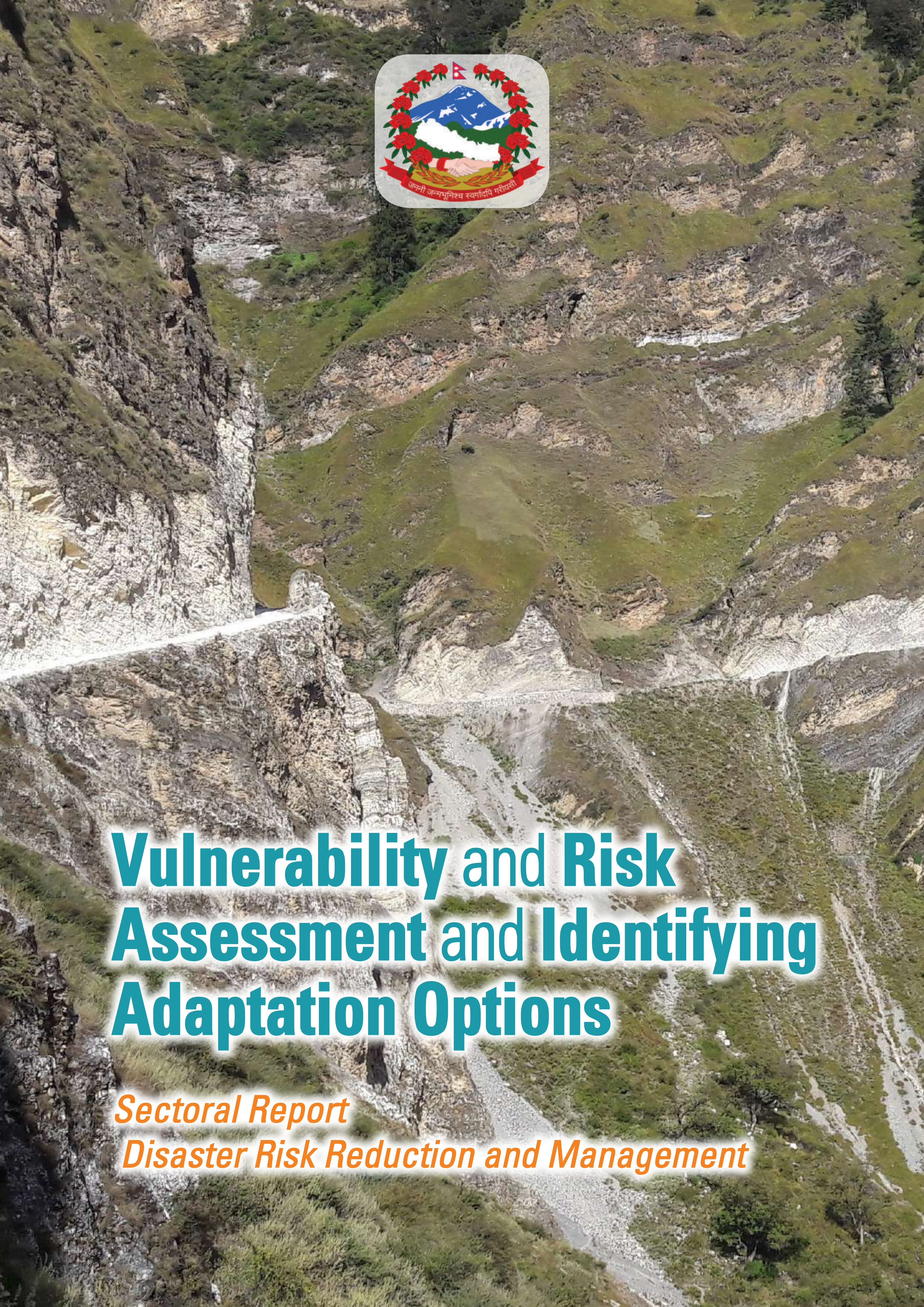

Vulnerability and Risk Assessment and Identifying Adaptation Options

Sectoral Report
Disaster Risk Reduction and 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 Disaster Risk Reduction and Management (DRRM) 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 distinguished Chair - the Joint Secretary of the Ministry of Home Affairs- 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)

Acknowledgment

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.

A 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 Disaster Risk Reduction and Management (DRRM) 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 Dilip Gautam, Dinanth Bhandari, Bamshi Acharya, 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, 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

CBS	Central Bureau of Statistics
CCA	Climate Change Adaptation
DFO	Dartmouth Flood Observatory
DHM	Department of Hydrology and Meteorology
DoFSC	Department of Forests and Soil Conservation
DRR	Disaster Risk Reduction
DRRM	Disaster Risk Reduction and Management
DSS	Decision Support System
ESSL	European Severe Storms Laboratory
FAR	Fraction of Attributable Risk
FY	Fiscal Year
GDP	Gross Domestic Product
GESI	Gender Equality and Social Inclusion
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flood
GoN	Government of Nepal
HDI	Human Development Index
HPI	Human Poverty Index
ICE	Information, Communication, and Education
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
IVR	Interactive Voice Response
L&D	Loss and Damage
METEOR	Modelling Exposure Through Earth Observation Routines
MODIS	Moderate Resolution Imaging Spectroradiometer
MoE	Ministry of Environment
MoF	Ministry of Finance
MoFE	Ministry of Forests and Environment
MoHA	Ministry of Home Affairs
MoHP	Ministry of Health and Population
MoPE	Ministry of Population and Environment
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NASA	National Aeronautics and Space Administration

NGO	Non-Governmental Organization
NPC	National Planning Commission
PWD	People With Disability
RCP	Representative Concentration Pathway
SMS	Short Message Service
SREX	Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
TWG	Thematic Working Group
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WMO	World Meteorological Organization
VRA	Vulnerability and Risk Assessment

सारांश

नेपाल सरकार वन तथा वातावरण मन्त्रालयले जलवायु परिवर्तन राष्ट्रिय अनुकूलन योजना (NAP) तयार गर्दैछ । जलवायु परिवर्तनका कारण सृजित सङ्कटासन्नता तथा जोखिमलाई कम गर्नु र सम्बन्धित विषयगत क्षेत्रका सबै तहका नीति, कार्यक्रम तथा कृयाकलापहरूमा जलवायु परिवर्तन अनुकूलनलाई एकीकृत गर्न सहजीकरण गर्नु राष्ट्रिय अनुकूलन योजनाको प्रमुख उद्देश्य रहेको छ । सङ्कटासन्नता र जोखिमको अध्ययन तथा विश्लेषण राष्ट्रिय अनुकूलन योजनातयारी प्रकृयाको एक अपरिहार्य चरण हो,जसले विभिन्न भौगोलिक तथा प्रशासनिक क्षेत्रमा जलवायुजन्य जोखिमको स्तर बुझ्न र जोखिम व्यवस्थापनको लागि स्थानीय, प्रदेश एवं संघीय संरचनाहरूको लगानीलाई प्राथमिकीकरण गर्न मद्दत गर्दछ ।

यस अध्ययनले विपद् जोखिम न्यूनीकरण तथा व्यवस्थापनको क्षेत्रमा जलवायुजन्य प्रकोपहरूको प्रवृत्ति र परिदृश्यको विश्लेषणका आधारमा जिल्ला, प्रदेश र भौगोलिक क्षेत्रहरूमा प्रकोप प्रभावित क्षेत्रहरू पहिचान गरेको छ । यस्ता सूचना तथा जानकारीहरूले जोखिममा रहेका वर्ग र क्षेत्रहरूका लागि जोखिम न्यूनीकरण गर्न र अनुकूलन तथा उत्थानशीलता अभिवृद्धि सम्बन्धी रणनीतिक पहलका लागि आवश्यक सहयोग पुऱ्याउँछन् ।

यो अध्ययन तथा विश्लेषण वन तथा वातावरण मन्त्रालयले निर्दिष्ट गरेको जोखिम तथा सङ्कटासन्नता विश्लेषणको राष्ट्रिय ढाँचा, जलवायु परिवर्तन सम्बन्धीअन्तरसरकारी समूह (Intergovernmental Panel on Climate Change, IPCC) द्वारा प्रकाशित पाँचौं विश्लेषण प्रतिवेदन (Fifth Assessment Report, AR5) र राष्ट्रिय अनुकूलन योजना निर्माणको लागि तयार गरिएका प्राविधिक दिशा निर्देशहरूमा आधारित छ । IPCC ले प्रतिपादन गरेको ढाँचा अनुसार जोखिमलाई प्रकोप, सम्मुखता र सङ्कटासन्नताको प्रकार्यका रूपमा मानिएको छ ।

यस अध्ययनमा निम्न दुईवटा विश्लेषणहरू समावेश छन्, १) जलवायुजन्य प्रकोपहरूको विगतको प्रवृत्ति र २) जलवायुजन्य चरम घटनाहरूको विगत र भविष्यको परिदृश्य । जलवायुजन्य प्रकोपहरूको विगतको प्रवृत्ति र भविष्यको परिदृश्य दुवैको विश्लेषण जलवायुजन्य प्रकोपहरूमा आएको परिवर्तनको पहिचान र परिवर्तित जलवायुजन्य प्रकोपहरूको जलवायु परिवर्तनसँगको सम्बन्धमा आधारित रहेका छन् । जलतथा मौसम विज्ञान विभागले तयार गरेको "नेपालको जलवायु प्रवृत्तिको विश्लेषण (सन् १९७१ देखि २०१४)" र वन तथा वातावरण मन्त्रालयले तयार गरेको "नेपालमा जलवायु परिवर्तनको परिदृश्य" लाई जलवायुजन्य प्रकोपहरूका विगत र भविष्यको परिदृश्यहरूलाई चित्रण गर्न प्रयोग गरिएको छ ।

सङ्कटासन्नता तथा जोखिम विश्लेषणका प्रकृयागत चरणहरूमा जलवायुजन्य प्रकोपहरू परिवर्तनका सूचकहरूको पहिचान; आवश्यक तथ्याङ्कको श्रोत पहिचान, तथ्याङ्कको प्रकृति तथा विशेषताको विश्लेषण; तथ्याङ्क संकलन, तालिकीकरण, छनौट; सामान्यीकरण, भार प्रदान, समग्र मानको गणना; नक्साङ्कन अनुकूलनका उपायहरूको पहिचान र प्राथमिकीकरण; तथा सरोकारवालाहरूसँगको छलफल र परामर्श मार्फत् प्रमाणीकरण रहेका छन् ।

सन् १९७१ देखि २०१९ सम्म जलवायुजन्य विभिन्न घटनाहरूबाट भएको नोक्सान र क्षतिको उपलब्ध तथ्याङ्कलाई अध्ययन गर्दा, प्रत्येक वर्ष नेपालमा जलवायुजन्य विपद्बाट औसतमा ६४७ जनाको मृत्यु भएको देखिन्छ । प्राप्त तथ्याङ्क अनुसार सन् २००१ मा जलवायुजन्य विपद्को घटनाले सबै भन्दा धेरैको मृत्यु भएको थियो । जसमा महामारी, पहिरो, चट्याङ, आगलागी, बाढी, भारी वर्षा र आँधीबेहरी जस्ता जलवायुजन्य विपद्का कारण १८६६ व्यक्तिको ज्यान गएको थियो । विपद्का कारण नेपालमा प्रतिवर्ष औसत आर्थिक क्षति २७७८ मिलियन नेपाली रूपैयाँ हुन्छ जुन आर्थिक वर्ष २०१८/१९ को कूल गार्हस्थ उत्पादन (GDP) को (वर्तमान मुल्यमा) ०.०८% हो । सबै भन्दा धेरै आर्थिक क्षति (नेपाली

रूपैयाँ ६३१८६ मिलियन) सन् २०१७ मा तराईमा आएको बाढीको कारणले भएको थियो, जुन आर्थिक वर्ष २०१७/१८ को कूल गार्हस्थ उत्पादनको (वर्तमान मुल्यमा) २.०८% हुन आउँछ।

बाढी, पहिरो, महामारी र आगलागी नेपालमा जलवायुसँग सम्बन्धित प्रमुख विपद्का घटनाहरू हुन्। जलवायुजन्य विपद्का कारण भएको मानवीय र आर्थिक क्षतिलाई तुलना गर्दा सबैभन्दा बढी मृत्यु महामारीबाट (५२.८%) र त्यसपछि क्रमशः पहिरो (१६.७%) र बाढीबाट (१२.७%) भएको देखिन्छ। यद्यपि बाढीले कुल प्रभावित जनसंख्याको करिब ७१% लाई प्रभावित गरेको छ भने पहिरोले ९.५% लाई र महामारीले ८.२% लाई प्रभावित गरेको छ। त्यस्तै आर्थिक क्षति आगलागीबाट सबैभन्दा बढी (५६.६%) र त्यसपछि बाढी (३१%) र पहिरो (३.७%) बाट भएको देखिन्छ।

बाढी, पहिरो र खडेरी नेपालका प्रमुख जलवायुजन्य प्रकोपमा पर्दछन् र यी प्रकोपहरू जलवायु परिवर्तनका कारण भविष्यमा अझ तीव्र हुने सम्भावना रहेको अध्ययनहरूले देखाएका छन्। हाल नेपालको करीब ८% भू-भागमा बाढी र करीब ५९% भू-भागमा पहिरोको उच्च प्रभाव रहेको छ। त्यस्तै औसतमा नेपालको करीब ५६% क्षेत्र खडेरीबाट प्रभावित छ भने खडेरीको औसत अवधि प्रति वर्ष ३.४ महिना (१०२ दिन) छ।

यस विश्लेषणले विपद् सम्बन्धी डाटाबेसमा अद्यावधिक भएका विभिन्न १५ वटा जलवायुजन्य प्रकोपहरूलाई समेटेको छ। जसमा बाढी, पहिरो, महामारी, आगलागी, चट्याङ, भारी वर्षा, खडेरी, हिमताल विष्फोटन बाढी (GLOF), तातो हावाको लहर, चिसो हावाको लहर, आँधीबेहरी, हिमपहिरो, हिमपात, असिना र वन डढेलो पर्दछन्। १४ वटा जलवायुजन्य प्रकोपहरू (GLOF बाहेक) को विगतको प्रवृत्तिलाई विश्लेषण गर्दा विशेष गरी सन् १९९० पछि यस्ता प्रकोपका घटनाहरूको प्रवृत्तिमा उल्लेखनीय वृद्धि भएको देखिन्छ। मौसमी खडेरी बाहेक सबै प्रकोपका घटनाहरूको प्रवृत्ति बढ्दो क्रममा रहेको छ। धेरै जिल्लाहरूमा वर्षात्का दिनहरू बढ्दो क्रममा रहेकोले मौसमी खडेरीका घटनाहरू घट्दै गइरहेको हुनसक्ने अनुमान गरिएको छ। महामारी, हिमपहिरो, असिना र खडेरीको प्रवृत्ति नगन्य मात्रामा (statistically insignificant) रहेको छ भने अन्य १० जलवायुजन्य प्रकोपहरूको प्रवृत्ति उल्लेखनीय (statistically significant at a 5% level) रूपमा बढी रहेको छ।

जलवायुजन्य प्रकोपका ऐतिहासिक घटनाहरूको विश्लेषणको आधारमा सुनसरी, कैलाली, मोरङ, झापा, रौतहट, बर्दिया, सर्लाही र सप्तरी जिल्लाहरू बाढीको उच्च प्रभाव क्षेत्र "हटस्पट" (Hotspot) को रूपमा पहिचान गरिएका छन्। त्यस्तै, धादिङ, संखुवासभा, बाग्लुङ, सिन्धुपाल्चोक, डोल्पा, ताप्लेजुङ, रोल्पा, मकवानपुर, म्याग्दी, लमजुङ, दोलखा, नुवाकोट, गोरखा, सोलुखुम्बु, काभ्रेपलाञ्चोक, दैलेख, दार्चुला, स्याङ्जा, पाल्पा, खोटाङ, बाजुरा, कालीकोट, कास्की, जाजरकोट, बझाङ, गुल्मी र इलाम जिल्लालाई पहिरोको उच्चप्रभाव क्षेत्र "हटस्पट" को रूपमा पहिचान गरिएको छ। मानवीय र आर्थिक प्रभावको आधारमा, मकवानपुर, रौतहट, बाँके, कैलाली, सिराहा, मोरङ, डोटी, चितवन, धनुषा, सर्लाही, महोत्तरी, पर्सा, सप्तरी, सुनसरी, सिन्धुपाल्चोक, दाङ, कास्की, कञ्चनपुर र झापा जिल्लालाई जलवायुजन्य विपद्को उच्च प्रभाव क्षेत्र "हटस्पट" को रूपमा पहिचान गरिएको छ।

जलवायु परिवर्तनका परिदृश्यहरू हेर्दा तापक्रमका हिसावले, ताता दिन/रात, र न्यानो अवधि बढ्ने सम्भावनाको संकेत गर्दछ भने चिसा दिन/रात र चिसो हुने अवधि कम हुने सम्भावना छ। त्यस्तै वर्षाको हकमा धेरै वर्षात्का दिनहरू र अत्यधिक वर्षात्का दिनहरू बढ्ने देखिन्छ भने नेपालभरि नै वर्षा हुने दिनहरू कम हुने सम्भावना देखिएको छ। लगातार सुख्खा दिनहरूमा वृद्धि र लगातार वर्षात्का दिनहरू बढ्ने सम्भाव्यता कम देखिन्छ।

परिवर्तित जलवायु तथा चरम मौसम सूचकाङ्कको परिदृश्यबाट भविष्यमा जलवायुजन्य प्रकोपहरूको परिदृश्य आँकलन गरिएको छ। भविष्यमा चिसो हावाको लहर र हिमआँधीहरू कम हुँदै जाने सम्भावना देखिन्छ। तातो हावाको लहर,

भारी वर्षा, चट्याङ, आँधीबेहरी, बाढी, पहिरो, हिमताल विष्फोटन बाढी, आगलागी, हिमपहिरो, महामारी र वन डढेलो बढ्ने सम्भावना देखिन्छ भने असिना र खडेरीमा वृद्धि हुन सक्ने सम्भावना कम देखिन्छ ।

बढ्दो तापक्रम र तातो हावाको लहरले रोगव्याधी, मृत्युदर, गाईवस्तु तथा वन्यजन्तुमा तापक्रमको नकारात्मक प्रभाव, बालीनालीलाई क्षति र हावाबाट सर्ने रोगहरूमा वृद्धि हुनसक्छ । बढ्दो भारी वर्षाले बाढी, पहिरो, हिमपहिरो, भूक्षय, जलजन्य रोगहरूमा वृद्धि हुनका साथै विपद् प्रतिकार्य, पुनःस्थापना, र पुनर्लाभका क्रियाकलापहरूमा चाप बढ्न सक्दछ । त्यस्तै हिमपातको कमीले पानीको उपलब्धता र हिउँदे बालीको उत्पादन कम हुनुका साथै रोग/किराहरूको संक्रमण बढ्न सक्छ ।

बढ्दो चट्याङ, आँधीबेहरी, बाढी, हिमताल विष्फोटन बाढी र पहिरोका घटनाहरूले मानवीय क्षति र मृत्युदर, गाईवस्तुको मृत्युदर, घरहरूमा क्षति, जग्गाको उर्वराशक्तिमा कमी, जीविकोपार्जनका स्रोत साधन तथा अन्य पूर्वाधार हरूमा हुने हानी तथा नोक्सानीलाई थप वृद्धि गर्न सक्छ । असिना बढेको खण्डमा बालीनाली नष्ट हुन सक्छ । बढ्दो खडेरीले बालीलाई नोक्सान गर्ने, अनिकाल बढाउने, पानीको अभाव बढ्ने, पानी प्रदूषण, महामारी, हावा र पानीबाट सर्ने रोगहरू बढ्न सक्छन् । आगलागीको बढ्दो घटनाले मानवीयमृत्यु दर र घर तथा सम्पत्तिको क्षति बढ्न सक्छ । वन डढेलोले वन विनाशका साथै वन्यजन्तुहरू र चराचुरुङ्गीको वासस्थानमा क्षति र वनमा आधारित जीविकोपार्जन प्रभावित हुन सक्छ । यसका साथै वन विनाशका कारण हुने अन्य विपद्हरू जस्तै बाढी र पहिरोको घटनाहरूमा वृद्धि हुन सक्छ । हिमपहिरो बढ्नाले मानवक्षति, मृत्युदर, घरहरू र पूर्वाधारमा क्षति बढ्न सक्छ । त्यस्तै महामारी बढ्दा रोगव्याधी र मृत्युदर बढ्न सक्छ, सार्वजनिक स्वास्थ्य सेवा र बीमा प्रणालीमा थप दबाव पर्न सक्छ ।

जलवायुजन्य विपद् जोखिम न्यूनीकरणका लागि राष्ट्रिय, प्रदेश र स्थानीय स्तरमा सरोकारवालाहरूसँग परामर्श गरेर अनुकूलनका उपायहरू पहिचान गरिएको छ । जलवायु परिवर्तन र विपद जोखिम न्यूनीकरण सम्बन्धी राष्ट्रिय र अन्तर्राष्ट्रिय नीति, रणनीति र कार्ययोजनाहरूको समीक्षामा आधारित भएर अनुकूलनका उपायहरूको पहिचान गरिएको छ । पहिचान गरिएका अनुकूलनका उपायहरूलाई संरचनात्मक/भौतिक, सामाजिक र संस्थागत गरी तीनवटा क्षेत्रमा वर्गीकरण गरिएको छ । संरचनात्मक र भौतिक विकल्पहरूमा ईन्जिनियरिङ्ग डिजाईन मार्फत् गरिएको निर्माण तथा वातावरणको विकास, प्रविधिहरूको प्रयोग, पारिस्थितिकीय प्रणालीमा आधारित संरचना, र सेवाहरूको प्रयोगलाई समावेश गरिएको छ भने सामाजिक विकल्पहरूमा जोखिमको ज्ञान बढाउने, सूचनाका रणनीतिहरू र व्यवहार परिवर्तनका उपायहरू संलग्न शैक्षिक कार्यक्रमहरू समावेश गरिएको छ । संस्थागत विकल्पहरूमा आर्थिक एवं वित्तीय सहुलियत, कानून तथा नियमहरू र सरकारी नीति तथा कार्यक्रमहरू समावेश गरिएको छ ।

विपद जोखिम न्यूनीकरणका विभिन्न कृयाकलापहरूलाई जलवायु परिवर्तन अनुकूलनका उपायहरूको रूपमा पहिचान गरिएको छ । विपद जोखिम न्यूनीकरणका लागि जोखिमको ज्ञान बृद्धि गर्ने, विपद् जोखिम न्यूनीकरणमा शासकीय प्रणालीको सुदृढीकरण, इन्जिनियरिङ्ग डिजाईन गरिएको पूर्वाधारको विकास, जीविकोपार्जनका अवसरहरूको विविधिकरणलाई प्रोत्साहन, जोखिमको साझेदारी र हस्तान्तरण, सूचनातथा सञ्चारका प्रविधिको विकास र पूर्वसूचना प्रणालीको प्रयोगको साथै विपद् पूर्वतयारी तथा प्रतिकार्य प्रणालीको विकास गर्ने जस्ता गतिविधिहरू समावेश गरिएका छन् ।

निश्कर्षमा, जलवायु परिवर्तनले भविष्यमा जलवायु सम्बन्धी प्रकोपका घटनाहरू र जलवायुजन्य विपद्हरू बढाउन सक्छ, जसले मानव जीवनको क्षति, सम्पत्तिको विनाश, आर्थिक क्षेत्रमा क्षति पुऱ्याउनुका साथै मानसिक स्वास्थ्यमा नकारात्मक प्रभाव, बोटबिरुवा, पशु र वातावरणीय सेवाहरू समेतमा हानी नोक्सानी बढ्न सक्ने देखिन्छ ।

यस अध्ययनका मुख्य सुझावहरू निम्नानुसार छन् ।

- स्थानीय स्तरमा जलवायु, विपद् र सामाजिक-आर्थिक स्थितिको विस्तृत तथ्याङ्क सङ्कलन प्रणालीको विकास गरेर सङ्कटासन्नता तथा जोखिमको आँकलन गर्ने ।
- विज्ञानमा आधारित भौतिक मोडल (physically based modeling) को प्रयोग गरी भविष्यमा हुने जलवायुजन्य प्रकोपहरूका परिदृश्यहरूको क्रमगत विकासको आँकलन गर्ने ।
- प्रत्येक जलवायुजन्य प्रकोपको लागि जलवायु परिवर्तनका सूचकहरूको न्यूनतम सीमा (Threshold) आँकलन तथा निर्धारण गर्ने । निर्धारित न्यूनतम सीमा (Threshold) को प्रयोग गरी परिवर्तित भू-उपयोग र सामाजिक-आर्थिक स्थिति समेतको आधारमा जलवायु सङ्कटासन्नता तथा जोखिम विश्लेषण अद्यावधिक गर्ने ।
- सबै विषयगत क्षेत्रका योजना तर्जुमा, डिजाईन, निर्माण र व्यवस्थापनमा जलवायुजन्य जोखिमलाई समेट्नका लागि सङ्कटासन्नता तथा जोखिम विश्लेषणको उपयोग गर्न निर्णय सहयोगी प्रणाली (Decision Support System) को विकास तथा कार्यान्वयन गर्ने ।

Executive Summary

The Ministry of Forests and Environment (MoFE) of Nepal is currently in the process of formulating the National Adaptation Plan (NAP), the aim of which is to reduce the country's vulnerability and risk due to climate change and to facilitate the integration of climate change adaptation (CCA) into policies, programs, and activities across all sectors and governance levels. An important component of creating an adaptation plan like the NAP is carrying out Vulnerability and Risk Assessments (VRAs). A VRA helps to understand the level of vulnerability and risk in each sector across different municipalities, districts, provinces, and physiographic regions and to prioritize investments for adaptation and climate risk management.

In the Disaster Risk Reduction and Management (DRRM) sector, trends and scenarios of climatic hazards have been assessed to identify "Key Hazard Hotspots" in districts, provinces, and physiographic regions. This study, a VRA of Nepal's Disaster Risk Reduction and Management (DRRM) sector, uses a framework that is based on suggestions from the MoFE and IPCC, and technical guidelines for formulation of the NAP. The IPCC framework considers risk as a function of hazard, exposure, and vulnerability.

The assessment approach included both trends of climatic hazards that have already occurred and the future scenarios of climate extreme events (especially the way that such scenarios are anticipated to change with climate change). For both past trends and future scenarios, a core focus of the assessment depends on the detection and attribution of changes in climatic hazards. The "Observed Climate Trend Analysis of Nepal (1971-2014)" prepared by the Department of Hydrology and Meteorology, and the 'Climate Change Scenarios for Nepal', prepared by the MoFE and the International Centre for Integrated Mountain Development (ICIMOD), were used to characterize broad past and future scenarios of climatic hazards.

The methodological steps used in this VRA included: i) identifying key indicators for the changes in climatic hazards; ii) exploring data sources; iii) analysing the nature and character of available data; iv) collecting and analysing data; v) tabulating, filtering and normalizing data; vi) assigning weightage and computing index values; vii) mapping and visualization; viii) identifying and appraising adaptation options; and ix) validating findings through consultations.

Based on the available data on losses and damage from different climate-induced disastrous events between 1971 and 2019, about 647 people on average die from climate-induced disasters in Nepal each year. The maximum number of climate-induced disaster deaths occurred in 2001, when 1866 people lost their lives due to epidemics, landslides, thunderbolts, fires, floods, heavy rainfall, and windstorms. The average economic loss per year is 2,778 million Nepalese Rupees, which is about 0.08% of the country's GDP (at the current price) for FY 2018/19. The maximum economic loss of 63,186 million Nepalese Rupees was incurred in 2017 during the Terai floods, which is about 2.08% of GDP (at the current price) of FY2017/18.

Floods, landslides, epidemics, and fires are the major climate-related disasters in Nepal. A hazard-wise comparison of the death, affected population and economic losses shows that epidemics caused the most deaths (52.8%) followed by landslides (16.7%) and floods (12.7%).

Floods affected about 71% of the total affected population, followed by landslides (9.5%) and epidemics (8.2%). Fires caused the most economic losses (56.6%), followed by floods (31%) and landslides (3.7%).

Floods, landslides, and droughts are the major climatic hazards in Nepal that are likely to be intensified in the future due to climate change. At present, about 8% of Nepal is flood-prone and about 59% of the area is landslide-prone. On average, about 56% of Nepal is affected by drought. The average duration of drought is about 3.4 months (102 days) per year.

This study considered 15 climate-related hazards that were recorded in disaster databases. These were floods, landslides, epidemics, fires, thunderbolts, heavy rainfall, droughts, glacial lake outburst floods (GLOFs), heatwaves, cold waves, windstorms, avalanches, snowstorms, hailstorms, and forest fires. The trend analysis of 14 climate-related hazards (except GLOFs) revealed that there is a significant increasing trend in hazard occurrences, especially after 1990. All hazard events are on an increasing trend, except meteorological droughts, which are on a decreasing trend. While the trends of epidemics, avalanches, hailstorms, and droughts were statistically insignificant, the trends of the other 10 hazards were statistically significant at a 5% level.

Based on the analysis of historical hazard occurrences, the Sunsari, Kailali, Morang, Jhapa, Rautahat, Bardiya, Sarlahi, and Saptari districts were identified as "**Flood Hazard Hotspots**". Similarly, the Dhading, Sankhuwasabha, Baglung, Sindhupalchok, Dolpa, Taplejung, Rolpa, Makawanpur, Myagdi, Lamjung, Dolakha, Nuwakot, Gorkha, Solukhumbu, Kavrepalanchok, Dailekh, Darchula, Syangja, Palpa, Khotang, Bajura, Kalikot, Kaski, Jajarkot, Bajhang, Gulmi, and Ilam were identified as "**Landslide Hazard Hotspots**". Lastly, based on human and economic impacts, the Makawanpur, Rautahat, Banke, Kailali, Siraha, Morang, Doti, Chitawan, Dhanusha, Sarlahi, Mahottari, Parsa, Saptari, Sunsari, Sindhupalchok, Dang, Kaski, Kanchanpur, and Jhapa districts were identified as the climate-related "**Disaster Hotspots**". Knowing these hotspots can support devising anticipatory risk management measures, as well as adaptation and resilience-building strategies/initiatives targeted at vulnerable populations and sectors.

Climate change scenarios indicate that, across Nepal, temperatures, warm days and nights, and warm spell duration are *likely* to increase in the future. Cold days and nights and cold spell duration are *likely* to decrease. Precipitation, very wet days, and extreme wet days are *likely* to increase, and rainy days are *likely* to decrease. An increase in consecutive dry days and an increase in consecutive wet days are *about as likely as not*.

Future scenarios of climatic hazards were inferred from the scenarios of climate variables and climate extreme indices. In the future, cold waves and snowstorms are *likely* to decrease. Heatwaves, heavy rainfall, thunderbolts, windstorms, floods, landslides, GLOFs, fires, avalanches, epidemics, and forest fires are *likely* to increase. Increases in hailstorms and droughts are *about as likely as not*.

Increased heatwaves may increase heat-related morbidity and mortality, heat stress in livestock and wildlife, damage to crops, and an increase in vector-borne diseases. Increased heavy rainfall may increase floods, landslides, avalanches, mudslides, soil erosion, water-borne diseases, and increase pressure on disaster response, rehabilitation, and recovery. Decreased snowstorms may reduce water availability and winter crop yield and increase pests and diseases.

Increased thunderbolts, windstorms, floods, GLOFs, and landslides may increase human morbidity and mortality, livestock mortality, and damage to houses, productive land/livelihood assets, and other infrastructure. Increased hailstorms may damage standing crops. Increased droughts may damage crops, increase famine, increase water shortages, water pollution, epidemics, and vector-and water-borne diseases. Increased fires may increase human morbidity and mortality, and cause loss of houses and assets. Increased forest fires may degrade forests, increase the loss of wildlife and bird habitat, and cause loss of forest-based livelihoods, and increase flash floods and landslides. Increased avalanches may increase human morbidity and mortality, and cause damage to houses and infrastructure. Increased epidemics may increase human morbidity and mortality, and put pressure on public health services and the insurance system.

Several adaptation measures for reducing climate-related disaster risks were identified by consulting with stakeholders at the national, provincial, and local levels. The identification of adaptation measures was also based on a review of national and international policies, strategies, and action plans related to climate change and disaster risk reduction. These measures were organized into three categories: structural/physical, social, and institutional. The structural and physical options include the development of an engineered and built environment, application of technologies, an ecosystem-based approach, and the use of services. The social options include educational programs for enhancing risk knowledge, informational strategies, and behavioural measures. The institutional options include economic instruments, laws and regulations, and government policies and programs.

Various DRRM activities were identified as adaptation measures. These include enhancing risk knowledge; strengthening DRRM governance; developing engineered infrastructure; promoting diversified livelihoods; risk sharing and transfer mechanisms; and developing an effective preparedness and response system with the use of information and communication technology and early warning systems.

It is highly likely that climate change will lead to an upsurge in climate-related hazard occurrences in the future, which may likely lead to increased loss of human lives, destruction of assets, disruption of economic sectors, mental health effects, and loss of and damage to plants, animals, and ecosystem services.

This VRA was not without limitations. Due to a lack of relevant data, the study could not look into the municipalities. The study also relied on an indicator-based approach to hazard assessment. Besides, the projection of climate-induced hazards was difficult. The main recommendations of the study are: (i) assess the vulnerability and risk by developing a comprehensive climate, disaster, and socio-economic database at the local level, (ii) assess the evolution of major hazard scenarios under future climate change using physically-based modelling, and (iii) assess the threshold values of climate variables for each climate-related hazard, and revise the VRA periodically using these threshold values and according to any changes in land use and socio-economic conditions.

Table of Contents

List of Tables

List of Figures

Chapter 1

Background and Sectoral Context

Nepal is bearing the brunt of climate change, and its consequences are seen across the country. To put the country on a path to a climate-resilient future, concerted measures are required. In addition to metrics and policy alternatives for dealing with climate-resilient development, cultivating an understanding of the links between climate change, climate-related disasters and development is increasingly viewed as more and more important by policymakers and practitioners. Climate change, climate-related disasters, and development are all intertwined in complex, dynamic, and ever-changing ways. In order to better understand and address climate-change-related risks and adaptation strategies, it is critical to first assess the trends and scenarios of climate change and climatic hazards. Towards this end, the Ministry of Forests and Environment (MoFE) of Nepal has taken the lead in developing the National Adaptation Plan (NAP). The NAP aims to 'reduce the country's vulnerability and risk due to climate change' as well as to facilitate the integration of Climate Change Adaptation (CCA) into policies, programs, and activities across all sectors and governance levels' (MoFE, 2018). One crucial component in developing an adaptation plan like the NAP is to carry out Vulnerability and Risk Assessments (VRAs). VRAs help in understanding the level of climate change related risk, evaluating the costs and benefits of risk reduction investments, and prioritizing these investments. Nepal's National Climate Change Policy of 2019 identifies eight thematic and four cross-cutting areas where CCA measures should be integrated (GoN, 2019). One of the eight sectors where CCA must be integrated is disaster risk reduction and management (DRRM).

The process for formulating the NAP includes determining vulnerability and risk, as well as developing short-, medium-, and long-term adaptation measures. VRAs can be used to identify vulnerability and risks in different sectors based on historical trends and future scenarios of climate change-related hazards and socioeconomic situations, as well as adaptation solutions for the sectors. Trends and baselines of climate hazards have been assessed in the DRRM sector to identify "hazard hotspots" at the district, province, and physiographic region levels. The identification and characterization of hazard-prone areas can help to inform and encourage proactive measures for reducing vulnerabilities and managing risks.

Chapter 2

Objectives and Scope of the Study

2.1 Objectives

The overarching objective of this work is to assess changes in climatic hazards as a result of climate change and to identify DRRM options to develop an evidence-based, risk-sensitive NAP. Specific objectives are to:

- analyse the trend of climatic hazards,
- assess past and future scenarios of climatic hazards, rank/categorize them, and identify key "climate hazard hot spots",
- identify adaptation measures for climate-induced disaster risks, and validate adaptation measures.

2.2 Rationale

Many disaster-related risks arise due to climate variability and climate extremes[1], such as floods, landslides, and droughts. As a consequence, efforts to reduce climate-related disasters have existed for a long time. In recent years, there has been growing attention to the relationship between climate change adaptation and disaster risk reduction. Considerable similarities exist in the types of actions needed to reduce both kinds of risks (i.e., those related to climate variability and climate extremes). There is great scope for mutual learning while noting that climate change has the potential to increase the intensity and frequency of disasters, which may require additional or new actions when compared to past trends. The overlap is therefore on issues related to shocks and stresses-climate-related disasters (Regmi et al., 2019).

As our experience with and understanding of CCA and DRRM grows, there is increasing recognition that these two fields share common objectives[2], such as

1 Weather is the condition of the atmosphere over a short period of time. Climate is how the atmosphere "behaves" over long periods of time, i.e. 20 or 30 years. Climate variability reflects periodic or intermittent changes from this average, such as caused by El Niño or La Niña events.

2 While noting there are differences, disaster risk reduction covers a much wider set of risks than climate related disasters. Climate change adaptation also addresses changing trends (not just shocks or disasters).

reducing risk and vulnerability of communities and their livelihoods, properties, and reducing risk to infrastructure and the built environment. In the long term, there is a need for resilience building and to achieve sustainable development goals (SDGs). Once the development basis of CCA and DRRM are considered, along with the role of vulnerability in the constitution of risk, the temporal scale of concerns, and the corrective as well as prospective nature of disaster risk reduction, the similarities between and options for merging of concerns and practices increase commensurately (Regmi et al., 2019).

However, considering the expected changes in the intensity and frequency of extreme climate events, the VRA of such events poses a significant challenge. Risk constitutes the product of an interaction between hazard, vulnerability, and exposure. Environmental and climate change may amplify any given hazards, whereas changes in socio-economic conditions may increase exposure and vulnerability (Malet et al., 2012). Figure 1 below demonstrates this interaction. Since climate change is expected to magnify existing risk levels, risk assessment should be the starting point for managing and eventually reducing future risks. Risk assessment can also form the basis of cost-benefit analysis of risk reduction strategies and optimization of public investment and development planning (EC, 2008).

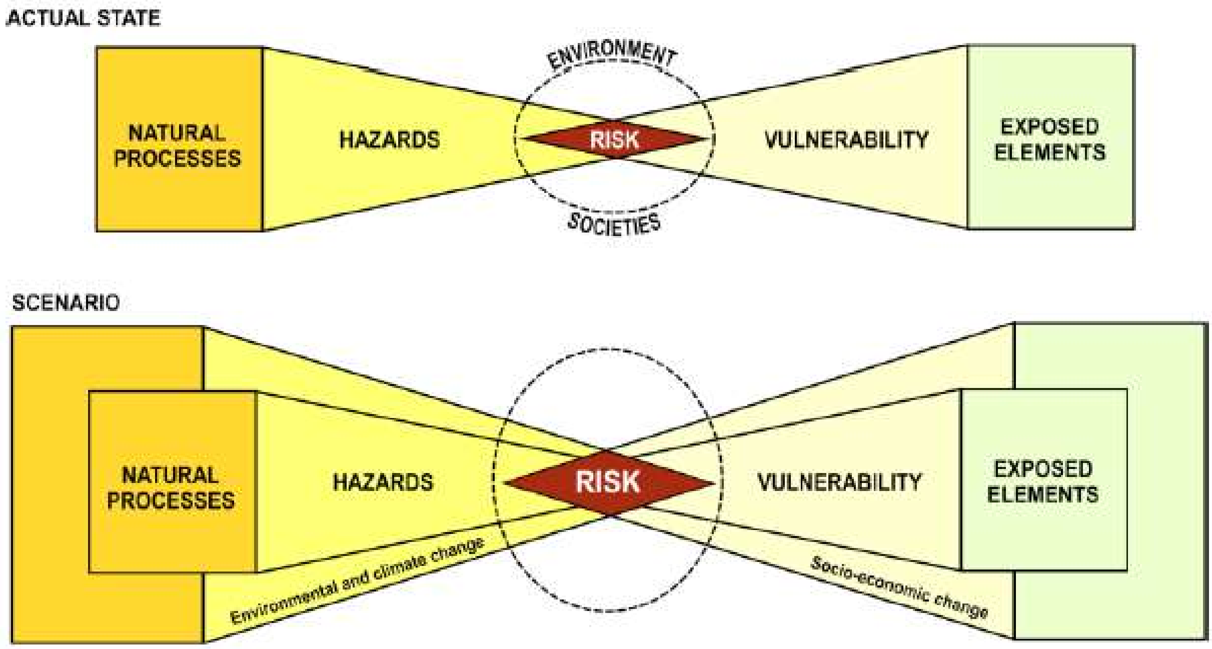


Figure 1 Increase in risk due to socio-economic and climate change

Source: Malet et al., 2012

A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes (Seneviratne et al., 2012, p.111). The impacts of climate extremes and the potential for disasters result from the climate extremes themselves and the exposure and vulnerability of human and natural systems. Observed changes in climate extremes reflect the influence of anthropogenic climate change in addition to natural climate variability, with changes in exposure and vulnerability influenced by both climatic and non-climatic factors (IPCC, 2012). With climate change contributing to an increase in disaster risk, DRRM has become a vital and urgent component of any adaptation program.

Taking into account the projected impact of climate change, the reduction of current and future vulnerabilities to climate change risk should build on and expand existing DRRM efforts (Pollner et al., 2008). DRRM measures such as preparedness, humanitarian relief, post-disaster recovery and reconstruction, and risk-sharing and transfer mechanisms at the local, provincial, and national levels can provide an opportunity to reduce climate-induced disaster risks and to improve adaptive capacity.

2.3 Scope

The aim of this study is to assess climatic hazards and identify adaptation options to inform the appraisal of climate change risks in the DRRM sector. The output of the hazard assessment is a compilation of hazard indices and their ranking.

Historical disaster and climate data from secondary sources are used to assess hazard scenarios under historical climate conditions. Climatic hazards are generally defined as those events when they cross the lower or upper threshold values of climate variables that result in a hazard. However, these thresholds are not available for Nepal. Therefore, descriptive scenarios of climatic hazards are inferred using scenarios of climate variables and extreme climate indices.

Uncertainties associated with climate change scenarios can directly contribute to uncertainties regarding climatic hazard scenarios. Some of the climatic hazards are triggered by complex processes and factors, and result from the combination of more than one climate variable and other non-climatic factors. Their relationships with climate variables are indirect, nonlinear, and weak. Linear relationships between such complex phenomena are difficult to establish. Given these limitations, this assessment adopts an indicator-based approach, where the weights for indicators are assigned subjectively based on expert opinion that can vary from person to person. It is hoped that these limitations will be addressed to some degree during the carrying out of the VRA over the next five years, as mandated by the Environment Protection Act 2019.

Chapter 3

Methodology

3.1 Framework

The NAP technical guidelines allow countries to develop their country-specific frameworks to assess vulnerability and risk (UNFCCC, 2012). The VRA framework developed by Nepal guides the country's assessment and illustrates the logical linkages between hazard, exposure, vulnerability and risk in identifying adaptation options specific to the country.

The IPCC framework considers risk as a function of hazard, exposure, and vulnerability (IPCC, 2012). Nepal's NAP formulation process has proposed a framework for VRA based on IPCC-AR-5 (MoPE, 2017).

- **Hazards** are extremes of climate events and their trends are derived from a combination of natural climate variability and anthropogenic climate change.
- **Vulnerabilities** are derived from both historical and prevailing cultural, social, environmental, political and economic contexts.
- **Exposures** are derived from the presence of people, assets, livelihoods, ecosystem services, environmental functions and infrastructure at hazardous places.

Figure 2 below shows the climate change Vulnerability and Risk Assessment Framework (MoPE, 2017).

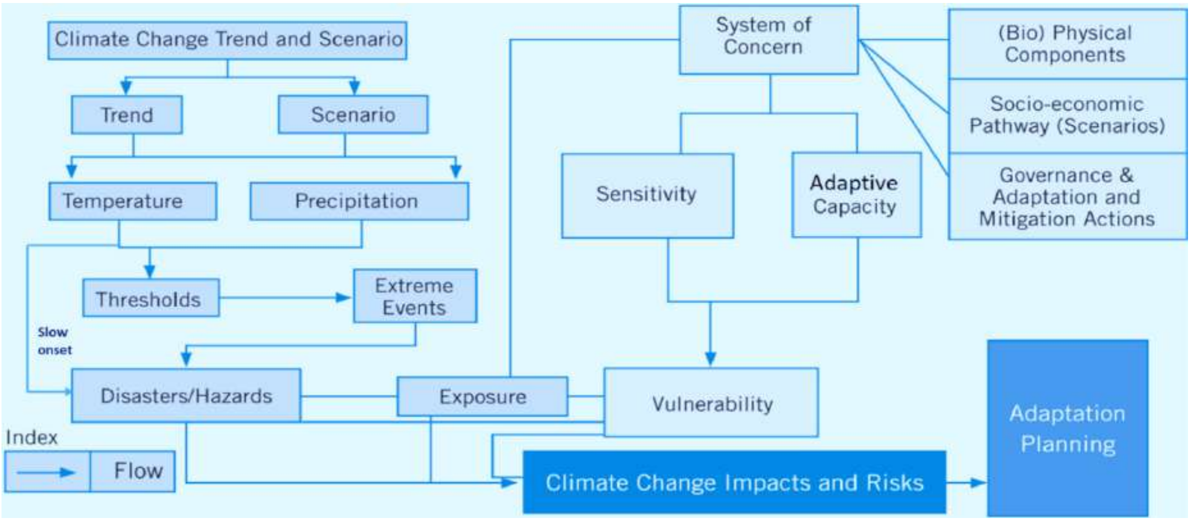


Figure 2 Climate Change Vulnerability and Risk Assessment Framework

Source: MoPE, 2017

3.2 Approach

The assessment approach used in this report includes both trends of climatic hazards that have already occurred and future scenarios based on extreme climate indices. It especially focuses on the way that such scenarios are anticipated to change with climate change. The first step in the characterization and assessment of hazards is to identify those that are likely/expected to impact the system. This identification is followed by further characterization and assessment that includes gathering and understanding information about the nature, strength, frequency, time of occurrence, and probability of occurrence of hazards. For the current risk assessment, the above-mentioned information is obtained from past occurrences of hazard episodes and trends. For future risk assessment, information is inferred from scenarios of climate variables and extreme indices.

For both past trends and future scenarios, a core focus of the assessment depends on the detection and attribution of changes in climatic hazards. In this report, the Observed Climate Trend Analysis of Nepal (1971-2014), conducted by the Department of Hydrology and Meteorology (DHM, 2017), and the Climate Change Scenarios for Nepal (MoFE, 2019a), are used to characterize broad past trends and future scenarios of climatic hazards.

- **Hazard** is defined by IPCC (2014) as "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".
- **Climatic hazards** are those climate extreme events that impose severe negative stress on both human society and the natural environment.
- A **climate extreme event** is generally defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends ('tails') of the range of observed values of the variable (IPCC, 2012). These 'extreme events' can lead to a disaster.

Climate events, even if not extreme in the statistical sense, can still lead to extreme conditions or impacts, either by crossing a critical threshold in a social, ecological, or physical system or by occurring simultaneously with other events (Seneviratne et al., 2012).

Many kinds of weather and climate extremes are the result of natural climate variability. Even if there were no anthropogenic climate change, a wide variety of natural weather and climate extremes would still occur (Seneviratne et al., 2012). This means that climate-induced disasters may occur with or without climate change. In other words, climate change is not a necessary or sufficient condition for a disaster to occur.

3.3 Methodological Steps

The methodology of climatic hazard assessment consists of the following steps:

Identifying key indicators for climatic hazards: In this step, the most relevant indicators were identified to assess changes in climatic hazards. These indicators were used for both quantifying and qualifying the extent, trends, and future scenarios of climatic hazards. They consisted of i) historical occurrence indicators, such as frequency, magnitude, and areal extent; and ii) climate change-related indicators, such as changes in climate variables and climate extreme indices.

Exploring data sources and their quality: We determined the availability and quality of data based on our data sources. These sources include government agencies, regional and global centres, international and national organizations, and other stakeholders. The data was available in time series and Geographic Information System (GIS) format as raster and vector layers. The disaster data was in the form of several disaster events, and losses and damages were aggregated in the form of annual time series from 1971 to 2019. Only district-level trends, scenarios, and disaster data were used in this study.

Collecting data: Trends of climate variables and extreme indices were taken from the 'Observed Climate Trend Analysis of Nepal (1971-2014)' conducted by the Department of Hydrology and Meteorology (DHM, 2017). Similarly, scenarios were taken from the 'Climate Change Scenarios for Nepal' (MoFE, 2019a) and ICIMOD. The data on climate-induced disasters was collected from the Nepal Disaster Risk Reduction Portal[3] and DesInventar[4], whereas GIS-format data on snow cover, glacial lakes, forest fires, and droughts was collected from ICIMOD. Flood and landslide hazard data in the form of GIS layers were collected by the UK Space Agency's METEOR project.

Analysing data: The analysis consisted of detection and attribution of changes in climatic hazards. 'Detection' is the process of demonstrating that the climate has changed in some pre-defined, statistically relevant sense. This process does not shed light on the reason behind this change. Changes in climatic hazards can be detected by assessing their trends. However, from a scientific point of view, assessing changes in climatic hazards rather than climate variables or climate extreme indices can be problematic for several reasons. First, the data that is available to study climatic hazards is biased towards recent years simply because of improved reporting, data keeping, communication technology, and early warning systems. Second, considering

3 http://drrportal.gov.np/
4 https://www.desinventar.net/DesInventar/statistics.jsp

these biases, methods for comparing reported events in an objective way are lacking. Third, even when corrected for improving communication technology, the number of reported climate-related disaster events may reflect factors representing not only the frequency of climatic hazards but also the trends in vulnerability and exposure (WMO, 2009).

Disaster impacts highly depend on exposure and vulnerabilities. The occurrence (number of events) of climatic hazards, however, is a natural phenomenon that is less likely to be affected by exposure and vulnerabilities. Hence, the trend analysis on the occurrences of climatic hazards may reflect the influence of climate change.

Historical climate-induced disaster data was analysed to identify trends in climatic hazard occurrences and their impacts. This was done using graphical and statistical methods. Then, the identified trends of climatic hazards were compared with the trends of climate variables and climate extreme indices to identify what could be attributed to climate change. Once this attribution of hazards to climate change was established, then the future scenarios of climatic hazards were inferred using the future scenarios of climatic variables and climate extreme indices descriptively.

Quantitative past scenarios of climatic hazards under historical climate were generated using historical hazard indices. These indices are computed from historical hazard occurrences. Since these occurrences tend to vary from place to place, historical hazard indicators can be based on the frequency of the hazard, such as the number of times a specific event occurred in a specific place, and/or the aerial extent of the hazard.

Quantitative future scenarios of climatic hazards were obtained using the Fraction of Attributable Risk (FAR) method. FAR is the approach of separating the causal factors of climatic hazards and calculating their relative contribution. This approach is widely used to calculate how a particular climate driver has changed the probability of an event occurring (Allen, 2003; Stott et al., 2004; IPCC, 2007, pp. 698). In other words, FAR is the fractional change in the likelihood of exceeding a hazard threshold as a result of anthropogenic influences. As such, it is a relative rather than an absolute metric.

Figure 3 compares two likelihoods: one of risk in the natural world without climate change and the other of the current world with climate change. In this figure, P_0: Probability of exceeding a threshold in a "world that might have been" (no anthropogenic forcing); and P_1: Probability of exceeding a threshold in a "world that is". Then, the FAR is given by FAR = $1-P_0/P_1$ (IPCC, 2007, pp 698). Computing the FAR required separately simulating physically based models (with and without anthropogenic influence).

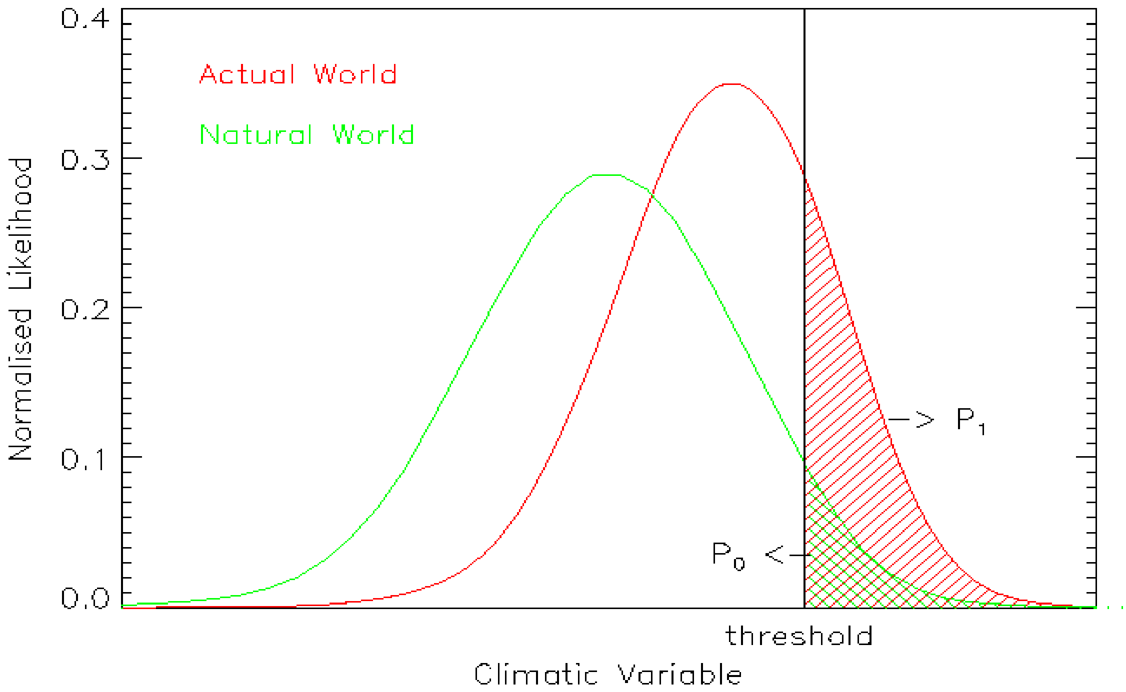


Figure 3 Likelihood of risk in the natural world and the actual world

Source: Peter Stott, Event Attribution, Met Office, Hadley Centre[5]

The detailed physically-based modelling is a rigorous and extremely resource-intensive method. It is also limited to modelling of particular spatial units, such as a river basin or watershed. Due to resource constraints and the spatial scale of this particular study, it was not possible to use this method. Therefore, quantitative analysis was not carried out for future scenarios of climatic hazards. Instead, their descriptive scenarios were inferred.

Data tabulation, filtering, and normalization: The historical hazard indicators data was tabulated, filtered, and normalized. The indicator data, which are directly correlated, was normalized to a scale of 0 to 1 using the following min-max normalization method:

$$Z_{i,j} = \frac{X_i^{max} - X_{i,j}}{X_i^{max} - X_i^{min}}$$

The normalized value for inversely correlated data were given by:

Where,

$Z_{i,j}$ = normalized value of the indicator of type i of region j

$X_{i,j}$ = value of the indicator of type i of region j

X_i^{min} = minimum value of the indicator of type i

X_i^{max} = maximum value of the indicator of type i

5 Available online: http://indico.ictp.it/event/a13211/session/7/contribution/35/material/0/0.pdf)

Microsoft Excel software was used to tabulate and process the data.

Assigning weightage and computing index values: An index is a single indicator or an aggregation of indicators (OECD, 1993). For historical hazard indicators, the normalized data were given weightage and index values were computed. While the weightage was obtained from consultation with experts, the historical hazard indices were calculated using the weighted linear combination of indicators as follows:

$$H_{index} = \frac{\sum_{i=1}^{n} W_i Z_i}{\sum_{i=1}^{n} W_i}$$

Where,

H_{index} = Historical hazard index
Z_i = Normalised hazard indicator i
W_i = Weight assigned to hazard indicator Z_i

Mapping and visualisation: The indices for the historical scenario of each hazard were imported into a GIS environment for visualization and mapping using R[6]. Using the Jenks natural breaks classification method (Jenks, 1967), class break values were identified. This resulted in the categorization of district-specific hazard indices into five classes: very low, low, moderate, high, and very high. Further, districts with high and very high hazard indices were labelled **"Key Hazard Hotspots"**.

Identifying and appraising DRRM strategies as adaptation measures: Identified hazards, impacts, and risks help in designing various adaptation measures for the NAP. For this study, adaptation measures were identified by reviewing national and international policies, strategies, action plans, technical reports, and journal articles. National and provincial level stakeholder consultation meetings also provided valuable input.

Adaptation measures were identified at the structural/physical, social, and institutional levels. The structural and physical options included development of an engineered and built environment, application of technologies, an ecosystem-based approach, and the use of services. The social options included educational programs for enhancing risk knowledge, informational strategies, and behavioural measures. The institutional options included economic instruments, laws and regulations, and government policies and programs.

Consultation meetings: Thematic Working Group (TWG) meetings, Technical Committee meetings, stakeholder consultations, online surveys, and provincial workshops were conducted to identify hazard indicators and their relative weightage, validate hazard maps, and identify potential adaptation options.

Provincial and local level consultations were conducted to inform stakeholders about this VRA, to understand their perception of the impacts and implications of climate change on various sectors and on the livelihoods of people, and to identify adaptation options.

6 R is a free software language and environment for statistical computing and graphics. More information is available at https://www.r-project.org/

3.4 Indicators and weightage

An indicator is a measure that is generally quantitative and useful to simply illustrate and communicate complex phenomena, including trends and progress over time (EEA, 2005). In this study, indicators were selected based on their ability to reflect the effect of a given hazard on a territorial system.

This study selected 15 climate-related hazards that were the most relevant for Nepal in terms of average annual losses and deaths. Historical hazard occurrences in the form of several events and/or hazard-prone areas were taken as indicators to obtain hazard indices based on historical climate. Climate change related indicators were used to infer descriptive future scenarios of climatic hazards.

The weights of historical climate-related indicators were obtained through an expert consultation process. The members of the Thematic Working Group (TWG) and experts from academia, regional organizations, and international non-governmental organizations working in the field of climate change and DRRM provided weightage for the indicators. It is important to note that the results from this process should be viewed with its limitations in mind: the potential uncertainty of climate change scenarios, indicator-based methodology, and the expert opinion-based allocation of weights for each indicator. Table 1 below provides the list of indicators for climate variables and climate extreme indices used in this study. Table 2 provides the list of indicators and their relative weights for past scenarios of climate-related hazards under historical climate. Table 3 provides the list of indicators for future scenarios of climate-related hazards.

Table 1: Indicators for Climate Variables and Climate Extreme Indices

Climate Variables and Extreme Indices	Indicators	Data Sources
Temperature	Change in Temperature (0C)	DHM, MoFE
Precipitation	Change in Precipitation (%)	DHM, MoFE
Very Wet Days (P95)	Change in Very Wet Days (%)	DHM, MoFE
Extreme Wet Days (P99)	Change in Extreme Wet Days (%)	DHM, MoFE
Consecutive Wet Days	Change in Consecutive Wet Days (%)	DHM, MoFE
Number of Rainy Days	Change in Number of Rainy Days (%)	DHM, MoFE
Consecutive Dry Days	Change in Consecutive Dry Days (%)	DHM, MoFE
Warm Days	Change in Warm Days (%)	DHM, MoFE
Warm Nights	Change in Warm Nights (%)	DHM, MoFE
Warm Spell Duration	Change in Warm Spell Duration (%)	DHM, MoFE
Cold Days	Change in Cold Days (%)	DHM, MoFE
Cold Nights	Change in Cold Nights (%)	DHM, MoFE
Cold Spell Duration	Change in Cold Spell Duration (%)	DHM, MoFE

Table 2: Indicators and their relative weights for the past scenario of climate-related hazards

Climatic Hazards	Indicators (Unit)	Weight	Data Sources	Data Length
Cold Wave	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Heatwave	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Heavy Rainfall	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Snowstorm	Number of Events (No.)	0.46	MoHA, DesInventar, ICIMOD	1971-2019
	Snow area (sq. km.)	0.54		
Thunderbolts	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Windstorms	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Hailstorm	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Floods	Number of Events (No.)	0.46	MoHA, DesInventar, UK Space Agency	1971-2019
	Flood-prone area (sq. km.)	0.54		
Landslides	Occurrence (No.)	0.45	MoHA, DesInventar, UK Space Agency	1971-2019
	Landslide prone area (sq. km.)	0.55		
GLOFs	Number of Events (No.)	0.29	ICIMOD	1971-2019
	Potentially dangerous glacial lakes (No.)	0.37		
	Distance from potentially dangerous glacial lakes (km)	0.34		
Drought	Number of Events (No. of months)	0.46	ICIMOD	1981-2019
	Drought-prone area (sq. km.)	0.54		
Forest Fire	Number of Events (No.)	1.00	ICIMOD	2001-2019
Fire	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Avalanche	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019
Epidemics	Number of Events (No.)	1.00	MoHA, DesInventar	1971-2019

Table 3: Indicators for future scenarios of climate-related hazards

Climatic Hazards	Indicators	Data Sources
Cold waves	Change in Cold Spell Duration (%)	DHM, MoFE
Heatwaves	Change in Warm Spell Duration (%)	DHM, MoFE
Heavy rainfalls	Change in Extreme Wet Days (%)	DHM, MoFE
Snowstorms	Change in Precipitation (%) Change in Temperature (0C)	DHM, MoFE
Thunderbolts	Change in Temperature (0C) Change in Precipitation (%)	DHM, MoFE
Windstorms	Change in Temperature (0C)	DHM, MoFE
Hailstorms	Change in Temperature (0C) Change in Precipitation (%)	DHM, MoFE
Floods	Change in Precipitation (%) Change in Extreme Wet Days (%)	DHM, MoFE
Landslides	Change in Precipitation (%) Change in Extreme Wet Days (%)	DHM, MoFE
GLOFs	Change in Temperature (0C) Change in Warm Spell Duration (%) Change in Precipitation (%)	DHM, MoFE

Climatic Hazards	Indicators	Data Sources
Droughts	Change in Precipitation (%) Change in Consecutive Dry Days (%) Change in Number of Rainy Days (%) Change in Warm Spell Duration (%)	DHM, MoFE
Forest fires	Change in Consecutive Dry Days (%) Change in Warm Spell Duration (%)	DHM, MoFE
Fires	Change in Consecutive Dry Days (%) Change in Warm Spell Duration (%)	DHM, MoFE
Avalanches	Change in Precipitation (%) Change in Temperature (0C) Change in Warm Spell Duration (%)	DHM, MoFE
Epidemics	Change in Temperature (0C) Change in Cold Spell Duration (%) Change in Warm Spell Duration (%) Change in Precipitation (%) Change in Consecutive Dry Days (%) Change in Consecutive Wet Days (%)	DHM, MoFE

Chapter 4

Observed and Projected Impacts of Climate-induced Disasters

Disasters cause loss of life and property, adversely affect ecological and physical systems, and impede the development of a country. Their impact can be gauged by the outcomes related to humans, society, and physical systems that these events bring about. These outcomes may have adverse effects such as destruction of assets, disruption of economic sectors, loss of human lives, mental health effects, or loss of impacts on plants, animals, and ecosystem services. The loss and damage (L&D) from extreme climate events can be better explained by taking a holistic approach that considers both the physical and social aspects of disaster risks. Whether an extreme event results in extreme impacts on humans and social systems depends on the degree of exposure and vulnerability to that event, in addition to its magnitude (IPCC, 2012).

Economic and non-economic L&D from weather and climate-related disasters have increased worldwide, but with large spatial and inter-annual variability. Increasing exposure of people and economic assets has been the major cause of long-term increases in economic losses from weather-and climate-related disasters. Long-term trends in economic losses, adjusted for wealth and population increases, have not been attributed to climate change, but a role for climate change has not been excluded (Handmer et al., 2012).

4.1 Association of Climate-induced Disaster Impact and Socio-Economy

Compared to the population size calculated in the country's 2011 census, it is expected that by the years 2030, 2040, and 2050, respectively, Nepal's total population is expected to increase by 28%, 44%, and 62%; and its urban population is expected to grow by a rate of 81%, 113%, and 145%. Its female-headed households are expected to increase by 51% and 83% by 2030 and 2040 respectively.

Compared to a baseline of the year 2010, remittances are expected to grow by 128%, 194%, and 264% by the years 2020, 2030, and 2040 respectively; total labour migrants, male migrants, and female migrants are expected to increase by 284%, 265%, and 1500% respectively by 2030; and the Human Development Index (HDI) is expected to increase by 60 to 80% by the year 2030. The annual Gross Domestic Product (GDP) growth rate for 2019 was 6.99%, while poverty continued to reduce by 2.2% per year in the last decade.

An analysis was done to explore the relationships between four socio-economic indicators of Nepal-Human Poverty Index (HPI), literacy rate, per capita income, and HDI-and the number of deaths due to climate-induced disasters. These relationships are captured in Figure 4 below. It can be seen that the number of deaths decreases with an increase in literacy, per capita income, and HDI. In contrast, the number of deaths increased with an increase in HPI.

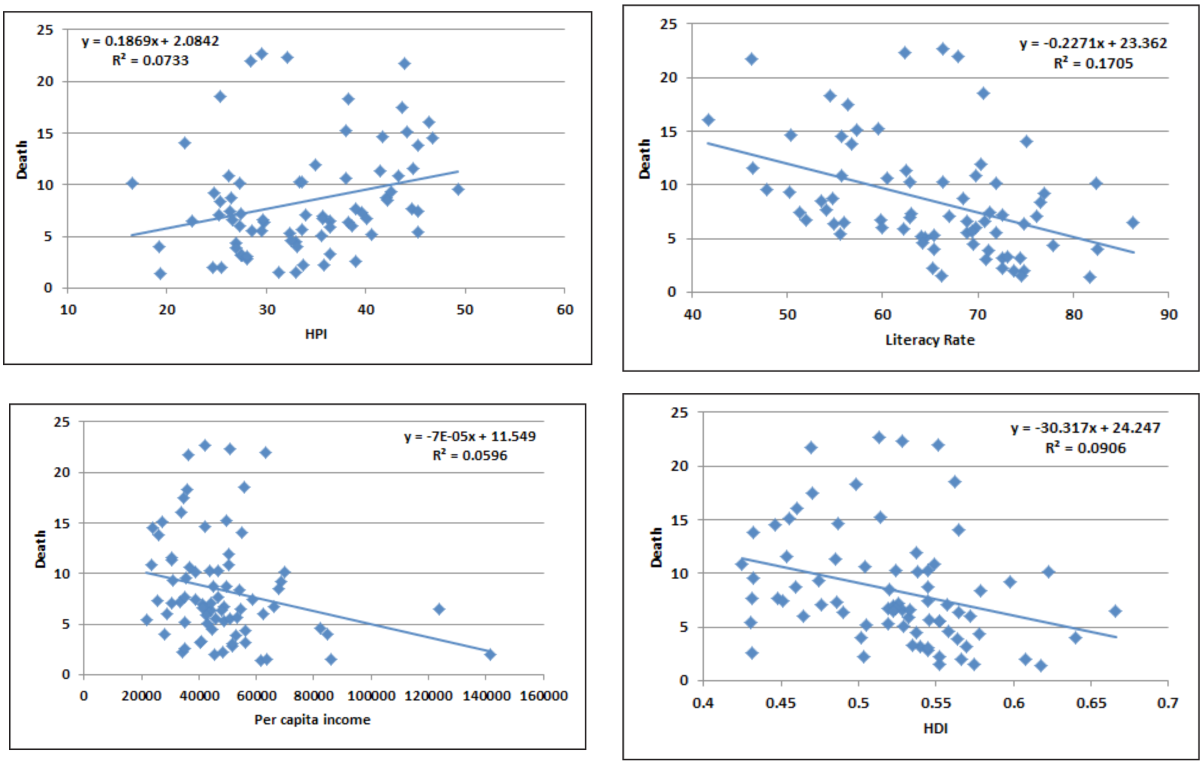


Figure 4 Relationship between the number of deaths due to climate-related disasters and socio-economic indicators in Nepal

Similarly, an analysis was done to explore the relationships between the aforementioned four socio-economic indicators and the economic losses due to climate-induced disasters in Nepal. As can be seen in the very small values of correlation coefficients in Figure 5 below, these relationships are very weak. This indicates that economic losses are more associated with exposure than vulnerabilities.

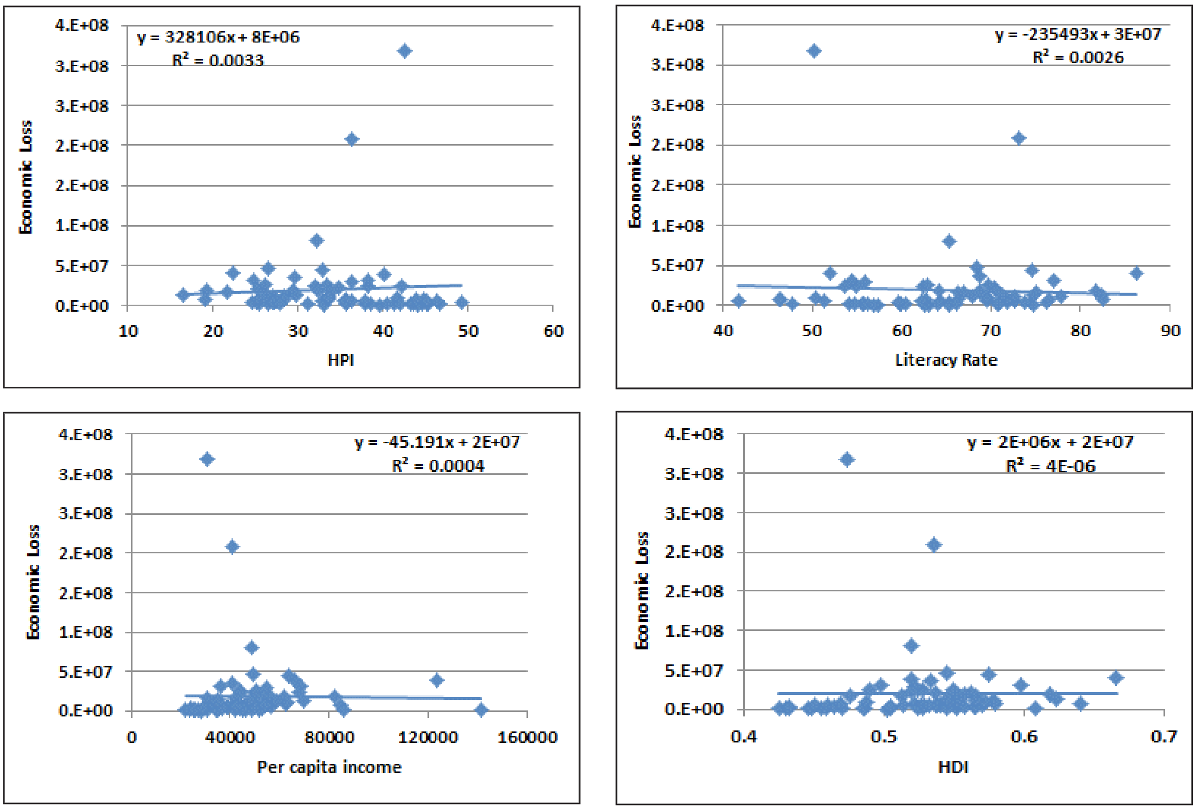
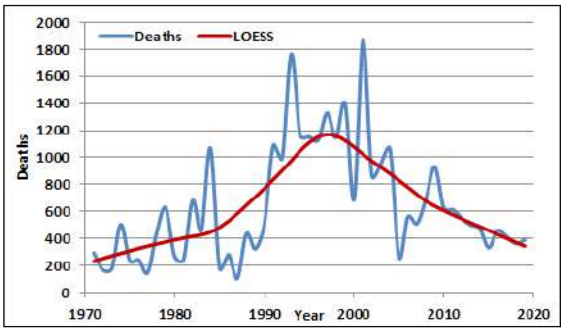


Figure 5 Relationship between economic losses due to climate-related disasters and socio-economic indicators in Nepal

Overall, increases in vulnerabilities lead to an increase in the loss of human lives, while increases in exposure lead to increases in economic losses. Hence, it is necessary to reduce the exposures and vulnerabilities in addition to the frequency and magnitude of hazards so that the cost and consequences of climate change can be minimized.

4.2 Observed Impacts of Climate-Induced Disasters

The trends of the number of deaths and economic losses from climate-induced disasters between 1971 and 2019 were analysed (see Figure 6), Locally Estimated Scatterplot Smoothing (LOESS) lines indicate these trends. While climate-induced disaster-related deaths are decreasing in recent years mainly due to improved early warning systems and better mitigation structures, there is an increasing trend of economic losses due to increased exposure and vulnerabilities.



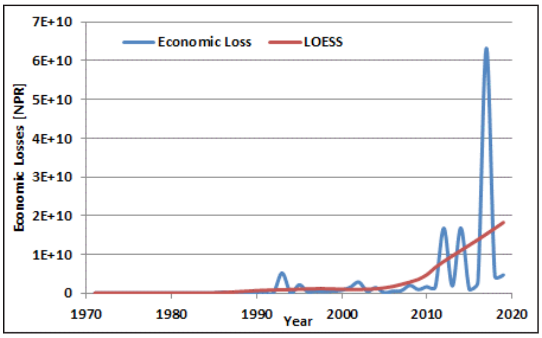


Figure 6. Trends of climate-change related deaths and economic losses between 1971 to 2019

Table 4 below presents the results of the Mann-Kendall test and Sen's slope for the aforementioned deaths and economic losses. Results of the Mann-Kendall test suggests that the economic losses show a statistically significant increasing trend. The number of death whereas the also show an increasing trend but this is statistically insignificant.

Table 4: Mann-Kendall test statistics for linear trend of climate-induced disaster deaths and economic losses

Series	Z-statistic	P-value	Sen's Slope	Significance (5%)
Deaths	1.67	0.094	5.44	No
Economic Losses	7.53	0.000	41854210	Yes

On average, 647 people die from climate-induced disasters in Nepal each year, which is about 65% of the total deaths from all disaster events except road (and other) accidents (MoHA, 2018a). The maximum number of climate-induced disaster deaths occurred in 2001, when 1866 people died due to epidemics, landslides, thunderbolts, fires, floods, heavy rainfall, and windstorms. The average economic loss per year is 2,778 million Nepalese Rupees, which is about 0.08% of GDP (at current price) for FY 2018/19. The maximum economic loss of 63,186 million Nepalese rupees occurred in 2017 during the Terai floods (NPC, 2017), which is about 2.08% of GDP (at current price) of FY 2017/18 (MoF, 2018).

Floods, landslides, epidemics, and fires are the most devastating climate-induced disasters in Nepal. Figure 7 shows the percentage of deaths, affected population, and economic losses due to 13 types of climate-induced disasters in Nepal from 1971 to 2019. A hazard-wise comparison of deaths affected population and economic losses revealed that epidemics cause the most deaths (52.8%) followed by landslides (16.7%) and floods (12.7%). Additionally, in terms of being affected by disasters, most appear to be affected by floods (71%), followed by landslides (9.5%) and epidemics (8.2%). Fires appear to cause the most economic losses (56.6%), followed by floods (31%) and landslides (3.7%).

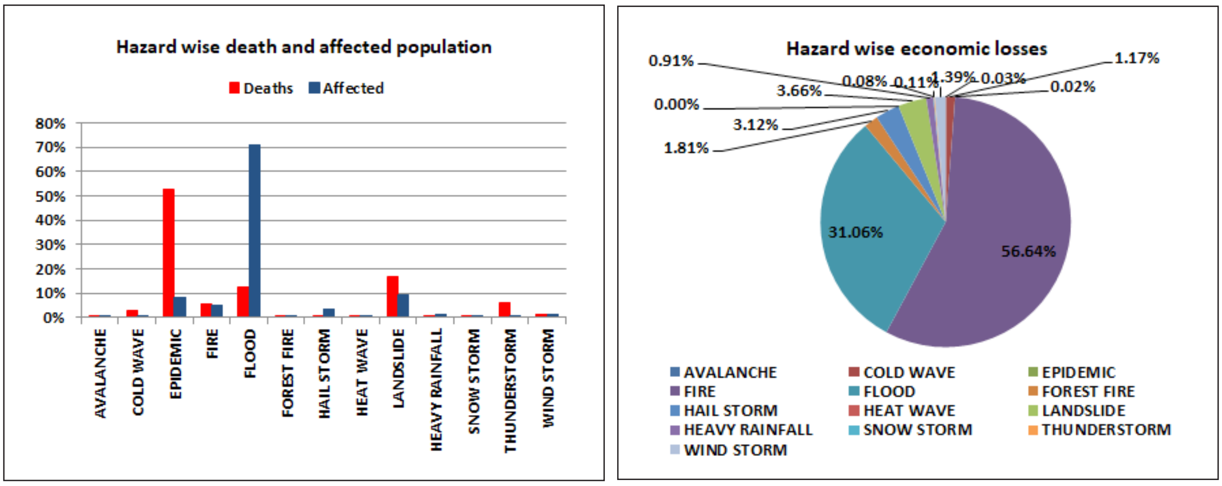


Figure 7 Hazard-wise deaths, affected people, and economic losses due to climate-induced disasters

Examples of some climate-related disastrous events and their impacts are included in Box 1 below.

Box 1: Observed impacts of climate-induced disasters

- Heavy rainfall and subsequent floods, landslides, and debris flow in central and eastern Nepal during 19-21 July 1993 directly affected more than 500,000 people. Out of 85,254 families, 1336 people were killed and 163 injured. 25,425 livestock were lost, and 17,113 houses were destroyed. More than 57,584 ha of agricultural land, 67 small and large irrigation projects, and thousands of farmer-managed irrigation schemes were seriously damaged. The floods caused heavy damage to the Bagmati barrage and the Kulekhani Hydropower Plant. Many villages and several bridges were washed away. Overall, the estimated loss of properties was worth 4904 million Nepalese Rupees (DWIDP, 1993).
- Several flash floods and landslides on 19-21 September 2008 in the mid-and far-western Terai region of Nepal affected 23,660 households, killing 15 people in the Kailali district. Many infrastructures, private property, and livelihoods were severely damaged (DDRC Kailali, 2009).
- A massive landslide on 2 August 2014 in Jure village in Sindhupalchok district killed 156 people, injuring 27 and displacing 1011 people (MoI, 2014). 165 houses were damaged completely, whereas 37 households were partially damaged. Additionally, the landslide damaged several schools, shops, fishponds, poultry firms, the Arniko Highway, five hydropower plants, and several bridges. Significant damage and losses also resulted due to road blockages, disturbance of livelihoods and economic activities, and damage to transmission lines and hydropower plants. The landslide also blocked the Sunkoshi River, creating a high dam, which created havoc for the people living downstream.
- A snowstorm and subsequent avalanche due to heavy rainfall brought by the Hudhud cyclone on 14 October 2014 around the Annapurna and Dhaulagiri areas in the Manang and Mustang districts killed at least 43 people, including 21 trekkers. Approximately 50 people were reported missing, and 175 people were injured due to severe cold. About 400 people were rescued from different areas of Manang and Mustang (Wang et al., 2015). This disaster brought about grave consequences for Nepal's tourism sector and its national economy.
- Unprecedented flooding in the Terai region on 11-13 August 2017 affected 36 out of 77 districts, 18 of them severely. About 1.7 million people were affected. 161 people died, 46 people were injured and 29 people went missing. More than 190,000 houses were destroyed or partially damaged. The total damage was estimated to be 60,716.6 million Nepalese Rupees (NPC, 2017), which was about 2% of the GDP (at current price) of FY 2017/18 (MoF, 2018). The nine most affected sectors were housing (32.1%), health (1%), education (2%), agriculture (11.9%), livestock (17.6%), irrigation (28.8%), transport (4.8%), water and sanitation (1.5%) and energy (0.4%). The largest affected sector was housing (NPC, 2017).

- A strong “tornado” on 31 March 2019 hit the Bara and Parsa districts, which killed 30 people, injured 1150 people, and made 2890 families homeless. Mosques, schools, industries, agricultural lands, businesses, the water supply, and electricity were also damaged (DHM, 2019).
- Nepal has experienced 24 GLOF events in the recent past, several of which have caused considerable damage and loss of life; for example, the Bhote Koshi Sun Koshi GLOFs of 1964 and 1981 and the Dig Tsho GLOF of 1985. The 1981 event damaged the only road link to China, disrupting transportation for several months, while the Dig Tsho GLOF destroyed the Namche Small Hydroelectric Project, in addition to causing other damage further downstream. Additionally, 14 GLOF events have been recorded in the Solukhumbu, Kaski, Sankhuwasabha, Mustang, Dolakha, Mugu, and Taplejung districts of Nepal. Moreover, several others in the Tibet Autonomous Region in China have crossed the international border to cause extensive damage in Nepal (ICIMOD, 2011).

Information included in Box 1 above shows that the amount of loss and damage from climate-related disasters is on an increasing trend in Nepal. Table 5 below shows the huge economic and non-economic losses suffered in the past. It should be noted, however, that due to the limitations of the database system, non-economic loss and damage were difficult to estimate.

Table 5: Accounting of losses and damages due to disasters in Nepal

Date	Nature of hazard	Regions	Losses and damages		
			Losses	Damages	
			NELD	ELD	NELD
Rainfall from 19-21 July 1993; mid-mountain cloudburst and flood	Weather	An unprecedented number of landslides and floods in South-Central Nepal	1,460 dead/missing	• 73,606 families affected • 39,043 houses completely/partially destroyed • 43,330 hectares of cultivated land washed away/covered with debris. • 367 kilometres of roads • 213 large and small bridges destroyed • 38 small and large irrigation schemes • 452 school buildings, hospitals, and government offices	N/A
August 24, 1998, Rohini River and other Terai floods	Weather	Ramgram Municipality, Nawalparasi	No death	• 100,000 square kilometres inundated for 65 days • 279 affected families in Nawalparasi • About 24 hectares of land washed away • Property damage NPR 680,000.	Agricultural loss
August 18, 2008, embankment breach	Agency failure	Kushaha	3 dead 12 missing	• 65,000 people were displaced.	Social and economic system affected
19th and 21st September 2008, flooding in Far-west, Nepal	Weather	Banke, Bardiya, Kailali, and Kanchanpur Dang, Dadeldhur, Doti and Salyan	11 males and 15 females dead; 2 males and 6 females missing in the Kailali District	• 2,152 houses completely damaged • 12,962 houses partially damaged • 5,647 households lost stored grains • 12,552 households lost some stored grains • 18 VDCs and Dhangadi municipality affected, • 30,733 people in 5961 households Dekhatbhuli and Shankarpur VDCs and Mahendranagar Municipality in Kanchanpur District worst hit	Loss of ecosystem. Loss of livelihoods

Date	Nature of hazard	Regions	Losses and damages		
			Losses	Damages	
			NELD	ELD	NELD
2008\2009 Winter drought	Weather		No death	• More than 330,000 ha of agricultural land in the Terai and western Hills/ Mountains were affected • Summer crop damaged • Diseases	Food production lowered
2009 Forest fires	Weather	.	43 deaths 12 injured	• 516 families affected • 375 livestock killed, • 74 houses and 22 cattle-sheds • NPR 14 crore • 100,000 cattle burned to death.	Biodiversity affected
2009 diarrhoea epidemic in the mid-western Hills	Weather	Mid-Western Development Region	143 deaths in Jajarkot > 2,000 ill 42 dead in Rukum	• 20,000 families affected	Health cost increased
2014	Weather	Kailali, Badia, Surkhet, Dang	222 dead 84 injured	• 5,167 houses fully damaged • 14,913 partially- damaged households • 6,859 displaced households • 117,580 affected population • Livestock • Embankments, dwellings, and agricultural land • Roads and bridges. • Many culverts were washed out	Bardiya National Park, Contaminated water supplies, leading to diarrhoea outbreaks. Health costs
2017	Weather	35 Terai districts	134 dead 22 injured	• Affected a total of around 1.7 million people • More than 190,000 houses destroyed or partially damaged, • Tens of thousands of people displaced and rendering many homeless. • NPR 60,716.6 (USD 584.7 million).[1]	Household assets and food grains damaged affected communities faced a shortage of food, water, and non-food items. infections from contaminated water Biodiversity NA.
2020	Weather	58 districts	297 dead 64 missing 223 injured.	• Million	N/A

Figure 8 shows district-wise climate-induced disaster deaths per year. The Kailali, Makwanpur, Banke, and Sarlahi districts have more than 20 deaths per year on average. Figure 9 shows the number of people injured per year, whereas Figure 10 shows the number of people affected per year. On average, more than 9,000 people are affected each year by climate-induced disasters in the Mahottari and Saptari districts. Figure 11 shows the economic losses per year. The districts with high economic losses are Siraha, Surkhet, and Bardiya. Figure 12 shows the overall (human and economic) impact of climate-induced disasters under historical climate conditions.

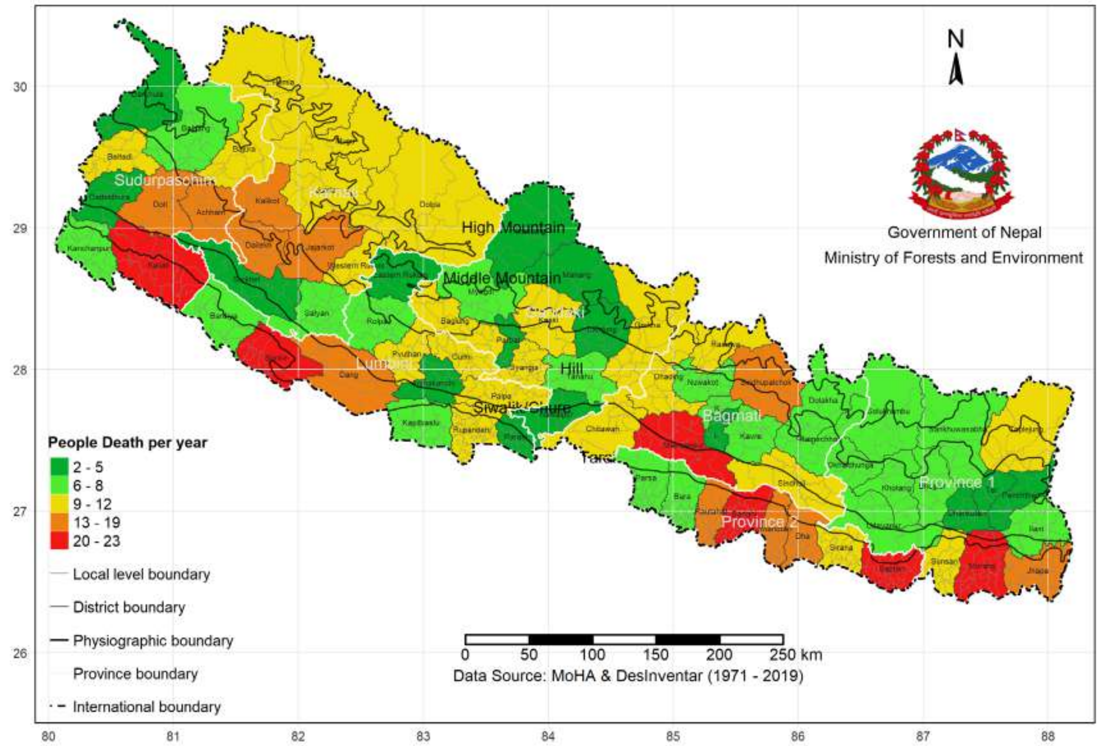


Figure 8 Number of deaths per year by climate-induced disasters

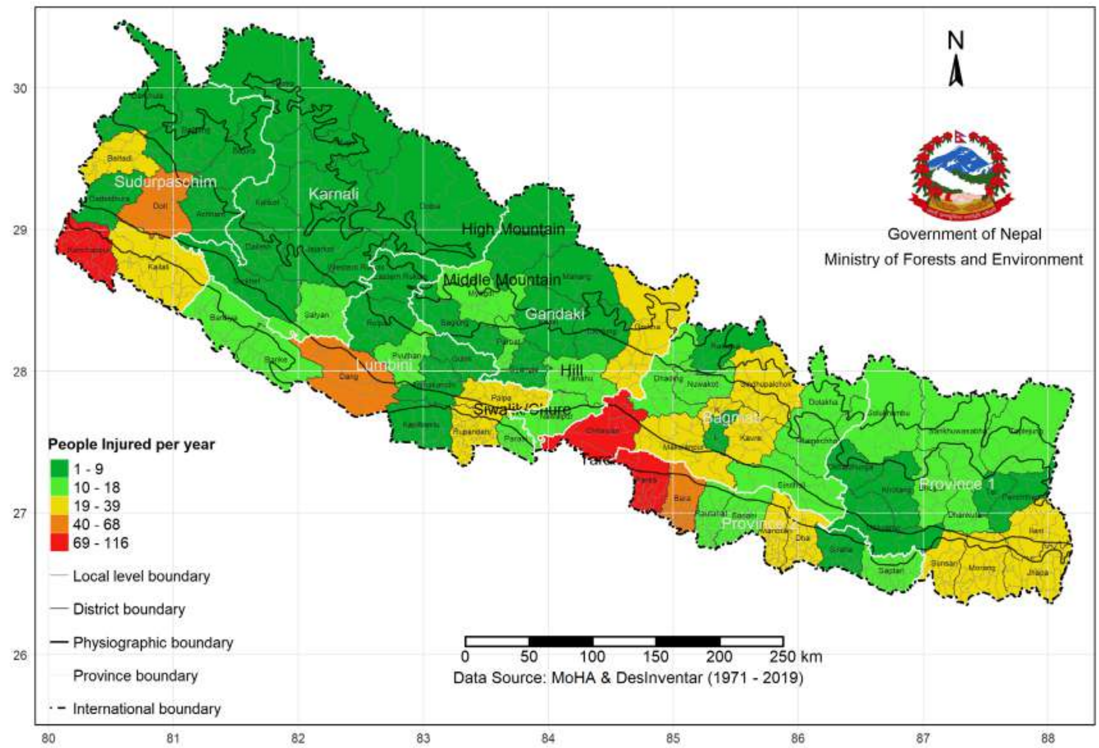


Figure 9 Number of people injured per year by climate-induced disasters

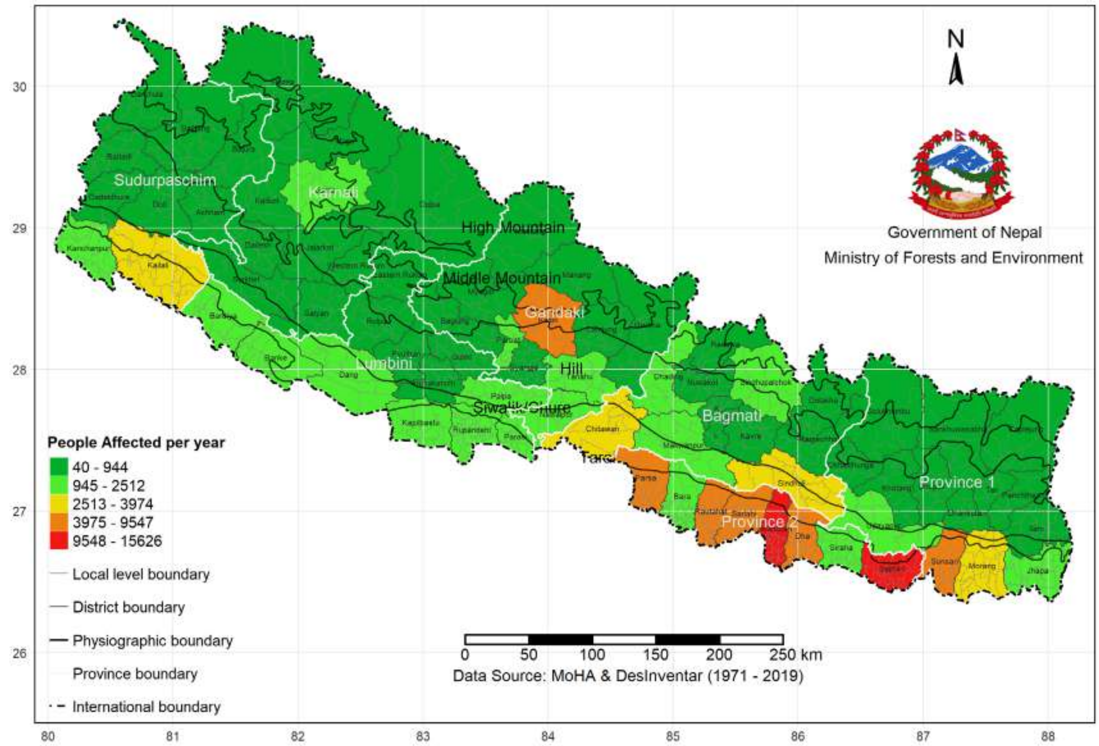


Figure 10 Number of people affected per year by climate-induced disasters

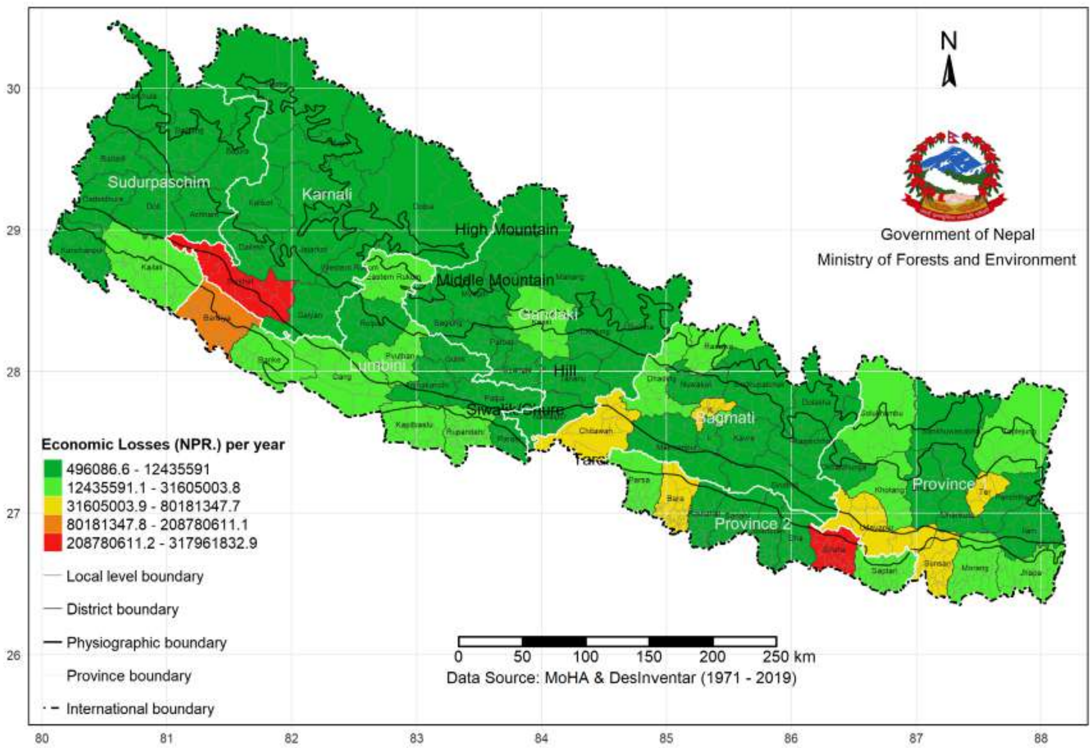


Figure 11 Economic losses per year by climate-induced disasters

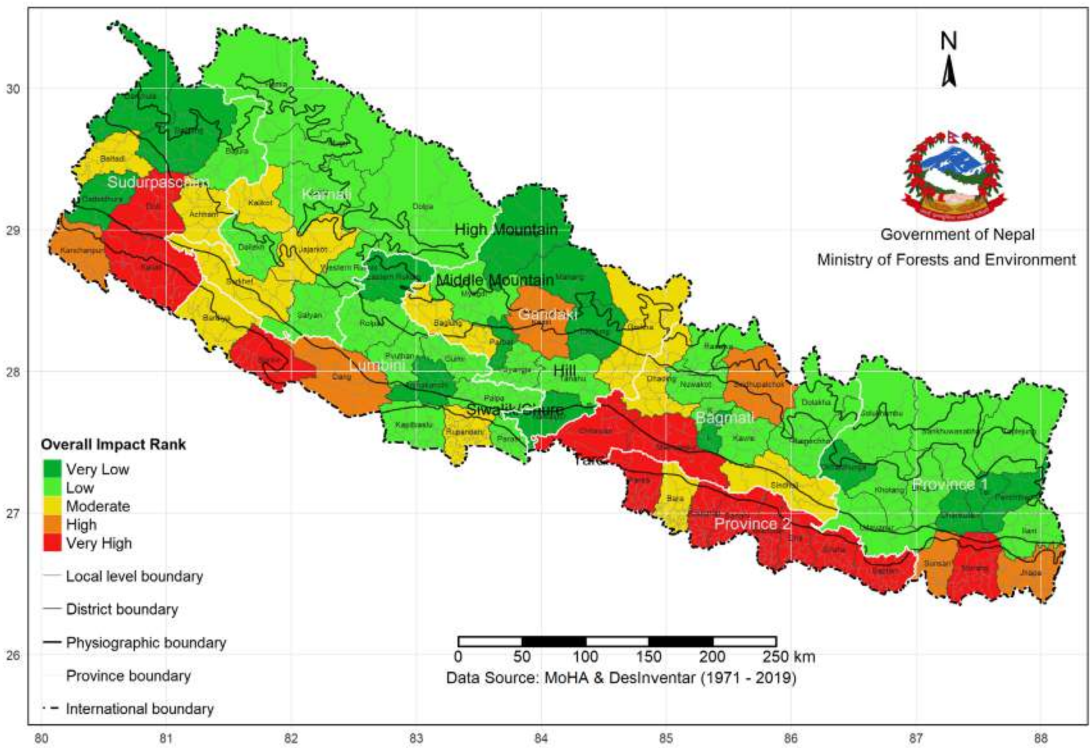


Figure 12 Overall impact of climate-induced disasters

Table 6 presents the district-wise ranks of the overall impact of climate-induced disasters. In terms of human and economic impacts, the Makawanpur, Rautahat, Banke, Kailali, Siraha, Morang, Doti, Chitawan, Dhanusha, Sarlahi, Mahottari, Parsa, Saptari, Sunsari, Sindhupalchok, Dang, Kaski, Kanchanpur, and Jhapa districts are the climate-related "Disaster Hotspots".

Table 6: District wise ranks of the overall impact of climate-induced disasters

Impact rank	Districts for historical impact scenario (1971-2019)
Very High (0.715 - 1)	Makawanpur, Rautahat, Banke, Kailali, Siraha, Morang, Doti, Chitawan, Dhanusha, Sarlahi, Mahottari, Parsa, Saptari
High (0.512 - 0.714)	Sunsari, Sindhupalchok, Dang, Kaski, Kanchanpur, Jhapa
Moderate (0.317 - 0.511)	Dhading, Baglung, Bardiya, Gorkha, Surkhet, Achham, Baitadi, Rupandehi, Sindhuli, Bara, Kalikot, Jajarkot
Low (0.146 - 0.316)	Rolpa, Humla, Kapilbastu, Mugu, Rasuwa, Myagdi, Dolakha, Nuwakot, Sankhuwasabha, Western Rukum, Solukhumbu, Tanahu, Kavrepalanchok, Dailekh, Udayapur, Pyuthan, Syangja, Dolpa, Palpa, Bhojpur, Salyan, Khotang, Bajura, Taplejung, Jumla, Parasi, Gulmi, Ramechhap, Kathmandu, Ilam
Very Low (0 - 0.145)	Lamjung, Dhankuta, Terhathum, Lalitpur, Bhaktapur, Parbat, Darchula, Arghakhanchi, Mustang, Manang, Eastern Rukum, Okhaldhunga, Nawalpur, Panchthar, Bajhang, Dadeldhura

Impacts of climate extremes are determined by the climate extremes themselves as well as by exposure and vulnerability. In other words, how severely a disaster impacts a district or a sector strongly depends on their level of exposure and vulnerability. The impacts of climate extremes can also be differentiated by socio-economic factors such as gender, livelihood strategies, and cultural practices, and biophysical factors such as landscapes and ecosystems (MoPE, 2017). As Figures 13 and 14 show, the districts with very high and high disaster impacts have also high socio-economic exposure and vulnerability.

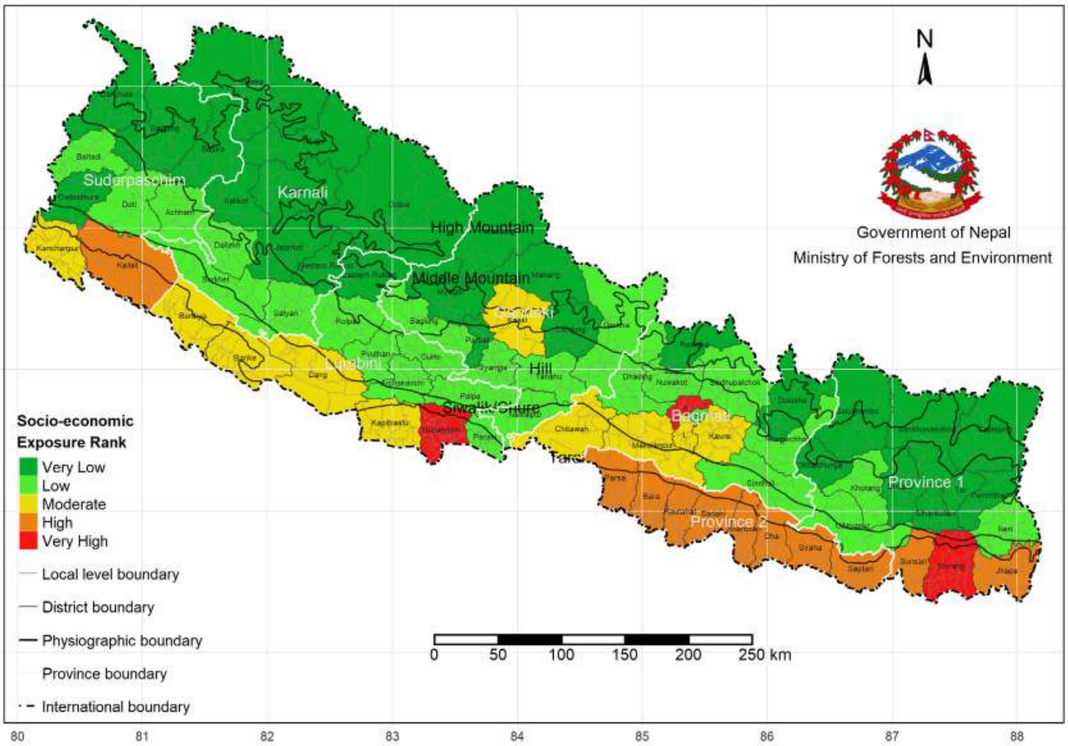


Figure 13 District-wise socio-economic exposure

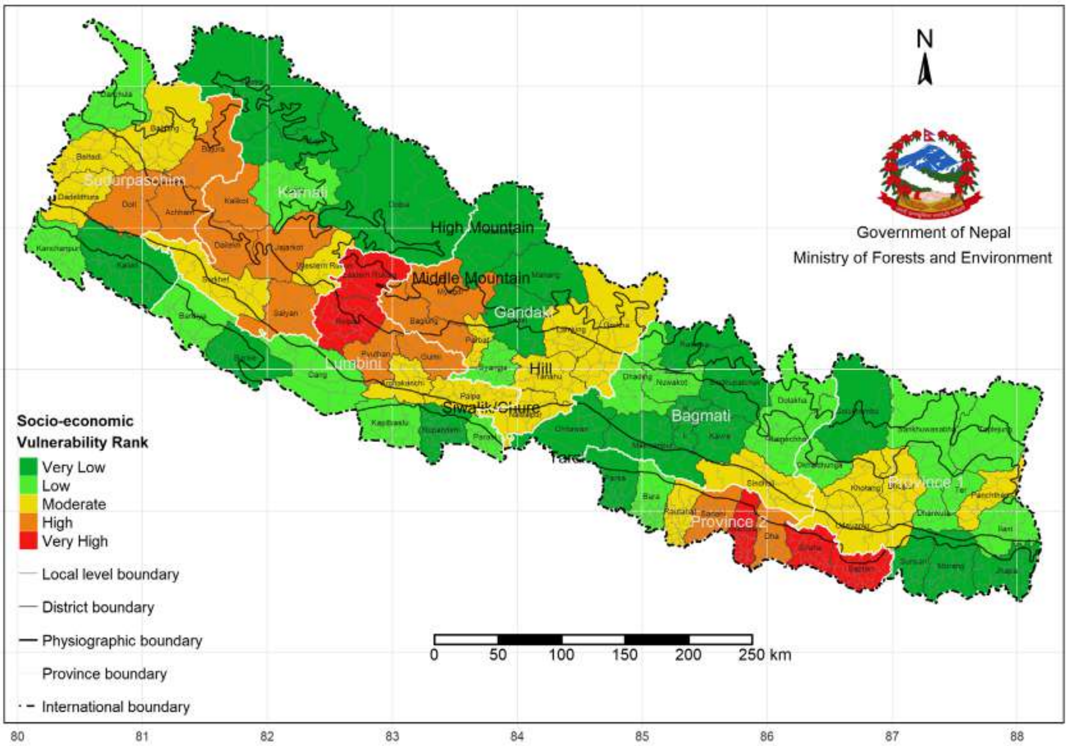


Figure 14 District-wise socio-economic vulnerability

Transport, infrastructure, water, and tourism are among the key sectors sensitive to climate extremes. Agriculture, in particular, is an economically exposed sector that is vulnerable. The economy of Nepal relies heavily on agriculture, dominated by small-scale and subsistence farming. Consequently, livelihoods tied to this sector are especially exposed to climate extremes.

The most vulnerable populations include the urban poor in informal settlements, internally displaced people, and those living in marginal areas. Women, children, senior citizens, people with disabilities, and socially and economically marginalized groups are also highly vulnerable. Additionally, population growth is a major driver of changing exposure and vulnerability levels.

4.3 Projected Impacts of Climate Extreme Events

The IPCC's Third Assessment Report projected changes in extreme climate events, which included more hot days and heatwaves; more intense precipitation events; increased risk of droughts; increase in winds and tropical cyclones (over some areas); intensified droughts and floods with El Niño events; and increased variability in the Asian summer monsoon (IPCC, 2001, p. 15). For a summary of these projected changes, see Table 7 below.

Table 7: Projected changes of climate extreme events

Projected Changes in Extreme Climate Phenomena and their Likelihood
Higher maximum temperatures, more hot days, and heatwaves over nearly all land areas (*very likely*)
Higher (increasing) minimum temperatures, fewer cold days, frost days, and cold waves over nearly all land areas (*very likely*)
More intense precipitation events (*very likely*, over many areas)
Increased summer drying over most mid-latitude continental interiors and associated risk of drought (*likely*)
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (*likely*, over some areas)
Intensified droughts and floods associated with El Niño events in many different regions (*likely*)
Increased Asian summer monsoon precipitation variability (*likely*)

According to the Climate Risk Profile of Nepal, put together by the World Bank Group and the Asian Development Bank, natural hazards such as droughts, heatwaves, river flooding, and GLOFs are all projected to intensify over the 21st century, potentially exacerbating disaster risk levels and putting human life at risk in the country. Modelling of various scenarios suggests that the number of people annually affected by river flooding could more than double by 2030 as a result of climate change. At the same time, the economic impact of river flooding could triple (World Bank, 2021). A recent study by the Asian Development Bank suggested that Nepal faces losing 2.2% of its annual GDP due to climate change by 2050 (Ahmed & Suphachalasai, 2014). The potential climate change impacts on the DRRM sector in Nepal are presented in Table 8 below.

Table 8: Projected climate change impacts in DRRM sector in Nepal

Climatic Hazard	Potential Impact
Cold Wave	Decreased cold waves may decrease cold-related morbidity and mortality.
Heatwave	The increased heatwave may increase heat-related morbidity and mortality, heat stress in livestock and wildlife, damage to crops, increase in vector-borne diseases.
Heavy Rainfall	Increased heavy rainfall may increase house collapse, crop damage, floods, landslides, mudslides, soil erosion, water-borne diseases, and an increase in the economic cost of disaster response, rehabilitation, and recovery.
Snowstorms	Decreased snowstorms may reduce water availability and winter crop yield and increase pests and diseases.
Thunderbolts, Windstorms, Floods, GLOFs, Landslides	Increased thunderbolts, windstorms, floods, GLOFs, and landslides may increase human morbidity and mortality, livestock morbidity and mortality, damage to houses, damages to productive land/livelihood assets, and other infrastructure.
Hailstorms	Increased hailstorms may damage crops, livestock, and poultry.
Droughts	Increased droughts may damage crops, increase famine, water shortages, water pollution, epidemic, vector-borne diseases, water-borne diseases.
Forest fires	Increased forest fires may degrade forests, increase the loss of wildlife habitat, loss of forest-based livelihoods, increase flash floods and landslides, decrease spring water availability, increase air pollution and aggravate health problems.
Fires	Increased fires may increase human morbidity and mortality, and loss of houses and assets.
Avalanches	Increased avalanches may increase human morbidity and mortality, and damage to houses and infrastructure.
Epidemics	Increased epidemics may increase human morbidity and mortality, and put pressure on public health services and the insurance system.

Chapter 5

Observed and Projected Changes in Climatic Hazards

Trend analyses of observed all-Nepal climate data from 1971 to 2014 by the Department of Hydrology and Meteorology (DHM) revealed that statistically significant positive trends (increase by 0.056 °C per year) are observed in the country's maximum temperature. The minimum temperature trend is also positive (increased by 0.002°C per year) but statistically insignificant. No significant trends were observed for precipitation in any season. In contrast, observed trends of climate extreme indices show that the number of rainy days and consecutive wet days are increasing significantly. However, very wet days, extremely wet days, and consecutive dry days are decreasing significantly. While the trends of warm days, warm nights, and warm spell duration are significantly increasing, cold days, cold nights, and cold spell duration are decreasing in a majority of the districts (DHM, 2017).

Climate change scenarios for RCP 4.5 and RCP 8.5 for the reference period of 1981 – 2010 indicate that both the average annual mean temperature and the average annual precipitation are projected to increase until the end of this century. Precipitation could increase by 11–23%. Scenarios of climate extreme indices show that intense precipitation events are likely to increase in frequency, with extremely wet days (P99) expected to increase at a higher rate than very wet days (P95). The mean temperature might increase by 1.7–3.6 °C by 2100. Warm days, warm nights, and warm spells duration are likely to increase, while cold days, cold nights, and cold spells duration are likely to decrease sharply in the future under both the RCP4.5 and RCP8.5 scenarios (MoFE, 2019a).

In general, the climate of Nepal is likely to be significantly warmer and wetter in the future. Indices of climate extremes related to temperature and precipitation suggest that more extreme events are likely. An increase in precipitation intensity, along with an increase in extremely wet days and consecutive wet days, is likely to create more water-related hazards such as floods and landslides in the future. Similarly, an increase in warm days and nights, and warm spell durations is likely to increase heatwaves, windstorms, lightning, forest fires, and epidemics, accelerate glacier melts, and trigger GLOFs.

5.1 Observed Trends of Climatic Hazards

Trends over 49 years (1971-2019) of several climatic hazards were analysed using data from the DesInventar database and the Nepal Disaster Risk Reduction Portal of the Ministry of Home Affairs. The methodology consisted of a graphical method for exploratory data analysis and statistical tests. The graphical technique is a very powerful tool to explore, understand and present data and is an essential component of any statistical analysis. Its first use is to examine the raw data, check ranges and find any outliers visually. The graphical plots can uncover temporal patterns (e.g., trend or step-change), seasonal variation, data problems (outliers, gaps in the record, etc.), and correlations (between variables). Following this, the statistical analysis gives the magnitude of the linear trend and its significance level.

Statistical analysis of the aforementioned climate hazard data was carried out using the Mann-Kendall Test and Sen's Slope Method. The Mann-Kendall test is a nonparametric method that tests the presence and significance of monotonic positive or negative trends in a time series. If a Z-statistic is greater than zero, it indicates an increasing trend and vice versa. The P-value gives the significance level. Significance levels of 0.01, 0.05, and 0.10 are widely used. Sen's slope method estimates the magnitude of the linear trend.

The trend analysis of the occurrences of 11 climatic hazards—thunderbolts, windstorms, epidemics, heavy rainfall, landslides, floods, avalanches, hailstorms, heatwaves, cold waves, and snowstorms—revealed that there is a significant increasing trend in climatic hazards, especially after 1990 (see Figure 15). The number of reported climatic hazards has increased from 79 in 1971 to 1333 in 2019. This figure does not include fires, forest fires, and drought events.

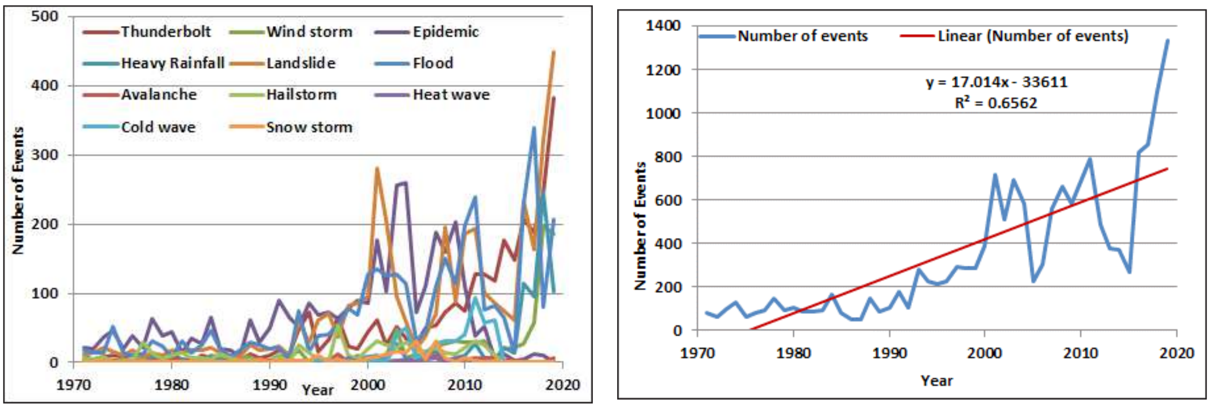


Figure 15 All-Nepal trends of eleven climatic hazards

Fires and forest fires are the most frequently occurring hazards in Nepal. The International Centre for Integrated Mountain Development (ICIMOD) has developed the Forest Fire Detection and Alert Information System for Nepal using the forest fire data from Moderate Resolution Imaging Spectroradiometer (MODIS) sensors of the USA's National Aeronautics and Space Administration (NASA). For this report, forest fire data from 2001 to 2019 were obtained from ICIMOD. Both fire and forest fire events are also in increasing trends (see Figure 16).

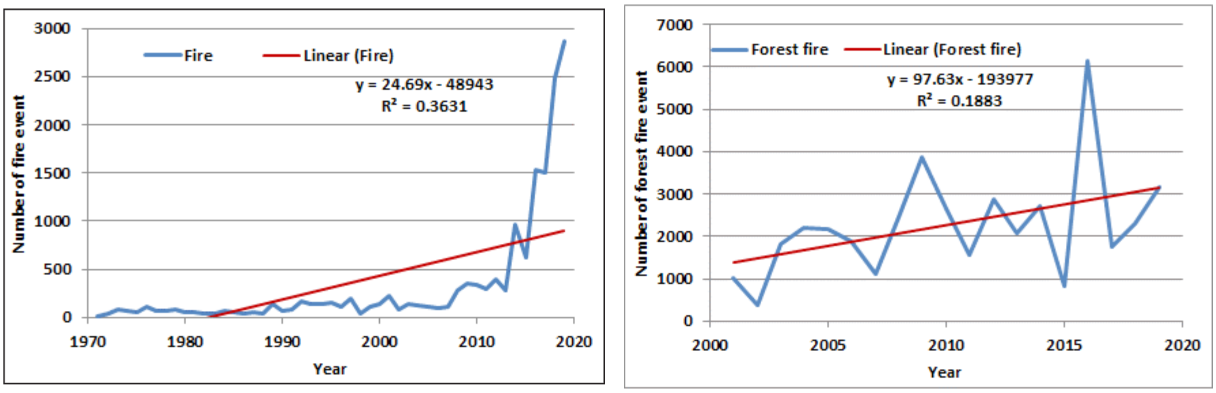


Figure 16 All-Nepal trends of fire and forest fire events

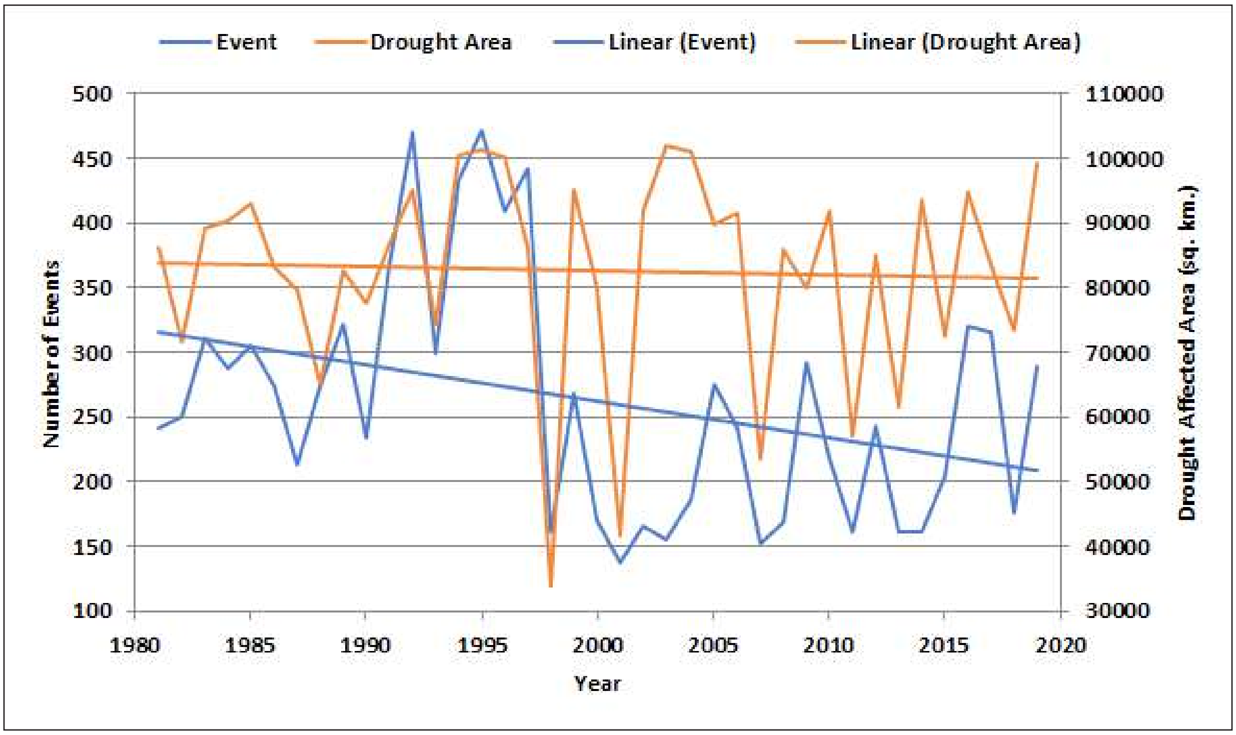


Figure 17 All-Nepal trend of drought events and areas

Meteorological droughts are defined as events with Standardized Precipitation Index (SPI) values less than or equal to -1. The raster data of SPI from 1981 to 2019 was obtained from ICIMOD. The analysis of SPI from 1981 to 2019 showed that the average duration of a drought in Nepal is about 3.4 months (102 days) per year. On average, about 56% area of the country is affected by drought. Both drought events (months) and drought-affected areas are in decreasing, but statistically insignificant, trends (see Figure 17 above).

Trend analysis was also carried out for the other two major hazards which have a strong relationship with climate variables: namely, floods and landslides (rain-induced). The (rain-induced) flood-prone and landslide-prone areas of Nepal are about 8% and 59% respectively. In the last 49 years (1971-2019), Nepal has suffered from 3443 flood events and 3787 landslide events. Flood and landslide events are highly correlated with each other. When flood events increase, landslide events also increase and vice versa. In Nepal, both events show an increasing trend (see Figure 18).

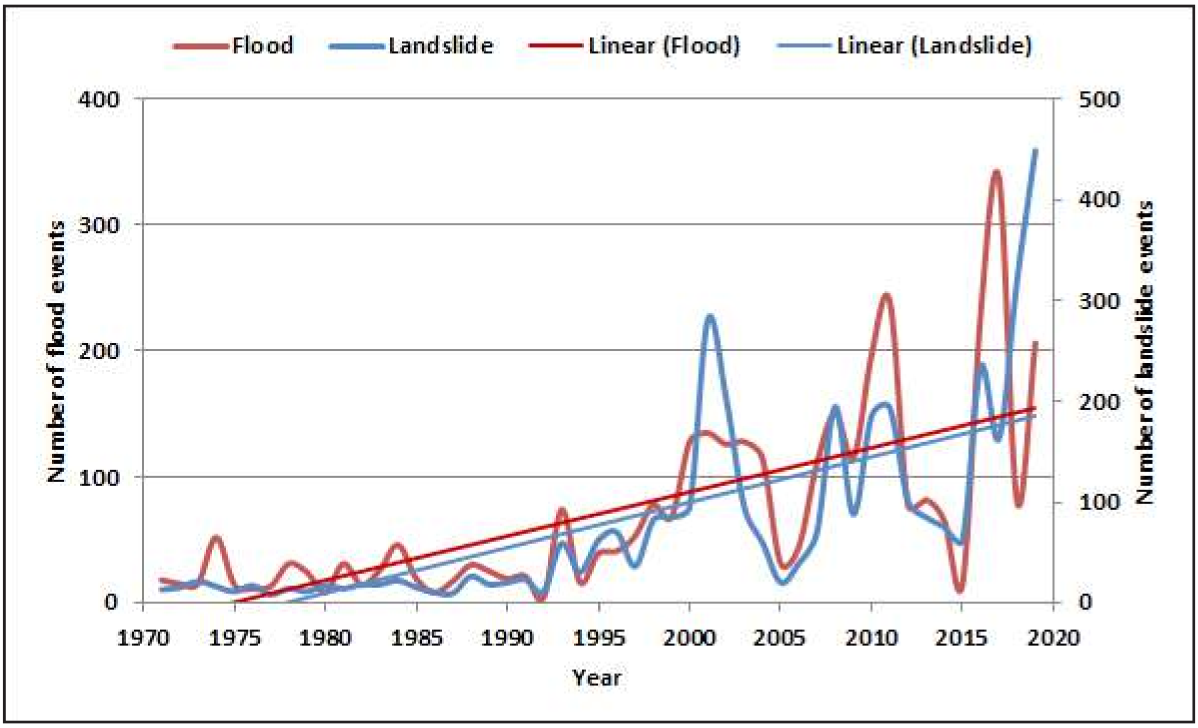


Figure 18 All-Nepal trend of flood and landslide events

Table 9 below presents the results of the Mann-Kendall test and Sen's slope for 14 climatic hazard events. Among 14 climatic hazards, it appears that all hazards are in increasing trends, except droughts which show a decreasing trend. While trends of epidemics, avalanches, hailstorms, and droughts are statistically insignificant, the trends of the other ten hazards are statistically significant at a 5% level.

Table 9: Mann-Kendall test statistics for linear trend of 14 climatic hazard events

Hazard	Z-statistic	P-value	Sen's Slope	Significance (5%)
Fires	6.40	0.00	7.32	Yes
Thunderbolts	7.44	0.00	2.70	Yes
Windstorms	5.23	0.00	0.57	Yes
Epidemics	1.63	0.10	1.16	No
Heavy rainfalls	4.53	0.00	0.25	Yes
Landslides	6.62	0.00	2.70	Yes
Floods	5.43	0.00	2.64	Yes
Avalanches	1.61	0.11	0.03	No
Hailstorms	0.34	0.74	0.00	No
Heatwaves	2.18	0.03	0.00	Yes
Cold waves	3.70	0.00	0.00	Yes
Snowstorms	2.60	0.01	0.04	Yes
Forest fires	1.96	0.05	83.50	Yes
Droughts	-1.73	0.08	-2.39	No

Many climatic and non-climatic factors may influence the trends of disaster events, including better reporting and data-keeping. Parts of the historical increase in hazardous events can be credited to better reporting. The remaining parts may be attributed to climate change. Economic development and land-use changes can also lead to changes in hazard patterns. Changes in land cover induce changes in rainfall-runoff patterns, which can impact flood intensity and frequency. Urbanization can aggravate flood problems by decreasing runoff retarding functions and accelerating flood flows due to pavements and drainage systems. Development activities such as cutting hill slopes in mountainous areas for road construction may increase landslides and debris flows.

5.2 Perceived Impact of Climate Change

The Central Bureau of Statistics (CBS) of the Government of Nepal conducted a National Climate Change Impact Survey from July to December 2016. This survey provided data on people's knowledge and perception about climate change, climate-induced disasters, human and socio-economic impacts, and adaptation practices (CBS, 2017).

According to the survey, a majority of households reported observing climate change and an increase in different climate-induced disasters such as floods, landslides, droughts, hailstorms, and the prevalence of diseases/insects in the last 25 years. About 99.3% of respondents observed increasing incidences of drought in the last 25 years, followed by disease/insects (97.7%), landslides (78.1%), and inundation (51.5%). Similarly, all households in the central mountain region reported an increase in the frequency of cold waves, while the ones in the central hill region observed a decrease. Additionally, 56.3% of eastern Terai households observed an increase in heatwaves. All sub-alpine households perceived an increase in droughts, landslides, avalanches, and the prevalence of diseases/insects, while 64.1% in the temperate zone observed an increase in fires in settlements over the last 25 years.

The survey also showed that 38.3% of households were impacted by windstorms, followed by landslides (35.2%), fires in settlements (31.8%), and floods (31.7%). In contrast, less than 10% of households reported an impact from heatwaves, snowstorms, sporadic rain or forest fires. It was also found that households have been practicing various CCA measures during the past 25 years, such as the use of chemical fertilizers, additional investment to protect livestock from disease, use of mixed and improved crop varieties, insurance of crops, change in food consumption habits, improvement of road infrastructure, and community-based management of natural resources.

5.3 Attribution of Changes in Climatic Hazards to Climate Change

Climate change refers to a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes (IPCC, 2007). The SREX confirms that extreme events have been and are projected to be on the rise. There is also increasing scientific evidence that the changing likelihood of extreme events is linked to human-induced climate change (IPCC, 2012).

Event 'attribution' is a process of understanding and quantifying the human and natural influences on individual extreme events. This process often uses a method called fractional attribution. This method tries to assess what fraction can be attributed to natural cycles and what can be attributed to human influence on climate. This approach is based on the physical understanding of the climate system and the individual hazard itself, on data comparison, as well as on climate models (Banholzer et al., 2014). Thus, attribution is derived from a combination of physical understanding and statistical analysis.

The first step in an attribution study is to have a time series dataset that indicates a trend over a certain period or a specific, unusual event that demands an explanation. The second step is to separate the human contribution from that of natural variability, which requires a model. It is important to recognize that both natural variability and global warming by humans are pervasive. Climate change from human influences is difficult to perceive and detect because natural weather-related variability is large. It is highly desirable to know how much of each we are experiencing, as this has implications for the future (Trenberth, 2011). This section presents the analysis of trends of selected climatic hazards and their relationship with the trends of climate variables to detect the changes in climatic hazards that can be attributed to climate change.

Heatwaves: The IPCC's Third Assessment Report (AR-3) projected that increasing atmospheric concentrations of greenhouse gases will result in changes in the frequency, intensity, and duration of extreme events, such as hotter days, heatwaves, heavy precipitation events, and fewer cold days (IPCC, 2001). Global warming will result in higher maximum temperatures, more hot days, and heatwaves over nearly all land areas. The IPCC's Fifth Assessment Report (AR-5) also highlighted that human influence has more than doubled the probability of the occurrence of heatwaves in some locations (IPCC, 2014). In Nepal, heatwaves have increased in recent years in the Banke, Bara, Bardiya, Kapilbastu, Parsa, Rautahat, Rupandehi, Saptari, and Sunsari districts. These districts have also shown an increasing trend in annual maximum temperature and warm spell duration.

Cold waves: IPCC's AR-3 projected that global warming will result in higher (increasing) minimum temperatures, fewer cold days, frost days, and cold waves in nearly all land areas (IPCC, 2001). In Nepal, many districts in the Terai region have historically been affected by cold waves, including Mahottari, Saptari, and Rautahat. However, since these districts have been experiencing an increasing trend in annual minimum temperature and a decreasing trend in cold spell duration in recent years, the cold waves are expected to decrease in these districts in the future as well.

Snowstorms: IPCC's AR-5 highlighted that as the atmosphere and ocean have warmed, the amounts of snow and ice have diminished and the sea level has risen (IPCC, 2014). The trend analysis of snowstorms in Nepal from 1971 to 2019 shows an increasing trend. The most snowstorm-affected districts are Humla, Jumla, Dolpa, and Taplejung. These districts have also shown a decreasing trend in winter minimum temperatures. With an increase in temperature, the frequency of snowstorms may decrease in the future.

Thunderbolts: Thunderbolts, also called lightning, are caused by charge separation within clouds, and to maximize charge separation, more water vapor and heavy ice particles have to be lifted into the atmosphere. The faster the updrafts, the more lightning occurs, and the more precipitation, the more lightning. With climate change, lightning is expected to strike far more regularly worldwide. Rising temperatures and humidity are potential causes behind an increase in the number of lightning strikes in certain regions. New research from the University of California, Berkeley, published in the journal Science by David et al. (2014), found that warming conditions would result in 50% more lightning strikes worldwide by the end of the century. Lightning strikes would increase by about 12% for every 1 °C of warming, resulting in about 50% more strikes by 2100.

In Nepal, thunderbolts or lightning have increased in recent years in the Makawanpur, Jhapa, Morang, and Udaypur districts. The trend of thunderbolt events in the Makawanpur district was compared with the trend of the annual average temperature and rainfall, revealing that thunderbolt events and annual temperature are both on increasing trends (see Figure 19). The number of thunderbolt events increases when the annual temperature increases.

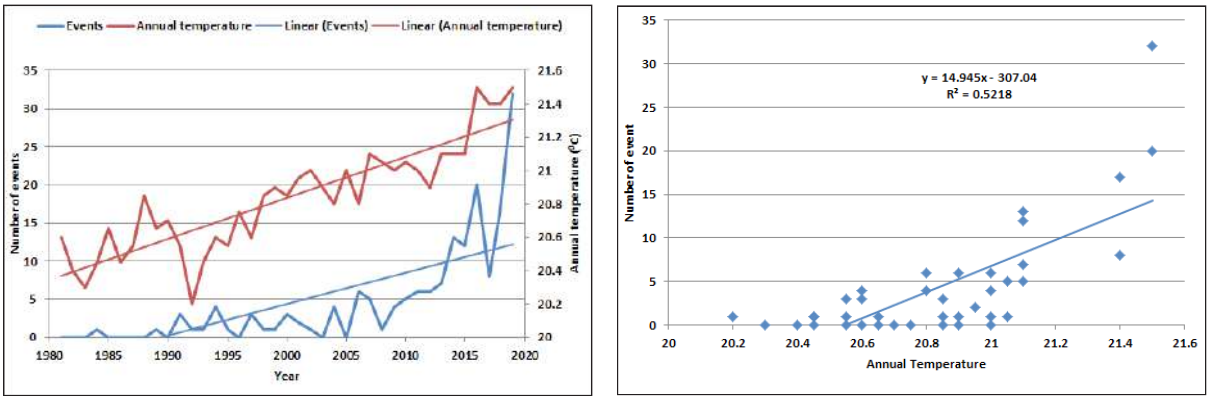


Figure 19 Trends of thunderbolt events and annual average temperature and their relationship

Similarly, Figure 20 below shows the trends of thunderbolt events and annual rainfall, and their relationship, in the Makawanpur district. Both the thunderbolt events and annual rainfall are in increasing trends. The number of thunderbolt events increases when the annual rainfall increases.

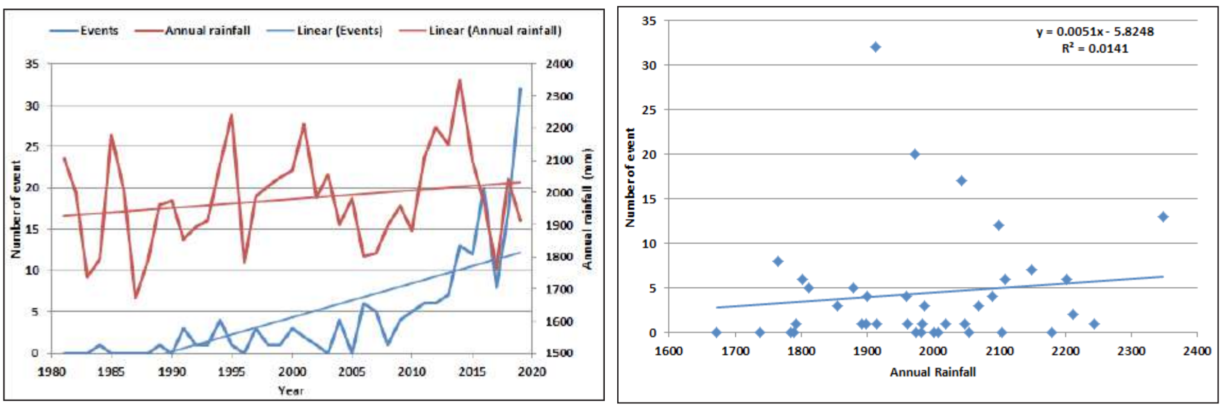


Figure 20 Trends of thunderbolt events and annual rainfall and their relationship

Windstorms: Scientists have pointed out that a warmer climate will result in more frequent and stronger windstorms, and higher wind risks in the future. IPCC's AR-5 showed that increases in the frequency or intensity of ecosystem disturbances such as droughts, **windstorms**, fires, and pest outbreaks have been detected in many parts of the world and, in some cases, are attributable to climate change (IPCC, 2014).

In Nepal, windstorm hazards have been increasing in recent years in the Achham, Morang, Saptari, Kailali, and Bardiya districts. Figure 21 shows the increasing trends of windstorm events and annual maximum temperature, and their relationship, in the Morang district. The number of windstorm events increases when the annual maximum temperature increases.

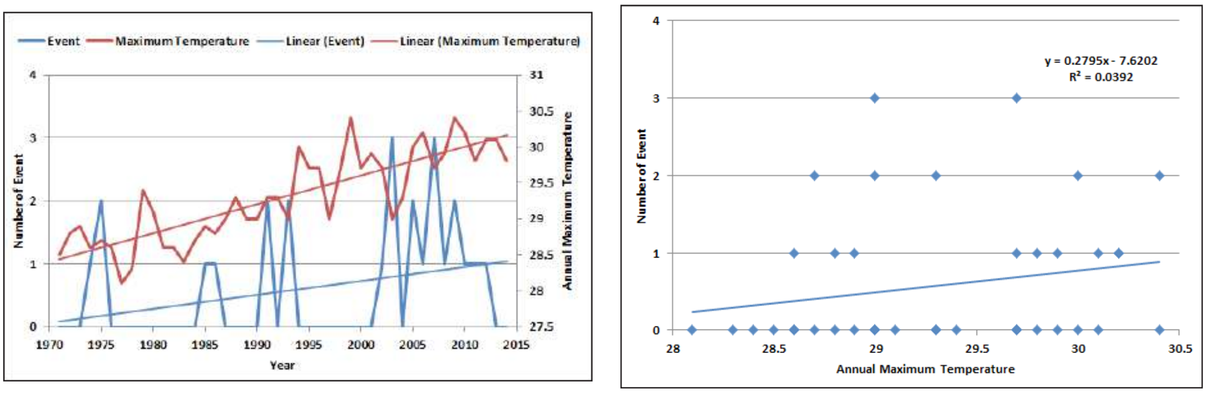


Figure 21 Trends of windstorm events and annual maximum temperature and their relationship

Hailstorms: Global warming leads to a warmer atmosphere that can hold higher amounts of moisture. Increased quantities of moisture in the air in a warmer future could lead to heavier rain or hail precipitation during an individual storm. Some studies have found a correlation between the frequency of reported hail damage and rising temperatures over some parts of the world. Extrapolations of the historical relationship between hailstorm damage and weather indicators under climate change scenarios project a considerable increase in future hailstorm damage (Botzen et al., 2010). A 30-40% increase in hail events with hailstones larger than 5 cm in diameter can be expected under the RCP 4.5 scenario almost everywhere in Europe[7]. The results were even more extreme for the RCP 8.5 scenario. If climate change continues unabated, severe hail events may occur almost twice as frequently in large parts of Central and Eastern Europe.

In Nepal, hailstorm hazards have appeared to be in an increasing but statistically insignificant trend in recent years. The most hailstorm-affected districts are Kaski, Parbat, Tanahu, Syangja, and Myagdi. In the last 49 years (1971-2019), 569 hailstorm events have occurred in various districts of Nepal.

Avalanches: A Special Report from the IPCC (2012) pointed out that at higher temperatures, more ice melts and the strength of the remaining ice becomes lower. As a result, the frequency and size of ice avalanches may increase. Warm extremes can trigger large rock and ice avalanches. Analysis shows increasing trends in recent years in the Solukhumbu, Kaski, Manang, and Dolpa districts in Nepal, but they are not statistically significant. With increasing temperatures in the future, avalanches in the country are also expected to increase.

7 https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/climate-change/climate-change-and-severe-hailstorms-in-europe.html

Floods: Flood frequency and the tails of flood duration (length of duration) have increased at both the global and the latitudinal scales. The increasing trend in frequency and duration of floods can be attributed to the long-term decadal to bi-decadal climate variability (Najib & Devieni, 2018). Based on data of several Asian countries from over 30 years (1973-2002), a trend analysis showed that the frequency of floods is increasing significantly in most countries (Dutta & Herath, 2004). This increasing trend can be attributed to mainly two factors: i) climate change and ii) land-use change. An analysis of changes in risk of great floods—i.e., floods with discharges exceeding 100-year levels from basins larger than 200,000 sq.km.—, using both streamflow measurements and numerical simulations of the anthropogenic climate change associated with greenhouse gases and direct radiative effects of sulphate aerosols, showed that the frequency of great floods increased substantially during the twentieth century (Milly et al., 2002)

A change in the climate physically changes many of the factors affecting floods (e.g., precipitation, snow cover, soil moisture content, sea level, glacial lake conditions, and vegetation) and thus may consequently change the characteristics of floods. Pluvial floods may increase with an increase in heavy precipitation. More recent literature has highlighted the influence of climate change on variables that affect floods, such as aspects of the hydrological cycle, including mean precipitation, heavy precipitation, and snowpack. An IPCC synthesis report (2014) evaluated the risk of floods to the global population and concluded that the number of people exposed to rare flood events is expected to increase worldwide.

In Nepal, the most flood-prone districts are Jhapa, Morang, Sunsari, Rautahat, Saptari, Sarlahi, and Nawalparasi. The Jhapa district experienced the highest number of flood events from 1971 to 2019. The trend of the flood events in Jhapa was compared with the trend of the monsoon rainfall (see Figure 22). The flood events are on an increasing trend, whereas the monsoon rainfall has no distinct trend. Additionally, trend analysis of historical rainfall data showed that very wet days are on an increasing trend in the Jhapa district (DHM, 2017). The number of flood events increases when the monsoon rainfall increases.It is a good way to start the day.

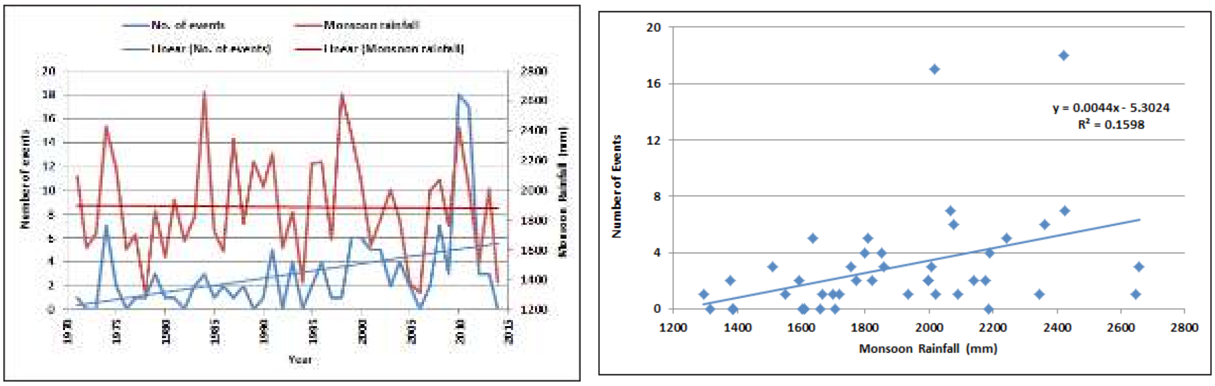


Figure 22 Trends of flood events and monsoon rainfall in Jhapa district

Landslides: Dhading, Baglung, Sindhupalchok, Sankhuwasabha, Taplejung, Nuwakot, and Syangja are the most landslide-prone districts in Nepal. The trend of landslide events in the Sindhupalchok district was compared with the trend of monsoon rainfall (see Figure 23). The landslide events are on an increasing trend, whereas the monsoon rainfall is on a slightly decreasing trend. Additionally, rainy days and consecutive wet days are on an increasing trend in the Sindhupalchok district (DHM, 2017). Taken together, this indicates that more landslides are occurring due to low-intensity continuous rainfall rather than high-intensity rainfall. The number of landslide events increases when the monsoon rainfall increases.

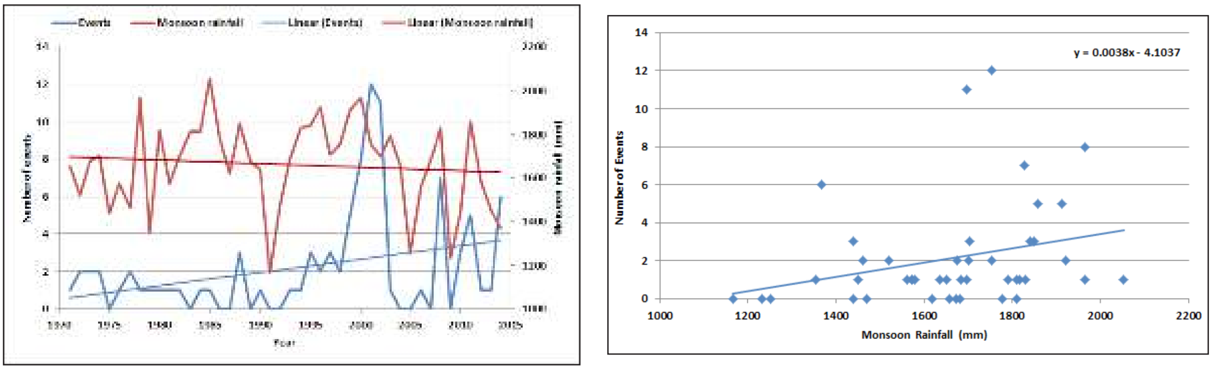


Figure 23 Trends of landslide events and monsoon rainfall in Sindhupalchok district

Extreme precipitation events are likely to become more common in the future as the climate warms. This could lead to an increased frequency of landslide activity in the border region of China and Nepal[8], which could see a 30-70% increase in landslide activity.

There is high confidence that changes in heatwaves, glacial retreat, and/or permafrost degradation will affect slope instabilities in the high mountains and medium confidence that temperature-related changes will influence bedrock stability. There is also high confidence that changes in heavy precipitation will affect landslides in some regions (Seneviratne et al., 2012). Variations in total rainfall influence rockslides, mudflows, and earth flows on both the local and regional scales, whereas variations in rainfall intensity directly affect rock falls and debris flows/ avalanches in the short-term and on the local scale. Changes in the air temperature directly influence ice falls and avalanches, and have an indirect impact on rockfalls (due to the formation and opening of fractures), and on deep-seated landslides (due to changes in the hydrological cycle). An increase in the total precipitation is expected to result in wetter antecedent conditions so that less rain is required to reach a critical level that can cause a slope to fail. It will also raise the water table, contributing to the reduction of shear strength, soil suction and cohesion, and an increase in the weight (wet density) of the slope materials, which may enhance slope instability (Gariano & Guzzetti, 2016).

An increase in rainfall intensity may result in higher infiltration and increased subsurface drainage and throughflow, which will contribute to the build-up and maintenance of perched water tables. This will lead to a reduction in effective normal stresses and the shear strength, again contributing to slope instability. High rainfall rates are associated with soil piping, which is related to soil erosion and landslides.

GLOFs: In response to climate fluctuations, glaciers grow and shrink in length, width, and depth. Receding and wasting glaciers are a sign of global climate change. With the melting of glaciers, glacial lakes are formed. Several of these lakes have burst in the past, producing catastrophic glacial lake outburst floods (GLOFs) that destroyed infrastructure and took human lives in the valleys downstream.

8 https://climate.nasa.gov/news/2951/climate-change-could-trigger-more-landslides-in-high-mountain-asia/#:~:text=They%20found%20that%20extreme%20precipitation,percent%20increase%20in%20landslide%20activity.

Droughts: Drought events can be intensified by reductions in overall precipitation and an increase in temperatures, which affect evapotranspiration (IPCC, 2012). In Nepal, the Dolpa, Humla, Gorkha, Mugu, and Kailali districts are the most drought prone. The trend of the drought-prone areas in the Dolpa district was compared with the trend of annual rainfall. As can be seen in Figure 24, the drought-prone areas are on a decreasing trend whereas the annual rainfall has no distinct trend. However, monsoon rainfall, the number of rainy days, and consecutive wet days are on an increasing trend in the Dolpa district (DHM, 2017). Drought-prone areas decrease when the rainfall increases.

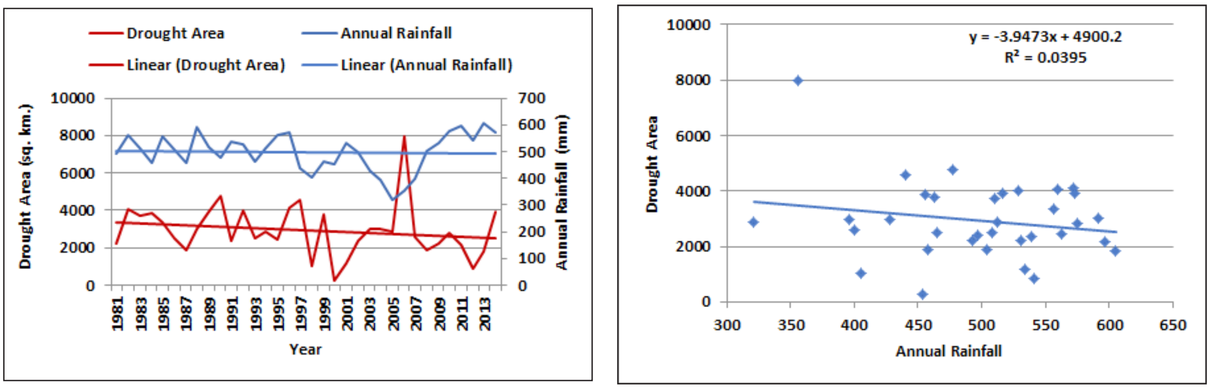


Figure 24 Trends of drought-prone areas and annual rainfall in Dolpa district

Fires and forest fires: Climate change may result in longer fire seasons in some parts of the country, easier ignition, and, therefore, potentially greater number of fires, faster fire spread, increased fire intensities, more prolonged fires, and greater amounts of areas/settlements burned. It may result in more difficult fire suppression and increased fire suppression costs and damage.

Weather elements influence the spread and control of fire. The key weather elements that increase fire risk and danger are temperature, humidity, wind speed, and rainfall. Increasing temperature, wind speed, decreasing rainfall and humidity in each region are the key influences on fire risk. The potentially hotter, windier, and drier weather in the future will increase fire risk.

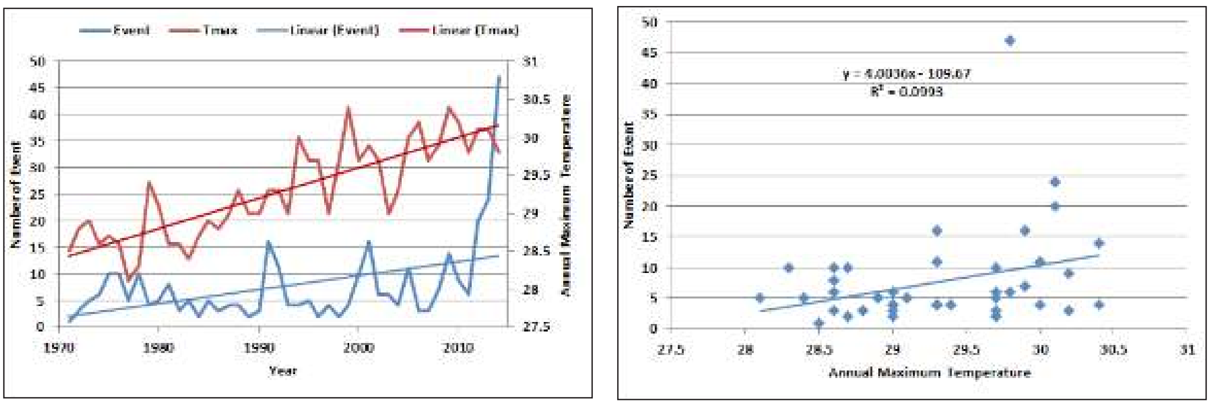


Figure 25 Trends of fire events and annual maximum temperature and their relationship

In Nepal, fire hazards have been increasing in recent years in Kathmandu, Morang, Saptari, Sunsari, and Jhapa districts. When the trend of fire events in the Morang district was compared with the trend of annual maximum temperature and rainfall, it was found that both the fire events and annual maximum temperature are in an increasing trend. However, annual rainfall appeared to have no distinct trend (see Figures 25 and 26)). The number of fire events increases when the annual maximum temperature increases, and decreases when the annual rainfall increases.

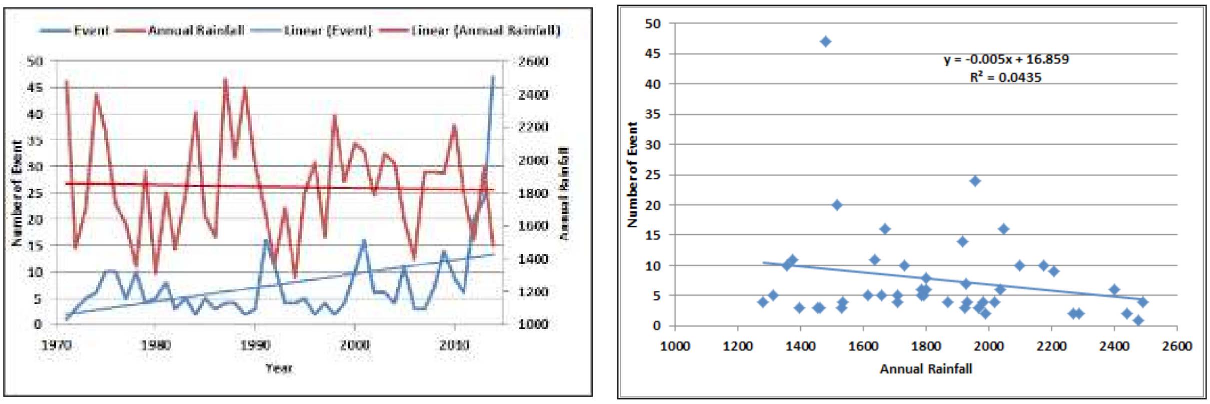


Figure 26 Trends of fire events and annual rainfall and their relationship

In Nepal, forest fire hazards have been increasing in recent years in Bardiya, Chitawan, Parsa, and Surkhet districts. When the trend of the forest fire events in the Bardiya district was compared with the trend of pre-monsoon rainfall and annual maximum temperature, it was found that forest fire events appear to be in an increasing trend whereas pre-monsoon rainfalls is in a decreasing trend (see Figure 27). The number of forest fire events decreases when the pre-monsoon rainfall increases.

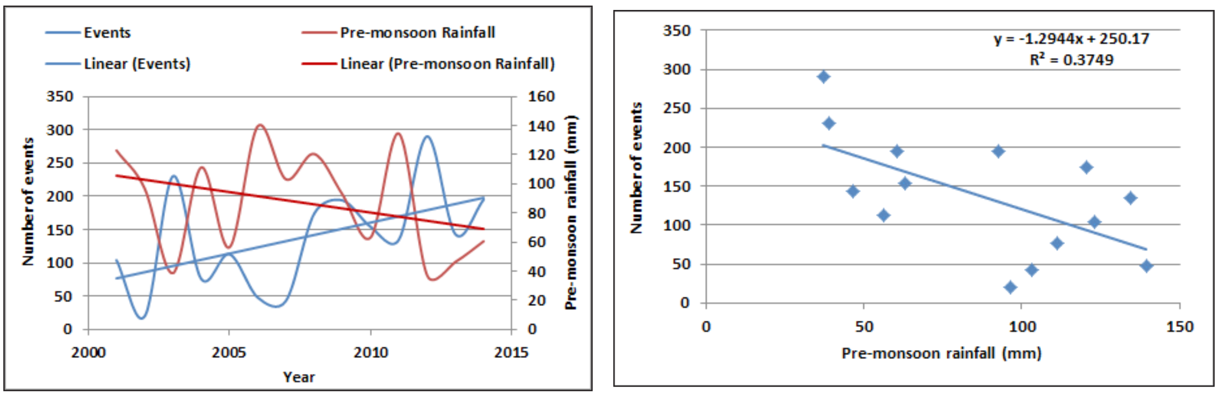


Figure 27 Trend of forest fire events and pre-monsoon rainfall and their relationship

Similarly, Figure 28 shows the trend of forest fire events and annual maximum temperature and their relationship in the Bardiya district. Both forest fire events and annual maximum temperature are in an increasing trend. The number of forest fire events increases when the annual maximum temperature increases.

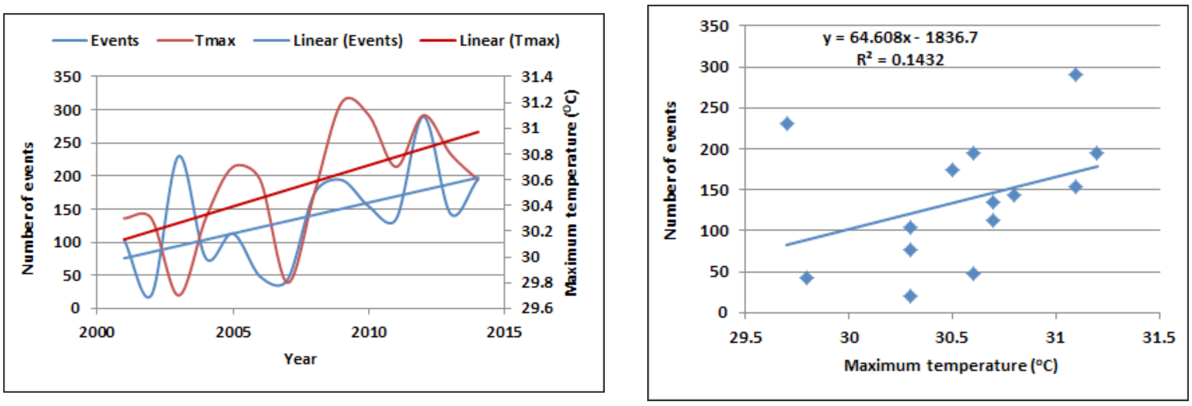


Figure 28 Trends of forest fire events and annual maximum temperature and their relationship

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 fatalities and extensive destruction of human settlements and forests (GON, 2013). The occasional precipitation was found to be the highest in March and lowest in April. The lowest occasional average precipitation showed decreasing trends in active fire season over a 15-year period. The number of wildfires and burned areas showed increasing trends over the same period. The highest numbers of wildfires were noticed in April of 2003, 2005, 2009, 2010, and 2012. There was a significant correlation between precipitation and wildfire activities (viz., number of wildfires and burned forest area). The occasional precipitation variable affects wildfire activities. These findings can be useful to both policymakers and local forest managers for developing the pre-fire alert system, preparing for fire control and mitigation, and managing wildfires in the field (Bhujel et al., 2018).

It is important to note that forest fire occurrences in protected areas and national and community forests might be influenced by controlled burning practices that happen every year to ensure the growth of grassland and vegetation.

Epidemics: The health effects of climate change are temperature-related illness and death, extreme weather-related health effects, air pollution-related health effects, water-borne diseases, and vector-borne diseases (WHO, 2003). Climatic conditions affect epidemic diseases. Vectors, pathogens, and hosts each survive and reproduce within a range of optimal climatic conditions. Temperature and precipitation are the most important climate variables to influence vector survival, reproduction, and transmission. Rainfall can influence the transport and dissemination of infectious agents, while temperature affects their growth and survival. Malaria is the vector-borne disease most sensitive to climate change. Malaria varies seasonally in highly endemic areas. Wet and humid climate conditions constitute a major factor behind increased mosquito breeding and survival. Many diarrheal diseases vary seasonally, suggesting climate sensitivity. In the tropics, diarrheal diseases typically peak during the rainy season. Both floods and droughts increase the risk of diarrheal diseases. Extremes in temperature can exacerbate cardiovascular and respiratory diseases.

The IPCC (2012) concluded with high confidence that climate change would cause increased heat-related mortality and morbidity, decreased cold-related mortality in temperate countries, a greater frequency of infectious disease epidemics following floods and storms, and substantial health effects following population displacement from sea level rise and increased storm activity.

Relationships between year-to-year variations in climate variables and infectious disease occurrence need to be explored to understand the attribution and future health impacts of climate change. Analysis of 49 years (1971-2019) of epidemic data revealed that Morang, Dang, Jajarkot, and Banke are the most epidemic-affected districts in Nepal. The trend of epidemic events in the Dang district was compared with the trend of annual rainfall and annual maximum temperature (see Figure 29).

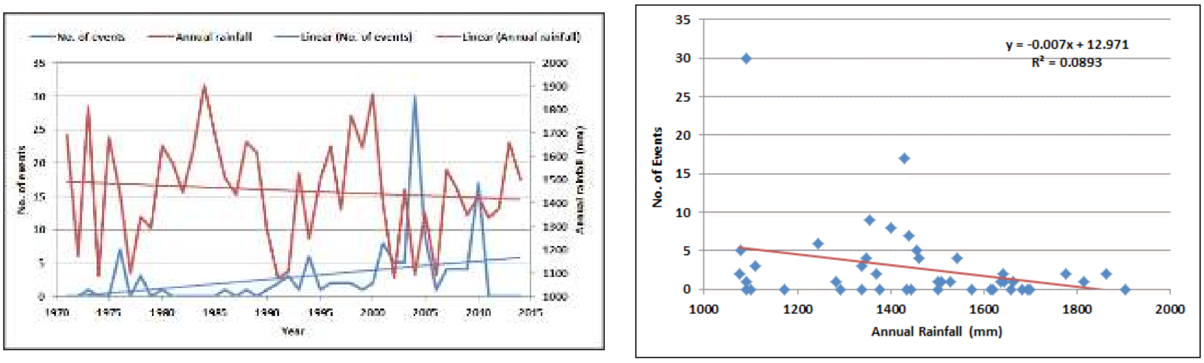


Figure 29 Trend of epidemic events and annual rainfall in Dang district

Figure 30 shows the trend of epidemic events and annual maximum temperature and their relationship. The epidemic events are in increasing trend, the annual rainfalls are in a slightly decreasing trend and maximum temperatures are in an increasing trend. Observed climate trend analysis by the DHM in 2017 showed that annual rainfall in the Dang district is in a decreasing trend and consecutive dry days are in an increasing trend. Additionally, annual temperature, warm days, and warm spell duration are in increasing trends. A warm and dry climate provides a favourable condition for the growth and spread of vector-borne and water-borne diseases.

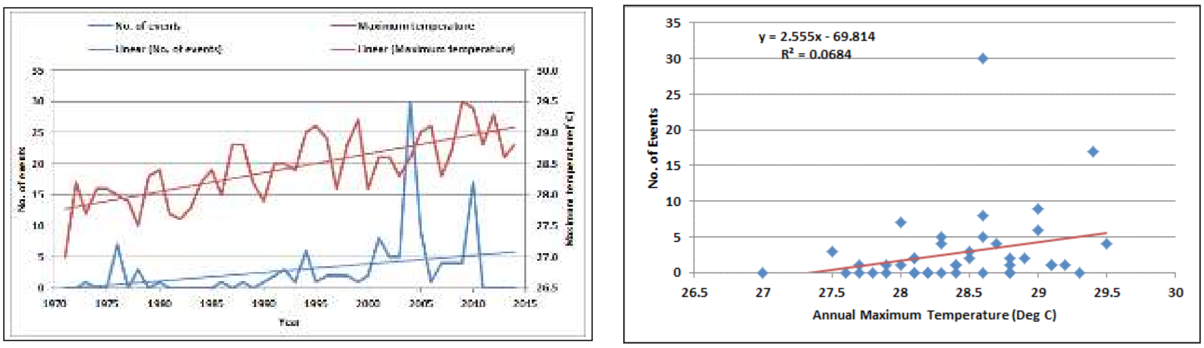


Figure 30 Trend of epidemic events and annual maximum temperature in Dang district

The significant increasing trends in the frequency of several climatic hazards show a strong linkage between climate change and an increase in climatic hazards. The observed increase in climatic hazards may be attributed to a "complex set of interactions between the physical Earth system, human interference with the natural world and increasing vulnerability of human communities"[9]. The IPCC (2014) also suggests with high confidence that "in urban areas climate change is projected to increase risks for people, assets, economies, and ecosystems, including risks from heat stress, storms, and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, and storm surge".

9 https://theconversation.com/explainer-are-natural-disasters-on-the-rise-39232

5.4 Scenarios of Climatic Hazards

The detection and attribution of changes in climatic hazards were described in the previous section. This section discusses how the past and future scenarios of climatic hazards can be obtained using historical hazard occurrences and climate change indices as indicators.

5.4.1 Quantitative Scenarios of Climatic Hazards under Historical Climate

The quantitative past scenarios of climatic hazards are obtained for historical climate using the indicators given in Table 2. Past scenarios and district-wise ranks of the flood hazard based on historical climate (1971-2019) are given in Figure 31 and Table 10 respectively. These show that Sunsari, Kailali, Morang, Jhapa, Rautahat, Bardiya, Sarlahi, and Saptari are the most flood-prone districts and identified as "**Flood Hazard Hotspots**".

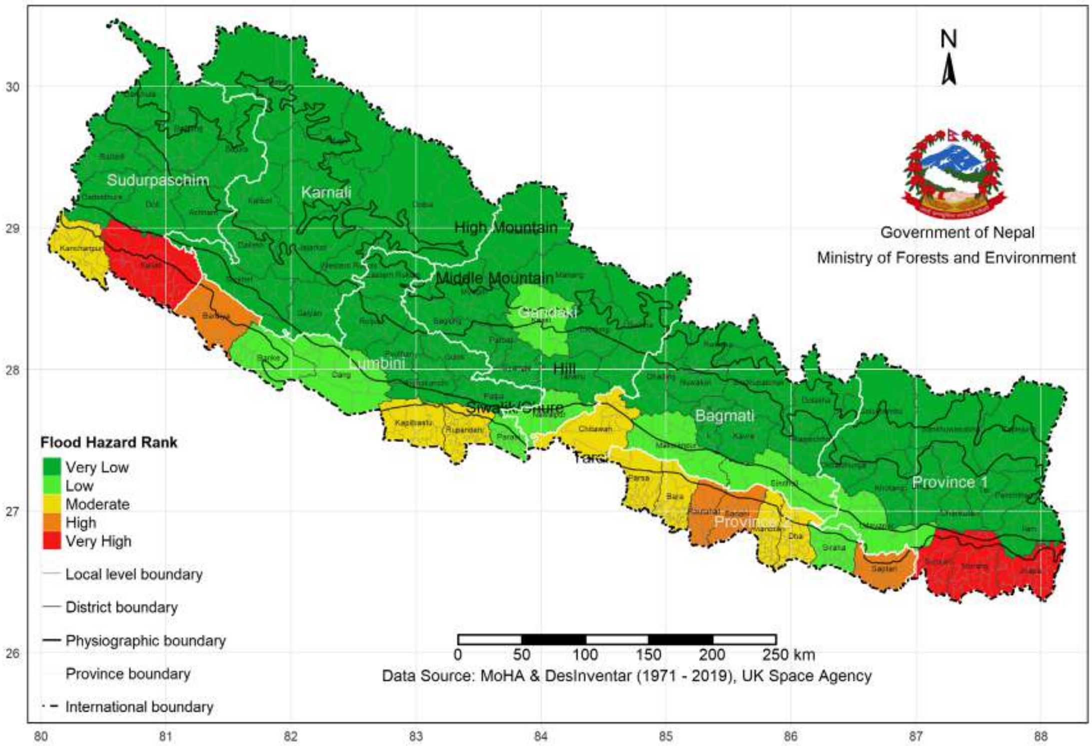


Figure 31 Past scenario of flood hazard based on historical climate

Table 10: District wise rank of flood hazard based on historical climate

Hazard Rank	Districts
Very High (0.731 - 1)	Sunsari, Kailali, Morang, Jhapa
High (0.595 - 0.730)	Rautahat, Bardiya, Sarlahi, Saptari
Moderate (0.412 - 0.594)	Kapilbastu, Rupandehi, Bara, Chitawan, Dhanusha, Kanchanpur, Mahottari, Parsa
Low (0.170 - 0.411)	Makawanpur, Udayapur, Banke, Siraha, Sindhuli, Dang, Nawalpur, Kaski, Parasi
Very Low (0 - 0.169)	Dhading, Rolpa, Humla, Mugu, Rasuwa, Myagdi, Lamjung, Dolakha, Dhankuta, Terhathum, Nuwakot, Sankhuwasabha, Baglung, Western Rukum, Sindhupalchok, Gorkha, Solukhumbu, Lalitpur, Tanahu, Kavrepalanchok, Dailekh, Bhaktapur, Parbat, Pyuthan, Darchula, Syangja, Dolpa, Surkhet, Achham, Arghakhanchi, Baitadi, Palpa, Bhojpur, Salyan, Mustang, Doti, Manang, Eastern Rukum, Khotang, Okhaldhunga, Bajura, Kalikot, Taplejung, Panchthar, Jajarkot, Jumla, Bajhang, Gulmi, Ramechhap, Kathmandu, Dadeldhura, Ilam

Past scenarios and district-wise ranks of the landslide hazard based on historical climate (1971-2019) are given in Figure 32 and Table 11 respectively. These show that Dhading, Sankhuwasabha, Baglung, Sindhupalchok, Dolpa, Taplejung, Kaski, Rolpa, Makawanpur, Myagdi, Lamjung, Dolakha, Nuwakot, Gorkha, Solukhumbu, Kavrepalanchok, Dailekh, Darchula, Syangja, Palpa, Khotang, Bajura, Kalikot, Jajarkot, Bajhang, Gulmi and Ilam districts are the most landslide-prone districts and identified as "**Landslide Hazard Hotspots**".

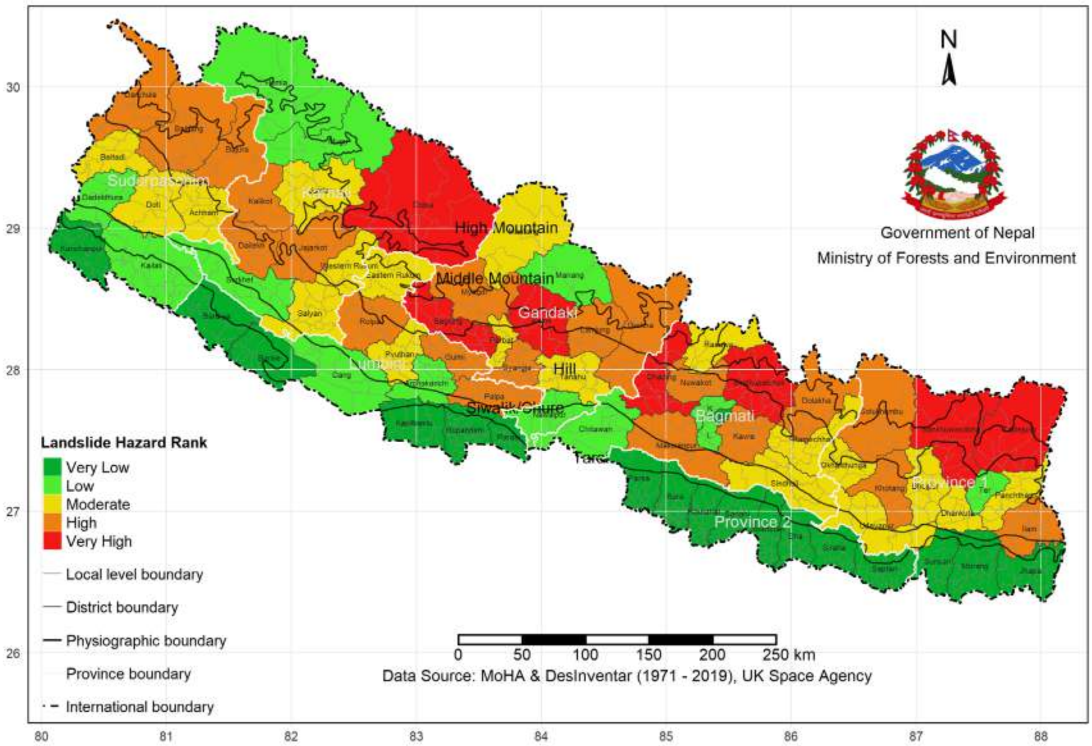


Figure 32 Past scenario of landslide hazard based on historical climate

Table 11: District-wise ranks of the landslide hazard based on historical climate

Hazard Rank	Districts
Very High (0.757 - 1)	Dhading, Sankhuwasabha, Baglung, Sindhupalchok, Dolpa, Kaski, Taplejung
High (0.539 - 0.756)	Rolpa, Makawanpur, Myagdi, Lamjung, Dolakha, Nuwakot, Gorkha, Solukhumbu, Kavrepalanchok, Dailekh, Darchula, Syangja, Palpa, Khotang, Bajura, Kalikot, Jajarkot, Bajhang, Gulmi, Ilam
Moderate 0.366 - 0.538)	Rasuwa, Dhankuta, Western Rukum, Tanahu, Udayapur, Parbat, Pyuthan, Achham, Baitadi, Bhojpur, Sindhuli, Salyan, Mustang, Doti, Eastern Rukum, Okhaldhunga, Panchthar, Jumla, Ramechhap
Low (0.143 - 0.365)	Humla, Mugu, Terhathum, Lalitpur, Kailali, Surkhet, Arghakhanchi, Manang, Chitawan, Dang, Nawalpur, Kathmandu, Dadeldhura
Very Low (0 - 0.142)	Kapilbastu, Sunsari, Rautahat, Bardiya, Bhaktapur, Banke, Siraha, Rupandehi, Morang, Bara, Dhanusha, Kanchanpur, Jhapa, Sarlahi, Mahottari, Parasi, Parsa, Saptari

Past scenarios of other hazards based on historical climate are given in **Annex A**.

Table 12 below presents major hazards province-wise, in addition to the ranking of provinces based on climatic hazards and their impacts, and disaster hotspots. Province-wise past scenarios of climatic hazards and overall impact based on historical climate are given in **Annex B**.

Table 12: Ranking of provinces based on climatic hazards and their impacts

Province	Major Hazards	Hazard Rank	Impact Rank	Climate-induced Disaster Hotspots
Province 1	Epidemics, fires, floods, landslides, GLOFs	2	6	Jhapa, Morang, Sunsari, Udaypur
Province 2	Epidemics, fires, floods, forest fires, hailstorms	1	1	Saptari, Sarlahi, Mahottari, Siraha
Bagmati	Epidemics, fires, floods, landslides, thunderbolts	4	2	Chitawan, Makwanpur, Sindhupalchok
Gandaki	Avalanches, epidemics, hailstorms, landslides, thunderbolts	3	7	Gorkha, Kaski, Baglung
Lumbini	Epidemics, fires, floods, forest fires, landslides	7	5	Banke, Dang, Rupandehi
Karnali	Epidemics, fires, floods, forest fires, thunderbolts	6	4	Surkhet, Jajarkot, Kalikot, Dailekh
Sudurpashchim	Epidemics, fires, floods, forest fires, landslides	5	3	Kailali, Doti, Kanchanpur, Achham

A province-wise comparison of the past scenarios of 15 climatic hazards based on historical climate data shows that Province 2 is the most affected by climatic hazards, followed by Province 1 and Gandaki Province. Similarly, a province-wide comparison of the impact of climatic hazards shows that Province 2 is the most impacted province, followed by Bagmati Province and Sudurpashchim Province. This may be due to the high socio-economic exposure and vulnerability in Province 2 as shown in Figures 13 and 14 respectively. Table 13 below presents the major climate-related hazards for each physiographic region.

Table 13: Major climate-related hazards in physiographic regions

Physiographic Region	Major Climate-related Hazards
High mountain	Avalanches, snowstorms, GLOFs
Middle mountain	Hailstorms, landslides, droughts
Hill	Heavy rainfalls, landslides, thunderbolts, windstorms, fires
Siwalik	Forest fires, thunderbolts, floods, landslides
Terai	Floods, heatwaves, cold waves, epidemics, fires, windstorms, forest fires

The high mountain region is affected by snowstorms, avalanches, and GLOFs. Avalanches are in an increasing trend and the risk of GLOF increases due to the increase in temperature. Hailstorms, landslides, and droughts are frequently occurring hazards in the middle mountain region. Heavy rainfalls, landslides, thunderbolts, fires, and windstorms are predominant hazards in the hilly region. The Siwalik region is frequently affected by forest fires, thunderbolts, landslides, and floods. There is an increasing risk of landslides in the middle mountain, hilly, and Siwalik regions due to an increase in very wet days. Similarly, floods, heatwaves, cold waves, epidemics, fire, and windstorms are the main hazards in the Terai region. There is an increasing risk of floods in the Terai region due to an increase in extreme wet days.

5.4.2 Descriptive Scenarios of Climatic Hazards under Future Climate Change

Information that enables the characterization of a future climatic hazard scenario is sourced either from the data of past hazard occurrences (Sharma & Patwardhan, 2008) or models (Lung et al., 2013; Metzger et al., 2006). However, both these sources at best enable only an approximation of the anticipated hazard and thus involve uncertainty (Jagmohan & Ravindranath, 2019). Future scenarios of climatic hazards can be inferred using the scenarios of temperature, precipitation, and climate extreme indices; these are indicators that can be expressed in descriptive terms.

Climatic hazards may become more frequent, widespread, longer-lasting, or intense under future climate change. There might be multiple events at the same time across different regions, which may turn out to be catastrophic. Coupled with degrading ecosystems and biophysical processes under climate change, climatic hazards may create chronic stresses and catastrophic shocks. Manifestation of climate change may be observed in the following forms (European Aid, 2010):

1) Changes in variability and extremes:
    a. Rainfall variability, seasonality – droughts, predictability
    b. Changes in peak precipitation intensity (flood and landslide risk)
    c. Changes in storm activity/behaviour/geographic distribution
    d. Heatwaves, wildfires, pollution events, etc.

2) Long term changes/trends in average conditions:
    a. Warmer, wetter, drier, more saline groundwater
    b. Shifts in climatic zones, ecological/species ranges

3) Abrupt /singular changes:
    a. Monsoon shifts, circulation changes
    b. Landscape & ecosystem transitions
    c. Glacial lake outbursts

The descriptive scenarios of climate variables and extreme indices under future climate change can be expressed as in Table 14 below (MoFE, 2019a).

Table 14: Descriptive scenarios of climate variables and extreme indices under future climate change

Climate Variables and Extreme Indices	Medium Term Scenario	Long Term Scenario
Increase in temperature	Likely	Likely
Increase in precipitation	Likely	Likely
Increase in very wet days	Likely	Likely
Increase in extreme wet days	Likely	Likely
Decrease in rainy days	Likely	Likely
Increase in consecutive dry days	About as likely as not	About as likely as not
Increase in consecutive wet days	About as likely as not	About as likely as not
Increase in warm days and nights	Likely	Likely
Decrease in cold days and nights	Likely	Likely
Increase in warm spell duration	Likely	Likely
Decrease in cold spell duration	Likely	Likely

Climate-induced hazards will be more intense and damaging in the future. The Climate Risk Country Profile of Nepal, put together by the World Bank Group and the Asian Development Bank, reported that the probability of droughts and heatwaves is projected to increase while the probability of cold waves is projected to decrease in the country. An increase in the median annual drought probability of at least 10% is projected by 2080-2099 under all emission pathways (see Figure 33a). The probability of heatwaves is projected to increase significantly, potentially as high as 27% by the 2090s (see Figure 33b) under the highest emissions pathway (RCP 8.5). Simultaneously, the probability of cold waves is projected to decrease significantly, to less than 1% annually over the same period.

There will be an increase in the frequency of extreme river flows. What would historically have been a 1-in-100-years flow is projected to become a 1-in-50-years or 1-in-25-years event in Nepal. The risk of GLOFs is also likely to increase (World Bank, 2021). For example, flood-related studies show that the damage caused by floods is expected to be massive. An increase in potential flooding impact has also been projected by Paltan et al. (2018), who demonstrated that even under lower emissions pathways coherent with the Paris Climate Agreement, almost all Asian countries face an increase in the frequency of extreme river flows. This increased severity of extreme river floods can also be seen in estimates by Willner et al. (2018), who projected that an additional 8,000–43,000 people will be affected by extreme flood events by 2035–2044 as a result of climate change (World Bank, 2021, pp 13-14).

The assessment of the flood hazard and agricultural damage (in quantitative terms) in the Bagmati River basin, including the Lal Bakaiya River basin, under climate change conditions showed that the total flood inundation area and agricultural damage area may increase in the future by 41.1% and 39.1% respectively in the case of a flood with a return period of 50 years, and 44.9% and 40.8% respectively in the case of a flood with a return period of 100 years (Shrestha, 2019). A similar analysis revealed that climate change will result in more extreme precipitation events in monsoon months and less precipitation in other months, which might result in a significant increase in flood events in the Bagmati river basin in the future. The range of change in floods with a return period of 200 years was from 24-40% (Mishra & Srikantha, 2014).

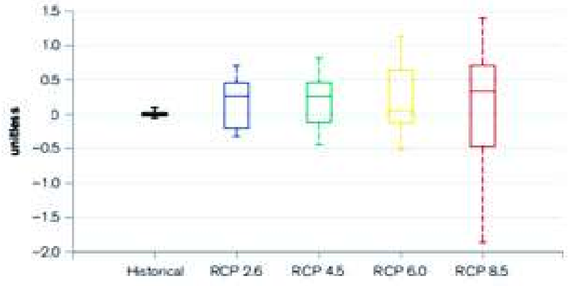


Figure 33a. Annual probability of experiencing a severe drought

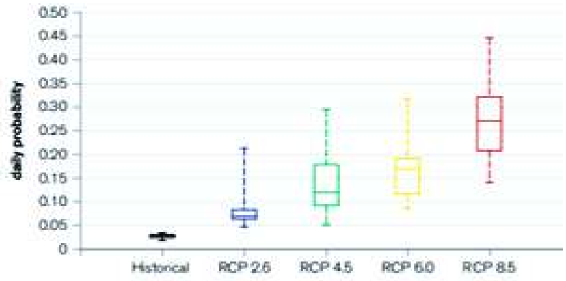


Figure 33b. Projected change in the probability of observing a heatwave.

Table 15: Estimated number of people in Nepal affected by the extreme flood from 1971-2004 and the future period 2035-2044

Estimate	Population exposed to extreme floods (1971-2004)	Population exposed to extreme floods (2035-2044)	Increase in affected population
16.7 percentile	350,844	358,940	8,096
50 percentile (median)	353,695	369,120	15,425
83.3 percentile	356,916	400,498	43,582

Table 16 below presents the descriptive scenarios of climatic hazards for future climate change inferred from the scenarios of climate variables and extreme indices as given in Table 15 above.

Table 16: Descriptive scenarios of climatic hazards under future climate change

Climate hazard	Medium-term scenario	Long-term scenario
Increase in heatwaves	Likely*	Very likely
Decrease in cold waves	Likely	Very likely
Increase in heavy rainfall	Likely	Very likely
Decrease in snowstorms	Likely	Likely
Increase in thunderbolts	Likely	Likely
Increase in windstorms	Likely	Likely
Increase in hailstorms	About as likely as not	About as likely as not
Increase in floods	Likely	Likely
Increase in landslides	Likely	Likely
Increase in GLOFs	Likely	Likely
Increase in droughts	About as likely as not	About as likely as not
Increase in forest fires	Likely	Likely
Increase in fires	Likely	Likely
Increase in avalanches	Likely	Likely
Increase in epidemics	Likely	Likely

*Note: Virtually certain (99–100% probability), very likely (90–100%), likely (66–100%), about as likely as not (33–66%), unlikely (0–33%), very unlikely (0–10%), exceptionally unlikely (0–1%).

Chapter 6

Adaptation Options in the Sector

Adaptation is the process of adjustment to the current or expected climate and its effects. It involves reducing risk and vulnerability; seeking opportunities; and building the capacity of nations, regions, cities, the private sector, communities, individuals, and natural systems to cope with climate impacts, as well as mobilizing that capacity by implementing decisions and actions. Adaptation options are the array of strategies and measures available and appropriate to address needs. Identifying needs is a critical step for selecting adaptation options (Noble et al., 2014). The adaptation needs in DRRM include measures to reduce exposure and vulnerability to climate extremes, and build resilience.

There is a wide range of complementary adaptation and DRRM approaches that can reduce the risks of climate extremes and disasters and increase resilience to remaining risks as they change over time (see Figure 34). These approaches include reducing exposure; reducing vulnerability, risk transfer and sharing; enhancing preparedness, response and recovery; and increasing resilience and transformational changes in the system. Actions that range from incremental steps to transformational changes are essential for reducing the risk of climate extremes. Incremental steps aim to improve efficiency within existing technological, governance, and value systems, whereas transformation may involve alterations of fundamental attributes of those systems. These approaches can overlap and can be pursued simultaneously. DRRM and adaptation approaches can enhance social, economic, and environmental sustainability.

Figure 34 Climate change adaptation and disaster risk management approaches
Source: IPCC (2012)

Various policies in Nepal have been set up to meet DRRM and adaptation goals. The National Adaptation Programme of Action (NAPA) 2010 has identified urgent and immediate adaptation options. The priority adaptation options for DRRM include strengthening the capacity of government and non-government organizations; strengthening forecasting and early warning systems; implementing structural measures; promoting rain-water harvesting systems and conservation ponds; reforestation/afforestation; risk mapping; awareness-raising; enhancing emergency preparedness and response; developing effective relief and rehabilitation systems; promoting community-based DRRM; restricting settlements in high-risk areas; and resettlement of vulnerable communities (MoE, 2010).

The National Policy for Disaster Risk Reduction, 2018 has set out a long-term vision to contribute to sustainable development by making the nation safer, climate adaptive, and resilient to disaster risk. It has adopted 59 policies for reducing disaster risks (MoHA, 2018b). Implementation of these policies will help to build adaptive capacities for facing climate-related disaster risks. The Disaster Risk Reduction National Strategic Plan of Action 2018-2030 aims to reduce disaster mortality and the number of affected people substantially, and to mitigate the disaster risk and losses in livelihoods, health, assets, businesses, and communities. It has identified four priority areas and 18 priority actions. The four priority areas are: i) understanding disaster risk; ii) strengthening disaster risk governance at federal, provincial, and local levels; iii) promoting comprehensive risk-informed private and public investments in disaster risk reduction for resilience; and iv) enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction (MoHA, 2018b).

In addition to the aforementioned priority areas, the DRR National Strategic Plan of Action 2018-2030 has identified strategic activities that will help to improve adaptive capacities and build resilience to climate-related disaster risks. These include enhancing risk knowledge; strengthening DRRM governance; developing engineered infrastructure; promoting diversified livelihoods; risk-sharing and transfer mechanisms; and developing effective preparedness and response systems with the use of information, communication, and early warning systems. Hence, these strategic activities can be considered as adaptation measures to climate change for the DRRM sector.

More recently, the National Climate Change Policy 2019 has set out a policy to reduce loss or damage caused by climate-induced disasters to lives and property, health, livelihoods, physical infrastructure, and cultural and environmental resources. The policy has identified various strategies, such as developing a DRRM system; making preparedness and response effective by developing monitoring, forecasting, and early warning systems; making the disaster-related information collection system more systematic and comprehensive; ensuring access to early warning information by all groups, levels, and areas; integrating DRRM activities into CCA plans and programs; ensuring social security for recovery; implementing rescue, rehabilitation, and reconstruction programs; mobilizing community organizations and the private sector; formulating standards for a culture of safety and resilience; and developing bilateral and multilateral cooperation (MoFE, 2019b).

The adaptation measures for reducing climate-related disaster risks were identified by reviewing national and international policies, strategies, and action plans related to climate change and disaster risk reduction. The aforementioned National Climate Change Policy 2019, National Adaptation Programme of Action (NAPA) 2010, National Policy for Disaster Risk Reduction, 2018, and Disaster Risk Reduction National Strategic Plan of Action 2018-2030 were the main sources of information for adaptation measures identified in this report. These measures can be organized into three categories: structural/physical, social, and institutional. The structural and physical options include the development of an engineered and built environment, application of technologies, an ecosystem-based approach, and the use of services. The social options include educational programs for enhancing risk knowledge, informational strategies, and behavioural measures. The institutional options include economic instruments, laws and regulations, and government policies and programs (IPCC, 2014).

It is also important to keep in mind the limits of adaptation and disaster risk reduction activities or interventions. Losses and damage occur where adaptation actions are unaffordable, not physically or technically possible, socially difficult, or simply not sufficient to prevent some harm to humans, the environment, and assets (Morrison & Pickering, 2013). The more global temperatures continue to rise, the more likely it is that limits to adaptation will be reached. The impacts of climate change that cannot or will not be avoided through mitigation or adaptation efforts are particularly challenging for those poor countries that are already exposed to harsh climate conditions. These impacts include the losses and damage both from changes in the frequency, intensity, and geographical distribution of extreme weather events such as storms and floods, and from slow-onset phenomena such as glacier melting, loss of biodiversity, and desertification. Climate adaptation policies and programmes typically involve ex-ante actions aimed at building resilience before the occurrence of extreme weather or slow-onset events. Actions to address losses and damage build on these efforts by also establishing mechanisms to help those who have already experienced losses and damage through financial or other forms of support, such as social safety nets or social protection programmes (ex-post relief).

DRRM adaptation options can also be tailored to address specific contextual hazard risks and vulnerabilities. As can be seen in Table 14, the prevalence of hazards and vulnerable hotspots differ across provinces. GLOFs, for example, are a one-of-a-kind hazard in Province 1. Avalanches are a major threat in Gandaki Province. Similarly, floods are a major threat to the Terai districts and Province 2, whereas landslides are a concern in almost all provinces except Province 2. In addition, fires and epidemics are common in all provinces. Hailstorms are a major problem in Province 2 and Gandaki Province. Furthermore, thunderbolts are a problem in the Gandaki Province, Bagmati Province, and Karnali Province. Adaptation options, therefore, need to be tailored based on the specific hazards and the needs of the local actors and communities. Various climate change adaptation measures for disaster risk reduction and management in the short term, medium-term, and long term are listed below in Table 17.

Table 17: Short, medium, and long term climate change adaptation measures for disaster risk reduction and management

Short-term (1-5 years)	Medium-term (1-10 years)	Long-term (1-30 years)
Engineered and built environment		
• Conduct regular maintenance of the urban drainage system and improve the existing drainage system • Construct a fire line in the forest areas • Construct flood shelters • Install a smoke detector and fire alarm in all public buildings, schools, hospitals, and important infrastructures • Install cooling system for heatwave affected urban areas	• Pursue structural measures to lower the lake level for reducing the glacial lakes outburst risk of the potential hazardous glacial lakes • Construct water conservation/ flood retention ponds, the rainwater harvesting system • Construct flood-resistant food and seed storage facilities	• Pursue the structural measures for flood and landslide risk reduction (embankment, reservoir, check dam, slope stabilization, geometry modification, surface erosion control, improved drainage, etc.) • Construct urban drainage system
Technological		
• Update and upgrade the existing operational flood and glacial lake outburst flood early warning systems • Develop weather and climate information based agro-advisory system • Develop diseases surveillance and early warning system • Use and promote modern science and technology (Web portal, Mobile Apps, SMS-CB, IVR) for effective communication and dissemination of climate risk information • Apply physically-based modelling to generate the evolution of major hazard scenarios under future climate change • Develop Decision Support System (DSS) for climate risk information application in each sector for the planning, design, construction, and management of development projects	• Develop and operate forecasting and early warning systems for major hazards like flood, GLOF, landslide, drought, thunderbolt, windstorm, heatwave, cold wave, fire, wildfire, and epidemics • Pursue the principle of green development and "build back better" in reconstruction	• Enhance lead time and accuracy of forecasting and warning system for major hazards • Develop and promote climate-smart agriculture, flood, and drought-resistant agricultural system • Develop climate-smart villages and cities

Table 17: Short, medium, and long term climate change adaptation measures for disaster risk reduction and management

Short-term (1-5 years)	Medium-term (1-10 years)	Long-term (1-30 years)
	Ecosystem-based	
• Conserve wetlands and create natural flood retention areas • Promote afforestation, forest conservation	• Promote the local resource-based green infrastructure • Promote bio-dykes	• Promote watershed protection, and restoration of floodplain for flood and landslide risk reduction
	Services	
• Improve social security, basic health, reproductive health, child health, adolescent health, and nutrition in disaster risk-prone areas • Enhance emergency medical services at the federal level • Develop effective search and rescue, relief, and rehabilitation system at the federal level	• Link social security programs to climate and disaster resilience • Enhance emergency medical services at the province level • Develop effective search and rescue, relief, and rehabilitation system at the province level	• Link insurance services to climate risk sharing • Enhance emergency medical services at the local level • Develop effective search and rescue, relief, and rehabilitation system at the local level
	Educational	
• Institutionalize the curriculum of climate and disaster risk management from school to the university level • Develop Information, Communication, and Education (ICE) Kit for awareness-raising against climatic hazard risks • Conduct training on Climate and Disaster Risk Impact Assessment method • Develop the capacity of the community Organizations (Child Club, Youth Club, Mothers Group, Senior Citizen Forum, Citizens Concern Centre, Forest Users Group, etc.) for disaster preparedness and response • Conduct disaster preparedness workshops, mock drills, and simulation exercises regularly at different levels (Federal, Province, Local, Community) and sectors (School, hospital) for effective preparedness and response • Conduct awareness programs on climate and disaster risks by workshops, meetings, and mass media	• Conduct training and capacity development program for stakeholders, professionals, and vulnerable communities on climate and disaster risk management	• Develop human and technical capacity on weather and climatic hazards forecasting • Conduct research on climatic hazards forecasting models

Table 17: Short, medium, and long term climate change adaptation measures for disaster risk reduction and management

Short-term (1-5 years)	Medium-term (1-10 years)	Long-term (1-30 years)
Informational		
• Establish a robust database to document and monitor climatic hazards, losses, and damages overtime at the federal level • Conduct assessment and mapping of all climatic hazard risks considering the effects of climate change and make them available publicly • Establish Real-Time Observation and Monitoring System for all climatic hazards • Increase access of vulnerable population (PWDs, senior citizens, single women) to preparedness related information (early warning system, lifesaving technique, knowledge, and skills) • Develop communication and dissemination procedures for climate risk information sharing with vulnerable groups (using different media and technologies such as mobile apps, websites, SMS, e-mail, radio, television, print media, phone, etc.)	• Establish a robust database to document and monitor climatic hazards, losses, and damages overtime at the province level • Develop and operationalize geographic information system-based Climate Risk Information Management System • Develop customized information materials (book, brochure, notice, electronic message, etc.) on an early warning system for vulnerable communities (women, children, elderly persons, disabled people, indigenous, Dalit, deprived)	• Establish a robust database to document and monitor climatic hazards, losses, and damages overtime at the local level • Conduct assessment and mapping of all climatic hazard risks at the local level • Promote bilateral, regional, and international cooperation in climate risk information sharing
Behavioural		
• Promote collaboration between government organizations, community-based organizations, non-governmental organizations, and media for climate risk information sharing	• Promote indigenous knowledge and practices in climate risk management	• Implement a gender-sensitive and inclusive approach in all processes of Climate and Disaster Risk Management

Table 17: Short, medium, and long term climate change adaptation measures for disaster risk reduction and management

Short-term (1-5 years)	Medium-term (1-10 years)	Long-term (1-30 years)
Economic		
• Establish National Adaptation Fund • Promote private sector investment in DRR and CCA activities • Promote life insurance of the climate-induced disaster vulnerable groups, individual, and communities • Strengthen livelihood recovery measures through integrated planning/ budgeting at all levels against climate hazards for the population at risk • Increase access of vulnerable people (senior citizen, single women, widow, people with disabilities, endangered people, etc.) to allowances and grants • Review and promote the existing practice of risk-sharing in agriculture and livestock insurance	• Establish Province Adaptation Fund • Develop and promote alternative and innovative financial instruments, such as forecast-based financing, micro-investment, microcredit, insurance, reinsurance, etc. • Arrangement of microfinance, interest-free loan, conditional cash transfer, etc. for climate-induced disaster-affected individual and community • Develop and implement the plans for community-based, cooperative based, contribution-based micro insurance, farmer's reserved fund • Promote public-private partnership to attract participation and investment of private sector in Climate and Disaster Risk Insurance, Risk-sharing programs (e.g., Micro Insurance, emergency fund, low-interest credit plan)	• Establish Local Adaptation Fund • Promote joint public-private partnership in DRR and CCA • Promote investment in DRR and CCA by the Bank, Cooperatives, and community-based organizations (Forest Users Group, Dairy Cooperatives) • Promote disaster insurance for public buildings, schools, hospitals, health posts, and critical infrastructures and review existing relevant insurance policies
Laws and regulations		
• Update Building Act, revise regulation and codes for the building construction considering climatic hazard risks (flood, landslide, lightning, fire, heatwave, cold wave, windstorm) • Develop guidelines for mainstreaming DRR and CCA into sectoral development plans • Incorporate Climate and Disaster Risk Impact Assessment into Environment Protection Act and Environmental Impact Assessment Guidelines • Prepare hazard-specific guidelines to manage major hazard risks (Flood, Landslide, Fire, Epidemic, etc.) • Prepare guidelines for Green Infrastructure and Ecosystem-Based Adaptation • Prepare guidelines for infrastructure designs and operations based on anticipated changes in temperature, rainfall, and flood return periods	• Prepare and implement the Climate and Disaster Risk Sensitive Land Use Plans • Implement guidelines for infrastructures design and operation for climate risk reduction incorporating climate change scenarios • Prepare Standard Operating Procedure and Directive for establishment and operation of multi-hazard early warning system	• Implement guidelines for mainstreaming DRR and CCA into sectoral development plans • Implement SOP for a multi-hazard early warning system

Table 17: Short, medium, and long term climate change adaptation measures for disaster risk reduction and management

Short-term (1-5 years)	Medium-term (1-10 years)	Long-term (1-30 years)
Government policies and programs		
• Establish coordination mechanism at the federal, provincial, and local level to integrate and implement DRR and CCA in every sector • Develop collaboration mechanism between government organizations, community-based organizations, non-governmental organizations, and media for climate risk information sharing • Strengthen National Disaster Risk Reduction Platform and expand it at the province and local level • Prepare Climate and Disaster Resilience Plan at the province and local level • Prepare Gender Equality and Social Inclusion Action Plan for Climate and Disaster Risk Management at each level and sector • Ensure GESI mainstreaming in policies, strategy, plans, program, budgets (Gender Responsive Budget), and implementation mechanisms • Prevent gender-based violence during a disaster • Ensure gender-sensitive response and recovery measures • Establish gender-responsive feedback mechanism/system • Strengthen Community Based Disaster Risk Management System • Establish and strengthen community information centres • Establish and expand the network of the community-based organizations for DRR and CCA	• Prepare a master plan for river basin management based on climate and disaster risk assessment • Develop community-based early warning system and link with Community Based Disaster Risk Management System • Ensure access, representation, and effective participation of women, children, elderly and disabled people, and vulnerable community in the decision-making bodies and programs and policy formulation processes for climate and disaster risk management • Strength mechanism to prevent/ respond to gender-based violence during a disaster • Regulate/restrict housing development, large scale construction, and industrial zone at high-risk areas • Strengthen the capacity of the Department of Hydrology and Meteorology for better observation systems, information sharing, and modelling • Strengthen National Disaster Risk Reduction and Management Authority with human, technical and financial resources • Update existing national, provincial, and local level Disaster Preparedness and Response Plans for forecast-based emergency preparedness and response	• Relocate settlements of high-risk areas to the low-risk areas • Establish Climate Change Research Centre and National Disaster Risk Reduction Research and Training Institute • Establish Fire Services at the Federal, Provincial and Local level and build their capacities

Chapter 7

Conclusion and Recommendations

7.1 Conclusion

This study considered 15 climate-related hazards for analysis, including thunderbolts, windstorms, epidemics, heavy rainfall, landslides, floods, GLOFs, avalanches, hailstorms, heatwaves, cold waves, snowstorms, fires, forest fires, and droughts. Trends for the occurrences of 14 climatic hazards (except GLOFs) were analysed, which revealed that there is overall a significant increasing trend in climatic hazards, especially after 1990. All hazard events are on an increasing trend, except for droughts, which are on a decreasing trend.

It was found that the increasing trends in hazard occurrences moderately to highly correlate with the increasing trends in temperature, precipitation, and climate extreme indices. This correlation indicates that the increased occurrences of these hazards can be attributed to climate change. The hazard indices were computed using hazard occurrences based on historical climate as indicators. Based on the analysis of historical hazard occurrences, the Sunsari, Kailali, Morang, Jhapa, Rautahat, Bardiya, Sarlahi, and Saptari districts were identified as "**Flood Hazard Hotspots**". Similarly, the Dhading, Sankhuwasabha, Baglung, Sindhupalchok, Dolpa, Kaski, Taplejung, Rolpa, Makawanpur, Myagdi, Lamjung, Dolakha, Nuwakot, Gorkha, Solukhumbu, Kavrepalanchok, Dailekh, Darchula, Syangja, Palpa, Khotang, Bajura, Kalikot, Jajarkot, Bajhang, Gulmi and Ilam districts were identified as "**Landslide Hazard Hotspots**". Based on human and economic impacts, the Makawanpur, Rautahat, Banke, Kailali, Siraha, Morang, Doti, Chitawan, Dhanusha, Sarlahi, Mahottari, Parsa, Saptari, Sunsari, Sindhupalchok, Dang, Kaski, Kanchanpur, and Jhapa districts were identified as the climate-related "**Disaster Hotspots**".

Climate-related disasters cause loss and damage to life and property, adversely affect every sector and impede the development of the country. On average, 647 people die from climate-induced disasters in Nepal each year. The maximum number of climate-induced disaster deaths occurred in 2001, with the loss of 1866 lives due to epidemics, landslides, thunderbolts, fires, floods, heavy rainfall, and windstorms. The average economic loss per year is 2,778 million Nepalese rupees. The maximum economic loss of 63,186 million Nepalese rupees occurred in 2017 during the Terai floods. Floods, landslides, epidemics, and fires are the most devastating climate-induced disasters in Nepal.

Climate trends and scenarios indicate that the frequency, intensity, spatial extent, duration, and timing of climatic hazards will change in the future. Climate hazards may become more frequent, widespread, longer lasting, or intense. There might be multiple events (e.g., floods and landslides) at the same time across different regions, which may turn out to be catastrophic. Coupled with degrading ecosystems and biophysical processes under climate change, climatic hazards may create chronic stress and catastrophic shocks. The impact of climate-induced disasters may increase with the increase in exposure and vulnerabilities due to increasing population and development activities. While climate-induced disaster-related deaths have decreased in recent years—mainly due to improved early warning systems and better mitigation structures—there is an increasing trend of economic losses due to increased exposure and vulnerabilities of economic assets. This trend is likely to persist in the future.

With climate change contributing to an increase in disaster risk, DRRM has become a vital and urgent component of any adaptation program. DRRM measures such as risk reduction, preparedness, humanitarian relief, post-disaster recovery and reconstruction, and risk-sharing and transfer mechanisms at the local, provincial, and national levels can provide an opportunity to reduce climate-induced disaster risks and to improve adaptive capacity. There are many areas of convergence between DRRM and adaptation. Both adaptation and DRRM seek to reduce climate-related risks, thus supporting and promoting sustainability in social and economic development. They both also share interconnected policy goals of reducing vulnerabilities and building resilience. Approaches that are used for one policy goal may support another. Policies that are designed for DRRM, such as enhancing risk knowledge, risk governance, building resilience, and disaster preparedness, may contribute to adaptation. Conversely, approaches and methods that have been used for adaptation, such as vulnerability and risk assessments, may support DRRM. Hence, closer integration of DRRM measures and CCA is beneficial at all levels.

However, there are also limits to adaptation and to DRR technology and practices. Transformative options are thus needed to fill any adaptation gaps. These options include approaches that change the system so that people and livelihoods exposed to risk are safeguarded. Examples of such approaches include relocation of settlements from landslide-prone areas, providing people with access to new livelihood options (such as the shift from traditional sustenance farming to the service sector), et cetera.

7.2 Recommendations

Climate-related disaster data at different spatial scales is required for a comprehensive analysis of hazards, vulnerabilities, and risks at different administrative levels. For this report, the unavailability of such data was a major constraint in conducting the analysis at the district level. In the future, VRAs at the local level are strongly recommended. Climate trends and scenarios also need to be identified at the municipality level. Therefore, disasters and socio-economic data should also be collected at the municipality level. Overall, it is strongly recommended to develop a comprehensive disaster, climate, and socio-economic database at the local level.

This study utilized a historical climate-related disaster dataset to generate scenarios of climatic hazards based on historical climate. Future climatic hazard scenarios were inferred in a descriptive way using future scenarios of climate variables and climate extreme indices as indicators. Quantitative scenarios of climatic hazards may be more useful for generating quantitative scenarios of climate change risks in different sectors. This requires physically-based modelling using natural forcing and climate change-related forcing separately to identify the fractions of attributable risk. Hence, it is recommended to implement physically-based modelling to generate major hazard scenarios under future climate change conditions.

Climate extreme events are generally based on the use of extreme indices, which can either be based on the probability of occurrence of given quantities or threshold exceedances (IPCC, 2012). Hence, climatic hazards or extreme events are defined using extreme indices with their fixed threshold values that have been associated with human or other impacts. A threshold is a critical climate condition to which a system of interest is sensitive and hence likely to be damaged. A threshold can be relative or absolute. Disasters may be triggered if climate extremes cross fixed **threshold levels**. But the threshold values of climate variables for climatic hazards are not yet available for Nepal. Hence, it is recommended to assess the threshold values of climate variables for each climate-related hazard and revise this VRA using these threshold values. This VRA should also be revised periodically to consider changes in land use and socio-economic conditions.

Lastly, this VRA needs to be made available to all stakeholders in a user-friendly way for its wider application in climate risk management. The web-based decision support system (DSS) will be very useful for visualizing the risks in different sectors under different climate change scenarios. The DSS should also have the facility to download the risk maps included in this report. Hence, it is recommended to utilize this VRA to develop a DSS for climate risk information application for planning, design, construction, and management of development projects in each sector.

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Annex A: Outcome of Provincial Consultations

Province 1: According to consultations in Province 1, landslides, floods, lightning, and GLOFs are found to be the major climate-induced disasters in the province. Stakeholders suggest that the districts of Solukhambu, Sankhuwasabha, and Taplejung are susceptible to GLOFs, whereas Sunsari, Morang, and Jhapa are at the forefront of risk of floods. Loss of life, physical damage, loss of property, and disruptions in the service sector are some of the major impacts seen as a result of these disasters. It was also stressed that the frequency of heavy thunderstorms and fires is also very high and that the Terai districts in particular are very vulnerable to such events.
Province 2: According to consultations in Province 2, floods, fires, epidemics, and storms are the primary climate-related disasters affecting the province. It was found that these events resulted in enormous economic losses and losses of life. During the monsoon season, most districts in Province 2 are flooded, and the frequency of this has been higher in recent years. Participants believed that almost all sectors are vulnerable to such disasters, rather than only some specific sectors.

Bagmati Province: Landslides, floods, hailstorms, and storms are the major climate-induced disasters in Bagmati province, according to local consultations. Landslides have caused significant economic losses, including damage to roads, bridges, culverts, drains, and, in particular, the transportation of people and goods. Hailstorms are also prevalent and have caused huge losses in agricultural production. Similarly, thunderstorms were also reported to be highly prevalent prior to monsoon, with higher magnitudes as well.

Gandaki Province: According to the consultations in Gandaki Province, landslides, hailstorms, extreme snowfalls and avalanches are some of the major climate-induced disasters. The stakeholders suggested that avalanches are very recurrent in the Himalayan region, where there was a landslide in the mid-mountain and hilly areas. A huge avalanche was also witnessed in the Annapurna region, in addition to disturbances in the trekking routes due to heavy snowfall, and massive landslides in Myagdi due to extreme rainfall. This led to major losses in the fields of trekking, transport, and agricultural production.

Lumbini Province: In Lumbini Province, floods, landslides, forest fires, and outbreaks were reported to be the major climate disasters with a high impact. According to the participants, flood events occurred in the Terai region, and forest fires are regularly reported in Banke, Bardiya, and some other districts in the hilly areas. Outbreaks are very common in the Terai region.

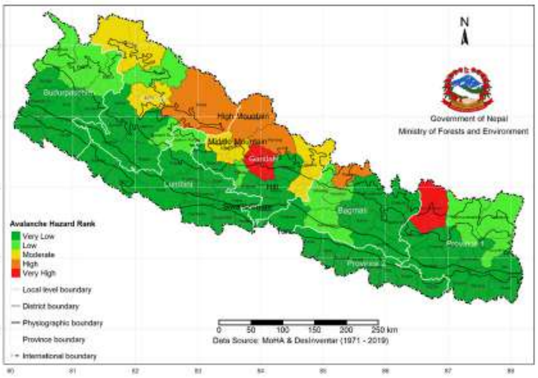
Karnali Province: Landslides, floods, epidemics, and lightning were reported to be the major climate-induced disaster events in the Karnali Province consultations. Stakeholders believed that the province is significantly behind other provinces in terms of development and that such events present an additional challenge to the overall growth of the province. Additionally, it was reported that due to poor WASH facilities, this province is facing huge epidemics, with climate change increasing the risks further.

Sudurpaschim Province: In Sudurpaschim Province, landslides, floods, epidemics, and fires were reported to be the major disasters. According to the consultation, regular floods have occurred in the Terai, and landslides have occurred in hilly regions. Loss of life and property, damage to physical infrastructure, and disruption of public services are among the major impacts of climate-related disasters in this province.

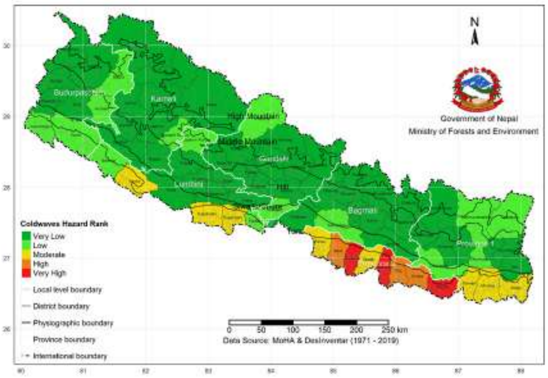
- **Suggested Adaptation Options**
- Carry out GLOF risk reduction activities
- Promote riverbank protection schemes, e.g., a plantation along the riverbank
- Implement early warning systems for floods
- Develop an early warning system for lightening
- Implement disaster preparedness activity
- Provide necessary training to the local government to be cautious regarding haphazard infrastructure construction
- Improve capacity of service providers and equip them with new knowledge and skills on climate resilient health and sanitation systems

Develop standards and guidelines for climate-resilient physical infrastructure development

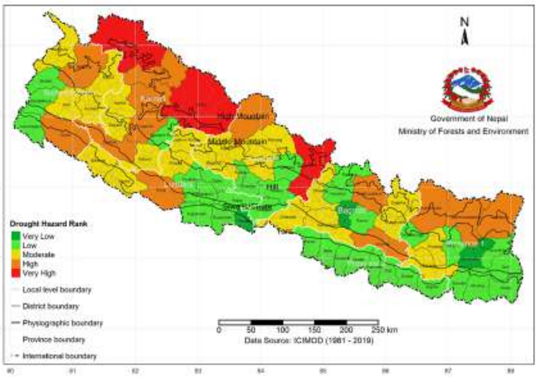
Annex B: District-wise Past Scenarios of Climatic Hazards Based on Historical Climate



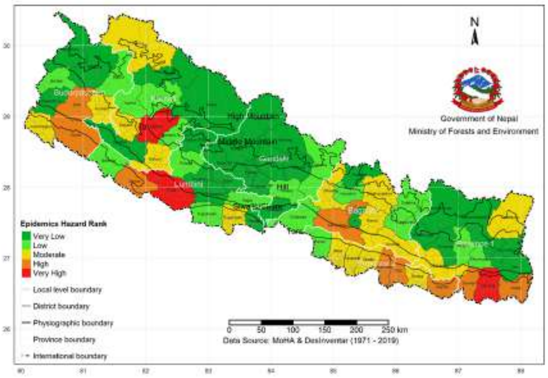
Avalanche Hazard Rank



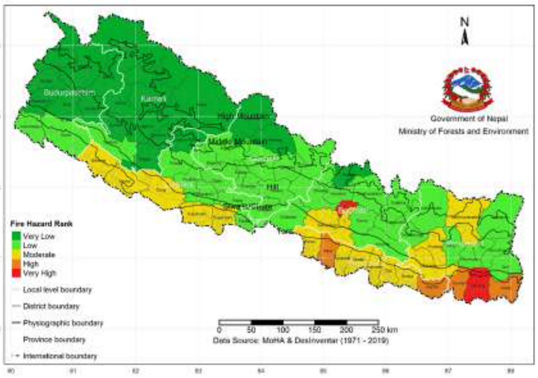
Cold waves Hazard Rank



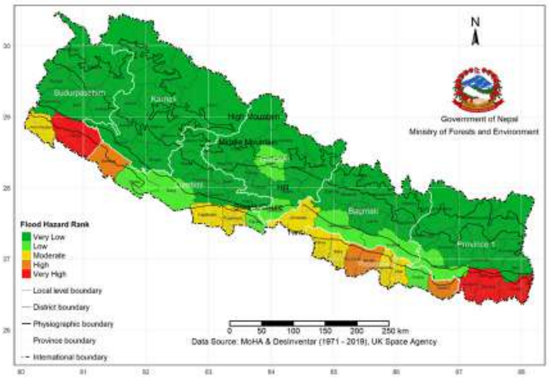
Drought Hazard Rank



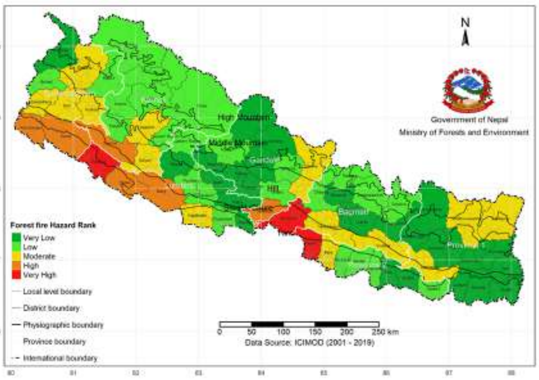
Epidemics Hazard Rank



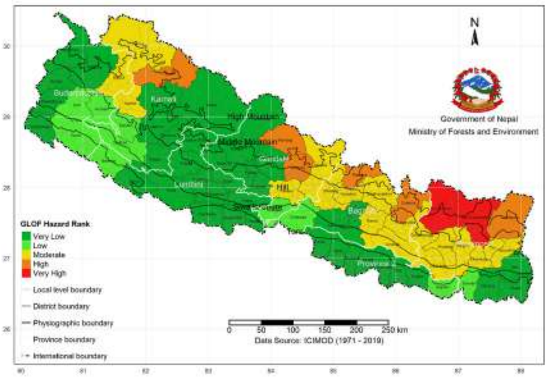
Fire Hazard Rank



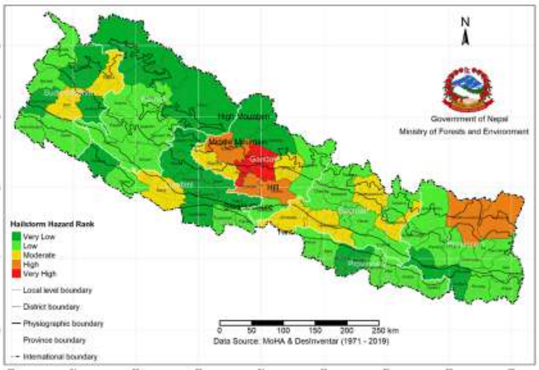
Flood Hazard Rank



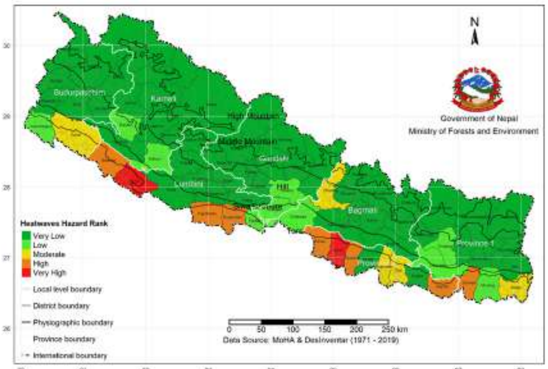
Forest Fire Hazard Rank



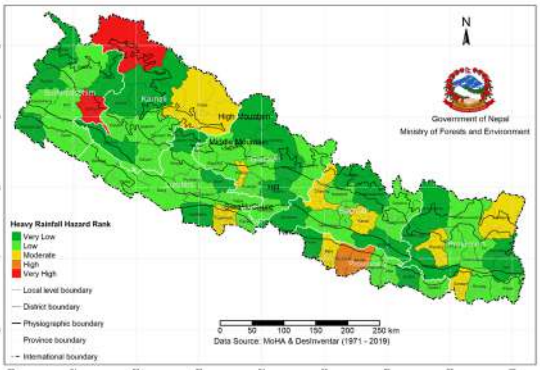
GLOF Hazard Rank



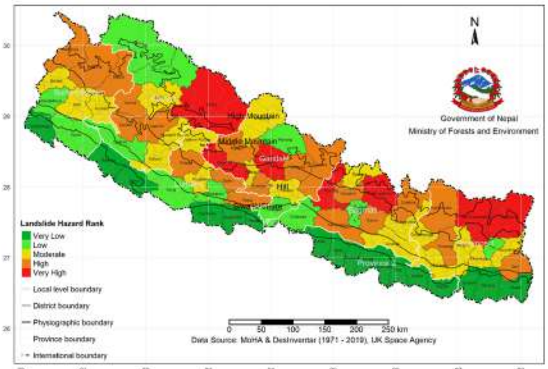
Hailstorm Hazard Rank



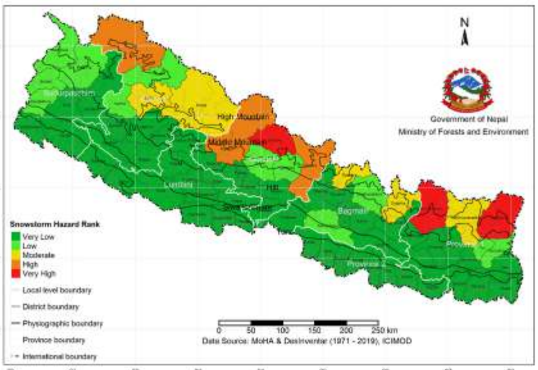
Heatwaves Hazard Rank



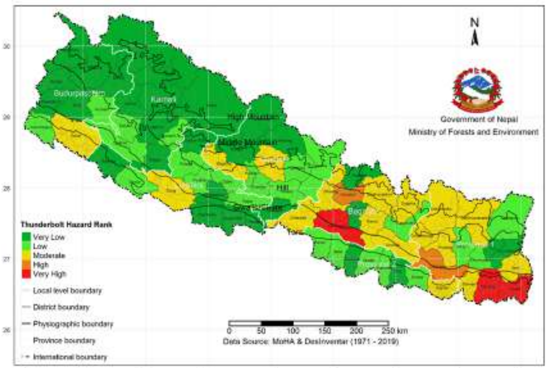
Heavy Rainfall Hazard Rank



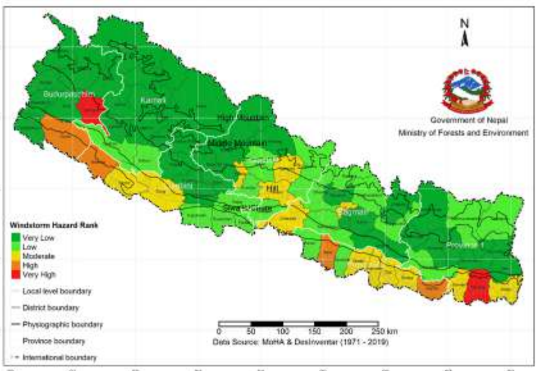
Landslide Hazard Rank



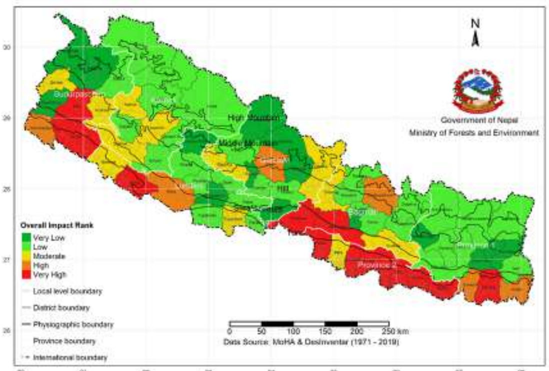
Snowstorm Hazard Rank



Thunderbolt Hazard Rank

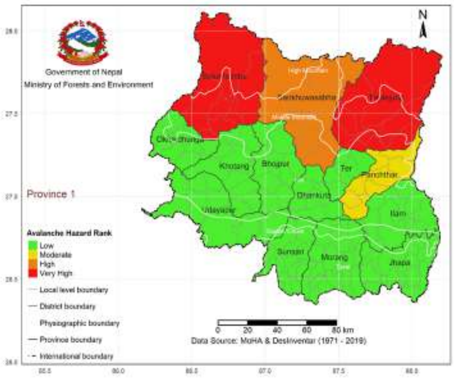


Windstorm Hazard Rank

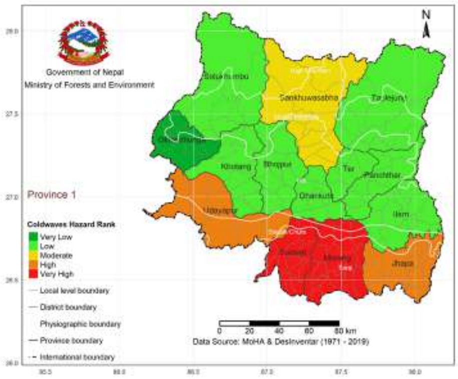


Overall Impact Rank

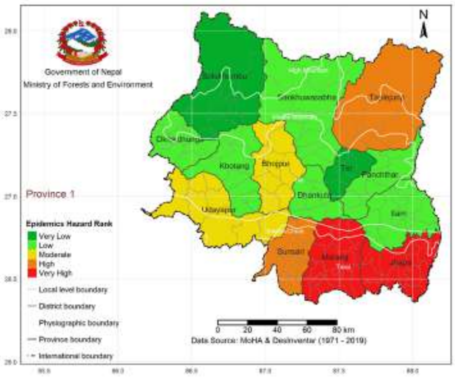
Annex C: Province-wise Past Scenarios of Climatic Hazards Based on Historical Climate



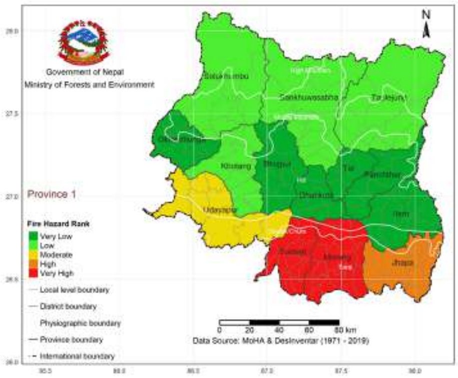
Avalanche Hazard Rank in Province 1



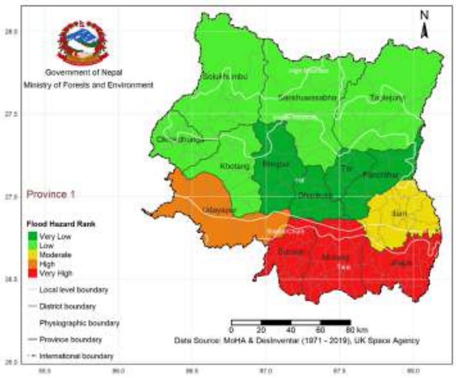
Coldwaves Hazard Rank in Province 1



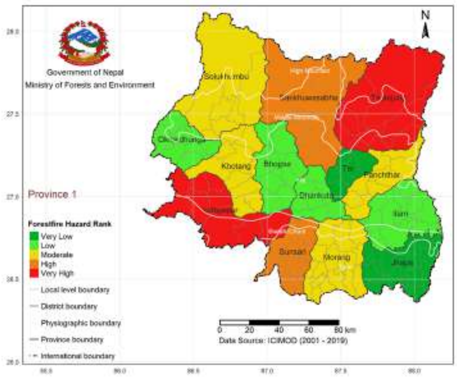
Epidemics Hazard Rank in Province 1



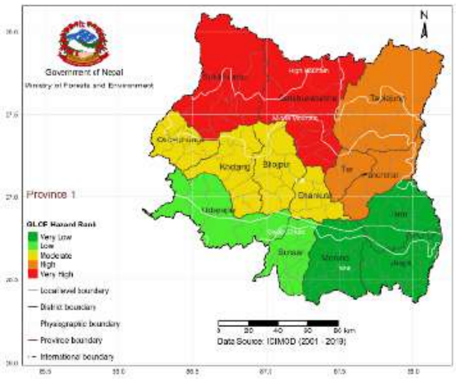
Fire Hazard Rank in Province 1



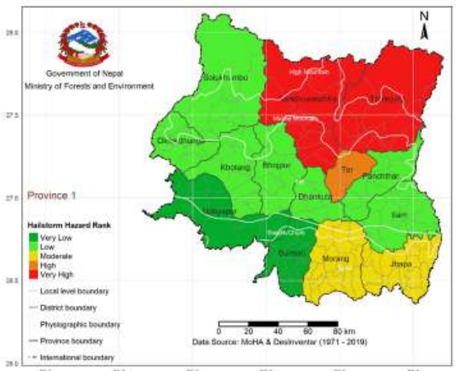
Flood Hazard Rank in Province 1



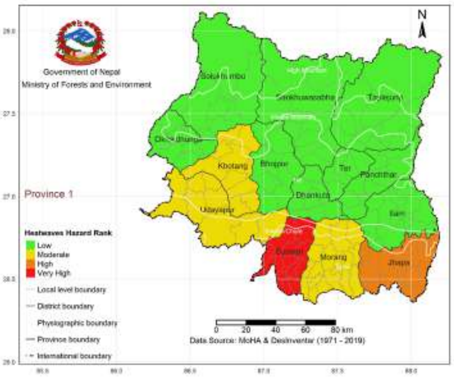
Forestfire Hazard Rank in Province 1



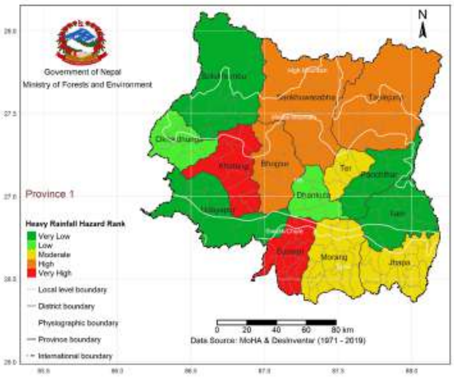
GLOF Hazard Rank in Province 1



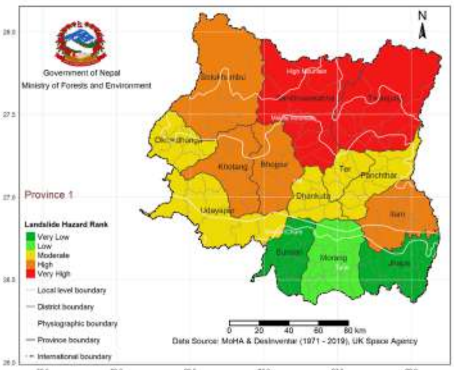
Hailstorm Hazard Rank in Province 1



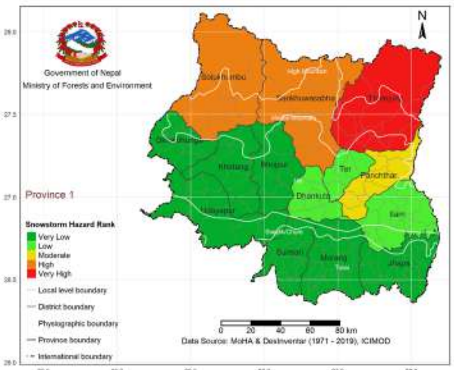
Heatwaves Hazard Rank in Province 1



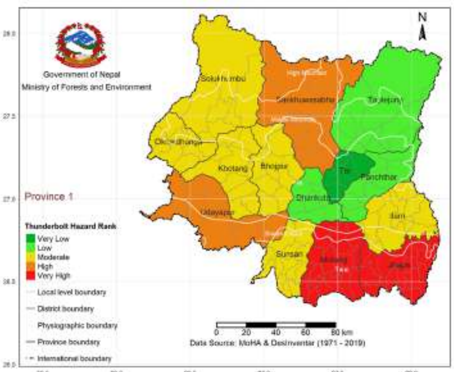
Heavy Rainfall Hazard Rank in Province 1



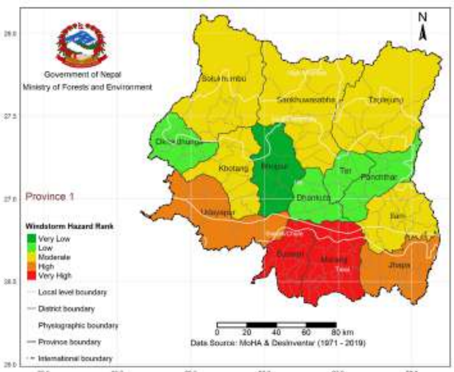
Landslide Hazard Rank in Province 1



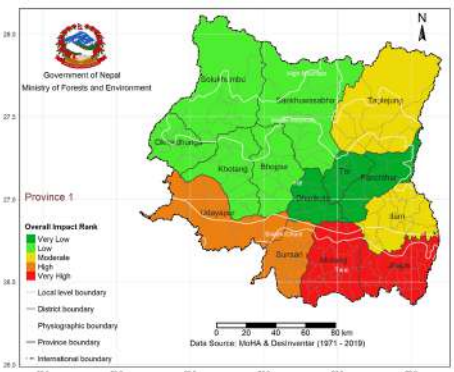
Snowstorm Hazard Rank in Province 1



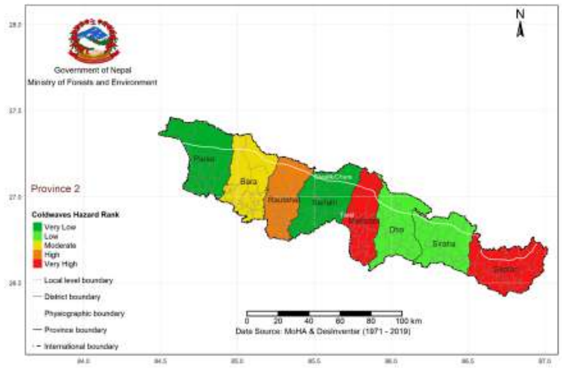
Thunderbolt Hazard Rank in Province 1



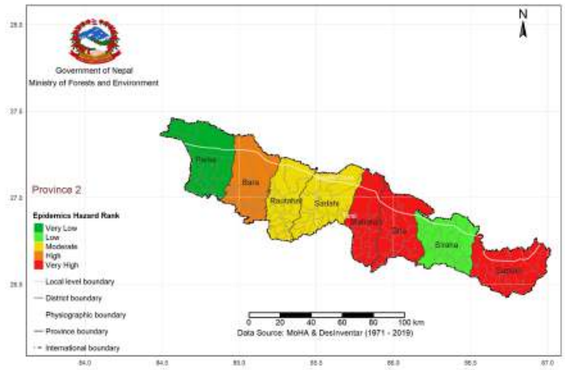
Windstorm Hazard Rank in Province 1



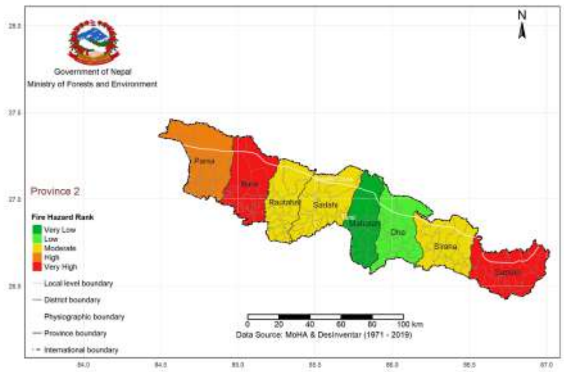
Overall Impact Rank in Province 1



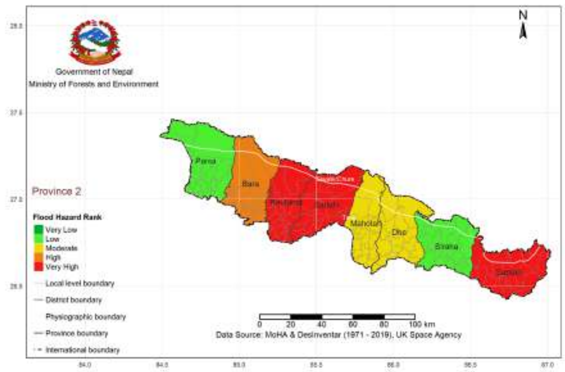
Coldwaves Hazard Rank in Province 2



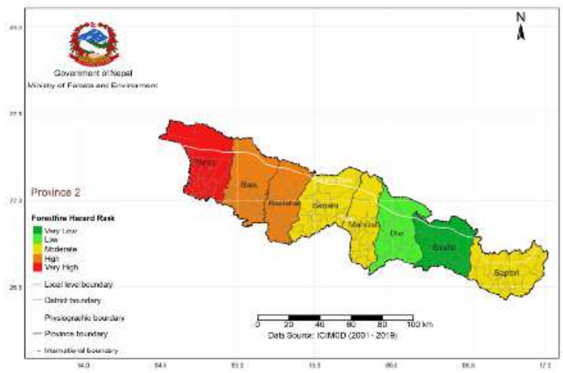
Epidemics Hazard Rank in Province 2



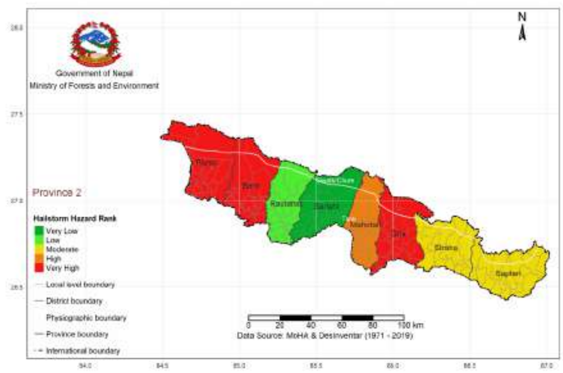
Fire Hazard Rank in Province 2



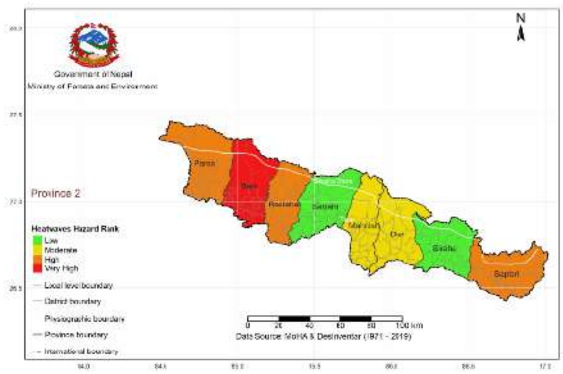
Flood Hazard Rank in Province 2



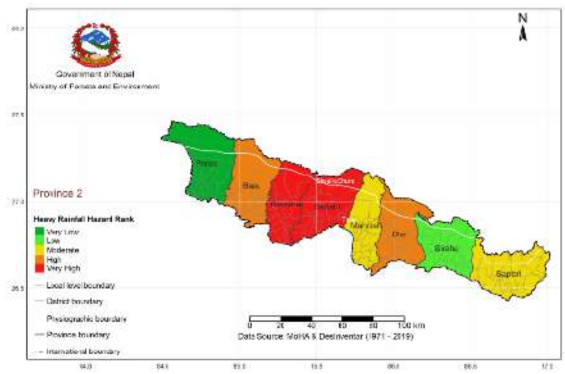
Forestfire Hazard Rank in Province 2



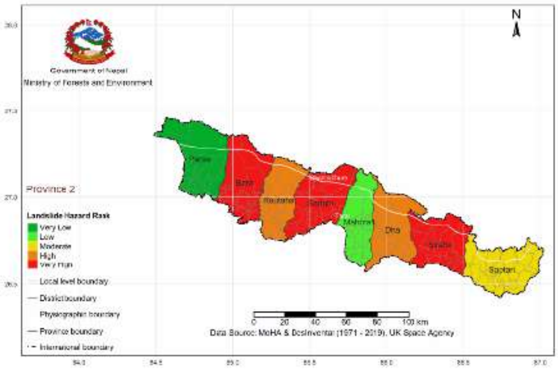
Hailstorm Hazard Rank in Province 2



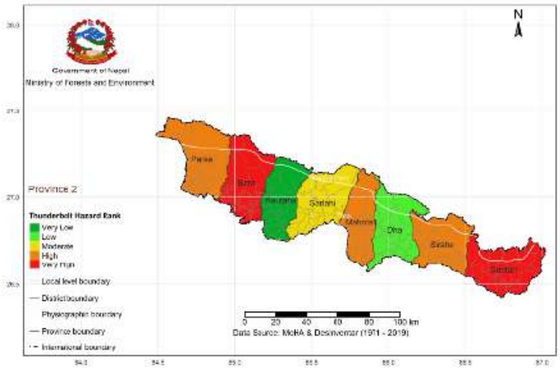
Heatwaves Hazard Rank in Province 2



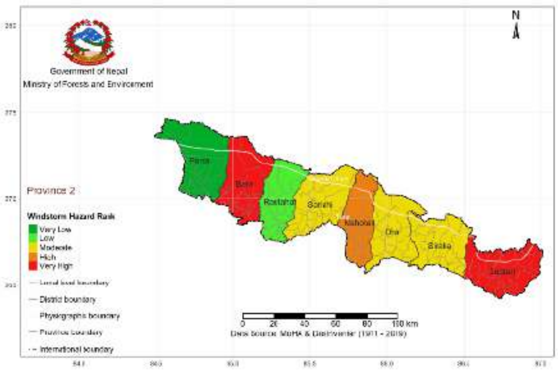
Heavy Rainfall Hazard Rank in Province 2



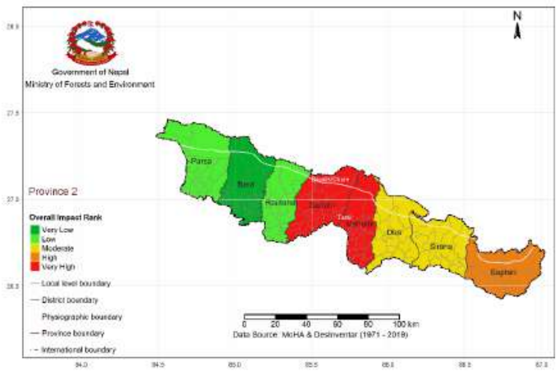
Landslide Hazard Rank in Province 2



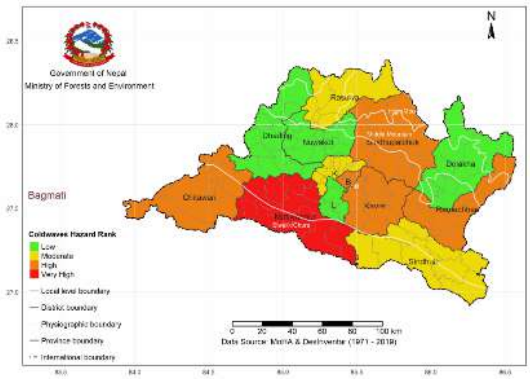
Thunderbolt Hazard Rank in Province 2



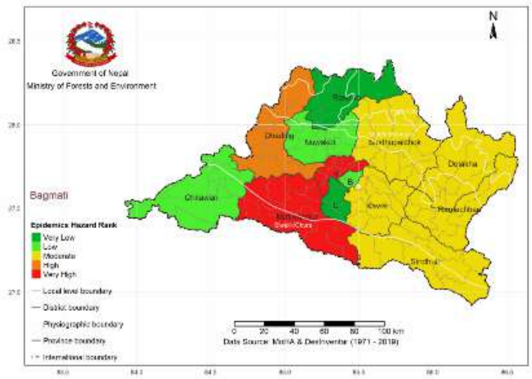
Windstorm Hazard Rank in Province 2



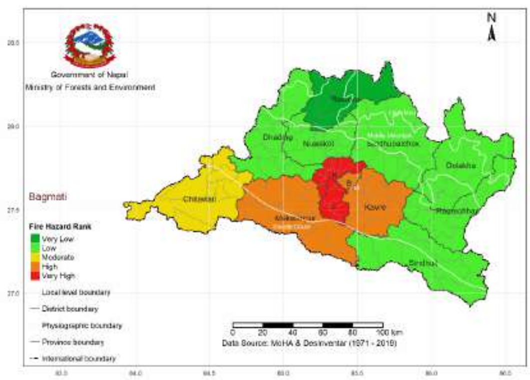
Overall Impact Rank in Province 2



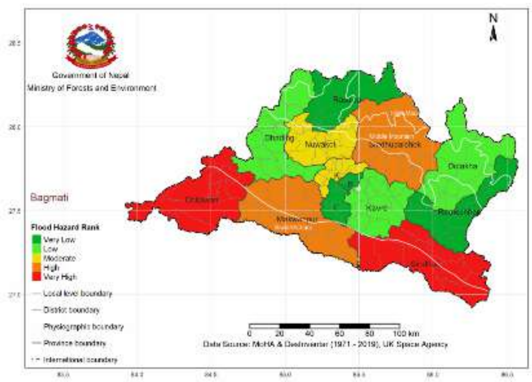
Coldwaves Hazard Rank in Bagmati Province



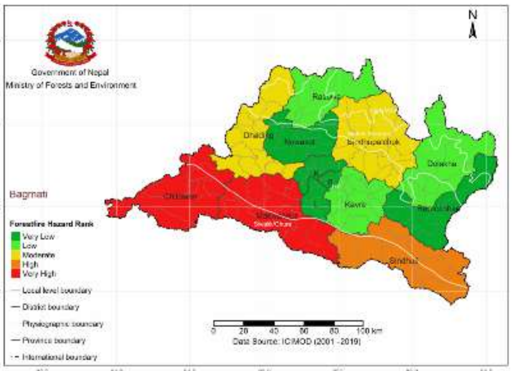
Epidemics Hazard Rank in Bagmati Province



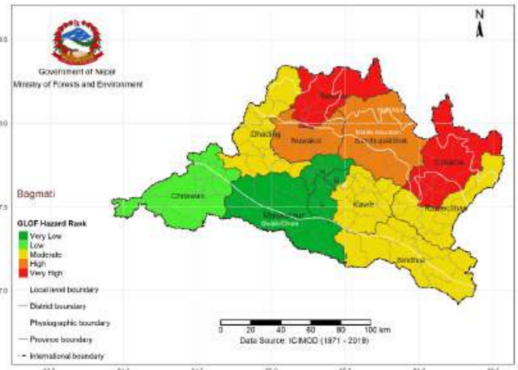
Fire Hazard Rank in Bagmati Province



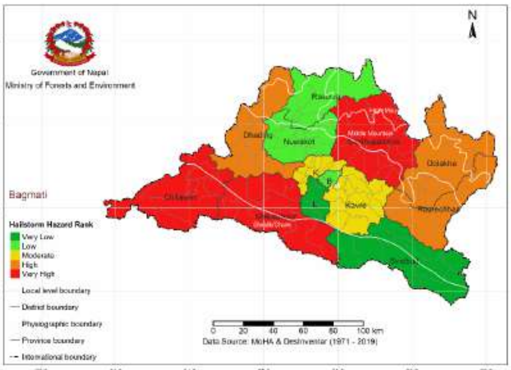
Flood Hazard Rank in Bagmati Province



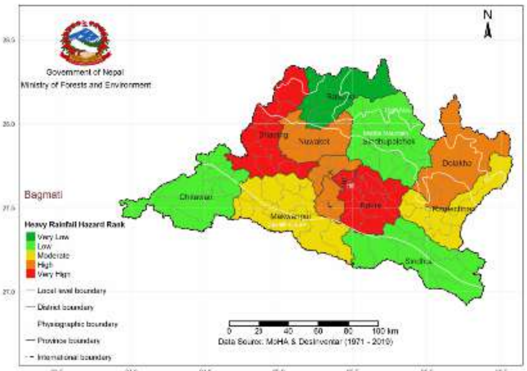
Forestfire Hazard Rank in Bagmati Province



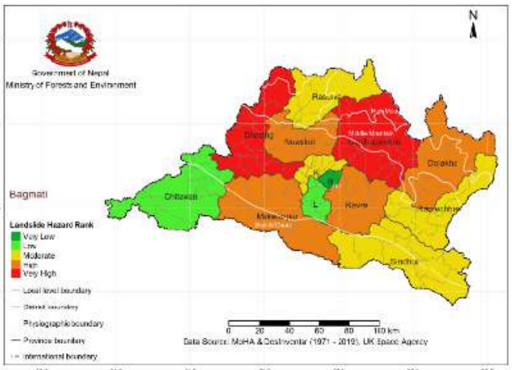
GLOF Hazard Rank in Bagmati Province



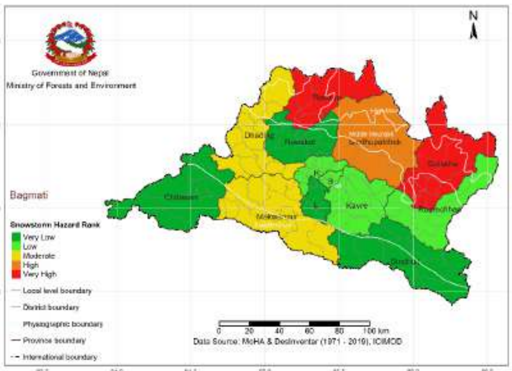
Hailstorm Hazard Rank in Bagmati Province



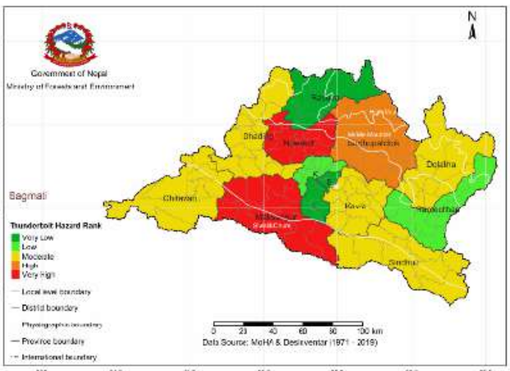
Heavy Rainfall Hazard Rank in Bagmati Province



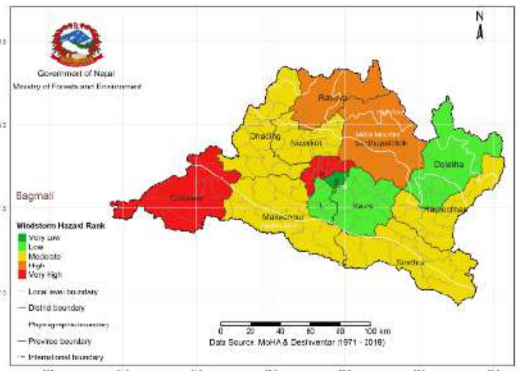
Landslide Hazard Rank in Bagmati Province



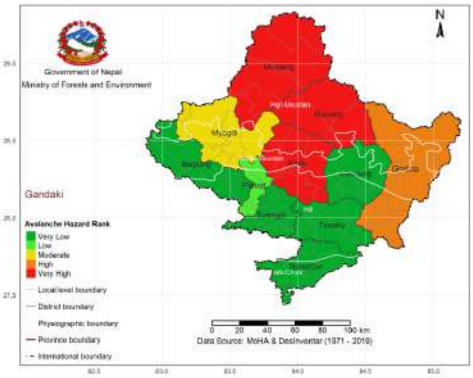
Snowstorm Hazard Rank in Bagmati Province



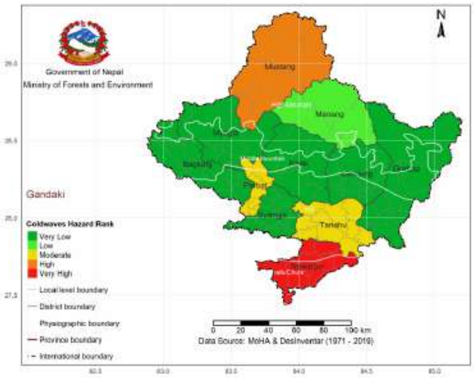
Thunderbolt Hazard Rank in Bagmati Province



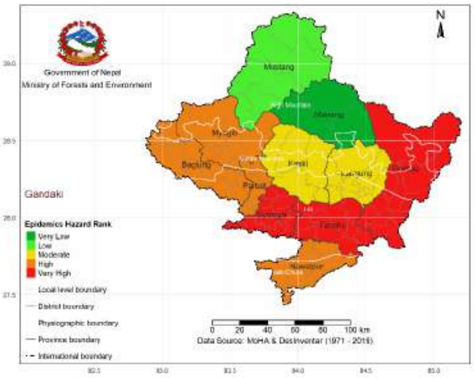
Windstorm Hazard Rank in Bagmati Province



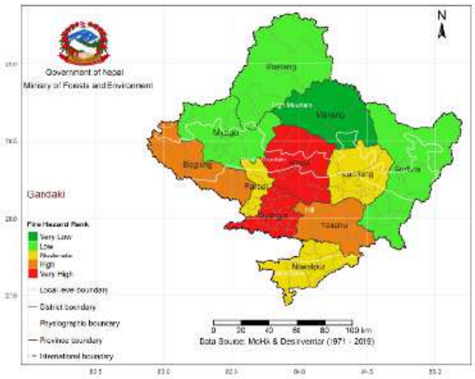
Avalanche Hazard Rank in Gandaki Province



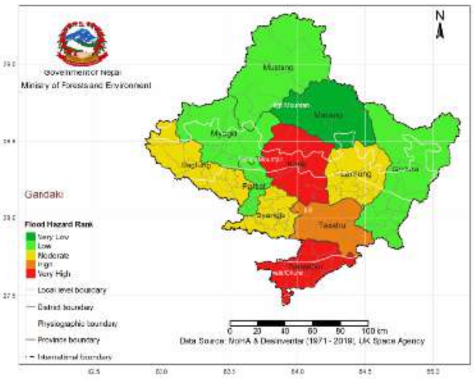
Coldwaves Hazard Rank in Gandaki Province



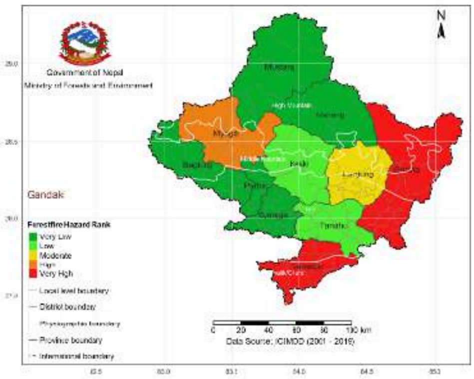
Epidemics Hazard Rank in Gandaki Province



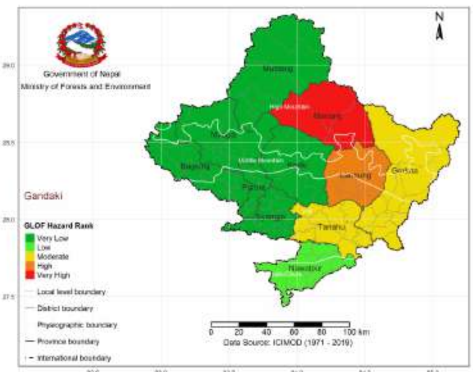
Fire Hazard Rank in Gandaki Province



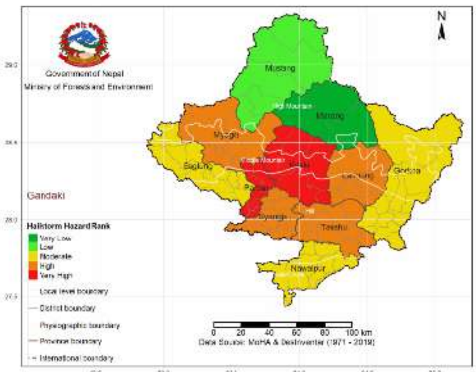
Flood Hazard Rank in Gandaki Province



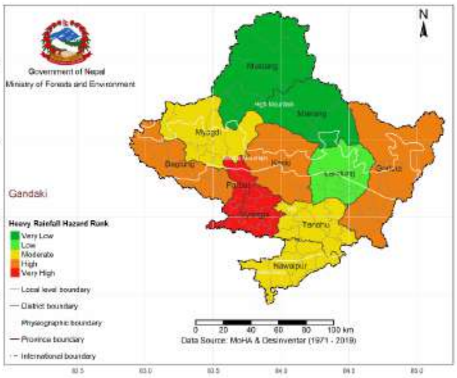
Forestfire Hazard Rank in Gandaki Province



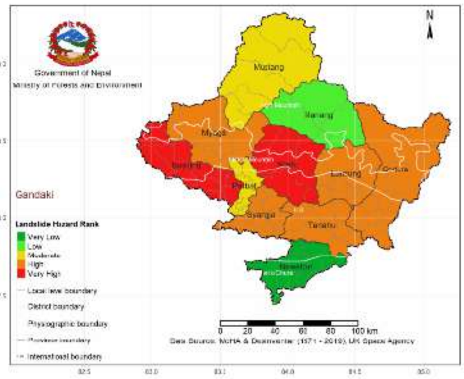
GLOF Hazard Rank in Gandaki Province



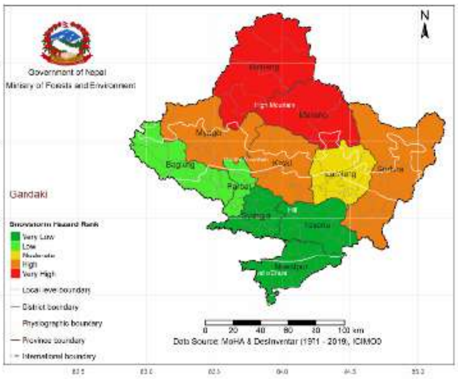
Hailstorm Hazard Rank in Gandaki Province



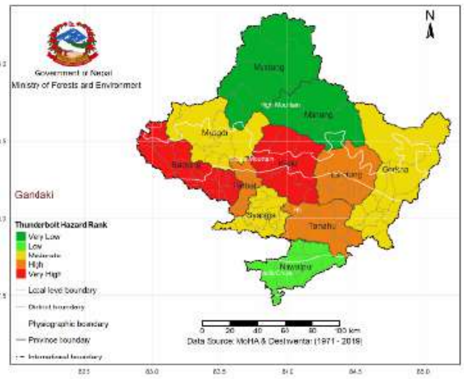
Heavy Rainfall Hazard Rank in Gandaki Province



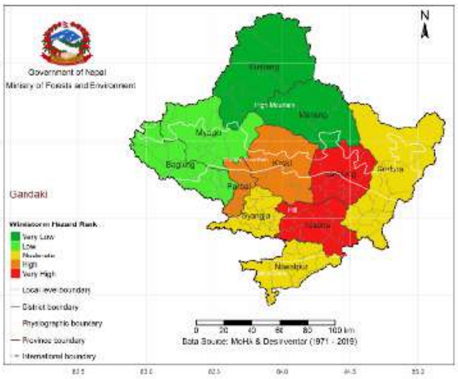
Landslide Hazard Rank in Gandaki Province



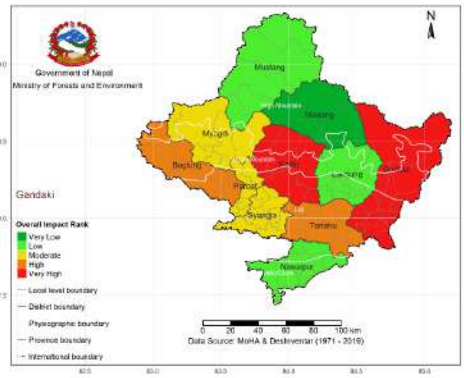
Snowstorm Hazard Rank in Gandaki Province



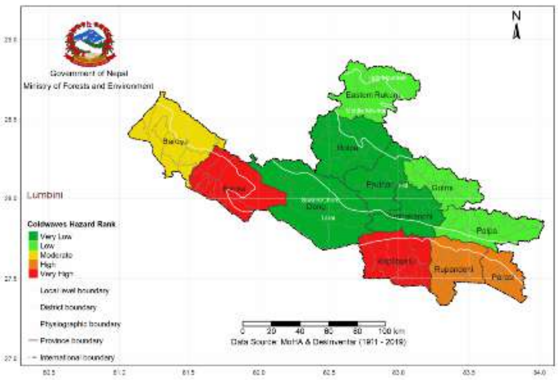
Thunderbolt Hazard Rank in Gandaki Province



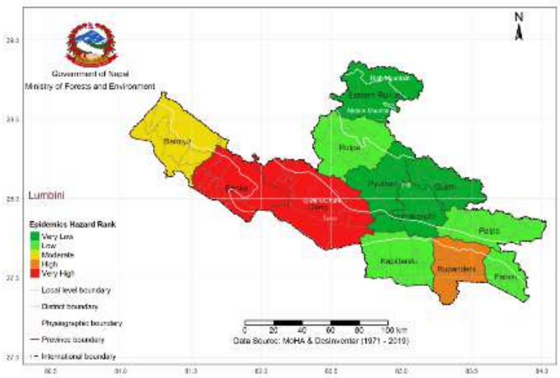
Windstorm Hazard Rank in Gandaki Province



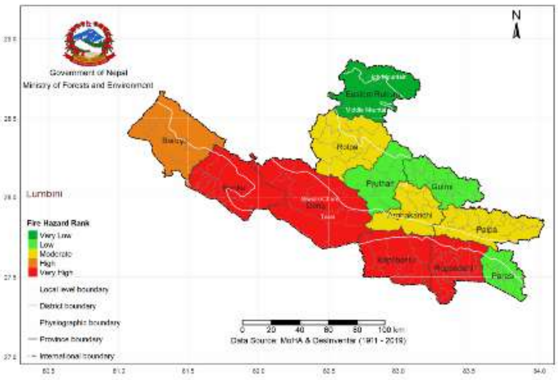
Overall Impact Rank in Gandaki Province



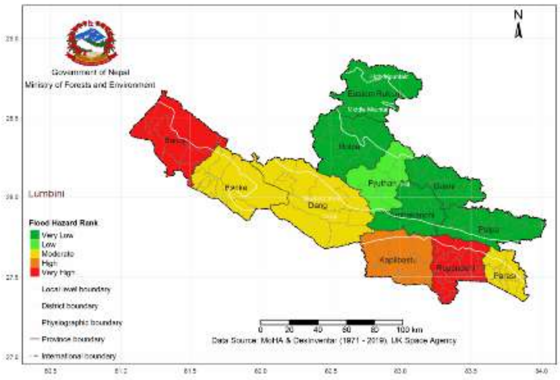
Coldwaves Hazard Rank in Lumbini Province



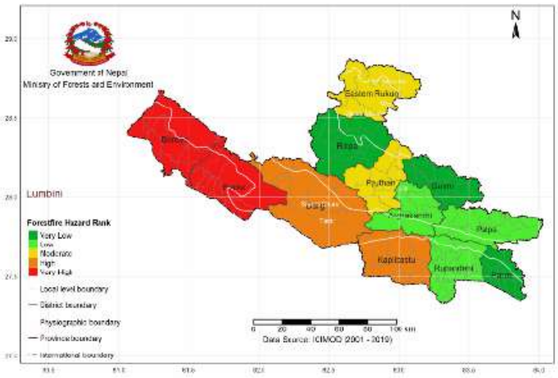
Epidemics Hazard Rank in Lumbini Province



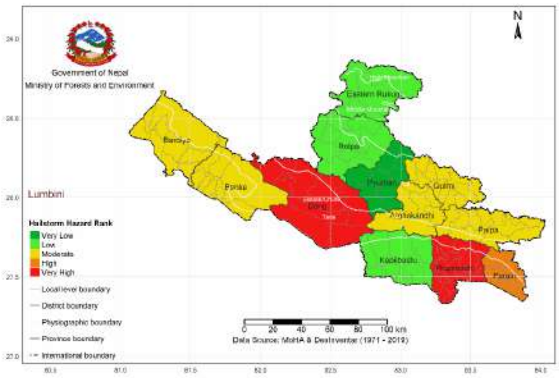
Fire Hazard Rank in Lumbini Province



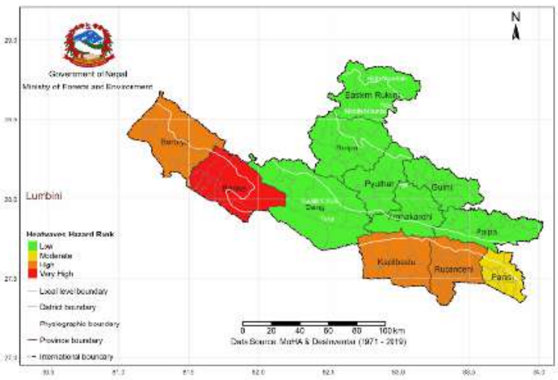
Flood Hazard Rank in Lumbini Province



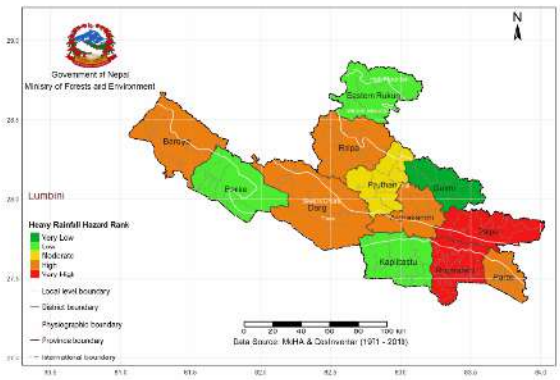
Forestfire Hazard Rank in Lumbini Province



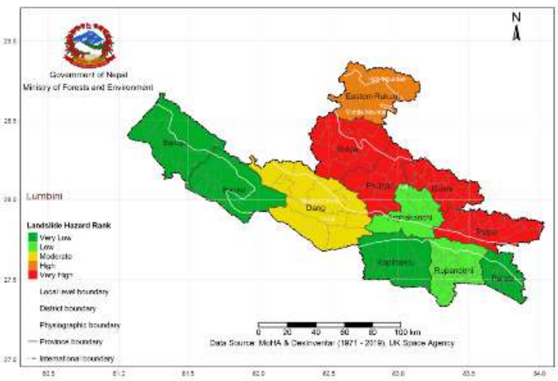
Hailstorm Hazard Rank in Lumbini Province



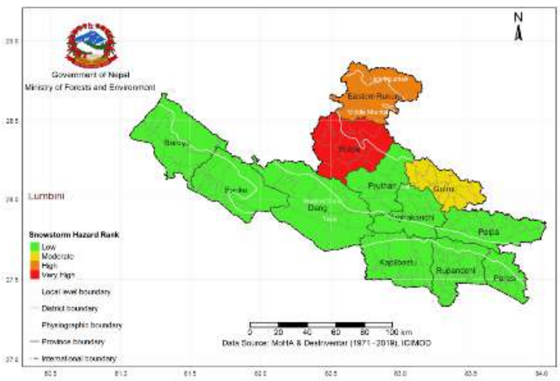
Heatwave Hazard Rank in Lumbini Province



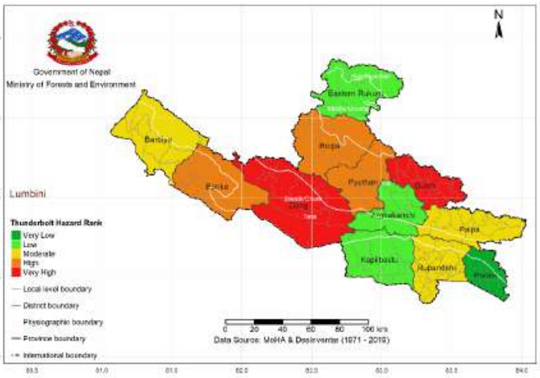
Heavy Rainfall Hazard Rank in Lumbini Province



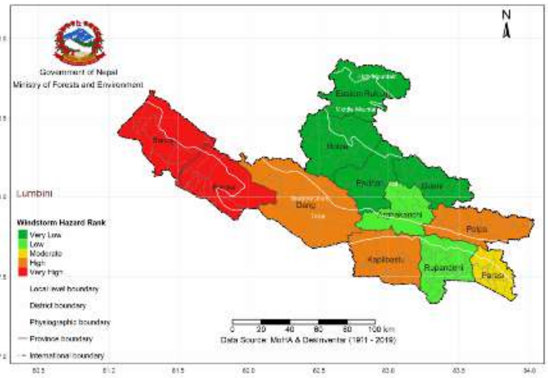
Landslide Hazard Rank in Lumbini Province



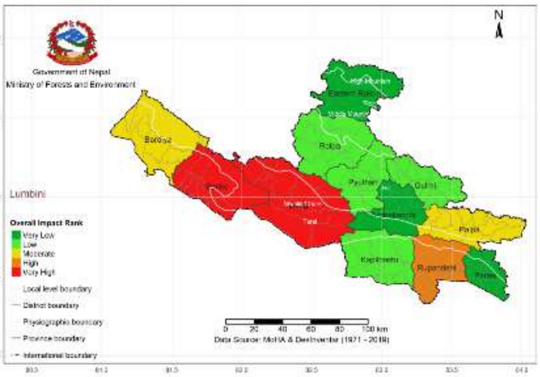
Snowstorm Hazard Rank in Lumbini Province



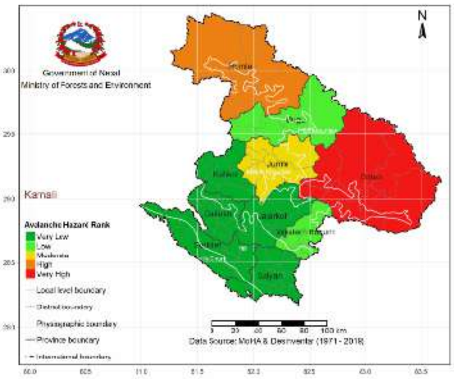
Thunderbolt Hazard Rank in Lumbini Province



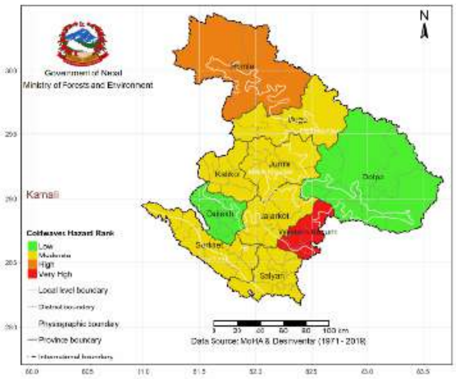
Windstorm Hazard Rank in Lumbini Province



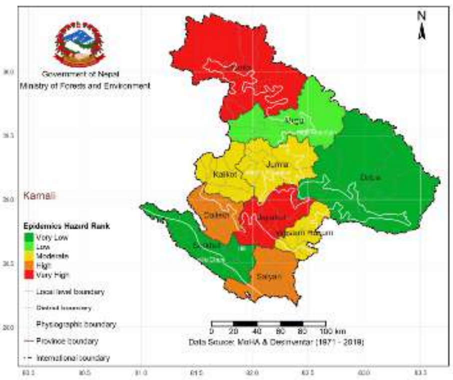
Overall Impact Rank in Lumbini Province



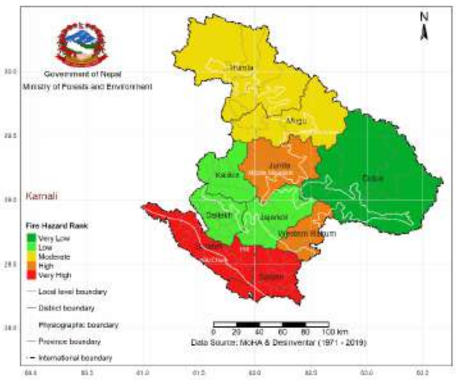
Avalanche Hazard Rank in Karnali Province



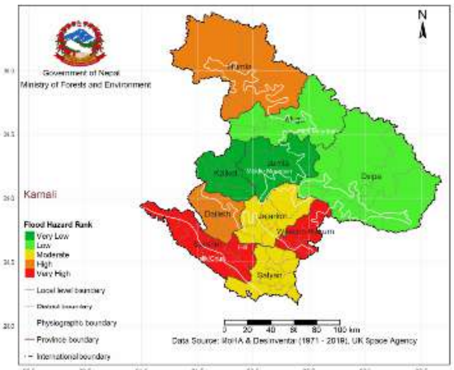
Coldwaves Hazard Rank in Karnali Province



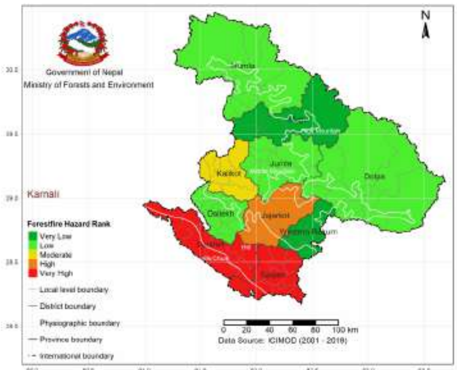
Epidemics Hazard Rank in Karnali Province



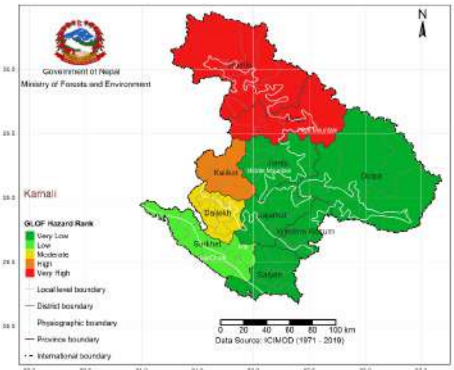
Fire Hazard Rank in Karnali Province



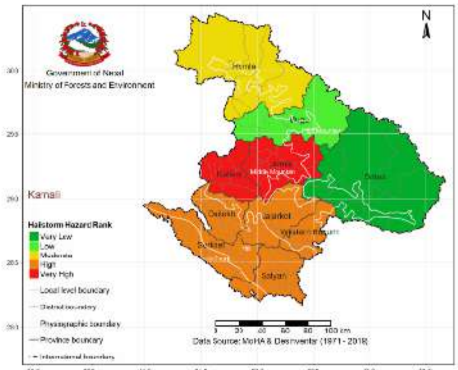
Flood Hazard Rank in Karnali Province



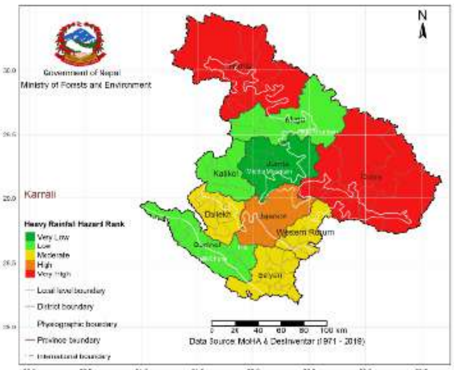
Forestfire Hazard Rank in Karnali Province



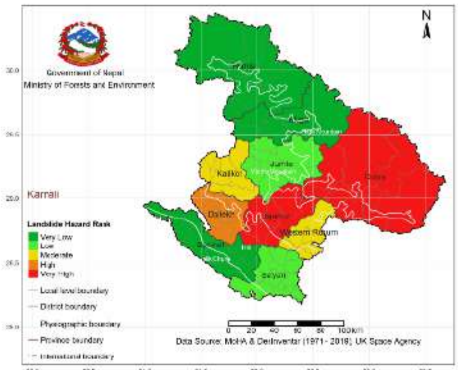
GLOF Hazard Rank in Karnali Province



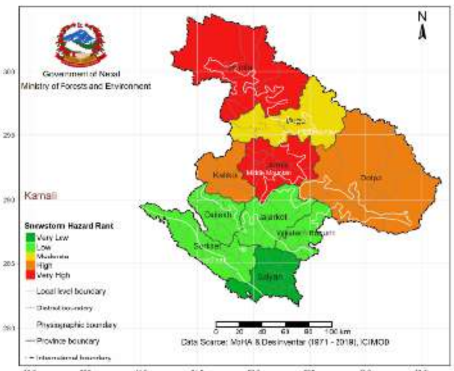
Hailstorm Hazard Rank in Karnali Province



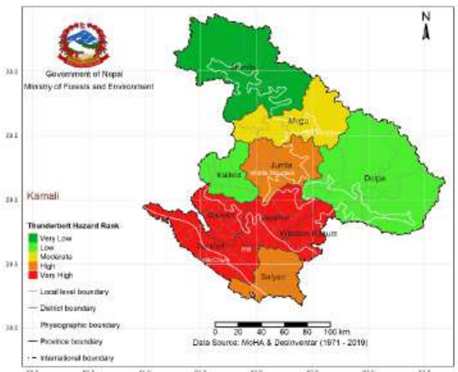
Heavy Rainfall Hazard Rank in Karnali Province



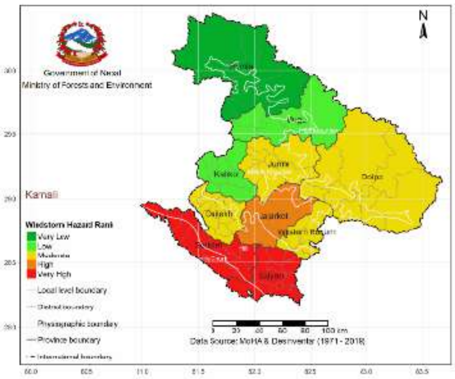
Landslide Hazard Rank in Karnali Province



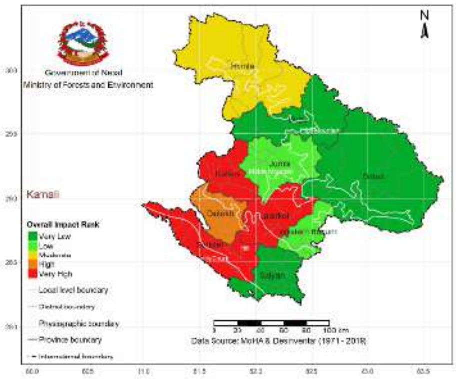
Snowstorm Hazard Rank in Karnali Province



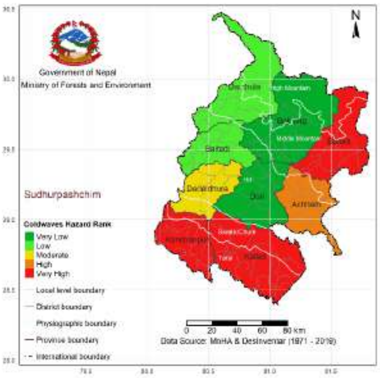
Thunderbolt Hazard Rank in Karnali Province



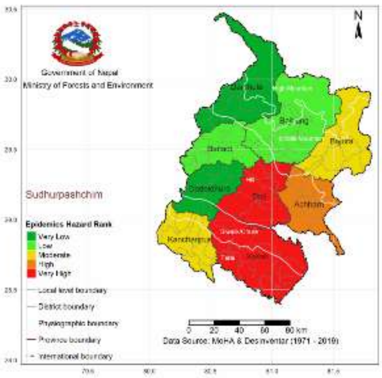
Windstorm Hazard Rank in Karnali Province



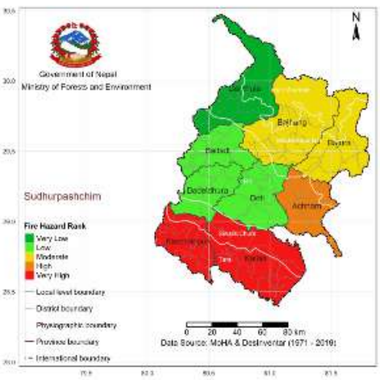
Overall Impact Rank in Karnali Province



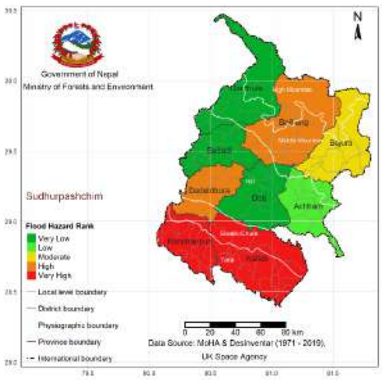
Coldwaves Hazard Rank in Sudurpaschim Province



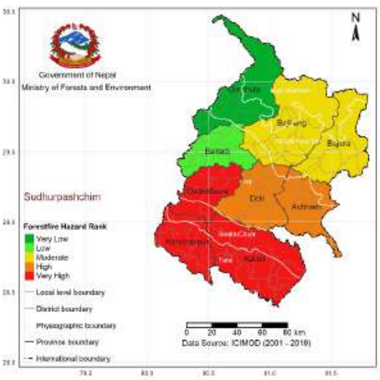
Epidemics Hazard Rank in Sudurpaschim Province



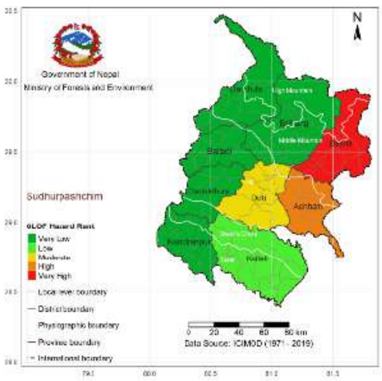
Fire Hazard Rank in Sudurpaschim Province



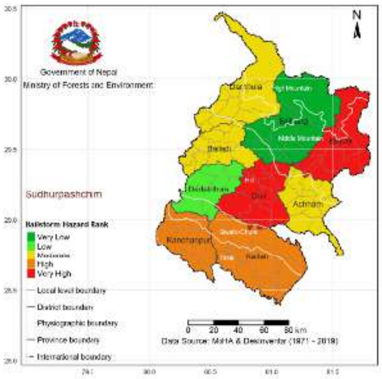
Flood Hazard Rank in Sudurpaschim Province



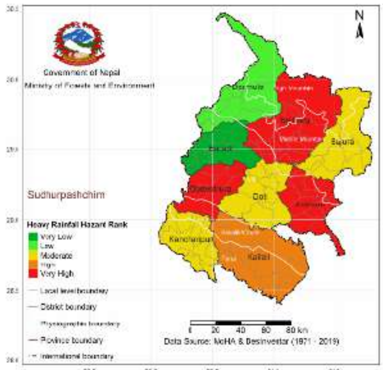
Forestfire Hazard Rank in Sudurpaschim Province



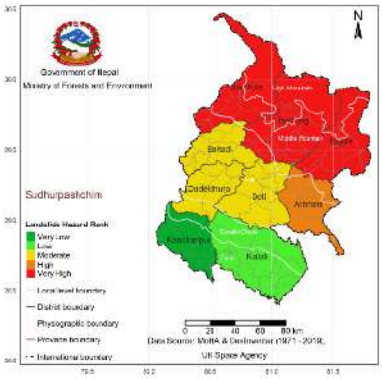
GLOF Hazard Rank in Sudurpaschim Province



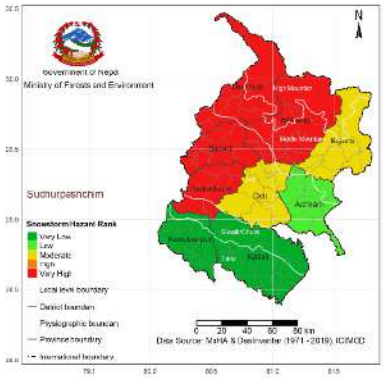
Hailstorm Hazard Rank in Sudurpaschim Province



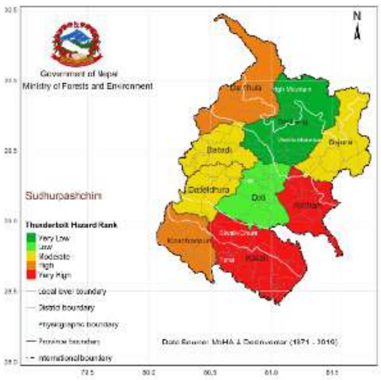
Heavy Rainfall Hazard Rank in Sudurpaschim Province



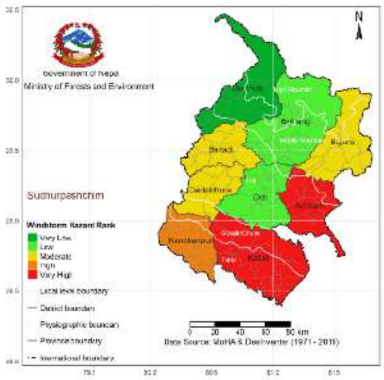
Landslide Hazard Rank in Sudurpaschim Province



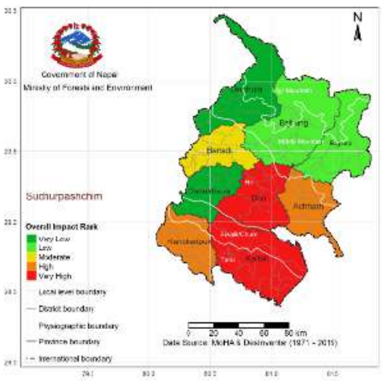
Snowstorm Hazard Rank in Sudurpaschim Province



Thunderbolt Hazard Rank in Sudurpaschim Province



Windstorm Hazard Rank in Sudurpaschim Province



Overall Impact Rank in Sudurpaschim Province

Annex D: Stakeholders Consulted During the Process

SN	Name	Institution
1	Kali Prasad Parajuli	MoHA (JS)
2	Indu Ghimire	MoHA (JS)
3	Kedar Prasad Rijal	TU, CDES
4	Deepak Chamlagai	TU, CDG
5	Ratindra Khatri	WFP Nepal
6	Man Bahadur Thapa	ADPC, Nepal
7	Rejina Maskey	TU
8	Santosh Dahal	AINTGDM
9	Luna Khadka	DPNET
10	Krity Shrestha	Practical Action
11	Ganesh Bikram Shahi	MoHA
12	Saraswoti Sapkota	MoHA
13	Chitra Bahadur Bhattarai	Nepal Police
14	Dr Radha Wagle	MoFE, CCMD (JS)
15	Dr Arun Bhatta	MoFE, CCMD
16	Srijana Shrestha	MoFE, CCMD
17	Srijana Bhusal	MoFE, CCMD
18	Raju Sapkota	MoFE, CCMD
19	Hari Krishna Laudari	MoFE, CCMD
20	Yam Nath Pokhrel	MoFE, CCMD
21	Ram P. Awasthi	MoFE, CCMD
22	Muna Neupane	MoFE, CCMD
23	Khemraj Kafle	MoFE, CCMD
24	Surendra Pant	MoFE, CCMD
25	Somnath Gautam	MoFE, CCMD
26	Dr Indira Kandel	DHM
27	Dr Archana Shrestha	DHM
28	Gyanendra Karki	NAP-UNEP
29	Basanta Paudel	NAP-UNEP
30	Anil Pokharel	NDRRMA
31	Dr Maheshwor Dhakal	MoFE
32	Bikram Zoowa Shrestha	DHM
33	Deepak KC	UNDP
34	Sumit Dugar	FCDO
35	Puja Shakya	Practical Action
36	Nitesh Shrestha	WFP Nepal
37	Dharam Raj Uprety	Practical Action
38	Gehendra Gurung	Independent DRRM Expert
39	Santosh Nepal	ICIMOD
40	Binaya Parajuli	UNEP
41	Surya Bahadur Thapa	DPNET
42	Murari Vasti	MoHA
43	Shiva Karki	MoHA