Tables

Table 1: Plant and Faunal Species in Nepal 3
Table 2: Data types and sources 13
Table 3: Scores for the importance of variables (Saaty Scale) 14
Table 4: Weightage for exposure indicators 15
Table 5: Weightage of sensitivity indicators 16
Table 6: Weightage of adaptive capacity indicators 17
Table 7: Summary of key findings from species and vegetation shift-related studies within and beyond Nepal 22
Table 8: Habitat-wise Mikania infestation change in Chitwan National Park, 2008–2011 28
Table 9: Observed trends of the climatic variables in Nepal between 1971 and 2014 37
Table 10: Seasonal and annual precipitation trends (mm/year) by the physiographic regions of Nepal 38
Table 11: Seasonal and annual maximum temperature trends (oc/year) by the physiographic regions in Nepal 38
Table 12: Projected multi-model ensemble means of change in precipitation and temperature in the medium-term and long-term period of Nepal 39
Table 13: Relative weights for hazard indicators associated with forests, biodiversity, and watershed resources 39
Table 14: Districts with different levels of exposure to climate change 44
Table 15: Districts with different sensitivity ranks 51
Table 16: Districts with different levels of adaptive capacity 59
Table 17: Districts with the different vulnerability of forests, biodiversity, and watershed management 66
Table 18: Province-level vulnerability rank (in %) 71
Table 19: Districts with different risk rank at baseline period 78
Table 20: Number of districts with different risk scenarios under RCP 4.5 and 8.5 for 2030 and 2050 78
Table 21: Short, medium, and long-term adaptation options 89

List of Figures

Figure 1: Climate change vulnerability and risk assessment framework (MoPE, 2017) 10
Figure 2: Steps of Vulnerability and Risk Assessment (MoPE, 2017) 11
Figure 3: Sub-sector indicators in forests, biodiversity, and watershed management 13
Figure 4: A Process to compute aggregation of weighted indicators to vulnerability and risk indices 18
Figure 5: Trend of Forest Fire Incidence in Nepal 25
Figure 6: Status of precipitation in active fire season; b) Trends of total precipitation in active fire season. 25
Figure 7: Occurrence of invasive alien plants in Nepal. Each dot represents the geographic coordinates of the species 26
Figure 8: Observed/predicted climate change impacts on fauna 29
Figure 9: Maximum temperature increase per year from 1971–2014 31
Figure 10: Projected maximum temperature in the lowland protected areas 32
Figure 11: Projected maximum temperature in the protected area in the middle mountains 32
Figure 12: Projected maximum temperature in the high mountains protected area 33
Figure 13: Baseline extreme events composite index of forests, biodiversity, and watershed management 40
Figure 14: Climate extreme events scenario under RCP 4.5 for 2030 (left) and 2050 (right) 41
Figure 15: Climate extreme events scenario under RCP 8.5 for 2030 (left) and 2050 (right) 41
Figure 16: Exposure of Forests, Biodiversity, and Watershed Management across Districts 43
Figure 17: District-wise exposure of forests & biodiversity and watershed 44
Figure 18: Exposure of forests and biodiversity across districts 45
Figure 19: Exposure of watershed management across districts 46
Figure 20: Exposure across physiography region and province 47
Figure 21: District-wise sensitivity of forests, biodiversity, and watershed management 51
Figure 22: Districts-wise sensitivity of forests & biodiversity and watershed management 52
Figure 23: District-wise sensitivity of forests and biodiversity 52
Figure 24: District-wise sensitivity of watershed management 54
Figure 25: Sensitivity across physiographic regions and provinces 55
Figure 26: District-wise adaptive capacity of forests, biodiversity, and watershed management 59
Figure 27: District-wise adaptive capacity of forests & biodiversity and watershed management 60
Figure 28: District-wise adaptive capacity of forest & biodiversity 61
Figure 29: District-wise adaptive capacity for watershed management 62
Figure 30: Adaptative capacity across physiographic regions and provinces 63
Figure 31: District-wise vulnerability of forests, biodiversity, and watershed management 65
Figure 32: District-wise vulnerability of forests, biodiversity, and watershed management 66
Figure 33: District-wise vulnerability of forests and biodiversity 67
Figure 34: District-wise vulnerability of watershed management 68

Figure 35: Vulnerability at a) sub-basin level; and (b) watershed level 69
Figure 36: Vulnerability across physiographic regions 70
Figure 37: (a-g) Province-wise vulnerability rankings 74
Figure 38: Different risk ranks for the baseline period 76
Figure 39: Risk of climate change impacts in terms of (a) watersheds and (b) sub-basin 76
Figure 40: Risk scenarios under RCP 4.5 for 2030 (left) and 2050 (right) 79
Figure 41: Risk scenarios under RCP 8.5 for 2030 (left) and 2050 (right) 79
Figure 42: Baseline risk across physiographic regions 80
Figure 43: Physiographic region-wise risk scenarios for 2030 (left) & 2050 (right) under RCP 4.5 81
Figure 44: Physiographic region-wise risk scenarios for 2030 (left) & 2050 (right) under RCP 8.5 81
Figure 45: Physiography-by-province-level risk ranks 82
Figure 46: Physiography-by-province-wise risk ranks for 2030 (left) and 2050 (right) under RCP 4.5 83
Figure 47: Physiography-by-province-wise risk ranks for 2030 (left) and 2050 (right) under RCP 8.5 83
Figure 48: Classification of adaptation measures (adapted from Burton, 1996) 87

List of Annex

Annex 1: Key Terminology 112

Annex 2: Summary findings of provincial consultations on forests, biodiversity, and watershed management in Nepal 113

Annex 3: TWG and experts consulted for pair-wise ranking 119

Annex 4: List of indicators of exposure, sensitivity, and adaptive capacity 120

Annex 5: Vulnerability ranks: physiography by province 122

Annex 6: Index values of exposure, sensitivity, adaptive capacity, vulnerability, climate extreme events, and risks 123

Chapter 1

Background and Sectoral Context

This chapter provides a brief overview of Nepal's forests, biodiversity, and watershed resources, focusing particularly on the present state of all three resources and their contribution to environmental conservation, and social and economic development. This chapter also highlights some emerging challenges in the conservation of these resources in the face of climate change.

1.1 Introduction - Forests, Biodiversity, and Watershed Management in Nepal

1.1.1 Forests

Forests are one of the major land-use systems in Nepal, covering 45% of the total land of the country (DFRS, 2015). Forest goods and services are critical to rural livelihoods, including Indigenous Peoples (IPs) and local communities, and provide the basic inputs (nutrients, minerals, and water) to agriculture and livestock production systems. They have also become a backbone for local and community development activities (MoFSC, 2013; Bhandari et al., 2019).

The forest sector plays a critical role in the national economy (MoFSC, 2009, p.16). Nepal's community forests alone generate over twenty-one thousand full-time jobs every year for timber management (Poudel et al., 2017). In the fiscal year 2073/74 B.S. (FY 2016/2017) alone, 7.32 million cubic feet of timber and 81,587 chatta[1] of fuelwood were supplied from forests in Nepal with a collection of USD 3.81 million as revenue (DoF, 2017, p. 147). Similarly, a total of NRs 3.39 million of revenue was collected from non-timber forest products for the same year.

The forests also provide economic safety nets in times of disasters and crisis through the provision of numerous goods and services [fuelwood, timber, fodder, water, and Non-Timber Forest Products (NTFPs) like Medicinal and

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[1] In Nepal, fuelwood is measured in *chatta*. Its dimensions are 20×5×5ft (equivalent to 14.15 m^3) and weighs 10.47 ton on average.

Aromatic Plants (MAPs)] for people's livelihood and welfare (MoFSC, 2016; Pokharel et al., 2011)Nepal's protected areas and surrounding forest areas also serve as recreational spots and are credible tourist destinations for both international and domestic visitors, generating local employment opportunities and revenue. IN FY 2017/18, around USD 6.597 million of revenue was collected from visitors in Protected Areas (PAs) (DNPWC, 2018).

Nepal's forests, especially community-managed forests, have played a critical role in carbon sinks and GHG removal contributing to the global efforts of emission reduction and climate change mitigation. Nepal's forests have around 1,055 million tonnes (176.95 t/ha) of carbon stock in 2015 (DRFS, 2015). The results of some studies have demonstrated a positive change in the annual increment of carbon stock in Nepal's community forests (Poudel et al., 2017; Rana et al., 2016).

The present success in maintaining the current state of forests is due to the constant reform of several policies and institutional arrangements undertaken over the past four decades (Laudari et al., 2019). Over this period, the initial state-centric and top-down forest management approach gradually transformed into a participatory approach (Ghimire & Lamichhane, 2020). The Government of Nepal (GoN) nationalized the privately-owned forest resources in 1957 and continued to expand the government's role in forest protection and management until 1970. During this period, the focus was geared towards forest protection. Management rights fell under the government and local communities were restricted in their use of forest resources (Gautam et al., 2004). This approach failed to achieve expected conservation outcomes and the GoN introduced participatory forest management practices in the late 1970s to tackle the inherent vulnerability of the national forests to degradation (Gautam et al., 2004). This concept was later backed by the Master Plan for Forestry Sector (MPFS) developed in 1988 (MoFSC, 1988) which outlined strategies for participatory conservation and sustainable management of the degraded forest.

The Community-based Forest Management (CbFM) system came into practice with the promulgation of the legislative foundation of the Forest Act (1993) and associated regulation in 1995 under which almost 39% of the country's total forests are currently managed (DoF, 2018). Community Forestry (CF) is the dominant approach among the existing CbFM systems in Nepal, which on its own manages over 2.3 million ha of forests through 22,500 Community Forest User Groups (CFUGs). The other four regimes, including collaborative, religious, leasehold, and buffer zone management community forests, are also being implemented in Nepal (DoF, 2018; Ghimire & Lamichhane, 2020). Though not formally recognized, traditional forest and other natural resources management practices have also been adopted by IPs.

The CbFMs in Nepal seems to be a highly favoured approach for showcasing the social and economic gains that have been made by protecting the environment. This system has succeeded in restoring degraded forests and improving greenery while simultaneously enhancing the participation of women, IPs, Dalit, Madhesi, and other marginalized people in forest-related decision-making processes (MoFSC, 2013; Pokharel et al., 2007).

Nepal's abundant forests potentially offer nature-based solutions and green recovery post-COVID to deal with stresses and shocks, including climate change. Forests and management of natural resources create hundreds of thousands of jobs and ensure that air, water, and land resources are developed sustainably (Paudel et al., 2017). Sustainable management of forests reduces erosion and landslide risks whilst locking in carbon and protecting ecosystems that are under threat from invasive species (migrating ever upward as temperatures in mountain areas increase at twice the global average).

1.1.2 Biodiversity

Nepal occupies a unique position in the Himalayas harboring several ecosystems, species, and genus level diversities with as many as thirty-five vegetation types (Stainton, 1972) and 118 ecosystems including 112 forest ecosystems, four cultivation systems, one water body ecosystem, and one glacier/snow/rock ecosystem (BPP, 1995, a,b,c,d,e,f,g,h). Furthermore, in Nepal, 55 forest types have been put forward by combining information related to altitudinal gradients, climatic zones, humidity types, descriptions of plant life forms, and human impacts (Miehe et al., 2015). These ecosystems together represent different physiographic regions and serve as home to many fauna and flora species. The country comprises 13,067 plant species which include algae, fungi, lichens, bryophytes, pteridophytes, gymnosperms, and angiosperms (MoFE., 2018a) (Table 1).

Table 1: Plant and Faunal Species in Nepal

Plant Species	Number	Faunal Species	Number
Plant species	13067	Mammals	212
Algae	1001	Birds	886
Fungi	2016	Reptiles	78
Lichens	792	Amphibians	118
Bryophytes	1213	Insects	10204
Pteridophytes	580	Fish species	187
Gymnosperm	41		
Angiosperm	6973		

(Source: MoFE, 2018a, p.125)

Nepal's forest ecosystems along with protected areas, agricultural land, wetlands, rangelands, and mountain ecosystems form mosaic biomes and serve as critical habitats to different fauna as shown in Table 1. From the management perspective, Nepal's National Biodiversity Strategy and Action Plan (NBSAP) 2014-2020 has grouped the floral and faunal biodiversity into six broad biodiversity strategies namely protected area biodiversity, forest biodiversity outside the protected area, wetland biodiversity, rangeland biodiversity, agro-biodiversity, and mountain biodiversity.

The country is committed to conserving its ecosystems, species (both faunal and floral), and gene-level diversity as per the national need and in the spirit of the Convention on Biological Diversity (MoFSC, 2016). In 1973, the establishment of Chitwan National Park and the National Parks and Wildlife Conservation Act helped ensure spatial and legal protections for rare and endangered flagship and keystone wild animals.

The enactment of the Buffer Zone Policy in 1996 recognized the importance of participatory conservation, enabling the locals to become an integral part of wildlife conservation. Nepal currently has 20 PAs covering 23.39% of the country's total land along with 13 buffer zone areas (DNPWC, 2019; Chaudhary et al., 2020). Nepal also has 10 sites designated as wetlands of international importance: the Ramsar sites (MoFE, 2018a) and 37 important bird and biodiversity areas (DNPWC & BCN, 2018). Nepal's ex-situ conservation for both plants and animals is a strategy that complements its in-situ conservation initiatives like twelve botanical gardens for flora and zoological gardens for faunal (e.g. central zoo, elephant conservation breeding center, vulture conservation center, and crocodile conservation center) (Dhakal, 2018). Nepal's species-focused and localized conservation efforts have shifted to transboundary landscape-level conservation (Bhattarai et al., 2017). To facilitate this strategy, Nepal has established transboundary cooperation with India and China for the conservation of some critical landscapes and species while at the same time it is actively implementing multilateral agreements such as CITES and UNESCO.

1.1.3 Watershed Management

Nepal's watershed system is a sub-set of Nepal's forestry sector contributing to the regulation of the hydrological cycle, prevention and control of soil loss/erosion and flood and sedimentation, and reclamation of degraded sub-watersheds (Thapa & Joshi, 2018). Watershed resources, forests, and biodiversity are functionally interdependent ecological entities, and the conservation of one element may complement and create synergies with other elements (Thapa et al., 2018). Soil and water conservation—collectively known as watershed management was initially started in 1980 (Sthapit, 2008). The GoN adopted Integrated Watershed Management (IWM) as a key strategy to address the conservation concerns of soil and water and other watershed resources. IWM embodies a holistic approach in managing watershed resources that integrate forestry, agriculture, pasture, and water management thereby contributing to the livelihood and well-being of the watershed resource-dependent people (Pandit et al., 2007).

Nepal has initiated river basin and sub-basin approaches as a holistic initiative for building the resilience of natural and human systems. Such approaches were undertaken in the Gandaki and Koshi rivers with the development of integrated river management plans (MoFE, 2018a). Under the broader river-basin framework, sub-river-basin and sub-water conservation and management are the other forms of IWM. USAID, under the Hariyo Ban Program, prepared 10 integrated sub-watershed Management Plans of critical sub-watersheds of Chitwan-Annapurna Landscape Area (MoFE, 2018a). Similar initiatives are under operation in 30 critical sub-watersheds mostly in the Churia region.

Nepal's hill and mountain watersheds are characterized by very fragile ecosystems, limited agricultural capacity due to steep slopes, fragile mountain geology, and poor soil quality (Pandit et al., 2007). Adoption of several forms of IWM strategy has enabled the sustainable management of upland watershed resources thereby conserving downstream resources with the available local, innovative bioengineering techniques (Thapa & Joshi, 2018).

1.1.4 Challenges in Forests, Biodiversity, and Watershed Management

Despite the achievement, Nepal's forests, biodiversity, and watershed management sector are still facing widespread challenges arising from natural and anthropogenic factors (MoFE, 2018b). Overexploitation, illegal and unsustainable harvesting practices, encroachment, unplanned infrastructure development are some causes along with some other underlying causes like high forest dependency, limited alternatives for some forest products, unclear tenure security, increased demand of land for resettlement leading to the loss and degradation of forests and associated floral and faunal diversity (MoFSC, 2010). Besides, alteration of natural habitats, such as the conversion of forests, grasslands, and wetlands into agricultural or urban lands, invasion by alien species; and pollution of water bodies remain the predominant threats to the productivity of natural ecosystems (Karki, 2015).

Watershed and wetland resources in Nepal have experienced a gradual degradation due to several natural and inherent factors including fragile geology, extremities in topography, and high seismic activities. Anthropogenic factors include population pressure, unsustainable water harvesting, and improper land use and farming practices. All have contributed to soil erosion, landslides, flooding, sedimentation, and desertification which has led to a decline in biological productivity, springs and other water sources drying up, and a decrease in land productivity (Thapa & Joshi, 2018).

In addition to these, climate change is emerging as a serious threat to forests, biodiversity, and watershed resources, and the effects of climate change on these resources in Nepal are evident (MoE, 2010). These can be seen over the last few decades in the form of hydro-meteorological extreme events like droughts, storms, floods, landslides, debris flow, soil erosion, wildfires, and avalanches (MoFE, 2019b). Recent years have seen shifts in agro-ecological zones, prolonged dry spells, higher incidences of pests and diseases, depletion of wetlands, shifting treelines, changes in phenological cycles of tree species, and an increase in the risk of extinction of species (MoE, 2010). These impacts are likely to increase in the future posing a direct threat to not just forests, biodiversity, and watersheds but the local and indigenous communities who are dependent on them (Braatz et al., 2011).

Therefore, an understanding of climate change's impact on the forestry sector as well as its impact on IPs, women, and local communities is essential to develop strategies to address and mitigate the mounting threats.

Chapter 2

Objectives and Scope of the Study

2.1 Objectives and Rationale of the Study

The overall objective of this assessment was to assist Nepal's NAP process in assessing climate-related risks and vulnerabilities and identify practical adaptation options for forests, biodiversity, and watershed management. Specific objectives include:

- Assessing risks and vulnerability to climate impacts on forests, biodiversity, and watershed management across physiographic regions through applicable frameworks
- Ranking/categorizing associated climate risks and vulnerabilities
- Identifying practical adaptation options to these risks across three scales (i.e., district, provincial, and physiographic regions) to address priority climate risks and vulnerabilities.

2.2 Scope and Limitation of Study

- The assessment was conducted using available authentic data, facts, and evidence, and to explore the adaptation measures to address these risks and impacts.
- This assessment included two broad sub-sectors: forests and biodiversity and watershed management. The forests and biodiversity sub-sector constitute socio-economic, population, and enterprise-related dimensions.
- The study integrates gender, social inclusion, and livelihood perspectives (FAO, 2018a). The vulnerability and risk are assessed at three levels: district, provincial, and physiographic regions. The district is the primary unit of analysis for this assessment. District-level results were later clustered into provincial and physiographic regions level analysis.
- The assessment provides results in the form of thematic maps and numeric values where is possible.

- The assessment has used information from case studies and local interactions during the VRA provincial workshops that were complimentary for some climate change impacts including tree phenology and vegetation shifts.
- The report further provides the observed impacts of climate change on forests, biodiversity, and watershed management. Impacts synthesized from peer-reviewed articles, government reports, and grey literature were verified and consolidated with the perception and observation of local communities and relevant experts and stakeholders (local perceptions are presented in boxes in the relevant sections and Annex 2).
- The report outlines a set of broader levels of short, medium (2016–45), and long-term (2036–65) practical and relevant adaptation options in line with the assessment results, observed and anticipatory impacts associated with climate change, and socio-economic scenarios for two consecutive periods: 2016–45 and 2036–65. The assessment has developed baseline information to reassess the risks and vulnerability which may be undertaken every five years (as suggested by the LEG expert group).
- Lack of district-wise disaggregate data of some indicators including the participation of IPs and Dalits of all 77 districts was one of the major limitations.

This assessment has adopted a consultative, transparent, inclusive, and iterative approach throughout the process. The subsequent sections present the framework, approaches, and methodologies adopted in the assessment.

Chapter 3

Framework, Approach, and Methodology

3.1 Defining assessment framework

This assessment undertook an extensive literature review as part of revisiting and refining the VRA framework. The literature review was primarily conducted to get overall insights into the VRA process and its key elements in the context of National NAP formulation. The major reviewed literature and documents include the IPCC–AR5, VRA technical guidelines developed by LEG, Cancun Adaptation Framework, GIZ–developed vulnerability sourcebook, FAO–Vulnerability Assessment Framework, NAP of other countries, and adaptation-related UNFCCC decisions. Nepal-specific major documents include a NAP approach paper, VRA framework, and indicators for NAP formulation, synthesis of the stocktaking of NAP, NAP's lesson learned document, NAPA (2010), and revised LAPA framework (2019). The other documents reviewed were the 15th periodic plan, National Climate Change Policy (2019), National Forest Policy (2019), Forestry Sector Strategy (2016–25), Environment Protection Act (2019) and Regulation (2020), National REDD+ strategy (2018), the Second Nationally Determined Contribution-NDC (2020), and the 6th CBD report (2018). Similarly, a review was undertaken of climate change-related reports produced by DHM, MoFE, development partners and ICIMOD, and other strategies and plans.

The overall assessment process was guided by the broader VRA framework as shown in Figure 1. This framework was developed by the GoN in 2017 and illustrates the logical linkages between hazard, exposure, vulnerability, and risk leading to adaptation planning (MoPE, 2017). The framework considers both impact and indicator-based vulnerability and risk assessment, whereby indicators of three attributes: exposures, sensitivity, and adaptive capacity, and the hazard context of this theme are the foundation of the assessment. This framework is underpinned by key elements indicated by the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC–AR 5). The working definitions of related terminologies associated with this assessment are given in Annex 1.

The IPCC–AR5 framework considers risk as a function of hazard, exposure, and vulnerability (Sharma & Ravindranath, 2019). Likewise, the framework recognizes vulnerability as the "presence of a vulnerable system at a location that could be adversely affected" i.e., vulnerability is the difference between sensitivity and adaptive capacity. This framework assumes vulnerability as an inherent characteristic and pre-existing state of people, species or ecosystems, services and resources, infrastructure, economic and social assets in place and settings, and are influenced by biophysical and socio-economic pathways and governance systems.

In line with IPCC-AR 5 framework, the proposed framework for the VRA assessment (Figure 1) also contemplates that climate-related risks result from the interaction of climate-related hazards (including hazardous events and trends) along with the exposure and vulnerability of human and natural systems. In other words, climate change risks manifest as adverse impacts when a vulnerable system is exposed to hazards. The framework describes hazards are the consequences of changes in the climate system (trends and scenarios), while vulnerability i.e., sensitivity and adaptive capacity is the result of interactions of the complex set of drivers related to the biophysical system, socio-economic processes including governance and adaptation, and mitigation actions (Figure 1). As reflected in IPCC-AR5, this assessment framework considers "exposure" as spatial connotation, which represents the presence of a vulnerable system at a location where harm is experienced if a hazard occurs.

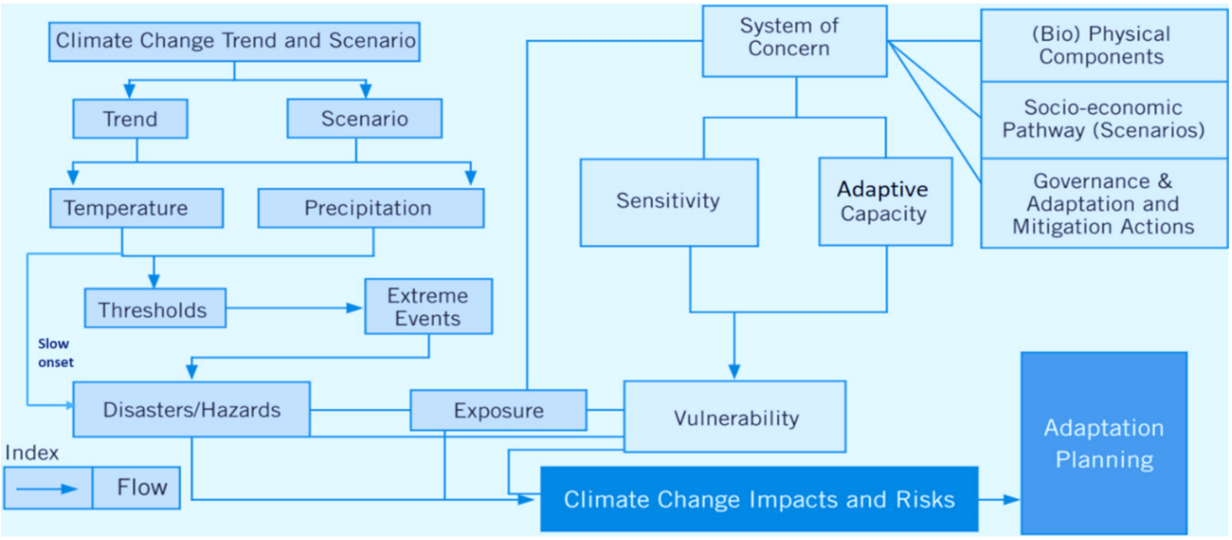

Figure 1: Climate change vulnerability and risk assessment framework (MoPE, 2017)

The assessment framework includes impacts that have already occurred and the risk of future climate impacts. Such risks are anticipated to be changed with climate change and with investments in adaptive infrastructure, ecosystems, and human settlements. Hence a central focus of the assessment depends on characterizing vulnerability, hazards, and exposure for both past impact and future risk.

3.2 Methodology

The assessment was carried out in a sequence following the VRA assessment framework discussed above. Several rounds of consultations with TWG members and the technical committee were undertaken throughout the assessment process. The simplified methodological framework prepared for the VRA process for forests, biodiversity, and watershed management sector is presented in Figure 2. As shown in the figure, scoping of vulnerability and risk, and revisiting and refining the VRA framework were two initial steps undertaken in the assessment.

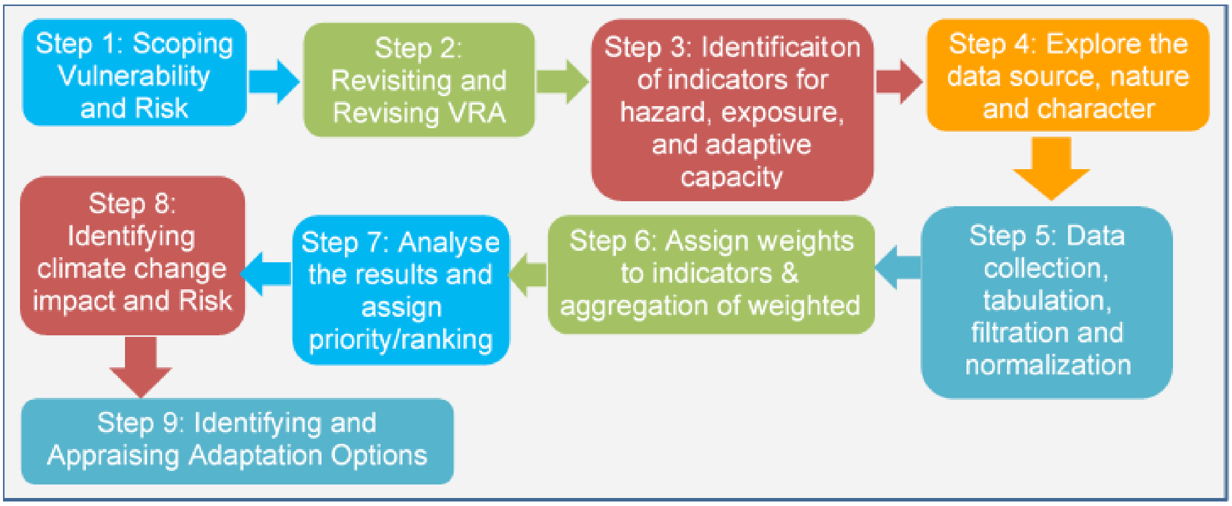

Figure 2: Steps of Vulnerability and Risk Assessment (MoPE, 2017)

As indicated in Figure 2, the third step was the entry point of the assessment whereby relevant indicators of exposure, sensitivity, and adaptive capacity concerning the forests, biodiversity, and watershed management were identified through an extensive literature review. These indicators were organized into two broad sub-sectors: forests and biodiversity, and watershed management. To characterize the exposure, sensitivity, and adaptive capacity-related indicators, the assessment used both biophysical (intrinsic) attributes and socio-economic and governance dimensions, especially management aspects (Sharma et al., 2018). The scientific facts, evidence, and data of these elements for the two sub-sectors were collected as the input of the vulnerability and risk assessment from several types of documents available from various sources.

The indicators were selected through discussion and in consultation with TWG members, technical committee members, and expert groups. Firstly, the relevant indicators were identified from the desk-based review mostly looking at impacts of climate change in the sector, which was shared with the TWG members and experts for their inputs, comments, and suggestions. Indicators were revised and refined with the inputs from TWGs and experts (Annex 3).

As indicated by the IPCC working group II report (IPCC, 2014, p.5), this assessment considers both biophysical and forests related socio-economic elements as the indicators. General consideration of indicator selection is given in Box 1.

Box 1: Key consideration adopted in selection of indicators

- Exposure: resources, assets and people at risk
- Biophysical dimensions: distribution size
- Social and economic dimensions: demography, enterprises
- Sensitivity: system susceptible to climate change
- Biophysical attributes: change, trend, land use condition (degraded, sparse, regenerated)
- Intrinsic characters: forest types, slope, landslide, and flood intensity
- Disturbance regimes: forest fires, invasive alien plants
- Socio-economic dimensions: dependency level
- Adaptive capacity: the ability of systems, institutions, and practices to adjust to potential damage of climate change
- Technological dimensions: conservation approach
- Institutional & governance dimensions: policies, strategies, participatory & inclusive decision-making process
- Management factors: rehabilitation and plantation activities, fund mobilization.

Indicators for exposure are considered as the distribution of forests, species or ecosystems, watershed resources, infrastructure, economic and social assets at the place, and settings that could be adversely affected by climate change. Some exposure indicators are forest area, NTFP plantation area; protected areas; ecosystem types (wetlands, rangelands, agricultural land, glaciers, watersheds); the households/population involved in forest management; enterprises; and forest-related physical infrastructure.

Sensitivity indicators constitute inherent attributes and characteristics of the forests, biodiversity, and watershed resources that make them susceptible to adverse effects of climate change (IPCC, 2014). Distribution of different forest types, the trend of change in forests, wetlands, and other ecosystems, the status of forest area—degradation, density, sparsity, frequency and intensity of disturbance regimes such as forest fires, invasive alien plants, the presence and incidence of pest, disease, and fungus, watershed fragility status, and percentage of forest-dependent people—are some of the indicators assigned to the sensitivity (FAO & CIFOR, 2019, p.48; Fisher et al., 2010; Seidl et al., 2010).

Indicators for adaptive capacity include the presence of systems and practices that support the adaptation of forests, biodiversity, and watershed resources with the adverse condition of climate change. Some indicators for adaptive capacity are forest rehabilitation practices, sustainable forest management, annual tree plantations (including NTFP species), conservation ponds, sub-watershed management plans, and human resource training. Further indicators include the involvement of women, Dalits, and IPs in the aforementioned practices, the percentage of households that have adopted the building code, the number of women-owned forest-based enterprises, and the provision of subsidies for forest-related enterprises. The description of sub-sector indicators for exposure, sensitivity, and adaptive capacity is given in Annex 3.

Altogether 75 indicators were selected for the two broad sub-sectors (Figure 3). Thirty-seven indicators belong to sensitivity, while adaptive capacity and exposure constitute 21 and 17 indicators, respectively. The forests & biodiversity sub-sector comprises a higher number of indicators (62) for three elements while 13 indicators belong to watershed management.

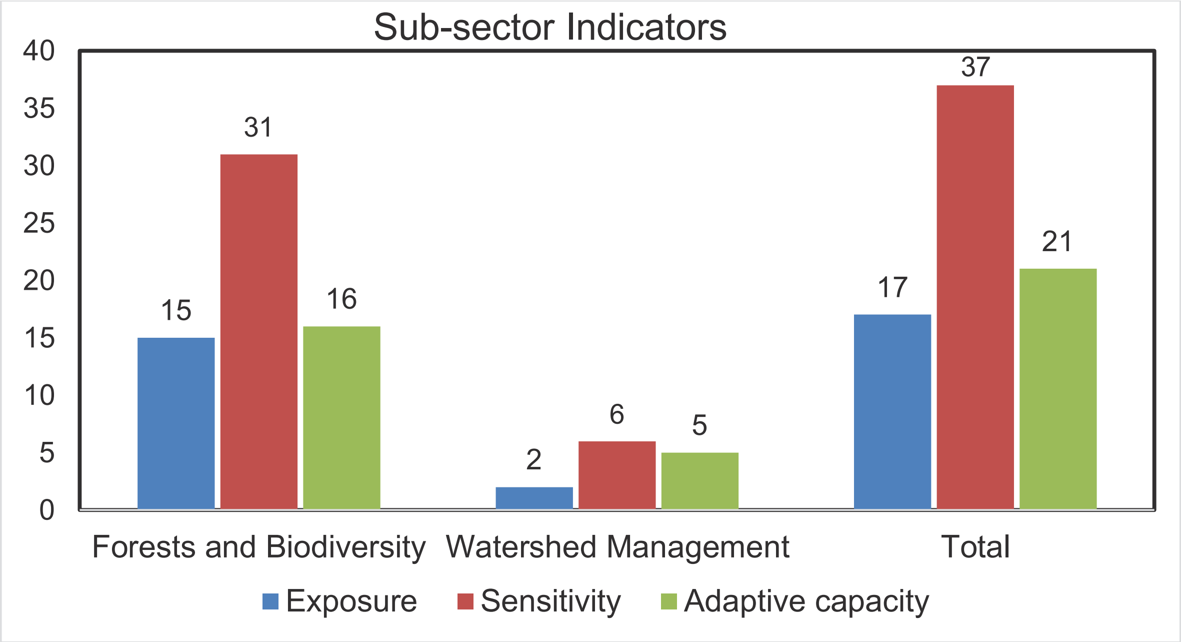

Figure 3: Sub-sector indicators in forests, biodiversity, and watershed management

Most of the data related to the indicators were collected from the progress reports (periodic, annual, and progress reports), study reports, policy briefs, policies, strategies, and plans (Table 2). Similarly, some data were collected from peer-reviewed articles and grey literature. The major sources of the data were the government and development organizations, civil society organizations (CSOs), the private sector, and individual experts and researchers. The government organizations were MoFE and its departments—DNPWC, DoFSC, FRTC, DoE, DPR, and REDD IC—and provincial forest directorate and division forest offices. The other government organizations were DoI, NPC, and CBS. The development organizations for data included UNEP, UNDP, ICIMOD, WWF, IUCN, NTNC, and Practical Action. Similarly, CSOs were FECOFUN, NEFIN, HIMAWANTI, and AFFON from where data such as the involvement of women in forest management and an update of CBFM groups were collected.

Table 2: Data types and sources

Data source	Name of organizations	Data collection documents (Source types)
Government organizations	MoFE, FRTC, DoFSC, DPR, DNPWC, REDD IC, NPC, CBS, NPC DoE, MoI, Provincial MoITFE, DFO, Local government, NAST	Reports (Periodic, annual, and progress report), study reports, Policy brief, Policy, strategy, peer review articles, grey literature
Development organizations	ICIMOD, WWF, NTNC, IUCN, UNDP, UNEP, FAO, CIFOR, RECOFTC, Practical Action	
Civil society organizations/ network	FECOFUN, NEFIN, HIMAWANTI, AFON	
Private sector	FenFIT, FNCCI	
Interview and consultation with experts and researchers	NTNC, CARE Nepal, UNEP-EbA, Central Department of Botany, Tribhuvan University.	Consultation, interaction (Data collection and verification)

3.3 Data Normalization, Weightage, and Analysis

The assessment has used cardinal data for most of the indicators. However, ordinal (categorical of at least five-point Likert scales) data were used only for a few indicators. Both categories of data were tabulated and filtered. The tabulated data were then normalized to transfer the value of different data set into unitless values on a common scale to develop aggregation of indicators.

The normalization of data was undertaken by using the min-max method. This method transforms the values between 0 and 1 by subtracting the minimum score and dividing it by the range of indicator values as shown in equation (I).

$$x_{norm\_i} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \qquad \text{..(I)}$$

Where;

x_i is data value to be transferred

x_{min} is the lowest value of this indicator,

x_{max} is the highest value and

x_{norm_i} is the normalized value.

Categorical datasets were normalized by adopting the five-class system, whereby the most positive condition having the lowest value and the most negative condition with the highest value as indicated by the vulnerability sourcebook (GIZ, 2017). The data was also then transformed from 0 to 1 by obtaining the class value range by dividing the class value by the maximum class value and get the mean of the range.

Every normalized data was given weightage by using a pair-wise comparison (Uribe et al., 2014) as indicated in the Analytical Hierarchy Process (AHP) model to prioritize the related decision indicators. For these scores of importance/priorities were given to 9 scales (Saaty Scale) (Saaty, 1984) as given in Table 3 and Figure 5. For this, a set of questionnaires was designed (Figure 5) and administered to 28 respondents including 17 members of TWG, expert representatives from the governments, I/NGOs, and civil society organizations for their judgment. A total of 22 responses were received. The respondents were requested to respond to each possible pair of criteria and rate one relative to the other on a scale from "equal importance" to "extremely important".

Table 3: Scores for the importance of variables (Saaty Scale)

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

The individual judgments were converted into group judgments (for each one of the paired comparisons) using their geometrical average. A comparison of all possible pairs resulted in a so-called ratio-matrix. The numerical weights were then determined by normalizing the eigenvector associated with the maximum eigenvalue of the ratio matrix.

The aggregated value of each indicator of exposure, sensitivity, and adaptive capacity was calculated by using the weighted linear summation method which is a linear combination of standardized values using weights as shown in equation II.

$$AC = \frac{\sum_{i=1}^{n} w_i \, x_i}{\sum_{i=1}^{n} w_i} \qquad \text{..............................(ii)}$$

Where;
AC is an aggregated indicator e.g., aggregated adaptive capacity,
x*i* is an individual indicatory of the adaptive capacity of a vulnerability component, and
w_i is the weight assigned to the corresponding indicator x_i. The most preferred alternative is that with the minimum value of AC.

Indicator-wise weightage for exposure, sensitivity, and adaptive capacity is given in Tables 4, 5, and 6 respectively. Aggregate weightage for exposure was calculated for 17 indicators.

Table 4: Weightage for exposure indicators

Sub-sectors	Exposure Indicators	Weightage
Forests and Biodiversity	Forest area	0.1575
	Areas under plantations	0.1251
	Area under NTFPs	0.1304
	Protected area	0.1391
	Wetland	0.0886
	Rangeland	0.0830
	Agro-ecosystem	0.0769
	Snow cover	0.0688
	Glacier area	0.0653
	Glacial lake area	0.0653
	Household involved in forest and biodiversity conservation	0.3333
	Forest-related Buildings	0.1114
	Others (View towers, machan, etc.)	0.0968
	Fire lines and forest roads exposed to hazards	0.1252
	Forest-based enterprises (infrastructure, operation)	0.3333
Watershed Management	Watersheds	0.5277
	Areas of exposed other water bodies (pond, rivers, lakes)	0.4723

Table 5: Weightage of sensitivity indicators

Sub-sectors	Sensitivity	**Weightage**
Forests and biodiversity	Forest types- *Abies spectabilis* and *Abies pindrow*	0.0141
	Betula utilis	0.0164
	Picea, *Tsuga dumosa*, Cedrus and *Cupressus torulosa*	0.0132
	Quercus Species	0.0128
	Pine forests	0.0123
	Upper mixed hardwood	0.0135
	Khair *(Senegalia catechu)*, Sisoo, and Okhar *(Juglans walichiana)*	0.0135
	Lower mixed hardwood	0.0104
	Tropical mixed hardwood and Sal	0.0146
	Change in forests (%)	0.0219
	Regenerated area	0.0207
	Degraded forest area	0.0202
	Semi-degraded area	0.0191
	Sparse forest area	0.0390
	Forest susceptible to diseases	0.0381
	Forest susceptible to Fungus	0.0367
	Forest susceptible to Insect/pest	0.0369
	Number of Invasive Alien Plan Species observed	0.0578
	The fragility of forest landscape- mean slope degree	0.0366
	Forest fire-prone area	0.0381
	Change in wetland	0.0707
	Change in rangeland	0.0671
	Change in agro-ecosystems	0.0639
	Change in snow- glacial area	0.0615
	Encroachment status	0.0869
	Occurrence forest fire incidences	0.0843
	Fragmentation-average forest patch size	0.0797
	Percentage of forest-dependent households	0.3333
	Fire lines and forest roads- prone to landslides and floods damage	0.1661
	Forest related buildings prone (proximity) to floods and landslide	0.1672
	No. of HHs directly engaged in the forest-based enterprises	0.3333
Watersheds Management	Proximity to landslide-prone area	0.1815
	Susceptibility to Landslide damage	0.1815
	Susceptibility to erosion	0.1686
	Susceptibility to flood damage	0.1716
	Level of sedimentation yield	0.1479
	Drainage density	0.1489

Table 6: Weightage of adaptive capacity indicators

Sub-sectors	Adaptive Capacity	Weightage
Forests and Biodiversity	Distribution of dense forest area	0.1620
	Status of income/employment in Protected areas and Community-based Forest Groups	0.1620
	Area of land under 'landscape level' conservation	0.1409
	Existence of Forest rehabilitation plan	0.1346
	% of forest area under sustainable/scientific forest management	0.1160
	No. of human resources in place (government-deployed human resource)	0.0608
	No. of seedling produced annually	0.1094
	No. of NTFP seedlings produced and planted	0.0707
	No. of plant species developed seed orchard	0.0436
	No. of HHs involved in women managed forest groups	0.0678
	Percentage of women-managed community forest user groups	0.1231
	Percentage of women's representation in forest groups' executive committee	0.1425
	Percentage of building compliance to safer buildings code	0.3333
	No. of enterprises use wood seasoning technologies	0.0307
	No. of forest-based enterprises receiving Insurance, subsidies including concessional loan	0.2914
	Percentage of women owning forest-based enterprises	0.0113
Watershed Management	Development and implementation of Sub-watershed plan	0.1972
	Wetland conservation and management plan in place	0.1847
	Management of conservation pond	0.3561
	Adoption of Bio-engineering as conservation technology	0.1356
	The practice of riverbank protection	0.1263

3.4 Calculation of the Vulnerability and Risk Index

The vulnerability of each sub-sector and aggregate of both sub-sectors was analysed with the aggregated value of sensitivity and adaptive capacity as shown in equation III and Figure 4 as defined by IPCC-AR5 (IPCC, 2014). According to IPCC-AR5, vulnerability is a function of sensitivity and adaptive Capacity. Figure 6 illustrates a typical process and analysis of the chain of vulnerability and risk with the indicator-wise data of sensitivity, adaptive capacity, and exposures.

$V = SE\text{-}AC$ ....(III)

Where;
V is the composite vulnerability indicator,
SE is the vulnerability component of sensitivity and
AC is the vulnerability component of adaptive capacity.

Similarly, sub-sector-wise and cumulative risk of the forests and biodiversity, and watershed management was estimated as a function of Hazard Intensity, Exposure, and Vulnerability as shown in (IV).

$R=H_{intensity}\times V\times E$ .... (IV)

Where;
R is the risk index
$H_{intensity}$ is the hazard intensity,
V is the vulnerability and
E is exposure

The final risk was rescaled by dividing the outcome values by the maximum risk values of all administrative units as in equation (V).
$scale=R/\max(R),\ R\in\{adminunits\}$ .... (V)

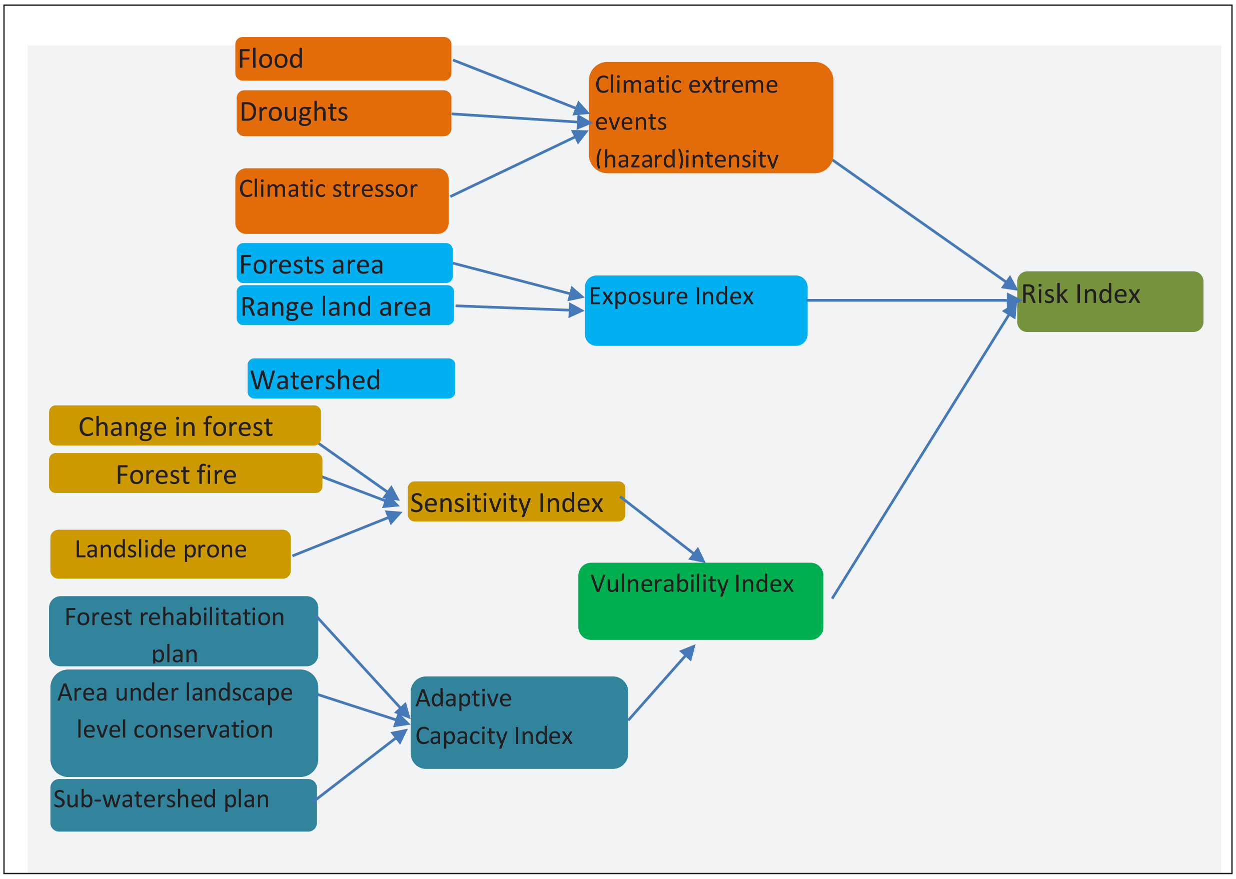

Figure 4: A Process to compute aggregation of weighted indicators to vulnerability and risk indices

3.5 Prioritizing and ranking vulnerability and risk

The calculated sub-sector and sector-wise aggregate vulnerability and risk indexes across the districts, provinces, and physiographic regions were ranked into five classes: (a) Very low (b) Low, (c) Moderate, (d) High, and (e) Very high. Each index was converted into 0–1 values and the values were then assigned to a class according to Jenks natural breaks method. The result of these risks and vulnerabilities is presented in the form of thematic maps. The rankings will enable decision-makers to prioritise relevant adaptation strategies and investments at a national, provincial, and local level, facilitate in the formation of a climate finance strategy and allow Nepal to meet the requirements of Article 9 of the Paris Agreement.

3.6 Error minimization

To minimize spatial and non-spatial errors, which inevitably occur during spatial analysis and data collection, data cleaning, uniformity, standardization, normalization, prioritization, and aggregation were carried out throughout the analysis process.

3.7 Identification of adaptation options

Adaptation strategies were identified based on risk and vulnerability assessments, costs of implementation, and efficacy and benefit (LEG, 2012). The most appropriate and relevant strategies were identified through a set of criteria in line with national goals and targets for sustainable development as well as national policy, sectoral policy, and national development goals relevant to climate change.

The process, broken down into steps, is as follows:

- Identifying potential adaptation options based on the impacts, vulnerability, and risk maps and tables generated by the analysis of secondary data
- Identifying the potential list of adaptation options based on literature review particularly those successful adaptation practices, effective local knowledge and practices, efficient technologies, and practices
- Consultation with relevant experts to map effective adaptation strategies in the sector and sub-sector
- Consultation at the provincial level to identify adaptation options in the context of the existing risk and vulnerability
- Validation of adaptation options in Thematic Working Groups (TWGs) and Technical Committee

While this assessment provides a long list of broader levels of relevant adaptation options, the NAP project will prioritize the adaptation options considering the site-specific (e.g. district, local government, and community level) needs and circumstances.

Chapter 3

Observed Climate Change Impacts on Forests, Biodiversity, and Watershed Management

Nepal has experienced noticeable impacts of climate change on forest ecosystems, biodiversity, and watershed resources. The following sections highlight some of the major impacts observed in forests, biodiversity, and watershed resources.

4.1 Observed impacts on forests

4.1.1 Species and vegetation range shift

The effects of climate change have been observed on vegetation and species range in Nepal. Summary findings of available studies presented in Table 7 indicate that climate change will encourage the maximum altitude of the treeline to increase, shrinking the size of the alpine ecoregion. Widespread conifer species including *Abies spectabilis, Betula utilis,* and *Pinus wallichiana* have been recorded spreading upslope movement in almost all regions across the Nepal Himalayas (Bhuju et al., 2016; Gaire et al., 2017). The estimated annual rate of these shifts varied by species and the regions (e.g. annual shifts of *A. spectabilis* were 2.61 m in Manaslu area, 0.93 m in Sagarmatha, 2.4 m in Kanchenjunga, Rara, and Api-Nampa-Darchula, and annual shift of *Betual utilis* was 0.42 m in Sagarmatha National Park) (Table 7) may be due to latitudinal difference and landscape context. However, these observations have confirmed the positive association between the occurrence of upward movement of some high mountain tree species and the increase in temperature and change in precipitation patterns.

The range shift has also been recorded in vegetation or tree communities' levels in some high-altitude locations. Such movements were mostly reported to have resulted from the change in regeneration pattern and standing density with the change in length of growing seasons of individual tree species in the localities (Gaire et al., 2014; Shrestha et al., 2012). Vegetation and species range shift also appeared in the Siwalik region. Over here, a gradual expansion of C4 plants[2] from 8.5 Ma and culminating 5.2 Ma was observed (Neupane et al., 2019). These consequences suggest that Nepal's vegetation of all regions will likely suffer from future climate dynamics.

Table 7: Summary of key findings from species and vegetation shift-related studies within and beyond Nepal

Reference	Biological organization *(Species or population/ community)*	Focal species and study areas	Key findings
Song et al. (2004)	Species	*Abies spectabilis, Picea likiangensis, Pinus densata, Larix griffithiana, Quercus aquifolioides, Betula utilis (Tibetan plateau)*	Range of *A. spectabilis, P. likiangensis, Pinus densata, L. Griffithiana, and Q. aquifolioides* projected to extend northwards and westwards under the future climate scenarios. *B. utilis* range projected to shift northwards and shrink in overall distribution under future climate scenarios. A significant difference in 7 alpine species distributions under current climate conditions versus future scenarios.
Gaire et al. (2011)	Species	*Himalayan fir (Abies spectabilis)* – Langtang National Park	High *A. spectabilis* recruitment rates in recent decades in Langtang Area. Lower average age along as altitude increases. Growth rate exhibits a negative response to temperature (particularly March-May season). Treeline is predicted to extend northwards due to future climate change.
Shrestha et al. (2012)	Population	*Vegetation systems* (Nepal – eastern and western Himalayas)	Early average onset of the growing season and increased length of growing season observed in the Himalayas. Late end of growing season observed in Western Himalayas, with mixed patterns in central and eastern Himalayas (overall longer growing season in the western region).
Shakya et al. (2013)	Species	*Abies spectabilis* (Manaslu Conservation Area, Gorkha)	Between 1990 and 2012, *A. spectabilis* shifted upslope at a rate of 10.8 m annually (shifting of 110 m with 1911 tree line reference). The recruitment of *A. spectabilis* was positively correlated with mean annual temperature ($r = 0.35$, $P = 0.04$) and negatively correlated with mean annual precipitation ($r = -0.36$, $P<0.5$).
Gaire et al. (2014)	Species	*Abies spectabilis* (Manaslu Conservation Area, Gorkha)	*A. spectabilis* contained an overwhelmingly high population (89%) of young plants (<50 years) indicating its high recruitment rate. Population age structure along the elevation gradient revealed an upward shifting of *A. spectabilis* at the rate of 2.61 m year-1 since 1850 AD. The regeneration of A. spectabilis was positively correlated with August precipitation and monthly temperature . The growing and regeneration were more sensitive to the maximum and minimum temperature rather than the average temperature.

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[2] C4 plants are plants which cycle carbon dioxide to 4-carbon sugar compounds to enter the C3 or the Calvin cycle. The C4 plants are very productive in climatic conditions that are hot and dry and produce a lot of energy. Some of the plants that we usually consume are C4 plants such as pineapple, corn, sugar cane, etc (Wang et al., 2012).

Reference	Biological organization *(Species or population/ community)*	Focal species and study areas	Key findings
Thapa et al. (2016)	Community/ Vegetation	*Forest/Vegetation systems* (Terai Arc Landscape, and Chitwan-Annapurna Landscape)	Lower- and mid-montane forests show higher vulnerability than upper montane and subalpine forests (providing microrefugia); Subalpine scrub vegetation projected to shift range northwards; Lower & mid-montane forests are predicted to become smaller patches of microrefugia and may provide important "climate corridors" for species forced to shift northwards.
Bhuju et al. (2016)	Species	*Abies spectabilis* (Kanchenjunga area, Rara (west), and Api-Nampa (Far-west)	A. spectabilis is shifting upward by 2.4 m annually. The tree-line position decreased from east to west Nepal. The tree-line species composition was almost similar, having *A. spectabilis* and *B. utilis* in all three study sites.
Dhakal et al. (2016)	Species	*Abies spectabilis and Pinus wallichiana* (Annapurna conservation area and the Shey-Phoksundo National Park area)	The spatiotemporal population age structure of *A. spectabilis, B. utilis, Juniperus recurva, Rhododendron campanulatum, and Sorbus microphylla* showed both stand densification and upward shifting of the treeline in many sites. However, the upward shifts of *P. wallichiana* and *A. spectabilis* were more prominent in some sites. The growth of the treeline forming species was limited by moisture and/or temperature, depending upon the site conditions and moisture regime.
Gaire et al. (2017)	Species	*Abies spectabilis, Betula utilis* (Sagarmatha National Park)	An annual upslope shift of *A. spectabilis B. utilis* was estimated 0.93 m by 0.42 m respectively. Warm temperatures during summer growing seasons combined with sufficient moisture favored the growth of *A. spectabilis.* The regeneration of *A. spectabilis* was favored by high temperatures throughout the year with sufficient moisture The climatic response of the regeneration of *B. utilis* was spatiotemporally different and variables.
Chen et al. (2011)	Community	*Species (Latitudinal* – Europe, North America, and Chile), and Elevational (Europe, North America, Malaysia, and Marion Island)	Velocity species range shifts as 11.0 meters per decade towards higher elevations and 16.9 kilometers per decade towards higher latitudes. These rates are approximately two and three times faster than previously reported. The distances moved by species are greatest in studies showing the highest levels of warming, with average latitudinal shifts being generally sufficient to track temperature changes.
Neupane et al. (2019)	Species/ Community	C4 vegetation (grasses, crops- maize, sugar cane, etc.), Nepal, Siwalik region (Surai Khola).	A gradual expansion of C4 vegetation from 8.5 Ma and culminating at 5.2 Ma. The dramatic ecological shift at the Miocene-Pliocene boundary was linked with intriguing tectonic-climate coupling the Himalaya -Tibetan region that prompted wetter summer and drier winters.

These findings are consistent with the perceptions and observations of local communities and stakeholders (Box 2). This shift in vegetation due to global warming, combined with unpredictable precipitation, could lead to noble climatic eco-regions leading to loss of the species (Zomer et al., 2014). Such a phenomenon becomes critical particularly to already vulnerable and endangered plant species having a narrow climatic range due to the limited ecological range and geographic opportunities (Xu et al., 2009).

Box 2: Upward movement of vegetation leads to the loss of forest types—observations from local communities

During the provincial sharing workshops, participants of Province 1, and Lumbini, Bagmati, and Karnali Province shared their observations about the upward movement of vegetation and tree species like Painyu (*Prunus cerasoids*) and Himalayan Fir (*Abies spectabilis*). According to them, lower tree and crop species are appearing in the upper belt rather than their usual altitude. Similarly, some high-altitude forests and tree species are slowly moving further north. If this continues, we are likely to see a decline in the regenerative capacity and productivity of forests, ultimately losing them.

4.1.2 Phenological change

Rising temperature and variability in precipitation affect phenological cycles such as the flowering, fruiting, and leaf shedding behaviour of plant and tree species. In the Kavreplanchok district, the *Rhododendron arboreum, Myrica esculenta* (kafal), and *Alnus nepalensis* have started flowering early, 15–30 days earlier than they normally would (Panta & Mandal, 2019). Box 3 shares the observations of locals from Bagmati Province and Province 1 about the now altered flowering schedule of rhododendrons.

Box 3: Early flowering of Rhododendron—Phenological change in the eastern mountain region

Early or late flowering and fruiting has been observed in mostly mid-hills and high mountain tree species. A participant from Province 1 shared her experiences: Rhododendron (*Rhododendron arboreum*) (in Nepali, "laligurans") is a beloved flowering tree with a special place in the hearts of Nepalis people, especially rural folks like me. The rhododendron forests are extensive and magnificent, making their way running through our village and throughout the mid-hill region of the country. During my childhood, rhododendron flowers would bloom between March and April and blanked hills with great beauty. In recent years, the Rhododendron has started blooming early. Many people used to tell that this happens because of "Jalbayu paribartan (climate change)". I'm now coming to understand that this is happening because of the increase in temperature and change in rainfall.

Phenological change can be a part of the autonomous response of tree species to climate change. However, the persistent occurrence of such a phenomenon can reduce seed viability and lead to the disappearance of species with a limited capacity to adapt to adverse conditions. The alteration of the growth (imbalance root-shoot growth) and change in the composition of plant species due to climate change may reduce productivity thereby posing a huge threat to the people who depend on them for their livelihood (MoE, 2010; MoFSC, 2016).

4.1.3 Forest fire incidences

Forest fires in Nepal now pose a serious risk to forest degradation. The rising incidences of forest fires in the lowland forests of Terai and Siwalik can be attributed to climate change (Bhujel et al., 2020; Rimal et al., 2015). It is generally observed that climate variability, including droughts and heatwaves, increases both the intensity and frequency of forest fires by causing vegetation to dry out (Keeley & Syphard, 2016). In a study undertaken between 2000 and 2017, Bhujel et al. (2018) recorded a gradual increase in forest fire incidences (Figure 5). The increase coincided with a change in precipitation patterns and rising temperature (Bhujel et al., 2018). This finding in Nepal (Bhujel et al., 2018, 2020; Khanal, 2015) and beyond (e.g. Chen et al., 2014; Withana & Auch, 2014) establishes a correlation between rising temperatures and increasing instances of damaged (forest) land, which would heighten the risk of forest fires incidences in Nepal.

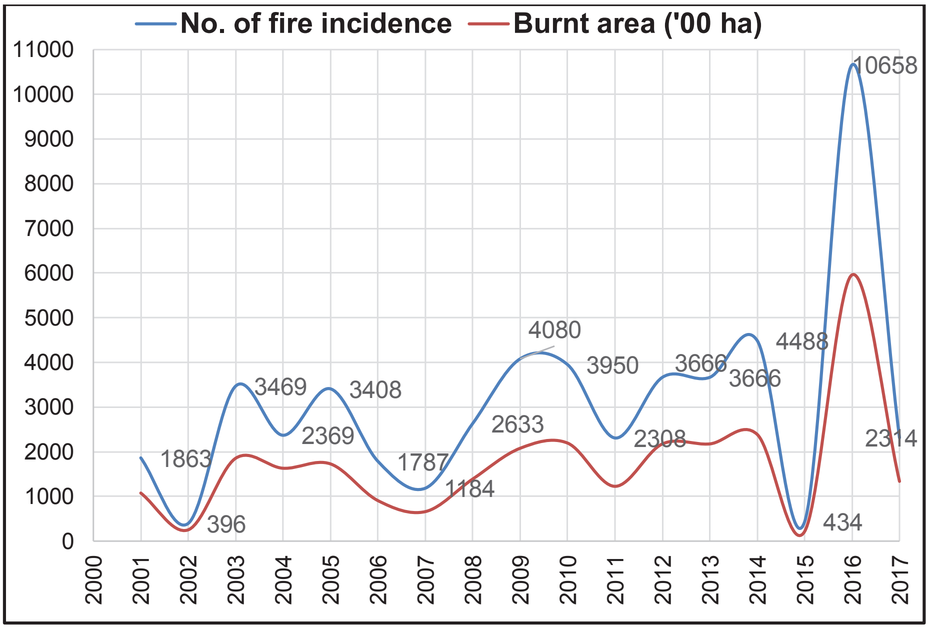


Figure 5: Trend of Forest Fire Incidence in Nepal

The experiences of the local communities match the results of Bhujel et al. (2018) report, noting an increase in forest fires due to "(an) extended drought period arising from the rising temperatures, heatwaves, and very warm days and nights. The major concerns we have are the loss of biodiversity for both plants and wild animals; the loss of non-timber forest products, and the burning of dried materials which we use as fuelwood. Forest fires don't just impact the forest, it affects our homes and livelihoods."

Other studies also show a strong correlation between precipitation and forest fires. Due to the prolonged drought in 2009, fire incidences increased significantly causing 41 deaths and extensive destruction of human settlements and forests (GoN, 2013). Occasional precipitation was found to be the highest in March and lowest in April. Over a period of 15 years, the lowest occasional average precipitation appeared to be decreasing while incidences of wildfires were going up. The highest numbers of wildfires were recorded in April 2003, 2005, 2009, 2010, and 2012 (Figure 6). The occasional precipitation variable affects the wildfire activities in the study area. The findings can be useful to both the policymakers and local forest managers for developing fire alert systems, managing fire preparedness for control and mitigation, and managing wildfires in the field (Bhujel et al, 2019, p. 4).

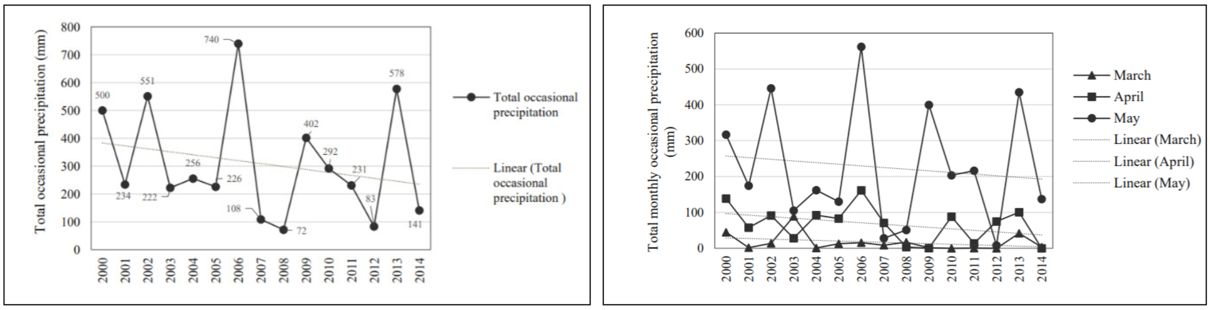


Figure 6: Status of precipitation in active fire season; b) Trends of total precipitation in active fire season.

4.1.4 Distribution of Invasive Alien Plant Species

The distribution and occurrence of Invasive Alien Plant Species (IAPS) have become a serious problem for forest management and biodiversity conservation in Nepal (Ghimire et al., 2021; MoFSC, 2014). The trend of spreading IAPS is gradually increasing at a faster rate in recent years. Climate change seems to be a contributing factor (Siwakoti et al., 2016; Shrestha et al., 2019; Rai & Scarborough, 2012, Ghimire et al., 2021). IAPS is spreading throughout community forests, government-managed forests (Khaniya & Shrestha, 2020), and those inside protected areas (Bhatta et al., 2020; Chaudhary et al., 2020; Lamichhane et al., 2018;).

Twenty-six IAPS are recorded in Nepal (Ghimire et al., 2021). Twenty-four IAPS distributed across 70 districts were recorded in one of the recent studies (Shrestha & Shrestha, 2019). These IAPS were previously restricted to Terai, Siwalik, and lower hills. However, some of the IAPS are now being reported in high mountain districts since the rising temperatures in the districts are proving to be favourable conditions for their growth (Figure 7). Lamsal et al. (2018) projected a likely increase in the expansion of some IAPS (e.g. *Ageratina Adenophora, Chromolaena odorata,* and *Lantana camara*) towards the north under both RCPs 4.5 and 8.5 and invading Nepal's Himalayan region by 2070. This phenomenon is consistent with the experiences of the provincial interaction participants. According to the participants of Karnali Province, IAPS were not observed in their place a decade ago, however, they have noticed an increase in the spread of some IAPS in recent years.

As expressed by the participants of other provincial workshops, several ecosystems and wildlife habitats are severely impacted by the rapid distribution of IAPS and already imperiled floral and faunal biodiversity (details in section 4.2), ultimately affecting the livelihood of farming communities (Siwakoti et al., 2016).

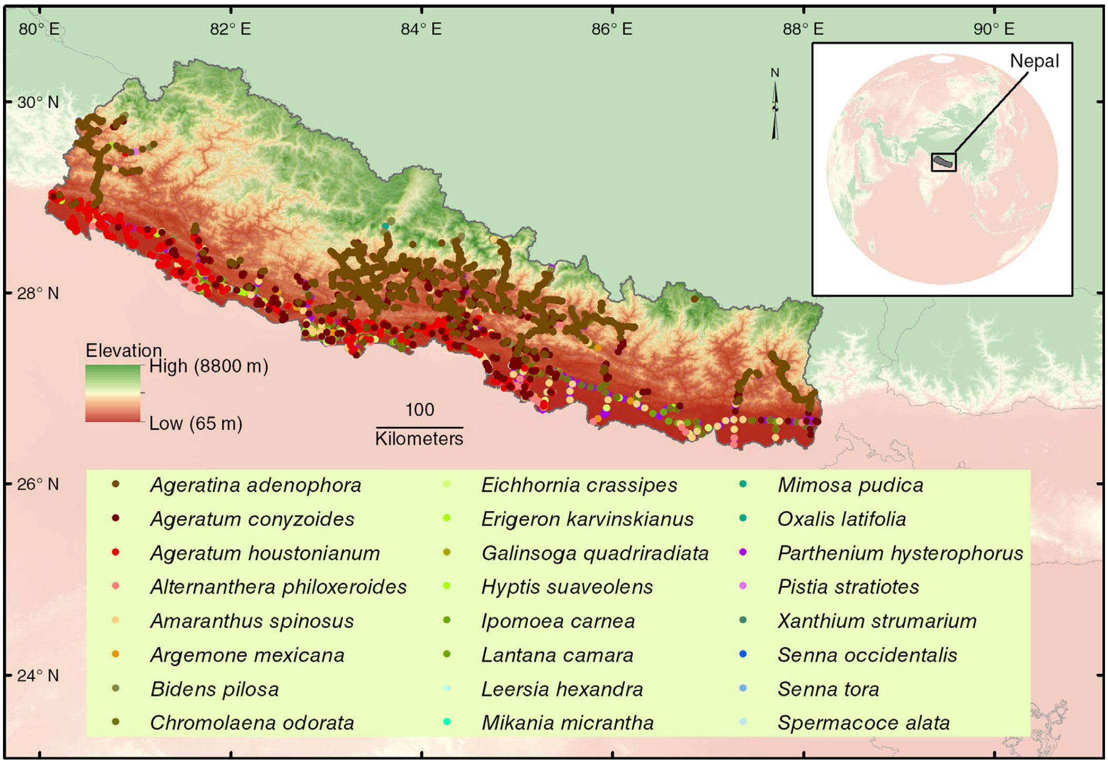


Figure 7: Occurrence of invasive alien plants in Nepal. Each dot represents the geographic coordinates of the species(Source: Shrestha & Shrestha, 2019, p. 1601)

4.1.5 Forests pests, diseases, and pathogens

Forms and extent of forest pests and diseases that impact the forest ecosystem in the face of climate change in Nepal and even globally are under investigation and research (Ramsfield et al., 2016). However, there is a growing consensus that climate change favors the pathogen's biological process and life cycle including reproduction and infection patterns (Hennon et al., 2020; Pureswaran et al., 2018). Rapid growth and expansion of pests and pathogens population may increase the range of their outbreaks which ultimately degrades forest quality and reduces forest productivity (Bebber, 2015; Lehman et al., 2020).

Several cases of loss and degradation of both natural and plantation forests have already been seen, caused by the infestation of insects, pests, and pathogens. Seedlings in forest nurseries were also found to be in feeble conditions due to various fungal diseases (Pokharel, 2017). Malla and Pokharel (2018) have documented a few insects and pests which are affecting Nepal's major tree species including Sal, Teak, Eucalyptus, Rajbrikschha (Cassia fistula), and Vijayasal *(Pterocarpus marsupium)* forests. The authors have warned that Nepal's forests are under threat and will see an increase in the outbreaks of pests and pathogens due to the combined effects of climate change and anthropogenic disturbances. Local communities (Karnali Province participants) also explained their observation of the outbreak of pests and disease in their localities, affecting especially Sal forests. The infestation of pests and diseases and their forest impact will likely grow with a rise of other climate-induced events, including the spread of wildfires, rising temperatures, and warm days (MoE, 2010; MoFE, 2019c; NCVST, 2009).

Additionally, climate change may greatly alter the biological process of pests and diseases such as host-parasite interaction. A well-documented example of climate change-related geographic range expansion is the northward movement of the protozoan *Perkinsus marinus*, the parasite disease which affects oysters *(Crassostrea virginica)*, and which has been able to expand its range because of the geographic distribution of oysters (Malek & Byers, 2018; Gallana et al., 2013). Similarly, Mongolian saiga antelope were massively affected by the sudden increase of the peste des etits virus (PPRV) (Pruvot et al., 2020) due to climate-related factors. In another extreme, amphibian populations have been affected by *Ranavirus* and *Chytridium* fungus that caused a global decline in amphibian populations (Martela et al., 2013). In addition to the anthropogenic stress on aquatic ecosystems, climate change has also created the possibility of disease in aquatic animals. In the case of Nepal, the outbreak of foot and mouth disease and parasitic infection have been reported in the isolated Blackbucks (*Antelope cervicapra*) Conservation Area (Chaudhari & Maharjan, 2017). This phenomenon could further increase because of climate change.

4.2 Impact on biodiversity

4.2.1 Impact on ecosystem-diversity

Biodiversity is heavily impacted by climate change in Nepal. Ecosystem-level diversity including forests (as discussed above), protected area biodiversity, wetlands and freshwater, rangeland and pasture lands, mountain biodiversity, and agro-biodiversity *(*discussed in agriculture theme) are sensitive to climate variability and climate-induced hazards (MoFE, 2018a). Some preliminary studies (e.g. Lamsal et al., 2017; Khatri, 2008) have shown the impact of climate change on freshwater and wetland systems with accelerated rates of degradation. These effects are more severe at high altitudes (2900–3500 masl) (Shah et al., 2015) and compounded by anthropogenic factors (Lamsal et al., 2017).

Findings obtained from provincial consultations and land use analysis of Lamsal et al. (2019) show how the Ramsar wetlands are seeing a change in rainfall patterns, extended periods of drought, depletion of water resources, sedimentation, debris flow, and landslides) which have all contributed to a decline in migratory birds, aquatic plants, and animal populations.-

4.2.2 Impact on species diversity

Faunal and floral species and their habitats are sensitive to the smallest changes in temperature and other climatic variables and hazards (MoFSC, 2014) making them some of the most vulnerable to climate change.

The invasion and rapid expansion of some alien species due to climate change have emerged as a major threat to both wetland and terrestrial species diversity especially fauna and endemic plant species (Siwakoti et al., 2016; Shrestha & Shrestha, 2019). For example, Lamichhane et al. (2014) and Murphy et al. (2013) observed significant growth of the Mikania infestation between 2008 and 2011 in all types of habitats except sub-tropical forests. The growth was high in wetlands habitat (30.38%) and short grasslands (11.33%). As shown in Table 8, the rapid expansion of *Mikania micrantha* has posed a threat of shrinking and destruction of rhino habitat in the Chitwan National Park (Lamichhane et al., 2014). Consistent with this, Pant et al. (2020) assessed that rhinoceros are likely to be moderately vulnerable under climate change due to invasive species, floods, habitat fragmentation, small population size, droughts, and forest fires in protected areas. Based on predictive models, Adhikari and Shah (2020) projected a loss of suitable habitats of rhinoceros by 51.25% and 56.54% under RCP 4.5 for 2050 and 2070 respectively. This may lead to increased instances of rhinoceros death and human-wildlife conflict in buffer zone communities of Terai protected areas (Aryal et al., 2013). Human-wildlife conflicts are already occurring in high-mountain protected areas due to resource competition between humans and wildlife (Aryal et al., 2014).

Table 8: Habitat-wise Mikania infestation change in Chitwan National Park, 2008–2011

Vegetation type	% of the plots having high Mikania infestation (>50%)		% Increase from 2008 to 2011
	2008	2011	
Riverine Forests	26.02	27.03	1.01
Sal Forests	2.23	4.24	2.01
Short Grassland	1.02	12.35	11.23
Tall Grassland	19.86	20.17	0.31
Subtropical mixed Forests	51.33	14.71	-36.62
Wetland	9.62	40	30.38
Other	14.89	11.67	-3.23
Not specified	N/A	2.94	2.94
Grand Total	15.12	17.95	2.83

Source: Lamichhane et al. (2014, p. 59)

Climate change has a direct effect on elephants by reducing forage and water availability (Sukumar, 2006). A long-term study conducted between 1965 and 2000 in Myanmar, Mumby et al. (2013) observed increased mortality in calves and young elephants with an average monthly temperature increase of ~1°C. The ensemble of species distribution models (SDMs) has predicted that Asian elephants will lose 41.8% of their habitat due to increasing variability under warming changing climate and human factors (Kanagaraj et al., 2019). This projected loss will be higher in human-dominated sites at lower elevations due to increasing droughts leading elephants to seek refuge at higher elevations or in the Himalayan Mountains along valleys with greater water availability.

Other mammals like herpetofauna, avians, fishes in the vertebrate group, and butterflies and mollusks in the invertebrate group also face significant challenges. However, minor taxa groups are relatively more sensitive to climate change compared to large taxa (Szpunar et al., 2008). As per the findings of a review study, most of the prominent impacts of climate change on fauna were observed at the range shift and distribution, growing instances of disease and pests, water availability, floods, population dynamics, wildfire, invasive species, and pollution (Figure 8).

Most of the studies indicated a range shift of species due to climate change has increasingly posing threats to mountain fauna. For example, due to shifting tree lines and consequent shrinking of the alpine zone in the Himalayas, Forrest et al. (2012) estimate that snow leopards will lose 30% of their habitat. Aryal et al. (2016) also predict habitat loss: snow leopards and blue sheep will lose 14.57% by 2030 and 21.57% by 2050. Similarly, water stress arising from prolonged droughts and rising temperatures has led to a decrease in the number of deer, monkeys, porcupine, pangolin, and bird species in the mid-hills of Nepal (TU, 2018). Additionally, red monkeys earlier found in the Siwalik region are now seen in the Mahabharat range due to changes in their habitats associated with climate change (MoFSC, 2016).

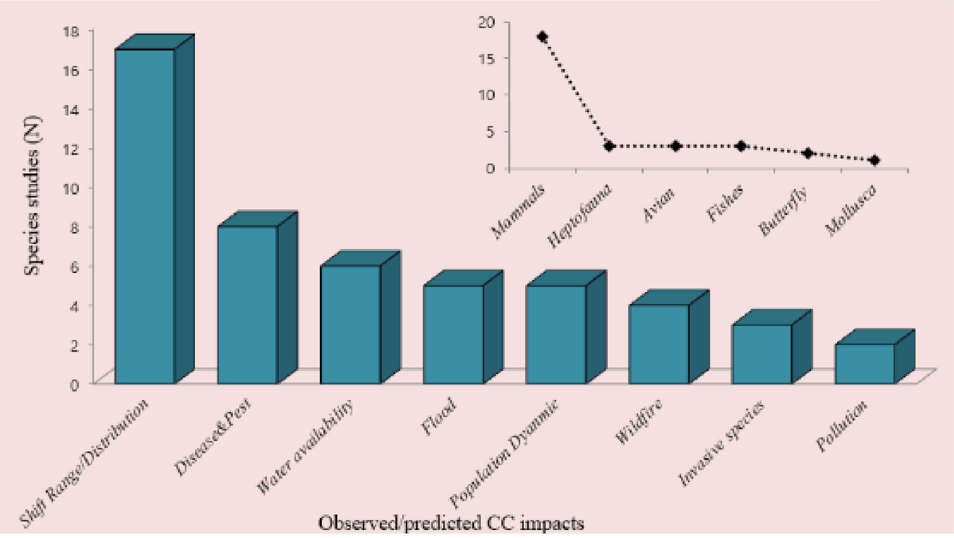


Figure 8: Observed/predicted climate change impacts on fauna

4.2.3 Loss and Damage (L&D) due to climate-induced disasters

In protected areas around the Terai region and Chitwan National Park, there are increasing instances of wild animals being swept away by flash floods. Box 4 describes these events and their reasons in further detail. Subedi et al., (2017) attribute flash floods to the decline of rhinoceros populations in Chitwan National Park. NTNC records show that 12 rhinoceros were swept away by the flash floods in 2017 (NTNC, 2020, p. 27). Such incidences may increase in the future and pose threats to conserving susceptible species.

Box 4: Climate change risks on wildlife flooding—case from Chitwan National Park

Increasing instances of flash floods which can be attributed to climate change, affect wildlife during the monsoon season particularly in Terai protected areas. Dr Babu Ram Lamichhane from the National Trust for Nature Conservation, project in-charge of Biodiversity Conservation Centre, Sauraha, shared his observations. Rivers Narayani and Rapti run through Chitwan National Park and are critical foraging and nesting grounds for several animals, including rhinoceros, crocodiles, and aquatic birds. Consequently, flash floods have affected these species greatly: rhino calves, wild boars, and deer are swept downwards and sometimes beyond the Nepalese border.

Forming rescue teams with a quick response time, erecting mud mounts (such as in Blackbuck conservation in Khairapur, Bardiya), and working on building stronger ties with India, could all serve as effective strategies to protect the affected wildlife.

4.2.4 Impact on floral diversity

As discussed in sections 4.1.1 and 4.1.2, vegetation shift, phenological change, and change in functional and physiological traits due to climate change will likely alter the tree composition thereby affecting species-level floral diversity. Such consequences will be severe for plant species with small climate ranges (Xu et al., 2009). There is growing evidence to support that climate change affects forests and NTFP in their availability and regeneration pattern. Several study findings (e.g. Pandey & Bhargava, 2010) and anecdotal evidence from local communities demonstrated a decline in the production and availability of NTFPs such as Panchaule *(Dactylorhiza hatageria)*, Shilajit *(Rock exudates)*, Amala *(Phyllanthus emblica)*, Ritha *(Sapnidus mukurosii)*, Timur *(Zanthoxylum armatum)*, and Bel *(Aegle marmelos)* (MoFSC, 2011). Chitale et al. (2014) observed a range with a reduction of three NTFP species: *D. butyracea*, *M. esculenta*, and *P. odoratissima* in Chitwan-Annapurna Landscape and predicted that the distribution of these species will likely concentrate in northern, central to northern, and north-east parts of the region respectively.

Floral diversity, including NTFPs, will likely be severely impacted in the future due to changes in temperature and precipitation. On a global scale, Suggitt et al. (2019) observed a 4.2% decline in alpha diversity, per decade, in sites that received the least amount of rainfall. Sedjo (2010) and Bazzaz (1998) have also predicted that vegetation patterns will change due to 2°C rise in temperature and a 20% increase in rainfall.

4.2.5 Distribution of alien invasive faunas

Invasive alien fauna is also threatening faunal diversity conservation in Nepal (GoN, 2014; Budha, 2015). Budha (2014) identified 69 species of Alien fauna: insects (21 species), freshwater prawn (one species), platyhelminths (one species), fish (16 species), wild mammals (two species), birds (three species), and livestock breeds (25 improved breeds). Unlike IAPS, the status, distribution, and impact of these invasive alien fauna on biodiversity conservation (in the face of climate change) is poorly investigated and documented.

Husen's (2014) study however shows how invasive alien fish species like *Nile tilapia* have had a negative impact on Nepal's native fish and freshwater species. Mooney and Chelnad (2001) have shown how alien fauna itself has been impacted by the alteration of the evolutionary pathway of native species due to competitive exclusion. It is often argued that the future change of climate and associated extreme events may provide favourable conditions for the distribution of alien fauna such as fishes, insects, birds, and mammals, posing a threat to biodiversity conservation efforts.

4.3 Potential impact of climate change on Nepal's protected areas

While Nepal's protected areas are home especially to several endangered wild animals, the ongoing pattern of climate change and its associated hazards including forest fires, IAPS, and flash floods may have an increasing trend of negative impacts. Several authors (Bhatta et al., 2020; Chaudhary et al., 2020; Lamichhane et al., 2014) have identified the increased distribution of IAPS in Terai's PAs and their effects in shrinking habitats of flagship wild faunas including rhinoceros.

Such consequences appear likely to increase in the future due to changing patterns of temperature and precipitation. The findings of a PA-scale analysis of climatic patterns using data from 1971–2014 shows a gradual increase in the annual maximum temperature: it ranged from 0.019°C to 0.095°C. A similar trend was predicted by Patra and Terton (2017), which indicated consistent and continuous warming after the mid-1970s with maximum temperatures rising at an annual rate of 0.04°C to 0.06°C in the country.

High altitude PAs including Rara National Park (RNP), Khaptad National Park (KNP), Manaslu Conservation Area (MCA), Annapurna Conservation Area (ACA), and Shey-Phoksundo National Park (SPNP) have experienced a higher increase in their maximum temperature range (Figure 9). These PAs are home to many endangered species such as Snow Leopard, Red Panda, Musk Deer and harbour numerous endangered flora such as *Rauvolfia serpentina, Neopicrorhiza scrophulariiflora, Dactylorhiza hatagirea*, and *Nardostachys grandiflora* (Chaudhary et al., 2010), and rising temperatures will alter and degrade their habitats, affecting their physiology, biological potential, and food reserves.

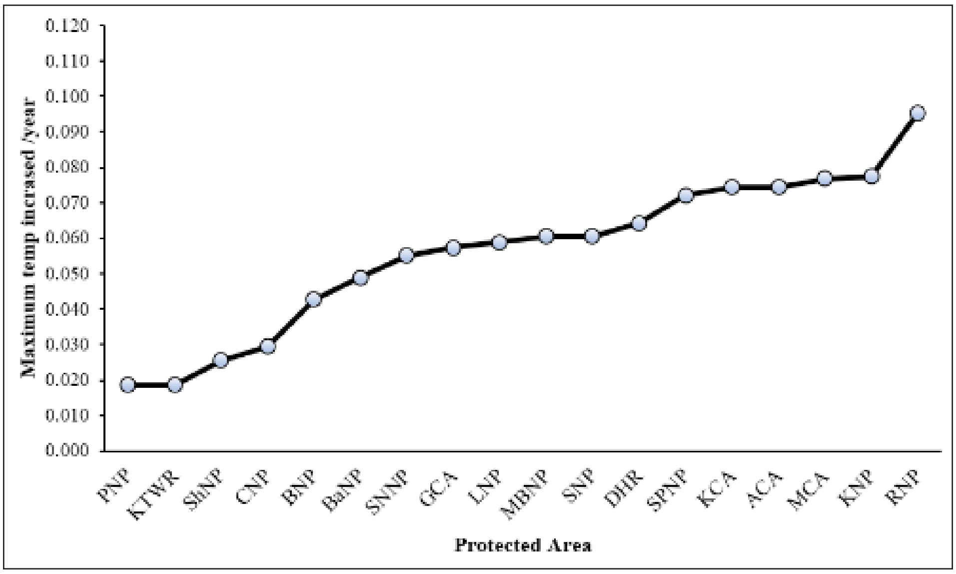


Figure 9: Maximum temperature increase per year from 1971–2014

The findings of projected future climate change scenarios analysed with global climate models (GCMs) under RCP 4.5 for four periods—2021–40, 2041–60, 2061–80, and 2081–2100—reveal that temperature change is projected to be higher in the PAs of both low land Terai and the high Himalayas in the western part of the country (Figure 9–11). However, changes in projected temperature will be higher in the High Himalaya's PAs than the PAs in the Terai region. Higher temperatures will be found in CNP followed by Krishnasar Conservation Area (KrCA), Shuklaphanta National Park (ShNP), Bardiya National Park (BNP), Banke National Park (BaNP), Parsa National Park (PNP), and the least in Koshi Tappu Wildlife Reserve (KTWR) in the Terai's PAs (Figure 10). Similarly, RNP, SPNP, Dhorpatan Hunting Reserve (DHR) will be subject to higher temperatures (Figure 11 and Figure 12).

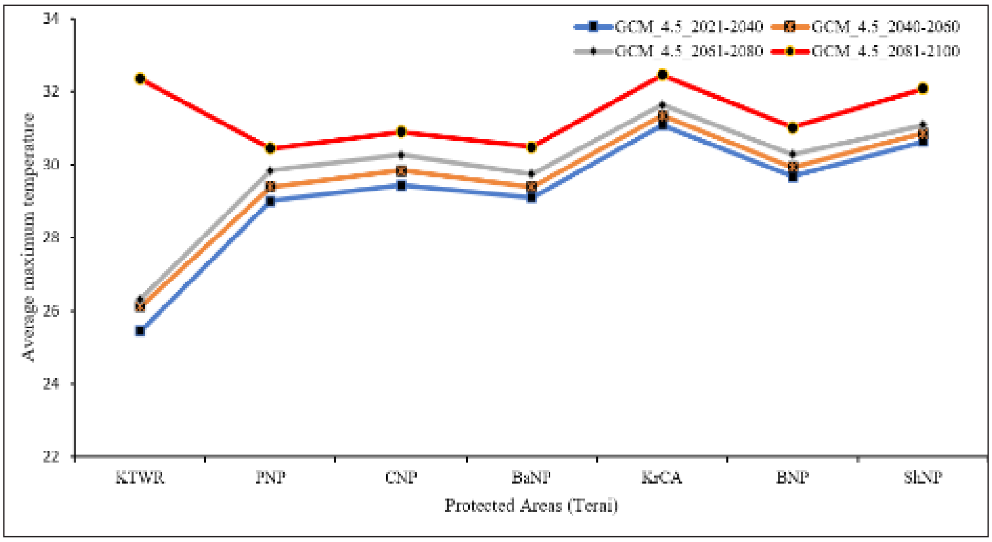


Figure 10: Projected maximum temperature in the lowland protected areas

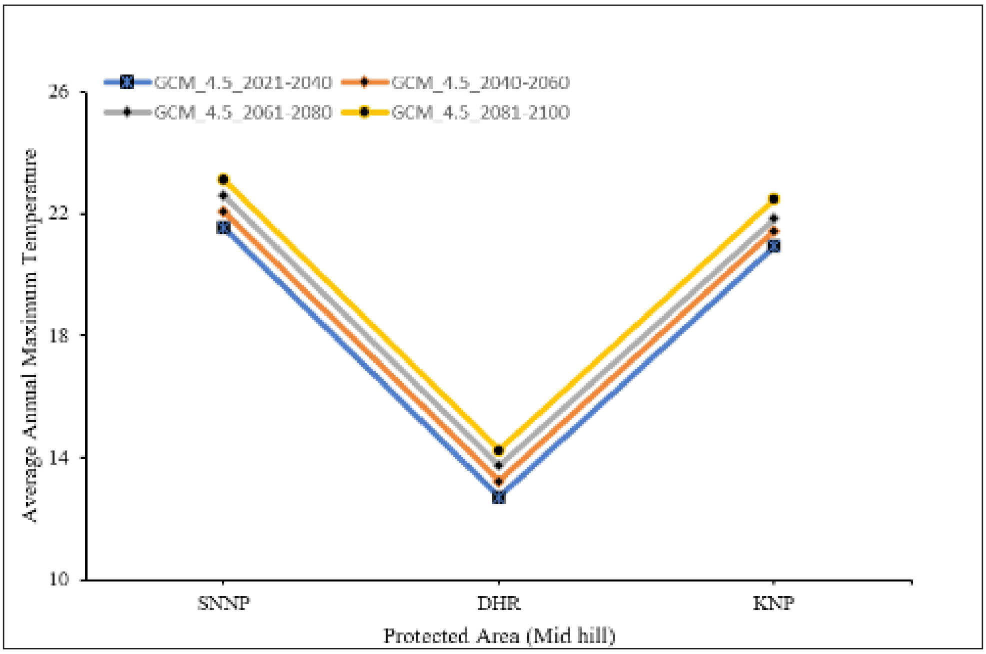


Figure 11: Projected maximum temperature in the protected area in the middle mountains

The findings also indicate that temperatures in high and middle mountain PAs will increase which will alter the habitat composition of several endangered native flagship wild animals including Musk Deer, Red Panda, Snow Leopard. While Terai PAs see a relatively small temperature change, they will face several climate-induced hazards including forest fire incidences and invasion of alien plant species.

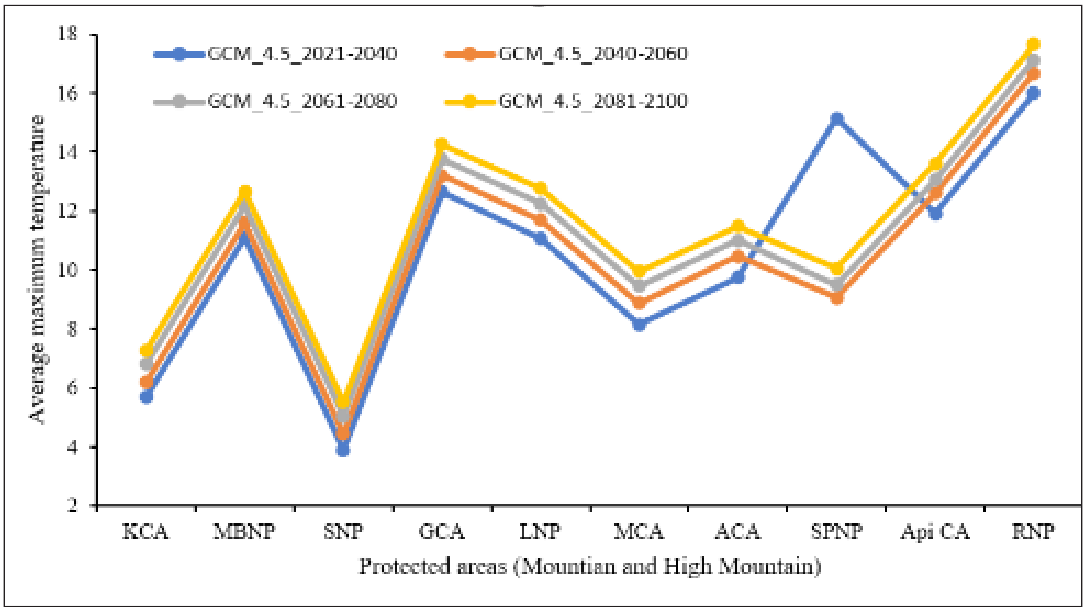


Figure 12: Projected maximum temperature in the high mountains protected area

4.4 Impact on watershed management

4.4.1 Disruption of hydrological cycles

Too much and too little water and the degradation of wetlands and watersheds are two major challenges of climate change in Nepal. Glaciers and glacial lakes are the sources of Nepal's major basins. The melting of glaciers and glacial lakes due to rising temperatures threatens to disrupt the hydrological cycles of river basins and their watersheds (Kaini et al., 2020; Nepal, 2016). Of the 2,070 glacial lakes in Nepal, 47 are reported to be potentially dangerous (Bajracharya et al., 2020). Nepal has experienced 24 Glacier Lake Outburst Floods (GLOFs) in the recent past, several of which have caused considerable damage in downstream river basins and watersheds, as well as

Box 5: Too much and too little water: sorrow of local communities

Local communities across the country are threatened by too much and too little water. VRA provincial workshops showed that the locals of Province 2, Sudurpashchim, and Lumbini have experienced the loss of riverain forests to flash floods, which led not only to the destruction of settlements but the loss of watershed resources like fertile soil and wildlife habitat. Participants in Karnali, Gandaki, and Province 1 reported decreases in snow cover and melting glaciers. They further explained that high-intensity rainfall has caused lake sedimentation, landslide incidences, and mass movement, leading to the loss of settlements, lives, and infrastructure. In some cases, mass movement, landslides, and floods impair both the quality and area of watersheds. On the other hand, local communities increasingly experience water shortages during winter due to prolonged droughts and long warm days and nights, as wetlands dry up and falling water levels in watersheds and catchments ultimately leads to degradation.

life (ICIMOD, 2011). The perceptions of local communities and stakeholders as mentioned in Box 5 support these findings. The major concern of local communities is that both "too much and too little water" conditions arising from climate change are harmful to the watershed's resources and thereby human societies as it obstructs water storage and triggers flash floods and landslides.

4.4.2 Watershed degradation

Changing patterns of precipitation is a major challenge for watershed conservation in Nepal. Nepal is prone to several forms of land and watershed degradation resulting from natural events like floods, landslides, soil erosion, and debris flow (Thapa & Joshi, 2018). However, climate-related stressors such as heavy rainfall events have triggered these natural events along with increasing soil erosion and mass movements and decreasing water holding capacity, which poses a significant threat to watersheds and watershed resources (Chalise et al., 2019). On the other hand, insufficient water availability and prolonged drought during winter (CBS, 2016; GoN, 2019) may also impair the hydrological cycle and nutrient supply, accelerating soil loss and wind erosion, which ultimately degrade watersheds (Chalise et al., 2018, 2019). Besides, irregularity of water flow degrades overall watershed quality, thereby reducing productivity (UN-habitat, 2015).

As mentioned by the local communities in the provincial consultations, mountain catchments of Nepal including mountain watersheds are more vulnerable to snow melt, resulting in a change in downstream river flow. In their study, Ghimire et al. (2016) observed a change in the flow of the Tamor and West Seti rivers due to a change in the glacier surface. Alteration of streamflow was also observed in mid-western river basins including the Bheri River (Mishra et al., 2018). Similarly, mid-hills watersheds are sensitive to the risk of erosion, landslides, and mudslides due to the change in precipitation patterns and streamflow. Flash floods, debris flow, and sedimentation are common incidences in the Terai and Siwalik regions (Churia) (ADB, 2012).

4.4.3 Wetland degradation

Climate change impact is also seen in wetland resources. Nepal's wetlands comprise diverse forms of water bodies including rivers, lakes, reservoirs, ponds, marshy land, and irrigated paddy fields across ecological regions (Bhuju et al., 2010, MoFE, 2018c) Most of these are prone to multiple climate extreme events and hazards (Lamsal et al., 2017). Most of the Ramsar and non-Ramsar wetlands in the lowlands and mid-hills of Nepal are fed by either glacier melt or riverine floods (MoE, 2012). Changes in water flow and availability due to change in volume of glaciers could change the water level of wetlands (Shrestha & Aryal, 2010), which then leads to the degradation of wetland resources and shrinkage of wetland areas (Lamsal et al., 2019; Ouyang et al., 2013).

As discussed in sections 4.1.4 and 4.2.5, invasive species (e.g. water hyacinth and Nile tilapia) could degrade habitats for wetlands fauna. In some cases, such changes alter wetland habitat through the formation of new assemblages such as planktonic and hydrophyte (Lou et al., 2015). Habitat alternation could further jeopardize many endangered wetlands and freshwater-dependent animals (MoFE, 2018c). Some species such as *Crocodylus palustris, Kachuga kachuga,* and *Gavialis gangeticus* have very poor dispersal capacity to respond to altered habitats

(Lamsal et al., 2017, p. 922). Similarly, the effects of wetland degradation will be detrimental to both migratory and resident waterbird communities that use wetlands as feeding, resting, and breeding habitats (Adhikari et al., 2018).

4.4.4 Shortage of water for domestic use

The decline of water flow in upstream and mid-hills watershed springs arising from inter-annual precipitation variation has led to a shortage of domestic water use. In an inventory of over 4,000 springs in the upstream watershed of western Nepal, Adhikari et al. (2020) observed a decrease in water availability for domestic purposes (drinking, cooking, and cleaning). Additionally, drainage density and topographical features are additional parameters that aggravate climate change impacts on watershed resources. Using ecological and human elements as sensitivity, a study by ADB (2012) has identified Karnali river basins and its watersheds as most vulnerable to emerging climate change dynamics.

4.5 Impact on forest-dependent populations, infrastructure, and enterprises

4.5.1 Impact on forest-dependent populations

The consequences of climate change for forest-dependent populations and communities have become evident in recent years (Saalu et al., 2020; Somorin, 2010). The negative impacts of climate change are severe to women, IPs, Dalit, and poor households, who mostly rely on forest resources for their survival (Goodrich et al., 2017). The impact of climate change on the human system and the disruption of the safety net in Nepal is an emerging challenge while over 65% of the total population depend on forests for their permanent livelihoods (Amatya, 2013). The effects are already being felt by several IPs in Nepal, such as Raute, Majhi, and Tharu (Thapa & Upadhaya, 2019). Similarly, high altitude IPs that depend on the seasonal flow of drinking water are facing acute water shortages. Some of the climate change impacts facing IPs in Nepal and elsewhere include the decrease in the availability of traditional and cultural food sources with the change in plant species (Baird, 2008). This is generally associated with the loss of productivity and quality of forest ecosystem services (Nellemann et al., 2011; MoPE, 2017b). The impact of climate change will thus be more severe for highly forest-dependent and poor households who have limited income sources and employment opportunities (UNEP, 2010).

Box 6: Impact of climate change on women, indigenous peoples, and marginalized communities

Climate change is particularly harmful for women, indigenous people, and marginalized communities. The VRA Provincial workshops reflected this. Participants from Province 1 shared that indigenous groups such as Sherpa and Bhutia are more affected than others by the loss of forest productivity and ecosystem services. Herders from Karnali and Gandaki said they were disproportionately affected, leading to a decline in transhumance practices. Province 2 participants reported that landless and land-poor households were more affected by floods and fragmentation. Participants from Bagmati and Sudurpashchim shared the loss of employment opportunity due to loss of raw materials including declining NTFP to forest-based enterprises. Drying up water resources, declining availability of forest products, e.g. fuelwood and water, women workload, and time has increased fetching water and collecting water, expressed by the participants of all provinces.

As mentioned by the local communities (see Box 6), another aspect of climate change's impact on the forest-dependent communities is an increase in workload especially of women who are responsible mostly for forest management and collection of forest products and water fetching. The usual working hours for women of Western Nepal are reported to be over 18 hours a day mostly for collecting fuelwood, grass, and fodder (Sugden et al., 2014). Similar situations were also observed in Baitadi, Surkhet, and Dailekh districts with an increasing time demand for traveling long distances for the collection of these forest products (Gum et al., 2009). The increased domestic drudgery in all cases was accompanied by diminishing forest product availability partly due to climate change (Haigh & Valley, 2010).

A decline in forest-based income and declining employment opportunities to forest-dependent households and loss of traditional occupation of IPs is another livelihood impact of climate change. This impact is also severe mostly to income-poor households, women, and IPs with limited alternative income sources and employment options (Goodrich et al., 2018). An increase in workload and decrease of income especially of women and women-led households can affect their daughters' education with an increase in the school dropout rate. Likewise, while women, Dalits, and IPs are already discriminated against from the access to quality forest resources, the diminishing trend of availability of forests product due to climate change may aggravate these vulnerable groups to access to quality forest resources (Khanal et al., 2019).

4.5.2 Impact on forest-related infrastructure and enterprises

In another extreme, forest-related infrastructure is more vulnerable to climate change hazards especially forest fires, floods, and landslides. As perceived by stakeholders, IPs, and local people, some forest-based enterprises have already faced an undersupply of raw materials. Resource sustainability has become a major challenge for several small and large-scale forest-based enterprises (Poudel et al., 2018). There are limited or no investigations were undertaken on the link between climate change and enterprise development, especially in Nepal. In some cases, climate stressors such as increasing temperature could increase forest growth and timber production for a short period (Sohngen & Sedjo, 2005; Tian et al., 2016). However, climate extreme events such as increasing forest fire incidences and spreading of IAPS and drought pose detrimental effects with restraining forest growth and production of other forest services (e.g., water) and goods (e.g., NTFP) (Ding et al., 2019). Ongoing climate trends will likely continue which will reduce forest productivity in the future and hinder forest entrepreneurs from optimizing their production (Kolk & Pinkse, 2008; Morin et al., 2018). The undersupply and uncertainties of raw materials supply may further cause a production cost increment thereby raising the concern of enterprise sustainability (Paudel et al., 2018).

Chapter 5

Observed and Projected Climate Change Hazards and Exposure

5.1 Climate change stressors/hazards in forests, biodiversity, and watershed management

5.1.1 Climate change trends

Some observed trends of two climate variables i.e., temperature and precipitation analysed with data available from DHM (2017) between 1971 and 2014 are shown in Table 9. The results which were analysed using Mann-Kendall and Sen's slope method, show a negative trend in the average amount of rainfall in all seasons. The seasonal trend of the precipitation was also decreasing with the highest decline (0.324 mm per year) during post-monsoon. On average, Nepal's annual precipitation has declined by 1.333 mm per year over the observed period (i.e., 1971-2014). In the last 40 years, the annual increment of Nepal's maximum and minimum temperature was 0.056ºC and 0.002ºC, respectively (Table 9).

Table 9: Observed trends of the climatic variables in Nepal between 1971 and 2014

Climatic variables	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
Precipitation (mm/year)	-0.072	-0.081	-0.085	-0.324	-1.333
Maximum temperature (°c/year)	0.054**	0.051**	0.058**	0.056**	0.056**
Minimum temperature (°c/year)	0.009	-0.003	0.014*	-0.005	0.002

Note: **significance (α) at 99% Confidence Level and *95% of Confidence Level. Source: DHM (2017, P.34)

Physiographic region-wise, a negative annual precipitation trend is observed in all regions except for Terai (Table 10). In terms of the seasonal precipitation trend, Terai, Siwaliks, and the Middle mountains show a slightly increasing winter precipitation trend (Table 10). In contrast, the Middle mountains and High mountains illustrate slightly decreasing winter precipitation. Although it is insignificant, the highest positive trend is observed in Terai and the highest negative trend is in the Middle mountains.

An increasing trend of pre-monsoon precipitation is observed in the lowlands Terai, Siwalik, and Middle mountains while the decreasing trend is observed in the Middle mountains and High mountains (Table 10). A decreasing trend for monsoonal precipitation is recorded for all regions except for Terai with the highest value (0.51 mm/year). The post-monsoon precipitation trend shows an insignificant decreasing trend in all five physiographic regions ranging from 0.26 mm/year in Terai to 0.50 mm/year in the Middle mountains.

Table 10: Seasonal and annual precipitation trends (mm/year) by the physiographic regions of Nepal

Physiographic regions	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
Terai	0.09^0	1.24^+	0.51^0	-0.26^0	0.49
Siwaliks	0.08^0	0.75^0	-0.60^0	-0.38^0	-1.48
Hill	0.03^0	0.03^0	-0.45^0	-0.43^0	-1.58
Middle mountains	-0.06^0	-0.82^0	-1.19^0	-0.50^0	-3.17^+
High mountains	-0.03^0	-0.74*	-0.21^0	-0.32^0	-1.46^+

Note: * Significance (α) at 95% of Confidence Level; CL: +, 0. Source: DHM (2017, P.37)

Like precipitation, the findings show a regional variation of temperature for both annual and seasonal trends. The winter temperature of the Terai has declined annually by -0.004°C whereas the positive change in annual and seasonal temperatures in all seasons is the highest in the High Himalaya region compared to other regions of the country (Table 11). The annual positive change in temperature of the Himalayan region is 0.086°C. Both annual and seasonal maximum temperature trend values even varied by large value across the districts. For example, the highest significant positive trend (0.092°C /year) is observed in Manang while the lowest positive trend (0.017° C/year) is observed in the Parsa district (DHM, 2017, p. 49). The overall findings reveal that both annual and seasonal temperature and precipitation trends vary across the physiographic regions.

Table 11: Seasonal and annual maximum temperature trends (°c/year) by the physiographic regions in Nepal

Physiographic regions	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
Terai	-0.0040	0.0180	0.036***	0.028**	0.021***
Siwaliks	0.0100	0.031*	0.040***	0.033***	0.030***
Hill	0.046***	0.049***	0.055***	0.052***	0.052***
Middle mountains	0.070***	0.062***	0.064***	0.064***	0.068***
High mountains	0.101***	0.076***	0.072***	0.085***	0.086***

Note: **significance (α) at 99% Confidence Level, *95% of Confidence Level; *** 99.9% CL, Insignificant at 95%, CL: +, 0. Source: DHM (2017, P.44)

The climate scenario prediction of Nepal analyzed based on ensemble mean of select 4 Global Circular Models (GCMs) indicates an increasing trend in both temperature and amount of precipitation, which will continue in the future as given in Table 12. The projected mean precipitation is likely to increase in the range of 2.1 to 7.9% for Representation Concentration Pathway (RCP) 4.5, and 6.4 to 12.1% for RCP 8.5 concerning the reference period (1981-2010). Similarly, the mean temperature may increase in the range of 0.92 to 1.3 °C for RCP 4.5 and 1.07 to 1.82 °C for RCP 8.5 for the reference period by the middle of the century. For, the end of century scenarios, both precipitation and temperature are likely to increase by 23% and 3.58°C respectively (MoFE, 2019a p. 20)

Table 12: Projected multi-model ensemble means of change in precipitation and temperature in the medium-term and long-term period of Nepal

Variable/time period	RCP 4.5			RCP 8.5		
	2016-2045	2036-2065	2071-2100	2016-2045	2036-2065	2071-2100
Precipitation Change (%)	2.1	7.9	10.7	6.4	12.1	23.0
Temperature Change (°C)	0.92	1.3	1.72	1.07	1.82	3.58

Source: MoFE (2019a, p.20)

5.1.2 Climatic extreme events trend and scenarios

As discussed in section 5.1.1, changes in temperature and precipitation are two climatic stressors that are having a rapid change over the decades. These stressors seem directly pertinent to the growth and distribution of forests, biodiversity, and management of the watershed. Some of the accelerating hydro-meteorological extreme events and climate-induced hazards associated with forests, biodiversity, and watershed resources are droughts, storms, floods, inundation, landslides, debris flow, soil erosion, fire, heatwave, extremely heavy rainfall, and avalanches (MoFE, 2019b). These stressors are the consequences of rapid changes in temperature and precipitation in recent decades. Perceptions and observations of local communities shared during the provincial workshop also demonstrate that these two stressors are critical to their livelihoods and the forests, biodiversity, and watershed resources in their surroundings.

This section presents the index of climate extreme events as proxy climate hazard scenarios associated with forests, biodiversity, and watershed management. The climate extreme events regarding the sector were initially identified considering their logical chain of impact as discussed in Section 5.1.1 and finalized considering the experiences of local communities (e.g., provincial sharing workshop), and the perspective of experts' judgments. Of the total 11 selected climate indices for the NAP (MoFE, 2019a, p. 16), altogether most relevant 8 climate extreme indices including change in temperature and precipitation have been identified as the most relevant extreme events for this sector. Relative weight for each extreme event was given by the expert considering the experiences shared by local communities as shown in Table 13. An increase in temperature was given with the highest weightage (35%) while both the change in precipitation and change in consecutive dry days were given with 15%.

Table 13: Relative weights for hazard indicators associated with forests, biodiversity, and watershed resources

Sub-sector	Hazards	Extreme Events composite	Weight (in %)
Forests and Biodiversity	Temperature, drought, forest fire, landslides, floods, epidemics, heatwave, rainfall	Temperature (^{0}C)	35
		Change in Precipitation (Decrease in monsoon and increase in winter rainfall) (%)	15
Watershed Management		Change in Consecutive Dry Days (%)	15
		Change in Number of Rainy Days (%)	10
		Change in Warm Spell Duration (%)	10
		Change in Extreme Wet Days (%)	5
		Change in Cold Spell Duration (%)	5
		Change in Consecutive Wet Days (%)	5

Composite indices of extreme events were estimated as proxy hazard scenarios based on the weightage assigned to each extreme event. The degree of composite index across the districts is scaled from low to the high and visualized baseline period (current) and future scenario projection for 2030 and 2050 under two Representative Concentration Pathways -RCPs 4.5 (medium) and 8.5 (highest greenhouse concentration scenario).

The findings show a clear pattern of the spatial distribution of districts with different degrees of baseline period climate extreme events. Terai and Siwalik districts generally are characterized by high climate extreme events (Figure 13). There is a clear east-west difference of climate extreme events for mid-hills and high mountain districts. Eastern mid-hill and mountain districts are generally characterized by moderate and high levels of climate extreme events, while high mountain districts like the west of Manang uniformly exhibit low and mid-hills generally represent the moderate level of climate extreme events. Such variation also exists even for lowland Terai districts. Far eastern Terai districts such as Jhapa, Morang, and Saptari represent high extreme events and the degree of climate extreme events has gradually diminished towards western Terai districts.

The attributing factors to the high climate extreme events in Terai and eastern hill districts could be the change in pre-and post-monsoon precipitation patterns and temperature change. For example, pre-monsoonal precipitation is increasing in western hills and decreasing in eastern lowlands (DHM, 2017; Karki et al., 2017). Although there is no substantial change in average annual precipitation, changes in precipitation intensity, pattern, duration, and time in this region will cause several uncertain extreme events including lowering wet days (Karki et al., 2017) leading to high intensity-precipitation extremes.

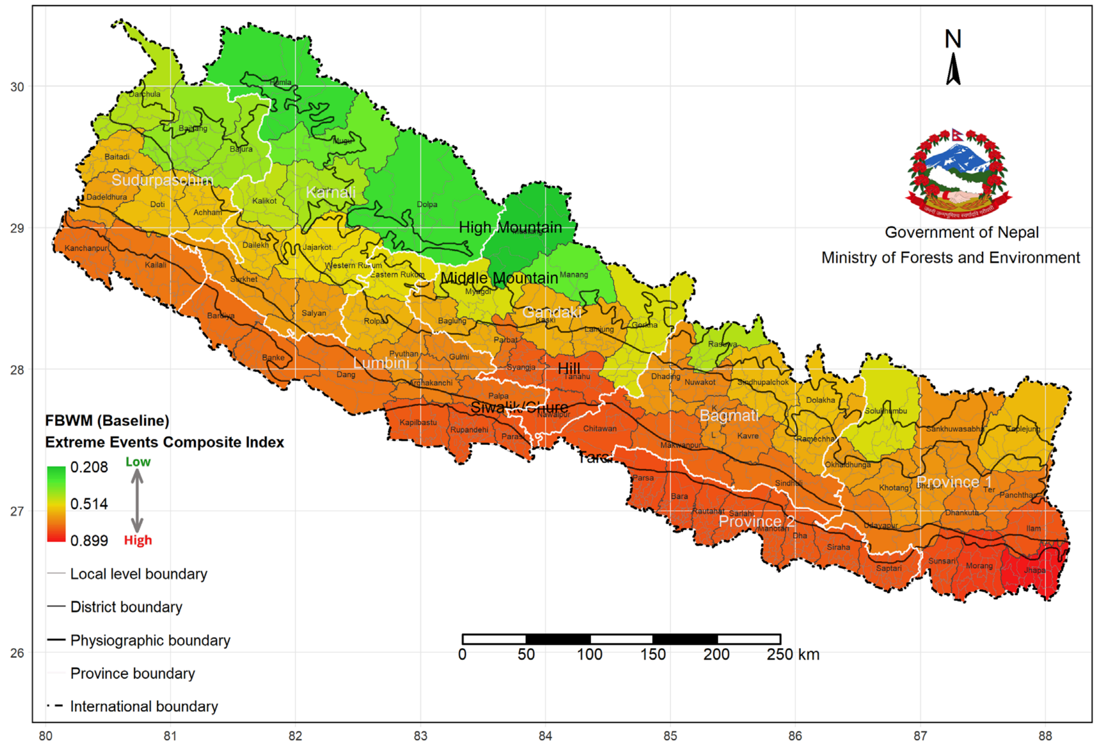


Figure 13: Baseline extreme events composite index of forests, biodiversity, and watershed management

There will be no considerable change in spatial (district) distribution of climate extreme events from the baseline period under RCP 4.5 for 2030, and 2050 (Figure 15 Left and Right). However, few districts will change their extreme event under RCP 4.5 for 2030 and 2050. Generally, Terai districts will shift towards a high level of extreme events under RCP 4.5 for 2030 from the baseline situation (Figure 14 and Figure 15 left). With minute observation, districts such as Gulmi, Pyuthan, Arghakhanchi, Syangja, Parbat, Palpa, Dhading, Nuwakot, Kavrepalanchok, Panchthar, Terhathum, Dhankuta, and Sankhuwasabha will move towards a high level of extreme under RCP 4.5 for this period.

Some western high mountain districts Humla and Dolpa will change towards a low level (from very low) of climate extreme events from 2030 to 2050 under RCP 4.5 (Figure 14 left and right). Under RCP 8.5, some western-high mountain districts including Humla, Mugu, Dolpa, and Mustang will move towards a less low level (from a high level of events) of climate extreme events from the baseline period to 2030 (Figure 15 Left and Right). Some eastern mid-hills and high mountain districts such as Dhankuta, Terhthum, Panchthar, and eastern Terai districts including Jhapa, Morang, Saptari, Siraha, Dhanusa, Mahottari, Sarlahi, and Rautahat will shift towards high extreme events in 2050 from a moderate level of extreme events in 2030 under RCP 8.5. This suggests that eastern mid-hills districts will have more climate extreme events in the future under RCP 8.5.

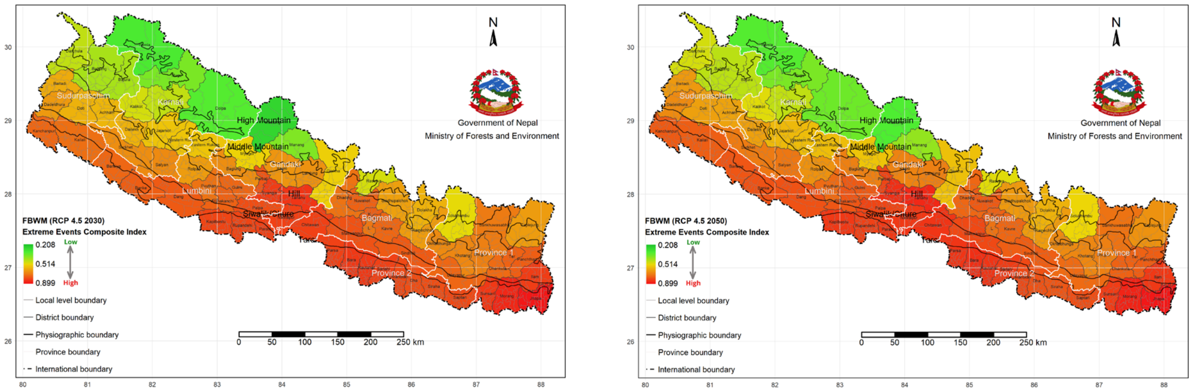


Figure 14: Climate extreme events scenario under RCP 4.5 for 2030 (left) and 2050 (right)

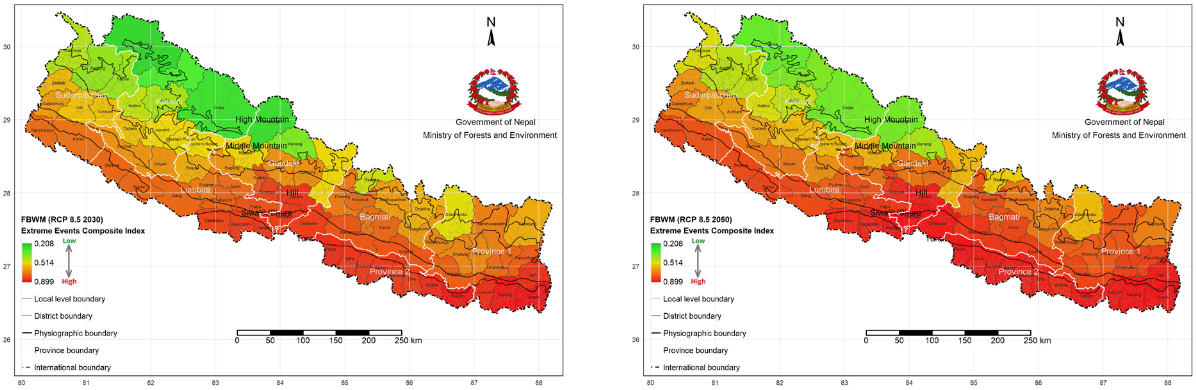


Figure 15: Climate extreme events scenario under RCP 8.5 for 2030 (left) and 2050 (right)

In summary, several Terai (mostly eastern) and Siwalik districts and some eastern mid-hills districts represent high climate extreme events. There is a clear east-west contrast for mid-hills and high mountain districts showing that eastern mid-hills and high mountain districts exhibit toward high extreme events while western mountain districts represent a low level of extreme events. While some districts will remain unchanged, several districts of eastern mid-hills and Terai will yet tend to change under RCP 8.5 in 2050. This suggests that generally, all districts will have a high extreme event in the future under high greenhouse concentration (i.e., RCP 8.5). Moreover, mostly eastern mid-hill districts Terai districts will have a high extreme event due to the combined effect of multiple stressors.

The results presented in the previous paragraph correspond with the temperature and precipitation-related data indicated in Table 12 (section 5.1.1). Both temperature and precipitation will increase under both RCPs 4.5 and 8.5 in the future which will render extreme events to most of the districts. A high level of extreme events will tend to occur in the eastern part of Nepal. While Nepal's monsoon both starts from and ends in the eastern part of Nepal, this region will have a severe effect even with a small change in precipitation (Pokharel et al., 2020). An increase in rainfall with an erratic pattern will increase the risks of flash floods, storms, debris flow, and mass movement. Similarly, decreased precipitation in western Terai will create drought-related risks (Lamsal et al., 2017).

A positive change in average annual temperature in mountain regions (discussed in Section 5.1.1.) may produce a positive effect with low and very low extreme events. This will create positive effects generally in western-high mountain districts with low extreme events. However, there is a need for long-term site-specific analysis of the effects of temperature and precipitation on forests, biodiversity, and watershed resources in high mountain and other regions.

5.2 Climate Change Exposure of Forests, Biodiversity, and Watershed Management

This section presents the exposure index of forests, biodiversity, and watershed management sector across the districts, provincial, and five physiographic regions including Terai, Siwalik, Hills, middle mountain, and high mountain. This provides the exposure rank of these scales as to the degree that they are exposed to climate change in terms of overall (combined) forests, biodiversity, and watershed management sectors and separately for two sub-sectors: forests and biodiversity and watershed management.

5.2.1 Climate change exposure across the districts

Exposure is defined as the presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructures, or economic, social, or cultural assets in places and settings that could be adversely affected by climate change (IPCC, 2014, p. 5). In this assessment, forest area, the area under plantations and NTFP, protected areas, wetland, rangeland, agro-ecosystem were considered as exposure units under forests and biodiversity sub-sector. Other indicators were snow cover, glacier area, the glacier lake area, households involved in forests and biodiversity conservation, forest-related buildings and infrastructures, and forest-based enterprises. Watershed management-related exposures units were exposed watershed, exposed wetlands, and areas of exposed other water bodies.

The overall findings illustrate that most of the districts (37) represent a low to a very low degree of exposure to climate change (Figure 16 and Table 14). The number of districts is characterized as high and very high exposure to climate change were 10 and 12 respectively, while 18 districts exhibit moderate exposure (Numerical value of exposure index are given in Annex 5).

High mountain districts generally represent high and very high levels of exposure to climate change. Some high mountain districts such as Taplejung, Sankhuwasabha, Solukhumbu, Gorkha, Dolpa, and Mugu were ranked very high exposure mainly due to the distribution of the relatively large area of protected areas, rangelands, and agro-ecosystem, snow cover areas, and glacier areas, while Humla represented a high level of exposure mainly due to relatively large forest areas and exposed watershed areas. Two high mountain districts – Mustang and Dolakha are characterized by a high level of exposure mainly due to the distribution of protected areas, agro-ecosystem, glacial-area, households involved in forests and biodiversity conservation, and exposed watershed areas. However, Rasuwa in this region was ranked as low level of exposure mainly due to small area of forests, annual plantation, wetland, exposed critical watershed, and the existence of few forest-based enterprises. Some high mountain districts such as Sindhupalchok, Dhading, and Manang were ranked as moderate exposure to climate change possibly due to a low number of forest-related infrastructure including buildings, roads, and fire lines, small area of wetlands.

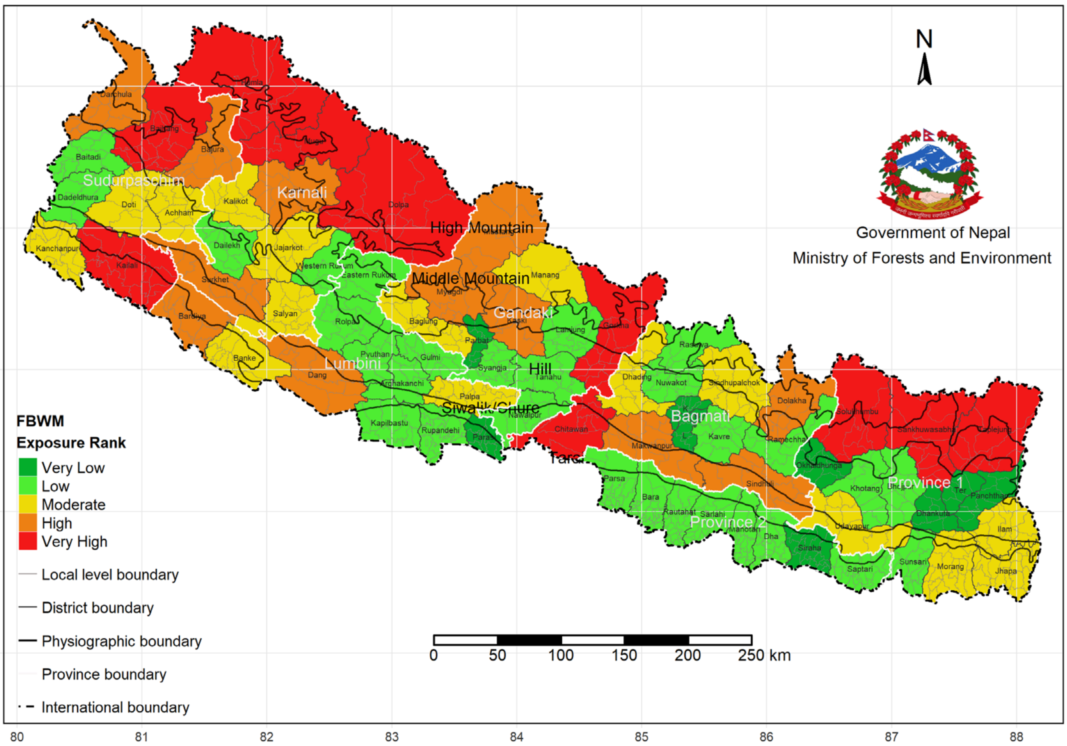


Figure 16: Exposure of Forests, Biodiversity, and Watershed Management across Districts

Similarly, some Terai districts including Kailali, Dang, Banke, and Chitawan were also ranked with high to a very high degree of exposure. The attributing factors to this include the large forest areas, wetland area, agro-ecosystem, large number of households involved in forests and biodiversity management, forest-based enterprises, and the presence of forest-related infrastructures such as forest roads, fire lines, view towers, and buildings.

Mostly eastern Terai districts such as Sunsari, Saptari, Dhanusa, Mahottari, Sarlahi, Rautahat, Bara, and Parsa and some western Terai districts including Nawalpur, Rupandehi, and Kapilbastu were ranked as low exposure. This is associated with the small area of rangeland and no snow-cover, glacier areas, and glacier lakes.

Two Terai districts such as Parasi and Siraha and eight mid-hills districts including Panchthar, Terhathum, Dhankuta, Okhaldhunga, Kathmandu, Bhaktapur, Lalitpur, and Parbat were ranked as very low exposure. The main attributing factors to this include the no protected area (except Kathmandu), small area of wetlands, no snow-cover, and glacier areas.

Table 14: Districts with different levels of exposure to climate change

Exposure Rank	Districts	Total number
Very High (0.651 - 1)	Humla, Mugu, Sankhuwasabha, Gorkha, Solukhumbu, Dolpa, Kailali, Chitawan, Taplejung, Bajhang	10 (12.99%)
High (0.510 - 0.650)	Makawanpur, Myagdi, Dolakha, Bardiya, Darchula, Surkhet, Sindhuli, Mustang, Bajura, Dang, Kaski, Jumla	12 (15.58%)
Moderate (0.368 - 0.509)	Dhading, Baglung, Sindhupalchok, Tanahu, Udayapur, Banke, Achham, Palpa, Salyan, Morang, Doti, Manang, Nawalpur, Kalikot, Kanchanpur, Jajarkot, Jhapa, Ilam	18 (23.38%)
Low (0.216 -0.367)	Rolpa, Kapilbastu, Rasuwa, Lamjung, Sunsari, Nuwakot, Rautahat, Western Rukum, Kavrepalanchok, Dailekh, Pyuthan, Syangja, Arghakhanchi, Baitadi, Rupandehi, Bhojpur, Bara, Eastern Rukum, Khotang, Dhanusha, Sarlahi, Mahottari, Parsa, Gulmi, Ramechhap, Saptari, Dadeldhura	27 (35.06%)
Very Low (0.035 - 0.215)	Dhankuta, Terhathum, Lalitpur, Bhaktapur, Parbat, Siraha, Okhaldhunga, Panchthar, Parasi, Kathmandu	10 (12.98%)

There is a small variation in the degree of exposure of some districts for two sub-sectors i.e., forests & biodiversity and watershed management. For forests and biodiversity, 41 districts were ranked with a low and very low degree of exposure (Figures 16 and 17); 20 districts represent a high and very high degree of exposure, while 16 districts exhibit a moderate exposure. Generally, high mountain districts have a similar pattern of exposure ranging from moderate to very high exposures for forests and biodiversity except for Rasuwa, while almost all Terai districts except for Morang, Chitawan, Dang, and Kailali characterize a low exposure (Figure 18).

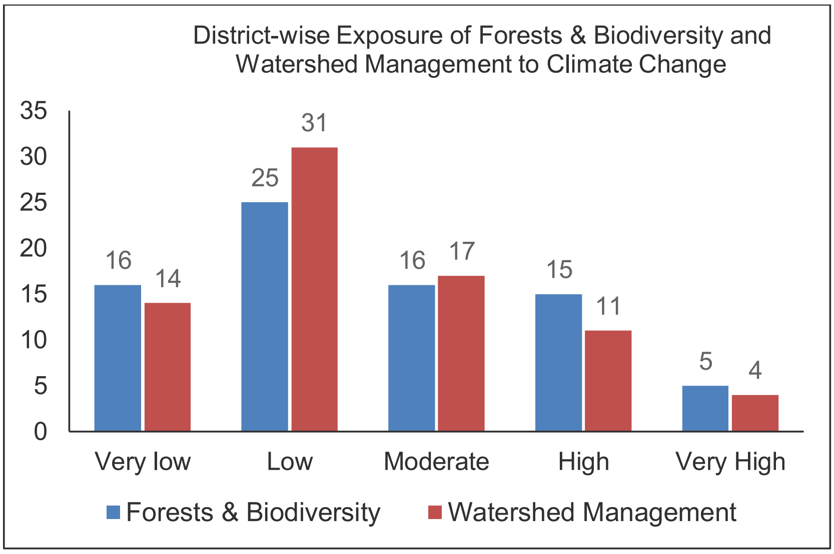


Figure 17: District-wise exposure of forests & biodiversity and watershed

Five high mountain districts such as Taplejung, Sankhuwasabha, Solukumbu, Gorkha, and Dolpa were ranked as high exposure for Forests and Biodiversity. This is associated mainly with the distribution of large, protected areas, forest areas, agroecosystem, rangelands, snow-cover, glacier areas, and glacier lakes. Other high mountain districts including Dolakha, Sindhupalchok, Mugu, Humla, and Darchula represented high exposure. Contrarily, Mustang and Manang districts are characterized by moderate exposure despite large, protected areas. The main reasons for this include a relatively small area of forests and the existence of few forest-related infrastructures development forest roads, fire lines, and view towers.

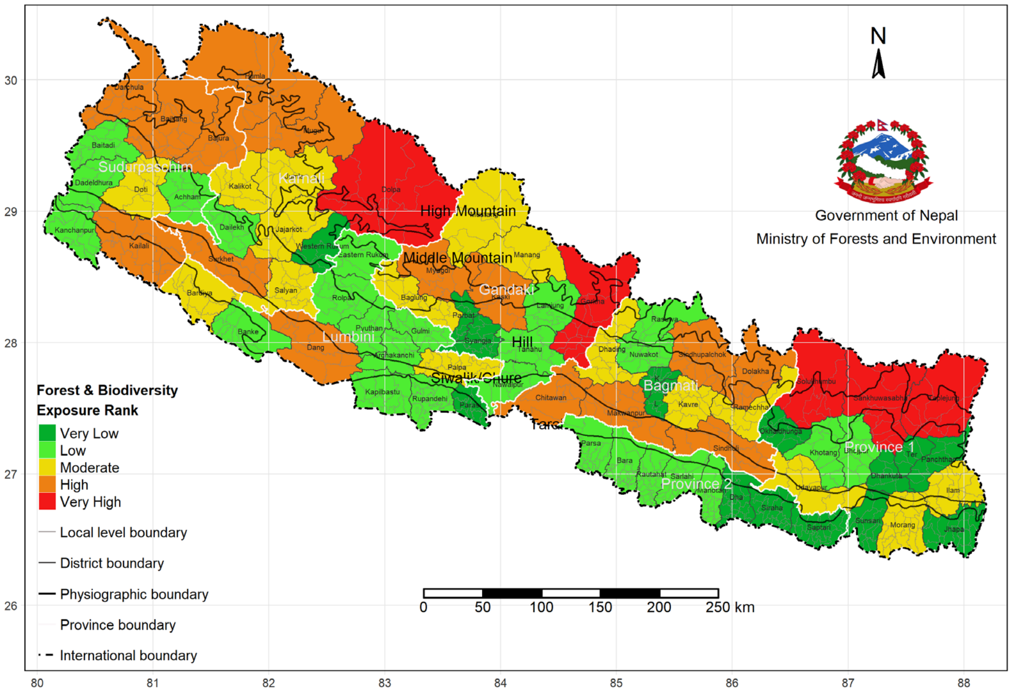


Figure 18: Exposure of forests and biodiversity across districts

As in forests, and biodiversity, the majority of districts (45) represent low to very low exposure also for watershed resources (Figure 17 and 19). 15 districts represent high to very high exposure, while 17 districts are characterized by moderate exposure. Three districts in the Karnali Province (high mountain districts) such as Humla, Mugu, and Dolpa were ranked as very high exposure for watershed management due to large, exposed watershed, wetlands, and presence of high waterbodies. Kailali was also ranked a very high exposure in watershed management, which is attributed to the large bodies, wetlands, and exposed watershed.

The findings reveal that few high mountain districts such as Dhading, Rasuwa, Sindhupalchok, and Dolakha ranked as low exposure, unlike other high mountain districts. The main factors attributed to this are the existence of exposed watershed areas, wetlands, and the presence of small waterbodies areas. Similarly, eastern Terai districts represent low exposure. However, Jhapa was ranked as high exposure possibly due to a large area of exposed watersheds, wetlands, and exposed waterbodies.

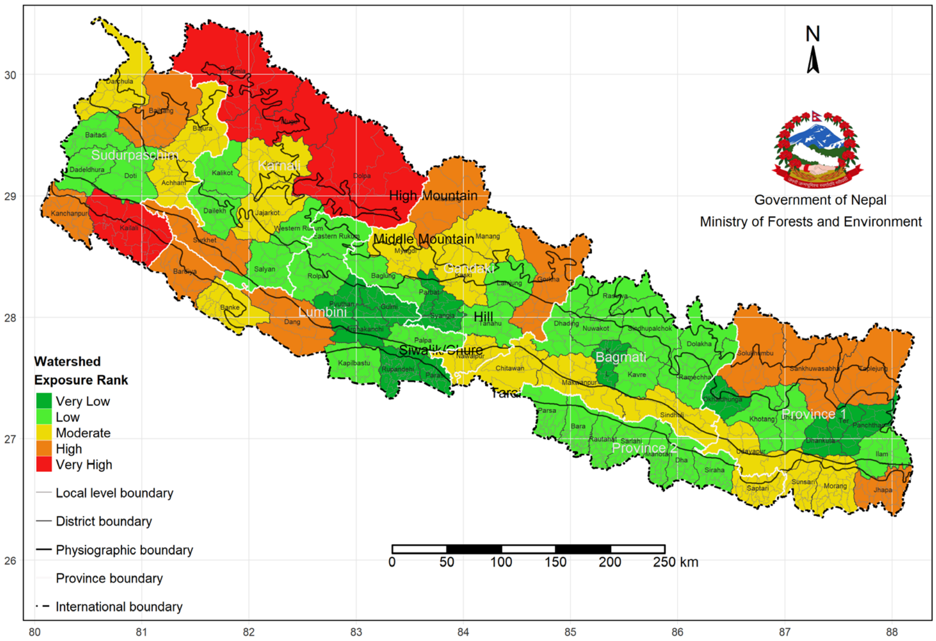


Figure 19: Exposure of watershed management across districts

Several districts represent a similar level of exposure for both sub-sectors - forests and biodiversity and watershed management, while some districts exhibit differences by one level. Dolpa, as a case in point, exhibits very high exposure for both sub-sectors with large forest areas, protected areas, NTFP area, rangelands, snow cover, glacier areas, and glacier lakes under the forest and biodiversity sub-sectors, and the existence of a large area of exposed watersheds, wetlands, and other water bodies.

However, some districts represent exposure to climate change by two levels or more for two sub-sectors. For example, Jhapa illustrates very low exposure for forests and biodiversity and high exposure for watershed management. The major factor for this variation is the difference in biophysical characters and the extent between the forests and biodiversity and watershed management in these districts.

5.2.2 Climate Change Exposure Across Physiographic Regions and Provinces

In the case of the physiographic region by provinces, the findings reveal that the high mountain region is generally characterized by high to very high exposure (Figure 20). The high mountain region of Karnali Province and Province 1 represented very high exposure while the high mountain of Gandaki Province represented high exposure to climate change. Interestingly, this region of Bagmati Province is ranked as low exposure mainly due to the presence of collectively small forest areas, forest-related infrastructure, the existence of small wetlands, exposed watershed areas, and other water bodies.

The findings reveal that the mixed level of exposure appeared in the middle mountain region. The middle mountain region of Sudurpshchim, Karnali, and Gandaki Province represented moderate exposure, while small parts of Lumbini and the whole parts of Province two presented very low exposure. Similarly, a major part of Bagmati Province (expect Siwalik/Chure region) and some parts (Siwalik/Chure and hill region) of Gandaki Province exhibit low exposure to climate change. Interestingly, the hill region of all Provinces represented moderate to very low exposure possibly due to the non-existence of snow-cover, glacier areas, and glacier lakes and the presence of a small area of wetlands, rangelands, watersheds, and water bodies.

Siwalik region exhibits moderate to high exposure. Specifically, the Siwalik region of Province one and Lumbini Province exhibit moderate exposure; Bagmati, Karnali, and the Sudurpashchim Provinces exhibit high exposure while Province two exhibit very low exposure to climate change. The Terai region is generally characterized by moderate to very low exposure except in the Sudurpashchim Province. The main attributing factors to this include the small area of rangelands, small area under NTFP, and exposed watershed and non-existence of snow-cover, glacier areas, and glacier lakes. However, high exposure in the Terai region of Sudurpashchim Province is associated with the large forest areas, agro-ecosystem, existence of forest-related infrastructures, and large areas of exposed watersheds, and wetlands area.

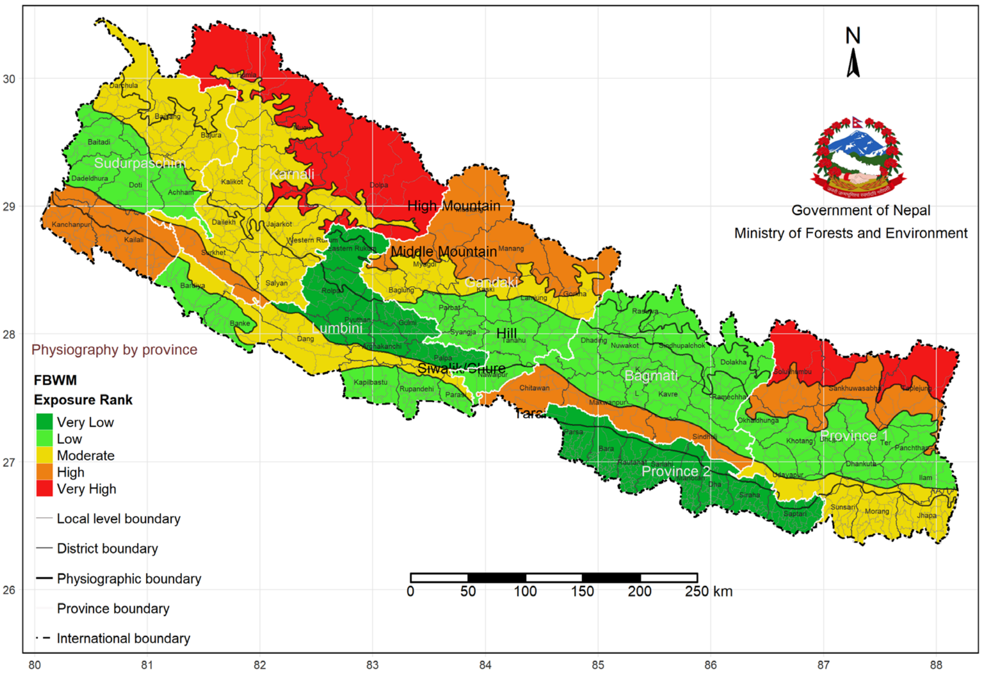


Figure 20: Exposure across physiography region and province

The findings of physiographic regions by Province-wise analysis reveal that Province 2 is ranked as very low exposure (Figure 20). Comparatively, Karnali Province represented high exposure. The middle mountain and hill regions of this Province are characterized by moderate exposure respectively mainly due to the existence of larger rangelands, agro-ecosystem, wetlands, and exposed watershed areas. However, the Siwaliks of this Province exhibit high exposure.

Sudurpashchim Province has mixed types of exposure across the regions. The Terai and Siwalik region of this Province exhibits high exposure while the Hills region of this Province represented low exposure. The Lumbini Province is characterized by low exposure as compared to others. The Siwalik region of this Province represents a moderate level of exposure, while the Terai region of this Province illustrates low vulnerability probably due to the non-existence of snow-cover, glacier area, glacier lakes, and rangeland, and the existence of a small area of exposed watersheds.

The high mountain region of Gandaki Province represented high exposure, while the middle mountain exhibit moderate exposure. The Hill region of Gandaki is ranked as very low exposure. The high mountain, middle mountain, and hills of Bagmati Province represent low exposure while the Siwalik region exhibits high exposure due to high exposed watersheds, distribution of large forest areas. Province one has four distinct exposure levels. High mountain and middle mountain regions re signified very high and high exposure respectively mainly due to the distribution of snow-cover areas, glacier areas, glacier lakes, protected areas, rangelands, exposed watersheds, and wetlands. On the contrary, low in hill and moderate levels of exposure in the Siwalik and Terai region of this Province are characterized by the non-existence of snow-cover areas, glaciers areas, glaciers lakes, protected areas despite high forest area, wetlands, and the existence of forest-related infrastructure.

Chapter 6

Observed Climate Change Vulnerability

6.1 Sensitivity of forests, biodiversity, and watershed management

Sensitivity in this assessment refers to the degree to which a system or species is affected either adversely or positively by climate variability or change. The sensitivity indicators for this sector broadly represent the intrinsic attributes of forests, biodiversity, and watershed resources, as well as the management system of these resources, which are susceptible to climate change. Some indicators for the forests and biodiversity sub-sector include the different forest types (such as alpine, upper mixed hardwood, lower mixed hardwood, tropical mixed hardwood, and Sal forests), the trends of forest change, and the percentage of forests under different stages of growth (regeneration, semi-degradation, and degraded). Other indicators include disturbance regimes such as forest fire incidences; invasive alien plant species (IAPS); the prevalence of insects, pests, and diseases; an encroachment, change in rangelands, wetlands, and agro-ecosystems; fragmentation; percentage of forest-dependent households, households directly engaged in forest-based enterprises, and landslide-prone forest-related infrastructure. Some watershed management-related sensitivity indicators include landslide-prone areas, landslide sensitivity, flood sensitivity, erosion sensitivity, sedimentation yield, and drainage density.

Sensitivity was analyzed as the aggregate value of indicators for forests and biodiversity and watershed resources at three scales – district, provincial, and physiographic regional. District-level sensitivity ranks comprise the sector (overall) and two-sub-sectors - forests and biodiversity and watershed management. The following sections highlight the key results of the analysis.

6.1.1 Sensitivity across districts

The findings reveal that a majority of districts (40 of 77) represent high to very high sensitivity to climate change, while 14 districts represent moderate sensitivity and 22 represent low to very low sensitivity (Figure 21 and 22, and Table 15).

The majority of Terai districts (Parsa, Rautahat, Dhanusa, Siraha, Saptari, and Sunsari) were ranked very low sensitivity mainly due to the non-existence of climate-sensitive forests such as alpine forests, low landslide sensitivity, and low change in rangelands and wetlands. Other Terai districts including Bara, Sarlahi, and Morang in the east and Nawalpur, Parasi, and Rupandehi in the mid and Kanchanpur in the far-west represent low sensitivity. The main attributing factors to this finding were the presence of large per patch forest sizes, the occurrence of few fire incidences, and low landslide and erosion sensitivity, low mean slope degree, absence of snow-glaciers, and positive change of forests.

The findings reveal that few high mountain districts including Mustang, Manang, Rasuwa, and Humla showed low sensitivity owing to low or non-existence of forest pests and diseases and IAPS, low sedimentation yield, small drainage density, few landslide-prone forest-related infrastructures, no change in wetlands, and low forest-fire prone areas. Similarly, five mid-hills districts including Kathmandu, Bhaktapur, Lalitpur, Panchthar, and Terhathum were ranked as low sensitivity to climate change possibly due to low forest pests and diseases, the small size of degraded, semi-degraded, and regenerated forest areas, positive change of forests, observation of the small number of IAPS, and low encroachment.

Conversely, some high mountain districts (such as Sankhuwasabha, Sindhupalchok, Dhading, and Gorkha) exhibit very high sensitivity, and Taplejung, Dolakha, and Dolpa were ranked high sensitivity, possibly due to high landslide sensitivity and disaster-prone area, erosion sensitivity, and sedimentation yield, small forest patch size, large sparse forest area, a high percentage of forest-dependent households, and a relatively large number of households engaged in forest-based enterprises. Some mid-hills districts including Bajura, Kalikot, Baglung, and Kaski also represented very high sensitivity. Chitawan, Makwanpur, Sindhuli, Dang, Surkhet, and Kailali were ranked as high sensitivity mainly due to occurrence of IAPS and forest fire, larger forest-fire-prone areas, a large number of households directly engaged in forest-based enterprises, high landslide- (such as in Sindhuli) and flood-prone areas, relatively large number of landslide and flood-prone forest-related infrastructure, and high drainage density.

The overall findings suggest the sensitivity of high mountain districts were generally associated with the distribution of climate-sensitive forest typesand landslides, while high sensitivity in mid and Terai districts are associated with disturbance regimes – forest fires, IAPS, and encroachment – indicating the future change of climate dynamics will be critical to all districts.

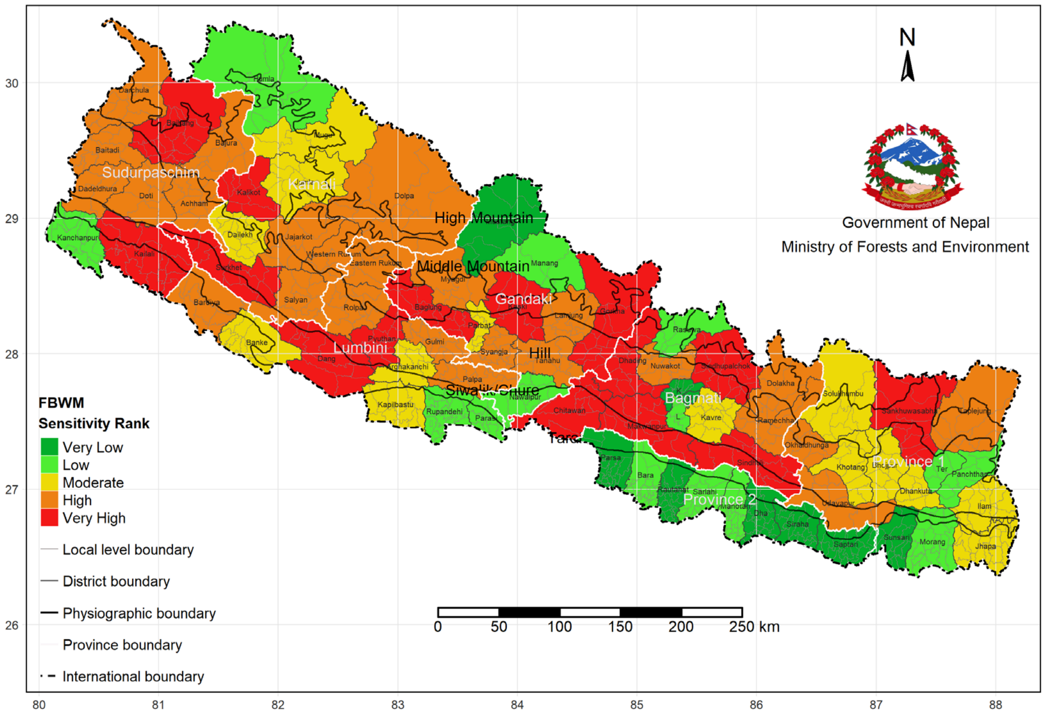


Figure 21: District-wise sensitivity of forests, biodiversity, and watershed management

Table 15: Districts with different sensitivity ranks

Sensitivity Rank	Districts	Number and Percentage
Very High (0.878 - 1)	Dhading, Makawanpur, Sankhuwasabha, Baglung, Sindhupalchok, Gorkha, Pyuthan, Kailali, Surkhet, Sindhuli, Chitawan, Dang, Kalikot, Kaski, Bajhang	15 (19.48%)
High (0.790 - 0.877)	Rolpa, Myagdi, Lamjung, Dolakha, Nuwakot, Western Rukum, Bardiya, Tanahu, Udayapur, Darchula, Syangja, Dolpa, Achham, Baitadi, Palpa, Salyan, Doti, Eastern Rukum, Okhaldhunga, Bajura, Taplejung, Jajarkot, Gulmi, Ramechhap, Dadeldhura	25 (32.47%)
Moderate (0.699 - 0.789)	Kapilbastu, Mugu, Dhankuta, Solukhumbu, Kavrepalanchok, Dailekh, Parbat, Banke, Arghakhanchi, Bhojpur, Khotang, Jhapa, Jumla, Ilam	14 (18.18%)
Low (0.620 - 0.698)	Humla, Rasuwa, Terhathum, Lalitpur, Rupandehi, Morang, Bara, Manang, Nawalpur, Kanchanpur, Panchthar, Sarlahi, Mahottari, Parasi	14 (18.18%)
Very Low (0.522 - 0.619)	Sunsari, Rautahat, Bhaktapur, Siraha, Mustang, Dhanusha, Parsa, Kathmandu, Saptari	9 (11.69%)

Sub-sector-wise, the findings reveal that a majority of districts represented moderate to very high sensitivity for forests and biodiversity (Figure 22 and 23). Thirty-two (32) districts exhibit a moderate level of sensitivity for forests and biodiversity, while 31 districts represent high to very high sensitivity. Only 14 districts are characterized by low (11) to very low (3) sensitivity.

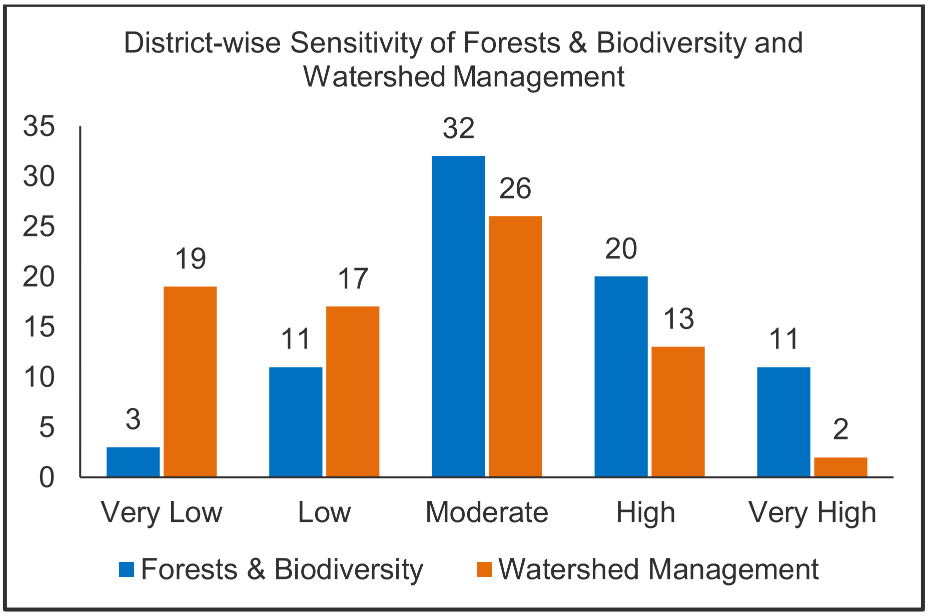


Figure 22: Districts-wise sensitivity of forests & biodiversity and watershed management

The findings revealed that Humla, Manang, and Rasuwa represented low sensitivity and Mustang was ranked very low sensitivity mainly due to low or non-existence of forest pests and diseases and IAPS, small forest fire-prone areas, positive change in rangeland, and few landslide-prone forest-related infrastructures. Similarly, districts located in eastern Terai regions such as Parsa, Rautahat, Sarlahi, Dhanusa, Saptari, and Morang were ranked low sensitivity owing to large per patch forest sizes, the occurrence of few fire incidences, low forest-dependent households, relatively few households engaged in forest-based enterprises, low mean slope degree, absence of snow-glaciers, and positive change of forests.

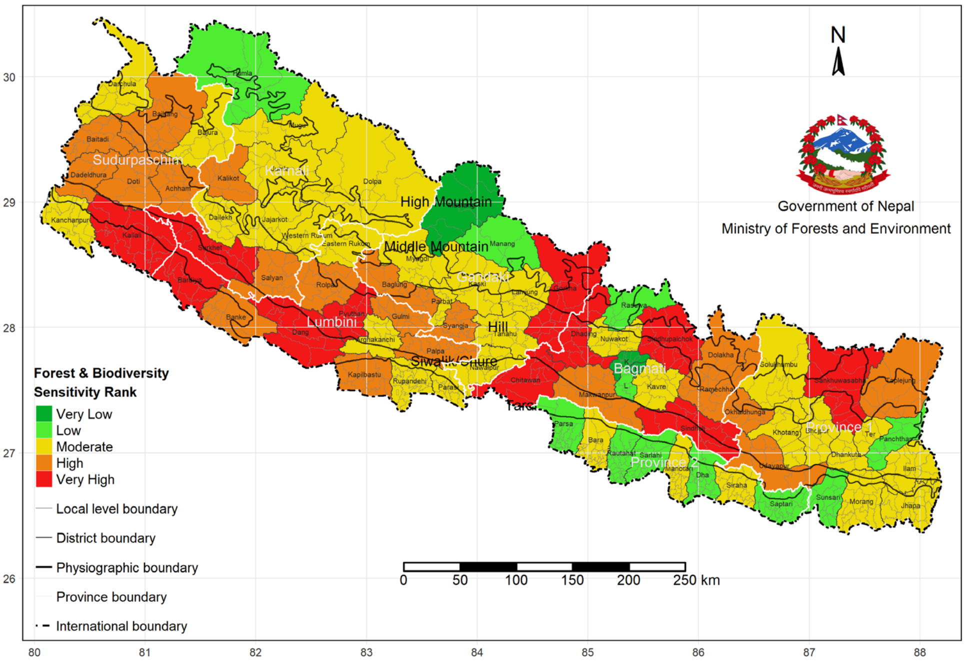


Figure 23: District-wise sensitivity of forests and biodiversity

Some mountain districts such as Gorkha, Dhading, Sindhupalchok, Sankhuwasabha, ad Taplejung represented very high and high sensitivity attributed to the presence of climate-sensitive forest types (e.g., *Abies spectabilis, Betula utilis*), small forest patch size, large sparse forest area, a large proportion of forest-dependent households including IPs, a large number of households directly engaged in forest-based enterprises, and negative change in agro-ecosystems and rangelands. Some far-western and western districts including Kailali, Bardiya, Surkhet, Banke, Dang, and Kapilbastu were ranked as high and very high sensitivity. Chitawan, Makwanpur, Sindhuli, and Udayapur were also ranked as high and very high in sensitivity for this sub-sector. This state of sensitivity is possibly associated with the occurrence of IAPS and forest fire, high encroachment, larger forest-fire-prone areas, many households directly engaged in forest-based enterprises, a high number of landslides, and flood-prone forest-related infrastructure.

In the case of watershed management sub-sector, around 47% of districts (36 with low 17 and very low 19) illustrate low to very low sensitivity, while 26 districts exhibit a moderate level of sensitivity (Figure 22 and 24). Only 15 districts represent high (13) to very high sensitivity (2).

The sensitivity of watershed management to climate change represents a generally uniform pattern (low and very low) across Terai districts except Kailali (moderate sensitivity). The low level of sensitivity in the Terai districts is mainly associated with the low landslide and erosion sensitivity, and the existence of small landslide-prone areas. The attributing factors for the moderate sensitivity of Kailali include a relatively high flood density and sedimentation yield.

More interestingly two districts such as Bajhang and Kaski were ranked as very high sensitivity for watershed management possibly due to large landslide-prone areas, high landslide and erosion sensitivity, high sedimentation yield, and drainage density. Mid-hills and high mountain districts generally represent a uniform pattern with moderate to high sensitivity. High sensitivity districts such as Darchula, Bajura, Dolpa, Western Rukum, Eastern Rukum, Myagdi, Baglung, Parbat, Gorkha, Lamjung, Tanahu, Dhading, Sindhupalchok, and Sindhuli were characterized by high sensitivity. The major factors attributed to this result were relatively high landslide and erosion sensitivity, sedimentation yield, and drainage density.

However, some high mountain districts such as Humla, Mugu, Manang, and Rasuwa represent a low sensitivity for watershed management possibly due to low landslide-prone area, low erosion sensitivity, and low drainage density in these districts compared to adjoining districts in this region.

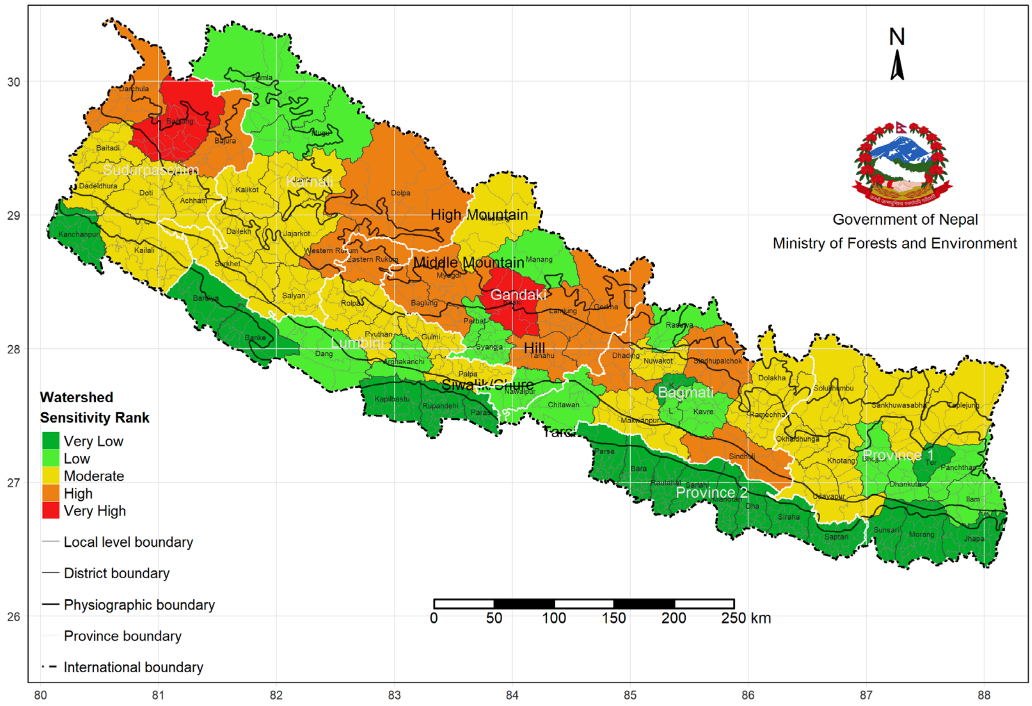


Figure 24: District-wise sensitivity of watershed management

The districts have different sensitivity ranks for two sub-sectors, i.e., forests and biodiversity and watershed management. It is observed that districts with similar sensitivity ranks for both sub-sectors produced the same level of sensitivity for the overall sector (i.e., forests, biodiversity, and watershed). Some districts such as Humla, Manang, Rasuwa, Lalitpur, and Panchthar characterized by low sensitivity for both sub-sectors yielded the same overall sensitivity rank (Figure 21- 24). Similarly, Kathmandu with very low sensitivity for both sub-sectors generated low sensitivity for the overall sector.

However, some districts with different sensitivity for two sub-sectors yielded an overall sensitivity with the dominating value of sub-sector. Mustang, for example, exhibits very low sensitivity for forests and biodiversity with moderate sensitivity for the watershed management and produced a very low sensitivity for the overall sector (Figure 21-24). Conversely, some districts produce aggregate sensitivity ranks other than the ranks they represented for the sub-sectors. For example, Kanchanpur is shown overall low sensitivity with a moderate sensitivity for forests and biodiversity and very low for watershed management. Similarly, Bardiya was ranked high sensitivity for the overall sector with a very low sensitivity for watersheds and very high sensitivity for forests and biodiversity.

6.1.2 Sensitivity across physiographic regions and provinces

The findings reveal a clear pattern of sensitivity for forests, biodiversity, and watershed management (Figure 25). The eastern Terai was ranked as low sensitivity due to the presence of large per patch forest sizes, absence of climate-sensitive forest types such as *Abies spectabilis, Betula utilis,* and *Pinus* species, low landslide, and erosion sensitivity, low mean slope degree, a relatively small percentage of forest-dependent households, absence of snow-glaciers, and positive change of forests.

Siwalik region was generally characterized by high sensitivity. The main attributing factors for this result could be the high incidences of forest fires, forest-fire-prone areas, increasing incidence of pests, disease, insects, and IAPS, high forest-fire-prone areas, and high flood and erosion sensitivity, sedimentation yield, and draining density.

The hill region generally represented high sensitivity except for small parts in eastern hills with moderate sensitivity. Attributing factors to the high sensitivity include the small forest patch size, higher proportion of forest-dependent households, high landslide-prone areas, high erosion, landslide, and flood sensitivity, increasing trend of IAPS, pests, insects, diseases, and forest fires.

The middle mountain region represented a mixed pattern with moderate to very high sensitivity. The far-western part exhibits very high sensitivity, and a small part of the western part of this region represented moderate sensitivity. High sensitivity in the far-western part is associated with climate-sensitive vegetation types, increasing trend of forest fire incidences, encroachment incidences, high forest-dependent households, a larger number of households engaged in forest-based enterprises, landslide-prone areas, high landslide and flood sensitivity, and a negative change in rangelands and agro-ecosystems.

In the case of the high mountains, two clear patterns of sensitivity appeared. The eastern part of the high mountains represented high sensitivity which could be due to the existence of climate-sensitive forest types; a negative change in rangelands, agro-ecosystems, and snow-cover areas; larger forest-prone areas; many households directly engaged in forest-based enterprises; high landslide-prone areas; and high erosion and landslide sensitivity.

Moderate sensitivity in the far-western high mountains despite the presence of climate-sensitive vegetation types, encroachment in few places, negative change in forests, and high landslide-prone areas could be due to absence or scarcity of IAPS, pests, insects, and diseases; low forest fire incidences; low flood sensitivity; and low drainage density.

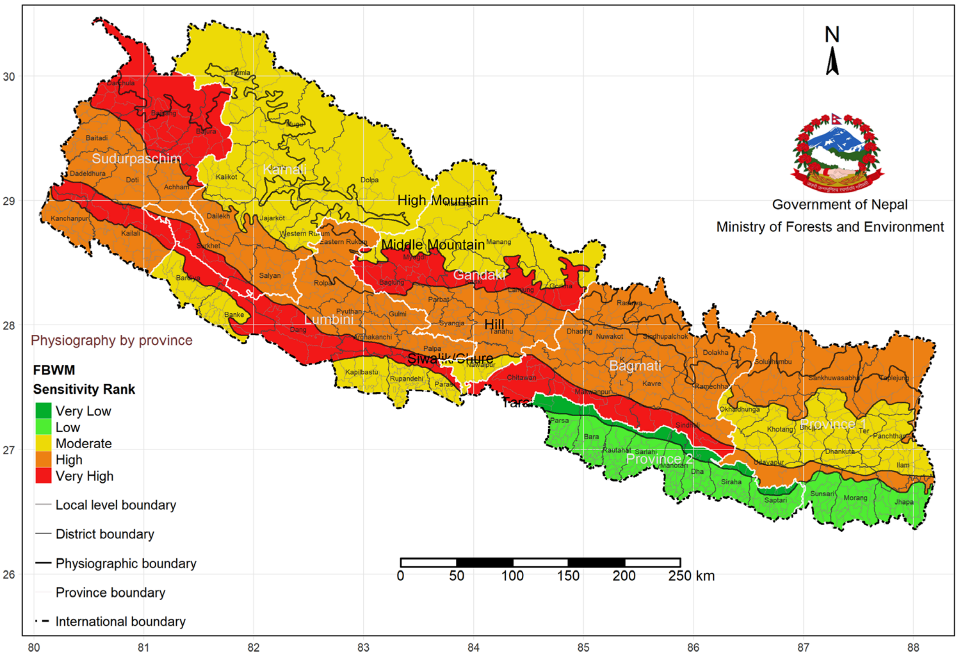


Figure 25: Sensitivity across physiographic regions and provinces

The findings of the physiography by province-level analysis show that Sudurpashchim and Bagmati Provinces represented very high sensitivity (Figure 25). These results for both provinces were generally associated with the existence of climate-susceptible forest types in high altitude regions, the occurrence of IAPS and forest fires in the lower region, high encroachment, larger forest-prone areas, a large number of households directly engaged in forest-based enterprises, the existence landslide-prone areas, a negative change in rangelands, agro-ecosystems, and snow-cover areas, and the existences of large flood and landslide-prone forest-related infrastructure.

Lumbini Province illustrated high to very high sensitivity excluding some lower parts of Banke and Bardiya and Kapilbastu, Rupandehi, and Parasi. The major factors for high sensitivity include relatively small forest patch size, a larger number of forest- and biodiversity-dependent households, large regenerating and semi-degraded forest area, larger forest-fire prone areas, high pest, disease, and insect incidences, a large number of households directly engaged in forest-based enterprises, the existence of relatively high landslide-prone areas, high landslide and erosion sensitivity, a negative change in rangelands and agro-ecosystems and the presence of large flood- and landslide-prone forest-related infrastructure. According to the district-level data, low sensitivity, despite many forest-dependent households and households engaged in forest-based enterprises, in Banke and Bardiya and Kapilbastu, Rupandehi, and Parasi were associated with some biophysical characteristics including low landslide sensitivity and landslide-prone areas, large forest patch size, and non-existence of climate-sensitive vegetation types.

Gandaki Province was also characterized by high sensitivity except for some parts of the part of Mustang, Manang, and Nawalpur with moderate sensitivity. Moderate sensitivity of these districts was generally attributed to the absence or scarcity of IAPS (especially Mustang and Manang) and pests, insects, and diseases, low sensitivity of floods, low number of landslide-prone forest-related infrastructures, and low draining density and sedimentation yield. However, other causes were the existence of climate-sensitive vegetation types, the negative change of forests, encroachment, landslide-prone areas, and high landslide and flood sensitivity.

The physiographic regions of Karnali Province represented moderate to very high sensitivity. This could be because the majority of parts of this Province represented with low or non-existence of IAPS, pests, insects, and diseases, low forest fire incidences, low flood sensitivity, and low drainage density despite the presence of high climate-sensitive vegetation types, encroachment in few places, negative change in forests, and high landslide-prone areas.

More interestingly, Province 2 represented low to very low sensitivity for this sector. As indicated in district-level data of this Province, low sensitivity could be due to the presence of large per patch forest sizes, non-existence of climate-sensitive forest types such as *Abies spectabilis, Betula utilis,* and *Pinus* species, low landslide and erosion sensitivity, low mean slope degree, a relatively small percentage of forest-dependent households, non-existence of snow-glaciers, and positive change of forests.

In the case of Province 1, the Terai region represented low while the hill region uniformly illustrates moderate sensitivity. However, Siwalik, middle mountain, and high mountain exhibit high sensitivity. High sensitivity in the high mountain region of this province is associated with the existence of climate-susceptible forest types, a negative change in rangelands, agro-ecosystems, and snow-cover areas, larger forest-prone areas, many households directly engaged in forest-based enterprises, hazard-prone areas (landslide-prone areas), erosion, and landslide susceptibility. However, high sensitivity in Siwalik regions is associated with high incidences of forest fires, IAPS, high forest-prone areas, high flood and erosion sensitivity, sedimentation yield, and draining density.

6.2 Adaptive capacity of forests, biodiversity, and watershed management

Adaptive capacity in this sector is interpreted as the ability of forests, biodiversity, and watershed resource management-related systems and institutions in terms of strategies, plans, programs, practices, and mechanisms, and human resources mobilized in the management that is supportive for the sector to adjust to potential damage of climate change as well as that facilitate the sector related system to take advantage of opportunities and to respond to consequences of climate change. Some adaptive capacity indicators for forests and biodiversity sub-sectors were the distribution of dense forest area, the status of income from the protected area, presence of buffer zones and community-based forest groups, land area under "landscape-level" conservation, the existence of forest rehabilitation plans, percentage of forests under sustainable and scientific forest management, number of human resources in place, annual seedling production, annual plantation of NTFP (non-wood) and medicinal plants, and number of plant species with established seed orchards. Other indicators for this sub-sector were the number of households engaged in women-managed CF, percentage of women-managed forest groups, percentage of women involved in forest groups' executive committee, number of enterprise use seasoning technologies, number of forest enterprises receiving insurance or any subsidies including concessional loan, and number of women owning forest-based enterprises. Indicators of watershed management sub-sectors include sub-watershed plan, number of Wetland conservation plan, management of conservation pond, adoption of watershed conservation and management technology, bioengineering activities, and riverbank protection.

Adaptive capacity was analyzed as the aggregate value of indicators for forests and biodiversity and watershed resources at three scales – district, provincial, and physiographic regions. District-level adaptive capacity ranks comprise the sector level and two sub-sectors - forests and biodiversity and watershed management. The following sector highlights the key results of the analysis.

6.2.1 Adaptive capacity across districts

The findings reveal that altogether 33 districts represent low to very low adaptive capacity, while only less than one-third of districts (25) have high to very high adaptive capacity (Figure 26 and Table 16). Around a quarter of districts (19) are with moderate adaptive capacity.

Five Terai districts including Sunsari, Dhanusa, Kapilbastu, Dang, and Kailali were ranked as very high adaptive capacity (Figure 26). The main attributing factors to this included a relatively larger forest area under sustainable forest management practice, more dense forest area, more annual production of seedling, and many human resources (staffs) deployed in the forest authority. These districts further represent many wetland conservation initiatives, management of conservation ponds, bioengineering activities, and riverbank protection interventions. Moreover, some districts such as Kailali, Dang, Kapilbastu were attributed to the larger land area under landscape conservation (Terai Arc Landscape), many households engaged in women-managed CF, the involvement of women in forest groups' executive committee, relatively high women-owned forest enterprises, and the existence of women-managed forests.

The rest of the eastern Terai districts such as Jhapa, Morang, Saptari, Siraha, Mahottari, Sarlahi, Rautahat, Bara, Parsa, and one western Terai district - Rupandehi were characterized by high adaptive capacity (Figure 26). Some associated factors to this included the distribution of dense forests, a land area under landscape-level conservation (in some districts – Rautahat, Bara, Parsa, and Rupandehi), the forest-based enterprise having insurance and subsidies, conservation of wetland, and management of conservation pond, implementation of bioengineering, and riverbank initiatives together with the adoption of sustainable forest management practices despite relatively few women-managed forest groups and household engagement in women-managed CF.

Some far-western mid-hills districts such as Dadeldhura, Doti, and Achham were ranked with a high adaptive capacity. This was associated with the implementation of several watershed-related activities including bioengineering, riverbank, conservation pond activities in these districts through ADB-supported "Building Climate Resilience of Watershed Mountain Eco-regions".

Similarly, some mid-hill districts such as Palpa, Kaski, and Tanahu were ranked as having high adaptive capacity possibly due to the implementation of several watershed-related activities, Ecosystem-Based Adaptation (EBA), management of conservation ponds, and bioengineering activities. Other factors were the implementation of sustainable forest management practices, the existence of dense forest area, seedling production and plantation of NTFP, the establishment of seed orchards, a higher number of households in women-managed CF, greater female representation engagement forest groups' executive committees, and a larger number of women-owned forest-based enterprises.

Districts including Sankhuwasabha, Manang, Dolpa, Mugu, Humla, Kalikot, Jumla, and Rolpa represent very low adaptive capacity. In these districts, a small percentage of the forest is dense, low female representation in the executive committee, few households in women-managed community forest groups, few women-owned forest-based enterprises, seed orchard establishment for only a few species, low seedling production, and plantation, lack of staff, implementation of very few watersheds management related activities such as bioengineering, riverbank protection, and conservation ponds.

Districts such as Taplejung, Panchthar, Terhathum, Solukhumbu, Bhojpur, Khotang, Okhaldhunga, Ramechhap, Rasuwa, Lamjung, and Mustang were characterized by low adaptive capacity. Some districts have a larger land area under landscape conservation. However, some factors such as low households in women-management community forest groups and women-owned enterprises, percentage of women represented in the executive committee, the establishment of seed orchard, dense forests, annual seedling production and plantation of NTFP, human and financial resources, implementation of few watersheds management related activities such as wetland conservation, management of conservation ponds, and riverbank activities, led to the low adaptative capacity.

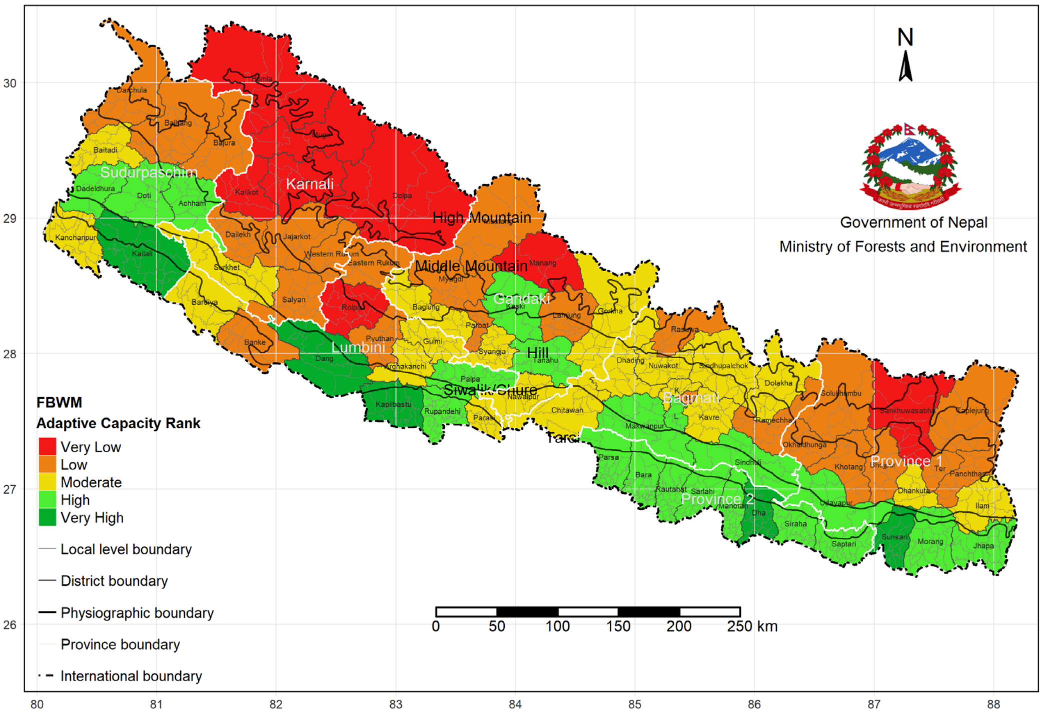


Figure 26: District-wise adaptive capacity of forests, biodiversity, and watershed management

Table 16: Districts with different levels of adaptive capacity

Adaptive Capacity Rank	Districts	Number and Percentage
Very High (0.769 - 1)	Kapilbastu, Sunsari, Kailali, Dhanusha, Dang	5 (6.49%)
High (0.572 - 0.768)	Makawanpur, Rautahat, Lalitpur, Tanahu, Udayapur, Achham, Siraha, Rupandehi, Palpa, Sindhuli, Morang, Bara, Doti, Kaski, Jhapa, Sarlahi, Mahottari, Parsa, Saptari, Dadeldhura	20 (25.97%)
Moderate (0.416 - 0.571)	Dolakha, Dhankuta, Nuwakot, Baglung, Sindhupalchok, Bardiya, Gorkha, Kavrepalanchok, Syangja, Surkhet, Arghakhanchi, Baitadi, Chitawan, Nawalpur, Kanchanpur, Parasi, Gulmi, Kathmandu, Ilam	19 (24.68%)
Low (0.272 -0.415)	Dhading, Rasuwa, Myagdi, Lamjung, Terhathum, Western Rukum, Solukhumbu, Dailekh, Bhaktapur, Parbat, Pyuthan, Darchula, Banke, Bhojpur, Salyan, Mustang, Eastern Rukum, Khotang, Okhaldhunga, Bajura, Taplejung, Panchthar, Jajarkot, Bajhang, Ramechhap	25 (32.47%)
Very Low (0.133 - 0.271)	Rolpa, Humla, Mugu, Sankhuwasabha, Dolpa, Manang, Kalikot, Jumla	8 (10.39%)

Sub-sector-wise, the findings show that over 55% (43) districts have low to very low adaptive capacity and only one-fifth of districts have high to very high adaptive capacity for the forests and biodiversity sub-sector (Figure 27 and 28). A quarter of districts (19) represent moderate adaptive capacity.

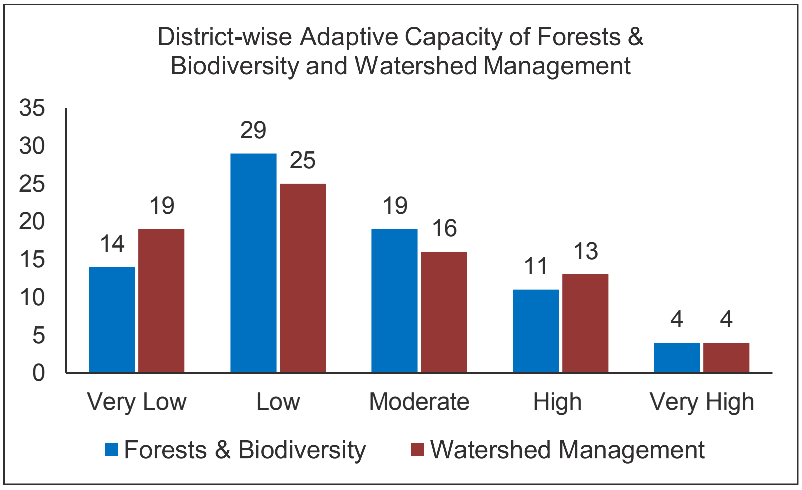


Figure 27: District-wise adaptive capacity of forests & biodiversity and watershed management

For the forests and biodiversity sub-sector, Kailali, Kapilbastu, Rupandehi, and Udayapur districts were ranked to have high adaptive capacity mainly due to more dense forests, a large area under landscape-level conservation (except for Udayapur), greater involvement of women in the forest user groups' executive committee, implementation of sustainable forest management, insurance and subsidies for forest-based enterprises, higher annual seedling production and plantation of NTFP, and the number of enterprises using seasoning technology.

Terai districts such as Jhapa, Morang, Sunsari, Dhanusa, Rautahat, Bara, Nawalpur, Parasi, Dang, and Kanchanpur and one hill district – Sindhuli were characterized by high adaptive capacity owing to implementation of sustainable forest management practices, women and IPs' involvement and their meaningful participation, insurance and subsidies for forest-based enterprises, production and plantation of NTFP seedling, and compliance with safe building practices.

Hills, middle mountain, and high mountain districts have uniformly low and very low adaptive capacity. Districts such as Sankhuwasabha, Ramechhap, Dolpa, Mugu in high mountain and Khotang, Ramechhap, Eastern Rukum, Western Rukum, Salyan, Jumla, Kalikot, Bajura, Achham, Doti, Baitadi, and Darchula in hills and middle mountain districts have very low adaptive capacity mainly due to small area under dense forests, low women engagement, low human resources, the establishment of seed orchards only for a few species, and lack of insurance and subsidies for forest-based enterprises.

Some districts such as Taplejung, Solukhumbu, Rasuwa, Manang, and Mustang were ranked low adaptive capacity despite the area under landscape conservation and collection of annual revenue. Other factors such as the maintenance of dense forests, strengthening of sustainable forest management, enhancement of women in forest groups' executive committees, women-managed CF, women-owned enterprises, accounted for the low adaptive capacity.

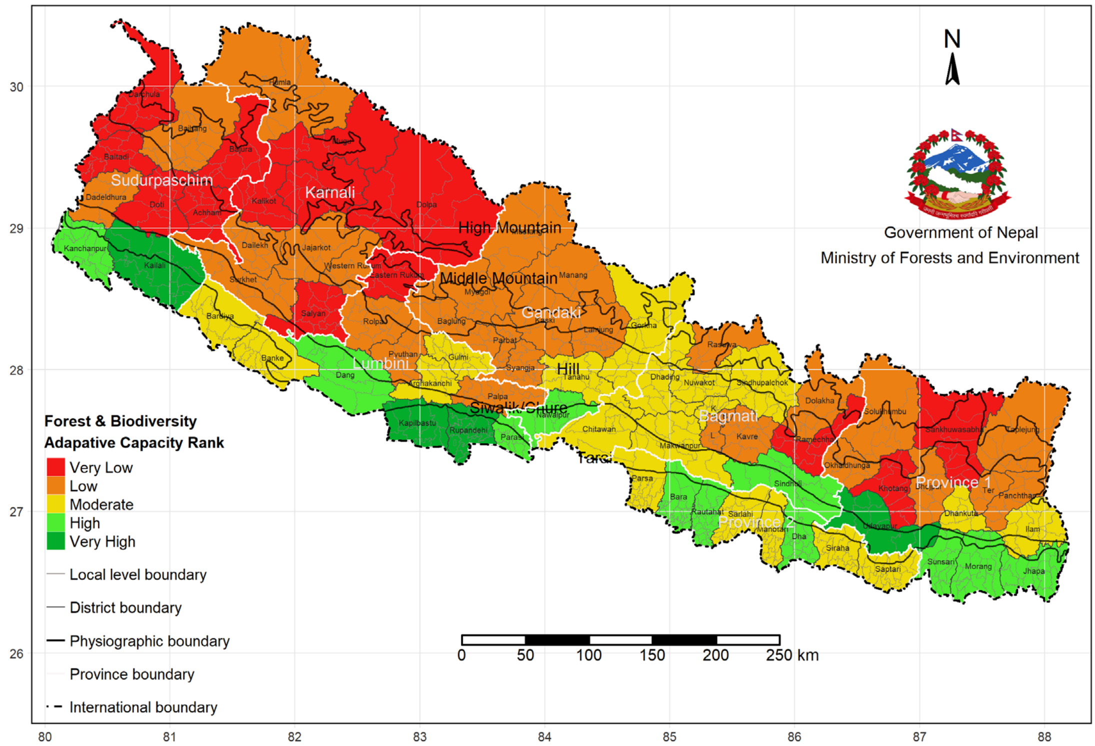


Figure 28: District-wise adaptive capacity of forest & biodiversity

In the case of the watershed management sub-sector, the findings reveal that nearly 60% (45 out of 77) of districts represent low to very low adaptive capacity for watershed management (Figure 27 and 29). Only four districts have a very high adaptive capacity and 13 districts have high adaptive capacity, while 16 districts have a moderate adaptive capacity.

Districts such as Doti, Achham, Dhanusa, and Saptari have a very high adaptive capacity mainly due to the development of watershed management plans and implementation of watershed management-related interventions such as bioengineering, riverbank protection, management of conservation pond, and wetland conservation initiatives. Such activities were implemented in Doti and Achham through the ADB project under the "Building Climate Resilience of Watershed Mountain Eco-regions" (ADB, 2012). Several conservation ponds are managed along with other bioengineering activities in the case of Dhanusa and Saptari.

Districts including Baitadi, Dadeldhura, Dang, Kaski, Palpa, and Makwanpur were ranked high in adaptive capacity. This state of adaptive capacity is associated with the implementation of watershed-related interventions such as bioengineering, riverbank protection, management of conservation ponds, and wetland conservation initiatives.

Several high mountain districts represented very low adaptive capacity in this sub-sector. These districts include Taplejung, Sankhuwasabha, Solukhumbu, Rasuwa, Manang, Mustang, Dolpa, Mugu, and Humla which have implemented limited watershed management activities.

Some districts have a distinct pattern of adaptive capacity in comparison to adjoining districts. As a case in point, the Bara district was ranked with a relatively low adaptive capacity comparing to its neighbors due to low management of conservation ponds, bioengineering, and riverbank protection activities. Similarly, Kaski was ranked with a high adaptive capacity in comparison to adjacent districts due to the development and implementation of many sub-watershed plans, management of conservation ponds, bioengineering, and river protection activities.

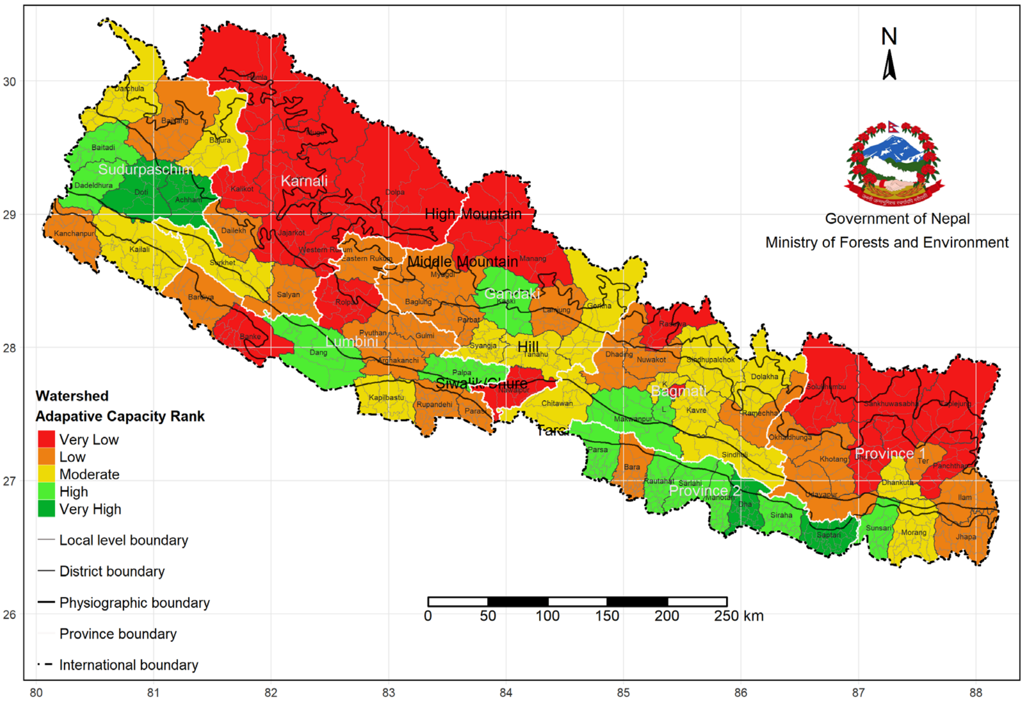


Figure 29: District-wise adaptive capacity for watershed management

Some districts have a different adaptive capacity for two sub-sectors. For instance, far-western mid-hills districts including Doti, Dadeldhura, Baitadi, and Achham represent a very high adaptive capacity for watershed management whereas most of these districts exhibit a very low adaptive capacity for forests and biodiversity mainly due to low dense forest area, seed orchards, presence of enterprises using seasoning technology, and provision of insurance and subsidies to forest-enterprise.

Similarly, the Bara district represents a low adaptive capacity for watershed management while this district exemplifies a high adaptive capacity for forests and biodiversity. Other districts including Rupandehi, Kapilbastu, and Parasi also demonstrate the varied pattern of adaptive capacity for two sub-sectors. These districts have a high to very adaptive capacity for forests and biodiversity but have moderate to high for watershed management.

6.2.2 Adaptive Capacity Across Physiographic Regions and Provinces

The findings reveal that there is a clear pattern of adaptive capacity across physiographic regions for forests, biodiversity, and watershed management (Figure 30). Both Terai and Siwalik regions generally appeared to have high to very high adaptive capacity. Siwalik region represented the east-west distinction of adaptive capacity whereby the eastern part of Siwalik is characterized as high adaptive capacity while the western part exhibits very high adaptive capacity. This pattern is opposite to the Terai region indicating that eastern Terai represented very high adaptive capacity while on the western side Terai regions of Lumbini Province appeared to have high adaptive capacity. The main attributing factors for high adaptive capacity for two regions include the extent of land area under landscape conservation (e.g., 13 districts – west from Rautahat to Kanchanpur except for Makwanpur) of this region assigned to Terai Arc Landscape, dense forests, the practice of several sustainable forest management practices (including scientific forest management), and a well-staffed forest authority (despite a low number of women-managed CF and women-owned enterprises). Other factors could be the implementation of wetland conservation initiatives, management of conservation ponds, bioengineering activities, and riverbank protection interventions.

On the contrary, hill regions have mixed patterns of adaptive capacity. Sudurpashchim and Gandaki Provinces of this region represented high adaptive capacity mainly due to the implementation of some watershed interventions (e.g., by ADB in Doti, Dadeldhura, and Achham and Phewa watershed activities in Kaski areas). While the hill regions of Province 1 and Karnali Province appeared to have low adaptive capacity due to the lack of insurance and subsidies for forest-based enterprises, non-use of seasoning technologies, and noncompliance with safe building codes.

Both middle mountain and high mountain regions generally represented low to very low adaptive capacity. Province 1 and Karnali Province show very low adaptive capacity in these regions, while the Sudurpashchim, Gandaki, and Bagmati Provinces represented low adaptive capacity. The main factors associated with low adaptive capacity include low women-owned enterprises, relatively low representation of women in the executive committee, only a few women-managed community forest groups, a small number of species with seedling orchards, and lack of implementation of watershed management-related interventions.

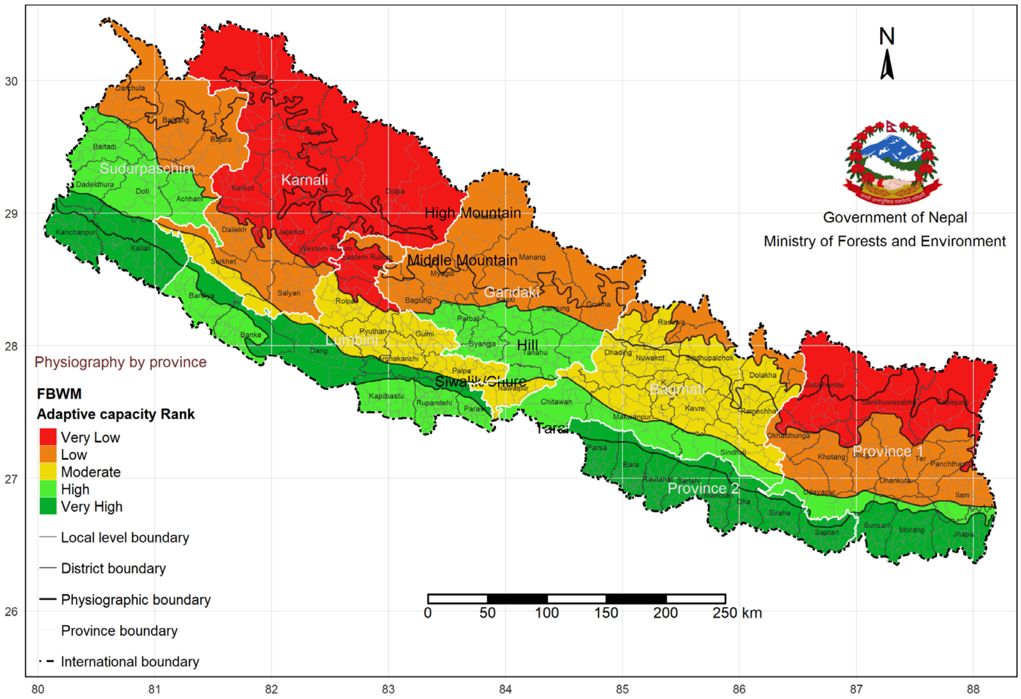


Figure 30: Adaptative capacity across physiographic regions and provinces

In the physiographic by province-wise analysis, Province 2 represented very high adaptive capacity possibly due to land area under landscape-level conservation (in some districts – Rautahat, Bara, and Parsai), the forest-based enterprise having insurance and subsidies, conservation of wetland, and management of conservation pond, implementation of bioengineering, and riverbank initiatives together with the adoption of sustainable management forest practices.

Province 1 has mixed patterns of adaptive capacity with very high to high adaptive capacity in the Terai and Siwalik region, and low to very low adaptive capacity in the hill, middle mountain, and high mountain region of this Province. Bagmati Province generally appeared to have moderate to high adaptive capacity. Small parts of the Siwalik region of this Province represented high adaptive capacity while hills and middle mountains exhibit a moderate level of adaptive capacity. In the Gandaki Province, the middle and high mountain region represented low adaptive capacity while some parts of the hill region appeared high adaptive capacity possibly due to the high involvement of women in the forest group executive committee, sustainable forest management practices, and implementation of watershed-management activities.

Most parts of the Karnali Province are characterized by very low adaptive capacity mainly owing to the small forest area under landscape-level conservation, dense forests, low women engagement in the executive committee, low human resources, the establishment of seed orchard, lack of insurance, and subsidies for forest-based enterprises, and limited watershed management activities.

Lumbini Province represented mixed patterns of adaptive capacity. The Terai and Siwalik region of this Province exhibit high to very high adaptive capacity. The main attributing factors to this were large areas under landscape-level conservation, the practice of diverse sustainable forest management practices, and dense forests. The hill part of this Province represented moderate adaptive capacity while the middle mountain region of this Province exhibit very low adaptive capacity.

Sudurpashchim Province has three distinct levels of adaptive capacity across the region. The Terai and Siwalik region have very high adaptive capacity mainly due to large areas under landscape conservation and dense forests. The hills with high adaptive capacity owing to the implementation of watershed management conservation. However, the middle mountain has low adaptive capacity possibly due to the non-existence of seed orchards, no use of seasoning technologies by enterprises, and no enterprises receiving subsidies and insurance provisions.

6.3 Vulnerability of forests, biodiversity, and watershed management

Vulnerability in this sector is understood as the propensity or predisposition of forests, biodiversity, and watershed resources to be adversely affected by climate change. In this assessment, the vulnerability has been measured as the difference between the sensitivity and adaptive capacity associated with the forests and biodiversity, and watershed management.
The vulnerability is assessed on three scales- districts, provincial, and physiographic regions. The following sections describe the results of these scales with possible factors associated with these outcomes.

6.3.1 Vulnerability across the districts

The findings reveal that most of the districts (over 60%) represent moderate to very high vulnerability to climate change, while around 38% of the districts are characterized by low to very low vulnerability to climate change (Figure 31 and 32, Table 17). More specifically High (28.57%) and very highly vulnerable (5.19%) districts together account for nearly one-third of the total districts, while one-quarter of districts is a moderate level of vulnerability to climate change.

The districts representing low to very low vulnerability form three clusters namely; eastern, mid, and far-western regions. The eastern cluster comprises Terai districts consistently east from Parsa with two inner Terai districts- Makwanpur and Udayapur and Dhankuta from the mid-hills. The mid-cluster comprises Tanahu from mid-hills and Terai districts west from Nawalpur, while the far-western cluster constitutes five adjacent districts including Kailali and Kanchanpur from Terai and Doti, Dadeldhura, and Achham from mid-hills.

Similarly, Kathmandu, Bhaktapur, and Lalitpur have very low vulnerability due to low to very low sensitivity and low to very high adaptive capacity. Unlike other mountain districts, Mustang exceptionally represents low vulnerability due to very low sensitivity despite low adaptive capacity. Very low sensitivity in Mustang is characterized by very low disturbance regimes including very low incidences of invasive alien plants, pests, diseases and fungus, and forest fire events, other intrinsic factors including low landslide-prone areas, low erosion, and landslide sensitivity, low sedimentation yield, and low drainage density despite the absence of women-managed CF and women-owned enterprise.

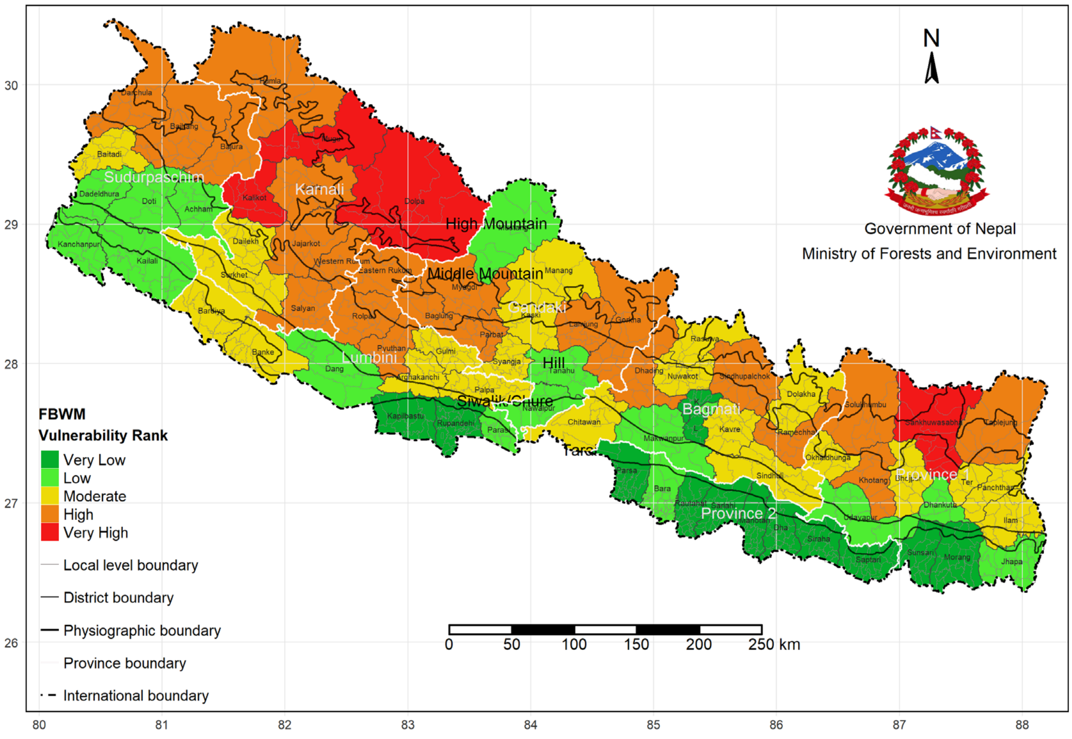


Figure 31: District-wise vulnerability of forests, biodiversity, and watershed management

Four high mountain districts including Sankhuwasabha from eastern mountain and Dolpa, Mugu, and Kalikot from western mountain exhibit very high vulnerability to climate change. This is associated with higher sensitivity to climate change with moderate to low adaptive capacity compared to their neighbors resulting from the low dense forest area, larger exposed watersheds and water bodies, low women-managed CF (in few districts), and women-owned forest-based enterprises.

Table 17: Districts with the different vulnerability of forests, biodiversity, and watershed management

Vulnerability Rank	Districts	Number and Percentage
Very High (0.786 - 1)	Mugu, Sankhuwasabha, Dolpa, Kalikot	4 (5.19%)
High (0.593 - 0.785)	Dhading, Rolpa, Humla, Myagdi, Lamjung, Baglung, Western Rukum, Sindhupalchok, Gorkha, Solukhumbu, Parbat, Pyuthan, Darchula, Salyan, Eastern Rukum, Khotang, Bajura, Taplejung, Jajarkot, Jumla, Bajhang, Ramechhap	22 (28.57%)
Moderate (0.418 - 0.592)	Rasuwa, Dolakha, Terhathum, Nuwakot, Bardiya, Kavrepalanchok, Dailekh, Syangja, Banke, Surkhet, Arghakhanchi, Baitadi, Palpa, Bhojpur, Sindhuli, Manang, Okhaldhunga, Chitawan, Kaski, Panchthar, Gulmi, Ilam	22 (28.57%)
Low (0.135 - 0.417)	Makawanpur, Dhankuta, Tanahu, Udayapur, Bhaktapur, Kailali, Achham, Mustang, Bara, Doti, Dang, Nawalpur, Kanchanpur, Jhapa, Parasi, Dadeldhura	16 (20.78%)
Very Low (0 - 0.134)	Kapilbastu, Sunsari, Rautahat, Lalitpur, Siraha, Rupandehi, Morang, Dhanusha, Sarlahi, Mahottari, Parsa, Kathmandu, Saptari	13 (16.88%)

Sub-sector-wise, most of the districts (over 70%) were ranked as moderate to very high vulnerability to climate change for forests & biodiversity (Figures 32 and 33). Districts of this category uniformly are situated in the mid-hills and the high mountain region except for a few mid-hill districts e.g., Kaski, Kathmandu, Bhaktapur, and Lalitpur, and Mustang in the high mountain region.

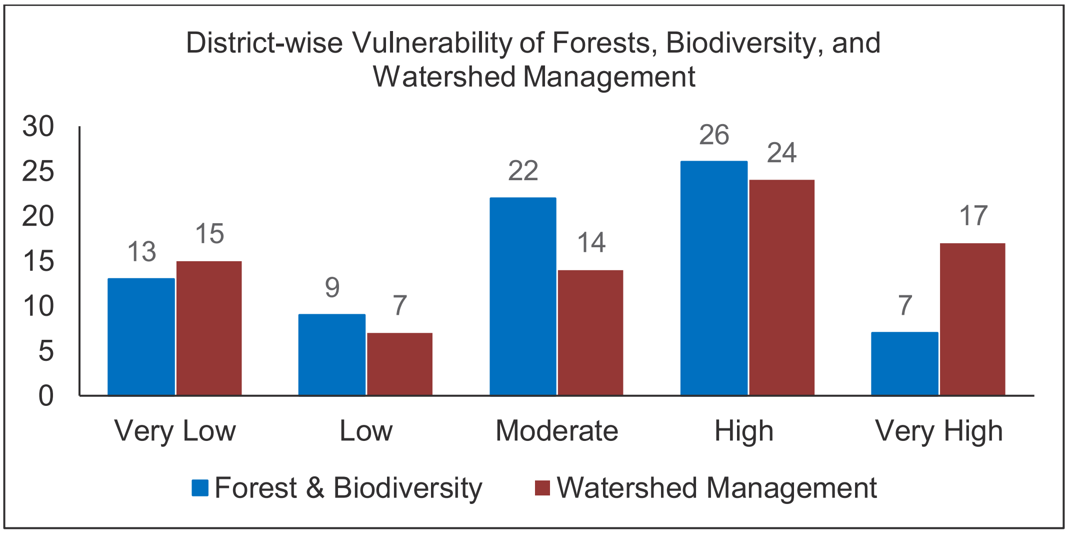


Figure 32: District-wise vulnerability of forests, biodiversity, and watershed management

Altogether seven districts represent a very high vulnerability. This category of vulnerability occurs in Sankhuwasabha, Ramechhap, Chitawan, and Pyuthan, and three western mid-hills districts: Doti, Achham, and Kalikot mainly due to high sensitivity and low adaptive capacity arising from relatively low representation of women in the executive committee, a small number of women-managed community forest groups, only a few species with seedling orchards, and implementation of watershed management-related interventions.

Low to very low vulnerable districts appeared largely in three clusters – eastern Terai, mid, and far western Terai. Four districts with low to very low vulnerability include Nawalpur to Kapilbastu in mid-Terai and Kailali and Kanchanpur in far western Terai. Eastern Terai districts (east from Parsa) have low to very low vulnerability except for Mahottari. Low to very low vulnerability is associated with moderate to low sensitivity and moderate to high adaptive capacity. Interestingly, a low vulnerability in Kailali was ranked mainly due to very high adaptive capacity despite very high sensitivity, while Mustang was ranked as very low vulnerability mainly due to very low sensitivity despite low adaptive capacity. The case of Kailali suggests that implementation interventions enhancing adaptive capacity can neutralize the sensitivity thereby reducing overall vulnerability. But for the Mustang case, although there presently is low vulnerability due to low sensitivity, this level may rise if interventions on adaptive capacity are not implemented.

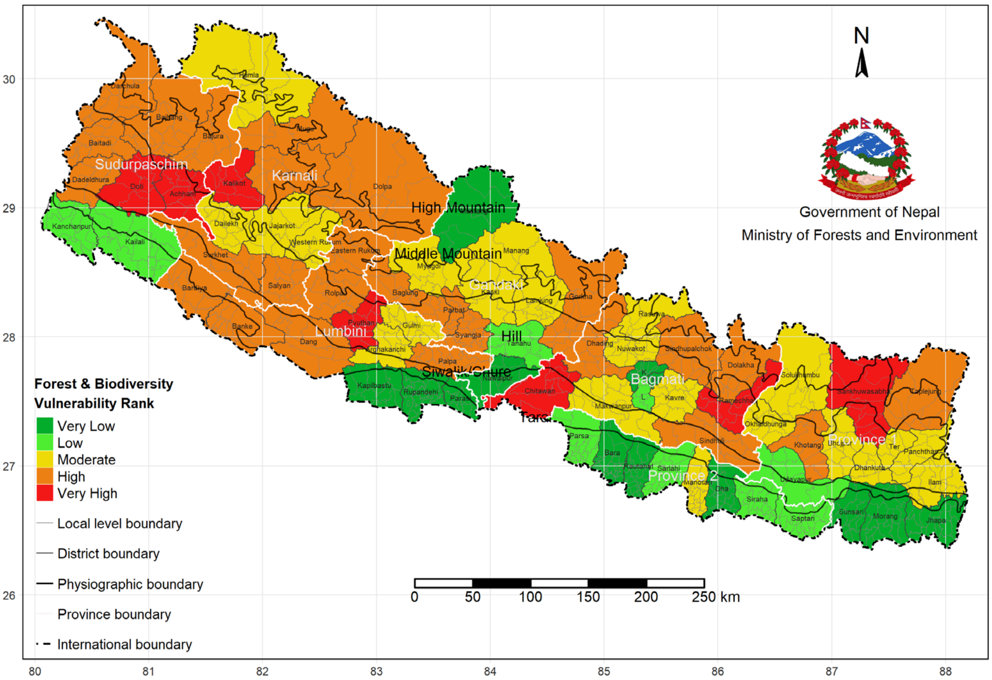


Figure 33: District-wise vulnerability of forests and biodiversity

For watershed management, over two-thirds of districts represent moderate to very high vulnerability to climate (Figures 32 and 34). The distribution of districts for this category forms a uniform pattern in mid-hills and mountain districts. Most of the Terai districts represent low to very low vulnerability except Banke, Bardiya, and Kailali in far western Terai, which exhibits a moderate level of vulnerability.

Low to very low vulnerability districts are clustered in eastern Terai, mid-Terai, and far western. Far-western districts comprise Kanchanpur from Terai and Achham, Doti, Dadeldhura, and Baitadi from the mid-hills. Low vulnerability in far-western mid-hills districts is attributed to multiple factors including the implementation of several watershed-related interventions (e.g., conservation of pond, watershed plan, bioengineering, and riverbank), a larger number of women representations in forest-management related decision-making committees, and the distribution of dense forest areas.

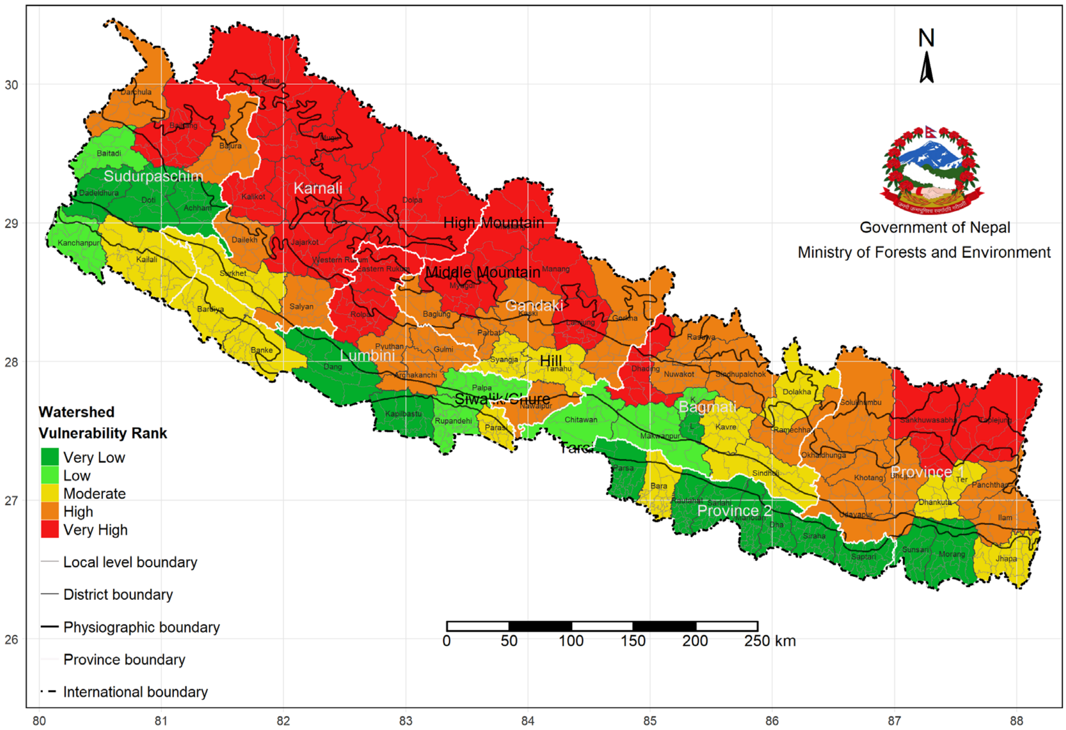


Figure 34: District-wise vulnerability of watershed management

Some districts represent a similar vulnerability rank for two sub-sectors – forests and biodiversity and watershed management (Figures 33 and 34). However, some districts have different vulnerability rank for two sub-sectors by one or two levels. For example, Mustang represents quite opposite vulnerability rank for two sub-sectors with very high vulnerability to watershed management and very low vulnerability for forests and biodiversity. On contrary, Doti, and Achham districts were ranked as a very low vulnerability for watershed management and as a very high vulnerability for forests and biodiversity.

A similar (low) vulnerability rank for both sub-sectors was observed in Kanchanpur. Similarly, Sankhuwasabha was ranked as a very high vulnerability for both forests and biodiversity, and watershed management. Kapilbastu, Rautahat, Mahottari, Dhanusa, Sunsari, and Morang show very low vulnerability for two sub-sectors.

The attributing factors for the difference in vulnerability rank between sub-sectors i.e., forests and biodiversity and watershed management are differences in sensitivity and adaptative measures between two sub-sectors, which directly corresponds with the differences in biophysical characteristics and the implementation of adaptation interventions. For example, the Annapurna Conservation Area Project (ACAP) and the establishment of the Division Forest Office both have a focus on the conservation of forests related to biodiversity and restoration of degraded forests through enhancement of local participation, landscape approach, and ecosystem-based adaptation.

Overall findings indicate that districts have a different level of vulnerability with a different value of indicators of biophysical, socio-economic, and management dimensions for sensitivity and adaptive capacity. Some districts such as Mustang, Manang, Dolpa, Mugu, and Humla represented high vulnerability despite low sensitivity. This is mainly due to low adaptive capacity which is largely associated with low women-managed CF, women representation in forest groups' executive committee, and women-owned forest-based enterprises despite supporting biophysical such as the area under landscape-level conservation level. This suggests that along with climate-friendly biophysical state and management practices, socio-economic dimensions especially gender equity and social inclusion aspects of indicators are equally crucial to enhance adaptive capacity thereby reduce vulnerability and climate risk.

The sub-basin and watershed wise assessment of the vulnerability also shows that the watersheds and subbasins in Karnali and Sundurpaschim provinces are more vulnerable in comparison to other provinces. Figure 35a shows that the sub-basins of the Karnali river basin have a higher vulnerability to climate change impacts. In the case of watersheds, the watershed in Province 1, Bagmati Province, and Gandaki Province have comparatively high vulnerability. On the contrary, the watersheds of Lumbini, Karnali, and Sudurpaschim Provinces have a comparatively higher degree of vulnerability (Figure 35b).

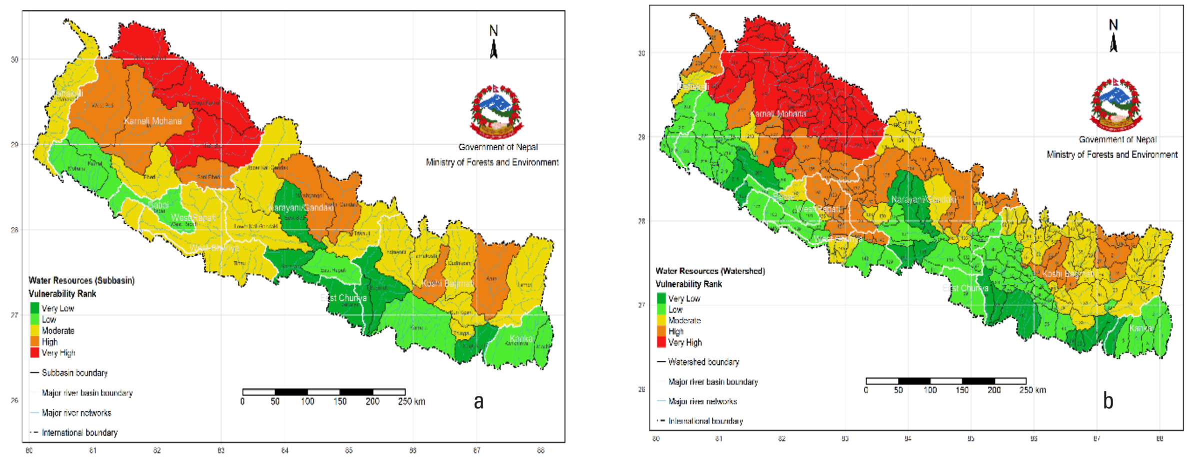


Figure 35: Vulnerability at a) sub-basin level; and (b) watershed level

6.3.2 Vulnerability across physiographic regions

The findings show a distinct pattern of vulnerability rank across the physiographic regions for this sector (Figure 36). The Terai region represented a very low vulnerability due to high adaptive capacity and low sensitivity. As discussed in the above sections (6.1.2), this region represented a low level of sensitivity due to the presence of large per patch forest sizes, non-existence of climate-sensitive forest types such as *Abies spectabilis, Betula utilis,* and *Pinus* species, low landslide, and erosion sensitivity, low mean slope degree, a relatively small percentage of forest-dependent households and households engaged in forest-enterprises, and positive change of forests. As discussed in Section 6.2.2 the Terai region was characterized by high adaptive capacity with the existence of land area under landscape conservation, dense forests, the practice of diverse sustainable forest management practice (including scientific forest management), a large number of human resources (staffs) deployed in the forest authority, and implementation of watershed management interventions.

As shown in Figure 36, the Siwalik region is characterized by low vulnerability despite relatively high sensitivity owing to incidences of forest fires, increasing incidence of pest, disease, insects, and IAPS, high forest-fire prone areas, high flood, and erosion sensitivity, and high sedimentation yield, and drainage density. However, high adaptive capacity is associated with the existence of land areas under landscape conservation, the practice of diverse sustainable forest management practices (including scientific forest management), a large number of human resources, and the implementation of watershed management interventions such as conservation pond.

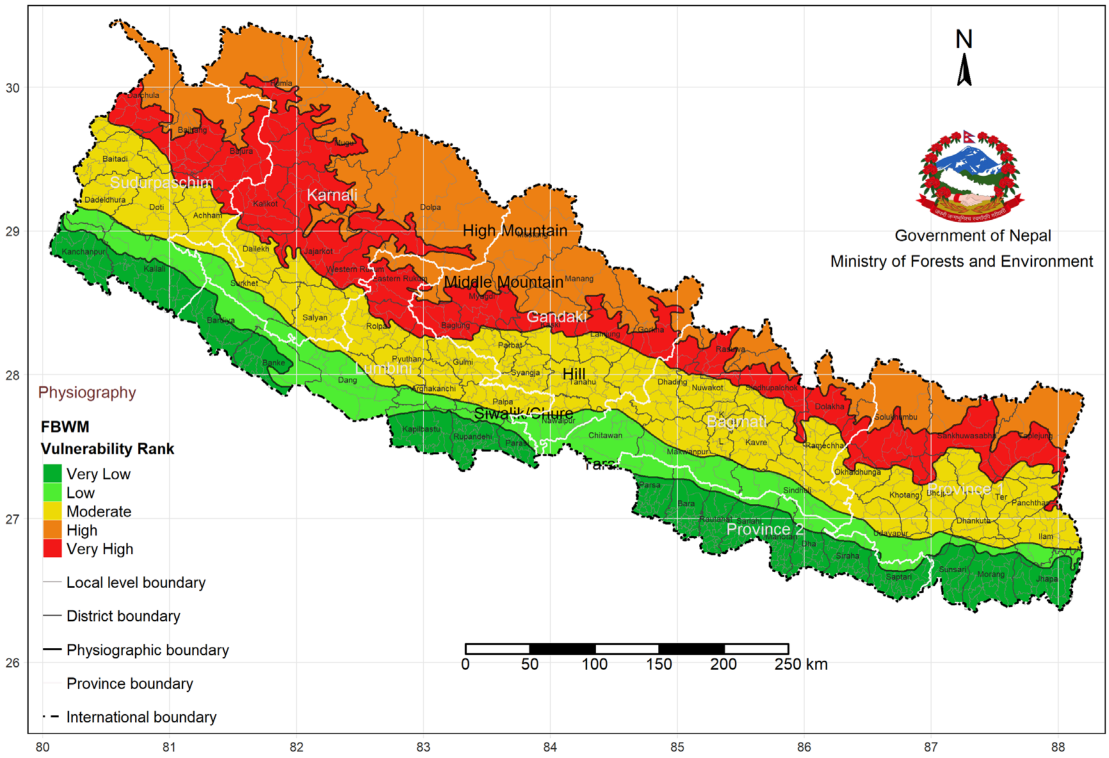


Figure 36: Vulnerability across physiographic regions

The hill region represented a moderate level of vulnerability possibly due to high sensitivity and a moderate to a high level of adaptive capacity (mixed pattern as described in Section 6.2.2). This region was ranked as high sensitivity due to small forest patch size, a higher percentage of forest-dependent households, high landslide-prone areas, high erosion, landslide, and flood sensitivity, increasing trend of IAPS, pest, insect, and diseases, and forest fires. However, with a moderate to a higher level of adaptive capacity which were attributed to the implementation of some watershed interventions (e.g., by ADB in Doti, Dadeldhura, and Achham and Fewa watershed activities in Kaski areas), provision of insurance and subsidies for forest-based enterprises, adoption of seasoning technologies in the enterprise and safe building codes, high percentage of women engaged in forest groups executive committee have mediated the sensitivity thereby resulting in a moderate level of vulnerability.

More interestingly middle mountain region represented very high vulnerability probably due to high sensitivity and low adaptive capacity. High sensitivity in this region was associated with coverage of climate-sensitive vegetation types, encroachment incidences, a larger number of households engaged in forest-based enterprises, the existence of landslides-prone areas, high landslide, and flood sensitivity, and a negative change in rangelands, and agro-ecosystems. This region was characterized by low adaptive capacity owing to low women-owned enterprises, relatively low representation of women in the executive committee, only a few women-managed community forest groups, the establishment of seedling orchards for a small number of species, and implementation of a few watersheds' management-related interventions.

High mountain regions represented high vulnerability. Like, the middle mountain region, this region was also characterized by a moderate to a high level of sensitivity and low to very low adaptive capacity attributed to the factors discussed in the middle mountain region including a low adaptive capacity for some parts with low women-managed forest groups, women-owned enterprises, and representation of women in groups' executive committee. Despite somehow similar attributes adjusted for both sensitivity and adaptive capacity for both regions, very high vulnerability for the middle mountain region could be due to some evolving disturbance regimes such as the incidences of IAPS and pests/insects, diseases, and fungus. As expressed by the local communities and literature review findings (Impact review section), incidences of IAPS and pests and diseases are slowly moving towards the middle mountains from lower regions. However, the boundary of sensitivity and adaptive capacity for the two regions should be investigated carefully.

6.3.3 Vulnerability across provinces

Province-wise vulnerability rank has been assessed by clustering district-wise data into each province. The rank of each province has been presented in terms of districts with different vulnerability ranks as presented in Figure 36a-g and Annex 6 respectively.

The findings of province-level vulnerability analysis reveal a variety of vulnerability ranks among provinces. The vulnerability rank of Province 2 districts ranges from low to high, while the rank for districts in other provinces arrays from very low to very high, suggesting that the vulnerability of other provinces is highly variable (Figure 37 a-g and Table 18). The number/percentage of districts of different vulnerability rank across provinces is also uneven.

Over two-thirds of districts of all provinces except for Province 2 represent moderate to very high vulnerability (Table 18). With a majority of districts in the low vulnerability category, Province 2 is less vulnerable than other provinces. Lumbini Province, Gandaki Province, Bagmati Province, and Sudurpashchim Province are characterized by high vulnerability. Karnali Province and Province 1 exhibit moderate vulnerability.

Table 18: Province-level vulnerability rank (in %)

Provinces	Number of districts with different Vulnerability Rank					Total # of districts
	Very High	High	Moderate	Low	Very low	
Province 1	2 (14.28)	1 (7.14)	7 (50)	3 (21.42)	1 (7.14)	14
Province 2	0 (0)	1 (12.5)	1 (12.5)	6 (75)	0 (0)	8
Bagmati	3 (23.07)	3 (23.07)	4 (30.76)	2 (15.38)	1 (7.69)	13
Gandaki	2 (18.18)	4 (36.36)	3 (27.27)	1 (9.09)	1 (9.09)	11
Lumbini	4 (33.33)	3 (25)	2 (16.66)	1 (8.33)	2 (16.66)	12
Karnali	2 (20)	2 (20)	3 (30)	2 (20)	1 (10)	10
Sudurpashchim	2 (22.22)	2 (22.22)	1 (11.11)	3 (33.33)	1 (11.11)	9
Total	14	17	21	18	7	77

Districts in Sudurpashchim Province represented a uniform pattern of vulnerability rank (Figure 37a). Terai districts of this province such as Kailali and Kanchanpur and two mid-hill districts (Doti and Achham) were ranked as low to very low vulnerability. High mountain districts such as Baitadi, Darchula, Bajhang, and Bajura were ranked high to very high vulnerability. Dadeldhura represents moderate vulnerability.

A mixed pattern of vulnerability is ranked in Karnali Province (Figure 37b). Districts such as Dolpa and Kalikot represent very high vulnerability whereas Jumla and Mugu were ranked as highly vulnerable districts. Surkhet, on other hand, represents very low and Dailekh and Humla exhibit a low level of vulnerability. This variation is mainly due to differences in biophysical characteristics and socio-economic contexts within the province. Low vulnerability in Humla may be due to low sensitivity resulting from low disturbance regimes (pests and diseases, IAPS), no loss or conversion of rangelands, and no threats of encroachment. Similarly, a very low vulnerability in Surkhet has mainly resulted from increased female representation in forest-related decision-making bodies, increased dense forest area, production of seedlings, and implementation of watershed conservation activities.

A large percentage (58.33%) of districts in Lumbini Province showed high and very high vulnerability (Figure 37c). Very high vulnerability districts include Bardiya, East Rukum, Rolpa, and Pyuthan and high vulnerability districts are Banke, Gulmi, and Arghakhanchi. However, Terai districts (Kapilbastu and Rupandehi) have a very low vulnerability, whereas Parasi was ranked as a low vulnerability. This result is consistent with the findings of a study on climate change and district risk context of Lumbini Province undertaken by PIF-OPM (Gautam et al., 2019). Some factors associated with the low to very low vulnerability include the implementation of sustainable forest management practices, distribution of dense forests, a large number of human resources, production and plantation of NTFP seedlings, and implementation of watershed management activities.

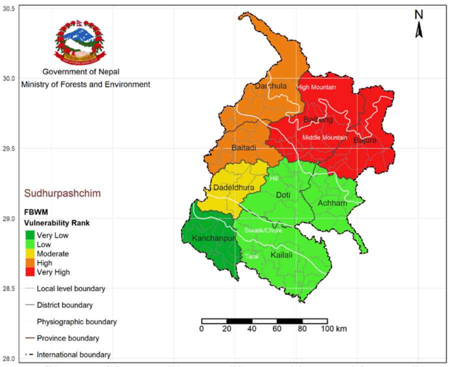
In Gandaki Province, Tanahu and Nawalpur districts were ranked as very low and low vulnerability respectively (Figure 37d). Other districts such as Gorkha, Manang, Myagdi, and Parbat were ranked as high while Lamjung and Baglung represented very high vulnerability.

Three valley districts in Bagmati Province (Lalitpur, Bhaktapur, and Kathmandu) were ranked low to very low vulnerability (Figure 37e). Four districts (Sindhuli, Kavrplanchowk, Makwanpur, and Rasuwa) were ranked moderate. Ramechhap, Sindhupalchok, and Dhading represented very high vulnerability, while Chitawan, Nuwakot, and Dolakha were ranked high vulnerability. Low to very low vulnerability in Lalitpur, Bhaktapur, and Kathmandu is associated with the number of women-owned forest-based enterprises, bioengineering and riverbank protection activities, management of conservation ponds, and preparation and implementation of sub-watershed plans.

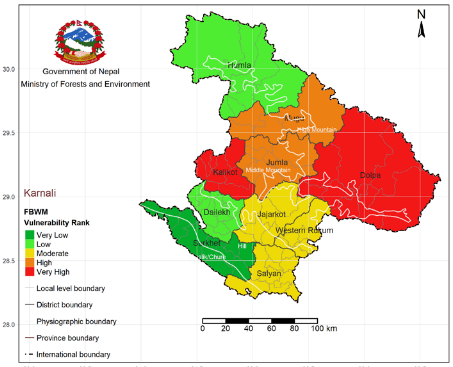
Of the eight districts in Province 2, Bara represents a high and Mahottari a moderate vulnerability rank, while the rest of the districts (6) of this province have a low vulnerability to climate change (Figure 37f). None of the districts in Province 2 show very high or very low vulnerability. The major attributing factors for low vulnerability in Province 2 despite the lack of women-managed CF and women-owned forest-based enterprises include the practice of sustainable forest management, seedling production, and plantation, and implementation of riverbank protection and conservation ponds.

In Province 1, two districts (Taplejung and Sankhuwasabha) were ranked at a very high vulnerability, while Khotang represents high vulnerability (Figure 37g). The majority of districts (Solukhumbu, Okhaldhunga, Bhojpur, Udayapur, Terhathum, Panchthar, and Ilam) showed moderate vulnerability. Sunsari is characterized by very low and Dhankuta, Morang, and Jhapa by the low vulnerability. Very low vulnerability in Sunsari district is mainly due to conservation of forests under wildlife reserves, implementation of riverbank activities and conservation of ponds, whereas very high vulnerability in Taplejung and Sankhuwasabha districts is associated with the small number of women-led households involved in forest management and implementation of the small number of wetland conservation, riverbank protection, and bioengineering activities, despite a larger area under landscape conservation.

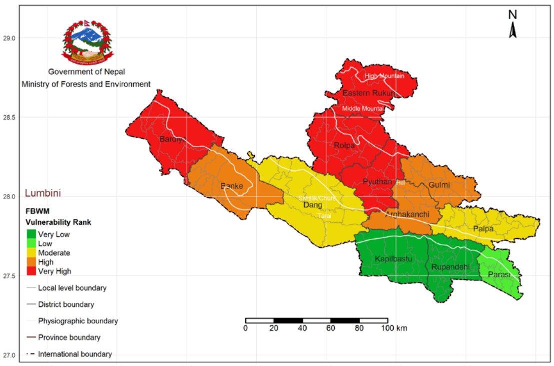
(a) Sudurpashchim Province



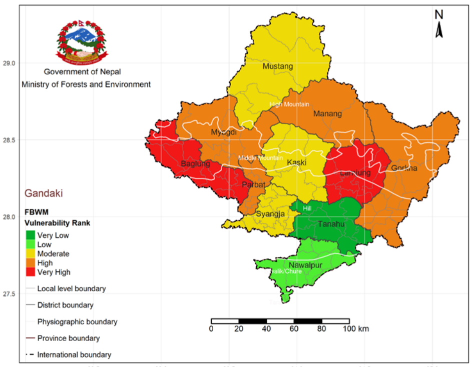
(b) Karnali Province



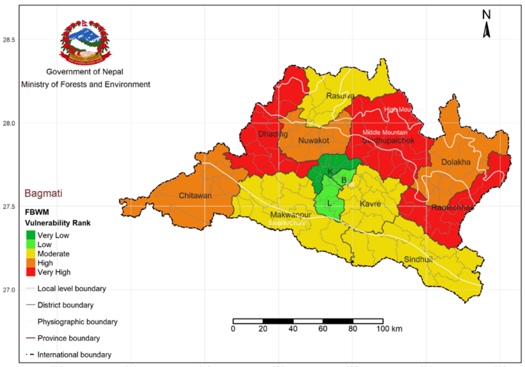
(c) Lumbini Province



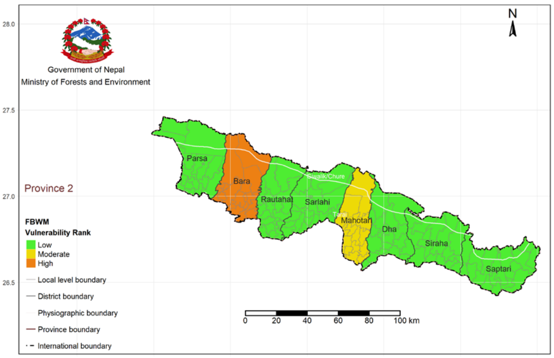
(d) Gandaki Province



(e) Bagmati Province



(f) Province 2



(g) Province 1

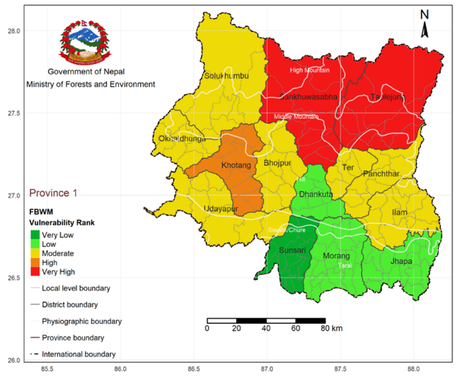


Figure 37: (a-g) Province-wise vulnerability rankings

Chapter 7

Projected Climate Change Risks

7.1 Climate change risks in forests, biodiversity, and watershed management

According to the IPCC AR-5, risk can be viewed as "the potential for consequences where something of value is at stake and where the outcome is uncertain," recognizing that risks will be characterized and perceived differently by people with diverse values. Risk is often represented as the probability of occurrence of hazardous events or trends multiplied by the magnitude of the consequences if these events occur (IPCC, 2015). In the assessment of this sector, risk was analyzed at three scales i.e., districts, provincial, and physiographic regions. It was determined as the result of the interaction between exposure, climate extreme events (as proxy hazards), and vulnerability of the sector, as suggested by the IPCC AR-5 (IPCC, 2014).

Indicators for exposure, sensitivity and adaptive capacity include variables such as gender equity and social inclusion (GESI) within the socio-economic dimension. As this dimension varies with time, analysis was done for two time periods: the present and the future. The current risk was analyzed as the interaction of current climate extreme events and the current levels of vulnerability and exposure, whereas future risk scenarios were analyzed using future climate extreme events and the current state of vulnerability and exposure since the latter two elements are influenced by socioeconomic status.

7.1.1 Risk Across the Districts

The district-wise risk at the baseline was categorized into five levels: very low, low, moderate, high, and very high. This baseline was also used to compare against the future scenarios of risk under RCP 4.5 (intermediate scenario) and 8.5 (worst-case scenario) for the medium term (2030) and long term (2050) respectively.

It was found that at the baseline, five districts—namely, Taplejung, Sankhuwasabha, Chitawan, Surkhet, and Bardiya—were ranked as having very high risk (see Figure 38 and Table 19), whereas eight districts—Dhading, Makawanpur, Gorkha, Sindhupalchok, Solukhumbu, Dolpa, Banke, Kailali, Salyan, Sindhuli, Dang, and Kaski—were ranked as having high risks. A quarter of the total number of districts was ranked as having a ranked with a moderate level of risk, and nearly half were ranked as having low to very low levels of risk.

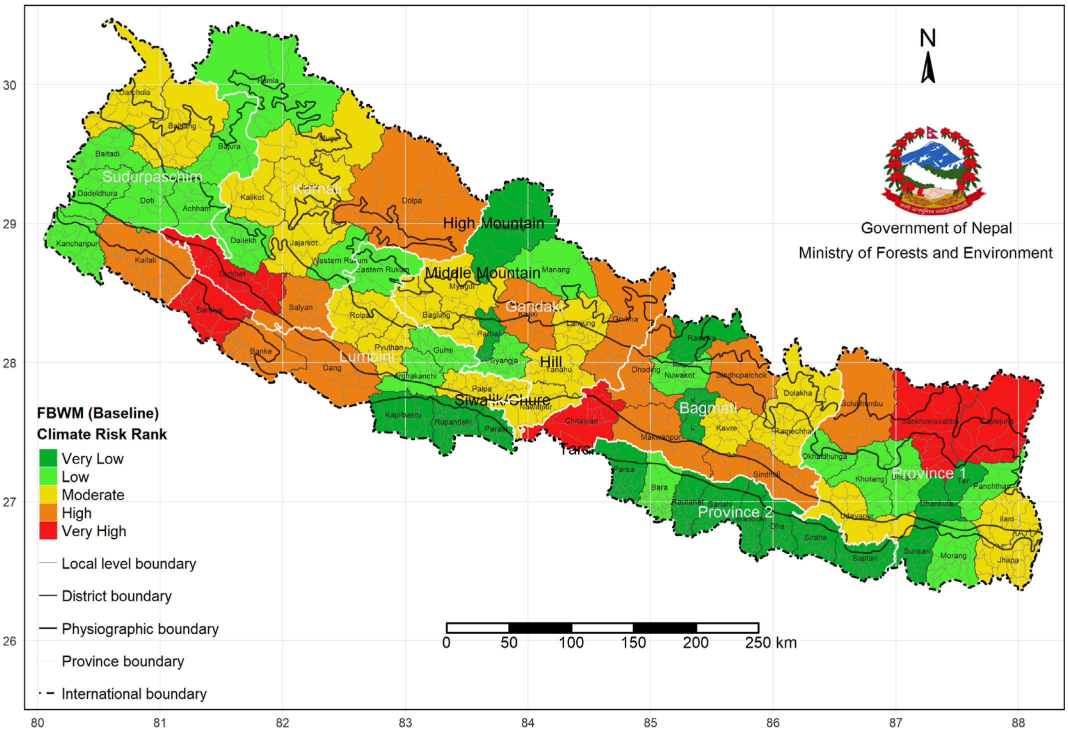


Figure 38: Different risk ranks for the baseline period

The very high level of risk in the Bardiya, Surkhet, Chitawan, Taplejung, and Sankhuwasabha districts was a result of the interaction between climate extreme events (proxy hazards), exposure, and vulnerability rank, with exposure being a key determinant. All five of these districts were also given very high to high exposure rankings, but their rankings for climate extreme events and vulnerability differed. For example, Chitawan had a high level of extreme events and a moderate level of vulnerability, whereas Bardiya represented had a high exposure ranking, resulting from its large forest and protected areas. Similarly, Taplejung was ranked with high levels of vulnerability and with a high level of climate extreme events, whereas Sankhuwasabha was characterized by high and very high levels of climate extreme events and vulnerability respectively. The high exposure ranking of all these districts was due to large forest areas and areas under landscape-level conservation; potential NTFP area; rangeland, agro-ecosystem, and wetlands; and exposed watersheds.

The subbasin-wise analysis of risk showed that there are high levels of risk from climate change impacts in the subbasins of Province 1, Gandaki, Karnali, and Sudurpaschim Provinces (see Figure 39a and 39b). Additionally, the watershed-wise analysis showed that Province 1, Bagmati, Karnali Provinces has comparatively high levels of risk.

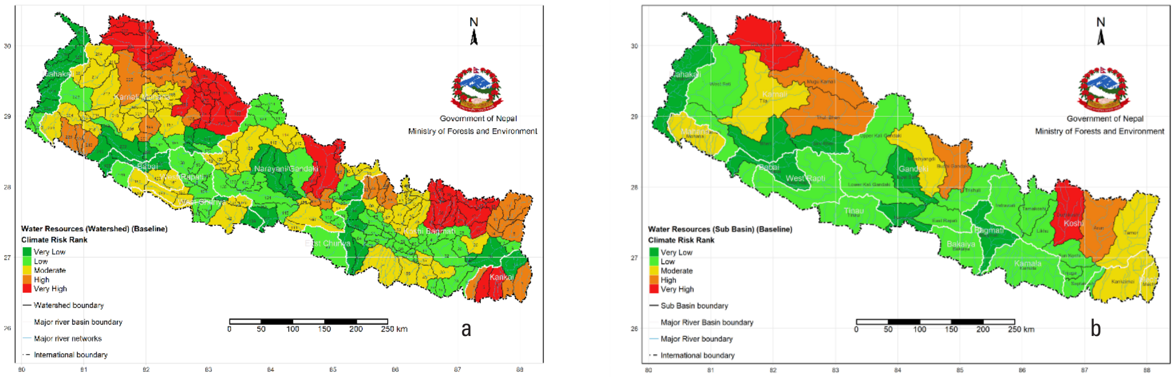


Figure 39: Risk of climate change impacts in terms of (a) watersheds and (b) sub-basin

Region-wise, districts in the eastern high mountain and western Terai regions were ranked with a very high level of risks, due to the combined effect of a very high level of exposure, very high to high levels of vulnerability, and high level of climate extreme events (see Figure 38). Increased vulnerability in these districts resulted from a combination of high sensitivity—due to factors such as landslide sensitivity and prone areas, erosion sensitivity, and sedimentation yield; small areas of forest patches and large areas of sparse forests—and low adaptive capacity—due to small percentages of women represented in executive committees, fewer women in forest management groups, and a small number of women-owned enterprises.

In contrast, other mid- and far-western mountain districts represented mixed levels of risk. For example, Dolpa represented high risks with very high exposure, and very vulnerability despite low climate extreme events whereas, Humla represents a low risk with very high exposure, high vulnerability, and low climate extreme events. Mustang was ranked as very low risk despite high exposure mainly due to low vulnerability and low climate extreme events.

Eastern Terai and eastern mid-hills districts were ranked as having low to very low levels of risks (except for Jhapa and Ilam). Their low level of risk was mainly due to the low levels of vulnerability and exposure, even though they had a high level of climate extreme events. Jhapa and Ilam were ranked as having moderate levels of risk, due to moderate vulnerability of the former and moderate level and high level of climate extreme events for both. Similarly, the far-western mid-hills districts—namely, Dadeldhura, Baitadi, Doti, Achham, Bajura, and Dailekh—were ranked as having a low level of risks.

The low to very low levels of risk in the eastern and mid-cluster Terai districts, including Kapilbastu, Rupandehi, Parasi, and Nawalpur, were attributable to low levels of exposure and vulnerability despite high levels of climate extreme events. In contrast, the high to very high levels of risk in western districts, including Kailali, Bardiya, Banke, Dang, Surkhet, and Salyan, were attributable to high levels of climate extreme events and high levels of exposure despite low vulnerability. This was mainly due to high numbers of women-managed community forests and the number of households involved, high representation of women in forest groups' executive committees, and high numbers of women-owned forest-based enterprises. The findings indicate that when coupled with low levels of exposure, low levels of vulnerability (in turn informed by enhanced adaptive capacity and low sensitivity) can reduce the overall levels of risk, even in regions/ districts with a very high level of climate extreme events. However, along with biophysical dimensions and management aspects, adjustment of socio-economic dimensions, including GESI, cultural values, and customary practices adopted by IPs, is critical for determining levels of adaptive capacity, sensitivity, and exposure. In many cases, the GESI factors, in particular, were found to be key in influencing levels of exposure, sensitivity, and adaptive capacity, and thereby overall vulnerability and risk.

Table 19: Districts with different risk rank at baseline period

Risk Rank	Districts	Number and Percentage
Very High (0.523 - 0.844)	Sankhuwasabha, Bardiya, Surkhet, Chitawan, Taplejung	5 (6.49%)
High (0.382 - 0.522)	Dhading, Makawanpur, Sindhupalchok, Gorkha, Solukhumbu, Banke, Dolpa, Kailali, Sindhuli, Salyan, Dang, Kaski	12 (15.58%)
Moderate (0.266 - 0.381)	Rolpa, Mugu, Myagdi, Lamjung, Dolakha, Baglung, Tanahu, Kavrepalanchok, Udayapur, Pyuthan, Darchula, Palpa, Nawalpur, Kalikot, Jajarkot, Jhapa, Jumla, Bajhang, Ramechhap, Ilam	20 (25.97%)
Low (0.150 - 0.265)	Humla, Nuwakot, Western Rukum, Dailekh, Syangja, Achham, Arghakhanchi, Baitadi, Bhojpur, Morang, Bara, Doti, Manang, Eastern Rukum, Khotang, Okhaldhunga, Bajura, Kanchanpur, Panchthar, Gulmi, Dadeldhura	21 (27.27%)
Very Low (0.006 - 0.149)	Kapilbastu, Rasuwa, Sunsari, Dhankuta, Terhathum, Rautahat, Lalitpur, Bhaktapur, Parbat, Siraha, Rupandehi, Mustang, Dhanusha, Sarlahi, Mahottari, Parasi, Parsa, Kathmandu, Saptari	19 (24.68%)

Regarding future risk scenarios, the findings revealed that risk scenarios will increase under both RCPs 4.5 and 8.5 by 2030 and 2050 respectively (see Table 20 and Figures 40 and 41). From five districts at baseline, the number of districts with a very high level of risk is expected to increase to seven districts in 2030 under both RCPs 4.5 and 8.5, meaning that risk under these two scenarios will roughly be the same for 2030. This trend will further continue, with the number of districts with very high risk expected to reach eight under RCP 4.5 by 2050 and ten under RCP 8.5 by 2050.

Table 20: Number of districts with different risk scenarios under RCP 4.5 and 8.5 for 2030 and 2050

Risk ranks	Baseline (Current)	RCP 4.5		RCP 8.5	
		Medium term (2030)	Long term (2050)	Medium term (2030)	Long term (2050)
Very high	5	7	8	7	10
High	12	13	12	13	13
Moderate	20	21	21	19	21
Low	21	19	20	20	18
Very low	19	17	16	18	15
Total	77	77	77	77	77

Under RCP 4.5, by 2030 the districts of Bajhang, Myagdi, and Jhapa are expected to move towards high risk from a moderate level of risk at baseline, while Gorkha and Sindhuli districts will likely shift towards a very high level compared to the high level at baseline. Further, the Rasuwa and Mahottari districts will shift towards low risk from very low risk. By 2050, Baglung will move towards very high-level risk from high-level risk at baseline.

Under RCP 8.5, Jhapa, Ilam, and Myagdi will move from a moderate level of risk in the baseline period to high risk by 2030. Gorkha and Sindhuli will move to very high levels from high, while Kanchanpur will shift to a moderate level from a low level of risks in the same period. Additionally, Mahottari will shift to low risk in 2030 from very low risk at baseline. By 2050, Bajhang, Myagdi, Ilam, Jhapa, and Dolakha districts will move towards high risk from moderate, and Baglung will move from high to very high. Further, Khotang and Bhojpur in the east and Bajura and Humal in the west will move towards moderate levels of risk from low risk at baseline, while Mustang, Rasuwa, and Dhankuta will shift to low risk from very low.

Five districts—Taplejung, Sankhuwasabha, Chitawan, Bardiya, and Surkhet—were ranked as having a very high level of risk at all three-time points—baseline, 2030, and 2050—under both RCPs 4.5 and 8.5. These districts were also ranked with very high exposure and moderate to very high vulnerability, and moderate to a high level of climate extreme events. Bardiya is expected to have a very level of risk under RCP 8.5 for 2050, primarily because climate extreme events will be at a high level during this period. Overall, the trend showed that future climate change is likely to elevate risk levels in the sector and have a negative impact on forests, biodiversity, and watershed management.

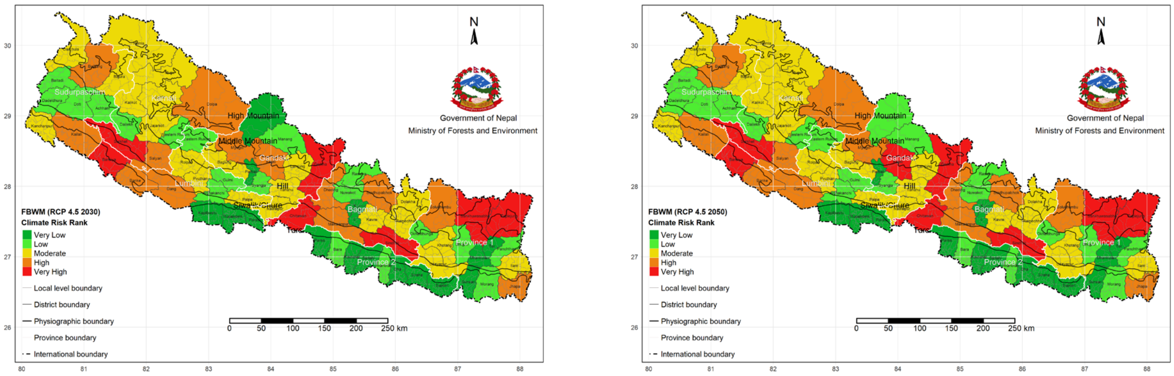


Figure 40: Risk scenarios under RCP 4.5 for 2030 (left) and 2050 (right)

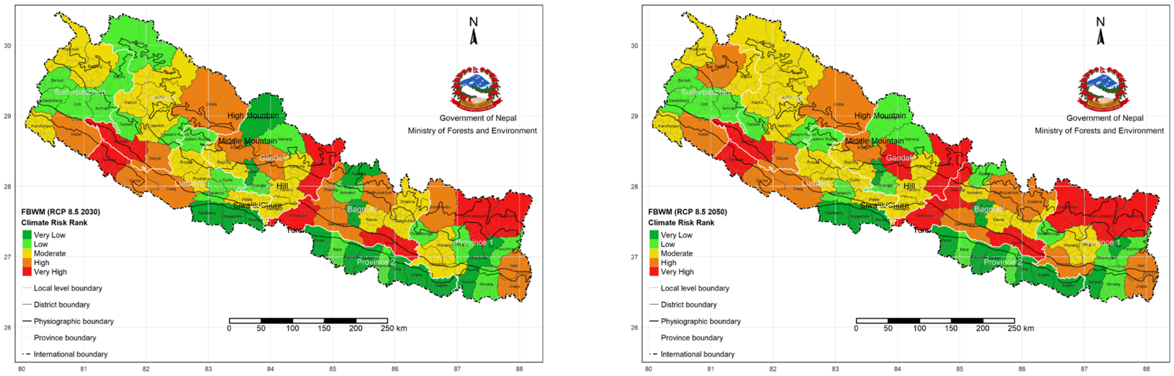


Figure 41: Risk scenarios under RCP 8.5 for 2030 (left) and 2050 (right)

7.1.2 Risk Scenarios Across the Physiographic Regions

It was found that the five physiographic regions have distinct patterns of risk at the baseline level. The Terai region was ranked as having very low risk despite the high level of climate extreme events (see Figure 42), which could be due to its very low vulnerability level as discussed in section 6.3.2.

At the baseline, the Siwalik region was ranked as having a very high level of risk, which is likely related to the high level of climate extreme events experienced by it. The hill region was found to be low-risk with moderate levels of climate extreme events and moderate vulnerability, which is probably due to its low level of exposure. Additionally, despite experiencing a moderate level of climate extreme events, the middle mountain region was ranked as having very high risk due to very its high vulnerability level. The high mountain region appeared to be at moderate risk, probably due to the mixture of high vulnerability and relatively low level of climate extreme events.

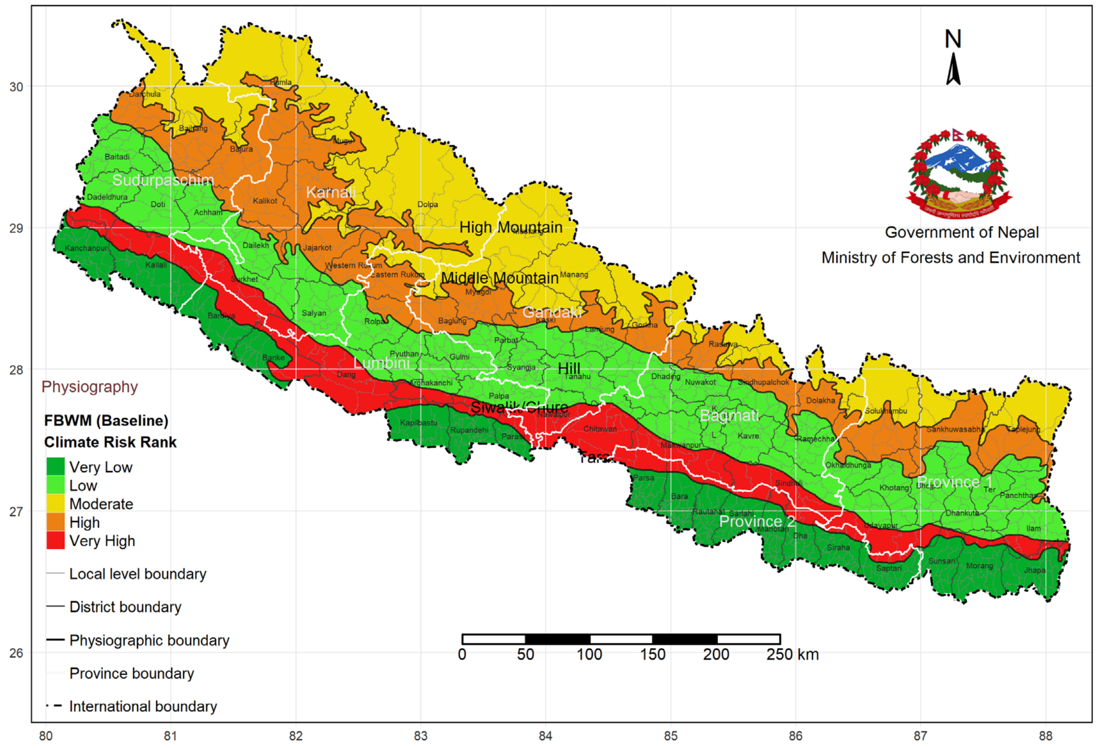


Figure 42: Baseline risk across physiographic regions

The Siwalik region will likely remain at very high risk under RCP 4.5 by 2030 (see Figure 43; left) compared to baseline (see Figure 42). The risk of the high mountain region will shift to very high in RCP 4.5 2030 from its moderate level at baseline, whereas the hill region will shift from low to moderate, and the middle mountains will shift from high to very high. Under RCP 4.5, the risk levels in the long term (2050) (see Figure 43; right) will remain the same as in the medium term (2030) (see Figure 43; left).

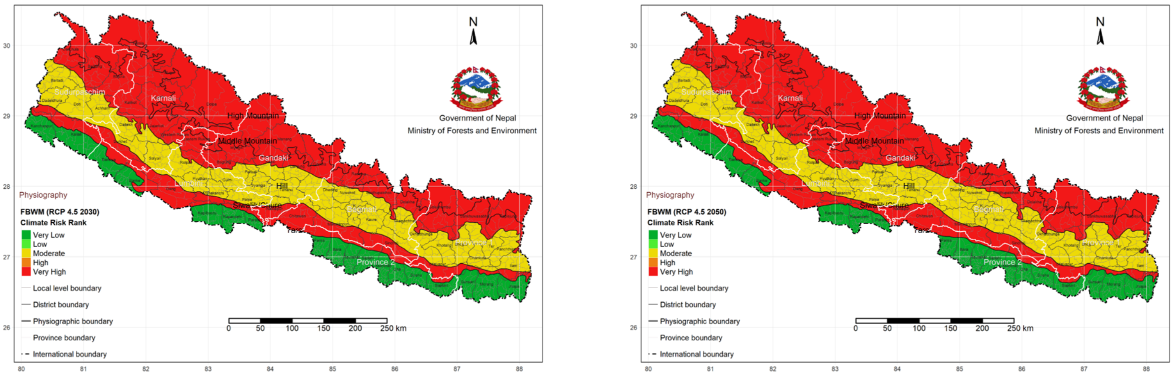


Figure 43: Physiographic region-wise risk scenarios for 2030 (left) & 2050 (right) under RCP 4.5

As in under RCP 4.5, the findings showed that for RCP 8.5, the risk of the Siwalik region will remain very high by 2030 (see Figures 42 and Figure 44; left). Similarly, a moderate level of risk in the high mountain region will change into high risk by 2030. In the Terai, hill, and middle mountain regions, the risk will remain unchanged under RCP 8.5 by 2030.

Under RCP 8.5, the risk in the hill region will shift to a high level by 2050, from low risk in the baseline period. Further, the future risk scenarios of the Siwalik and high mountain regions under both RCPs 2030 and 2050 will be high to very high (see Figure 44; left and right).

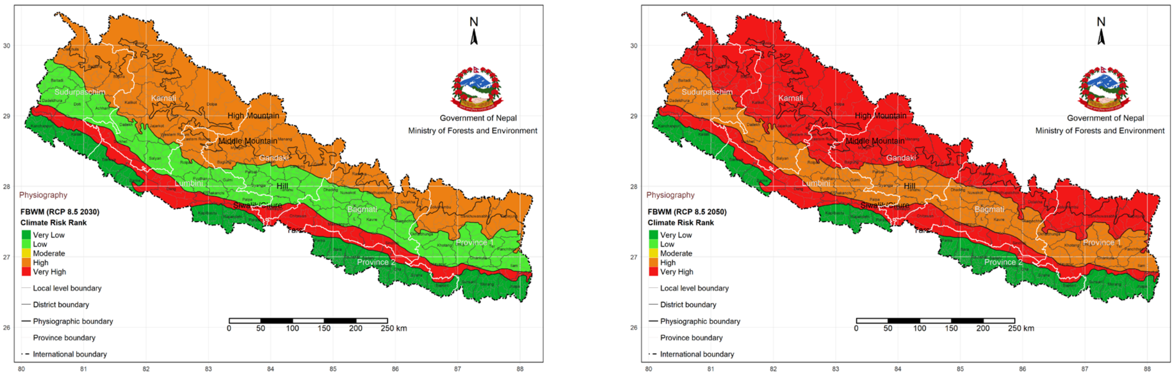


Figure 44: Physiographic region-wise risk scenarios for 2030 (left) & 2050 (right) under RCP 8.5

The findings generally point to the conclusion that the high mountain regions currently have a moderate level of risk. However, in the future, this level will move towards high risk, in line with the middle mountain region. The risk of Siwalik will remain as high in the future as it is now. The hill region will shift from being a low-risk zone to a moderate- to high-risk zone under different RCPs.

7.1.3 Risk scenarios across physiography by provinces

When considering the intersection between physiographic regions and provinces, the findings revealed that Karnali Province generally has a moderate level of risk at the baseline, except for a small part of its Siwalik region that has a very high level of risk (see Figure 45). Despite experiencing a high level of climate extreme events, Province 2 has low to very low levels of risk due to low levels of vulnerability and exposure. With a moderate to a high level of risk overall in Bagmati, the Siwalik region in the province, including the Chitawan valley, has a very high level of risk due to high levels of climate extreme events (see section 5.1.2), high exposure (see section 5.2.2), and high vulnerability (see section 6.3.3).

Sudurpashchim Province generally has mixed patterns of risk, with moderate risk in the middle mountain regions, high risk in the Terai and middle mountain regions, and low risk in the hill regions. In the case of Lumbini Province, the middle mountain regions are at low risk, the Terai and hill regions at moderate risk, and Siwalik region at very high risk. Gandaki Province is also characterized by varying levels of risk across different physiographic regions. The middle mountain regions are at high risk, whereas the remaining regions are at moderate risk.

As shown in Figure 45, Province 1 was found to have three patterns of risk that vary according to physiographic regions. The Terai region is at low risk, while the Siwalik and hill regions are at moderate risk. The middle and high mountain regions of this province are at very high risk mainly due to high levels of climate extreme events (see section 5.1.2), very high exposure (see section 5.2.2), and high vulnerability (see section 6.3.3).

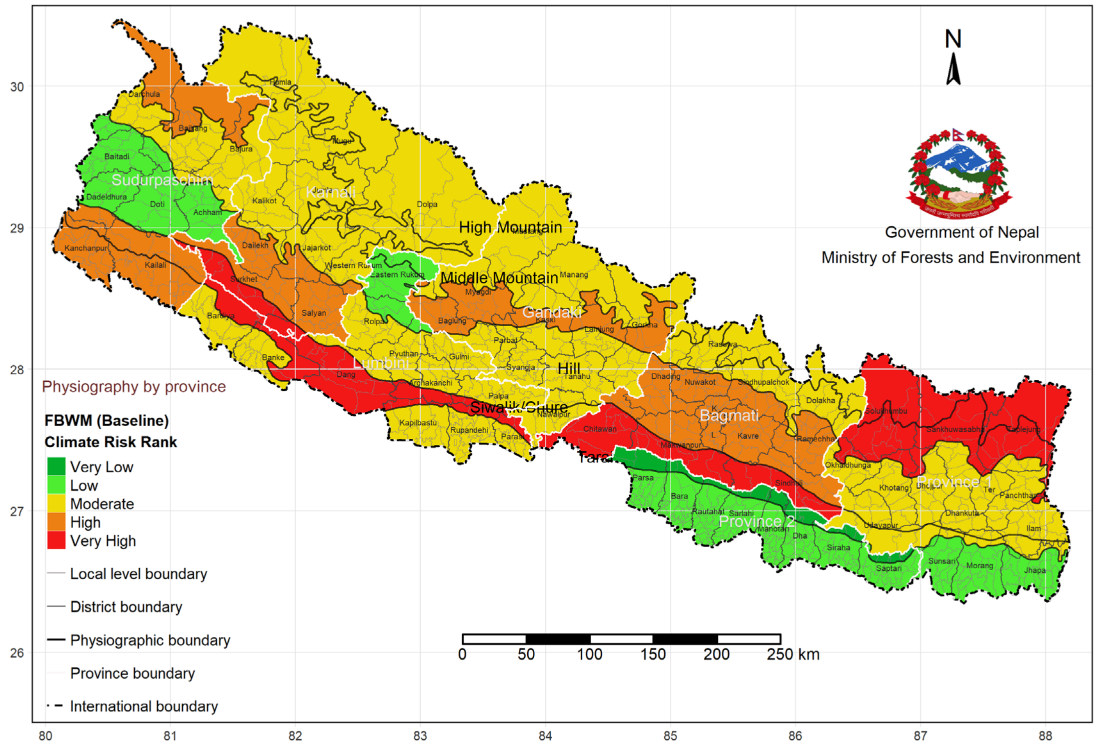


Figure 45: Physiography-by-province-level risk ranks

Overall, the findings revealed that the risk levels of Province 1, Province 2, and Bagmati Province will remain unchanged by 2030 and 2050 under RCP 4.5 (see Figure 46, left; and Figure 46, right) compared to the baseline (see Figure 45). This indicates that the risk of Province 2 will remain at a low level under RCP 4.5 in the medium and long terms. In the same periods, the risk in Bagmati Province will vary according to regions, with moderate levels in the hill and middle mountain regions, and very high levels in the Siwalik region.

However, the risk in other provinces will move towards higher levels. A moderate level of risk in the middle mountain region of the Sudurpashchim Province will shift to high risk under RCP 4.5 by 2050. The amount of area under this high level of risk in this region will also increase by 2050 (see Figure 46, left and right). A similar change will occur in the middle mountain region of Karnali Province, whereby a moderate level of baseline risk will change to a high level by 2030 (see Figures 45 and 46, left).

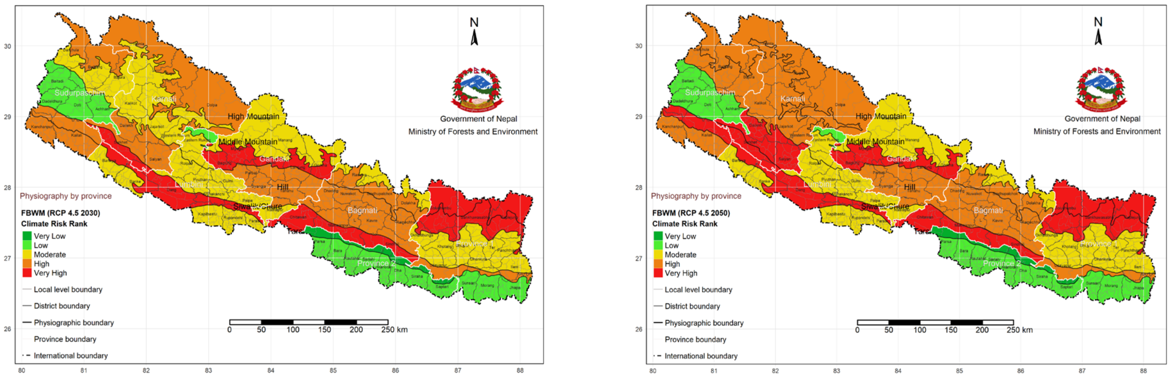


Figure 46: Physiography-by-province-wise risk ranks for 2030 (left) and 2050 (right) under RCP 4.5

In the case of Gandaki Province, moderate baseline risk in the high mountain region will remain the same under both scenarios of RCR 4.5, whereas the middle mountain region will shift from high to very high-risk regions under these scenarios.

Under RCP 8.5 (2030), there will be a very slight change for Province 2 (see Figures 45 and 47, left). The overall risk level in Bagmati Province will be unchanged by 2030; however, the high level of baseline risk in its middle mountain region will shift to a very high level under RCP 8.5 (2050). Similarly, in the Gandaki Province, the moderate level of risk in the Siwalik and high mountain regions will remain unchanged under RCP 8.5 (2030). However, the levels of moderate risk in the hill region and high risk in the middle mountain regions will shift to high and very high levels of risk respectively. These levels will further shift towards high risk by 2050 meaning that Gandaki Province will experience high risk in the future under both RCPs.

There will be no change in risk level in any of the regions in Lumbini Province under both RCPs by 2030, compared to the baseline risk. However, the low level of risk in the hill region of this province will change to the moderate level under both scenarios of RCP 8.5 by 2050.

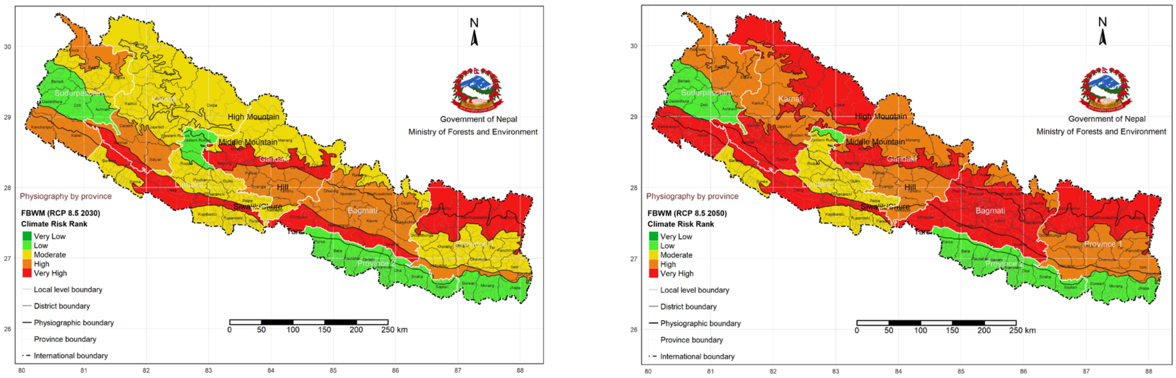


Figure 47: Physiography-by-province-wise risk ranks for 2030 (left) and 2050 (right) under RCP 8.5

A similar pattern is expected to occur in the Karnali and Sudurpashchim Provinces. In the high mountain region of the former, the level of risk will go from being high to moderate (under RCP 4.5) by 2030. No other changes will occur under both scenarios of RCPs 4.5 and 8.5 by 2030, except that the moderate level of baseline risk in the middle and high mountain regions of Karnali Province will shift from high to very high levels of risk by 2050. In the case of Sudurpashchim Province, the moderate level of baseline risk in the middle mountain region will shift to a high level of risk by 2050.

The aforementioned findings generally indicate that while the risk levels in some provinces will remain unchanged, several will experience a unidirectional change towards high risk in the future. The levels of risk vary according to different physiographic regions in the provinces. However, Province 2 is expected to have roughly the same level of risk across its administrative boundary, possibly due to the similar levels of exposure and extreme events across its physiography.

Chapter 8

Adaptation Options in the Sector

This section provides a broader level of adaptation measures as a first step in response to the risks and observed and anticipatory impacts associated with future climate change and socio-economic scenarios, and their potential impact on forests, biodiversity, and watershed management.

The possible adaptation options were initially identified through the review of mostly Nepal-specific policies, strategies, and plans and annual and study and progress reports. These documents were mostly sectoral and cross-sectoral policies, strategies, and plans including Climate Change Policy–2019, 15th Periodic Plan, NAPA–2010, LAPA framework–2019, Gender Equity and Social Inclusion (GESI) Strategy 2008, National REDD+ Strategy 2018, the Second NDC 2020, Forestry Sector Strategy (2016–2025), CBD 6th report, Third National Communication Report (Draft) 2019, National Forest Policy–2019, NPC-produced SDG related documents, and National Ramsar Strategy and Action Plan (2018–2024) and NEFIN's position over climate change and land and forest resources and MoEST (2015) and documents related to indigenous and local knowledge and practices for climate resilience in Nepal.

The review of policy documents helped identify sectoral priorities and possible adaptation measures in line with these priorities. Similarly, these identified adaptation options were further consolidated with the field-level adaptation practices documented in adaptation-related reports of various development organizations such as CARE Nepal and WWF Nepal (Hariyo Ban Program), WFP, UNDP, IUCN and UNEP (EbA, Panchase area), ICIMOD, NTNC, Practical Action, and UNDP (NCCSP). The selected adaptation options were synthesized with global adaptation practices and scientific evidence reflected in the NAP of Brazil and Kenya, and adaptation interventions suggested by LEG, UNFCCC Secretariat, and the reports of GIZ, FAO, UKCIP, and USDA, and several peer-reviewed articles.

The compiled adaptation measures were initially refined through several rounds of consultation with VRA thematic experts and PIF/OPM team members. The adaptation measures were further refined and verified with the perceptions and observations of IPs, Dalits, Muslims, Madheshi, and other local communities and stakeholders during the VRA Provincial workshops and the inputs of other sector-specific experts including forest ecologists, biologists, watershed specialists, and biodiversity specialists (as shown in Annex 3).

As indicated in Figure 48, the adaptation options broadly include resource conservation and management, physical and technological, capacity building and monitoring, regulatory and institution, research and innovation, and governance, inclusion, and participation based on the form of activities and their response to two sub-sectors. In terms of response characters, adaptation options are characterized by resistance, resilience, and transition (Michael et al., 2012). Resistance measures include the activities regarding the protection of high-value resources (e.g., NTFP and medicinal herbs) from climate change stressors, while resilience measures (e.g. development of climate refugee) are suggested as ways to manage forests that can return to normal conditions after climate change-related disturbances (e.g. vegetation shift). The transition (response) adaptation measures (e.g., plantation of drought-tolerant and fire-hardy plant trees) are recommended recognizing that the climate will continue to change and the adaptation activities tend to facilitate or accommodate these changes.

The options broadly comprise the on-site operations such as forest management, change in use practices and behavior, preventive and controlling effects, and modifying the management practices. Some options characterize promoting and improving current practices and the creation of sustainable financing sources.

As shown in Figure 48, the adaptation options are multidimensional, which is consistent with the strong recommendation of the local communities and stakeholders in the provincial workshop. The adaptation measures include both resource conservation and management-related activities and social, governance, inclusion, participation, and policy and institutions related options associated with the sustainable management of forests, biodiversity, and watershed resources (Lawler, 2009; Rannow et al., 2016). Social inclusion and governance-related measures include gender equity, equitable-benefit sharing, and engagement of women, IPs, Dalits, and vulnerable communities in the decision-making process. Policy and institutions and system-related interventions comprise the formulation of efficient and enabling forestry-sector policies and strategies for integrating adaptation interventions thereby enhancing the resilience of natural resources and the communities (Seddon et al., 2016). Other options include the research and innovations, capacity building and institutionalization of the monitoring system, and development of climate-proofing infrastructure and technology to enhance climate-friendly forests, biodiversity, and watershed resources conservation.

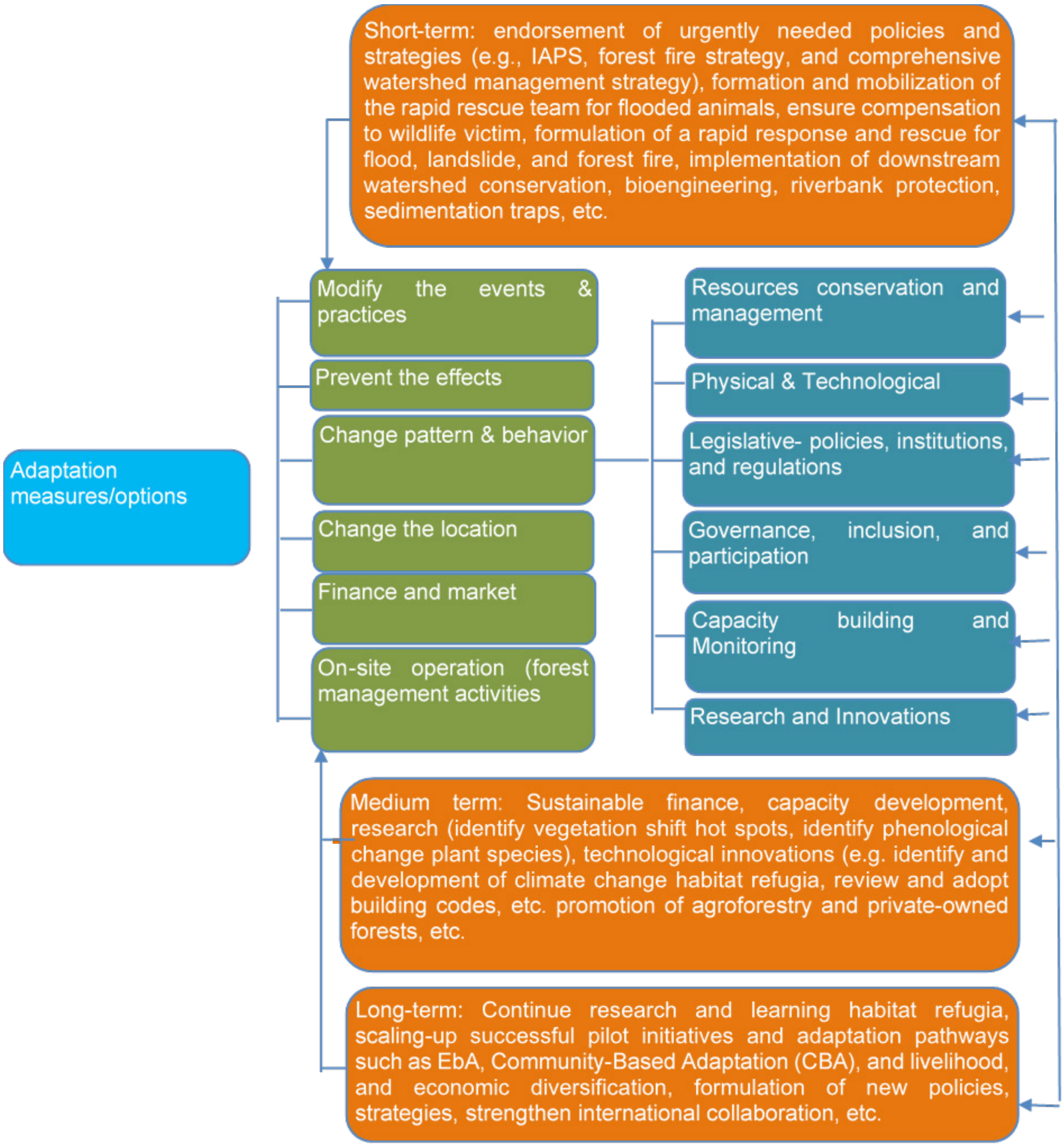


Figure 48: Classification of adaptation measures (adapted from Burton, 1996)

Similarly, this assessment has indicated the phased-based implementation approach, in which adaptation options are carried out for today's observed risk as a starting point towards addressing anticipatory risks and opportunities associated with long-term climate change. Similarly, adaptation options related to the promotion of existing traditional, indigenous, and socio-cultural practices are also included to harness existing traditional practices for enhancing environmental and social sustainability. Additionally, both incremental (e.g., diversifying livelihood options) and transformative adaptation options (e.g. formulation of policy provision for the concessional loan to women-owned forest-based enterprises) are included in the list (Fedele et al., 2019; Kates et al., 2012; Lonsdale et al., 2015).

The outlined options are coherent with Nepal's policy priorities. The options are grouped into short-term, medium, and long-term (Table 21) in terms of their scope and the urgency of the action, effectiveness, and geographical and population coverage (Fuenfgeld & McEvoy, 2011; Smit & Pilifosova, 2010). As hinted by Smit & Pilifosova (2010) and Regmi & Pandit (2016), short-term options include coping strategies and actions that are urgent to implement for a quick result, relatively localized, and cover small geographic and population coverage.

Each measure does not apply equally across all the regions, districts, provinces, and even communities, and individuals of the same family. There are regional variations of climate change impacts across physiographic regions, gender, and socio-economic and ethnic groups. The list of adaptation options below details flexible and generic options to allow the selection of strategies and approaches based on management goals, feasibility, and needs.

This chapter summarizes some lessons learned from the VRA process and key findings of the assessment result. The recommendation section outlines some strategic actions concerning the long-term assessment of risks and vulnerabilities, data management and monitoring, and future research needs.

Table 21: Short, medium, and long-term adaptation options

Key Risks and Vulnerabilities	Priority activities	Short-term (2025)	Medium-term (2030)	Long-term (2050)
The forests of the Western region are more frequently vulnerable to forest fires as compared to those in Eastern Himalayas. This is because forests of the Eastern Himalayas grow in high rain density. Tropical dry deciduous forests are more vulnerable to forest fire than any other forest across Nepal. Coniferous forests are susceptible to fire because of the high flammability of the pine It is projected that there will be a reduction of biodiversity and potential losses of important ecosystem services. Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms Increased tree mortality and associated forest dieback are projected topose risks for carbon storage, biodiversity, wood production, water quality, amenity, and economic activity. Exceedance of eco-physiological climate tolerance limits of species (limited coping and adaptive capacities), increased viability of alien species both flora and fauna Risks of loss of species example Painyu (Prunus cerasoids) in Lumbini Province and Himalayan Fir (Abies spectabilis) in Province 1due to vegetation shift High risks of habitat destruction of some fauna such as Snow Leopard, Red Panda, Musk Deer, Rhino, etc. High risk of degradation of critical wetlands, watersheds, and other water bodies, and risk of GLOF	**a. Resources Conservation and Management**			
	Promote agroforestry in private and public lands to reduce forest dependency and enhance biological corridors, including managing the sloping, and degraded lands	🟩		
	Increase redundancy across the forest ecosystems and tree species through the plantation of mixed species *(conservation and commercial value)*		🟩	
	Promote conservation of plant and animal genetic resources outside of their natural environment—in gardens, zoos, breeding programs, seed banks, or gene banks—to create an "insurance" against both climate change and other sources of biodiversity loss and impoverishment		🟩	
	Facilitate tree community adjustment through Assisted Migration[1] (e.g., tree species with a small population, at-risk and threatened tree species)		🟩	
	Identify and create Climate Refugiafor the conservation of some at-risk and sensitive plant species or ecosystem, or animal species or their habitat (e.g., Nepal's TAL Strategy, 2016 has identified 1,511.13 km^2 of important *Climate Refugia* along the northern flanks of the Siwalik and Inner Dun Valleys between the Siwalik and Mahabharat ranges) which can be naturally buffered from contemporary climate change impact		🟩	
	Establish fuel/firebreaks around high-risk areas *(Terai, Siwalik,* and *mid-hills)*		🟩	
	Identification and plantation of drought-adapted tree species in water-deficit areas of Terai, mid-hills, high mountain regions) to maintain the forest productivity (e.g. *Gmelina arborea* in Terai)		🟩	
	Rehabilitate and restore the degraded forests and watersheds through both protective measures (e.g., protection from fire, grazing, overharvesting, etc.) and acceleration of natural recovery (e.g. direct seeding and plantation, etc)	🟩		
	Reforest short-rotation and fast-growing tree species to enhance fire resilience and to resist possible disturbances from forest/wildfires		🟩	
	Promote site-specific forest control measures (e.g., promotion of evergreen tree species plantation particularly in the south-east aspect, moisture maintenance)		🟩	
	Identify Integrated Control Measures of IAPS (e.g., physical control-removal, Phytosanitary treatments, herbicides, habitat management, utilization, and introduction of biological control)in IAPS affected areas (mostly in eastern Terai and Terai Protected Areas)	🟩		
	Scale-up Ecosystem-based Adaptation approaches particularly in high-forest and biodiversity dependent communities (maybe in mid-hills and middle mountains)			🟩
	Promote landscape connectivity (biological corridor) especially in Mid-hills through mainstreaming the biodiversity conservation roles of community-based forest groups		🟩	
	Create mosaic habitats especially in IAPS affected protected areas through habitat restoration and rehabilitation interventions to allow multiple habitats for several wild animals thereby maintaining biodiversity		🟩	
	Identify and delineate the flood-prone areas (potential wildlife habitats) and construct mount to prevent wildlife flooding	🟩		
	Promote integrated and resilience approach of the watershed conservation (river-basin, sub-river basin, watershed, sub-watershed, and micro-watershed)	🟩		

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4 Assisted Migration is the concept of human deliberately moving species or genotypes to new locations that should better match their climatic suitability in the future (Pelai et al., 2021, Ste-Marie et al., 2011).

Increases in the frequency or intensity of ecosystem disturbances such as droughts, windstorms, fires, and pest outbreaks have been detected in many parts of Nepal and some cases are attributed to climate change. Changes in the ecosystem disturbance regime beyond the range of natural variability had and will alter the structure, composition, and functioning of ecosystems Susceptibility of human systems, agro-ecosystems, and natural ecosystems to (1) loss of regulation of pests and diseases, fire, landslide, erosion, flooding, avalanche, water quality, and local climate; (2) loss of provision of food, livestock, fiber, and bioenergy; (3) loss of recreation, tourism, aesthetic and heritage values, and biodiversity The establishment, growth, spread, and survival of populations of invasive alien species have increased and will spread fast in the future. Future movement of species into areas where they were not present historically will continue to be driven mainly by increased dispersal opportunities Pasture, rangeland, and husbandry are susceptible to drought and extreme precipitation High risk of loss and damage to infrastructure from the climate extreme events and climate-induced disasters e.g. flood, landslide, fire, GLOF, snowstorm	Promote and regulate water recycling, utilization, reuse, and enhance multiple uses of water: drinking water and irrigation. Also, preserve and restore the natural water springs and sources (ponds, water collection measures)		■	
	Promote water-efficient- technology (e.g., rainwater harvesting, construction of recharge, and conservation ponds). Promote water-saving/efficient technology for irrigation and drinking water (e.g., drip irrigation)		■	
	Forestation and watershed restoration: stabilize land slopes and regulate water flows, and preventing flash floods	■		
	Strengthen sustainable management of upland resources (wetlands, rangelands, pasturelands, and watersheds) and floodplains for maintenance of water flow and quality	■		
	Ensure climate resilience in critical ecosystems (e.g., protected areas, cultural heritage sites, high mountains)		■	
	Implement innovative financing mechanisms such as PES and benefit-sharing mechanisms for enhancing collaboration among upstream and downstream communities in the conservation of wetlands and watersheds.		■	
	Promote adaptation and mitigation co-benefit interventions like bioenergy, renewable energy (biogas, improved cookstoves)		■	
	Conservation of the critical and sensitive ecosystems and geographic niches such as Chure and other vulnerable hotspots		■	
	Strengthen forest fire detection and monitoring system (e.g., collaborate with MoDIS) to reduce the impact		■	
	b. Capacity building			
	Strengthen human resources (e.g., Division Forest Office) and equip them with contemporary climate change responses (identification and implementation of adaptation activities)		■	
	Strengthen the efficient and effective national forest fire monitoring and management unit, tailoring provincial and local level management unit		■	
	Strengthen existing impact based foresting system, Forest Fire Monitoring Unit within DoFSC		■	
	Enhance capacity and facilities the community-based forest user groups to integrate biodiversity conservation and climate-responsive activities in their operational plans in line with national conservation strategy and climate initiative		■	
	Form and mobilize the rapid rescue team for flooded animals and equip them with skills and an early warning system	■		
	Scale-up of LAPA initiatives across the country through local institutions such as forest groups, women groups, youth groups, and conservation groups in coordination with local government.			■
	Enhance the capacity of indigenous peoples and local communities to enable them for meaning participate in the planning, implementation, and monitoring processes	■		■
	Strengthen and promote local indigenous knowledge, monitoring systems for resource management	■		■
	Identify/document the vegetation shift/range and hotspot of phenological change to assess the climate change impact linking them with the climate-related data		■	
	c. Research and Innovations			
	Promote systematic research and climate monitoring by establishing a focal institution at aprovincial level (e.g., use of Climate Envelop Model)		■	
	Review planting season in response to changing condition and establishment success and promote natural regeneration		■	

	Study of dynamics of IAPS, plant pathogens/diseases/pests (to understand and document the biological process and infestation pattern)	🟩		
	Establish a national IAPS Information Centre to maintain a database and to facilitate the cross-sharing about the IAPS management practices		🟩	
	Carry out long-term research on phenological change (flowering and fruiting) with climate variables (temperature or precipitation)		🟩	
	Promote systematic research on the socio-economic impact of IAPS to harness the beneficial impact of IAPS on local livelihoods			🟩
	Carry out wetlands inventory and identify the significance, and develop a management plan with specific conservation goals (e.g., species conservation, cultural conservation, habitat conservation, etc)		🟩	
	Promote community Gene-bank (NARC has already established one gene bank) for at-risk NTFP, herbs, and plant species		🟩	
	Carry out the systematic geological study and identify the landslide-prone areas (mid-hills and middle mountain districts)	🟩		
	Research and promote IPs adaptation practices, and IPs related documents to gain an understanding of socio-economic and cultural impacts on IPs	🟩	🟩	
	Promote the widespread transformation of forest ecosystems to mitigate climate change, such as carbon sequestration through planting fast-growing tree species into ecosystems where they did not previously occur, or the conversion of previously uncultivated or non-degraded land to bioenergy plantations.			🟩
	d. Policy development and institutional strengthening			
	Establish sustainable financing for long-term ecological research and studies to review vulnerability and risk thereby identify adaptive options	🟩		
	Effectively implement National Forest Fire Management Strategy to regulate forest fire control initiatives in Nepal	🟩		
	Localize forest fire detection and alert information system (e.g., collaborate with ICIMOD -MODIS system and mobile application for enhancing access to local forest groups' representatives) (Currently alert system reaches only focal persons of FECOFUN of 77 districts and 84 Division Forest Offices)		🟩	
	Develop rules –penalty, reward to guide the community-based fire management plans/approaches	🟩		
	Develop Institutional Framework (responsible institution) for IPAS, pest and disease control	🟩		
	Formulate IAPS Management Strategy and Plan (already prepared but not endorsed yet)and implement them through a designated agency	🟩		
	Strengthen Quarantine System (strong coordination among organizationse.g., DPR, FRTC, and Plant Quarantine and Pesticide Management Centre (PQPMC)		🟩	
	Mainstream locally control practices in the National Pest and Disease Management Strategy and Plan		🟩	
	Develop an international collaboration for IAPS/pest/diseases prevention			🟩
	Formulate private-forest enabling policy- forest product harvest (increase supply raw materials to enterprises)		🟩	
	Update Environmental Impact Assessment (EIA) standards with climate change perspective		🟩	
	Develop and update conservation plan of flagship and keystone wildlife species with climate change perspective			🟩
	Strengthen ex-situ conservation measures for threatened and endangered species (flora and fauna)		🟩	
	Establish transboundary cooperation and coordination for the Rapid Rescue of flooded animals			🟩

	Integrate the concept of *Habitat/Climate Refugia* in Nepal's National Conservation Policies and Strategies (e.g., TAL strategy, 2015–25 is already included)		🟩	
	Review wildlife victim compensation policy (engage local governments and facilitate timely and easy access to compensation)	🟩		
	Strengthen provision and practice of biodiversity monitoring in community-based forest groups (mandatory provision in Forest Operation Plan)		🟩	
	Formulate comprehensive watershed management policy with participatory and integrated watershed management strategy		🟩	
	Promote PES incentive mechanism for multiple upstream-downstream watershed resources (e.g., sedimentation, clean water for hydropower, drinking, irrigation, carbon, etc.)		🟩	
	Formulate safe-relocation strategy- landslides, floods, and forest fires victims	🟩		
	Integrate adaptation initiatives with climate change mitigation objectives such as the REDD+ initiative (to fulfill the spirit of National Climate Change Policy and National REDD+ strategy)			🟩
	Develop a functional mechanism (with two-ways communication and reporting system) of climate change adaptation among three tiers of government: national, provincial, and local government and local communities		🟩	
	e. Governance, inclusion, and participation		🟩	
	Diversify forests and non-forest-based income sources (off-farm income activities) and reduce pressure on forests and protected area		🟩	
	Enhance women, IPs, and Dalit-owned forest-based enterprises through the provision of seed grants, insurances, and concessional loans	🟩		
	Promote gender-responsive, IPs, Dalit, and Poor Households responsive benefit distribution in CBFM groups, PES schemes including REDD+	🟩		
	Ensure equitable distribution of CBFM groups' funds for women, IPs, Dalit, and vulnerable households	🟩		
	Ensure policy provision of (e.g., 50% involvement of women) of women and enhancing IPs/Dalit representation in forest-managed decision-making bodies (e.g. executive committee) and process	🟩		
	Promote traditional, indigenous practices, and local knowledge,cultural values, and customary practices (e.g., Kghyama system of Lhoba, Bad-Ghar (head man) and Khyala (forum) of Tharus, Bheja (social and religious organization) of Magar, Naalsabha (general assembly) of Gurungs and Dhikur and 13Mukhiya (heads) of Thakalis, and Nawa of Sherpa in forest management. Generate multiple social, economic, and environmental co-benefits, etc.)		🟩	
	Integrate transhumance system and customary forest management practices in the sustainable forest management framework			🟩
	Mainstream local efforts in national IAPS management initiative		🟩	
	Integrate biodiversity conservation initiative with the livelihood objective to generate synergies between Biodiversity Conservation and Livelihood Improvement (Link conservation and social goal for sustainable development)		🟩	
	Promote private sector engagement in forest-based enterprises		🟩	
	Develop participatory river-basin-level watersheds conservation by engaging upstream-downstream communities		🟩	
	Improve access of women, IPs, Dalits, and vulnerable households to quality resources (e.g., forests, water, biodiversity) and innovating skill enhancement initiatives	🟩		
	Acknowledge, respect, and recognize customary rights and institutions of indigenous peoples	🟩		

	Ensure full and effective participation of indigenous peoples and local communities in the decision-making process, and equitable benefit sharing	🟩		
	f. Infrastructure development	🟩		
	Construct safety structure for flood-susceptible animals (e.g., construction of mud mount) in potential flood-prone areas in Terai Protected Areas	🟩		
	Construct water pond in highly fire-sensitive forest areas to maintain moisture		🟩	
	Revisit and update National Building Codes (105:2020) for forest-related infrastructures to adjust additional risk zoning criteria (risk zoning standards/criteria should be different for the infrastructure constructed in and around forest areassuch as forest fires, landslides, floods in addition to earthquakes common to all and do-no-harm-to wild animals)			🟩
	Introduce climate-proofing and environmental-friendly infrastructure development (e.g., road, settlements, urban, electricity, hydropower, view tower, etc.)		🟩	
	Promote post-construction rehabilitation plan with activities such as forest roadside rehabilitation and plantation within the forests		🟩	
	Promote bioengineering activities: conservation and plantation and construction of Embankments, riverbank, sedimentation traps in highly risk flooding zone	🟩		

Chapter 9

Conclusion and Recommendations

9.1 Lessons learned and conclusions

Nepal's forests, biodiversity, and watershed resources are both critical to local sources of livelihood and environmental conservation. However, climate change has posed threats to the natural resources and human livelihood dependent on these resources.

Two climatic stressors, change in temperature and precipitation, are directly related to the conservation of forests, biodiversity, and watershed resources. Some of the accelerating hydro-meteorological extreme events and climate-induced hazards impacting forests, biodiversity, and watershed resources are droughts, storms, floods, inundation, landslides, debris flow, soil erosion, fire, heatwave, heavy rainfall, and avalanches.

The negative impact on forests, biodiversity, and watershed management is seen through vegetation range shift in high mountain regions, change in phenological pattern, and increasing forest fire incidences and spreading rate of IAPS mostly in the Terai, Siwalik and Hill regions. Increasing landslides, floods, and drying up of water resources are associated with watershed degradation-related impacts.

Differential exposure levels were observed across the physiographic regions and the districts within these regions. The findings showing a high exposure of middle and high mountain regions are mainly attributed to the distribution of forest area, rangelands, agro-ecosystem, wetlands, snow, and glacier-covered areas, climate-sensitive non-timber forest products, and exposed watershed areas. A relatively high level of climate extreme events across the Terai and eastern hill and mountain region could be linked with changing patterns of monsoon precipitation, which has further marked a clear east-west difference of climate extreme events in Nepal (a decrease of climate extreme events towards the western region).

Climate-sensitive vegetation types, water bodies, and low levels of adaptive capacity within the middle and high mountain ranges make them more vulnerable to climate change. Nevertheless, there are several vulnerable districts in other regions due to district-specific biophysical characteristics and forests, biodiversity, and watershed management interventions.

Eastern Terai districts including Province 2 generally represent low climate risks despite high climate extreme events in the baseline period with the current level of vulnerability and exposure. However, the findings point to be a unidirectional shift of the future climate risk towards the higher level (in this case, in 2030 and 2050) in all scales: district, physiographic region, and provincial. High and middle mountain regions and districts of these regions are expected to experience very high climate risk. Such shifts towards higher levels will also occur in the Hill region (low to moderate). While the Terai region and the Siwalik seem to remain unchanged with low and very high climate risk respectively, some districts of this region should also expect to have high risk in the future. It suggests that the finer level of the climate risk assessment will serve to have a differential level of risk result from even a small variation of biophysical and landscape dimensions. The overall findings highlight the need for a district-wise and also local level assessment to adjust with higher scale results – physiographic region level.

Given the uneven pattern of vulnerability and climate risks and their future scenario, the implementation of context-specific adaptation measures will be effective in addressing the site-level vulnerabilities and risks. While the forests, biodiversity, and forest management sector is sensitive to multi-climate extreme events, no or low regrets in combination with EbA of adaptation are critical to maximizing the advantages of these approaches in the face of uncertain and long-term nature climate and socio-economic scenarios. Outlining adaptation options into short, medium, and long-term temporal scales may offer an opportunity to align them into contemporary development planning thereby enhancing co-benefits and synergies between sustainable development goals and ecological and social resilience.

One of the lessons learned in this VRA is that the engagement of stakeholders and local communities throughout the VRA process is crucial to harness unique perspectives in identifying climate change impacts and identifying adaptation measures related to these impacts. Such practices do not just reinforce the participatory, inclusive, and consultative process but also strengthen legitimization with enhanced ownership over the VRA outcomes among local communities and stakeholders.

This VRA was not informed by data at the local level due to the unavailability of such data. Maintenance of Spatio-temporal break-down data through collaborative efforts among federal, provincial, and local governments along with development organizations and local communities will be crucial for the future VRA and similar assessment in the sector.

9.2 Recommendations: Process, data gaps, and future needs

Data management

- There is a need to maintain district-level time-series climate-responsive data on forest management, and biodiversity and watershed conservation by using a consistent and compatible methodology.

- It is essential to maintain break-down data of other social groups such as IPs, Dalits, Madhesis, and Muslims involved in forests, biodiversity, and watershed management.
- District-level data are currently maintained at the provincial forest directorate. Some data are maintained by the DoFSC at the federal level. However, it is recommended to establish a data portal at the federal level to maintain climate change-related data at a single window.

Need for future studies and monitoring systems

- There is a need to establish a systematic (longitudinal) ecological study and forest monitoring mechanism to understand the impact of climate dynamics on forests, biodiversity, and watershed resources. Designate a federal entity for this task to streamline the studies and coordinate with academic institutions, governments, civil society institutions including IPs, women and Dalit network, and development organizations.
- Further study is required to identify, document, and enhance the knowledge, experiences, and adaptation practices of indigenous peoples and mainstream them into the National Adaptation Plan.

Implementation Considerations

- This assessment provides a broader level of adaptation measures. These may not be equally relevant to every district, province, and physiographic region. It is thus strongly recommended to localize the adaptation options considering the site-specific or local government level and community-specific climate change impact, experienced hazard, vulnerability and risks, and socio-economic context.
- There is a need to integrate traditional knowledge and customary practices in the adaptation interventions to enhance ecological and social-cultural resilience.
- In designing context-specific VRA and adaptation interventions, we need to engage with community institutions including the representative organizations of IPs, Dalit, women, Muslims, and Madhesi.

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Annexes

Annex 1: Key Terminology

Adaptation	The process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change and its effects.
Adaptive capacity (AC)	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
Climate Trends	Patterns in climate variables such as temperature and precipitation are observed in historic datasets.
Climate Projections	A projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Projections are distinguished from climate predictions. Projections are subject to substantial uncertainty as they are based on assumptions concerning future socio-economic and technological developments that may or may not be realized.
Climate extreme events	The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) end of the observed values of the variable such as high temperatures (e.g. heatwave), or extremely heavy rainfall.
Disasters	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require an immediate emergency response to satisfy critical human needs and that may require external support for recovery
Exposure (E)	The presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructures, or economic, social, or cultural assets in places and settings that could be adversely affected.
Hazards (H)	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events such as droughts, floods, hurricanes, etc.
Impacts (I)	Effects on natural and human systems. It generally refers to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate change or hazardous climate events occurring within a specific time- period and the vulnerability of an exposed society or system. They are also referred to as consequences and outcomes.
Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.
Risk (R)	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as a probability of occurrence of hazardous events or trends multiplied by the impacts of these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.
Sensitivity (S)	The degree to which a system or species is affected, either adversely or beneficially by climate variability or change. The effect may be direct (e.g. change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise).
Thresholds	A critical limit within the climate system induces a non-linear response to a given forcing.
Transformation	A change in the fundamental attributes of natural and human systems.
Vulnerability (V)	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Vulnerability Index (VI)	A metric characterizing the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent a vulnerability.

(Source: IPCC AR-5, 2014)

Annex 2: Summary findings of provincial consultations on forests, biodiversity, and watershed management in Nepal

1. Province 1

Mountain: Local communities identified increasing temperature, change in precipitation, droughts, avalanches, and GLOFs as main climate extreme events in the high mountain regions of Province 1. These events have caused several ecological disasters including upslope vegetation shift, habitat destruction leading to species loss, and reduction in the wildlife population. Other reported impacts were phenological changes leading to loss of productivity. These impacts were experienced by marginalized and vulnerable communities especially Sherpa and Bhutiya who depend on high-mountain forest ecosystems.

Suggested adaptation options

- Carry out awareness-raising and sensitization programs
- Provide sole rights of forest and plants management to local communities
- Promote the 'one village, one forest' concept, and greenery
- Develop a management plan for rare and endangered plant and animal species such as Yarsagumba

Hills: Landslides, droughts, and rainfalls were the main extreme events in the region, from temperature increase and variation in rainfall. These have led to increased forest fires, habitat destruction of the Red Panda and other faunas, and threats to the extinction of avifauna. Similarly, other observed impacts were decreased eco-tourism activities, change in plant phenology (particularly early flowering of Rhododendron), loss of vegetation and NTFPs, decreased availability of forest products, drying up of springs, and diminishment of other water resources. The most impacted groups were said to be the forest- and livestock-dependent households, women, ethnic and indigenous peoples, Dalit communities, local-tourism operators, and forest-based entrepreneurs.

Suggested adaptation options

- Promote fire resistance species (e.g., Khair, Sal)
- Promote drought-resistant species
- Promote awareness and sensitization of public and user groups
- Carry out massive plantations in degraded and barren areas
- Promote agroforestry practices
- Develop and implement community- and ecosystem-based adaptation plans
- Conserve rare and threatened plant and animal species
- Promote landscape-level conservation to retain the habitat of keystone species

Terai: According to consultations, excess and scarcity of water, floods, heat and cold waves, and inundation were the main climate extreme events in the Terai region. These have led to forest fires, loss of riverine forests, loss of key species, and degradation of habitats. An increase in the spread of Invasive Alien Plant Species poses a threat to local plant species, decreasing productivity. Forest-dependent communities—particularly women, ethnic groups including Dalits, Madheshis, and Muslims, and other marginalized households—were also gravely affected.

Suggested adaptation options

- Implement biodiversity- and ecosystem-based adaptation activities
- Implement an early warning system for floods and forest fires
- Promote rapid rescue efforts/mechanisms and rehabilitate animals impacted by the flood
- Ensure sustainable financial support to and investment in research
- Identify and implement context-specific adaptation strategies
- Promote alternative energy use to reduce pressure on forests

2. Province 2

An increase in temperature, changes in precipitation patterns, warm days and warm nights, floods, and forest fires were identified as the main climate extreme events, according to consultations in this province. Forest fires, IAPS, and fragmentation, and degradation of habitats have led to a loss of diversity in endemic plants and wildlife, and to change in forest composition, especially in the Churia region. Floods have caused river widening and change river direction have threatened human life and property. Lowering of the water table, rising of riverbeds, and depletion of water resources were also reported. These impacts were experienced by mostly the poor and marginalized households, including women, ethnic minorities, and Dalits, who have high forest-dependent sources of livelihood.

Suggested adaptation options

- Promote agroforestry practices (production based on demand; free distribution; technical support during plantation; and post support activities)
- Promote conservation-based forest management in the Churia region
- Promote IAPS control measures
- Promote fire control measures (e.g., awareness, equipment, and fireline construction)
- Regulate the over-extraction of resources in the Churia region through grazing, stone quarry, and gravel extraction
- Conduct work related to integrated watershed management, conservation plantation, and riverbank protection
- Develop a policy for Churia conservation, ensuring its environment and ecological stability
- Develop and implement land-use management policy targeting the climate-vulnerable forest and land areas
- Promote habitat conservation and grazing land management
- Promote conservation of native species
- Develop early warning systems for floods

3. Bagmati Province

Mountain: Increased temperature and change in precipitation are the main climate stressors causing snow-cover change, snow line shifts, and melting of glacier lakes. Upslope vegetation and habitat shifts, increasing IAPS incidences, and human-wildlife conflict have led to biodiversity losses, threats of extinction of NTFP, plant and animal species, loss of potential of forest regeneration, declining wildlife species' numbers, and loss of forest types and productivity. Floods and landslides damage forests and high mountain ecosystems. Reductions in forest product availability have contributed to women's workload and loss of employment in forest-based enterprises. Most people with forests- and NTFPs-based livelihoods, especially ethnic communities, women, those dependent on the tourism sector, and private investors have been especially affected by these consequences.

Suggested adaptation options

- Promote community-based adaptation plans, including ecosystem-based adaptation approaches targeting vulnerable areas
- Implement landscape-level conservation to conserve species
- Integrate climate change in the planning and budgeting processes at all levels
- Promote conservation of habitats, and threatened plant and animal species
- Promote in-situ and ex-situ conservation
- Establish research areas for long-term monitoring changes of climate and impacts on animal and plant species

Mid-hills: In the mid-hill region of Bagmati Province**,** rising temperatures and changes in precipitation were reported to be the main climate extreme events that have caused increased landslides and flash floods. Increased temperature has led to forest fire incidences, phenology change, vegetation shifts, and the spreading of IAPS. This has caused high mortality of plants; disruption of the food chain, regeneration potential, and seedling growth; loss of habitats; and degradation of wetland ecosystems and watersheds. These impacts were mostly experienced by forest and natural resource-dependent ethnic, indigenous, and poor households.

Suggested adaptation options

- Develop and implement adaptation plans targeting communities and resources
- Develop conservation plans for threatened animal and plant species
- Sensitize communities and local governments about climate change
- Implement fire control measures
- Establish early warning systems for fires and flash floods
- Undertake ecological research in landslide-prone areas
- Implement habitat restoration programs
- Identify and conserve vulnerable wetlands
- Promote climate-resilient watershed management plans

Terai: In this region, the main problems were reported to be an increased frequency of floods and forest fires; spread of IAPS causing loss of habit and wild animal species; and degradation of wetland ecosystems and watersheds. Ethnic and Indigenous poor households who are dependent on the forest were highly impacted in the region.

Suggested adaptation options

- Carry out research identifying impacts of climate change on fauna and flora, particularly in protected areas
- Develop conservation plans to reduce loss and damage due to floods, targeting some faunal species
- Implement fire control measures
- Implement riverbank and flood protection measures
- Establish early warning systems for floods
- Promote formation and mobilization of rapid rescue teams for animals being flooded

4. Gandaki Province

Mountain: In the mountain region of Gandaki Province, temperature rise, shifting snow line, snowmelt avalanches, and GLOFs were reported to be the main extreme events. These have caused biodiversity loss, habitat alteration, and food web disturbance. The major victims of such consequences were the Indigenous peoples, women, and marginalized households.

Suggested adaptation options

- Promote climate-friendly species
- Establish early warning systems
- Promote habitat conservation
- Provide alternative job opportunities
- Raise awareness
- Adopt an integrated planning approach
- Promote payment for ecosystem services

Hills: Temperature rise, changes in precipitation, floods, and landslides were identified as the extreme events that have caused an increase in forest fire incidences, IAPS, and human-wildlife conflict. These phenomena have led to a loss of habitats, sedimentation in lakes, and threats to biodiversity.

Suggested adaptation options

- Promote sustainable forest-based enterprises
- Promote bioengineering activities
- Promote the management of recharge and conservation ponds
- Consider GESI issues in benefit sharing and for ensuring a resilient society
- Manage human-wildlife conflict
- Raise awareness and build capacity for forest fire management
- Raise awareness about climate change mitigation, including carbon sequestration
- Implement planned and climate-friendly infrastructures, including roads
- Promote roadside plantation
- Promote planned resettlement programs

5. Lumbini Province

Gradual increase in temperature, along with delay in the monsoon season was the extreme events identified in Lumbini Province. These events have caused both too little and too much water, resulting in conditions like drying of wetlands and less water in the watersheds and catchment areas. Other observed impacts were loss of species due to vegetation shifts particularly in higher altitudes (e.g., Painyu), phenological changes, and variation in plant growth (such as early and late flowering, unbalance root, and shoot growth, and decrease in seed viability). These have led to the loss of mountain habitats, especially of snow leopards. Similarly, loss and degradation of habitat due to IAPS (especially Michania) was identified as one of the main problems in the Terai region, which poses threats to rhinos and elephants. Groups reported to be severely impacted include forest-dependent, marginalized households including women, Dalits, and IPs.

Suggested adaptation options

- Promote wetland and watershed rehabilitation programs
- Promote alternative sources of livelihood for wetland-dependent communities
- Promote in-situ and ex-situ conservation for keystone and flagship species
- Promote landscape-level conservation programs
- Explore environmental stresses-tolerant species
- Promote flood control measures (e.g., riverbank protection)
- Promote rapid rescue mechanism of flooded animal species
- Implement biodiversity conservation programs
- Strengthen the role of user groups and communities in conserving habitats and biodiversity
- Implement wetland and watershed management programs
- Implement conservation of water through efficient technologies
- Implement bioengineering and other sustainable soil and water management practices, such as riverbank and flood protection measures
- Establish early warning systems for floods
- Promote research and control measures (mechanical and biological) of invasive species and pests and diseases
- Invest in research and development, particularly for identifying best-suited management practices
- Rehabilitate degraded habitats

6. Karnali Province

The main extreme events identified during consultations included increased temperature, extreme weather events, off-season snowfall, droughts, and intense rainfalls. These events have caused an increase in fire incidences and dry landslides, drying up of water resources, decrease in snow cover area, spreading of IAPS, decrease in local vegetation, loss of forest area and quality, loss, and degradation of wildlife habitats, watersheds, and biodiversity. The increase in the spreading rate of IAPS in the high mountain region of the province was widely reported.

Suggested adaptation options

- Strengthen habitat conservation of critical wild animals
- Enhance protection and management of watershed resources, including springs
- Promote public awareness and identify suitable species for the plantation
- Enhance proper implementation of forests, biodiversity, watershed management related laws and regulations
- Expand bioengineering activities
- Control pests and invasive species and instead plan the disease- and pest-resistant varieties.
- Adopt appropriate species for plantation
- Increase the availability of skilled human resources and instruments for better forest management

7. Sudurpashchim Province

Change in weather events, increase landslides, floods, prolonged droughts, diminishing rainfalls, and intense and heavy rains were the main extreme events reported in the Sudurpashchhim Province. The major impacts observed were increased forest fire incidences, drying up of water sources, desertification, and riverbank cuttings. Other impacts were loss of forests and biodiversity, wildlife habitat, depletion of forests, agriculture unproductivity, and increase in diseases and pests. Women, IPs, Dalits, and marginalized forest-dependent households were reported to be the most impacted.

Suggested adaptation options

- Identify fire-prone areas and construct a fire line
- Expand in-situ conservation
- Promote conservation, plantation, and afforestation
- Promote bioengineering activities
- Develop early warning systems for floods and forest fires
- Review IEE/EIA standards from a climate change perspective and institutionalize them in forest, biodiversity, and watershed management
- Conserve water sources and ponds
- Promote alternative energy for reducing forest dependency
- Strengthen climate-related awareness campaigns
- Carry out research and studies on forests and biodiversity

Annex 3: TWG and experts consulted for pair-wise ranking

SN	Name	TWG/Expert	Position	Organization
1	Ms. Madhudevi Ghimire	TWG	Under-secretary	DPR
2	Ms. Madhuri Karki (Thapa)	TWG	Under-secretary	DoFSC
3	Mr. Haribhadra Acharya	TWG	Under-secretary	DNPWC
4	Ms. Sunita Ulak	TWG	Under-secretary	FRTC
5	Mr. Yagyamurti Khanal	TWG	Under-secretary	REDD IC
6	Mr. Dolraj Luitel	TWG	Under-secretary	DoE
7	Dr Manish Raj Pandey	TWG	Forest Conservation Officer	NTNC
8	Mr. Sarad Babu Pangeni	TWG	Under-secretary	President Chure- Terai Madhesh Conservation Development Board
9	Mr. Ganesh Bishwokarma	TWG	Chairperson	RDN
10	Mr. Birkha Shahi,	TWG	General Secretary	FECOFUN
11	Ms. Kanti Rajbhandari	TWG	Chairperson	HIMAWANTI
12	Mr. Tunga Bhadra Rai	TWG	National Coordinator	NEFIN
13	Mr. Dipesh Joshi	TWG		WWF
14	Mr. Nirajan Khadka	TWG	Member	NFA
15	Dr Janita Gurung	TWG	Manager	ICIMOD
16	Mr. Bhogendra Rayamajhi	TWG		ZSL
17	Mr. Shyam Sundar Dhakal	TWG	Chairperson	FenFIT
18	Dr Jagannath Joshi	Expert	Climate change Adaptation Specialist	CARE Nepal
19	Dr Naresh Subedi	Expert		NTNC
20	Dr Baburam Lamichhane	Expert	Chief	NTNC/Sauraha
21	Dr Krishna Bahadur Bhujel	Expert	Forest Fire Expert	Freelance
22	Dr Ngamindra Dahal	Expert	Hydrologist	SIAS
23	Mr. Dev Raj Gautam	Expert	Project coordinator	CARE Nepal
24	Mr. Keshav Khanal	Expert	EbA and Climate Finance	UNEP

Annex 4: List of indicators of exposure, sensitivity, and adaptive capacity

Exposure

- Total forest area (ha): Government managed, community-managed, and private forest
- Annual plantation area (ha)
- Potential NTFP areas (ha)
- Protected area (ha)
- Ecosystem diversity
    - ◊ Wetland area (ha)
    - ◊ Rangeland area (ha)
    - ◊ Agro-ecosystem Area (ha)
    - ◊ Snow-care area (ha)
    - ◊ Glacier area (ha)
    - ◊ Glacier lake area (ha)
- Households involved in forest and biodiversity conservation
- Forest-related buildings (no.)
- Others (View towers, machan, etc.)
- Fireline and forest road
- Forest-based enterprises
- Exposed watershed area
- Area of exposed other water bodies area

Sensitivity

- Types of forests
    - ◊ Abies spectabilis & abies pindrow
    - ◊ Betula utilis
    - ◊ Piece, Tsuga Dumosa, cedrus and Cupressus torulosa
    - ◊ Quercus spp
    - ◊ Pine forests (P. roxburghii & P. wallichiana)
    - ◊ Upper mixed hardwood
    - ◊ Acacia catechu & Dalbergia sisoo, & Juglans walichiana
    - ◊ Lower mixed hardwood
    - ◊ Tropical mixed hardwood and sal
- Change in forests (%)
- Regenerated area
- Degraded area
- Semi-degraded area
- Sparse forest area
- Disease
- Fungus
- Insect/Pest
- No. of Invasive Alien Plant Species
- The fragility of the forest: mean slope degree
- Forest fire-prone area
- Change in wetland
- Change in rangeland/grassland
- Change in agro-ecosystem area
- Change in lakes and snow-glacier area
- Disturbance regime: encroachment
- Disturbance regime: occurrence of forest fire incidences (no.)
- Fragmentation: average forest patch size
- Percentage of forest-dependent households
- Fire lines and forest roads: prone to landslides and floods

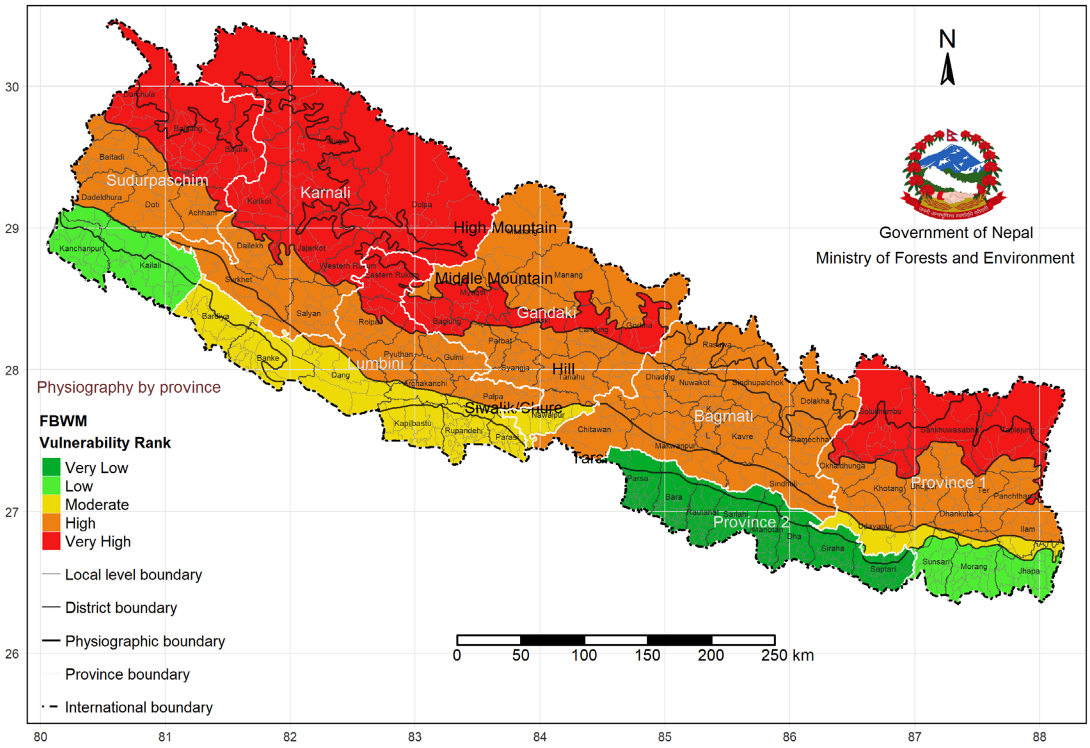
Sensitivity

- Forest related buildings: prone to landslides and floods
- No. of households directly engaged in forest-based enterprises
- Land degradation: landslide-prone area
- Landslide sensitivity
- Erosion sensitivity
- Flood sensitivity
- Level of sedimentation yield
- Drainage density

Adaptive capacity

- Distribution of dense forest areas
- Status of income from the protected area, buffer zone, community-based forest groups
- Area of land under "Landscape-level" conservation
- Existence of forest rehabilitation plan
- Percentage of forests under scientific forest management
- Number of human resources in place (government deployed human resource)
- No. of seedlings produced annually
- No. of NTFP (non-wood) and medicinal plants planted annually
- No. of plant species established seed orchard
- No. of households engaged in women-managed community forests
- Percentage of women-managed community forest groups
- Percentage of women involved in forest groups' executive committee
- Percentage of buildings compliance to safer building code
- No. of enterprise use seasoning technologies
- No. of forest enterprises receiving insurance or any subsidies including concessional loan
- Percentage of women owning forest-based enterprises
- Sub-watershed plan
- No. of wetland conservation plans
- No. of managed of conservation ponds
- Adoption of watershed conservation and management technology
    - ◊ Bioengineering activities
    - ◊ Riverbank protection

Annex 5: Vulnerability ranks: physiography by provinc



Annex 6: Index values of exposure, sensitivity, adaptive capacity, vulnerability, climate extreme events, and risks

District	Exposure	Sensitivity	Adaptive capacity	Vulnerability	Baseline context of climate extreme events	RCP4.5 2030 of climate extreme events	RCP4.5 2050 of climate extreme events	RCP8.5 2030 of climate extreme events	RCP8.5 2050 of climate extreme events	Baseline Risk	RCP4.5 2030 Risk	RCP4.5 2050 Risk	RCP8.5 2030 Risk	RCP8.5 2050 Risk
Achham	0.402	0.815	0.619	0.34	0.563	0.584	0.617	0.56	0.623	0.211	0.219	0.231	0.209	0.233
Arghakhanchi	0.278	0.753	0.43	0.475	0.686	0.745	0.767	0.742	0.799	0.22	0.239	0.246	0.238	0.256
Baglung	0.378	0.878	0.416	0.652	0.602	0.656	0.684	0.647	0.707	0.324	0.352	0.368	0.348	0.38
Baitadi	0.316	0.815	0.537	0.434	0.583	0.605	0.637	0.582	0.644	0.196	0.203	0.214	0.195	0.216
Bajhang	0.725	0.937	0.403	0.741	0.374	0.407	0.431	0.376	0.432	0.372	0.406	0.429	0.374	0.431
Bajura	0.556	0.82	0.322	0.683	0.379	0.411	0.429	0.384	0.441	0.254	0.275	0.287	0.257	0.295
Banke	0.482	0.764	0.399	0.525	0.719	0.75	0.78	0.74	0.804	0.456	0.475	0.494	0.469	0.509
Bara	0.283	0.673	0.64	0.135	0.787	0.825	0.842	0.835	0.882	0.15	0.157	0.16	0.159	0.168
Bardiya	0.648	0.875	0.483	0.571	0.716	0.733	0.769	0.735	0.796	0.646	0.661	0.694	0.663	0.718
Bhaktapur	0.036	0.523	0.314	0.314	0.685	0.745	0.742	0.723	0.793	0.022	0.024	0.024	0.023	0.025
Bhojpur	0.283	0.728	0.316	0.573	0.641	0.683	0.684	0.668	0.757	0.244	0.26	0.26	0.254	0.288
Chitawan	0.651	0.925	0.537	0.575	0.769	0.814	0.834	0.822	0.886	0.666	0.705	0.723	0.712	0.768
Dadeldhura	0.319	0.863	0.647	0.37	0.621	0.635	0.667	0.627	0.69	0.2	0.205	0.215	0.202	0.222
Dailekh	0.304	0.754	0.364	0.552	0.56	0.59	0.62	0.563	0.619	0.211	0.222	0.233	0.212	0.233
Dang	0.633	1	0.846	0.32	0.71	0.758	0.779	0.736	0.793	0.427	0.456	0.468	0.442	0.477
Darchula	0.588	0.837	0.374	0.646	0.426	0.449	0.478	0.428	0.483	0.314	0.332	0.353	0.316	0.357
Dhading	0.455	0.95	0.414	0.746	0.647	0.709	0.732	0.696	0.76	0.453	0.496	0.512	0.487	0.532
Dhankuta	0.189	0.72	0.493	0.361	0.69	0.731	0.743	0.729	0.808	0.131	0.139	0.142	0.139	0.154
Dhanusha	0.258	0.596	0.921	0	0.76	0.787	0.78	0.813	0.867	0.007	0.007	0.007	0.008	0.008
Dolakha	0.51	0.855	0.468	0.564	0.559	0.585	0.588	0.591	0.666	0.352	0.369	0.37	0.372	0.42
Dolpa	1	0.813	0.168	0.849	0.25	0.284	0.307	0.257	0.317	0.395	0.447	0.484	0.405	0.499
Doti	0.415	0.872	0.665	0.361	0.564	0.587	0.621	0.563	0.626	0.235	0.244	0.258	0.234	0.261
Eastern Rukum	0.33	0.823	0.31	0.701	0.511	0.55	0.564	0.517	0.576	0.233	0.25	0.257	0.235	0.262
Gorkha	0.798	0.981	0.54	0.642	0.482	0.529	0.561	0.519	0.581	0.511	0.561	0.595	0.55	0.616
Gulmi	0.272	0.823	0.439	0.555	0.673	0.737	0.761	0.731	0.781	0.234	0.256	0.265	0.254	0.272
Humla	0.827	0.683	0.248	0.593	0.247	0.273	0.282	0.244	0.298	0.244	0.269	0.278	0.241	0.294
Ilam	0.391	0.746	0.429	0.468	0.768	0.818	0.824	0.846	0.884	0.355	0.378	0.381	0.391	0.409
Jajarkot	0.474	0.79	0.336	0.629	0.514	0.555	0.576	0.515	0.573	0.32	0.345	0.358	0.32	0.356
Jhapa	0.463	0.721	0.609	0.232	0.899	0.947	0.951	0.989	1	0.371	0.391	0.392	0.408	0.413
Jumla	0.528	0.774	0.21	0.751	0.408	0.439	0.447	0.397	0.453	0.297	0.32	0.326	0.289	0.33
Kailali	0.742	0.931	0.859	0.217	0.703	0.718	0.751	0.714	0.777	0.435	0.444	0.465	0.442	0.481
Kalikot	0.423	0.901	0.134	1	0.444	0.478	0.5	0.438	0.492	0.325	0.35	0.366	0.32	0.36
Kanchanpur	0.449	0.662	0.569	0.201	0.722	0.738	0.765	0.729	0.797	0.265	0.27	0.28	0.267	0.292
Kapilbastu	0.332	0.699	1	0	0.761	0.805	0.826	0.802	0.861	0.025	0.026	0.027	0.026	0.028
Kaski	0.627	0.924	0.572	0.532	0.598	0.646	0.678	0.65	0.714	0.468	0.505	0.53	0.509	0.559
Kathmandu	0.133	0.544	0.528	0.097	0.68	0.749	0.746	0.721	0.786	0.053	0.058	0.058	0.056	0.061
Kavrepalanchok	0.362	0.76	0.447	0.465	0.686	0.737	0.739	0.735	0.805	0.283	0.303	0.304	0.303	0.331
Khotang	0.286	0.752	0.297	0.625	0.637	0.67	0.67	0.669	0.75	0.256	0.269	0.269	0.269	0.301
Lalitpur	0.151	0.637	0.617	0.115	0.655	0.706	0.711	0.705	0.778	0.06	0.065	0.065	0.064	0.071
Lamjung	0.351	0.804	0.303	0.685	0.601	0.652	0.689	0.651	0.717	0.308	0.334	0.353	0.334	0.367

District	Exposure	Sensitivity	Adaptive capacity	Vulnerability	Baseline context of climate extreme events	RCP4.5 2030 of climate extreme events	RCP4.5 2050 of climate extreme events	RCP8.5 2030 of climate extreme events	RCP8.5 2050 of climate extreme events	Baseline Risk	RCP4.5 2030 Risk	RCP4.5 2050 Risk	RCP8.5 2030 Risk	RCP8.5 2050 Risk
Mahottari	0.309	0.649	0.643	0.1	0.763	0.793	0.792	0.826	0.869	0.148	0.154	0.154	0.16	0.169
Makawanpur	0.532	0.891	0.665	0.386	0.733	0.777	0.797	0.772	0.836	0.408	0.433	0.444	0.43	0.466
Manang	0.481	0.66	0.242	0.57	0.295	0.338	0.369	0.337	0.399	0.181	0.208	0.227	0.207	0.245
Morang	0.503	0.669	0.729	0.029	0.822	0.862	0.866	0.886	0.913	0.219	0.23	0.231	0.236	0.243
Mugu	0.736	0.739	0.141	0.786	0.3	0.326	0.334	0.281	0.339	0.317	0.343	0.352	0.296	0.357
Mustang	0.595	0.61	0.35	0.384	0.208	0.241	0.279	0.25	0.309	0.124	0.143	0.166	0.149	0.184
Myagdi	0.583	0.831	0.373	0.64	0.48	0.524	0.552	0.527	0.588	0.351	0.383	0.404	0.385	0.43
Nawalpur	0.368	0.679	0.47	0.335	0.769	0.814	0.827	0.832	0.894	0.289	0.306	0.311	0.313	0.336
Nuwakot	0.281	0.819	0.452	0.535	0.671	0.743	0.757	0.725	0.788	0.234	0.259	0.263	0.252	0.274
Okhaldhunga	0.204	0.815	0.405	0.583	0.632	0.665	0.663	0.67	0.741	0.173	0.181	0.181	0.183	0.202
Palpa	0.386	0.85	0.59	0.418	0.719	0.783	0.799	0.781	0.839	0.292	0.318	0.324	0.317	0.34
Panchthar	0.197	0.676	0.289	0.538	0.69	0.749	0.755	0.752	0.813	0.172	0.187	0.188	0.188	0.203
Parasi	0.186	0.662	0.565	0.206	0.769	0.814	0.827	0.832	0.894	0.111	0.117	0.119	0.12	0.129
Parbat	0.137	0.774	0.327	0.619	0.713	0.773	0.799	0.77	0.823	0.129	0.14	0.145	0.14	0.149
Parsa	0.273	0.572	0.674	0	0.787	0.813	0.838	0.852	0.9	0.09	0.093	0.096	0.098	0.103
Pyuthan	0.274	0.927	0.386	0.749	0.652	0.71	0.728	0.69	0.743	0.282	0.307	0.315	0.299	0.322
Ramechhap	0.342	0.854	0.342	0.704	0.6	0.631	0.628	0.635	0.706	0.303	0.319	0.317	0.321	0.357
Rasuwa	0.268	0.653	0.293	0.502	0.428	0.476	0.504	0.466	0.537	0.134	0.15	0.158	0.146	0.169
Rautahat	0.282	0.589	0.763	0	0.78	0.829	0.839	0.824	0.874	0.067	0.071	0.072	0.07	0.075
Rolpa	0.33	0.818	0.252	0.76	0.587	0.632	0.653	0.601	0.661	0.301	0.324	0.335	0.309	0.339
Rupandehi	0.277	0.654	0.758	0	0.77	0.801	0.813	0.816	0.873	0.09	0.094	0.095	0.096	0.102
Salyan	0.41	0.816	0.306	0.696	0.633	0.668	0.699	0.648	0.702	0.382	0.403	0.422	0.391	0.424
Sankhuwasabha	0.78	0.942	0.224	0.951	0.65	0.698	0.712	0.684	0.77	0.844	0.907	0.925	0.889	1
Saptari	0.307	0.59	0.708	0	0.77	0.798	0.79	0.887	0.887	0.098	0.102	0.101	0.113	0.113
Sarlahi	0.274	0.62	0.729	0	0.771	0.814	0.819	0.827	0.876	0.089	0.094	0.094	0.095	0.101
Sindhuli	0.589	0.985	0.665	0.505	0.714	0.757	0.754	0.766	0.823	0.52	0.551	0.549	0.558	0.6
Sindhupalchok	0.501	0.966	0.522	0.643	0.576	0.62	0.636	0.627	0.699	0.411	0.442	0.453	0.447	0.498
Siraha	0.212	0.594	0.712	0	0.759	0.783	0.77	0.854	0.851	0.065	0.067	0.066	0.073	0.073
Solukhumbu	0.728	0.783	0.335	0.622	0.48	0.509	0.518	0.5	0.575	0.456	0.485	0.492	0.475	0.547
Sunsari	0.348	0.567	0.769	0	0.787	0.826	0.823	0.843	0.884	0.071	0.074	0.074	0.076	0.08
Surkhet	0.638	0.895	0.543	0.529	0.638	0.658	0.691	0.647	0.706	0.523	0.54	0.567	0.531	0.579
Syangja	0.216	0.855	0.473	0.556	0.753	0.819	0.843	0.815	0.863	0.209	0.228	0.234	0.226	0.24
Tanahu	0.368	0.811	0.641	0.31	0.768	0.835	0.86	0.833	0.877	0.266	0.289	0.298	0.288	0.304
Taplejung	0.783	0.839	0.272	0.764	0.572	0.629	0.648	0.605	0.688	0.645	0.709	0.729	0.681	0.775
Terhathum	0.141	0.654	0.295	0.502	0.682	0.742	0.747	0.733	0.811	0.116	0.126	0.127	0.125	0.138
Udayapur	0.483	0.853	0.634	0.372	0.697	0.735	0.73	0.749	0.805	0.352	0.372	0.369	0.378	0.407
Western Rukum	0.264	0.799	0.293	0.69	0.511	0.55	0.564	0.517	0.576	0.186	0.2	0.206	0.188	0.21