Climate Change Vulnerability, Impact, and Adaptation Assessment

A Report Submitted to
Government of Nepal
Ministry of Forests and Environment
Third National Communication Project
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Executive Summary

Introduction

This study report, *Vulnerability, Impact and Adaptation Assessment*, is a supplementary document of the Third National Communication to United Nations Framework on Climate Change (to be) submitted by Nepal. The Parliament of Nepal ratified the UN Framework Convention on Climate Change in 1994, and the Kyoto Protocol in September 2005. Nepal as a Non-Annex I Party to the Convention is regularly implementing obligations pursuant to its status. The development of the Third National Communication of Nepal on Climate Change and submission to the Conference of the Parties to the Convention is the country's basic obligation. This report on VIA Assessment includes information for the period covering 2012-2018. The report has been prepared through desk review of available reports both academic and project-based, and consultation with experts at government as well as non-governmental levels.

Nepal's share of emissions of global emissions is trivial; however, the country is facing profound challenges emanating from global climatic impacts. The country is especially vulnerable to changes in precipitation patterns and rates and timing of glacial melt, which could impact agriculture, biodiversity, and hydropower energy production. Nepal has been ranked as one of the most vulnerable countries to climate change, water-induced disasters and hydro-meteorological extreme events such as droughts, storms, floods, inundation, landslides, debris flow, soil erosion and avalanches. The 2013 study on Economic Impact Assessment of Climate Change in Key Sectors (agriculture, hydropower and water-induced disasters) has estimated direct cost of current climate variability and extreme events equivalent to 1.5 to 2% of current GDP/year (approximately USD 270-360 million/year in 2013 prices) and much higher in extreme years.

To address climate related risks and vulnerability, Nepal prepared a comprehensive National Adaptation Programme of Action (NAPA) in 2010. In 2015, it undertook preparation of National Adaptation Plan (NAP). NAP has identified eight major sectors of thematic areas: 1) Agriculture and food security (including nutrition); 2) Forests and biodiversity; 3) Water resources and energy; 4) Public health (WASH); 5) Climate-induced disasters; 6) Urban settlements and infrastructure; 7) Tourism, natural and cultural heritage; and 8) Gender and marginal groups (social inclusion), and Livelihoods and governance. NAP has defined the assessment of impacts, adaptation, and vulnerability as to evaluate how patterns of risk or potential benefit are shifting due to climate change, and considers how impacts and risks related to climate change can be reduced and managed through adaptation.

Methodology

Sector-wise information on the vulnerability, impacts and adaptation were collected from the peer-reviewed scientific articles, documents and reports from sector ministries and departments. Information was obtained for different sectors including Agriculture, Water Resources, Forests and Biodiversity, Public Health, Climate Induced Disasters, Human Settlement and Infrastructures, and Gender and Social Inclusion. Consultation meetings were organized at various levels including provincial planning commissions and ministries. To understand the projected change, two Representative Concentration Pathways (RCPs) scenarios were selected: RCP4.5 and RCP8.5. The scenarios for medium-term (2016-2045) and long-term (2036-2065) were prepared by comparing with the reference period 1981-2010.

Climatic Trend and Scenarios

For the NAP process, two major climate change science documents were prepared for Nepal: Observed Climate Trends in Nepal (1971-2014) (DHM, 2017) and Climate Change Scenarios for Nepal (MoFE, 2018). These two reports have used improved methodology since SNC and provide a basic scientific understanding about past and future climate change in Nepal. Both reports analyzed climate trends for districts and physiographic regions. Observed climate trend of Nepal showed 0.056 ºC/yr rise in annual maximum temperature significant at 99.9%, while 0.002 ºC/yr rise minimum temperature but not significant even at 95%. The maximum temperature trend showed a clear signal of warming country wide with highest rate of increasing in higher altitudes. The maximum temperature trend also captured the cooling effect due to fog episodes observed in Terai districts since last decade. The minimum temperature trends did not show signal as clear as in the maximum temperatures. The pattern of annual minimum temperature trend showed positive trend in low elevation districts and negative trend in high elevation districts as in all the seasons. While majority of the districts showed clear positive trend of warm extreme temperature indices, only few districts showed mixed trends (positive and negative) in cold extreme temperature indices and extreme precipitation indices.

Future climate change report of Nepal used RCP4.5 and RCP8.5 to project range of changes in medium-term and long-term periods with respect to reference period (1981-2010). Average annual precipitation is likely to increase by 2-6% in medium-term and 8-12% in the long-term. Average annual mean temperature is likely to increase by 0.9-1.1 ºC in the medium-term and 1.3-2.8 ºC in the long-term. Warm extreme temperature indices are likely to increase while cold extreme indices are likely to decrease in future. Extreme precipitation events are likely to increase in frequency in future. Uncertainty is higher in precipitation projections while is smaller in temperature projections.

Vulnerability and Impact Assessment

Agriculture and Food Security

Agriculture is a major sector of the economy in Nepal engaging two thirds of the population and contributing to nearly one-third of the gross domestic production. But agricultural productivity is low and large proportion of farmers are food insecure. Poor and vulnerable suffer from under nutrition. Malnutrition contributes to child mortality and diminished lives due to impaired cognitive development, reduced economic productivity and the increased risk of malnutrition-related chronic diseases.

Agriculture in Nepal is highly vulnerable to climate change. It is sensitive particularly due to increased temperatures and changing patterns of precipitation. The sensitivity of agriculture to climate hazards, variation and extremes depends on crop phenology, availability of irrigation, plant varieties, livestock breeds, cropping pattern, fodder and forage availability and landholding size. But the adaptive capacity of the farmers is very low due low level of infrastructure and limited investment on knowledge and development.

The climate risks are high in Nepalese agriculture as the farming is facing several hazards, exposure to extreme weathers and farmers are vulnerable. Nepalese agriculture and nutrition are facing many climate-induced hazards and extremes trends particularly drought, crop diseases, livestock diseases, cold waves, inundation, river bank cutting and flood. Most of the farms are exposed to one or the other

hazards. The exposure of agriculture system to climate change is very high due to farm lands in difficult terrains, limited irrigation schemes, poor road accessibility, large but low productive rangeland- based livestock population, poor market network, traditional livestock sheds and heavy dependency on traditional agriculture for livelihood.

Impacts of climate change are visible in crop and livestock production, fisheries and malnutrition. Land and labour productivity and competitiveness are low; adoption of improved technology is slow. Increasing temperature and extreme variability in rainfall have major implications for the agriculture sector.

Climate change adaptation is just initiated in the country. Though National Adaptation Programme of Action (NAPA) has recommended about USD 95 million for adaptation in agriculture in the short run, funding is always in short supply. Some technologies are already available that are useful for climate change adaptation and vulnerability reduction such as drought resistant and submerge tolerance varieties of crops, micro-irrigation technologies and soil management, but they have very limited access to the farmers. These efforts are in the beginning stage and need further revising and development along with other new initiatives.

Water Resources and Energy

Nepal has immense potential for water resources development, however only less than 7% of total available water resources has utilized so far. Agriculture is the major water use sector accounting for 96% of the total withdrawal, whereas domestic sector uses 3.8% and industrial sector use is very minimal. Energy-sector in general is dominated (80%) by biomass as a primary source of energy in total supply mix; however, there is dominance (63%) of hydropower in total electricity supply. The climate variability and change have impacts on resources endowment, energy supply, energy use, and water-energy infrastructure setting. In terms of resources endowment, climate change/variability is affecting spatio-temporal distribution of water availability in various ways such as accelerating evapotranspiration, melting of glaciers, formation of glacial lakes in the mountain valleys, and expansion of existing glacial lakes. The accelerating retreat of glaciers and associated alterations in hydrology affects water availability, its timing, and subsequently on energy generation. The contribution of snow and glacier melt to total discharge during the period of 1985 to 1997 was about 34% annually, whereas it was 63% in the pre-monsoon season (March to May). The anticipated future adverse impact on the electricity generation of the hydropower plants, however, depends on various factors such as variation in inflows to the plant, rate of temperature increase, and location of plant, among others. The inflow to reservoir further depends on the rainfall variability. In general, the electricity generation potential is expected to increase initially with the rise in temperature, and then decrease gradually. Vulnerability of water resources sector is exacerbated by climate variability and changes; however, actual impacts depends on locations as different catchments have their own biophysical, socio-economic, and institutional-policy characteristics. Impacts on hydro-energy sector are not only due to alteration of hydrology, but also by increasing water-induced disasters such as sedimentation, floods, and geo-hazards.

Any substantial change in the frequency of floods and droughts, or in the quantity and quality of water or seasonal timing of water availability, will require adjustments that can be costly, not only in monetary

terms but also in terms of societal and ecological impacts. Potential adaptation measures for water resources and energy sector depends certainly on context and location, however some generic ones may include investing on data, information, and generating evidence; establishing and operationalizing early warning systems; lowering of glacial lakes; and making the water-energy infrastructure climate resilience in various ways.

Forests and Biodiversity

Forests and biodiversity are considered to be one of the crucial climate sensitive thematic sectors in Nepal through both NAPA, 2010 and NAP, 2017 documents. Some of the known impacts of climate change on forests and biodiversity are: (i) shifts in agro-ecological zones, prolonged dry spells, and higher incidences of pests and diseases, (ii) increased temperature and rainfall variability, (iii) increased emergence and quickened spread of invasive alien plant species, (iv) increased incidence of forest fire in recent years, (v) changes in phenological cycles of tree species, (vi) shifting of treeline in the Himalaya, and (vii) depletion of wetlands.

Besides, mountain plants will be affected by overall warming with changes in precipitation pattern. Fringe forests are more vulnerable to landslides. Due to climatic stress such as less water, and change in weather patterns, herbs in the high-altitude rangelands are more vulnerable and this has been proved by decrease in availability of medicinal plants. Rise in temperature has led to upward shifting of ecological belts where the tree line of *Abies spectabilis* and *Betula utilis* are shifting upwards.

Reduced snowfall, untimely rains, and increased dryness have altered the flowering and fruiting behaviour of plants which is closely related to the survival of wildlife.

Public Health and WASH

The projected increase of climate disasters under climate change, particularly from floods related to glacier melt, would have a direct impact on health in Nepal. The projected impacts in human health due to climate change include: increase in cardiovascular disease mortality in tropical region; increase in the burden of diarrheal diseases in low income regions, increase in heat-related mortality and morbidity. Vector and water-borne disease have been found to be increasing within country, along with a strong identified relationship between these diseases and temperature and precipitation. It is already evident that malaria, Kalaazar, Japanese encephalitis, and other water borne diseases such as typhoid and cholera are commonly seen in different parts of the country. Likewise, heat waves, cold waves, diseases and disasters like floods and landslides impart higher risk of disease outbreaks, leading to public health crisis.

Tourism, Natural and Cultural Heritage

Climate change induced disasters impact the tourism industry both directly and indirectly by damaging tourism-related infrastructure and resources, and disturbing tourism activities, water supply, organic farming, and the wellbeing of tourism service providers. Receding snow lines, melting glaciers, increased frequency of cloudbursts, floods, and landslides have the potential to change the nature and quality of tourism resources. Activities of major tourist attraction, like mountaineering, trekking and rafting are directly affected by tourism.

Infrastructure and Urban Settlement

Almost two-thirds of the country's population now live in municipalities. On one hand, settlements across the country are rapidly urbanizing. On the other hand, climate change is directly affecting water and other natural resources on which human lives depend critically. Settlements, whether in mountains, hills or Terai, have already started experiencing water scarcity. In cities, people have started experiencing 'urban heat island' effect caused by the heating of concrete and asphalt surfaces, which is leading to health concerns and more energy demand for cooling purpose.

Likewise, occurrence of heavy and untimely rainfall has increased threats of landslides, floods and debris flow. Ironically many settlements in Nepal, including informal settlements, are built on steep slopes prone to landslides and riverbanks prone to floods. Urban floods, dispersion of pollutants to water bodies, and outbreaks of water and vector-borne diseases are increasingly being experienced in the cities during monsoons and during heavy rains. Damage to roads and drainage structures poses huge economic loss as transport services and overall daily lives are disrupted.

Climate Induced Disasters

Disasters such as GLOFs, landslides, floods, Landslide Dam Outburst Floods, windstorm, hailstorm, avalanche, fog, cold waves and heat waves are common in Nepal. Government of Nepal has been putting its efforts to reduce vulnerability from the climate induced disasters. Moreover, increased melting of snow and ice including permafrost can induce an erodible state in the mountain soil which was previously non-erodible. This has increased likelihoods of landslides in the mountains.

Gender and Social Inclusion

Nepal has a wide altitudinal variation within short horizontal span and is supporting the livelihood of population comprising over 125 ethnic social groups with its ecosystem services depending on the natural resources. Nepal is experiencing extreme climatic events in which strong wind storm has been the recent phenomena which has adversely affected the southern plain of Nepal resulting losses of lives and properties putting additional burden to the women and socio-economically disadvantaged community members.

The ultimate impact of the climate change is on the ecosystem, which serves the society with food, fibre and shelter in which women, men and socially excluded communities are more depend on. Depletion of the ecosystem services not only affect the food security but also affect more on the community members who are engaged in farming agricultural land. It also decreased the adaptive capacity of men and women along with the change of climate due to weak economy, decision making power, access to the information of the extreme climate early warning system.

The marginalized or indigenous groups, particularly Majhi, Raute, Chepang, Satar are more vulnerable to food insecurity due to disasters like floods, landslides, fire and windstorm. Women as primary caretakers of water and forest resources management face an increased work burden with the drying up of water sources and forest resources. There has been challenge for the women, men and socially excluded communities and groups on how to cope with existing and emerging extreme climatic event and to adapt with it as they are the vulnerable group in the society at risk.

Adaptation Measures

The report discusses adaptation measures for each sector. Emphasizes has been given to awareness raising, capacity building and technology transfer. Several technologies are already available that are useful for climate change adaptation and vulnerability reduction, but the information on their adoption and effectiveness need strengthening.

Lack of appropriate technology and financial resources seriously impede Nepal's ability to implement adaptation options by limiting the range of possible responses. Many of the adaptive strategies identified directly or indirectly involve technology which include warning systems, protective structures, crop breeding and irrigation, settlement and relocation or redesigning flood control measures, improved irrigation techniques to cope with drought, and new plant varieties which are resistant to drought or flood, etc. Most of these technologies are in continuous development and practice in Nepal. However, they warrant further development and refinement tailored to meet additional requirement in order to face further climate change variability and extremes.

Community-based disaster management, Glacial Lake Outburst Floods (GLOFs) monitoring, , hazard /vulnerability mapping, disaster risk reduction, strengthening early warning system and forecasting, promotion of reforestation/afforestation programme including bio-engineering techniques, improvement of degraded land, development of crops and promotion of agriculture practices and strengthening capacity of concerned governmental and non-governmental agencies are some of the adaptation options to reduce the impacts of climate change.

Adaptation Action Plans

The report has put forward adaptation action plans for each sector. Some major plans are listed below.

- Agriculture and Food Security: improved governance, increasing productivity, commercialization of agriculture and increased competitiveness
- Water Resources and Energy: disaster monitoring and risk reduction, watershed management programme, improved irrigation system
- Forests and Biodiversity: sustainable management of forests, promotion of non-conventional energy sources, control of forest-fires and over-grazing
- Public Health and WASH: capacity development of health care professionals, monitor air quality and air-borne diseases
- Tourism, Natural and Cultural Heritage: sustainable tourism, eco-cultural trekking trails, application of early warning systems
- Infrastructure and Urban Settlement: risk-sensitive land use planning, construction of climate-resilient infrastructure, investment in green and blue infrastructure, increased insurance coverage.
- Climate Induced Disasters: Develop Disaster Risk Reduction plans, local level planning, strengthen capacity of disaster response
- Gender and Social Inclusion: equal representation of women in decision making of climate change policy, develop and deliver special livelihood skills to marginalised, poor and disadvantaged families

Acronyms

AEPC	Alternative Energy Promotion Centre
APHRODITE	Asian Precipitation Highly-Resolved Observational Data Integration towards Evaluation
AR5	Fifth Assessment Report
CAPA	Community Adaptation Plan of Action
CBS	Central Bureau of Statistics
CCI-WMO	Commission for Climatology, World Meteorological Organization
CDES	Central Department of Environmental Science
CMIP	Coupled Model Intercomparison Project Phase
CoP	Conference of the Parties
CRI	Climate Risk Index
CWG	Cross-Cutting Working Groups
DFRS	Department of Forest Research and Survey
DHM	Department of Hydrology and Meteorology
DJF	December-January-February (Winter Season)
DLS	Department of Livestock Services
DNPWC	Department of National Parks and Wildlife Conservation
DOA	Department of Agriculture
DoF	Department of Forests
DoHS	Department of Health Services
DoLIDAR	Department of Local Development and Agricultural Roads
DoR	Department of Roads
DUDBC	Department of Urban Development and Building Construction
DWSS	Department of Water Supply and Sanitation
ECDF	Empirical Cumulative Distribution Functions
EIA	Environmental Impact Assessment
ETCCDI	Expert Team on Climate Change Detection and Indices
FCHV	Female Community Health Volunteers
FMI	Finnish Meteorological Institute
FNCCI	Federation of Nepalese Chambers of Commerce and Industries
GCM	Global Circulation Model
GDP	Gross Domestic Product
GHG	Green House Gas
GIS	Geographical Information System
GLOF	Glacial-lake outburst flood
GoN	Government of Nepal
GSI	Gender and Social Inclusion
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management

IUCN	International Union for Conservation of Nature
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
JJAS	June-July-August-September (Monsoon Season)
LAPA	Local Adaptation Plan of Action
LDC	Least Developed Countries
LEG	LDC Expert Group
LEG	Least Developed Country Expert Group
MAM	March-April-May (Pre-monsoon Season)
masl	meters above sea level
MoCTCA	Ministry of Culture, Tourism and Civil Aviation
MoFE	Ministry of Forests and Environment
MoFSC	Ministry of Forests and Soil Conservation
MoPE	Ministry of Population and Environment
MoSTE	Ministry of Science, Technology and Environment
MoUD	Ministry of Urban Development
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NARC	National Agriculture and Research Council
NAST	Nepal Academy of Science and Technology
NBCC	National Biodiversity Coordination Committee
NPC	National Planning Commission
NTB	Nepal Tourism Board
NTNC	National Trust for Nature Conservation
NUDS	National Urban Development Strategy
ORC	Outreach Clinic
PAN	Practical Action Nepal
PHC	Primary Health Care
PMO	Project Management Office
QC	Quality Control
RCM	Regional Climate Model
RCPs	Representative Concentration Pathways
SNC	Second National Communication
TNC	Third National Communication
TWG	Thematic Working Group
UNFCCC	United Nations Framework Convention on Climate Change
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization

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1. Introduction

1.1 Background

The Intergovernmental Panel on Climate Change (IPCC), in its fifth assessment report (AR5), defines vulnerability as the propensity or predisposition to be adversely affected. Vulnerability encompasses the sensitivity or susceptibility to harm and lack of capability to cope and adapt (Oppenheimer et al., 2014). Vulnerability is dynamic and context specific, determined by human behaviour and societal organization, which influences for example the susceptibility of people (e.g., by marginalization) and their coping and adaptive capacities to hazards (IPCC, 2012). In the context of Asia, several key risks from climate change are identified with high confidence including increased risk of heat related mortality, drought related water and food shortages causing malnutrition, exacerbated poverty, inequalities and new vulnerabilities, and mountain-top extinction (Oppenheimer et al., 2014).

Nepal is ranked as one of the most vulnerable countries (fourth in 2017 and eleventh in the 20 years period, 1998-2017) in the Global Climate Risk Index (CRI) developed by Germanwatch (Eckstein et al., 2019). During 1998-2017 period, average annual fatalities of 235related to climate change in Nepal was reported, accounting annual average loss of US$230.83 million (MoSTE, 2014a). Water-induced disasters, notably floods (in the plains) and landslides (in the hills), associated with the monsoon rains, are the most common natural weather hazard in Nepal. These events claim the loss of life and cause major damage to property and infrastructure. They also have major impacts on livelihoods, affecting tens to hundreds of thousands of people every year. The estimated direct costs of current climate variability are equivalent to 1.5–2% of GDP yr^{-1} in Nepal based on 2013 prices (MoSTE, 2014a).

To address climate related risks and vulnerability, Nepal prepared a comprehensive National Adaptation Programme of Action (NAPA) in 2010. The NAPA document, based on the existing climate vulnerabilities, outlines the adaptation actions targeted in six thematic sectors; namely, Agriculture and Food Security, Water Resources and Energy, Forests and Biodiversity, Public Health, Urban Settlements and Infrastructure, and Climate Induced Disasters. Nepal has started the preparation of National Adaptation Plan (NAP) since 2015 and is underway.

1.2 Objectives and Scopes

This document provides a detailed and representative description of the climate change vulnerability, impacts, and adaptation assessment of Nepal. The following scope is defined for the assignment as stipulated in the terms of reference (ToR).

i. Review and update existing data and information;
ii. Identify, acquire, adopt and utilize appropriate models, methodologies and guidelines for assessing and/or updating vulnerability of the major sectors due to climate change;
iii. Analyse the existing climate parameters by months and years for about 30 years based on availability in different geographical areas;
iv. Prepare climate maps using GIS technology showing clear updates from previous works;
v. Identify and evaluate ongoing adaptation practices for combating impacts due to climate change;
vi. Assess vulnerability of the sectors of agriculture, water resources, forestry and biodiversity, public health, tourism and human settlement and infrastructure including cross-cutting sectors;

vii. Develop climate change adaptation measures suitable for Nepal with due consideration to subsistence economy and gender issues (focus on poor, women, children and marginalized communities);
viii. Update and refine programmes/projects containing measures to adapt to climate change as contained in National Adaptation Programme of Action (NAPA) / Local Adaptation Plan of Action (LAPA), Community Adaptation Plan of Action (CAPA) document;
ix. Prepare an adaptation action plan taking into consideration the NAPA and ongoing process related to LAPA and CAPA to implement those measures being of highest priority including clear distinction of responsibility among the relevant stakeholders, timeframe for fulfilment/implementation of the recommended measures, financial means for implementation of the measures and identification of the possible barriers and risks;
x. Prepare a chapter on "Programmes containing measures to facilitate adequate adaptation to climate change" in accordance with the UNFCCC guidelines;
xi. Prepare and/or update the report on the vulnerability and adaptation assessment as per IPCC guidelines.

1.3 Approaches and Methodology

1.3.1 Climatic Trends and Projections

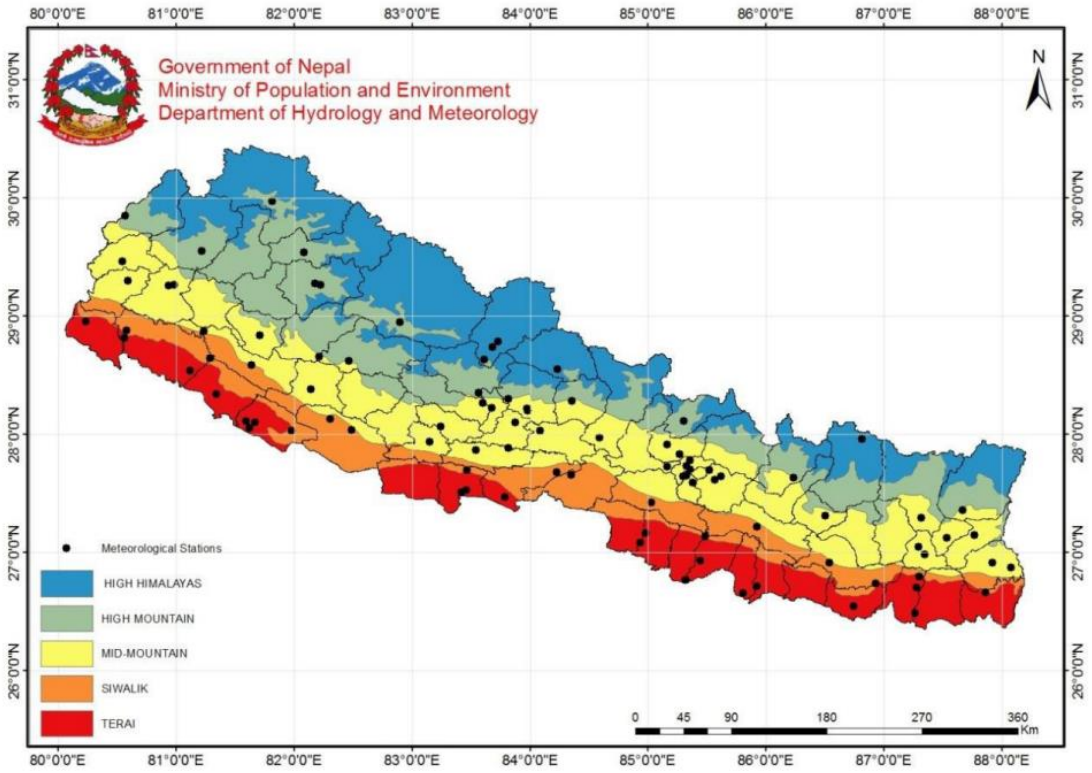
A number of improvements for the analysis of the climatic data to have more reliable situation of the climate, trends and projection, climate vulnerability assessment has been achieved after the Second National Communication (SNC; MoSTE, 2014b). This report has considered all the available peer-reviewed articles and Department of Hydrology and Meteorology findings as the main source of information. The DHM has published a comprehensive report on analysis of climate trends of Nepal from using 1971 to 2014 data (DHM, 2017).

DHM (2017) report includes data and information on climate normal, climate trends, precipitation and temperature trends in seasons for districts and physiographic regions of Nepal. Following considerations are made during the preparation of this report:

- Use the best available data based on quality checked meteorological data in order to enhance the quality of the report and assure the best output/outcome.
- Apply 1 km x 1 km for temperature and 5 km x 5 km for precipitation daily gridded data set.
- Present all Nepal data, individual district average and individual physiographic region average of normal annual and seasonal rainfall and maximum and minimum temperatures using gridded data.
- Calculate the maximum and minimum temperature and precipitation trend for annual and four seasons for each district with significance test at 95%, 99%, and 99.9% confidence levels.
- Prepare the maps of 11 extreme climatic indices trend at district level.
- Present the district normal climate and climate trends in the maps for annual and four seasons.
- Use the available data of two high altitude stations (> 2800 masl up to 5000 masl), and calculate district and physiographic trends using district average time series.

In the DHM (2017), temperature and preparation data from the ground stations have been used. For temperature analysis, daily temperature data from 93 climate stations were used (Figure 1.1). Out of 93, 92 stations were established by DHM and one station, Pyramid Laboratory at Lobuche (5050 masl), established by NAST and Ev-K2-CNR. For precipitation analysis, 0.05-degree APHRODITE daily gridded data were used (Yatagai et al., 2009). This database was based on DHM rain-gauge data of Nepal. The APHRODITE data was considered as the best gridded data available in the Himalayan front

for the temporal scale (Andermann et al., 2014). The methodology for quality checking and interpolation was provided by Yatagai et al. (2012). This document has used temperature and rainfall trend analysis results from the daily data from 1971 to 2014.



Source: DHM (2017)

Figure 1.1: Distribution of 93 meteorological stations in Nepal

1.3.2 Future Scenarios Analysis

The Government of Nepal, Ministry of Forests and Environment (MoFE) has produced a report on "Climate change scenarios for Nepal" under the formulation process of National Adaptation Plan (NAP). This report is considered as the main document for analysing vulnerabilities of various sectors of Nepal.

To understand the projected future climate change in Nepal, the report has identified two Representative Concentration Pathways (RCPs): RCP4.5 and RCP8.5 to address the uncertainties of the changes. Climate scenarios for temperature (mean, maximum, and minimum) and precipitation were developed for the whole of Nepal at 10 km resolution. The climate scenarios were prepared by comparing two future periods with the reference period 1981-2010. The results have been presented for a change in precipitation and temperature for districts and physiographic zones in the medium-term period (2016-2045) and the long-term period (2036-2065) respectively. The future projection was provided in the range suggested by RCP4.5 and RCP8.5 so that adaptation plans can be proposed with consideration of these possible ranges of future changes. In addition, the period of 2071-2100 was considered to understand how the climate might change by the end of the century. The future scenarios for precipitation and temperature were carried out at the annual and seasonal level for 75 districts and five physiographic divisions. The future climate scenarios are helpful in providing a range of projected climate change and in proposing adaptation strategies for various sectors that might get affected.

1.3.3 Sector-Wise Vulnerability and Adaptation

Sector-wise data on the vulnerability, impacts and adaptation were collected from the peer-reviewed scientific articles, official reports and documents from sector ministries. Data were obtained for different eight sectors: a) Agriculture; b) Water Resources, c) Forests and Biodiversity, d) Public Health, e) Gender and Social Inclusion, f) Infrastructure and Urban Settlement, g) Climate-Induced Disasters, and h) Tourism.

The methodology commonly used for the vulnerability assessment framework in Nepal is as suggested in the United Nations, IPCC Fourth Assessment Report, Working Group II, 2007 (Parry et al., 2007). In this framework, Vulnerability is defined as a function of exposure, sensitivity, and adaptive capacity to the impacts. In 2012, IPCC put forward a risk-centred new framework that identified the functional relationship between vulnerability, hazards and exposure together constituting risk.

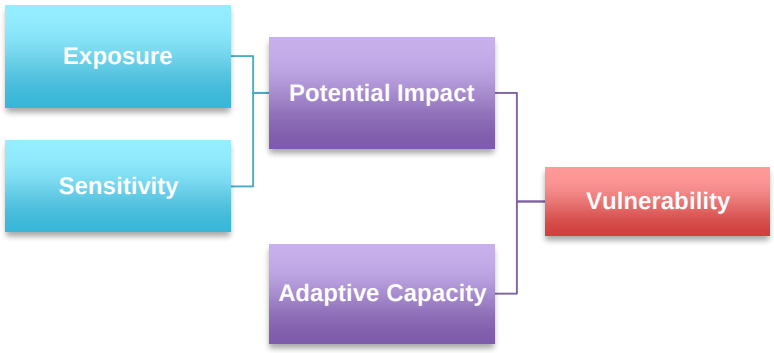


Figure 1.2: Vulnerability assessment framework of the IPCC AR4

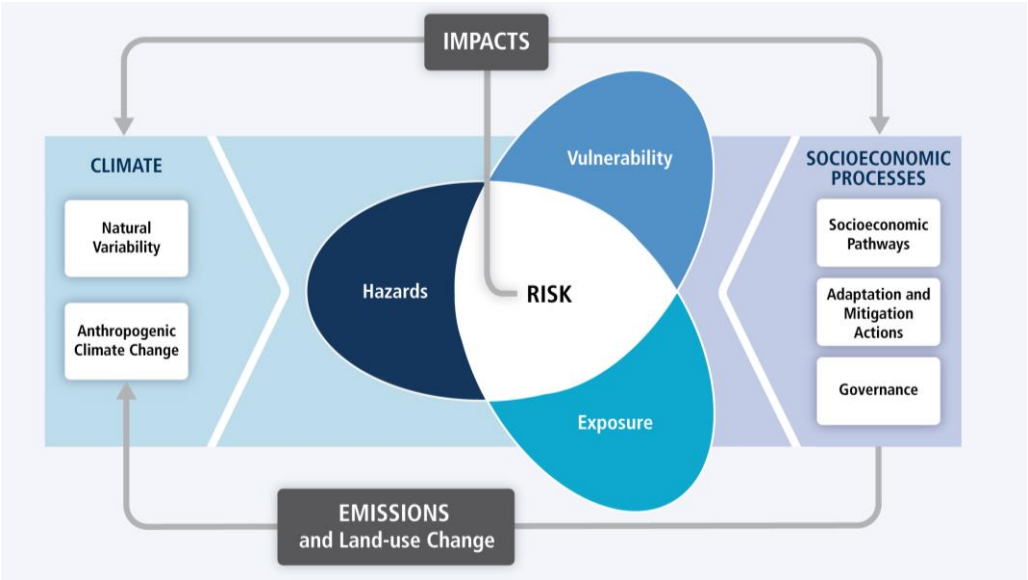


Figure 1.3: Risk assessment framework of the IPCC AR5

The risk assessment is a tool to identify the potential impacts of climate change besides other stressors. The tool requires assessing the adaptive capacity of the country. The procedure identifies a set of direct indicators from existing national database to evaluate the exposure, sensitivity and adaptive capacity. MoE/NAPA (2010) using these three dimensions from the IPCC vulnerability assessment framework

and adopting the procedure outlined by Yusuf & Francisco (2009) prepared the vulnerability mapping for Nepal. IPCC (2014) reconciled the vulnerability and risk with modification in the 2007 framework. Under the formulation process of National Adaptation Plan (NAP), the Government of Nepal developed vulnerability and risk assessment framework and indicators for NAP formulation process that identified the sectoral indicators and data sources in the country Mope (2017a). This document used the IPCC-AR5 as the base, however in the country no vulnerability assessment exists in the new framework. In this document, the vulnerability assessment is presented considering IPCC 2007 framework. For each sector, an overview of the sector, potential impacts, adaptation measures, and the vulnerability are presented.

2. Climatic Trends and Scenarios of Nepal

2.1 Climatic Trends

2.1.1 Temperature

National report on observed climate trend of Nepal (DHM, 2017) presents trends in maximum temperature and minimum temperature in districts and physiographic regions. All-Nepal annual maximum temperature shows positive trend of 0.056 °C yr^{-1} significant at 99.99%. Figure 2.1a shows annual maximum temperature trend in Nepal. Majority of the districts (60 out of 75) showed positive trends of annual maximum temperature higher than 0.04 °C yr^{-1}. The magnitude of the positive trend is larger in the mountain districts than the districts in lower elevations. This pattern is evident also in all the seasons (e.g. the highest trend of 0.12°C/yr is observed in Manang in winter) and is more evident in monsoon season (DHM, 2017). Moreover, this is clear among 5 physiographic, Terai has the lowest positive trend (0.036 °C yr^{-1}) and the high Himalaya has the highest positive trend (0.072 °C yr^{-1}) (DHM, 2017).

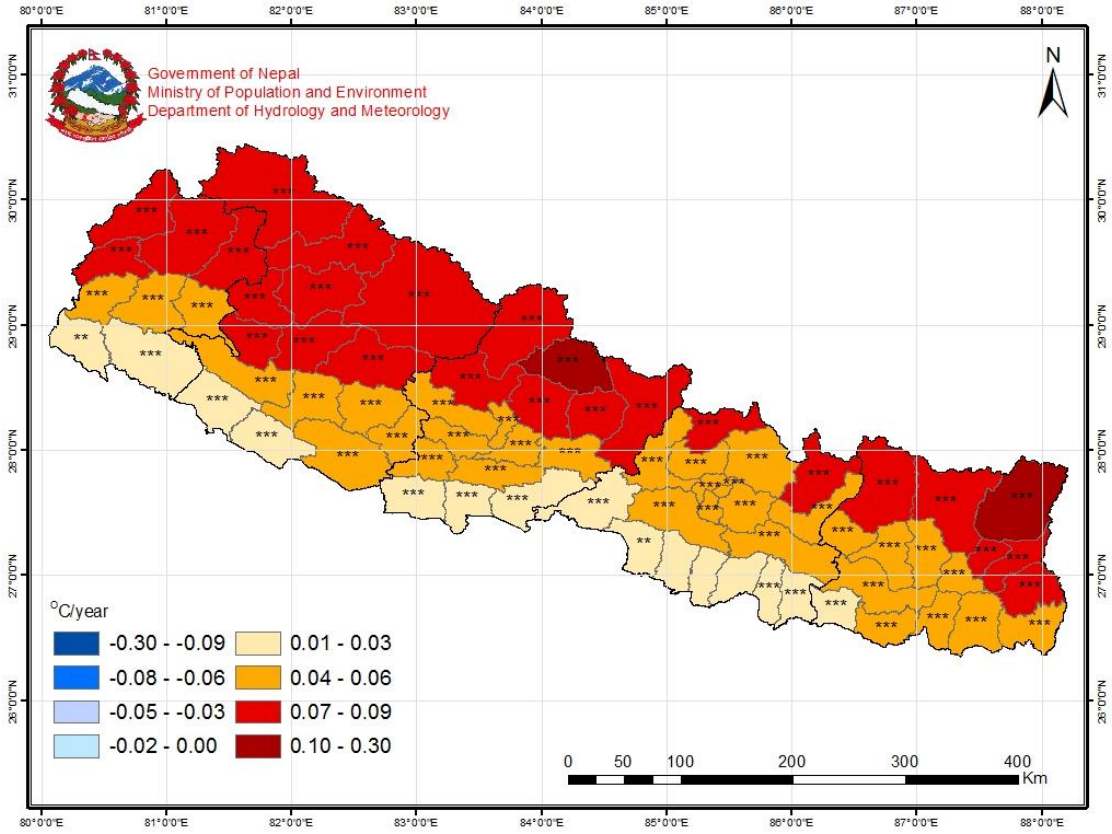


Figure 2.1: Annual maximum temperature trends in the districts of Nepal

(Significance: * 95% CL, ** 99% CL, *** is 99.9% CL; blank means insignificant at 95% CL)

This is backed by scientific studies revealing that the greatest amount of warming is seen in the mountain stations (Kattel & Yao, 2013; Baidya et al., 2008; Shrestha et al., 1999). Another signal in maximum temperature trend is that some of the Terai districts showed decreasing but insignificant trends, mainly during winter and pre-monsoon seasons. This pattern is associated with long duration

fog episodes observed since last decade in winter in the Terai. Therefore, this trend in the Terai cannot be ignored even though the trend is not significant statistically, Moreover, district-wise maximum temperature signals a robust positive trend in most of the districts and for all seasons (Figure 2.1b). More than 75% of the districts of Nepal showed positive trend in maximum temperature significant at 0.95% (Figure 2.1b). This provides a certainty on increasing maximum temperature trend in Nepal. District-wise temperature trends in maximum temperature trends are calculated and listed in DHM (2017) which can be used for the vulnerability assessment of the exposures that are sensitive to maximum temperature trend.

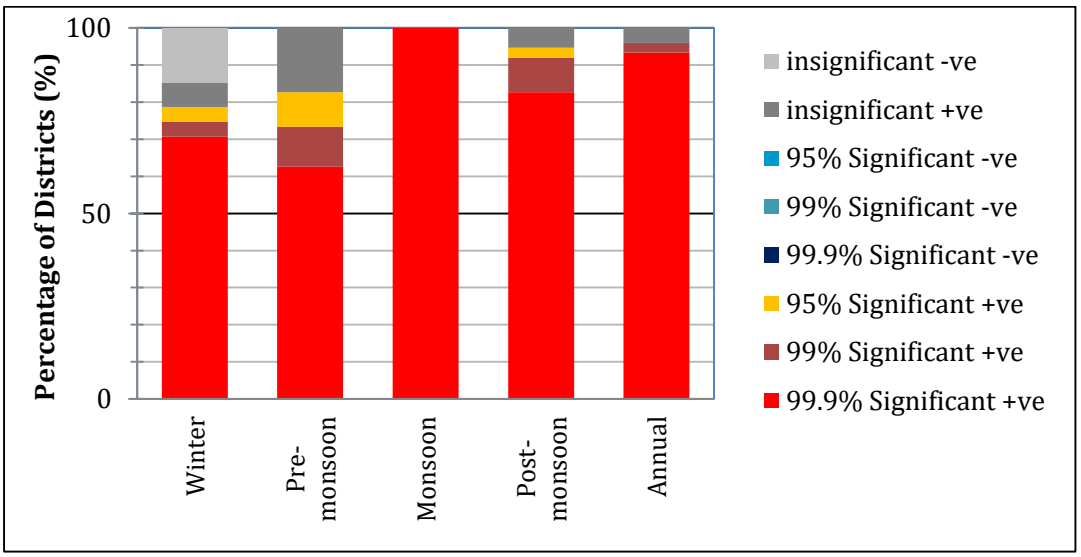
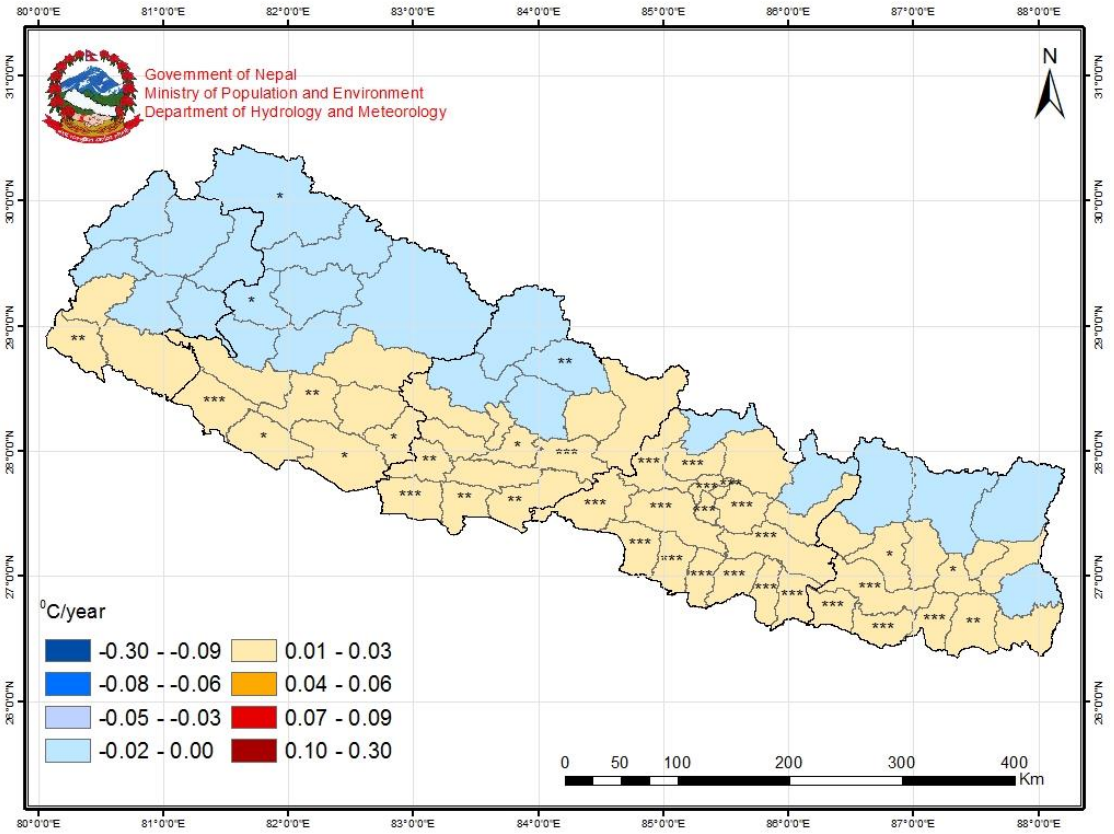


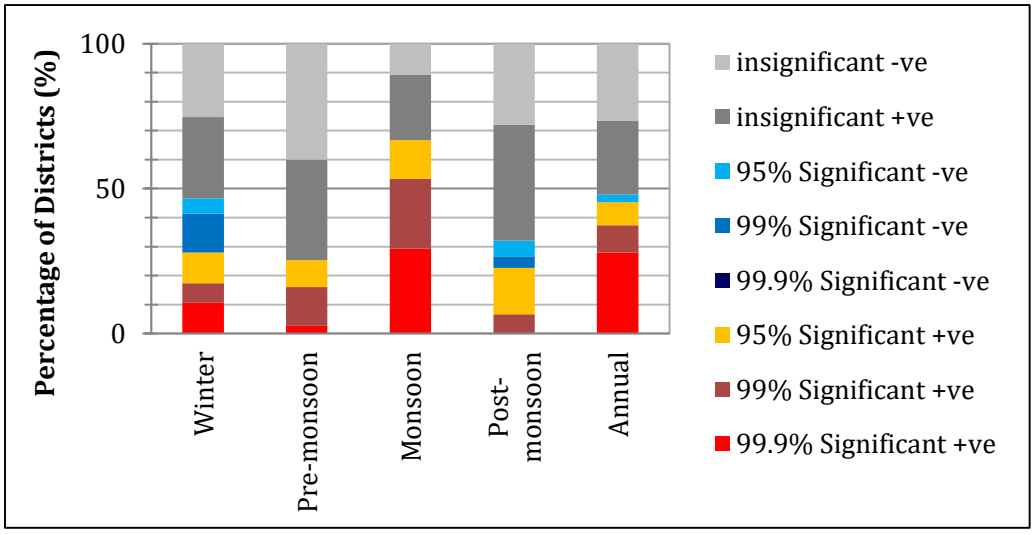
Figure 2.2: Number of districts (in %) with significance levels in maximum temperature trends

DHM (2017) has analysed annual and seasonal minimum temperature trends for districts and physiographic regions of Nepal. Annual minimum temperature trends in the districts of Nepal are shown in Figure 2.2a. All-Nepal minimum temperature trend is 0.002 °C/yr but not significant event at 95% confidence level. Annual minimum temperature showed a positive trend in low elevation districts and negative trend in high elevation districts, which is opposite pattern than that of maximum temperature trends. This pattern is slightly different in monsoon season with positive trend across the country but the magnitude of the trend is smaller in the higher elevation than in the lower elevations (DHM, 2017). For example, the minimum temperature in Terai showed the highest positive trend (0.025 °C yr^{-1}) in winter while High Himalaya and High Mountain regions showed the lowest increasing trend (0.013 °C yr^{-1}) in monsoon season. Minimum temperature signals are not as robust as that of the maximum temperature. Only about 30% of the districts show significant trends (either positive or negative) in minimum temperature (Figure 2.2b). Therefore, minimum temperature trends should be used cautiously in vulnerability assessment and preparing adaptation measures. District level minimum temperature trends are tabulated for all the seasons in DHM (2017) and can be used for vulnerability assessment.



Source: DHM (2017)

Figure 2.3: Annual minimum temperature trends in the districts of Nepal
(Significance: * 95% CL, ** 99% CL, *** is 99.9% CL; blank means insignificant at 95% CL)



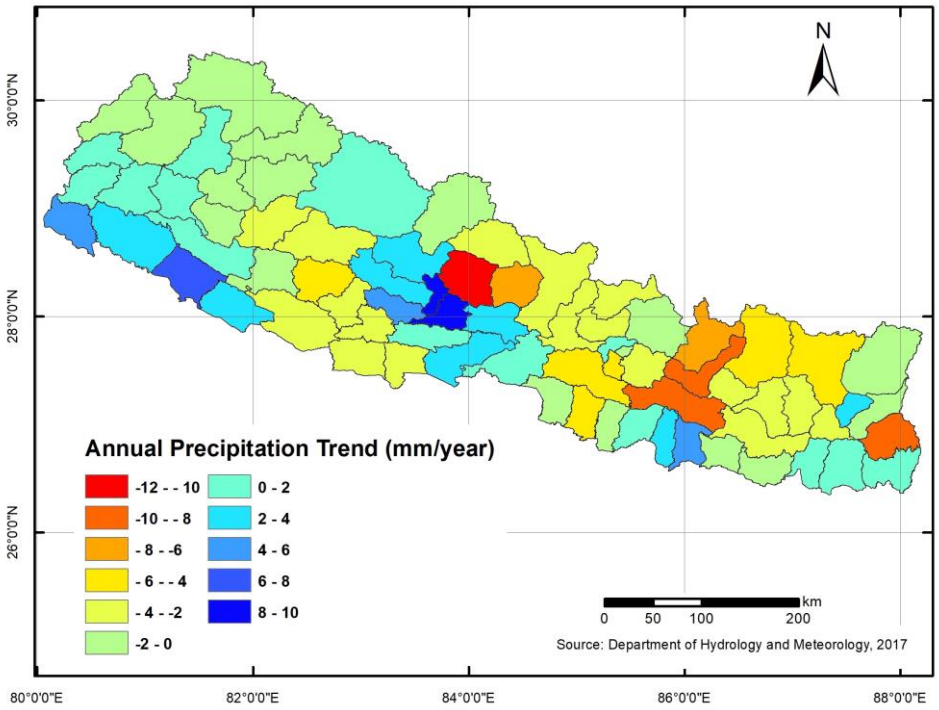
Source: DHM (2017)

Figure 2.4: Number of districts (in %) with significance levels in minimum temperature trends

2.1.2 Precipitation

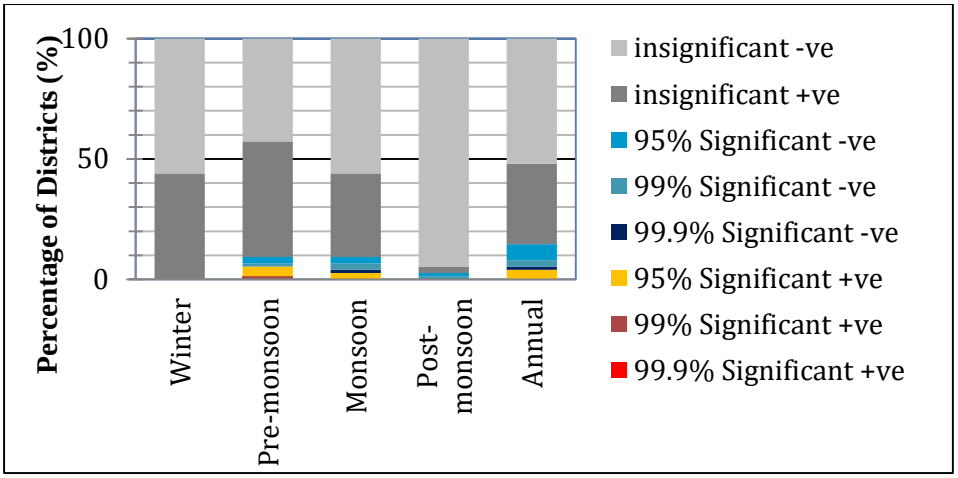
National report on observed climate trend of Nepal (DHM, 2017) presents trends in seasonal and annual precipitation for districts and physiographic regions. Figure 2.3a shows annual precipitation trends. The figure shows that in majority of high mountain districts annual precipitation trend is decreasing, with higher rate in the east. Among 5 physiographic regions precipitation is in decreasing trend mainly in High Mountains and High Himalayas in all the seasons (DHM, 2017). In monsoon, the highest significant increasing precipitation trend (9.0 mm yr-1) is found in Syangja and decreasing trend (-7.5 mm yr-1) is observed in Ilam district (DHM, 2017). Winter precipitation trend shows increasing trend in the Terai, Chure (Siwalik), and Middle Mountains while it is decreasing in High Mountains and Himalayas. The precipitation trends are even less robust compared to the minimum temperature signals in Nepal. Figure 2.3b shows that only less than 10 % of the districts showed significant trends (either positive or negative). Therefore, precipitation trends should be used cautiously in the vulnerability assessments.

Scientific studies about the trend of snow-precipitation are limited in the Himalayan region of Nepal. A study by Ménégoz et al. (2013) reveals that Western Himalaya can receive snowfall during the whole year. Therefore, future study needs to address this aspect of precipitation trend.



Source: DHM (2017)

Figure 2.5: Annual precipitation trend in districts of Nepal



Source: DHM (2017)

Figure 2.6: Number of districts (in %) with significance levels in minimum precipitation trends

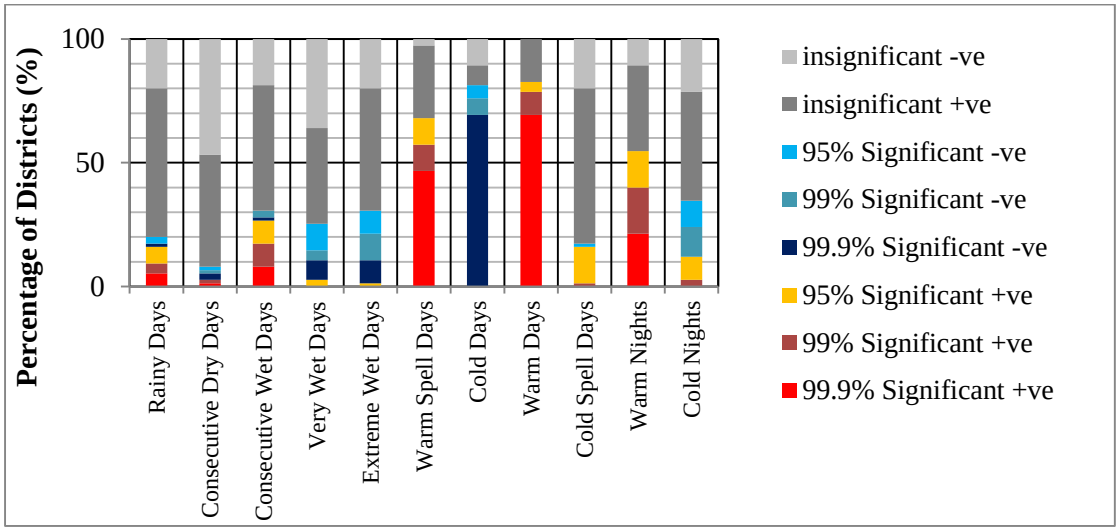
2.1.3 Extreme Climate Trends

Table 2.1: Extreme climate trends in Nepal based on observed data 1971-2014

	Extreme Climate Indices (Description)	**Trend pattern/regions**
Extreme Temperature Indices	1. Warm days (Percentage of days when maximum temperature >90th percentile) 2. Warm nights (Percentage of days when minimum temperature >90th percentile) 3. Warm spell duration (Annual count of days with at least 6 consecutive days when maximum temperature > 90th percentile)	• increasing in majority of districts
	4. Cool days (Percentage of days when maximum temperature <10th percentile)	• decreasing in majority of the districts
	5. Cool nights (Percentage of days when minimum temperature >90th percentile)	• increasing significantly (northwest) • decreasing significantly (southeast)
	6. Cold spell duration (Annual count of days with at least 6 consecutive days when minimum temperature < 10th percentile)	• increasing significantly only in the Far-western districts • Insignificant trends in other districts
Extreme Precipitation Indices	1. Number of rainy days (Annual count of days with daily precipitation > 1mm)	• increasing significantly in the north-western districts
	2. Very wet days (Annual total precipitation when daily rainfall >95th percentile) 3. Extremely wet days (Annual total precipitation when daily max rainfall >99th percentile)	• decreasing significantly, mainly in the northern and mountain districts
	4. Consecutive wet days (Maximum number of consecutive days with daily precipitation >1mm)	• Increasing significantly in the northern districts of Karnali Province and central part of Gandaki Province and Province 1.
	5. Consecutive dry days (Maximum number of consecutive days with daily precipitation <1mm)	• decreasing significantly, mainly in the north-western districts

Source: DHM (2017)

DHM (2017) has analysed in 11 climate extreme indices trends, of which 6 are extreme temperature indices and 5 are extreme precipitation indices. These indices and trends in climate extreme indices are summarized in Table 2.1 and the trend values can be obtained from DHM (2017). Extreme temperature trends showed more robust signal than the extreme precipitation trends. Warm days, warm nights and warm spell duration are increasing and cool days are decreasing significantly in majority of the districts, while cool nights and cold spell durations showed mixed signal (increasing in the west and decreasing in the east).



Source: DHM (2017)

Figure 2.7: Number of districts (in %) with significance levels in extreme climate trends

Extreme precipitation trends showed spatial variability and the significant level also indicates less certainty in the trends. Figure 2.4 shows number of districts with robust (significant) trend in the extreme climate indices. The figure shows that less than 30% of the districts have robust significant trend while the rest of the districts have insignificant trend.

2.2 Climate Change Projection for Nepal

The future changes in temperature and precipitation were projected by comparing two future periods: medium term (2016-2045) and long term (2036-2065) with the reference period 1981-2010. End of the century climate projections are also discussed. The results used in this section are based on MoFE (2018).

2.2.1 Temperature Projection

Table 2.2 presents the range of mean temperature changes, based on RCP4.5 and 8.5, for the medium-term, long-term and end of the century with respect to the reference period in different seasons. The Table shows that mean annual temperature increase is within the of 0.92 to 1.07 °C in the medium-term and 1.3 to 1.8 °C in the long-term and even higher rate at the end of the century. The highest temperature increase is projected for the post-monsoon season for both medium-term and long-term periods.

Table 2.2: Projected range of multi-model ensemble mean change in temperature (°C) of Nepal for different seasons in three time periods with respect to reference period

Seasons	Medium-term (2016-2045)		Long-term (2036-2065)		End of the Century 2071 – 2100	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Winter	1.0	1.2	1.5	2.0	2.1	4.0
Pre-monsoon	0.7	1.0	1.0	1.6	1.2	3.4
Monsoon	0.8	0.8	1.1	1.5	1.4	3.0
Post-monsoon	1.3	1.4	1.8	2.4	2.5	4.5
Annual	0.92	1.07	1.3	1.8	1.72	3.58

Source: MoFE (2018)

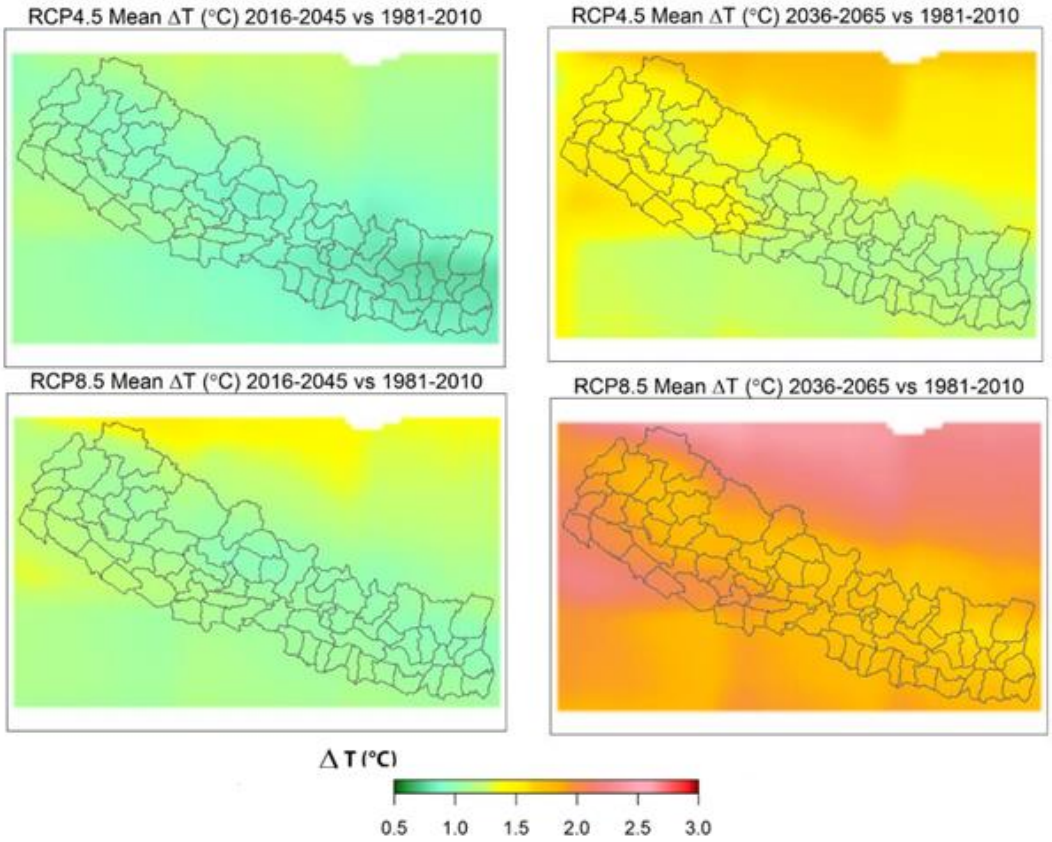
Table 2.3: Projected range of multi-model ensemble mean change in temperature (°C) in 5 physiographic regions of Nepal for three time periods with respect to reference period

Physiographic regions	Medium-term (2016-2045)		Long-term (2036-2065)		End of the Century 2071 – 2100	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
High Mountain	0.95	1.09	1.36	1.86	1.79	3.61
Middle Mountain	0.89	1.04	1.27	1.76	1.66	3.44
Hill	0.9	1.06	1.26	1.8	1.69	3.56
Siwalik	0.94	1.1	1.29	1.87	1.72	3.66
Terai	0.93	1.11	1.29	1.87	1.73	3.69

Source: MoFE (2018)

The ranges of mean annual temperature projection in physiographic regions are shown in Table 2.3. The Table shows that under RCP4.5 scenario, the highest temperature increase is in the High Mountains among the 5 physiographic regions for all three periods. Under RCP8.5 scenario, the temperature increase is maximum in the Terai and then second in the High Mountains in all 3 time periods. The annual mean temperature is projected to increase by 0.95 °C in medium-term and 1.36 °C in long-term in RCP4.5 for the High Mountains and by 1.11 °C in medium-term and 1.87 °C in long-term in RCP8.5 for Terai.

Moreover, spatial pattern of projected changes in mean annual temperature is shown in Figure 2.5 for medium term and long-term periods and values of changes for the districts are tabulated in MoFE (2018). The district values are useful for the vulnerability assessment.



Source: MoFE (2018)

Figure 2.8: Multi-model ensemble mean changes in average annual mean temperature in the medium-term (2016-2045) and the long-term (2036-2065) periods with respect to the reference period (1981-2010) for RCP4.5 and RCP8.5

2.2.2 Precipitation Scenarios

Table 2.4: Projected range of Multi-model ensemble mean change in precipitation (%) in three time periods for different sessions

Seasons	Medium-term (2016-2045)		Long-term (2036-2065)		End of the Century 2071 – 2100	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Winter	-5.8	7.2	13.6	5.0	24.4	20.9
Pre-monsoon	-5.0	-4.0	-7.4	4.2	-7.8	-3.1
Monsoon	2.7	7.8	9.4	13.6	12.4	27.1
Post-monsoon	18.6	6.0	20.3	19.0	16.5	22.9
Annual	2.1	6.4	7.9	12.1	10.7	23.0

Source: MoFE (2018)

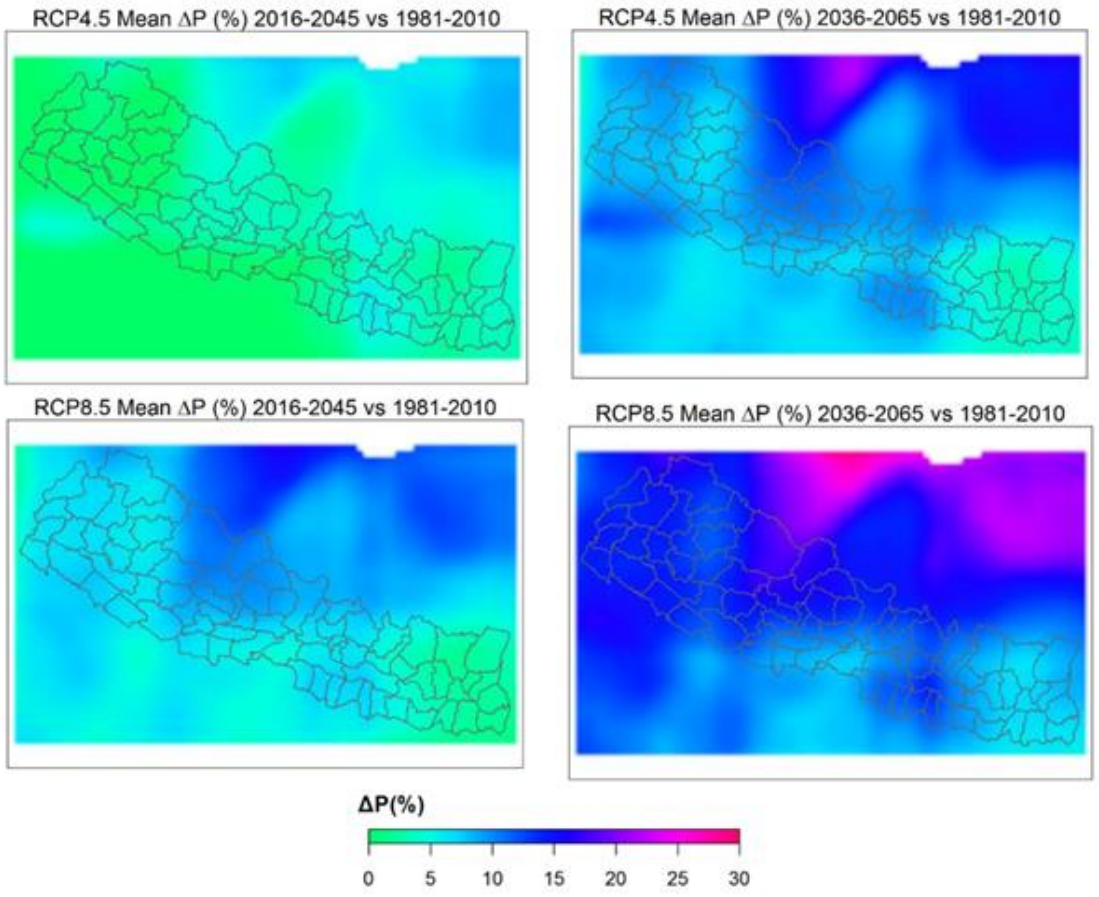
Table 2.4 presents the range of mean precipitation changes, based on RCP4.5 and 8.5, for the medium-term, long-term and end of the century with respect to the reference period in different seasons. Annual, monsoonal and post monsoon precipitation projections showed increase in precipitation all time periods for both RCPs (Table 2.4) while pre-monsoon precipitation is projected to decrease for both RCPs and

for all time periods (except for RCP8.5 in the long-term period). Winter precipitation is projected to increase in the long-term and at the end of the century for both RCPs. Maximum precipitation increase is observed during the post-monsoon season followed by the monsoon season. The end of the century period also suggests an increase in precipitation for all seasons except the pre-monsoon season.

Table 2.5: Projected range of multi-model ensemble mean change in precipitation (%) for different regions of Nepal in three time periods with respect to reference period

physiographic regions	Medium-term (2016-2045)		Long-term (2036-2065)		End of the Century 2071 – 2100	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
High Mountain	2.6	8.0	9.5	14.4	12.6	25.1
Middle Mountain	1.7	6.3	7.6	12.4	10.3	21.7
Hill	2.1	5.8	7.2	11.2	9.9	22.6
Siwalik	1.6	5.8	7.4	11.1	9.9	21.9
Terai	2.1	5.4	7.3	10.6	10.2	22.7

Source: MoFE (2018)



Source: MoFE **(**2018**)**

Figure 2.9: Multi-model mean change in average annual precipitation in the medium-term (2016-2045) and long-term (2036-2065) with respect to the reference period (1981-2010) for RCP4.5 and RCP8.5

Table 2.5 shows a mean change in annual and seasonal precipitation for different physiographic zones in three time periods. The changes in precipitation are higher in the High Mountains than other physiographic regions for most of the periods. The High Mountains is likely to warm at a higher rate than the rest of the regions, except Terai and Siwaliks in RCP8.5 scenario. Spatial pattern of projected changes in mean annual precipitation is shown in Figure 2.6 for medium-term and long-term periods and values of changes for the districts can be obtained from MoFE (2018). The district values are useful for the vulnerability assessment.

Snowfall is projected to decrease considerably because of temperature increase leading to reduction of snow storage, ultimately resulting in a distinct decrease in snowmelt runoff from non-glaciated areas (Nepal, 2016).

2.2.3 Projection of extreme indices

Table 2.6 shows mean change in extreme temperature indices (days) in medium-term and long-term with respect to reference period for Nepal. Compared to reference period, warm extreme events (warm days, warm nights and warm spell duration) are projected to increase while cold extreme indices (clod days, cold nights and cold spell duration) are projected to decrease for both medium-term and long-term periods. The rate of increase in warm nights is highest in both periods: (30.5-37.8 days) in the medium term and (43.3-59.6 days) in the long-term.

Table 2.6: Projected range of multi-model ensemble mean change in extreme temperature indices (days) in Nepal for in two time periods with respect to reference period

Indices	Mean annual days in the reference period (1981-2010)	Medium-term (2016-2045)		Long-term (2036-2065)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
	(Days)	(Days)	(Days)	(Days)	(Days)
Warm days	36.5	23.9	26.4	32.3	46.1
Warm nights	36.5	30.5	37.8	43.3	59.6
Warm spell Duration	17.6	19.3	27.6	26.2	43
Cold days	36.5	-15.4	-20.5	-19.3	-27.5
Cold nights	36.5	-15	-19.9	-19.7	-27.3
Cold Spell Duration	20.3	-10.5	-11.2	-12.9	-14.8

Source: MoFE (2018)

Table 2.7: Projected range of multi-model mean changes in extreme precipitation indices (days) in Nepal for two time periods with respect to reference period

Indices	Mean annual days in the reference period (1981-2010)	Medium-term (2016-2045)		Long-term (2036-2065)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
	(Days)	(Days)	(Days)	(Days)	(Days)
Very Wet Days	18.1	0.3	2.2	2.2	3.4
Extremely Wet Days	3.5	0.9	1.0	1.4	2.1
Rainy days	166.4	-3	-1.6	-1.7	-0.8
CDD	45.3	2.7	-0.7	1.1	-1.3
CWD	78.1	-3.3	2.5	-1	1.7

Source: MoFE (2018)

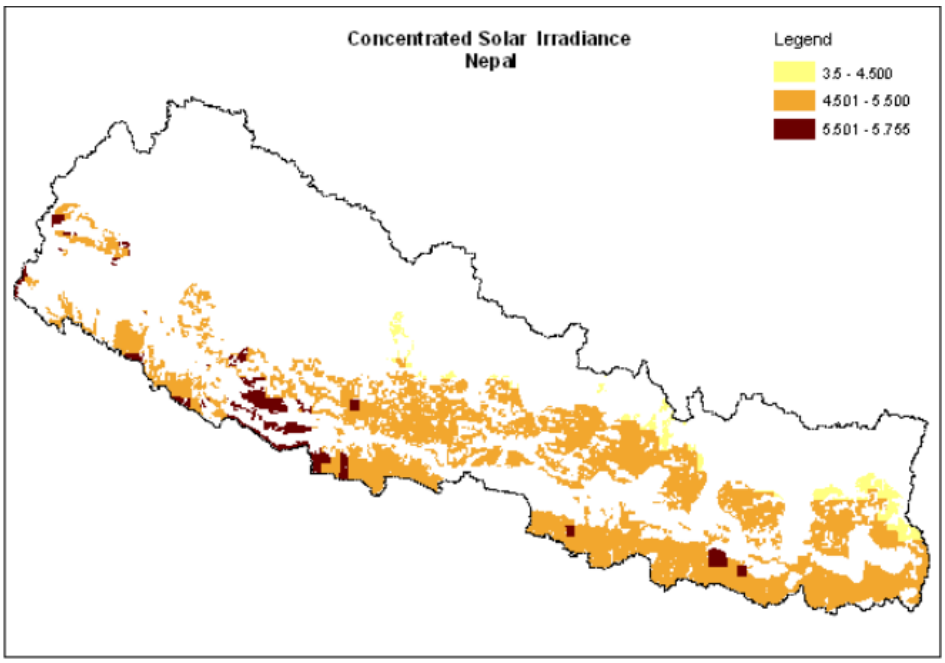
Compared to reference period, very wet and extremely wet days are expected to increase in future than in reference period (Table 2.7). Rainy days are expected to decrease in medium-term and long-term. This decrease is higher in RCP4.5 than in RCP8.5. Dry Spell and wet spells changes seems to be opposite in two RCP scenarios.

2.2.4 Wind and Solar Radiation Scenario

Alternative Energy Promotion Centre (AEPC) executed the Solar and Wind Resource Assessment (SWERA) project in 2008. Report published as the output of SWERA project is probably the most comprehensive literature available so far. Information contained in this section is based on the findings of the SWERA report 2008. Since 2018, the AEPC with support from the World Bank has been measuring the solar radiation and wind speed as a part of ESMAP project.

2.2.3.1 Solar Radiation

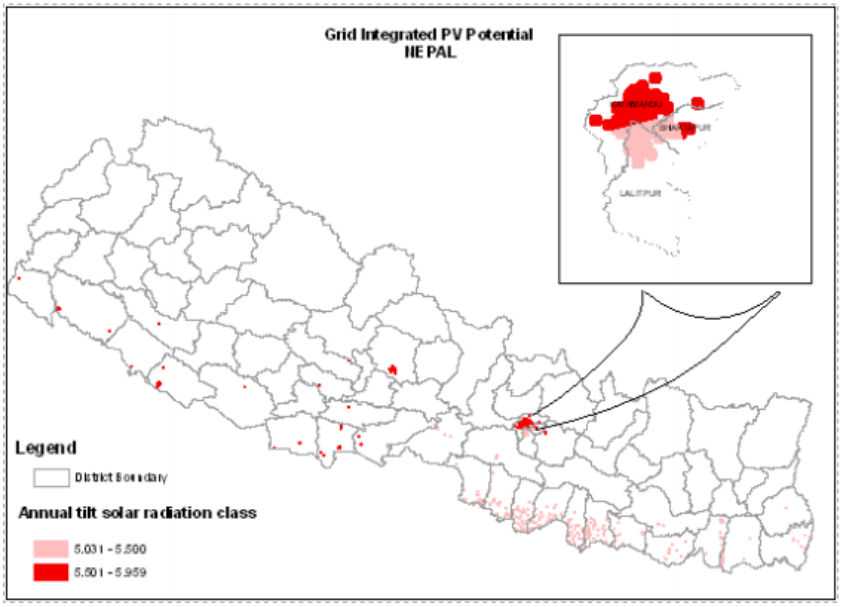
Figure 2.7 presents the map of potential Concentrated Solar Power (CSP) installation area in Nepal as identified by the SWERA report. SWERA reports that 2,729 km^2 areas receives average annual solar radiation greater than 5.5 kWh m^{-2} d^{-1} which, the report concludes, to have potential to generate 1,829 MW of electricity even if the 2% best solar irradiance is taken for power generation.



Source: AEPC (2008)

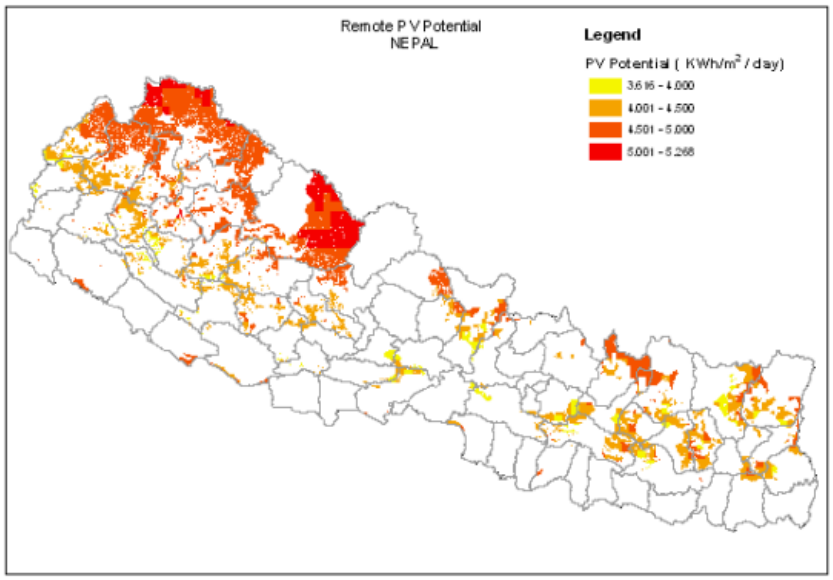
Figure 2.10: Concentrated solar power potential (kWh m^{-2} d^{-1})

The report came up with a total area of 2,167.98 km^2 as the potential area for the installation of the grid connected integrated photovoltaic (PV). Considering a power generation potential of 50 MW km^{-2} d^{-1} and assuming that 2% of the total potential area be exploited, 2100 MW electricity could be generated. Figure 2.8 presents the potential map for grid integrated PV potential of Nepal and Figure 2.9 presents the potential map for remote PV potential of Nepal.



Source: AEPC (2008)

Figure 2.11: Grid connected integrated PV potential



Source: AEPC (2008)

Figure 2.9: Potential remote solar PV for Nepal

2.2.3.2 Wind

SWERA report has identified a total area of 6074 km^2 as the area that has commercially viable wind power density (WPD) of 300Wm^{-2}. Considering 10% of the area as feasible for wind energy production at the rate of 5$MWkm^{-2}$, gross wind energy potential is estimated to be 3000 MW electricity. The report further analyses the case considering the commercially exploitable potential of wind power considering the area within 15 km from the existing national electricity grid as the potential area as 11 kV transmission line is available for power evacuation. This assumption has been made on the basis that power generated from wind farm within 15 km of the national grid will be viable for grid connection

considering the topography of Nepal. This analysis is basically bounded to the area connectable to the grid. Based on these criteria, the total wind power potential for the areas with wind density equal to or greater than 300 has been estimated to be 489 MW (Table 2.8).

Table 2.8: Area under different WPD

Wind Power density	Average WPD	Area (km^2)	Power Potential (5MW km^{-2})
<100	25	37,178.08	0
100-200	124	449.86	0
200-300	217	27.74	0
300-400	353	21.99	109.95
400-500	474	31.74	158.7
>600	819	44.07	220.35
Total		37,753.48	489

3. Sector-Wise Vulnerability and Adaptation

3.1 Agriculture and Food Security

3.1.1 Overview of Agriculture and Food Security Sector

Agriculture

Agriculture is the backbone of socio-economic development in rural Nepal. This sector employs more than 66% population (>70% of women population) and contributes more 27.6% Gross Domestic Product of the country (CBS, 2014; MoF, 2018). The total agricultural land of the country is 4,243,160 ha (29.7% of total area) with per capita availability of 0.082 ha and households owning less than 0.5 ha 51% (MoAD, 2014). Nepal's physiographic regions (Terai, Siwalik, Middle Mountains, High Mountains-consisting of inner Himalayan valleys, and the High Himalaya) are the key determinants of Nepalese farming systems production and variety of crops cultivated across the country due to heterogeneous elevation, climate, water-catchments, and agro-ecological zones. Paddy, maize, wheat, millet, buckwheat and barley are the major cereal crops grown in Nepal; among these, paddy and maize are the dominant cereal crops. Among the commonly cultivated crops in Nepal, rice, buckwheat, soybean, foxtail millet, and mango have higher genetic diversity as compared to other food crops (MoAD, 2017).

Livestock is also an integral part of the Nepalese farming system with cattle, goat, sheep and buffalo as major reared animals. The major livestock species reared by farmers in FY 2015/16 include 7.3 million cattle, 5.1 million buffalo, 10.9 million goats, 1.2 million pigs and 68.6 million poultry (MoAD, 2017). Livestock contributes over 10% of the national GDP and over quarter of the agricultural GDP (MoLD, 2017), and the sector alone outweighs the GDP of fishery and agricultural cash crop combined. Livestock also accounts for about 14% of total protein requirement (Farquher et al., 2018) and constitutes the highest portion of household income (Neupane et al., 2018).

Table 3.1: Livestock population by category or type of livestock in Nepal

Type of livestock	Number of holding	Number of heads	Per capita holding
Cattle	2,280,542	6,430,397	2.82
Buffalo	1,668,820	3,174,389	1.90
Sheep	98,464	612,884	6.22
Goat	2,463,253	11,225,130	4.56
Pig	477,984	870,197	1.82
Yak/Nak/Chauri	6,235	48,865	7.84
TOTAL	**6,995,298**	**22,361,862**	**3.20**

Source: MoAD (2017)

Fisheries employs 700 thousand people (53% women) and contributes US$ 154 million (>1.32% GDP) of total national income (MoAD, 2017). The demand for fish and fish products is on rise making the aquaculture and fisheries one of the fastest growing food sectors in the country. The demand is expected to further increase from 46,000 to 364,000 metric tons between 2008 and 2032 (94% from aquaculture and 6% from capture fisheries) (MoAD, 2017).

Economic growth rate of Nepal (FY 2007/08-2016/17) has been (on average) around 4.2% yr^{-1} over last ten years (MoF, 2017). Although agriculture is one of the prominent contributors to the Nepalese economy, government's investment in the sector has stayed as low as 23% of GDP in recent decades. Consequently, poverty, food insecurity and malnutrition continue to plague the country. Almost 50% households in the country are food insecure, nearly one-fourth are poor, and 14% are undernourished (MoALMC, 2018). The country also faces a huge agriculture trade deficit. Women have poor access to productive resources (especially land), which limits their ability to make long-term agricultural investments on the land. As a result, they are further pushed to food insufficiency (FAO, 2010). Poverty and food security are further exacerbated by climate change.

Newly enacted Constitution of Nepal has converted the unitary system of governance into federal system and divided powers and authorities for agricultural development and food security among federal, provincial, and local government levels.

Food Security

Large sect of Nepali people particularly poor and vulnerable suffers from under nutrition. Multi-Sectoral Nutrition Plan (MSNP 2018-22) in Nepal aims to address the problem of chronic malnutrition emphasizing the measures for its prevention. The goal of the plan is to improve maternal, adolescent and child nutrition by scaling up essential nutrition-specific and sensitive interventions and creating an enabling environment for nutrition. The plan has three outcomes (I) improved access to and equitable use of nutrition-specific services; (ii) improved access to and the equitable use of nutrition-sensitive services and improved healthy habits and practices; and (iii) improved policies, plans and multi-sectoral coordination at federal, provincial and local government levels to enhance the nutrition status of all population groups.

Table 3.2: Nepal's status on SDG nutritional targets

	SDG targets for 2030	**Base year situation (2011)**	**Progress (2016)**	**Nepal's SDG targets (2030)**
1	Achieve 40% reduction in the number of children unde-5 who are stunted	40.5%	35.8%	15%
2a	Achieve 50% reduction of anaemia in women of reproductive age	35.0%	40.8%	10%
2b	Achieve 50% reduction of anaemia in children	46.2%	52.7%	10%
3	Achieve 30% reduction in low birth weight	12.1%	24.2%	-
4	Ensure no increase in childhood overweight	1.4%	1.2%	-
5	Increase rate of exclusive breast feeding in first 6 months to at least 50%	69.6%	66.1%	-
6	Reduce and maintain childhood wasting to less than 5%	10.9%	9.7%	4%

Source: NPC (2017)

Though Nepal has significantly improved across the different types of malnutrition indicators like stunting, wasting, underweight, low body mass index, micronutrient deficiency, overweight and obesity, malnutrition continues to affect poor and sensitive people like children and women. Malnutrition contributes to be more than a third of child mortality in Nepal, and children who survive often lead diminished lives due to impaired cognitive development, reduced economic productivity and

the increased risk of malnutrition-related chronic diseases (National Planning Commission, 2017). At the same time the problem of overweight and obesity is increasing among urban population. Stunting among children and anaemia among children and women are still at high rate.

The plan has examined factors limiting the government's capacity to address food and nutritional issues. The plan identifies gaps and future needs for sustainable nutrition. It has proposed nutrition-sensitive approach dedicated to support food security and aims at strengthening governance to reinforce nutrition-specific and nutrition-sensitive approaches. The Plan with a budget of USD 193 million for five years, emphasizes strengthening of multi-sectoral nutrition information system to track the progress of implementation, with links to existing food security early warning system.

Agricultural Development Strategy (2015) proposed self-sufficiency in food grains by 2020 and five percent surplus by 2025. The plan is also to reduce food poverty from 24% in 2010 to 5% by 2035.

Table 3.3: Nutritional indicators and targets for ADS vision

Vision	Indicators	Existing Situation (2010)	Target Short Term (5 years)	Target Medium Term (10 years)	Target Long Term (20 years)
Self-reliance	Self-sufficiency in food grains	5% trade deficit in food grains	0% trade deficit	0-5% trade surplus	0-5% trade surplus
Food and Nutrition Security	Food Poverty	24%	16%	11%	5%
	Stunting	41.5%	29%	20%	8%
	Underweight	31.1%	20%	13%	5%
	Wasting;	13.7%	5%	2%	1%
	Women with low BMI	18%	15%	13%	5%

Source: MoAD (2014)

For food and nutritional security, a Monitoring and Evaluation system needs to be developed based on participatory knowledge management process and stakeholder coordination that can be helpful to share information on the status of eradicating poverty, hunger and malnutrition among all stakeholders. Policies such as the Zero Hunger Challenge (ZHC), ADS, Food and Nutrition Security Plan of Action (FNSPA), and MSNP have proposed several coordination committees and horizontal coordination structures at federal, regional, district, and local levels. The federal government will have a decisive role in coordinating actions across ministries and government offices down to the local level, channelling donor and civil society efforts, and developing compelling narratives around nutrition as a poverty reduction priority. ZH National Action Plan (2025) covers ways of creating ability of vulnerable groups in obtaining access to food and nutrition security as their basic rights. It proposed mechanisms for the identification of possible areas of improvements, which would ensure access to entitlement for food and related income generating opportunities.

3.1.2 Vulnerability and Impact of Climate Change

3.1.2.1 Impacts

The agriculture, fishery, and livestock sectors underpin Nepal's economic growth, local livelihoods, and food security. Although the majority of the population is engaged in agriculture, the sector is not fully developed. Productivity and competitiveness are low, adoption of improved technology is slow, and even though most cultivated areas are devoted to cereal crops, there is a growing food deficit and prevalence of malnutrition (MoAD, 2014).

Agriculture is significantly impacted by increasing temperature and extreme variability in rainfall. About 70% of the performance of crop production is determined by climatic variability, and rain deficit, drought and floods cause significant (between 10% and 30%) decline in crop production (IDS-Nepal, PAC and GCAP, 2014). Between 1971 and 2007, nearly 850,000 ha of planted crops were lost to weather and climate-related events. Of all hydro-meteorological hazards, droughts have had the most severe impact on crops which, for instance, alone account for 38.9% of the loss of agricultural crops, while floods account for 23.2% (UNDP, 2009). In 2006 alone drought caused losses of 11% in rice yield and 7% in wheat yield in Nepal (MoHA & DPNet-Nepal, 2015). On the contrary, higher altitude areas have observed early ripening of crops and increase in yield, with the increase in temperature and precipitation (Malla, 2008).

Livestock are affected by rising temperatures as their reproduction, breeding seasons, digestion pattern changes, often exacerbated by heat- and drought-related deaths and diseases (Wagle et al., 2011; Shrestha et al. 1999). Movement of herds and migratory species are also affected (Pokhrel & Pandey, 2011). Likewise, the impacts of climate change in fisheries are also noteworthy. Rise in temperature causes loss of fish and deterioration of water quality brings diseases and causes mass morbidity. Climate change is expected to cause a huge economic loss in agriculture sector. A recent Government of Nepal report estimates a 2–4% drop in current GDP per year due to climate change, with the need for USD 2.4 billion in adaptation by 2030. In the agriculture sector, losses to droughts for paddy alone amounted to USD 753 million from 2001 to 2010, with USD 75 million being lost on average annually (UNDP, 2013).

Increased temperature will result in increased evapotranspiration leading to increased irrigation water demand, and decreased river flows. It has been suggested that glacier-fed perennial rivers will be converted into rain-fed seasonal rivers after the glaciers disappear. The ratio of maximum to minimum flows of rain-fed rivers is substantially higher than that of snow-fed rivers indicating a possible future re-distribution of water among months after glacier-fed rivers will become the rain-fed ones. Furthermore, increased temperatures will widen the gap between the water supply and demand for irrigation. A water balance analysis of Bagmati river basin in Kathmandu Valley has shown that a one-degree centigrade rise in annual temperature may increase the water demand by 3.7% and reduce the annual river flow by 1.5% (Chaulagain, 2007).

Due to monsoon dominated flow pattern, the Bagmati River basin has already been facing water shortage during non-monsoon seasons, though there is surplus water during monsoon. The increase in temperature will further worsen the situation of too much water during rainy season and too little during dry seasons. Increase in frequency of climate extremes may lower crop yields (Tubiello et al., 2007). Increased evapotranspiration and increased soil moisture deficit due to increased temperature can have significant adverse impacts on agriculture production and food security. Water availability is a key component of food security as the availability of water supplies is the single most important factor in

food production (McGuigan et al., 2002). Changes in glacier melt, along with other changes in high-altitude hydrology, will affect agricultural production (Malone, 2010). Nepal's agriculture contributes to 31.2% of GDP (MoF, 2016). Due to climate variability and uncertainty, the small landholdings, subsistence farmers and the poorest of the poor will face the biggest adverse impact of reduced agriculture production due to reduced water availability, which ultimately may lead to the famine (Chaulagain, 2015).

Impact of Climate Change on Agriculture

- The impact of climate change is leading towards increased food insecurity in Nepal. Over 10% of decline in production is attributed to climate induced disasters and lack of adaptation action (MoSTE, 2013).
- Eleven percent in rice and seven percent in wheat yield reductions were recorded in Nepal due to drought in 2006. The drought in the eastern region decreased rice production by 30%, and heavy flooding in the mid-western and far-western regions in 2006 and 2008 destroyed crops in many places (FAO, 2016).
- The period from 1971 to 2007 is reported to have more than 150 droughts events in Nepal affecting about 330 thousand hectares of agriculture land (UNDP, 2009).
- Due to extreme weather conditions, the rice yield in the Terai region is projected to decrease by 10% by 2070s (MoSTE, 2014).
- The Third National Communication Report of Nepal (in the process) projects around1.6% decline in rice production and 15.5% decrease in wheat yield by 2020. In addition, it has also been estimated that food grain production in Nepal will decrease by 5.3% in 2020 (MoPE, 2016).

Source: NAP (2016)

Most studies on climate change and agriculture have focused on the analysis of climate change on crop productivity or farm incomes, with the two respective approaches used being crop models and Ricardian (econometric) analysis. Both of these have been applied in Nepal, and there is also a broader literature available on the future impacts of climate change in Nepal (Sherchand et al., 2007; Malla, 2008; Rai et al., 2011; Pokhrel & Pandey, 2011; Thapa & Joshi, 2010; Pant, 2011; Lama & Devkota, 2009; Bastakoti et al. 2011). A study conducted by MoSTE (2014) and Devkota et al. (2017) used the Decision Support System for Agrotechnology Transfer (DSSAT) model, a crop model (agronomic model) which assesses the soil-plant-atmosphere components for plant growth and yield, to evaluate the effects of future climate change on crop productivity in nine sample districts representing country; the physiographic zones and east to west (Table 3.4). The study targeted three major crops; the rice, wheat and maize, and the results are summarized in the following sections:

Table 3.4: Sample districts by region used in the DSSAT analysis

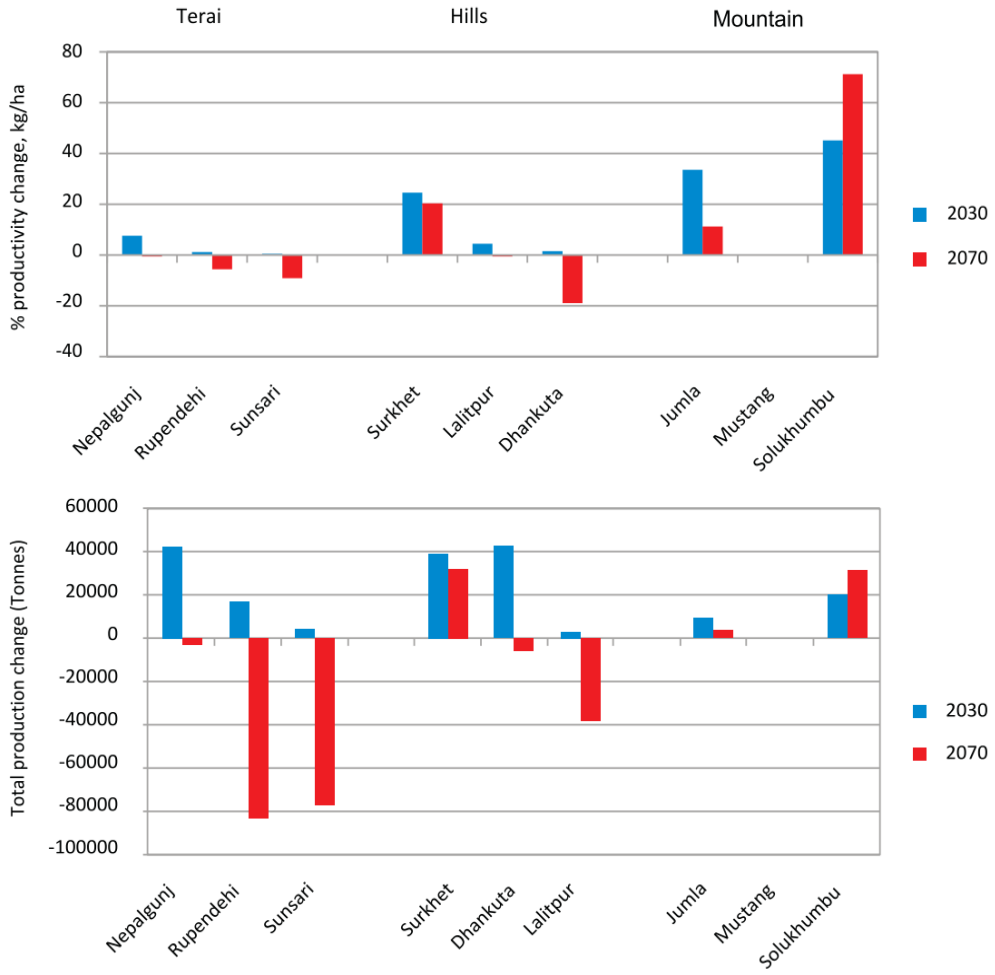
	West	Central	East
High Mountains	Jumla	Mustang	Solukhumbu
Mid-hills	Surkhet	Lalitpur	Dhankuta
Terai	Banke	Rupandehi	Sunsari

Rice

Rice is the most important crop in Nepal. It contributes nearly 20% to the agricultural GDP and provides more than 50% of the total calorie requirement of the Nepalese people. It is grown across some 1500 thousand ha and is the major crop, by area, grown in Nepal. The total production of rice (with husk) is about 5 million tons with average productivity of 3.3 tons per hectare.

The analysis of the impacts of climate change on rice production reveals relation with the changing climate trends over time (such as temperature and long-term rainfall trends). Results are shown for the change in yield in the 2030s and 2070s compared to the 2010s. Since most rice is currently produced in Terai, changes in production in this region are important in terms of national production.

The results show a complex mix of increase or decrease in yield which varies over time (2030s and 2070s) and by location (east to west/Terai to mountains). In Terai, the short-term analysis (2030s) indicates an increase in yields. However, in the longer-term (2070s) there will be reductions in rice yields up to 10%. This is due to a combination of lower rainfall and higher temperature during the growing season.



Source: MoSTE (2014a)

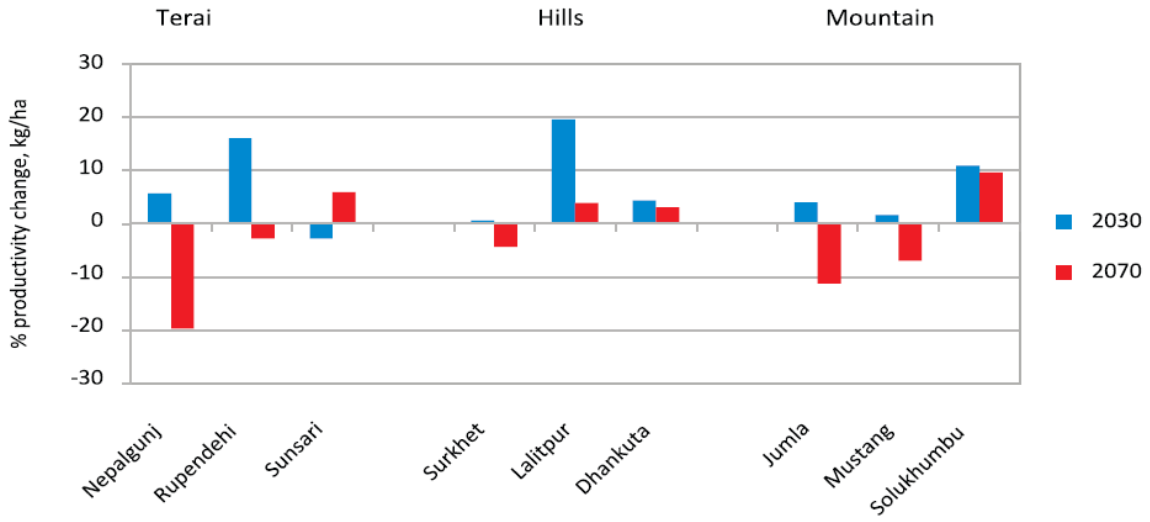
Figure 3.1: Top -Percentage change in rice yield from climate change, relative to baseline period.
Bottom - Total change in rice yield from climate change (based on production area), relative to baseline.

In the hill region, there is generally a more positive trend with productivity increase in the short-term (2030s), especially in the western district, driven by increased temperature during the growing season. In the longer-term (2070s), the pattern will be mixed: while a positive trend will continue in the west, there will be a decline in productivity growth for the east (almost 20%). In the mountain region, there will be a trend of increasing yield in the short and the long-term, due to rising temperatures during the growing season.

Maize

Maize is the second most important crop in Nepal, with a cultivated area of 870 thousand hectares, and a total production of just over 2 million tonnes (MOAD, 2012). It is particularly important in the hills, where it represents 78% of the total cultivated area. Average national productivity is, however, low with 2.5 metric ton per hectare.

The general trend for the impacts of climate change on maize is more differentiated than for rice. In the Terai region, there is an initial increasing production trend (in the 2030s) for the west and central areas (but not the east), followed by a sharply decreasing trend (20%) in the west in the long-term (2070s) (noting this is already a dry region). In the hills, there are increasing yields projected in the short-term (2030s), as well as in the long-term (2070s) in the east and central regions, but a small decline in the west in the long-term. In the mountains, there is a strongly increasing trend across all areas (though especially in the east) in short term. In the long-term (2070s) there are reductions in yield in western and central areas.

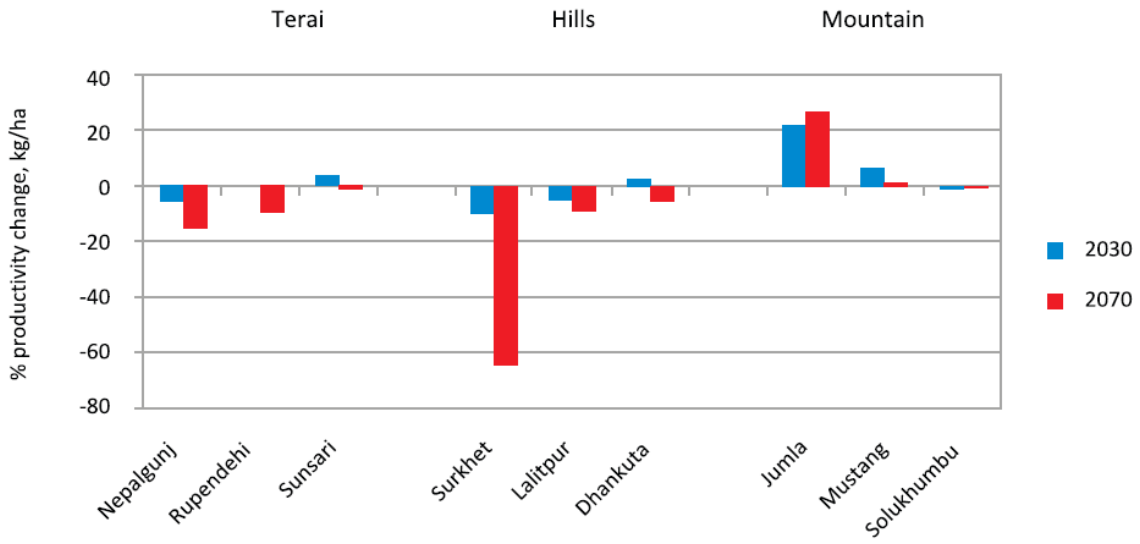


Source: MoSTE (2014a)

Figure 3.2: Percentage change in maize yield from climate change, relative to baseline period.

Wheat

Wheat is the third most important cereal crop in the country, grown over some 765 thousand hectares, and with annual production of around 1.8 million tonnes. Wheat is cultivated in 25% of the total cultivated land area and contributes 19% to the total national cereal production. The wheat yield in the base year (2010) is 2.41 tonnes ha^{-1}. The analysis of the impacts of climate change predicts an initial increase in wheat production (2030s), while there will potentially be large decreases in the central and western areas of the Terai in long-term (2070s). For the central and western region, higher temperatures will drive the decreases. For the hills, there will be more mixed impact in the 2030s, but with decrease in yields across all areas in 2070s. There will particularly be high decline in the western hills whereas only modest changes will occur in eastern areas.



Source: MoSTE (2014a)

Figure 3.3: Percentage change in wheat yields from climate change, relative to baseline period.

3.1.2.2 Vulnerability

Main climatic hazards affecting agriculture include flood, drought, windstorm, hailstorm, cold wave, heat wave, and various kinds of extreme events. Since a large number of people are involved in agriculture, proportion of population exposed to climatic hazards is very high. Agriculture and food security are also highly sensitive to climate change since climate change affects crop, livestock and fish productivity, food access, utilization and price stability (Paudel & Kotani 2013; Xiong et al., 2014). Floods, droughts and erratic rainfall are recurrent problems exposed to agriculture, livestock and fisheries (Sherchand et al., 2007). Since more than 50% of farming is dependent on natural rainfall, it is highly sensitive to drought (Adhikari, 2018).

Nepalese agriculture is represented by small holding farmers with almost half of them depending on natural rainfall. Of the total cultivated area, some 69.92% is irrigated while 30.08% area is rain-fed (MoAD, 2017). Major activities of irrigation infrastructure development have been primarily concentrated in the Terai. Much of the irrigation comes from surface flows; however, during the winter (dry) season, surface flow is reduced drastically and groundwater becomes the main source of irrigation. As a result, intensive irrigation in Nepal differs in summer and spring seasons. There is an increasing trend of groundwater utilization for irrigation. Statistics based on the land area by mode of irrigation has been presented in the table below:

Table 3.5: Status of irrigation in Nepal

SN	Land area by mode of irrigation	Values (%)
1	Surface irrigation	55.67
2	Ground water irrigation	29.38
3	New-technology based irrigation	0.42
4	Improved farmers irrigation canal	14.53

Source: MoF (2017)

Agriculture in Nepal is a highly climate sensitive sector. Climatic factors (like rainfall, temperature, humidity) are critical to crop yields. Historically, the sector has been affected by climatic extremes and studies indicate that the performance of crop production can largely be explained by climatic variability

and temporal weather conditions (Sherchand et al., 2007). The major hazards and climate extreme events that impact agriculture and food security are extreme hot and cold days, consecutive wet and dry days, extreme weather variability, and climate-induced hazards such as floods, landslides, crop inundation, drought, and hailstorms. These have negative impacts on crop and livestock productivity and food supply systems, which in turn have major implications for the livelihoods of poor and vulnerable households. The increasing trends in temperature and extreme events are high potential hazards for agriculture.

The evidence of climate change in Nepal indicates increasing temperatures and changing patterns of precipitation. There is increasing evidence of the effects of climate change on agriculture, particularly in developing countries (Rosenzweig & Parry 1994; Parry et al., 2004; Mendelsohn et al., 2006; Cline, 2007; Easterling et al., 2007; Lobell et al., 2008). These effects involve many potential climatic phenomena which can impact directly and indirectly on many aspects of crop production (e.g., crop distribution, growth rates, development and flowering, maturity periods) as well as wider agricultural supply and value chains. The potential effects of climate change on productivity from higher temperatures, and changes in rainfall and rainfall variability can be positive (such as CO_2 fertilization and extended growing seasons in colder regions) as well as negative (e.g. low rainfall). However, there may also be additional effects like changes in the length or timing of seasons and increasing intensity or frequency of extremes (floods and droughts), changes in pests and diseases (range and prevalence/incidence), factors affecting soil conditions or soil erosion, and from other impacts on the value chain (e.g. on rural roads). These risks affect various kinds of livelihoods, from farm level (subsistence farmers) to agricultural imports/exports, noting that the overall effect on demand and prices is linked to regional and global demand and production, and the effects of climate change elsewhere.

Sensitivity of agriculture to climate hazards, variation and extremes depends on crop phenology, availability of irrigation, plant varieties, livestock breeds, cropping pattern, fodder and forage availability and landholding size. For example, crop phenological cycle determines level of impacts of hazards and extreme events on the sowing period, early growth period, flowering period and harvesting period. Similarly, mono cropping practice is more sensitive to climate induced hazards and pest and insects because of the risk of loss and damage of the crops, more exposure for weeds production henceforth decreasing the yield of the crops. Fodder requires different climatic conditions and it has immense variation in growth as well as yielding ability of quality green fodder. The quality of green fodder changes with the variation with climate, which also impact the quality of animal products. Hence, the availability of fodder and forage in dry and wet season determines sensitivity of livestock to climate change. Nepal has very limited practice of growing fodder for livestock, but depends mainly on grazing. Degradation of grazing land due to climate change has made livestock sector more sensitive to climate change.

3.1.3 Adaptation Measures to Reduce Vulnerability

Adaptive capacity of Nepalese farmers is weak as they have poor human capital, inadequate physical capital, weak social and political capital, low level of economic capital and low level of productivity. The low level of human capital is due to limited knowledge of impacts of climate change, low level of awareness and limited skills and technical resources for climate change adaptation. The knowledge and skill in agriculture development, trained personnel and skill in agro-based technologies are weak.

Likewise, physical capital is inadequate. Infrastructure and tools and technology being used in agriculture is either traditional or of low quality. The infrastructure needed for adaptive capacity such

as road connection, bridges, collection centres, storage centre and communication centres are either absent in many rural areas or of low quality. Tools and machines used in agro-based industries are traditional.

Similarly, socio political system necessary for agriculture is weak. Crop and livestock insurance system is not well adopted, association with formal and informal groups are not so strong, linkage with saving and credit organizations are weak and linkage with financial institutions is poor due to deserving collaterals and necessary awareness. Political institutions like municipalities (Nagarpalika) and rural-municipalities (Gaunpalika) that are directly concerned with agricultural development at local level are recently instituted and their capacity is still weak.

Economic capitals like investment, machines, loan provisions are weak. Crop and livestock productivity are weak. Since the major sources of income of people are agriculture hence crop production is important for livelihood. The major crops such as maize, wheat and rice are for substance rather than for marketing. In the case of livestock production goat meat, poultry meat, buffalo milk, cattle milk and egg production are the main products but their productivity is low. The adaptive capacity of farmers in Nepal is very weak hence the farmers are highly vulnerable to climate change.

National Adaptation Programme of Action (NAPA) has recommended several adaptation programmes for reducing vulnerability to the climate change (MoE, 2010). It emphasizes on awareness raising, capacity building and technology transfer. Several technologies are already available that are useful for climate change adaptation and vulnerability reduction. But, the information on the level of adoption of these technologies is scanty.

Nepal Agriculture Research Council (NARC) is engaged in breeding drought-tolerant varieties of the crops such as Hardinath-1, Radha-4, Barkhe varieties of rice, Gautam and WK 1204 varieties of wheat and Manakamana, Rampur Composite, and Deuti varieties of maize. Additionally, NARC has released rice variety for submerged condition (IR 64). There is immense scope for climate change adaptation through developing drought tolerant varieties, submerged varieties, early maturing and pest resistance varieties, and varieties suitable for high temperatures. In addition, many farmers and some NGOs are also involved in developing crop varieties suitable for changed climatic conditions.

Government of Nepal has initiated a number of efforts to reduce vulnerability of climate change. These include: System of Rice Intensification (SRI); green manuring; conservation tillage practices; use of plastic house and water sprinklers; sustainable agriculture soil and water conservation; slope stabilization and landslide control; rainwater harvesting, rangeland and forage improvement; cultivation on river beds and shrub land; livestock shed improvement; bioenergy; and adoption of biogas. These efforts are in the beginning stage and need further revising and development along with other new initiatives.

3.2 Water Resources and Energy

3.2.1 Overview of Water Resources and Energy Sector

Water Resources

Nepal has immense water potential of 226 BCM per annum. However, very small proportion (around 15 BCM) has been utilized for socio-economic purposes (WECS, 2011). Out of the total water used, agriculture is the major water use sector accounting for 96% of total water use (WECS, 2011), around

3.8% for domestic purpose and only about 0.3% has been used for industrial purpose (ADB/ICIMOD, 2006). Since there is extreme seasonal variation in the availability of water in the rivers of Nepal, except for a few run-of-the river schemes, the larger perennial rivers have been virtually left untapped (WECS, 2011).

The energy sector is dominated by biomass as a primary source of energy, accounting for 80% of the total energy supply mix (ADB, 2017). In terms of electricity supply, there is dominance of hydropower. Therefore, vulnerability of hydropower sector to climate change is likely to represent overall vulnerability of energy sector in Nepal.

3.2.1.1 River System

The rivers of Nepal are generally characterized by a wide seasonal fluctuation of flows with the monthly flow generally reaching their maximum in July-August and declining to their minimum in February-March. The rivers with smaller catchment generally have wider flow fluctuations around the year. The total surface water available in the country per annum is equivalent to an average flow of 7,124 m^3s^{-1} including the total basin area and about 5,479 $m^3 s^{-1}$ excluding the area outside Nepal (WECS, 2002; cf. WECS, 2011; Table 3.4).

The available water resources are unevenly distributed in space and time in Nepal. About 78% of the average flow in Nepal is available in four major river basins, 9% in the medium basins and 13% in the smaller southern rivers of the Terai. The southern slopes of the Mahabharat range, the Himalayan range and the eastern two-third of Nepal receive the highest amount of precipitation and there is relatively high contribution of flows of the rivers within the catchments of these areas. About 74% of the total annual surface flow occurs in four months from June to September (WECS, 2011).

Table 3.6: Estimated runoff from the major river systems of Nepal

SN	Name of river	Length (km)	Drainage Area (km^2)		Estimated runoff ($m^3 s^{-1}$)	
			Total	Nepal	From all basin	From Nepal
1	Mahakali	223	15,260	5,410	698	247
2	Karnali	507	44,000	41,890	1441	1371
3	Babai	190	3,400	3,400	103	103
4	West Rapti	257	6,500	6,500	224	224
5	Narayani	332	34,960	28,090	1753	1409
6	Bagmati	163	3,700	3,700	178	178
7	Saptakoshi	513	60,400	31,940	1658	878
8	Kankai	108	1330	1330	68	68
9	Others	-	24,921	24,921	1001	1001
Total			**194,471**	**141,181**	**7124**	**5479**

Source: WECS (2002) cited from WECS (2011) & CBS (2013)

3.2.1.2 Lakes

Nepal has been reported to consist around 5,000 lakes, 1,380 reservoirs, and 5,183 village ponds (DOAD, 1992). IUCN inventory (1996) recorded 163 wetlands in Terai, and 79 in the hills and mountains. Similarly, 3,252 glaciers and 2,323 glacial lakes have been identified in the high mountain

region above 3500 masl (Mool et al., 2001). Recently, 5,358 lakes have been identified using the topographical sheets. Among them, 2712 (50.62%) are distributed below 500 m, 2227 above 3000 m and only 419 (<8%) are distributed in Mid-hill in the altitudinal range between 500 m and 2999 m (Bhuju et al., 2010; NLCDC, 2009). Presently, 10 Ramsar sites (Table 3.5), representing high altitude, mid-hills and low-land Terai wetlands are under the Wetlands of International Importance or Ramsar sites in Nepal that covers an area of 60,561 hectares.

Table 3.7: Lakes recognized as Ramsar sites in Nepal

SN	Name of Ramsar Site	Location	Inclusion Date	Area (ha.)	Elevation (m)
1	Koshi Tappu	Koshi	17 December1987	17500	75-81
2	Beeshazari and Associated Lake	Chitwan	13 August 2003	3200	286
3	Ghodaghodi Lake Area	Kailali	13 August 2003	2563	205
4	Jagadishpur Reservoir	Kapilvastu	13 August 2003	225	197
5	Gokyo and Associated Lakes	Solukhumbu	23 September 2007	7770	4700-5000
6	Gosaikund and Associated Lakes	Rasuwa	23 September 2007	1030	4000-4700
7	Phoksundo Lake	Dolpa	23 September 2007	494	3611.5
8	Rara Lake	Mugu	23 September 2007	1583	2990
9	Mai Pokhari	Ilam	28 October 2008	90	2100
10	Pokhara Valley Lake Cluster*	Kaski	02 February, 2016	924	-

Source: WWF Nepal, http://www.wwfnepal.org/?260713/Declaration-of-the-Pokhara-Valley

3.2.1.3 Glaciers and Glacial Lakes

About 23% of the total area lies above the permanent snowline of above 5,000 meter in Nepal (MoPE, 2004; cf. WECS, 2011). In 2001, it was estimated that about 3.6% of the total area of the country is covered by glaciers (Mool et al., 2001), whereas about 10% of the total precipitation falls as snow (UNEP, 2001). The first glacial inventory in Nepal, reported about 3,252 glaciers with a surface area of 5,324 km^2 and an ice reserve of 481.32 km^3 (Mool et al., 2001) (Table 3.8). The inventory also mapped all lakes above 3,500 m elevation and identified a total of 2,323 glacial lakes with an area of 75 km^2. However, the study carried out in 2009 has revealed 1,466 glacial lakes with an area of 64.78 km^2 (Ives et al., 2010; ICIMOD, 2011b; Table 3.9).

One of the most recent glacier inventories analysed Landsat satellite images of 2010 and reported 3,808 glaciers with an area of 3,902 km^2 with total ice reserve 312 km^3. The total number of glaciers was reported to be the highest in the Karnali and Gandaki basins, whereas the area and ice reserves were reported to be the highest in Gandaki and Koshi basins (Bajracharya et al., 2014). The average area of individual glaciers was reported to be less than 1 km^2 in the Mahakali and Karnali basins, greater than 1 km^2 in the Gandaki and Koshi basins, and just over 1 km^2 in overall. With respect to area-elevation distribution, two-third of the glacier area (2,577 km^2) lies between 5,000 and 6,000 m asl; less than 50 km^2 of glacier area has been reported to found in each 100 m elevation above 6,500 m asl and below 4,700 m asl. The study by Mool et al. (2001) and Bajracharya et al. (2011) have shown Gandaki basin has the highest elevation glaciers and the Mahakali basin has the lowest one (Table 3.8).

Table 3.8: Distribution of glaciers in the major river basins of Nepal

	2001 inventory*				2010 inventory**				
Basin	**Number**	**Total area (km^2)**	**Mean area (km^2)**	**Ice reserve (km^3)**	**Number**	**Total area (km^2)**	**Ice reserve (km^3)**	**Highest elevation (masl)**	**Lowest elevation (masl)**
Koshi	779	1,410	1.81	152.06	843	1,102.6	110.64	8,437	3,962
Gandaki	1,025	2,030	1.98	191.39	1,337	1,664.5	134.75	8,093	3,273
Karnali	1,361	1,740	1.28	127.8	1,461	1,022.8	60.04	7,515	3,631
Mahakali	87	143.34	1.65	10.06	167	112.5	6.97	6,850	3,695
Total	**3,252**	**5,324**	**1.64**	**481.31**	**3,808**	**3,902.4**	**312.40**	- -	- -

Source: *Mool et al. (2001); **Bajracharya et al. (2014)

Table 3.9: Distribution of glacial lakes and their area in the major river basins of Nepal

	2001 inventory*		2009 inventory**				
Basin	**Number**	**Area (km^2)**	**Number**	**Area (km^2)**	**Mean area (km^2)**	**Max area (km^2)**	**Min area (km^2)**
Koshi	1062	25.09	599	25.958	0.043	1.452	0.001
Gandaki	338	12.5	116	9.538	0.082	3.322	0.002
Karnali	907	37.67	742	29.147	0.039	4.814	0.001
Mahakali	16	0.38	9	0.137	0.015	0.049	0.003
Total	**2323**	**75.64**	**1466**	**64.780**	**0.044**	**4.814**	**0.001**

Source: *Mool et al. (2001); **Ives et al. (2010); cited from ICIMOD (2011)

3.2.1.4 Ground Water

Terai region of Nepal has a good potential of groundwater resources. With a thick layer of saturated sediments of alluvial origin, Terai is one of the most productive aquifers in the South Asian sub-continent (UNEP, 2001). It is estimated that the Terai region has a groundwater recharge potential of about 6.5 billion cubic meter and about 3.1 billion cubic meters in Chure/Bhavar making a total of 9.6 billion cubic m (JVS/GWP Nepal, 2014). The corresponding volume of water available for groundwater extraction is estimated to be between 5.8 yr^{-1} and 12 billion m^3 yr^{-1}. In the Kathmandu Valley, the annual rechargeable estimates vary from 4.6 million m^3 yr^{-1} to 14.6 million m^3 yr^{-1} (Pandey et al., 2014), however, groundwater extraction is already many folds higher than the recharge rate (Shrestha et al., 2012).

Groundwater extraction in Nepal for various uses (e.g., irrigation, domestic and industrial) is estimated at 1.935 BCM/year, of which nearly 1.8 BCM/year is used for agriculture and 0.46 BCM/year is for domestic purposes (Shrestha et al., 2018). There is huge potential of groundwater use for different productive uses in Terai areas and therefore contribute to national economy. Around 1,300 Deep Tube-wells (DTW) and 50,000 Shallow Tube-wells (STW) - excluding hand, rower and treadle pumps - have been installed in the country (WECS, 2011). The exact rate of decline in groundwater recharge because of climate change has not been estimated; it shows different trends of increase or decrease in different climate change scenarios (Brouyere et al., 2004; Chen & Chen, 2004).

3.2.1.5 Uses of Water Resources

Major water uses in Nepal are agriculture, hydropower, and domestic (including sanitation). Agriculture is the largest water use sector, which involves about 63% of the total population and contributes 31% to the Gross Domestic Product (MoF, 2016). The country has a cultivated area of 2,642,000 ha (18% of its land area); two-third (or 1,766,000 ha) of that is potentially irrigable. However, only 42% of the cultivated area has irrigation facilities so far and only 17% of the cultivated area has year-round irrigation (i.e., only 41% of the irrigated area gets year-round irrigation) (Table 3.10). In Terai, 82% of the total irrigated area (889,000 ha) is irrigated through surface irrigation and the remaining 18% through groundwater irrigation (WECS, 2011). Most of the present irrigated area (and future potential area) are situated in the fertile lowlands of the Terai. It is estimated that the irrigation schemes contribute approximately 65% of the country's agriculture production (WECS, 2005) as compared to the 40% crop output from 18% irrigated land in the world (Schultz, 2002).

Table 3.10: Irrigation potential and development in Nepal

Geographic Region	Total Area (10^3 ha)				Irrigated as % of cultivated	Year round irrigated as % of irrigated
	Cultivated	Irrigable	Irrigated	Year-round irrigation		
Terai	1,360	1,338	889	368	65	41
Hills	1,054	369	167	66	16	39
Mountains	227	60	48	18	21	38
Total	2,642	1,766	1,104	452	42	41

Source: WECS (2005, 2011)

Table 3.11: Existing major hydropower plants in Nepal

SN	Name of the river	Capacity (MW)
1	Kaligandaki A	144.0
2	Middle Marsyangdi	70.0
3	Marsyangdi	69.0
4	Trishuli	24.0
5	Sun Koshi	10.05
6	Gandaki	15.0
7	Kulekhani I	60
8	Devighat	14.1
9	Kulekhani II	32.0
10	Puwa Khola	6.2
11	Modi Khola	14.8
Sub-total		459.15

Source: NEA (2017)

Water use for hydro-energy is another key sector, which contributes to 1.09% of the national GDP. Considering all the electricity dependent sectors such as industry, construction, service and agriculture, they provide a substantial contribution to GDP (MoPE, 2017a). The hydropower potential of Nepal was estimated to be 83,000 MW in 1966, out of which only 42,000 MW was identified as technically and

economically feasible (Shrestha, 1966). The recent estimate at 40% dependable flows and 80% efficiency for the ROR hydropower potential in Nepal stands at 53,836 MW (Jha, 2010). At present, the country's installed hydropower capacity is only about 918.98 MW (NEA, 2017; Table 3.11), which is largely below the energy demand. Installed capacity, energy generation and other associated features of major hydropower plants under operation in Nepal are shown in Table 3.11. The National Energy Strategy of Nepal (2013) has vision to meet the demand for energy services by ensuring security, sufficiency, and sustainability for the economic development of the nation through the efficient use of indigenous energy resources and prioritized hydropower as a lead energy resource (WECS, 2013). Accordingly, Government of Nepal has initiated construction of storage hydropower projects such as Dudhkoshi (762 MW), Uttar Ganga (828 MW) and Andhikhola (180 MW) (NEA, 2017).

The domestic water demand, including sanitation, is the other water use sector in Nepal. According to Department of Water Supply and Sanitation (DWSS), national water supply facility coverage has reached 83.59% against the MDG target of 73% by 2015. In the same period national sanitation coverage reached 70.28% (NMIP, 2014). By ecological region, water supply facility reached 80.19% in mountain, 84.89% in hill and 84.78% in Terai. The sanitation coverage in 2014 reached 74.48% in mountain, 87.14% in hill and 56.93% in Terai (NMIP, 2014; Table 3.12).

Table 3.12: Water and sanitation coverage by region and ecological zone

Region	2010			2012					Mid 2014		
	Water	Sanitation	Projected	Total	Water		Sanitation		Water	Sanitation	Projected
	%	%	Population	HHs	HHs	%	HHs	%	%	%	population
EDR	76.4	42.2	6,374,298	1,142,476	885,902	77.5	560.752	49.1	82.45	62.58	5,997,378
CDR	81.3	46.1	9.859,227	1,723,142	1,340,244	77.8	894,612	51.9	85.21	62.77	10,324,734
WDR	84.6	53.5	5,468,946	900,637	791,925	87.9	623,169	69.2	82.84	80.6	5,076,207
MWDR	76.3	30.7	3,646,321	638,510	491,595	77.0	341,692	53.5	80.92	86.29	3,776,833
FWDR	83.32	29.1	2,694,765	43,2659	331,282	76.6	170,353	39.4	84.68	78.19	2,660,729
	Ecological										
Mountain	77.6	33.6	1,987,700	296,850	221,366	74.6	136,469	46.0	80.19	74.48	1,549,734
Hill	79.9	52.9	12,292,169	2,265,392	1,819,154	80.3	1,450,040	64.0	84.89	87.14	12,220,211
Terai	81.2	35.6	13,763,688	2,261,182	1,800,428	79.6	1,004,069	44.4	84.79	56.93	14,065,936
Nepal	**80.4**	**43.3**	**28,043,657**	**4,823,424**	**3,840,948**	**79.6**	**2,590.578**	**53.7**	**83.59**	**70.28**	**27,835,882**

Note:

Abbr.	Development Region
EDR	Eastern Development Region
CDR	Central Development Region
WDR	Western Development Region
MWDR	Mid-Western Development Region
FWDR	Far-Western Development Region

Energy Sector

Total electricity supply in 2018 was 7,057 Gigawatt-hours (GWh), nearly 63% of that was generated from hydropower (from Nepal Electricity Authority as well as Independent Power Producers) (Nepal Electricity Authority, 2018). Installed power generation capacity has grown steadily from 706 MW in FY2011 to 856 MW in FY2016, or by an average of 3.9% per annum. Interestingly, peak demand for the same period has increased even faster, from 946 MW to 1,385 MW, or by an average of 7.9% per annum (Table 3.13). In terms of energy, total energy supply has increased by 102%, from 5,789 kilotonnes (kton) in 1990 to 11,690 kton in 2014 (Table 3.14). The widening gap between demand and supply has been bridged to some extent by imports from India.

Table 3.13: Electricity demand, supply and deficit for the period of Fiscal Year (FY) 2011-2016.

Item			2011	2012	2013	2014	2015	2016	Annual Growth Rate (%)
Installed capacity (MW)*			706	7,19	762	787	787	856	3.9
Peak demand (MW)			946	1,027	1,095	1,201	1,292	1,385	7.9
Supply capacity shortage (MW)			240	308	333	414	505	529	17.1
Electricity requirement (GWh)			4,833	5,195	5,446	5,910	6,335	6,920	7.4
Supply (GWh)	NEA	Hydro	2,122	2,357	2,273	2,288	2,366	2,168	0.4
		Thermal	3	2	19	10	1	0.1	0
		Total NEA	2,125	2,359	2,292	2,298	2,367	2,169	0.3
	IPPs		1,039	1,074	1,176	1,070	1,269	1,173	2.5
	Imports		694	746	790	1,319	1,370	1,758	20.4
	Total		3,858	4,179	4,258	4687	5,006	5,100	5.7
Supply shortage (GWh)			975	1016	1,188	1,223	1,329	1,820	13.3

Source: ADB (2017b)

* includes power generation capacity of both NEA and IPPs. |
(GWh is Gigawatt-hour; IPP is Independent Power Producer; MW is Megawatt; NEA is Nepal Electricity Authority)

Table 3.14: Energy supply and consumption trend in kilotons of oil equivalent (kton) unit, 1990-2014

Item	1990	1995	2000	2005	2010	2014
Total Primary Energy Supply	**5,789**	**6,712**	**8,108**	**9,132**	**10,211**	**11,690**
Coal	49	74	258	248	303	484
Oil Products	244	501	713	724	983	1,359
Natural gas	0	0	0	0	0	0
Hydro	75	100	140	216	276	326
Biomass	5,425	6,039	6,988	7,928	8,592	9,403
Total Final Energy Consumption	**5,761**	**6,667**	**8,041**	**9,050**	**10,107**	**11,534**
Industry	106	161	379	388	449	665
Transport	111	203	270	275	637	858
Residential	5,465	6,170	7,199	8,128	8,718	9,624
Commercial and public services	43	60	97	165	171	219
Agriculture/Forestry	33	60	75	72	118	151
Non-energy use	4	7	11	20	10	8

Source: ADB (2017b)

Main source of primary energy in Nepal are biomass, oil products, coal, and hydropower. There is consistent dominance of biomass in the form of firewood, agricultural waste, and animal dung, as the source of energy supply over the years. The biomass contributes 80% of the energy supply mix, which is followed by oil products (12%), coal (4%), and hydro-electricity (4%) (Table 3.14). In terms of consumption, residential sector is the major consumer (84%) followed by transport (7%), industry (6%), commercial and public (2%), and agriculture (1%). The share of residential sector, however, is decreasing over the years; from nearly 95% in 2011 to 84% in 2016 (Table 3.14). It is because of increase in consumption of both industry and transport sectors were more than five-fold for the period of 2011-2016 whereas that of residential sector was less than two-fold (Table 3.14).

3.2.2 Vulnerability and Impacts Assessment

3.2.2.1 Impacts

Impacts of water resources and energy sector to climate change can be discussed from following lenses as did in Schaeffer et al. (2012): i) impact on resources endowment; ii) impacts on energy supply; iii) impacts on transmission, distribution, and transfer; iv) impacts on energy use; and v) impacts on infrastructure sitting.

a) Impacts on resources endowment

Water availability, its spatio-temporal distribution, and hydrological cycle are altered by climate change/variability, and therefore, impacts on resources endowment to this sector. The variations in climate phenomena have resulted in accelerated melting of glaciers, formation of glacial lakes in the mountain valleys and expansion of existing glacial lakes (Gardelle et al., 2011; Salerno et al., 2012) in Nepal Himalaya. This retreat of glaciers and associated change in hydrology affects availability of water resources and subsequent impacts on energy generation. For instance, the comparison of imageries and field-observation has shown formation of supra-glacial lakes in the Ngozompa and Imja Glaciers (Benn et al., 2012; Thakuri et al., 2016). Between 1975 and 2000, the area occupied by major lakes has also increased by 8.3% (WECS, 2011). The contribution of snow and glacier melt to total discharge during the period of 1985 to 1997 was about 34% annually, whereas it was 63% in the pre-monsoon season (March to May). Future projections indicate a 13% increase in annual discharge by mid-century followed by a slight decrease; and a 16% increase in evapotranspiration by the end of the century. The increase in annual discharge will result mostly during the monsoon season, leading to more frequent flood events (Nepal, 2016). The projected rate of change is not consistent across the country. For example, the figure is +15% by the end of century in Chamelia, a tributary of Mahakali river (Pandey et al., 2019a), and up to 50% in some sub-watersheds of Karnali river basin (Pandey et al., 2019b). The contribution of snowmelt is projected to increase by 90% by 2090 (Bajracharya et al., 2018).

The current trend analysis of discharge in Central Nepal revealed an increase in annual average, maximum, and minimum flows. This increase in streamflow coincides with the increasing rainfall trend of the yearly monsoon (June–September) and pre-monsoon (March–May) periods (Gautam et al., 2010). Glacial melt is expected to increase up to mid-century and start decreasing thereafter, which have impacts on resources endowments. The decrease in snowfall may result in an upward shift of snow-line (Nepal, 2016).

A study from the Everest region, specifically Imja Tsho Lake and Imja Glacier resulted that the lake had expanded from 0.03 to 1.35 km^2 between 1962 and 2013. In the lower part of glacier, it was noted that the mean glacier elevation had changed from -1.29 m yr^{-1} during 2001 to 2008 and 1.56 m yr^{-1} during 2008 to 2014 (Thakuri et al., 2016). Here, the changes in glacier dynamics, e.g., glacier thinning and expansion of glacial lakes, could be the consequences of change in precipitation and temperature (Thakuri et al., 2016). Another study in the Eastern Nepal showed that glaciers that do not contain debris have lost 11.2% of their area since 1992. At the same time, the number of glaciers has increased by 5%. The change in area of glaciers could be correlated with elevation, range of altitude, mean slope and area of glacier. Sixty-one small glaciers with 2.4 km^2 area have been found to disappear (Ojha et al., 2016).

ICIMOD (2011) has identified 21 glacial lakes to be potentially dangerous. These glacial lakes are classified into 3 categories. Among the 21 glacial lakes, six are classified as Category-1, four as Category-2, and 11 as Category-3. The Category-1 lakes include; Tsho Rolpa, Lower Barun, Imja Tsho, and Lumding, and Category-2 lakes include; Nagma, Hungu (2), and Tam Pokhari. Substantial areas of different land-use and land-cover have been reported to be exposed to potential GLOFs risk of major three glacial lakes- Tsho Ropla, Thulagi Lake, and Imja Tsho (Table 3.15).

Table 3.15: Land-cover types exposed to potential GLOF risks from the three lakes up to 100 km downstream

Land-cover type	Tsho Rolpa		Thulagi Lake		Imja Tsho	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture land	169.8	20.4	188.7	16.7	87.6	8.7
Forest	68.6	8.2	73.9	6.5	206.9	20.5
Shrubland	37.4	4.5	-	-	24.1	2.4
Grass	4.2	0.5	33.3	2.9	54.1	5.4
Barren land	38.1	4.6	15.6	1.4	35.8	3.5
River course	515.0	61.8	821.3	72.5	567.0	56.1
Other	-	-	-	-	34.4	3.4
Total	833.2	100	1132.8	100	1009.9	100

b) Impacts on energy supply

The amount of energy that can be generated from a hydropower plant depends not only on the installed generation capacity, but also on the variation in water inflows to the power plants, rate of temperature increase, and location of hydropower plant, among others. Changing climatic conditions may affect the operational plan of existing hydropower system, which are built based on historical records of climate patterns, and therefore, impacts on energy supply. Initially, the electricity generation potential may increase with the rise in temperature, and then gradually decline (NDRI/PAC/GCAP, 2017). Higher the rates of temperature increase in the future, earlier the peak of the electricity generation potential of the hydropower plant. However, the electricity generation (or energy supply) may also depend on the rainfall contribution, which is adversely affected due to changed precipitation pattern (i.e. too much of rainfall during monsoon and too little during non-monsoon seasons). Out of the total available energy

in 2012, less than 1% was harnessed from thermal sources and about 80% was from domestic hydropower plants (NEA, 2013). Because of the insufficient river flows during dry season, the existing hydropower plants could generate just around 30% of the total installed capacity of the hydropower plants (NEA, 2013). Decrease in glacier ice reserve causes decreased river-flow, further deteriorating the electricity generation situation. Another factors that relates to energy supply to a consumer is the geographical dispersion and the level of integration through transmission capacity. Highly interconnected transmission lines may play an important role is coping with regional climate variability by supplying adequate energy. Furthermore, characteristics of individual plants also influence the vulnerability of hydropower systems to climate change. Small ROR plants offer little operational flexibility and are more vulnerable to climatic variations compared to reservoir or storage plants.

c) Impacts on transmission, distribution, and transfer

Transmission and transfer of energy extend to thousands of kilometres and can therefore be exposed to a series of weather and climate events. For example, extreme winds, ice loads, combined wind-on-ice loads, avalanches, landslides, flooding, etc. are the climate/weather phenomenon that may impact on transmission, distribution, and transfer of energy. However, there is no data/information on these types of impacts of climate change in Nepal.

d) Impacts on energy use

In addition to energy generation and supply, climate change in the form of variations in temperature and rainfall may also impact on final energy use. For example, higher temperature may imply in lower demand for heating and higher demand for cooling. In addition, performance of motors and engines can vary with temperature. Similarly, climate change may also affect the water (and electricity) demand in industries and in agriculture for irrigation purposes.

e) Impacts on infrastructure sitting

Increase frequency and intensity of extreme events triggered by climate change may impose a new set of condition for which some of the existing water and energy infrastructure, may not have been projected to withstand. There is no comprehensive assessment on impacts of infrastructure sitting in Nepal, and therefore, an effort towards that end may provide useful feedback in designing future water and energy infrastructures.

3.2.2.2Vulnerability

Nepal's annual renewable water availability is 7,173 m^3 $capita^{-1}$ yr^{-1} (2014 value) (FAO-AQUASTAT, 2019), which is well above the global average water availability of 5,920 m^3 $capita^{-1}$ yr^{-1} (World Development Indicators, 2019) and the water stress level of 1700 m^3 $capita^{-1}$ yr^{-1}. However, due to topographical challenges, investment priorities, and other reasons, a large section of population and irrigation lands are still waiting for adequate access to water. The analysis of different scenarios of future temperature increase and the United Nations population projection have revealed that the annual renewable water availability in Nepal even in 2100 AD will be above the critical line of water stress (Chaulagain, 2015). However, water stress is already a common phenomenon during non-monsoon seasons within many regions of Nepal. Furthermore, pollution of river system, mainly in cities, due to disposal of untreated sewage in threatening ecological security. Despite existence of a wide variety of

issues, successful cases of appropriate management tools to deal with those challenges are hard to find. Water resources in Nepal are therefore vulnerable due to resources stress, development pressure and subsequent increase in demands, ecological insecurity, and management challenges (Pandey et al., 2012).

Inadequate access to water leading to water poverty is impacting differently among the sectors and income levels. The water issue that is leading to vulnerability is also mean different to different people and sector. For example, lack of safe drinking water and sanitation are the major water issues for poor people. Water scarcity for poor people, therefore, is not only about droughts or rivers running dry, but also threatening their rights for the fair and safe access to water needed to sustain their lives and livelihoods. Decreased runoff will make it harder to improve access to safe drinking water, which leads to additional costs for the water supply sector and higher socio-economic impacts and follow-up costs. In the areas, where water-induced extreme events become more intense and more frequent, the socio-economic costs of those events will increase significantly. Poor communities can be particularly vulnerable in such areas.

Any substantial change in the frequency of floods and droughts, or in the quantity and quality of water or seasonal timing of water availability, will require adjustments that can be costly, not only in monetary terms but also in terms of societal and ecological impacts, including the need to manage potential conflicts between different interest groups. Increased risk of food security, water shortage for industries and societies, decrease in hydropower generation, natural hazards like floods and landslides and potential migrations caused by them are some of the likely reasons that make different sectors vulnerable, which will ultimately increase vulnerability of water resources itself. Enhanced melting and increased length of the melt season of glaciers leads at first to increased river runoff and discharge peaks, while in the longer time-frame, glacier runoff is expected to decrease. The future socio-economic pathways will most likely increase the future water demand resulting in widening gap between water supply and demand, which will further exacerbate the existing water stress particularly during dry season (Chaulagain, 2015). As different locations and basins have their own biophysical, socio-economic, and institutional-policy characteristics, sources of vulnerability of water resources in various locations are likely to be different. For example, a study by Pandey et al. (2012) showed that medium river basin in Nepal are more vulnerable to large river basins. In large basins, vulnerability of water resources is mainly due to lack of management capacity followed by resources stress and less related to development pressure. In case of medium basins, due to their relative locations, sources of vulnerability are different in different basins and therefore no generic conclusions could be drawn.

In case of future vulnerability, increased temperature will not only affect the annual glacier mass balance, but also change precipitation pattern, i.e. more rainfall and less snowfall. Rainfall, unlike snowfall, will not be stored in the mountains, but will immediately be drained out from the basin resulting in less ground water recharge upstream and more floods downstream during the monsoon. Therefore, projected change in climate is likely to have exacerbate the vulnerability of water resources from various angles, such as increased risk of flash floods following glacial lake outbursts. MoEST (2012) has revealed that the water-induced disasters in Nepal are increasing in terms of magnitudes and frequency. Likely changes in the river flows in the future vary widely from river to river; the rain-fed rivers are likely to have a decreasing trend during lean seasons and an increasing trend during rainy

season; and magnitude of the change is expected to be relatively high in rain-fed rivers compared to the snow/glacier-fed rivers. Early shift of the hydrographs might also be possible (Chaulagain, 2016). All the aforementioned phenomena will render water resources more vulnerable and impact the normal water withdrawal pattern of the river.

Furthermore, in terms of vulnerability to GLOFs, different districts are likely to have different degree of vulnerability. Figure 3.4 shows ranking of the districts based on vulnerability to GLOF impacts. Six districts are identified as very highly vulnerable, six more are as highly vulnerable, and seven as moderate.

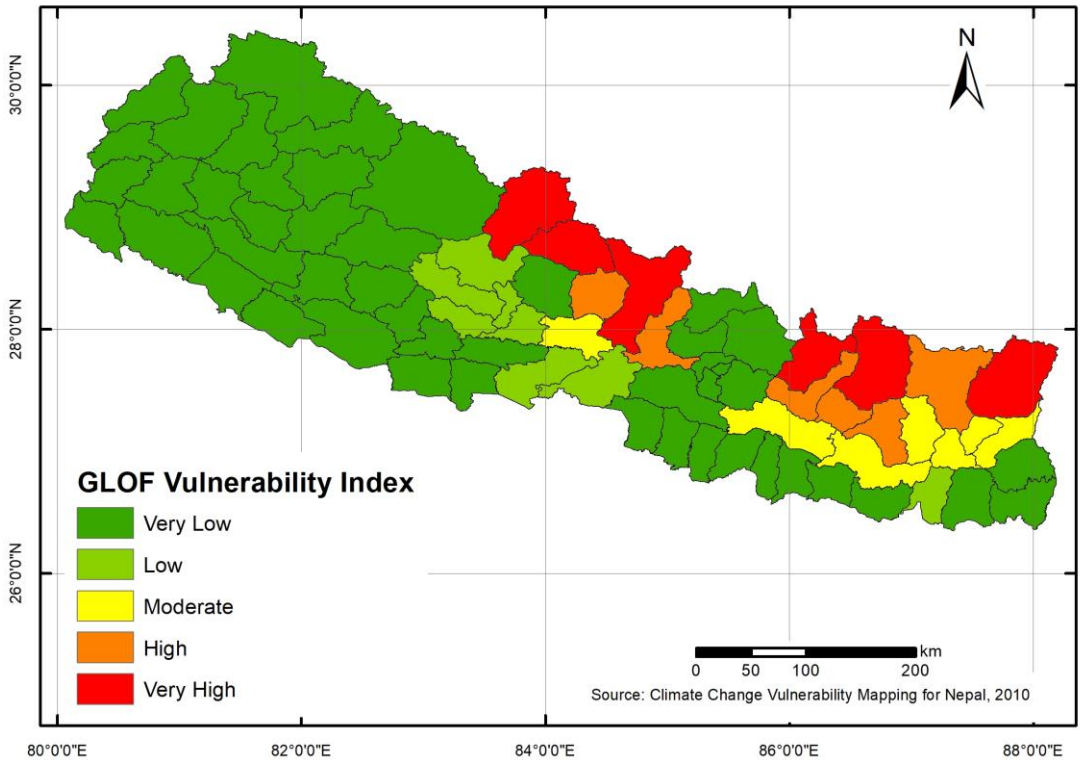


Figure 3.4: GLOF vulnerability ranking of different districts in Nepal

In terms energy sector in general, and hydropower in particular, it is affected by a multitude of issues and uncertainties. Climate change is the one more factor that is enhancing vulnerability of the energy sector. Climatic variability and associated hydrologic variability is likely to result high vulnerability for the overall energy system, and cause high economic impacts. Electricity operators will face large financial costs from low flows, high floods and sediment load and geo-hazards (NDRI/PAC/GCAP, 2017). The vulnerability, however, is influenced by catchment size, elevation and location, as well as type of plants. Climate change is likely to have the most impact on hydro-energy sector not only by altering hydrology, but also by increasing climate-induced hazards such as sedimentation, floods, and geo-hazards, including Glacial Lake Outburst Floods (GLOFs), and Landslide-induced Dam Outburst Floods (LDOFs). For a short-term, for existing as well as new planned hydro-electric plants planned for the next decade, the effects of current climatic variability, climate-induced hazards and particularly uncertainty regarding institutional and regulatory issues are likely to be more important (NDRI/PAC/GCAP, 2017). For the hydroelectric plants planned post-203, the impacts of climate change could be much more significant. For those plants, as we have more time to design, there are

opportunities to learn more from emerging trends and adjust these investments in light of climate change.

3.2.3 Adaptation Measures to Reduce Vulnerability

Technological measures have been applied to reduce vulnerability of climate change on water resources.

3.2.3.1 Early Warning Systems

The DHM, under the Ministry of Energy, Water Resources and Irrigation, is the institution for monitoring all hydrological and meteorological activities in Nepal. The DHM has 282 meteorological (http://www.dhm.gov.np/meteorological-station/) and 51 hydrological stations (http://www.dhm.gov.np/hydrological-station/) nationwide (DHM, 2018a). Based on the rainfall and water level data, and information acquired from these hydro-meteorological stations, a number of early warning systems have been placed to forewarn communities. For instance, DHM has set up a GLOF early warning system downstream from Tsho Rolpa glacial lake in the Tama Koshi River basin in the eastern Nepal. The system reportedly worked for a few years, but inadequate operation and maintenance, vandalism, and others led to the system becoming defunct (Ives et al., 2010). Likewise, the Bhote Koshi Power Company (BKPC) has set up an early warning system on the Bhote Koshi River. The BKPC carried out community awareness raising activities to inform and prepare the local people, and installed warning signs at four different river crossings. Similarly, DHM has made efforts to develop a web-based telemetry system in various rivers to provide real-time data and information on water levels and provide flood warnings to the various stakeholders. It has upgraded 11 hydro-meteorological stations in the Koshi River basin to improve flood forecasting and provide early warnings in real time. Moreover, there are community-based early warning systems.

3.2.3.2 Glacial Lake Lowering

To reduce the risk of GLOF incidence from the potentially dangerous glacial lakes, in 2016, the DHM has reduced the water level (3.4 m) of Imja Glacial Lake, one of the potentially dangerous glacial lakes of Nepal (Sharma, 2017). Further, the DHM had successfully mitigated Tsho Rolpa Glacial Lake by lowering the lake level by 3m in 2000 (Shrestha et al., 2004) through the construction of drainage channel for controlled discharge of water, the first of its kind in Nepal.

3.2.3.3 Climate-Resilient Water and Energy Infrastructures

Two potential options for adapting to hydro-energy sector could be retrofitting existing ones to reduce the risks of climate variability on current plants and/or over-design new plants to mitigate against all possible risks such as design to cope with the most extreme climate scenarios. The earlier one is often a very expensive option and is further complicated by existing power purchase agreements (PPAs), and the latter one also does not make a good sense in financial terms (Basnyat & Watklss, 2017). The decisions therefore are complicated by the nature of climate change and the economics of investment decisions. Early adaptation (to future climate change) has the potential to increase the costs of capital or operation of hydropower plants, and affects the rate of return for the entire project period. However, the benefits of these investments in terms of reduced damage from climate change will arise in long-term. The effective adaptation depends not only in identifying appropriate option and investing, but also on understanding the institutional context and barriers and addressing them.

3.3 Forests and Biodiversity

3.3.1 Overview of Forests and Biodiversity Sector

Nepal occupies a unique geographic position on Earth, possessing high elevational and climatic variation within the small area (147, 181 km^2) which ranges from 59 m to 8,848 m, (the highest point in the world). Nepal's unique geography with its dramatic changes in elevation along the relatively short (150-250 km) north-south transect and associated high variability in the physiographic and climatic conditions have resulted in a uniquely rich diversity of flora and fauna (MoFSC, 2014). Nepal is also considered a crossroad of plant migration in the Himalayan region, with rich floral diversity Nepal. Its phytogeographical provinces comprise various vegetation types, including tropical lowland rain forest (*Shorea robusta* forests), temperate forests of oak and conifers in the mid hills to dwarf scrubs of rhododendron and alpine meadows in the higher regions (MoFSC, 2014; Miehe et al., 2015). Within Nepal the amalgamation of various floristic elements includes drier Western and Central Asiatic floral provinces, a more humid Sino-Japanese province, South East Asiatic elements penetrating into the foothills of Eastern Nepal, African-Indian desert elements towards the western part of Nepal, and typical Indian floristic elements in the southern part (Welk, 2016). This in turn, furnishes Nepal with 118 different ecosystems with 75 vegetation types, providing ecosystem services to the people living within broader range of geographic and climatic conditions (MoFSC, 1995).

Nepal occupies about 0.1% of the global area, but harbours 3.2% and 1.1% of the world's known flora and fauna respectively (MoFSC, 2014). This includes 5.2% of the world's known mammals, 9.5% birds, 5.1% gymnosperms, and 8.2% bryophytes. A total of 312 flowering plants, 160 species of animals (including one species of mammal), one species of bird, and 14 species of herpetofauna are reported to be endemic in Nepal. The richness of endemic plant species increases steadily from low to high elevations. The high-altitude rangelands are especially important from the perspective of endemism (MoFSC, 2014, Tiwari et al., 2019). Multiple overlapping and interacting gradients based on topography and climate are active in a heterogeneous landscape (Dewar & Richard, 2007; Slaton, 2015), such as in Nepal, which forms an incredible distribution of flora and fauna. The first systematic classification of phyto-geographic boundaries based on climate, vegetation and floristic composition has classified Nepal's forest into 35 types (Stainton, 1972). These types are often categorized into 10 major groups; i) tropical, ii) subtropical and broadleaved, iii) subtropical conifer, iv) lower temperate broadleaved, v) lower temperate mixed broadleaved, vi) upper temperate broadleaved, vii) upper temperate mixed broadleaved, viii) temperate coniferous, ix) sub-alpine, and x) alpine scrub (MoFSC, 2014).

Although Nepal is a repository of unique biodiversity, the documentation of biological resources is not adequate and many areas in the Nepal Himalayas are still unexplored due to their remote and inaccessible locations and lack of resources. For example, Nepal is still struggling to complete the long-awaited Flora of Nepal project despite an early start of botanical exploration in Nepal Himalayas by Buchanan-Hamilton (1802-03) and N. Wallich (1820-21) (Miehe et al., 2015; Rajbhandari et al., 2017). Assessing spatial distribution, conservation status, and threats to biological resources is necessary for the formulation of effective conservation actions and their implementation in order to conserve the unique biodiversity of the region.

Forests cover over one third of the Earth's land surface that are vital to human's very existence (Millennium Ecosystem Assessment, 2005). Forests have been increasingly recognized as a key component of global climate moderation (Bonan, 2008), streamflow regulation, purification, and erosion control (Segura et al., 2013), carbon sequestration (Pan et al., 2011), and many other ecosystem services that humans need (Millennium Ecosystem Assessment, 2005). Forest and fresh water resources are increasingly threatened by ongoing global climate and land cover changes, despite the fact that human civilizations originate from forests and water (Ryan et al., 2012). One of the emerging challenges of the modern era across the planet is the fresh water scarcity due to increasing population growth, land use change such as deforestation, and climate change variability (Vörösmarty et al., 2000). The global change has resulted in a series of chain reactions in both natural ecosystems and human dominated systems, and there has been a growing concern over watershed degradation, water scarcity, poverty, and social sustainability due to the fact that such global changes require new approaches to manage forests and water resources. Currently, there is little science-based guidance for resource managers and policy makers to adapt to the novel and ever-changing environment in the 21st century (IPCC, 2007a), and it is highly challenging to manage biological resources in poor countries like Nepal where majority of poor people rely on forest resources for their livelihood. Although the recent government report has indicated overall increased forest cover in comparison to that of 1980, 1990; there has also been substantial forest cover decline in lower plain area of Terai and Chure as well as from western Nepal (DRFS, 2015). Climatic changes in Nepal have significant impact on forests of lowland as well as mountains in terms of forest composition, tree biomass production and range shift of tree species. Hence the understanding of the interactions among forests, climate, water resources, and human activities is essential in advancing actionable science and developing robust climate change mitigation and adaptation strategies and methodologies globally as well as regionally.

3.3.2 Vulnerability and Impact Assessment

3.3.2.1 Impacts

In Nepal, we have already seen the impacts of rapidly changing climate, and the changes are observed both in high mountains, mid hills and low lands. It has been quite clear that the maximum temperature has the highest increasing trend than that of minimum and mean temperature in Nepal, and the precipitation trend over whole Nepal showed slightly increasing besides the relatively dry regions of west Nepal (Shrestha et al., 1999; DHM, 2015). Meteorological data indicated that warmer days are right ahead with unpredictable precipitation patterns in Nepal which corresponds to the global trend as indicated by IPCC (2014). Some of the known impacts of climate change on forests and biodiversity in Nepal are: (i) shifts in agro-ecological zones, prolonged dry spells, and higher incidences of pests and diseases, (ii) increased temperature and rainfall variability, (iii) increased emergence and quickened spread of invasive alien plant species, (iv) increased incidence of forest fire in recent years, (v) changes in phenological cycles of tree species, (vi) upward shifting of treeline in the Himalaya, and (vii) depletion of wetlands (MOSTE, 2010).

Forests and biodiversity are considered to be one of the highly crucial climate sensitive thematic sectors in Nepal as identified both by NAPA (2010) and NAP (2017) documents. There have been considerable shifts in agro-ecological zones, prolonged dry spells, and higher incidences of pests and diseases

throughout Nepal (As per the NAPA documents of MOSTE, 2010), this is mainly attributed to increased temperature and rainfall variability. Similarly, highly rapid biological invasion is seen in Nepal with new alien and invasive species and their emerging (MoFSC, 2014). Extreme climatic conditions have also led to increased incidence of forest fire affecting human as well as productive forestland, increased disaster risks such as urban flood, lightening, landslide, hailstorms etc. Seasonal changes have also been observed in terms of early sprouting, flowering and fruiting. Similarly, National Biodiversity Strategy and Action Plan 2014-2020 of Nepal outlines following climate change impacts in the forests and biodiversity sector.

a) The climate range of many species will move upwards in elevation from their current location. This will have different effects on species. Some species will migrate through fragmented landscapes whilst others may not be able to do so.
b) Many species that are already vulnerable are likely to become extinct. Species with limited climate ranges and/or with limited geographical opportunities (e.g. mountain top species), species with restricted habitat requirements, and/or small population are typically the most vulnerable.
c) Changes in frequency, intensity, extent and locations of climatically and non-climatically induced disturbances will affect how and at what rate the existing ecosystems will be replaced by new plant and animal assemblages. The High Himalaya and High Mountain ecosystems are likely to be worst affected by climate change. Among the natural habitats, remnant native grasslands are highly vulnerable to the impacts of climate change (BCN & DNPWC, 2011).
d) The impacts of climate change are likely to increase in future, which will not only affect biodiversity but also livelihoods of millions of local and indigenous people who depend on biodiversity. Disruption of ecological services on which they depend due to climate change is expected to especially affect the poorest and most vulnerable communities.

a) Impact on Forest Ecosystem

Plant species which are highly sensitive to changing climate are most vulnerable to climate change in all ecological zones of Nepal. The rate of deforestation in Nepal is very rapid, following the global trend, which is further exacerbated by changing climate and increased anthropogenic pressure in the region. According to Reddy et al. (2018) the forested area of Nepal decreased from 76,710 km^2 in 1930 to 39,392 km^2 in 2014, accounting a net loss of 37,318 km 2 (48.6%) in last eight decades. According to this estimates the annual rate of net deforestation for the recent period was 0.01% during 2005–2014, and the increase in the number of forest patches from 6925 (in 1930) to 42,961 (in 2014), that has definitely created a huge mismatch in species distribution in Nepal. High mountain forests have already shown their response to increasing warming and altered environmental conditions in Nepal, upward shifting of treeline has been observed for species such as *Abies spectabilis* and *Betula utilis* (Gaire et al., 2017, Tiwari et al., 2017a, Sigdel et al., 2018). This shift of ecological zone along with competition with existing species has made some tree species like Birch (*Betula utilis*) and Taxus (*Taxus baccata*), Cedar (*Cedrus deodara*) highly vulnerable (MOFSC, 2011). In Trans-Himalayan zone of Mustang, the warming induced growth decline has been reported for *Betula utilis* (Tiwari et al., 2017b), which may reduce the reproductive performance and affect survival of the species in the region.

The government report (MoFSC, 2011) has also indicated that mountain plants will be affected by overall warming with changes in precipitation pattern. Fringe forests are more vulnerable to landslides. In case of mid hills, trees species such as Banjh (*Quercus lanata*), Kharsu (*Quercus semecarpifolia*),

Katus (*Castenopsis indica*), Champ (*Michelia champaca*) are becoming more vulnerable due to rise in temperature. Upward shifting has also been experienced in trees like utis (*Alnus nepalensis*). Similarly, diseases such as stem borer (Benikira) and Aijeru or mistletoes (*Scurrula* sp.) have been reported in fodder trees like *Ficus sp*. Farmlands have been infested by defoliator resulting ultimate death of trees. Another insect named Guheykira (*Scarabaeoida* sp.) has also been found to be infested in Banjh (*Quercus leucotrichophora*) and Painyu (*Prunus cerasoides*).

In case of Terai area, Sal (*Shorea robusta*) trees have reportedly been infested by caterpillar during March-May. Due to prolonged seasonal drought, incidences of forests fires are increasing, and plants with broad-leaves are prone to fire and cannot thrive in stress conditions (MoFSC, 2014). Invasion and rapid expansion of some alien species, such as *Mikania micrantha*, *Ageratina adenophora* (syn *Eupatorium adenophorum*), *Chromolaena odorata* and *Lantana camara* has emerged as a major threat to forest biodiversity especially in case of degraded land (Thapa et al., 2018). For example, *Mikania micrantha* is a climber that spreads extremely fast over forest canopy, and blocks sunlight for native plants, and eventually kills them or stunts their growth. Its invasion has been a serious problem in the forests and grasslands of the Chitwan Valley (Shrestha & Dangol, 2014) and the Koshi Tappu Wildlife Reserve and many other areas in the Terai, Siwalik and Middle Mountains (MoFSC, 2014).

b) Impact on Rangeland Ecosystems

In high altitude, due to climatic stress such as less water, and change in weather patterns, herbs in the high-altitude rangelands are more vulnerable and this has been proved by decrease in availability of medicinal plants like Yarshagumba (*Cordeyseps sinensis*), Jatamansi (*Nordostachys grandiflora*), Kutki (*Neopicrorhiza scorphularifolia*) and Sughadhawal (*Valerina wallichii*). Less availability of herbs directly poses threats to indigenous rangeland dependent communities and their livelihood. In case of mid hills, there has been declining reports for herbal fruits like Amala (*Phylanthus emblica*), Ritha (*Sapindus mukrossi*), Timur (*Zanthoxylum armatum*), Bel (*Aegle marmelos*), Satawari and Sugandhakokila (*Cinnamomum glaucescens*), mainly due to erratic rainfall and reduction in moisture. Similarly, production of non-timber forest products like Nigalo (small bamboo), bamboo, mushroom and rattans have also declined. In case of Lowlands (Terai region), there also has been changes in temperature and water related characteristics, affecting herbs like Kurilo (*Asparagus recemosus*), Pipala (*Piper longum*), Dalchini (*Cinamomum zeylanicum*), Kaulo (*Cinamomum grandiliferum*) to their decline in the forests and making them more vulnerable to both climatic changes and anthropogenic pressure.

c) Impact on Wetland Ecosystem

Wetlands are an integral part of the ecosystem that regulate water and have a unique role in maintaining the food chain, they are also habitats for several species of wildlife, from aquatic animals to migratory birds, which lie within various ecosystems of both the high mountains and lowland plains. Hence wetlands functions as a corridor connecting aquatic and terrestrial ecosystems in Nepal. Wetlands are particularly vulnerable to climate change, further increased human pressure as well as changes in land cover and land use patterns are posing more threats to these highly productive ecosystems. As physiographically limited systems, they are unable to migrate and, hence, are vulnerable to changes in hydrology and nutrient inputs (MoFSC, 2014). Invasion of water hyacinth (*Eichhornia crassipes*) is a major threat to tropical and sub-tropical wetlands. Many internationally important wetlands, including

the Beeshazari Lake in the Barandabhar corridor forest in Chitwan and Phewa Lake in Pokhara, are already severely invaded by water hyacinth. The plant grows fast and soon covers the entire water surface. The substantial reduction in light and air (oxygen) reaching below the surface due to its invasion affects aquatic organisms. *Ipomoea carnea* and *Mikania micrantha* are also becoming more abundant around wetlands, thereby affecting habitats of wetland dependent fauna.

Nepal is gifted with one of the world's most treasured water systems including various declared Ramsar sites that have put the country on the global map of conservation significance. Nepal has to build synergy in conservation efforts starting with strong political commitment and driven by cooperation from the local to national and global levels, in order to sustain the benefits from wetlands and their resources, for the present and the future and for people and biodiversity.

d) Impact on Agro-biodiversity

The expansion and intensification of agriculture is a key driver of forest shrinkage, forest fragmentation and biodiversity loss, and the threat to biodiversity is projected to increase with increased human population growth and food demand. Hence, food production with a minimal ecological footprint is highly critical ecological issue, and an important development goal of 21st century. Agroforestry, as practiced in the hilly populated agricultural landscape of the central Himalaya demonstrate a scenario of land sharing with a balance in the trade-offs between forest management and tree protection/retention in agricultural land. Nepalese agriculture is predominantly small-scale farming, which is heavily dependent on natural rainfall. Local communities have identified changes in climate as being largely responsible for declining crop and livestock production. According to NAPA (2010), Nepal's vulnerable subsistence farming economy is facing risk due to change in the reliability of stream flows, a more intense and potentially erratic monsoon rainfall and the impacts of flood (MoSTE, 2010).

According to the Nepal Disaster Report (GoN, 2011), the most frequently occurring disaster during the months of March/April and October are hailstorms. In addition to summer crops, hailstorms can also damage winter crops, especially in the mountainous areas of the country. Although most of the hail is relatively small in size, there have been cases of larger hail stones, which has caused extensive damage to standing crops and even inflicted injuries and death. Major damage from such storms has been recorded in eastern Nepal (1980) and mid-western Nepal (1983).

It has been found that the production of buckwheat, which comprises almost 30% of the total crop production in the Mustang district has been affected in recent years, potentially due to higher level of warming that has occurred at higher elevations in Nepal. Climate change is likely to exacerbate these impacts (MoSTE, 2014b). The time duration of growing buckwheat has increased and productivity had declined with the reported increasing incidence of pests, among others (MoSTE, 2014b). This is consistent with studies that indicate shade conditions and temperature affect the viability of pollen and seed and that bud formation is reduced as temperature increases (Wang & Campbell, 2004). Studies indicated that the farmlands in a landscape with a sharing strategy are richer than corresponding forests in terms of tree species diversity and it presents counter-evidence to the conventional view on agriculture–biodiversity relationship (Sharma & Vetaas, 2015), indicating that we could significantly improve tree species diversity with well-planned agro-forestry practice in Nepal.

e) Impact on Faunal Diversity

Nepal's rich faunal diversity with many species of birds and animals are already experiencing greater threats due to higher deforestation rate and increased human activities (Bhattacharjee et al., 2017) . The wildlife and vegetation in Nepal correspond to that of the natural settings due to the higher proportion of mountain topography in Nepal. Forest losses have been so widespread and extensive in the lower and middle hills that invaluable habitat linkages between forests in the high Himalaya and lowlands have been lost. As a result, many bird species no longer have the continuum of habitats that they require to move altitudinally with the seasons and their distributional range is restricted. Furthermore, the loss of a continuum of habitats across a high altitudinal gradient means that many species are less able to shift their distribution based on climate change and is therefore at more risk (BCN & DNPWC, 2011).

Changes in climatic factors and associated impacts in and around high-altitude forests has led to limitation of food and habitat for local and migratory birds like Danphe pheasant (*Lophophorus impijanus*) in high altitude. As a result, the population of migratory birds like domicile crane (*Anthropodis virgo*) and other birds like pheasants are already declining. In high altitude, there has also been the migration of high-altitude animals as well. For e.g., Pikas (*Ochotona* sp.), which used to reside mostly in 2800 m in the past, have now found to be migrated up to 3200 m altitude. Similarly, leopards are now seen at higher altitude, which was not the case in the past. In case of mid hills, water stress has led to decrease in a numbers of local bird species such as dove, Bhyakur (*Bablar* sp.), ducks, vulture, eagle and bat. Early flowering and early fruiting in plants also make birds vulnerable due to change in food availability. Due to shortage of water, the number of deer, monkey, porcupine, and pangolin is decreasing. Red monkeys earlier found in Chure range are now seen in Mahabharat range. Increased water scarcity in Terai has led to decrease in number of peacocks, waterducks, and Mynah. Birds like Kilhat and migratory birds like Malchari are being more vulnerable and decreasing in and around forests. In 2010, the alarming number of 149 bird species (17%) of Nepal’s birds was considered nationally threatened, out of which as many as 61 were thought to be Critically Endangered, 38 Endangered and 50 Vulnerable. An additional 16 species were considered threatened in 2010 compared to 2004. Over half of Nepal’s nationally threatened birds inhabit forests, with over a quarter in wetlands, and smaller numbers in grasslands (Nepal’s Birds, 2010). Most of these species occur in the lowlands, and the number of threatened birds is ever increasing due to higher human population pressure in the lowlands of Nepal.

3.3.2.2 Vulnerability

Nepal is experiencing anthropogenic pressure, land use change, and rapid climatic changes impacting all ecosystems, disproportionately more in the High Himalayas and the Trans Himalayas (Shrestha et al., 1999). A healthy environment, the availability and quality of natural resources, and rich biodiversity are critical components for life-supporting systems and key determinants of economic performance. Hence it is critically important to manage biological resources in accordance with the development needs in Nepal. Nepal's National Adaptation Plan (NAP) has also considered forest and biodiversity as one of the crucial climate sensitive thematic sectors. Vulnerability and risk assessment for Nepal's NAP process mentioned that indicators for vulnerability are drawn from the sector's sensitivity and adaptive capacity. Sensitivity indicators for biophysical elements include forest growth, productivity, and species distribution; bottlenecks for faunal migration; habitat fragmentation, and pressure on forest and biodiversity resources, and phenological changes. The sensitivity indicators for forest dependent communities include the economic status of households, extent of dependence on forest resources, and gender and ethnicity (MoPE, 2017a). Upward shifting of ecological belts is expected with the rise in temperatures (Gaire et al., 2017; Tiwari et al., 2017a; Sigdel et al., 2018) as in case of high mountain tree species like *Abies spectabilis* and *Betula utilis* in Nepal Himalaya.

However, upward movement of species will be limited due to adverse environment for their growth (e.g. soil and moisture conditions) and biological interactions (Liang et al., 2016). Upper timberline trees should primarily move upslope in the mountains due to warming, owing to the altitudinal temperature gradient, as has been frequently documented during the recent decades (Kelly & Goulden, 2008; Gottfried et al., 2012). The mountains usually have conical shape; hence the upslope movement inevitably results in range loss and may even lead to 'mountain-top extinctions' (Colwell et al., 2008) in extreme cases.

High altitude species, such as birch, Jatamansi, Kutki are likely to become more vulnerable with increase in climatic and human induced stresses along with biotic interaction among species. Similarly, the habitats of mountain fauna such as snow leopard are increasingly threatened due to increased temperature. Reduced snowfall, untimely rains, and increased dryness have altered the flowering and fruiting behaviour of plants which is closely related to the survival of wildlife. When seasons of food availability change, it changes the periodicity of life cycles of animals and insects such as reproduction, migration, and hibernation. This results into serious vulnerability for wildlife and possesses a huge threat to the people who depend on biodiversity for their livelihoods (MoSTE, 2010). Due to being climate sensitive sectors, there is dire need of intensive studies for vulnerability and risk assessment of forest and biodiversity sectors to reduce the climate risk.

3.3.3 Adaptation Measures to Reduce Vulnerability

Addressing climate change issues related to forests and biodiversity become more challenging without specific policies, guidelines and tools relevant for the sector. Informed decision making regarding the issues of biodiversity and sustainability requires highly reliable, regularly updated and context-specific data achieved through in situ research. Adaptation to climate change has been considered as an emerging challenge to achieving and sustaining the development outcomes as mitigation measures appear to be inadequate (Eriksen, 2011), for rapidly changing climate and faster impacts than the natural

process can sustain, and they are interlinked with and embedded into a range of social, economic and political processes (Ayers, 20 11). It is necessary to have a long-term vision and plan in order to properly address future challenges related to climate change in this sector (MOPE, 2017).

Government of Nepal has been initiating a number of efforts to reduce the vulnerability and impacts of climate change on forests and biodiversity. There has been a strong legal framework for biodiversity conservation, climate change adaptation and mitigation measures (see chapter 9 for details). The quite good legislature has to be implemented more sincerely in order to achieve all commitments, which certainly needs more stable political situation and pro-active government delivery along with active involvement of concerned people in Nepal.

There have been initiatives on forest fire control programme in all districts of Nepal. Integrated Chure Conservation Programme has been initiated to reduce the vulnerability of the area, and various in-situ and ex-situ conservation activities have been undertaken to protect endangered, threatened and rare wild life (MoFSC, 2014). Similarly, mountain landscape management programme and Terai landscape management and conservation programmes have also been initiated to promote biodiversity conservation at ecosystem level both on protected and productive areas by involving local institutions.

Nature Conservation National Strategic Framework for Sustainable Development, 2015-2030 (NPC, 2015) intends to promote nature responsive development and thereby contribute to achieve sustainable development goals which ultimately address climate smart initiatives. The framework serves as an umbrella strategic framework in order to guide sectoral agencies on nature-responsive development along with improving accountability on nature conservation. The framework has five strategic pillars: 1) Mainstream nature conservation in development efforts, 2) Harmonize sectoral policies and strategies, 3) Strengthen coordination among sectoral bodies, 4) Valuing and accounting ecosystem goods and services on investment decision, and 5) Improving accountability on conservation.

In a nutshell, activities to reduce the vulnerability of climate change on biodiversity and forest ecosystem include: sustainable and scientific forest management through watershed and landscape level planning and management, improved governance capacity, low cost soil and water conservation practices with inclusion of socio-economic factors; control of forest fire; effective implementation of forest and biodiversity conservation legislation, proper monitoring of forest health through management of landscape-level ecosystem and corridor, improved ecological connectivity, restored ecosystem and species, and control of invasive species; increased understanding of changes in habitat with intensive study; emphasis on management of herbs; ex-situ conservation of threatened species; afforestation/reforestation and reduction of deforestation and forest degradation; improved protected areas in mountains; reduced anthropogenic stresses; provision of minimum flow water requirement in river for fish and aquatic species; awareness raising, capacity building and technology transfer; incentive for private landowner, strengthening the early information system of climate variability and implementing the preparedness measures to reduce the risk of climate induced disasters.

3.4 Public Health and WASH

3.4.1 Overview of Public Health Sector

Section 3 Article 35 of the Constitution of Nepal states the rights to free basic health care services, right to information regarding medical treatment, equal access to health services, and access to clean drinking water and sanitation. Health care system in Nepal is based on primary health care (PHC), which was adopted after Nepal became signatory to the Alma Ata Declaration (Declaration of Alma Ata, 1978). Currently, the Department of Health Services, functioning under the auspices of the Ministry of Health and Population is responsible for the implementation of health care services.

The health services are delivered by a Curative service division, Epidemiology and Disease Control Division, Family Welfare Division, Nursing and Social Security Division, National AIDS and STD control centre, National tuberculosis control centre, National Public Health laboratory, and National health, education, information and communication centres. The organogram above provides a detailed representation of the sections that implement health programmes within the DoHS. The National Health Training Centre provides capacity enhancement of the health care service providers. To ensure that the health sector can achieve its goals the Nepal Health Sector Strategy, states that the MoHP will focus on the strategic principles of equitable access to health services, quality health services, health system reform, and a multi-sectoral approach (NHSS, 2015).

As Nepal moves into a federalist state the onus of health care delivery will fall to the Federal, Provincial and Local levels of government. Accordingly, the locally elected officials have the authority to make critical decisions on funding, policy and programming of health. At the primary tier are community health centres, primary health care centres, urban health promotion centres, primary health centres, at the secondary tier are municipal and village health offices with tertiary level referrals to Provincial and Federal level specialized hospitals (PPICD, MoHP, 2017).

Table 3.16: Number of hospitals in Nepal

SN	Hospitals types	Number
1	Private hospitals	301
2	Zonal hospitals	10
3	District public health offices	26
4	Districts and other hospitals	83
5	District health offices	49
6	Primary health care and health centres	202
7	Health posts	3803
8	FCHVs	51,416
9	PHC-ORC clinics	12,660
10	Epi-Outreach clinics	16,134

Source: DoHS (2017); CBS (2014)

Despite many positive strides in improving health outcomes, Nepal still faces many challenges regarding the health issues, viz. poverty, illiteracy, inadequate health services, geography, etc.

3.4.2 Vulnerability and Impact Assessment

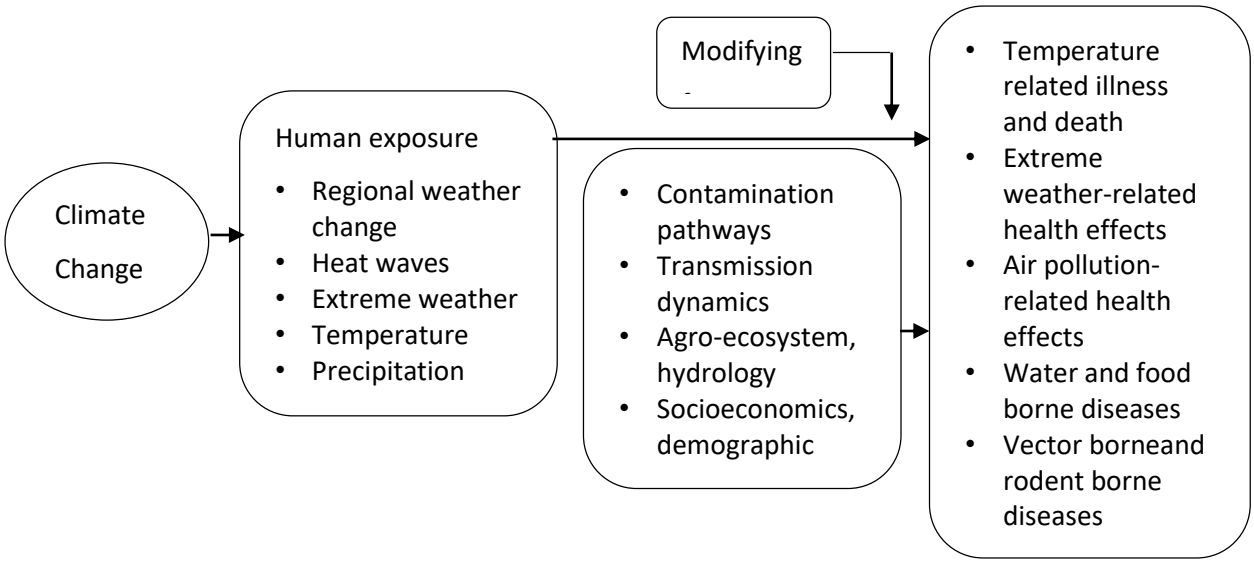
The multi-factorial nature of health lends to the knowledge that health is influenced by multiple determinants and conditions in Nepal. Factors like biological determinants, behavioural and socio-cultural conditions, the environment, economic status, education, occupation, political system, health care services, aging populations, gender, access to information technology, food and agriculture and industry etc. Studies on the association between climate factors and reported cases of health-related issues have shown that the diseases and health-related hazards have increased in the country. There are reports showing association between the incidence of climate-sensitive diseases and changes in temperature and precipitation trends (examples, Pradhan, et al., 2013; Dhimal et al., 2014; Regmi et al., 2016; Dhital et al., 2016).

3.4.2.1 Impacts

Human health is affected by various physical and biological system of the earth along with climatic system. Global climate change is thus a major addition to the variety of environmental health threats encountered by people (WHO, 2003). The IPCC AR5 concludes that health of human populations is responsive toward the various aspects of climate change causing global burden of diseases and pre mature death (IPCC, 2014b). The negative impacts of climate change are augmented by factors such as widespread poverty, diseases and high population density, which are estimated to double the demand for food and water in the next 30 years (IPCC, 2007b). Changes in temperature and humidity play an important role on human health and some increased health risk are attributable to extreme weather conditions (Franchini & Mannucci, 2015). The implications of climate change to human health can be grouped into following six major categories (IPCC, 2007b):

i. Cardio-respiratory diseases
ii. Injuries
iii. Nutritional deficiencies /malnutrition
iv. Diarrheal diseases
v. Vector-borne disease and
vi. Psychological stress/diseases

Similarly, the projected impacts in human health due to climate change include: increase in cardiovascular disease mortality in tropical region; increase in the burden of diarrheal diseases in low income regions, increase in heat-related mortality and morbidity (Dhimal, 2007). Nepal faces a triple burden of health problems: threats from natural disasters, adverse effects of climate change, accidents, violence, and injuries (MoPE, 2015). The climate change together with health inequality and human diseases is a major challenge to public health in Nepal (Ramin, 2009). Episodes of intense rainfall events can accelerate the flooding, which claims human lives. Flood is one of the most frequent disasters in terms of total death toll and economic loss (MoHA & DPNet-Nepal, 2015). Heat and cold wave have been increased in various regions of Nepal where mortality and mobility due to heat wave has been testified (MoSTE, 2011).



Source: Based on: Patz et al. (2000); Mc Michael et al. (2003)

Figure 3.5: Concept of climate change and health

a) Vector-borne Diseases

Malaria: Malaria is endemic to 65 districts of Nepal. It is evidenced that increase in annual maximum temperature makes vulnerable to the risks of malaria. About 13.02 million population of Nepal which is almost 47.9% of people live in malaria endemic regions (EDCD, 2017). Though there seems some control, new areas have been reported with malaria (DoHS, 2011) particularly in the context of mountains and uplands, the propagation of malaria is an indicator of climate change (Beniston, 2003). The number of cases of malaria reported in different years is given in Table 3.17:

Table 3.17: Mortalities due to malaria in Nepal

Year	2010	2011	2012	2013	2014	2015
Malaria cases	-	2,634	1,674	-	-	991

Source: DoHS (2017)

Dengue: Dengue is the most rapidly spreading mosquito-borne viral disease, showing a 30-fold increase in global incidence over the past 50 years (WHO, nd). The principal vectors for dengue, *Aedes aegypti* and *A. albopictus*, are climate sensitive (IPCC, 2014) and the evidence of the presence of dengue vector *A. aegypti* in Kathmandu valley shows that it may be attributed to increased temperature creating favourable environment for mosquitoes which was traditionally not found in that region (Dhimal & Bhusal, 2009). Dengue fever showed its major outbreak in Nepal in the year 2010 in the Central part of Nepal (Sedhain et al., 2012). The number of cases of dengue fever across different year is represented in Table 3.18.

Table 3.18: Mortalities due to dengue in Nepal

Year	2010		2011		2012		2013		2014		2015	
Dengue	Cases	Death	Cases	Death	Cases	Death	Cases	Death	Cases	Death	Cases	Death
	917	5	79	0	183	0	785	0	302	-	134	-

Source: DoHS (2017)

b) Diarrheal Disease

Increase in extreme weather events (extreme heat, drought or rainfall) caused by climate change have been strongly linked to the incidence of diarrhoea-associated disease (Chou et al., 2010). Increases in diarrheal and respiratory diseases are reported, in both high- and low-income countries. Diarrhoea increases by 8% for each 1 ºC increase in temperature, which suggests that the number of patients will be increasing with the rise in temperature globally (Checkley et al., 2000). Diarrheal disease is one of the water-borne diseases, which accounts about 3.3% of total death in Nepal (WHO, 2012). The major role of climatic phenomena is the delivery of conditions favourable to the propagation and transmission of pathogens (Colwell, 1996). Bhandari et al. (2013) found that there is strong significance between diarrheal cases occurrence and temperature and rainfall. The classification of diarrheal diseases is represented in Table 3.19 which includes incidence and case fatality of diarrhoea among children under 5 years of age, by region (FY 2014/15 to 2016/17).

Table 3.19: Incidence and case fatality of diarrhoea among children under 5 years of age

Indicators	Year	Region					National
		EDR	CDR	WDR	MWDR	FWDR	
Estimated <5-year population that are prone to diarrhoea	2014/15	579,372	981,253	482,756	450,398	314,400	2,808,179
	2015/16	604,096	1,019,943	508,025	400,118	287,878	2,820,060
	2016/17	635,097	1,102,200	534,361	400,270	287,251	2,959,179
Incidence of diarrhoea/1000<5 years population	2014/15	655	482	538	749	1,009	629
	2015/16	481	377	414	693	873	501
	2016/17	407	315	338	634	724	422
Diarrheal deaths	2014/15	3	4	7	16	6	36
	2015/16	26	16	3	24	11	80
	2016/17	18	43	6	7	15	89

Source: DoHS (2017)

3.4.2.2 Vulnerability

Climate change can affect the public's health in a number of ways, from causing direct health impacts to indirect impacts because of change in vector transmitters (Ministry of Health, 2015). Changes in temperature and precipitation pattern have been linked to the occurrences of various diseases. Diseases like malaria (Beniston, 2003), dengue (Dhimal & Bhusal, 2009), diarrhoea (Checkley et al., 2000) are affected by climatic phenomena. Ministry of Health (2015) has estimated that public health could get exposed to the impacts of climate change if it follows the projected RCP scenarios. The exposure thus, can be summarized as follows:

- The occurrence of cold waves is increasing in Terai region with the total death of about 822 from the year 1974-2014 (MoHA & DPNet-Nepal, 2015). Every year, various parts of Nepal

mainly in Terai region experience high temperature during the months of March to June with the higher temperature in the decade 2001-2010 (MoHA & DPNet-Nepal, 2015).

- Similarly, decrease in food-production possesses a threat of insufficient nutrient.
- Change in temperature and precipitation phenomena increases the risk of diseases (Ministry of Health, 2015). It involves the ecosystem-mediated impacts of climate change or indirect impacts from environmental and ecosystem changes, such as shifts in patterns of disease carrying mosquitoes and ticks, or increases in waterborne diseases due to warmer conditions and increased precipitation and runoff (IPCC, 2014). The increased temperatures due to climate change may create conducive environment to mosquitoes breeding. Global warming phenomenon can extend the geographic areas capable of sustaining transmission of vector borne diseases like malaria (Narain, 2008).

Considering that Nepal possess a higher risk to the effects of climate change, there is a greater risk of deaths related to climatic phenomenon, such as intense heat-waves, cold and forest fires (Dhimal et al., 2017). People living in sensitive areas, such as flood- and landslide-prone zones, as well as densely populated urban areas are exposed to bigger risks (MoE, 2010). There is also a higher risk of disease outbreaks, leading to public health crisis. Especially in the mountain areas, the chances of vector-borne and water-borne diseases are higher (Dhimal et al., 2017). In terms of heat waves, much of the excess mortality from heat-waves is related to cardiovascular, cerebral-vascular and respiratory causes and is concentrated in the elderly. The projected effects of climate change include a wide range of health problems (Box 1).

Box 1. Projected effects on Nepal of unabated climate change

- Greater risk of injury, disease and death, owing to more intense heat waves, cold waves and forest fires
- Increased risk of undernutrition, resulting from diminished food production in resource-poor regions
- More negative health consequences of lost work capacity and reduced labour productivity in vulnerable populations
- Increased risk of vector-borne, waterborne and foodborne diseases, especially in mountain areas, and leading to perennial occurrence in the lowlands
- Increase in cardiorespiratory diseases, owing to higher ambient air pollution and haze in urban areas, resulting from climate change
- Increase in mental health problems, owing to extreme climatic events such as droughts, floods and landslides
- Modest reductions in cold-related mortality and morbidity in the highlands, owing to fewer cold extremes
- Increased morbidity and mortality related to cold waves in the southern Terai lowlands
- Reduced disease-transmission capacity of vector insects in the Terai, owing to higher temperatures exceeding their thermal thresholds.

Source: Dhimal et al. (2017)

The sensitivity to the impact of climate change differs in individual as well as community level. In the community level, the resources available to cope with the adverse impacts play an important role, whereas in the individual level, age and gender determine sensitivity (Ministry of Health, 2015). The vulnerability to a factor in one group of population might not be the same as others. For instance, women are primarily the caretakers of Nepali households and are responsible for providing water. Water scarcity caused by climate change might increase their workload, limiting their personal and social development, and exposing them to poor sanitation or personal hygiene (Dhimal, 2015). The vulnerability of different genders can be attributed to socio-cultural factors such as decision-making capacity and control over resources (MoE, 2010).

Agriculture may be influenced by climate and nutrition is function of agriculture. Higher temperatures and changes in precipitation may reduce both the quantity and quality of food harvested, which may ultimately lead to undernourishment.

3.4.3 Adaptation Measures to Reduce Vulnerability

Climate change has severe effect on the human health and such health effects will be further influenced by factors such as socioeconomic development and the degree to which effective adaptation measures are implemented (Haines et al., 2006). National malaria control programme 2009, which shows significant decrease in cases of malaria throughout the country where the number of confirmed malaria cases dropped from 1,674 in 2070/71 to 991 in 2072/73 (DoHS, 2017). To reduce vulnerability and enhance adaptation measures to reduce adverse effects of climate change on human health, the Government of Nepal has prepared five-pronged strategies (MoH-GoN, 2015). The strategies include objectives of:

- Raising public awareness about climate change and its effects on health;
- Generating evidences on health effects of climate change at national and sub-national levels through research and studies;
- Reducing the morbidity and mortality of infectious diseases (vector, water, air and food-borne diseases) and malnutrition attributed to climate change;
- Managing the risks of extreme climatic events; and
- Protecting human health from climate change through multi-sectoral response ensuing health in all policies.

In line with the strategies, the Government has prepared National Climate Change Health Adaptation Strategies and Action Plans of Nepal (2016-2020) (MoH-GoN, 2015). It aims to develop the national strategies on climate change and health with an adequate focus on health sector and inter-sector collaboration for protecting health from adverse effects of climate change. The action plans are guided by the Constitution of Nepal 2015, National Health Policy of Nepal 2014, Health Sector Adaptation Strategy (2015-2020), National Population Policy 2014 as well as National Climate Change Policy 2011, and is a step forward in mainstreaming health in overall national adaptation plan (NAP). The general goal of the strategy is to reduce vulnerability and to enhance adaptation measures to reduce adverse effects of climate change on human health in the Nepal. It has suggested various ways forward for the reduction of vulnerability and reduce the risk to the vulnerable population. Different types of control strategies are being adopted for the mitigation of water, air, food and vector borne diseases.

Various programmes such as immunization, awareness enhancement, vaccination help in reduction of the vulnerability. Another effort for the reduction of the vulnerable population toward risk includes training community health volunteers (CHVs) for the treatment of diarrheal disease which was seen effective in control of diarrhoea.

Table 3.20: Adaptation measures in public health sector

SN	Exposure	Diseases	Adaptations
1	Water Quality, food quality, change in precipitation pattern	Water borne diseases; food borne diseases	Sanitation, Personal hygiene, nutrition
2	Heat wave and Cold wave	Heat stroke,	Awareness, Housing and basic for protection from heat and cold
3	Air pollution	Cardio-respiratory mortality, ARI, Respiratory diseases	Monitoring of the emissions, Awareness to public, Use of protection measures
4	Flood induced health issues	Snake bite, drowning, injury	Housing settlement management

3.5 Tourism, Natural and Cultural Heritage

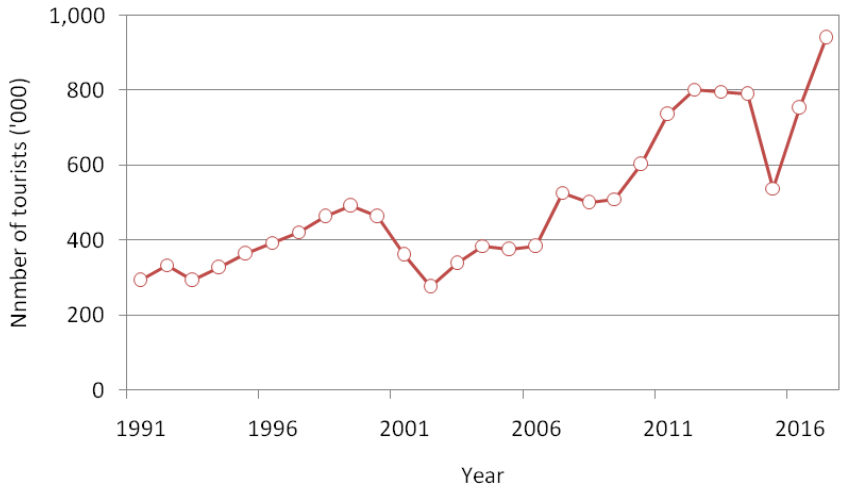
3.5.1 Overview of the tourism sector

Tourism represents a small, but expanding industry in Nepal (Figure 3.6). In 2017, the number of international tourists visiting Nepal was 940,218, which is an increase of 25% compared to the previous year (NTB, 2018). According to the Economic Survey by the Ministry of Finance 2016/17, the GDP was slightly above US$ 7 billion, with major contribution of agriculture (34%) and tourism accounting for 7.5% (MoF, 2017). In climatic perspective, Nepal has been identified as one of the most vulnerable countries to climate change in South Asia (MoSTE, 2014b). Its geographic location in the fragile landscape of the Himalaya has made it inherently prone to several natural hazards, specifically landslides in the mountain hills and floods in the Terai. Nepal's climate regime is mainly the monsoon, receiving much water in short time period. In combination with this fragile physical feature, climate change has exacerbated their vulnerability.

Nepal's economic growth is supported mainly by service sector (45%) and agriculture (35%) followed by industry (20%). Tourism industry has been perceived with huge potential, which is contributing about 3% of the country's total GDP. In 2015-2016, the tourism sector contributed over 427,000 jobs, which was 2.9% of total employment in the country. Among the various sectors of tourism, the trekking business is employing more than 50,000 persons (MoCTCA, 2014). Similarly, the hotel business is providing 26,808 employments and the travel agencies are providing 25,238 employments. With a stable government in the country after general election, this figure of employment is expected to grow at least by 100% in the coming years (WTTC, 2017).

Tourism is a vehicle for socio-economic development as a result of its potential to earn foreign exchange, create employment, reduce income and employment disparities, strengthen linkages among economic sectors, control outmigration of local youth, and help alleviate poverty (Kurk, 2009). The 2014 tourism employment survey identified a total of 138,148 persons directly engaged in the tourism

sector in Nepal (MoCTCA, 2018). The World Travel and Tourism Council (WTTC) 2014 report indicated that travel and tourism in Nepal generated 504,000 direct jobs in 2012 (3.2% of total employment), and this figure was expected to grow to 536,000 (3.3% of total employment) in 2014 (MoCTCA, 2018). The Government of Nepal has put highest priority in increasing the tourism sector's contribution to country's economy through its stated goal "to contribute greater GDP growth and employment, reduce poverty and increase sustainable access to foreign exchange for national development" (MoCTCA 2015).



Source: MoCTCA (2018)

Figure 3.6: Total arrival of tourists in Nepal until 2015

3.5.2 Vulnerability and Impact Assessment

Seasonality and environmental condition largely influence tourism industry. Similarly, the seasonality and environmental condition depends on the climatic variables that directly or indirectly affect the economy and livelihoods of the tourism dependent entrepreneurs and communities. The climatic condition of destinations plays an important role in the tourism industry. Climate change induced disasters impact the tourism industry both directly and indirectly by damaging tourism-related infrastructure and resources, and disturbing tourism activities, water supply, organic farming, and the wellbeing of tourism service providers. The abrupt changes in climatic variables and extreme events can be damaging to the health and safety of tourists and people directly involved on tourism activities. Increase in the frequency and intensity of climate induced disasters negatively impact the sustainability of tourism activities. Receding snow lines, melting glaciers, increased frequency of cloudbursts, floods, and landslides have the potential to change the nature and quality of tourism resources (Sharma, 2011). In November 1995, avalanches caused 43 deaths (including foreign trekkers) in the Khumbu and Kanchanjunga areas. On 2nd January 1999, five people were swept away by an avalanche in Gorkha district. In November 2014, unseasonal snowfall and avalanches resulting from the effects of Cyclone Hudhud killed at least 43 trekkers and guides between 2005 and 2014, a total of 235 people lost their lives due to inclement weather in the country, including avalanches and snowstorms (MoHA & DPNet-Nepal, 2015). The changing climate will have adverse impact on tourism in Nepal increasing stress on the environment and bringing more risks than opportunities for economies based on tourism (K.C.,

2017). Climate and climate change are expected to impact tourism sector differently but mostly adversely. Mountaineering, trekking and rafting are the key tourist attractions likely to be adversely impacted by climate change.

Mountaineering: Mountains have been a major attraction of tourists in the world. In 2016, a total of 8,176 climbers were given permission by the Department of Tourism and Nepal Mountaineering Association (MoCTCA, 2018). The mountains, however, have been extremely vulnerable to changing climate and extreme events in recent decade. Recently, Ballesteros-Cánovasa et al. (2018) have presented evidences that the warming in recent decades has been simultaneous with increased frequency of snow avalanche in the Western Indian Himalaya. They observed very high activity between 1970 and 1977 and from 1989 to 2003 (with occurrence rates >0.875 yr^{-1}). Accelerated melting of snows and glaciers in the Himalaya would reduce the number of trekkers/mountaineers. Considering the average vertical lapse rate of 6.5 °C km^{-1}, the present glaciated area above 5,000 m is likely to be free of snow with an increase in temperature of 1 °C in the next few years. Similarly, an increase in temperature of 3-4 °C could result in the loss of 60-70% of snow cover from the Himalaya (Alam & Regmi, 2004). This will be the major cause of mountain landscapes losing their beauty that will adversely impact tourism industry.

Trekking: In recent years, Nepal is attracting over 200,000 trekkers annually. According to the NTNC officials, the total number of visitors for trekking in Annapurna region was 114,187 in 2016. In the second popular destination, the Everest region, the number of tourists increased from 1,406 in 1971 to 37,124 in 2014 (Rai, 2017). However, the vulnerability to natural calamities, climate change impacts have evidently increased in the high mountains (UIAA, 2015). In October 2014, more than 32 people were killed and hundreds of trekkers were trapped at Thorong La (> 5000 m asl) by sudden snowstorm in Annapurna area. Similarly, the increasing incidents of low visibility may discourage the nature treks on one hand and flight cancellation on the other. For example, tourists travelling to Namche and beyond towards Khumbu often are stranded in Lukla due to bad weather as the flights are cancelled for days sometimes and it takes almost a week by road.

Rafting: Under the umbrella of Nepal Association of Rafting Agencies, there are at least 30 Rafting agencies providing water-rafting services. Most of the rivers originate from the glaciers and snow fed lakes in the Himalaya availing perennial source of water. The changing climate, specifically the increased temperature will contribute in the increase of water level; however, the associated disasters like floods and landslides will reduce the quality and current of the running water. The increasing melting rate of the glaciers in long run will ultimately collapse the flow and volume water.

An economic assessment of climate change impact on tourism has been conducted recently (Practical Action Nepal, 2018). The assessment showed that the overall loss and damage on tourism GDP has increased from NPR 0.0778 billion in the period of 1985-1990 to NPR 1.4624 billion in the period of 2010-2015. The share of loss is higher from outdoor and adventure tourism and leisure and recreation tourism within the overall tourism sector. The overall seasonal maximum temperature in Nepal is projected to increase up to 4.5 °C in spring and 3.3 °C in summer, whereas the minimum temperature might increase up to 5.4 °C in winter and 3.4 °C in summer at the end of the 21st century (MoSTE, 2014b). This increased temperature has the possibility to enhance snow melting in high Himalaya, bring

heat wave and heat related allergy in the destination affecting the outdoor tourism activities. Similarly, the overall annual precipitation in the country is projected to be decreasing by 2% of the baseline amount by 2020s. According to MoSTE (2014b) the precipitation will increase by 6% and 12% of the baseline by 2050 and 2080s respectively. Overall, these will have direct impact to the tourism industry of the country.

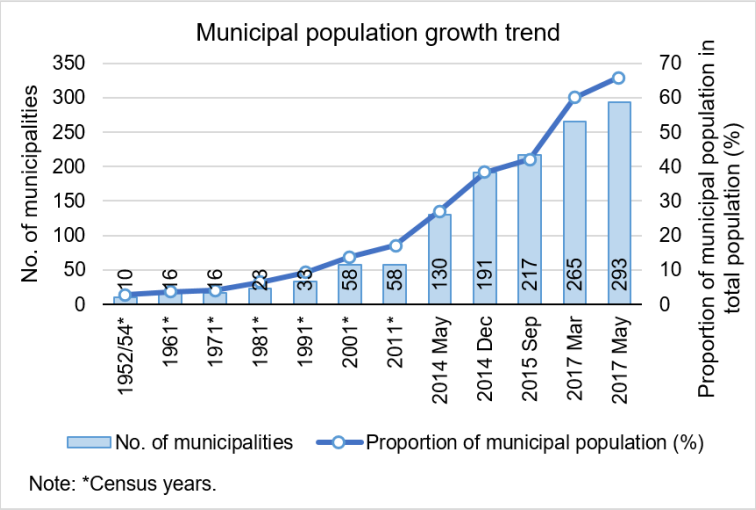
3.5.3 Adaptation Measures to Reduce Vulnerability

Considering the climate vulnerability in tourism sector, the study by Practical Action (2018) recommends a set of measures, including the application of weather and climate information system, sustainable tourism practice, supply chain management, tourism products diversification, policy reforms and exploiting the situation for immediate opportunity. In conformity of the United Nations World Tourism Organization declarations, further recommendations are reiterated, which include, analysis and enhancement of understanding of the climate change in tourism sector in Nepal, international and regional cooperation to respond to the opportunities and challenges posed by climate change in the sector, and mainstream climate mitigation and adaptation while conceiving plans for the resilient development of tourism sector.

3.6 Urban Settlement and Infrastructure

3.6.1 Overview of Urban Settlement and Infrastructure

Urbanization is a global phenomenon with more than half of the world population living in cities today with the urban population share expected to rise to 66 percent by 2050 (UN DESA, 2015). The population of Nepal may be small on global scale but the country is one of the most rapidly urbanizing countries in the world. Urban population is rapidly growing over the past two decades in Nepal. As per the census data and list of municipalities, urban population has increased from 9.2% in 1991, 17.1% in 2011 to 58.4% in 2017 with the inclusion of the new political division which embraces six metropolitans, 11 sub-metropolitans and 276 municipalities (MoFALD, 2017).



Source: Joshi (2019) citing Subedi (2014), NPC (2016)

Figure 3.7: Municipal population growth trend

Note: The year labels in the horizontal axis are not proportionately spaced.

Urban growth in Nepal is primarily characterized by (i) an increase in the number of municipalities, (ii) an expansion in the urban area, (iii) a relatively steady increase in the population of municipalities in the initial years, and (iv) a rapid increase in population in recent years (Subedi, 2014).

In 1981, 6.4% of the total population of the country lived in 23 municipalities. Between 1991 and 2011, the number of municipalities remained constant at 58, but the share of municipal population rose from 13.9 to 17.1% at the population growth rate of 3.38% per annum. At present, about two-third of the national population of the country live in its 293 municipalities. Figure 3.7 shows the changing number of municipalities, their population size and percentage share of the municipal population since 1952/54 census.

Considering municipal population as a proxy indicator of urbanization and using population data of Census 2011, the Karnali Province is the least urbanized, whereas the Province 3 is the most urbanized among the seven provinces in Nepal. The number of municipalities is the lowest in the Karnali Province and Province 7 (24 each) and the highest in Province 2 (73) (Figure 3.8 and 3.9).

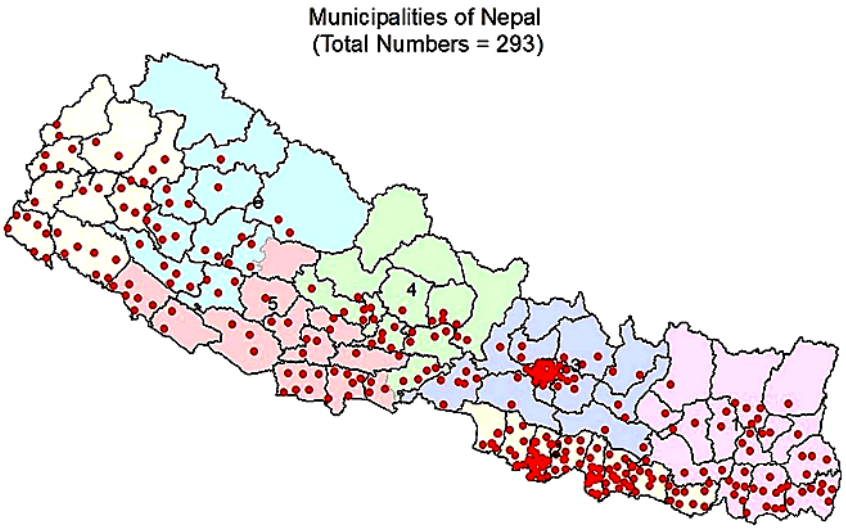
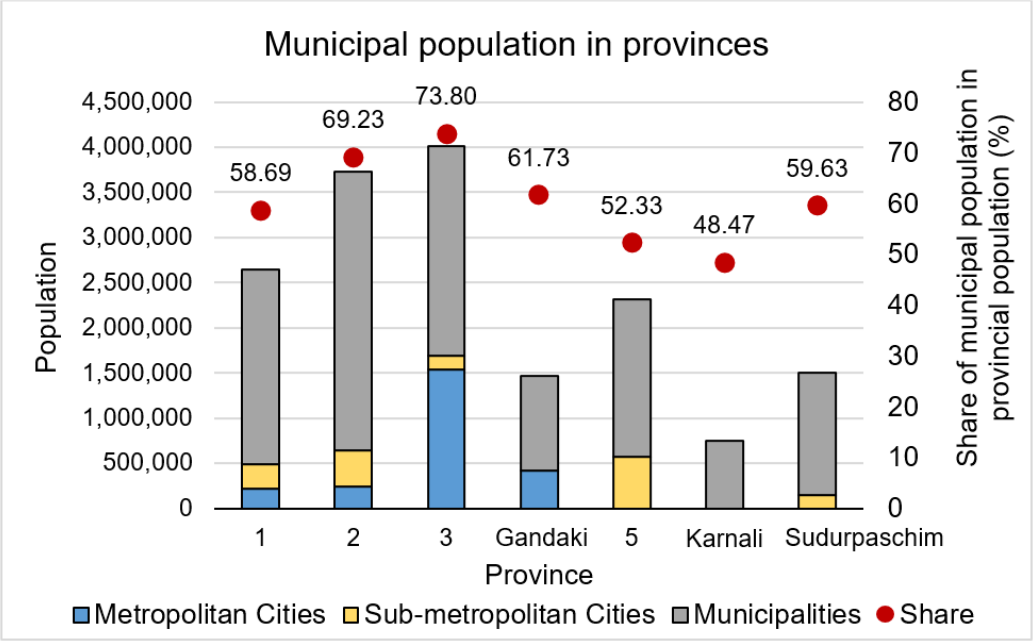


Figure 3.8: Distribution of municipalities in provinces

Measuring urbanization in terms of municipal population has its limitations. In particular, with such definition, it becomes easy to overlook that most municipalities are still predominantly rural in character and that Nepal is still in an early phase of urbanization. However, municipalities are often the places where in-migration is high, and are likely to grow into towns and cities sooner than later due to expectations of public investment on infrastructure.

Urbanization in Nepal is primarily fuelled by rural-to-urban migration. Cities offer diverse economic opportunities which attract rural migrants including the poor. Cities have been hailed as drivers of economic growth, but urbanization in Nepal has been mostly haphazard. Infrastructure and services in most municipalities, including old cities, lack adequacy, both in terms of quantity and quality. Numerous challenges exist in meeting even the basic needs of the burgeoning urban population, including housing, drinking water and sanitation, jobs, transportation, and healthcare, among others. In an assessment of basic urban infrastructure in old 58 municipalities conducted for National Urban Development Strategy (NUDS), 2017, only 26 (45%) municipalities scored 50 or more out of total 100 (MoUD, 2017).



Source: Joshi (2019) using population data from the 2011 National Census.

Figure 3.9: Municipal population in provinces (Census 2011 data)

There are wide deficits as well as geographical disparity in the availability of basic urban infrastructure (housing, roads, water supply and sanitation, sewage drainage, electricity, and solid waste management, among others). According to MoUD (2017), only one-third of households in urban Terai have access to piped water supply as compared to 81% of households in urban hills. The quality and quantity of drinking water is insufficient in all urban regions. Likewise, slightly more than half of the urban households have access to sanitation system. Out of old 58 municipalities, only six have sanitary landfill sites and five practice-controlled waste dumping. The average road density in the urban areas is significantly low at 3.26 km/sq. km. Lack of affordable housing is a major emerging concern in many urban areas, resulting into growth of squatter settlements and urban slums.

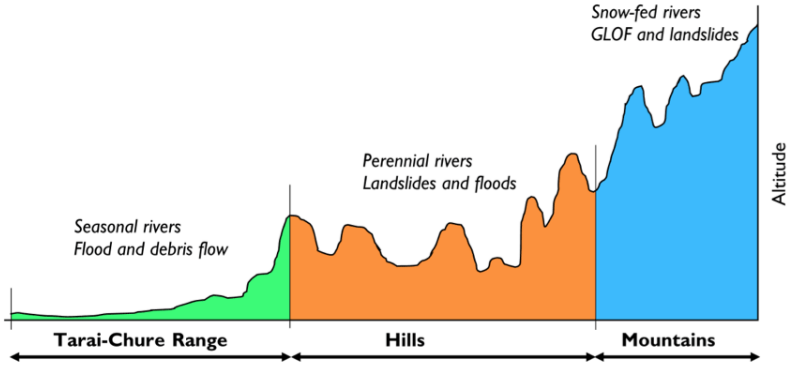
3.6.2 Vulnerability and Impact Assessment

3.6.2.1 Impacts

The key indicators of climate change are rising temperature and erratic rainfalls. Both have direct effect on water resources on which human lives depend. Moreover, unusual weather patterns and rise in extreme events are putting urban settlements and infrastructure at increased risks. There are now more events of rainfall than snowfall in mountains resulting into reduced snow deposition. Increasing temperature, on the other hand, is melting small glaciers causing them to ultimately disappear. This will eventually lead to water scarcity for irrigation and drinking purposes in the mountains and hills.

In the mid-hills, drying up of water springs has been reported making water scarcity even more pronounced particularly in dry seasons. In Terai, people have experienced decrease in the river discharge and decline in ground water table in dry seasons. The nature of rainfall has changed with an increase in the frequency of extreme events such as drought and torrential precipitation.

Many settlements in Nepal are built on risk-prone areas such as on steep slopes prone to landslides and riverbanks prone to floods. Occurrence of heavy and untimely rainfall has increased threats of landslides in high mountains, landslides and floods in middle mountains, and floods and debris flow in Terai (Figure 3.10). On top of that, informal settlements have grown rapidly in cities across Nepal, particularly along river banks. Poor are more sensitive to climate change, and are thus more vulnerable.



Source: Joshi (2018) from https://www.urbanet.info/climate-change-adaptation-cities-nepal/

Figure 3.10: Schematic representation of Nepal's topography and hazards

Urban floods, dispersion of pollutants to water bodies, and outbreaks of water and vector-borne diseases are increasingly being experienced in the cities during monsoons and during heavy rains. Damage to roads and drainage structures poses huge economic loss as transport services and overall daily lives are disrupted. Because urban areas are mostly covered by built-up areas such as concrete and asphalt, both atmosphere and surface in the cities are warmer than in the rural areas creating 'urban heat island' effect. Increased temperature leads to health concerns, and puts pressure on energy use for cooling purpose.

The fifth assessment report (AR5) explains the observed and forecast impacts of climate change to the urban infrastructures (such as water supply, waste water and sanitation, energy supply, transportation and communication, built environmental and recreational and heritages sites, green infrastructure and ecosystems services). Increased in temperature, drought, erratic rainfall or extreme weather will affect in water supply and sanitation (Revi et al., 2014) and also have high risk of climate induced disasters such as drought, flood, epidemics, heat waves, cold waves, etc (Rosenzweing, 2011) and effects are even more in lower income countries. Epidemics which claims the most lives in Nepal (more than 50%), increases with overcrowded settlements exposing more population at risk (MoHA, 2011). Climate-induced disasters possess a threat to the physical and social infrastructures (Patra & Terton, 2017). Most of the cities are developed in river basins and in the coastal regions, the number is projected to more than 660 by 2030 in the world (UNDESA, 2014). Development of cites near the bank of river and change in precipitation pattern due to climate change leads to decrease the ground water recharge mainly in urban areas where the ground is blocked due to concrete path. Similarly, increase in extreme rainfall may cause urban floods (Jha & Shrestha, 2013). In addition, built up areas create urban heat island which in general increases the heat of buildings through heating effect (Tromeur et al., 2012). This kind of effect is seen in Kathmandu, where urban development contributes to higher city temperatures with the loss of vegetation in surrounding area, which further compounds heat island effect (Thapa and

Murayama, 2010). Kathmandu metropolitan city is affected by some other potential factors like climate change and its associated disasters (Brown & Dodman, 2014) and more extreme weather conditions (DUDBC & MoSTE, 2014). The direct impact of climate induced disasters like damage of road or bridge by landslides or flooding is happening each year in Nepal (Revi et al., 2014).

National Urban Development Strategy (2015) recognizes climate change as a major risk factor, particularly in the context of increasing poverty trends in urban areas and the likelihood of increased numbers of people moving to urban areas due to disasters. The trend of migration will over-populate the informal settlements in urban areas (Patra & Terton, 2017). Many developing countries are deficient of necessary services to provide for the high rate of population increase, often resulting in a significant decrease in the cities' resilience (Unruh et al., 2005). Due to the construction of buildings, roads and other infrastructures, the agriculture land, forest and green spaces will decrease in urban areas, as a result, there will create food and water insecurity (Unruh et al., 2005).

Climate change also impacts the availability of various forms of energy or increases the consumption of energy. Either increased or decreased in temperature, the cooling or heating system should operate to adjust the changing temperature inside the building. It consumes more resources and energy. Seasonal variation in hydrological systems causes fluctuation in hydropower generation (Yadoo & Cruickshank, 2012).

Although the first impacts of climate change are on biophysical resources and physical assets, these impacts ultimately lead to socioeconomic consequences. Rapid urbanization and growth of large cities have been accompanied by expansion of highly vulnerable urban communities living in informal settlements. Many such settlements are located on land exposed to extreme weather such as river banks prone to flash floods. In most urban areas, low-income groups, whether informal settlers or not, face large climate change risks because of housing in slum conditions, tenure insecurity, poor accessibility to formal infrastructure and services due to unaffordability, lack of provision for medical and emergency services, and lack of measures against disasters such as floods, fire, and winds.

Table 3.21 summarizes primary and secondary impacts of climate change on urban settlements.

3.6.2.2 Vulnerability

Some areas will expose to hazards by naturally or people build infrastructures in the risky zones. Low land cities nearby rivers are more vulnerable, particularly informal settlements where a large number of people residing near the slum areas are affected (Patra & Terton, 2017). Moreover, the exposure is to the poor people who seem to be more vulnerable towards its impact and they build houses of weak raw materials are likely to subject toward severe weather conditions (Unger & Riley, 2007). Exposure is high with low income people who reside in overcrowded housing and lack of proper infrastructure and poor nutrition as well as health service, which can be easily affected by any type of climate induced disasters. Localized flooding and fires are most common type of disasters that can have significant effect to the vulnerable groups such as women, children, the elderly and disabled people (World Bank, 2011).

Least developing countries are more vulnerable due to their weak adaptive capacity (UNFCCC, 2011). The degree of vulnerability of human settlement and infrastructure to climate change varies. They are directly affected due to change in the temperature and precipitation pattern while indirectly due to impacts on the natural resources and manmade infrastructures mainly because of climate induced disasters (IPCC, 1997; IPCC, 2007b). The natural system of water and energy will be put under pressure, on the face of urban growth (Patra & Terton, 2017). The urban poor build houses of weak, inadequate materials, often against hillsides that are subject to landslides during heavy rains (Unger & Riley, 2017).

Large population concentration in cities make the latter more vulnerable to climate change, but high population density also leads to cost-effective adaption options. As the saying goes, cities are where the climate battle will be won or lost.

3.6.3 Adaptation Measures to Reduce Vulnerability

Urban sector demands different adaptation measures such as adapting in housing and urban settlements, roads and transport systems, electric power and energy systems, telecommunications, waste and storm water management, water supply systems (Revi et al., 2014). It is essential multiple approaches, strategies and measures from reducing physical exposure to integrated development planning to adapt and recover the urban systems (Allan & Bryant, 2011). Adaptation strategies such as consideration of climate change in developing infrastructure, proper management of municipal waste, enhance productivity of water sources, and capacity building of individuals and institutions will be effective in adaptation (Patra & Terton, 2017). Similarly, use of biogas as energy (Yadoo & Cruickshank, 2012; Sapkota et al., 2014), improved cooking stove (Sapkota et al., 2014) and solar and wind energy (Yadoo & Cruickshank, 2012) can act as an adaptation strategy. These alternative sources do not only provide energy, but impart other social and environmental benefits, like women empowerment, access to education, improvement in health status and cleanliness (Sapkota et al., 2014).

Adaptation planning needs to be mainstreamed in municipal development planning, involved multiple stakeholders in urban management, applied community-based adaptation and ecosystem-based adaptation approaches (Revi et al., 2014). Urban green infrastructure and nature-based solutions (Emilsson and Ode Sang) will also be a better option for adaptation in the developing country like Nepal. Enforcing the urban plans and policies (Rimal, 2013) as well as generation of building codes (Patra & Terton, 2017) can help enhance the adaptive capacity of urban areas. In addition, adequate public (open) spaces, community infrastructures, rain water harvesting and recharging, providing adequate flow path to urban drainage, separate sewerage system, creation of artificial water bodies like ponds, etc can enhance adaptive capacity of urban areas. Vulnerability assessment of urban areas is vital, however, recognizing specific vulnerable region of any urban area is a time-consuming process (Rafael et al., 2015), it needs implement the adaptations measures effectively to solve the environmental problems in coordination with research institution, planning and implementing institutions (UNFCCC, 2011).

It is important that adaptation measures should be hazard-specific. Table 3.22 provides a summary of adaptation measures to reduce climate change vulnerability regarding urban settlements and infrastructure.

Table 3.21: Nature of climate change impacts on urban settlements and infrastructure

Climate Change Indicators	Primary Impacts	Secondary Impacts	Impacts on		
			People and Settlements	Roads and Transportation	WSS Systems
Increase in temperature	Melting of glacier and snow faster than accumulation	- Drying of water springs	- Water scarcity		- Underperformance of WSS schemes reliant on springs
		- Increase in glacier lakes outburst flood (GLOF) risks	- Potential loss of lives and properties	- Potential damage to road infrastructure	- Potential damage to WSS infrastructure
		- Increase in forest area in higher altitudes	- Threat to local people from wildlife and wild fires		
	Desiccation of soil moisture	- Drying of water springs	- Water scarcity		- Underperformance of WSS schemes reliant on springs
		- Dropping down of ground water table	- Water scarcity - Increase in the cost to access ground water		- Underperformance of WSS schemes reliant on groundwater
	Increase in new disease vectors (insects and pests)	- Increased cases of diseases against which locals are often not immunized	- Increase in health service costs, particularly in high-altitude settlements		
	Heat waves	- Increased cases of heat stroke - Escalation of 'urban heat island' effect	- Increase in energy use and cost for cooling - Health problems, particularly for children and elderly - Disruption of economic activities	- Cracks in concrete and bitumen roads, resulting into potholes - Potential buckling of railway tracks	- Cracks in ferro-cement structures - Cracks in pipelines leading to water or sewer leakage - Damage to equipment in pumping stations and treatment plants - Disturbances to biological process in septic tanks - Offensive odours from unmanaged solid waste
Deviation in nature of precipitation	No rainfall when expected	- No ground water recharging	- Rise in water insecurity		- Water scarcity
	Off-seasonal rainfalls	- Water induced disasters as communities are ill-	- Potential loss of lives and properties - Disruption of economic activities and daily lives	- Potential damage to road infrastructure - Traffic disruption	- Potential damage to WSS schemes

Climate Change Indicators	Primary Impacts	Secondary Impacts	Impacts on		
			People and Settlements	Roads and Transportation	WSS Systems
		prepared during off-seasons		- Poor visibility affecting driving safety	
	Increase in intensive rainfall	- Increased intensity and frequency of landslides, floods, flash floods, and urban floods	- Potential loss of lives and properties - Disruption of economic activities and daily lives - Entry of high waters into drainage system leading to back-flow and flooding in settlements	- Road erosion - Formation of potholes - Hill roads blocked or destroyed by landslides and mudslides - Poor visibility affecting driving safety - Bridge foundation scour due to water level rise.	- Blockage of drains discharging to rivers due to high water level and sediments - Sediment loads on source points - Sediment loads on intake structures raising operation and maintenance costs - Soil erosion around pipelines - Damage to pipelines (particularly in hills where large segments of pipelines cross rivers) - Reduction in reservoir capacity - Intrusion of rainwater with sediments into pumping stations and treatment plants - Overflow from septic tanks
	Rainfall instead of snowfall	- No snow deposition in the glaciers	- Fluctuation in regular flow volume of glacier fed rivers		
			- Damage to earthen structures (walls, roofs) by rain		
	Increase in hail		- Damage to buildings and physical infrastructures		

Acronym: WSS: Water supply and sanitation.

Source: Joshi (2017a) based on DUDBC & MoSTE (2014), DoR & MoSTE (2014), and DWSS, DoLIDAR & MoSTE (2014).

Table 3.22: Adaptation measures for urban settlement and infrastructure sector

Hazard	Objective	Current Situation	Possible Futures (Undesirable)	Adaptation Options
Floods	– Safeguard existing settlements and infrastructure lying on flood plains – Restrict settlement growth on flood plains	– Increase in the cases of torrential and sudden rains leading to floods and flash floods – Significant loss of lives and properties, particularly in Terai every year – Loss of farmlands affecting livelihoods – Haphazard settlement growth in flood-prone areas	– Increased flooding events to continue – Increased growth of settlements in flood-prone areas to continue	***a. Plans and policies:*** – Flood inundation mapping – Appropriate planning policy including determining setbacks from rivers, reviewing building code, and regulating hazard zones – Appropriate design guidelines for critical infrastructure (roads, bridges, dams, buildings) – Emergency plans for supply disruption of water, electricity, and essential goods – Review and refine indigenous adaptation practices ***b. Protection strategies:*** – Awareness programmes on emergency flood management including early warning system – River training and protection works including at the upstream – Improved drainage system – Construction of flood retention ponds – Insurance of lives and properties against natural disasters ***c. Retreat:*** – Relocation of at-risk communities and infrastructure
Landslide	– Safeguard existing settlements and infrastructure from landslides – Restrict settlement growth on landslide-prone areas	– Increase in the cases of torrential rains leading to landslides in hills – Significant loss of lives and properties in hills every year – Loss of farmlands affecting livelihoods – Haphazard settlement growth in landslide-prone areas	– Increased cases of torrential rains to continue – Increased growth of settlements in landslide-prone areas to continue	***a. Plans and policies:*** – Mapping of landslide-prone areas (e.g., slope steeper than 30 degrees) – Appropriate land use planning and byelaws for new settlements including determining setbacks from dangerous slopes and delineation of hazard zones – Appropriate design guidelines for critical infrastructure (roads, bridges, dams, buildings) – Emergency plans for supply disruption of water, electricity, and essential goods ***b. Protection strategies:*** – Awareness programmes on safety from landslides and mudslides

Hazard	Objective	Current Situation	Possible Futures (Undesirable)	Adaptation Options
				– Slope stabilization programmes and construction of retaining walls and other protective structures – Improved drainage system – Insurance of lives and properties against natural disasters ***c. Retreat:*** – Relocation of at-risk communities and infrastructure
Glacial lake outburst flood (GLOF)	Prevent GLOF and minimize damages from GLOFs	– Rapid melting of glaciers due to increased temperature leading to GLOF threats – Downstream settlements at risk	– Increase in the number of potentially dangerous glacial lakes	***a. Plans and policies:*** – Hazard mapping – Analysis of hydrograph along the river channel downstream using proper simulation models to predict and understand damage in case of GLOF – Emergency plans for supply disruption of water, electricity, and essential goods ***b. Protection strategies:*** – Installation and operation of monitoring and early warning system at potentially dangerous lakes – Regular extraction of water to a safe level – Construction of trapping dams with sufficient capacity to capture the debris and to dissipate the GLOF impact – Insurance of lives and properties against natural disasters ***c. Retreat:*** – Relocation of at-risk communities and infrastructure
Increased temperature (leading to heat island effect)	Ensure safety of citizens from health problems related to heat strokes and safeguard infrastructure from extreme heat	– Steady rise in average temperature – Increase in built-up areas in cities – Drying-up of water sources and depletion of groundwater level – Cracks on roads leading to formation of potholes	– Increased 'heat island effect' in cities – Increased water insecurity – Distress migration to cities/towns due to droughts in rural areas – Increased energy use for cooling	***a. Plans and policies:*** – Health plans to address heat strokes and disease outbreaks – Water management plan – Land use plan to protect and promote urban green spaces and water bodies – Tree planting programme – Building code to support sun shades, building openings, and green roofs to reduce building temperatures

Hazard	Objective	Current Situation	Possible Futures (Undesirable)	Adaptation Options
			– Energy crisis due to high demand – Rising cases of people suffering from heat strokes – Decreasing level of service of infrastructure such as roads – Disruption of daily lives and economic activities	– Building byelaws to restrict use of concrete or asphalt surface in open spaces ***b. Energy management strategies:*** – Energy demand management (domestic and business) – Reduction of energy and water consumption in new and existing homes, businesses and public buildings – Renewable energy generation – Incentives for green (energy efficient/ eco-friendly) buildings – Construction of climate-responsive buildings through the use of appropriate building materials, design, and construction technology **c. Water management strategies:** – Groundwater recharging – "Low regrets" infrastructure upgrades and repair (e.g. ground water recharge/impoundment areas) – Water conservation and awareness programme – Rainwater harvesting, groundwater recharge and improved infiltration – Minimization of system leaks and other water loss (e.g. surface reservoir evaporation) – Expanded or new reservoir capacity – "Low regrets" infrastructure upgrades and repair (e.g. reservoirs, water supply network) **d. Infrastructure management strategies:** – Construction of infrastructure resilient to adverse weather – Regular maintenance of infrastructure such as roads
Increased rainfall (leading to urban floods)	Minimize disruption of daily lives and economic activities from heavy rainfalls	– Increased cases of urban floods in heavily built urban areas – Deterioration of roads (e.g., formation of potholes)	– Increased cases of torrential rains to continue – Urban flooding to worsen due to increase in built-up areas	***a. Plans and policies:*** – Land use plan to protect and promote urban green spaces and water bodies – Building byelaws to promote use of pervious materials in private open spaces to minimize surface runoff

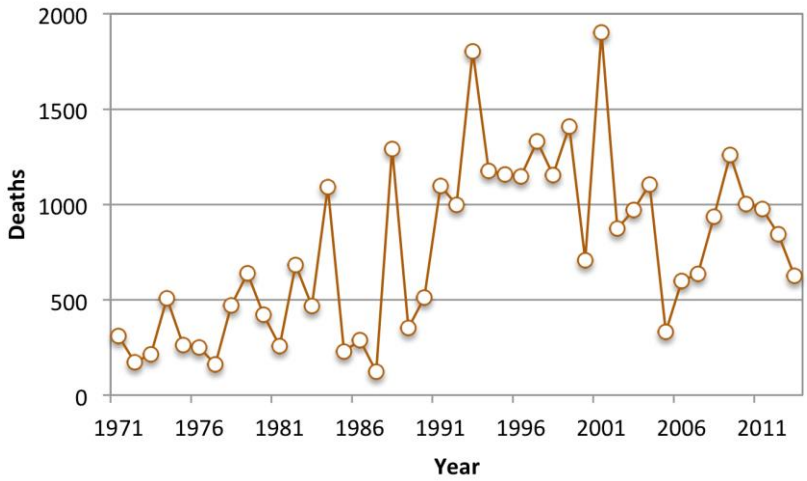
Hazard	Objective	Current Situation	Possible Futures (Undesirable)	Adaptation Options
		– Increase in vector borne diseases		– Incentives to promote backyard gardening to minimize surface runoff – Promotion of rainwater harvesting at household level ***b. Protection strategies:*** – Improved drainage system – Construction of retention ponds – Early warning system
Cold wave	Ensure safety of citizens from health problems related to cold waves	– Rising cases of cold waves particularly in Terai	– Increased energy uses for heating including increased consumption of fuelwoods – Increased cases of heating-related fire hazards – Energy crisis due to high demand – Rising cases of people suffering from cold waves – Disruption of daily lives and economic activities	***a. Plans and policies:*** – Health plans to address cold waves – Emergency plans for supply disruption ***b. Energy management strategies:*** *same as above*

Source: Joshi (2017b) following UN-Habitat (2014) and, in the case of GLOF, Yamada (1998)

3.7 Climate Induced Disasters

3.7.1 Overview of Climate Induced Disaster

World Bank has articulated Nepal as one of the global "hot spots" for natural disasters in terms of high mortality risk from multiple hazards (Dilley et al., 2005). The hilly areas of Nepal are prone to landslides and Terai plains are prone to floods, while higher Himalaya, higher mountains, and middle-mountains experience debris flow and glacial lake outburst floods (GLOFs). Drought affects the entire country; forest fires and, higher Himalaya affect middle-mountain and Terai by avalanche. The demographic factors such as rapid population growth, human encroachment into the vulnerable lands, poverty and widespread ignorance towards sustainable use of natural resources has further worsened the level of disasters risk. By ecological zones, hilly area is the most prone to disaster events (Aryal, 2012).



Source: DisInventer (2018)

Figure 3.11: Number of fatalities due to various disasters from 1971 to 2011

The death record due to various disasters during the period from 1971 to 2011 reveals that the number of such deaths is increasing over the time (DisInventer, 2018; Figure 3.11). This indicates the insufficiency of existing policy and legal framework and institutional arrangement to deal with the disaster events. The disasters data from 1980 to 2010 depict that altogether 78 major events have occurred in two decades causing fatalities of 11,112 people with economic damage equivalent to USD 43 million (CFE-DMHA, 2012). The history of last 100 years' disaster events show water induced disaster like floods to be the most recurrent and account for most of the economic damage in the country.

3.7.2 Vulnerability and Impact Assessment

3.7.2.1 Glacier Lake Outburst Floods

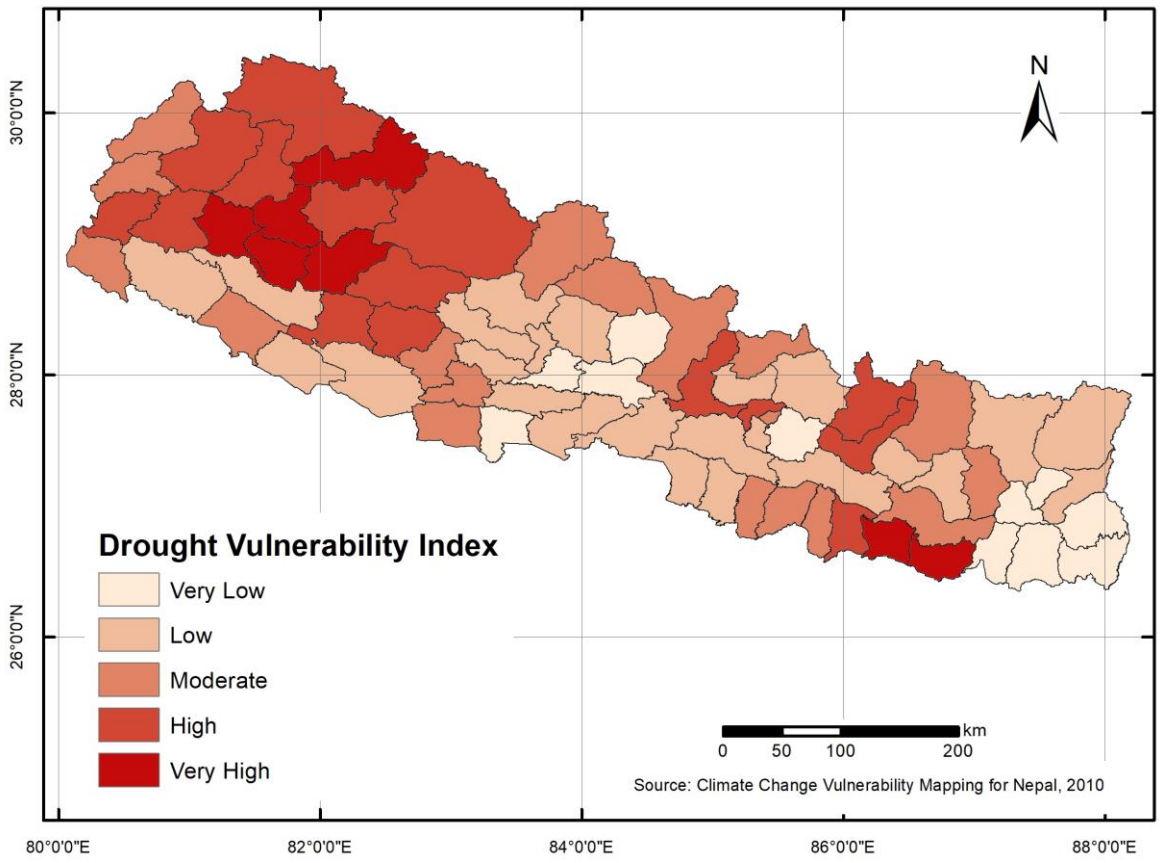
In Nepal, GLOF events are common in the High-mountain areas, as there are large numbers of glacial lakes. Among the glacial lakes existing in Nepal, 32 are considered to be potentially dangerous. The historical GLOF events in Nepal reportedly occurred about 450 years ago. Since then, 24 GLOFs have been reported. Among them, 14 have occurred in Nepal (ICIMOD, 2011b).

Table 3.23: GLOF events recorded in Nepal

SN	Date	River basin	Lake
1	450 years ago	Seti Khola	Machhapuchhre
2	3 Sep, 1977	Dudh Koshi	Nare
3	23 Jun, 1980	Tamor	Nagma Pokhari
4	4 Aug, 1985	Dudh Koshi	Dig Tsho
5	12 Jul, 1991	Tama Koshi	Chubung
6	3 Sept, 1998	Dudh Koshi	Tam Pokhari
7	15 Aug, 2003	Madi River	Kabache Lake
8	8 Aug, 2004	Madi River	Kabache Lake
9	NA	Arun	Barun Khola
10	NA	Arun	Barun Khola
11	NA	Dudh Koshi	Chokarma Cho
12	NA	Kali Gandaki	Unnamed (Mustang)
13	NA	Kali Gandaki	Unnamed (Mustang)
14	NA	Mugu Karnali	Unnamed (Mugu Karnali)

Source: ICIMOD (2011b); NA= Not Available

3.7.2.2 Drought



Source: MoSTE (2014)

Figure 3.12: Drought vulnerability ranking of different districts in Nepal

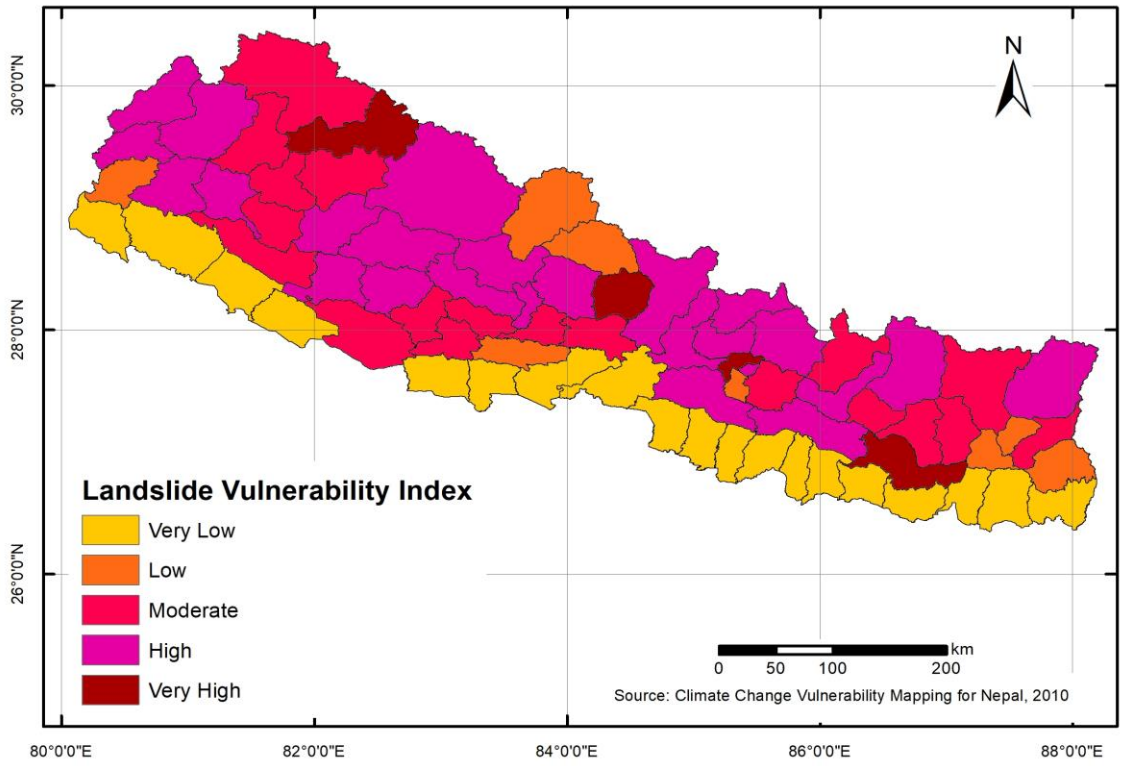
In Nepal, the drought-like condition persists from the end of March till the monsoon arrives in June. However, in the Trans-Himalayan region (Manang & Mustang) are extremely dry throughout the year. The Terai and western hills are more frequently affected than other regions. About 5,000 families living in the Hills and Terai are badly affected by drought each year (MoHA & DP-NET, 2009). The drought of 1994 affected 35 districts of the country; crops over 157,628 hectares of land were destroyed. The lack of irrigation facilities makes the problem even worse, as prolonged drought conditions have adverse effects on crop production (Nepal Disaster Knowledge Network, 2014). Figure 3.12 presents the drought vulnerability for the districts of Nepal.

3.7.2.3 Water-induced Disasters

Water-induced disasters are more frequent in recent times in Nepal. Statistics indicate that 6,026 people have lost their lives in floods and landslides between 1983 and 2001 and the estimated economic losses from these calamities amounted to around NRs 11,860 million (MoPE, 2004).

3.7.2.4 Landslides

Landslides and floods are the most recurrent, intertwined and the most destructive hazards in terms of loss of lives and properties in Nepal (Figure 3.13).



Source: MoSTE **(**2014)

Figure 3.13: Landslide vulnerability ranking of different districts in Nepal

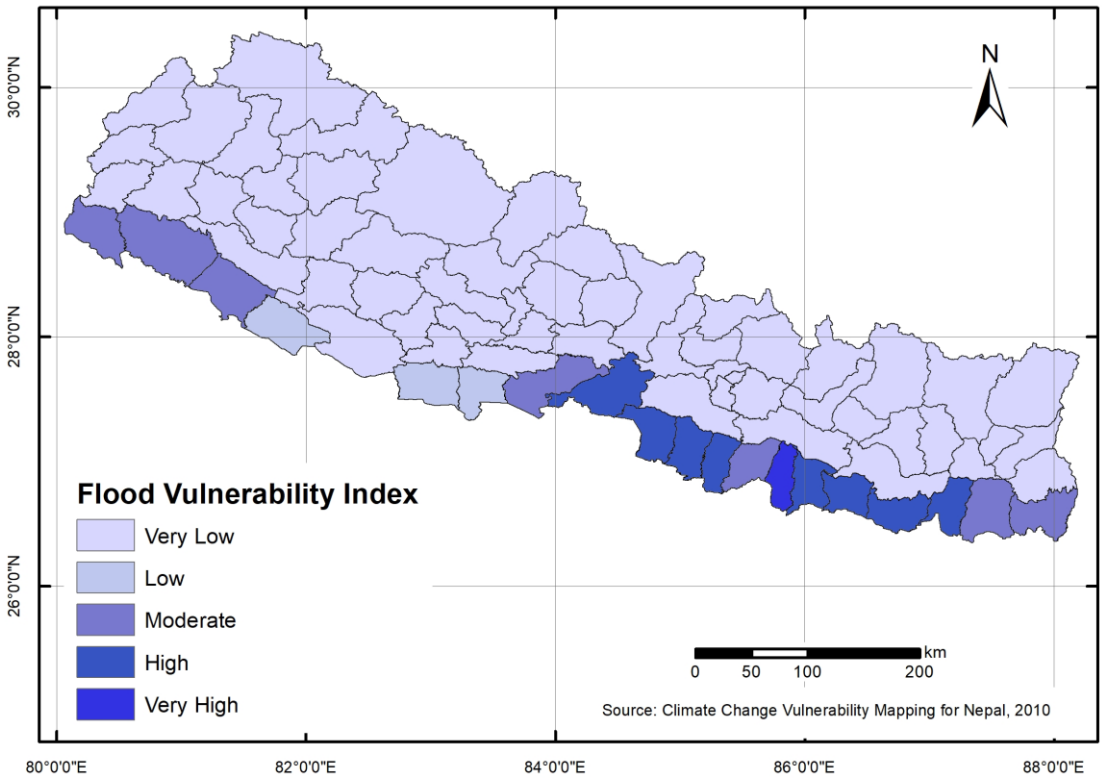
In August 5, 2014, mass landslides occurred in Sindhupalchok district blocking Sunkoshi River resulting in the loss of 156 lives, making the event the deadliest in three decades. The landslide also damaged part of the Arniko Highway disconnecting the capital city Kathmandu with the Tibetan capital Lhasa (Koirala, 2014). In 1993, a "mass movement" disaster (landslides combined with a flood) was

the second most devastating natural disaster in Nepal after the 1934 earthquake. More than 2000 landslides triggered by cloudburst were along mountain slopes and highways. Death of around 1,170 people was caused and around 500,000 were affected by the dual disaster. About 42,995 ha of arable land, roadways bridges and other infrastructures were damaged and economic losses were estimated to be around NPR 5 billion.

3.7.2.5 Landslide Dam Outburst Floods (LDOFs)

Eleven disastrous LDOFs have been reported in the period between 1967 and 1989 (Khanal, 1996). The Budhi Gandaki river near Lukubesi (1968), the Sun-Koshi River near Barhabise (1982), the Balephi Khola in Sindhupalchok (1982) and the Gyangphedi Khola, Nuwakot (1986) were dammed by landslides. The resultant outburst floods took a heavy toll of human lives and infrastructure. An earlier example of this type of flash flood occurred in Larcha, Nepal in July 1996, taking away 22 houses and killing 54 people within few minutes. In early May 2012, flash flooding in the Kaski district of north-western Nepal, near Pokhara, resulted in the death of at least 31 people, dozens missing, and caused great loss of property (ICIMOD, 2012). Landslide dam outburst events are generally random and cannot be predicted with any precision. Hazard assessment and identification of risky areas, a good communication system, and preparedness at local level are some essential measures for minimizing the LDOF risk.

3.7.2.6 Floods



Source: MoSTE (2014)

Figure 3.14: Flood vulnerability ranking of different districts in Nepal

Each year floods cause loss of human lives and immense damage to agricultural land, crops, human settlements and other properties (Figure 3.14). The Koshi flood in 2008 affected about 200,000 people in the eastern Nepal. The landslides and flood events in 2011 resulted in death of 241 people in different parts of the country. Similarly, there was a heavy loss of lives (70 people, including 40 missing) and properties by the flood and landslide of Seti River on May 5, 2012. The flood resulted to damage 4 houses, 2 local temples, 16 temporary erected sheds, 2 suspended trail bridges, and 11 vehicles (MoHA & DPNet-Nepal, 2015).

The floods triggered as a result of poor infrastructural design are also common in Nepal. Eight such floods have been reported. The failure of check dams and embankments in Butwal in 1981 led to loss of 41 lives, 120 houses and one bridge being swept away (ICIMOD, 2007). Similarly, in 1990, 26 people and 880 houses were swept away by a flood triggered by the failure of a check dam on the Rapti River in Chitwan. In 1993, the Bagmati River was dammed for a few hours due to blocking by tree logs at the Bagmati barrage; the ensuing outburst flood swept away 816 people in Rautahat and Sarlahi districts. The Larcha River was dammed by a boulder at the bridge over the highway in 1996; the subsequent outburst flood swept away 54 persons and damaged 22 houses (ICIMOD, 2007).

3.7.2.7 Windstorm, Thunderbolt, and Hailstorm

In Nepal, windstorm occurs mainly during the dry seasons between March and May. Thunderbolt occurs during monsoon and hailstorm takes place during the beginning and end of the monsoon. Hailstorm causes heavy losses of agricultural crops, but seldom affects human lives; whereas, windstorm and thunderbolt cause the loss of human life as well as properties. In 1999, windstorm and thunderbolt together killed 22 and injured 37 people. The disaster caused total loss of about NRs 7.2 million killing 50 cattle, destroying 85 houses and cattle-sheds and affecting 348 families. During 2011, thunderbolt took the lives of 107 people in different parts of the country. In 2012, 56 people were killed in Udayapur, Sunsari, Saptari, Morang, Kaski, Jhapa, Dhanusha, Taplejung and Lamjung districts (Nepal Disaster Knowledge Network, 2014).

3.7.2.8 Cold-wave/Heat-wave

Terai region have been severely affected by the cold wave claiming the lives of a number of people and livestock each year. Most importantly, a cold wave gives rise to death and injury to livestock and human life. People, who do not have sufficient warm clothes and firewood for winter season, may suffer from cold wave. In January, February and December 2011, at least 65 people died due to the cold wave in Siraha, Mohattari, Rauthahat, and Dhanusa districts. The Government of Nepal has endorsed the cold wave as a disaster event since 2011 (Nepal Disaster Knowledge Network, 2014). Heat waves that rise in atmosphere average temperature well above the average of a region have been reported to induce adverse effects on human population, crops, properties and services. This is common in Terai region in southern Nepal.

3.7.2.9 Fog/Drought

A study has reported that 3-month period drought associated with agriculture occurs evenly, whereas 12-month period drought associated with hydrology is consistent with 3-month drought for summer. Analysis of 33-year data shows that 9% of the area is covered with moderate drought, 5% with severe drought and 5% with extreme drought. Western and North-western regions have higher risks of short-

term drought, whereas central and north-eastern regions possess risk of long-term drought. In case of drought related with El-Nino however, south-eastern region is under the higher risk (Sigdel & Ikeda, 2010).

3.7.2.10 Avalanche

The northern part of the country particularly the Higher-Himalaya is prone to avalanches because of thick snow cover on steep slopes. The avalanche of November 1995 took lives of 43 people including some foreign trekkers at Khumbu and Kanchanjungha areas. On 2 January 1999, 5 people were swept away by the avalanche that occurred in Gorkha district (Nepal Disaster Knowledge Network, 2014).

3.7.2.11 Extreme Events

Increased melt of snow and glaciers in Nepal Himalaya has resulted in formation of glacial lakes and expansion of existing ones in the mountain valleys (Ives et al, 2010). Higher temperature increases the likelihood of precipitation falling as rain rather than snow (IPCC, 2007a), which can result in increased likelihoods of floods during rainy season and decreased river flows during dry season. Chaulagain (2009) has revealed that decrease in snow cover areas exponentially increases the ratio of maximum-to-minimum stream-flows (i.e., increased maximum flows and decreased minimum flows simultaneously) in Nepalese rivers. Moreover, increased melting of snow and ice including permafrost can induce an erodible state in the mountain soil which was previously non-erodible. This has increased likelihoods of landslides in the mountains. Because of warming, snowmelt begins earlier and winter becomes shorter, which ultimately affects river regimes, natural hazards, water supplies, infrastructures and people's livelihoods (Jianchu et al., 2007).

3.7.3 Efforts to Reduce Vulnerability

Government of Nepal has been putting its efforts to reduce vulnerability from the climate-induced disasters. The wider inter-ministerial coordination committee is formed to deal with the policy and institutional arrangements, whereas at the implementation level respective departments are engaged.

The Department of Hydrology and Meteorology (DHM; http://www.dhm.gov.np), under the Ministry of Energy, Water Resources and Irrigation, is the institution for monitoring all hydrological and meteorological activities in Nepal. DHM has established 282 meteorological and 51 hydrological stations nationwide (DHM, 2018b). Based on the rainfall and water level data, and information acquired from these hydro-meteorological stations, a number of early warning systems have been placed to forewarn communities. For instance, DHM set up a GLOF early warning system downstream from Tsho Rolpa glacial lake in the Tama Koshi basin in the eastern Nepal. The system reportedly worked for a few years, but inadequate operation and maintenance, vandalism, and others led to the system becoming defunct (Ives et al., 2010). Likewise, the Bhote Koshi Power Company (BKPC) established an early warning system in the Bhote Koshi River at Barhabise. The BKPC carried out community awareness raising activities to inform and prepare the local people, and installed warning signs at four different river crossings. Similarly, DHM has made efforts to develop a web-based telemetry system in various rivers to provide real-time data and information on water levels and provide flood warnings to various stakeholders. It has upgraded 11 hydro-meteorological stations in the Koshi Basin to improve flood forecasting and provide early warnings in real time. Moreover, there are community-based early warning systems. To reduce the risk of GLOF incidence from the potentially dangerous glacial lakes,

in 2016, Government of Nepal has reduced the water level (3.4 m) of Imja Glacial Lake, one of the potentially dangerous glacial lakes of Nepal (Sharma, 2017).

3.8 Gender and Social Inclusion

3.8.1 Overview of Gender and Social Inclusion

Vulnerability to climate change is context-specific and differs for each segment of society. It is influenced by a range of conditions varying from their degree of exposure and dependency upon weather patterns for livelihoods and adaptation capacities, which are influenced by gender, social status, economic poverty, power, access, and control and ownership over resources in the household, community and society (Nellemann et al., 2011). In the social constructivist view, vulnerability is not simply a consequence of natural hazards alone. Instead, it is related to one's resilience and capacity to cope with, or adapt to, the context of natural hazards, a process which is intricately connected to social structures such as gender, class, caste and ethnicity (Sugden et al., 2014; Regmi et al., 2016). Often, women are more vulnerable to climate change than men. This is because they make up the majority of the world's economically poor, do most of the agricultural works, bear unequal responsibility for household food security, carry a disproportionate burden for harvesting water and fuel for everyday survival, and rely on threatened natural resources for their livelihoods (UN Women Watch, 2009).

In Nepal, 'gendered' vulnerability to climate change relates to highly inequitable gender division of labour, as the workload of women is increased by drying up of water spouts and diminishing forest resources. Notably, women are the primary caretakers of water and forest resources management. The other reason is that the women's control over income is more limited than that of men. Gendered vulnerability can also emerge from more complex processes such as male out-migration, which is often a primary response to climate stress on agriculture for the most marginal cultivators (Nellemann et al., 2014; Koirala et al., 2015). In the communities, particularly in rural settings, many men are free from climatic and economic risks due to their migration or engagement in labour work, women left at home take double responsibilities and are still exposed to both risks (Nonoguchi, 2012). As such poor uneducated women particularly suffer from food shortage and financial burdens.

Men, women, boys and girls and socially excluded people are affected in different ways by policies, interventions and changing environments, based on their unique experiences, priorities, social norms and their relationships with nature and its ecosystem services. Their interaction with natural resources is not only supporting their livelihood but it may have also adverse impact to their day to day life if these resources are affected. Women have unequal access, control and ownership to these natural resources, and are often excluded from important decision and policy-making forums and institutions that govern them. Nepal's constitution has ensured 33% of seats for women representatives in its parliament and local bodies; however, their number is less than 10% in senior level positions in judiciary and administration (UNDP, 2010). Table 3.24 shows the increase of women percentage from 50.06% to 51.44% in a decade between 2001 and 2011 and similarly increased in households headed by female. Thanks to the increase in literacy percent among women from 34.9% to 57.4% that may help cope up with new burdens including those posed by climate change recently.

Table 3.24: Demographic Statistics of Gender (%)

Year	2001		2011	
Indicator	**Women**	**Men**	**Women**	**Men**
Population	50.06	49.94	51.44	48.56
Literacy	34.9	62.7	57.4	75.1
Female Headed Households	14.87	85.13	25.75	74.25

Source: Nepal Living Standard Survey (2010/2011) retrieved from Gurung & Bisht (2014)

Women headed households and those with limited access to modern agricultural input, infrastructure and education are more sensitive to impacts of extreme events on food security. It is therefore important to identify specific vulnerabilities, risk and impacts of climate change on women and marginalized groups in order to help designing gender and social inclusion responsive adaptation plans and strategies for specific thematic sectors. In the aftermath of flooding, cases of water-borne diseases are significantly higher. Apart from facing a personal security issue, women are endowed with the responsibility of providing resources for themselves and their families (Alam, 2015). Recognizing the differentiated roles that women and men play as natural resource managers and food providers, there is a necessity of engaging women and men in early warning systems and disaster preparedness programmes (Shrestha et al., 2014).

Key livelihood dependent sectors are agriculture, forest, biodiversity, tourism and hydropower. Water resources are more exposed due to unpredictable weather patterns and extreme weather events. Similarly, communities whose livelihoods depend on forest-based products are exposed to the impacts of climate change due to pests, disease attacks, changes in rainfall pattern and rising temperatures leading to forest fires and forest degradation. Extreme climate events can wash away essential infrastructure like roads, bridges, houses, schools and public buildings that directly impact the lives of poor and marginalized people living in isolated and remote areas (MoPE, 2017).

According to the 2011 census, the indigenous nationalities (Adivasi Janajati) of Nepal comprise 36% of the nation's total population. This population embrace over 100 castes and ethnic groups including 15 Dalit castes. Although the laws have banned untouchability and affirmed the rights of all citizens, irrespective of caste or gender, to equal treatment, discrimination based on caste persists. Because the Dalits are socially excluded, they have no access to potable water and compromise with the polluted water which may worsen in the wake of climate change. The incidence of poverty is higher among ethnic minorities such as the Tharu and Mushahar, and tribal groups such as the Chepang and Raute than for the population as a whole (ADB, 2002). As poverty and food insecurity are closely related, these people have high food insecurity.

3.8.2 Vulnerability and Impacts of Climate Change on Gender and Social Inclusion

3.8.2.1 Vulnerability

Poor, marginalized and landless farmers practicing subsistence agriculture are more exposed to the adverse impact of climate change such as floods, cold waves and heat waves. About 90% of crop loss in Nepal is caused by weather or meteorological events (UNDP, 2009). Tribal and members of lower caste groups are also particularly vulnerable to food insecurity, they have large food production deficits. In addition to differences in food insecurity between agro-ecological zones, there are also differences and inequalities along the east to west gradient. In general, marginal farm households in western districts are more vulnerable than similar households in central and eastern districts of the country (FAO, 2004).

Besides agriculture, the anticipated losses resulting from increased intensities of weather-related hazards, epidemics and diseases are likely to add to the sufferings of the population with overall damage to the national infrastructure (Sharma, 2009). The Climate Induced Disasters TWG suggests that women are more vulnerable to climate-induced disasters (CIDs) since they have lesser access to early warning systems and fewer survival skills. Moreover, in post disaster temporary settlements women are vulnerable to sexual violence. They are excluded from disaster recovery decision-making in policies and programmes. In addition, food scarcity after CIDs leave women with fewer options for food, and they often eat less causing negative impacts on their health (Mainlay & Tan, 2012).

3.8.2.2 Impacts

Shifts in the monsoon season, longer dry periods and decreased snowfall push poor and marginalized community more vulnerable. Floods and droughts adversely affect agricultural production and productivity resulting in income shortages. Increasing need for livelihood diversification triggers outmigration (predominantly men, with 12% women migrant workers). The primary responsibility for agricultural and household work falls on women (Leduc, 2009; ICIMOD, 2011a), resulting in increased drudgery, but also increased decision-making power, as women become key natural resource managers at the household level (Nellemann et al., 2011). Outbreaks of pests and diseases in crops and livestock are increasing, with devastating crop and biodiversity loss posing a direct threat to the livelihoods of poor and marginalized people (Leduc, 2009).

The marginalized or indigenous groups, particularly Majhi, Raute, Chepang, Satar, are more vulnerable to food insecurity due to disasters like floods, landslides and fire. Women have indigenous knowledge, skill and practice in production, seed preservation and other related activities. Regarding forest and biodiversity issues, among the poor and marginalized people, women are highly responsible to manage the household need like fuel wood and fodder for livestock. Climate change vulnerability impacts on forestry seem additional burden in household activities for women because of their social and cultural roles and responsibilities towards families and communities. Women often have to bear physical risks to collect fuel wood and fodder as they have to walk a long distance. Regarding water and energy sector, women are primarily responsible for water use (cooking, health and hygiene, kitchen garden and livestock etc.). So, they have to walk long distances to collect water and fuel, exposing women and girls to harassment or sexual assault.

3.8.3 Adaptation measures to reduce vulnerability

Recognizing the reality and differences in the case of gender and social inclusion part, the Government of Nepal aims to promote inclusive development by ensuring participation, access to opportunities and sharing of benefits across all individuals and groups. The goal of climate adaptation and equitable development can only be achieved if a fair share of benefits is distributed among all fraction of society, irrespective of their caste, class, ethnicity, gender, age and disability status (NAP, 2017). Livelihood based social protection integrating the climate change adaptation and disaster risk reduction is crucial for sustainable societies (Sharma, 2011).

Nepal has developed policies plans, programmes and mechanisms for addressing climate change (Climate Change Policy 2011, NAPAs, LAPAs,) where women's differentiated impacts, capacities and larger engagement are acknowledged. Climate change contributes to impacts on women because of the conjunction of the feminization of poverty and environmental degradation caused by current climate variability and climate change. Nepal's Human Development is almost one third lower than it could be if it were more equally distributed and by 2050 the South Asia Human Development Index (HDI) would be 12% lower than the baseline in an "environmentally challenged scenario" and globally 15% lower in more adverse "environmental disaster scenario" (HDR, 2011; adopted from IDS-Nepal, PAC and GCAP, 2014).

The Ministry of Forests and Soil Conservation has adopted a separate strategy to address gender and social inclusion issues. The strategy has identified the following four change areas in order to attain the institutional vision: (i) gender and equity sensitive policy and strategy, (ii) equitable governance, (iii) gender and equity sensitive organizational development and programming, and (iv) equitable access to resources and benefits (MoFSC, 2007). Accordingly, Community Forest User Committees are required to have representation of women, Dalits and members of indigenous community in required proportions. The National Agricultural Policy (2004) has targeted 50% representation of women in farmers' groups and community-based programmes. The Climate Change Policy (2011) has provision for women's participation in the implementation of climate adaptation programmes. Section 8.4.2 of the Policy calls for ensuring the participation of poor people, Dalits, marginalized indigenous communities, women, children and youth in the implementation of climate adaptation and climate change related programmes. The Gender Equality and Environment Section within the Social Development Division of NPC is responsible for addressing gender and social inclusion issues in national plans and policies. Likewise, Gender Equity and Social Inclusion section under the General Administration Division of the Ministry of Federal Affairs and Local Development looks after this issue.

A separate Dalit and Adivasi Janajati (indigenous people) Coordination Committee and their respective commissions have been formed to coordinate and implement various activities related to gender and social inclusion. Most other government and non-government agencies also have gender and social inclusion policies. Federation of Community Forestry Users Nepal (FECOFUN), for example, has established rules to include women in the decision-making process and it encourages local forest user groups to include women and disadvantaged groups for involvement in the committee and participation in every activity of CFUG (MoFSC, 2017).

MoPE (2017), MoFSC 2017), Mainlay & Tan (2012) raise the following issues and recommend the gender and social inclusiveness to overcome the disparity of climate change impact.

- There is an absence of sex-disaggregated data in most sectors to measure the differential impacts of climate change between men and women, and the most marginalized segments of society. In this regard, the first step is producing disaggregated data to describe men's and women's differing livelihoods strategies, circumstances and opportunities. This information is crucial to measure and to properly understand the gendered effects of projects to address climate change vulnerability.

- There is also inadequate documentation and sharing of existing climate resilient adaptation knowledge and practices that are GESI responsive on specific thematic sectors. To address these issues, detailed and context specific research also needs to be carried out on the differential impacts of climate change on women and men in Nepal. This should draw on existing studies of traditional livelihoods highlighting existing local knowledge of natural resource management and of coping strategies to deal with climate variability. To replicate the good practices, there is also need to enhance awareness and capacity building programmes.

- There is still lacking of coordinated and integrated efforts for formulating adaptation plans and strategies at different levels (national and district). To overcome these challenges, involving communities in identifying the challenges they face and their effective participation in formulation, implementation and evaluation of any climate smart initiatives leads to more sustainable and appropriate outcomes. It also enables programmes to build on existing mechanisms and initiatives which share gender equity objectives such as Aama Samuha (Mothers' Groups) and Community Forest User Groups (CFUGs) rather than creating new institutional mechanisms. Strengthening existing organisations and initiatives which work to achieve gender equity can offer opportunities for effectively achieving the sustainable development within a context of climate change.

- One key aspect to achieving gender equity and reducing women's vulnerability is empowerment. Women must have the skills and capacity to ensure that their needs are met. It is recommended that a gender focused service delivery mechanism be developed to strengthen women's ability to adapt to climate change.

- Gaps are also evident in institutional and functional linkages between gender focal points and climate change focal points in ministries. In this regard, a coordinated and collaborative efforts while planning and implementations needs to strengthen. Proper policy regarding gender and social inclusive should be ensured and context specific indicators needs to put and also needs to properly implement as prepared by National Planning Commission in Sustainable Development Goals.

There is strong need of intensive study to determine the societal dependency over natural resources. In the meantime, how they have been affecting by climate change, how they are adapting to changing climate in individual, household and community level, and what capacities they need to enhance are important aspects to know. Proper monitoring and evaluation mechanism need to strengthen to ensure the gender and social inclusive society to combat the climate risk.

3.9 Summary of the Impacts

Table 3.25 presents summary of the likely impacts of climate change in key sectors.

Table 3.25: Likely impacts of climate change in key sectors

Sector	Likely impacts of climate change
Agriculture and food security	• Declining crop, fisheries and livestock production • Impact on subsistence farming, which is more vulnerable to erratic monsoon rains and floods • Decline in the production of winter and spring crops because of temperature and precipitation anomalies • Decline in rice and wheat yields, with serious implication of food security for a large section of the population, particularly in the western region • Loss of local and traditional crop varieties, leading to negative impacts on food and nutrition security
Water resources and energy	• Water stress will negatively impact agricultural productivity, human health, nutrition security, and sanitation facilities • Excess water, such as during heavy precipitation and flooding events, will damage infrastructure, human settlements, and crops • Changes in river flow will impact micro-hydro projects, disrupt the power generation system, and decrease the system's efficiency, leading to large-scale power shortages and blackouts, given that 90% of the country's electricity is derived from hydropower • Solar power systems will be affected by heavy precipitation, prolonged cloudy days, heavy snowfall, and hailstorms • Increased incidence of forest fires will lead to loss of forest resources and biodiversity, and result in a fuel-wood crisis
Forests and biodiversity	• Temperature and rainfall variability have resulted in shifts in ecological regions and tree-line • Higher incidences of pests and diseases have been reported • Emergence of alien and invasive species is increasing, leading to habitat loss and the loss of biodiversity in many regions • Increasing occurrence of forest fires has caused damage to critical habitats and affected human settlements • Changes in flowering and fruiting timings of many horticultural crops have been observed • Decline in migratory birds and other birds • Decline in the provision of ecosystem services by vital ecosystems such as wetlands and forests
Public health and WASH	• Nepal's already poor health care infrastructure makes it more vulnerable to climate change • Greater risk of outbreaks of vector-borne diseases such as malaria, Kalaazar, and Japanese encephalitis, Dengue incidence reported • High incidence of water-borne diseases due to a lack of access to clean sources of water during disasters such as floods or droughts • Heart stroke, cardio-respiratory diseases, ARI, snake-bite cases increasing
Tourism, Natural and Cultural Heritage	• Climate induced disasters affecting tourism industry by damaging infrastructure and disturbing tourism activities • Accelerated melting of snows and glaciers in the Himalaya may reduce the number of trekkers/mountaineers • Overall loss and damage on tourism GDP increasing
Infrastructure and Urban Settlements	• Key infrastructure, such as roads, water and sanitation, hospitals, schools, and public buildings, is at risk of being damaged by natural disasters such as landslides and floods • Water and energy systems in urban areas are at greater risk • Large influx of disaster-induced migrants displaced from rural areas will result in overcrowding in slums and informal settlements, leading to public health challenges

Climate-induced Disasters	• Hills prone to landslides, Terai plains to floods, and high mountains experience debris flow and GLOFs • Number of disasters and victims increasing • Drought incidents, landslide, thunderbolt, windstorms, and flood increasing
Gender and Social Inclusion	• Shifts seasons, longer dry periods and decreased snowfall push poor and marginalized community more vulnerable • Out migrations triggered • Increased vulnerability to marginalized populace • Additional burden to women

Source: Modified from MoE (2010)

4. Climate-Related Policies and Activities

4.1 Legal Provisions, Policies, Plan and Programmes, Strategies and Frameworks

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, Nepal speeded up climate change-related activities after the endorsement of the National Adaptation Programme of Action (NAPA) in 2010, Climate Change Policy in 2011 and the National Framework on Local Adaptation Plan for Action (LAPA) in 2011. The Ministry of Forests and Environment is the authority to formulate plans and policies on climate change and environment. The Government has initiated implementing climate change adaptation and mitigation programmes with the defined policy and guideline framework through proper monitoring arrangements. Under the Ministry (MoFE), a Climate Change Management Division (CCMD) has been created which is the focal point for the national and international organizations regarding climate change and responsible for matters relevant to the climate change and proper management of the climate change risk and climate induced disasters.

Realizing the increasing impacts of climate change, the Government of Nepal has prepared and promulgated policy documents, which addresses the national deliberation regarding the impact of climate change and suggests coping strategies. All these policy documents unanimously identified rural communities as highly vulnerable to the impacts of climate change and emphasize to increase adaptive capacity of communities by identifying the potential threats/hazards and suitable adaptation interventions, and implementing these adaptation activities. LAPA is an adaptation plan prepared at local level and is considered as the best practice to ensure the bottom up planning process. The concept of LAPA was coined to: identify the impacts of climate change; identify best possible adaptation options (suited to local condition); prepare adaption plans; integrate the prepared local level plans in VDC level planning process; and to make local development process more climate change sensitive and climate proofed.

4.1.1 Legal Provisions

Constitution of Nepal (2015)

The Constitution of Nepal has defined healthy and clean environment as the fundamental right of the citizen (Article 30). The directive principles include policies regarding conservation, management and use of natural resources. In annexes of the constitution, schedule 5, 6, 7, 8 and 9 provide list of the roles, responsibilities and coordination mechanisms. The municipalities shall make rules required under its defined domains or jurisdictions to operate the given responsibilities and regulate procedures, while complying with provincial and national laws.

Local Government Operation Act (2017)

The Government Operation Act 2017 came into effect in October 2017. It has paved a legal foundation towards institutionalizing legislative, executive and quasi-judiciary practice of the local governments (municipalities). It clarifies the rights of the municipalities to formulate local laws, rules and regulations and criteria for environmental conservation, control pollution and manage solid wastes. It also authorizes the local government in implementing climate change mainstreaming into local plans, including GESI, and building institutional capacities through making operational guidelines, procedures and criteria.

Environment Protection Act (1997), Environment Protection Regulation (1997)

The Environment Protection Act (1997) makes legal provisions in order to maintain clean and healthy environment by minimizing, as far as possible, adverse impacts likely to be caused from environmental degradation on human beings, wildlife, plants, nature and physical objects. It also defines the provisions of Environment Impact Assessment (EIA) and Initial Environment Examination (IEE) while implementing development projects.

4.1.2 Policies

Climate Change Policy (2011)

The Climate Change Policy (2011) aims at improving livelihoods by mitigating and adapting to the adverse impacts of climate change. It has envisioned the provision and commitment to disburse at least 80% of available funds to target local communities to build adaptive and resilient capacity to the negative impacts of climate change.

Renewable Energy Subsidy Policy (2016)

The Renewable Energy Subsidy Policy (2016) aims to reduce the dependence on traditional and imported energy by increasing access to renewable energy to improve the livelihoods of local people and create employment activities. The policy provides an overview of the specific subsidies and conditions provided, depending on technology, region and local context.

National Agriculture Policy (2004)

The National Agriculture Policy (2004) is designed to address the needs of both farmers with access to resources and farmers with comparatively less access and opportunities to address issues of agricultural production and productivity. It has mentioned interventions targeted to farmers with less than half a hectare of land without irrigation and farmers belonging to Dalit, Utpidit and other marginalized groups. Other areas of promotion include commercial farming, conservation, promotion and utilization of natural resources and the environment and establishing a monitoring and assessment system.

Forestry Sector Policies and Strategies

There are at least five policies in forestry sector which have considered/included provisions on climate change. They are Forest policy (2015), Forest Act (1993), Forestry Sector Strategy (2016-2025), Nepal Biodiversity Strategy and Action Plan (2014-2020) and Community Forestry Development Guideline (Third Revision, 2014).

Forest Policy (2015) was formulated with a long-term vision of contributing to local and national prosperity through sustainable management of forest, biodiversity and watershed. Adaptation to and mitigation of adverse impacts of climate change is one among the seven major themes of this policy. It emphasizes both the adaptation and mitigation through community-based forest management. It aims to implement Reducing Emission from Deforestation and Forest Degradation (REDD+) programme to enhance carbon stock in the forests.

Nepal prepared Forestry Sector Strategy (2016-2025) with the vision of sustainable management of forest ecosystems and optimization of biodiversity and watersheds for national prosperity. One of the goals of the Strategy is to make forest resources climate resilient. There are five expected outcomes to achieve through the goal stated in the FSS, and one of them is “climate resilient capacity of society and forest ecosystems enhanced”.

A party to the convention on biological diversity (CBD) since 1992, Nepal has prepared Biodiversity Strategy and Action Plan (2014-2020). One of the cross sectoral themes of the NBSAP is adaptation and mitigation to address the impacts of climate change. Two identified strategies under this theme are: Adaptation to and mitigation of the impacts of climate change on biodiversity, and Enhancing the resilience of ecosystems, species and human communities to the climate change impacts.

Promulgated in 1993, the Forest Act addresses the contemporary forestry issues in changing context. The second amendment of the Act in 2016 has mentioned about the concept of environmental services and carbon storage as one of the environmental services. The Community Forestry Development Guideline third revision (2014) has included provisions on climate change adaptation. It has briefly illustrated the importance of climate change adaptation activities in community forestry and that the CFUGs can prepare the community adaptation plans.

Energy Policy and Environment-Friendly Vehicle and Transport Policy

In context to the climate change, two more policies are relevant; viz. Energy Policy and Environment-Friendly Vehicle and Transport Policy. The Energy Policy highlights the maximum utilization of hydropower potential to meet its domestic demand of electricity by mitigating adverse environmental impacts and accelerate renewable energy services, and increase access to the Renewable Energy technologies with subsidy provisions. Environment-Friendly Vehicle and Transport Policy aims to reduce emission from transport sector, increase the share of electric vehicle up to 20% by 2020, promote the transformation of other regular vehicle to electric vehicle, and provide subsidy scheme for the promotion of electric and non-motorized vehicles.

4.1.3 Plan and programmes

Since 1956, Nepal's socio-economic has been guided by medium-term development plans. The issue of climate change was first mentioned in Ninth Plan (1997-2002), which envisioned programmes to minimize negative economic and social impacts of climate change. The Tenth Plan (2002-2007) mentioned to develop implementation mechanism of international treaties including that of climate change, and also proposed research activities in glacial lakes outburst flood (GLOF), establishment and operation of a centre to study climate change in the Himalayan range. The Eleventh Plan (2008-2010) showed serious concern to climate change and proposed to formulate a national policy on it to use the opportunities of clean development mechanism (CDM) and others under Kyoto Protocol while developing programmes to mitigate adverse effects of climate change. Giving importance of plan and programmes in climate change, the Twelfth Plan (2011-2013) brought 'Environment and Climate Change' in a separate chapter. It emphasized on the implementation of NAPA and Strategic Programme for Climate Resilience (SPCR), and reiterated to establish international research centre and develop legal framework for climate change fund. To further strengthen its commitment, the government started ear marking the climate change budget since the Thirteenth Plan (2013-2015). The plan aimed preparing local adaptation plan of action (LAPA) for at least 74 village and municipalities in mid- and far western region. The Fourteenth Development Plan (2015-2018) came up along with the development roadmap of SDGs. Highlighting the Paris Accord, the plan focuses to achieve development goals through implementing adaptation measures to reduce the impact of climate change. It has adopted green development strategy to reduce the impact of climate change and has emphasized to reform policies and strengthen legal frameworks and institutional settings.

National Adaptation Programme of Action (NAPA)

The National Adaptation Programme of Action (NAPA), 2010 is the first comprehensive government response to climate change. It has identified nine urgent and immediate climate change adaptation priority programmes related to six thematic sectors (agriculture, forest biodiversity, water resources, health, infrastructure, and disaster). NAPA also specified a coordination mechanism and implementation modality for climate change adaptation programmes (MoE, 2010).

National Adaptation Plan (NAP)

In 2015, the government initiated the process of National Adaptation Plan (NAP) engaging seven Thematic Working Groups (TWGs) and two Cross-cutting Working Groups (CWGs), which covered the major climate change sensitive sectors. NAP aims to reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience; and integrate of climate change adaptation into existing policies/plans and programs within all relevant sectors and at different levels (MoPE, 2017b). It also worked to develop a common understanding on the 'Vulnerability and Risk Assessment (VRA)' methodological framework and tools for Nepal's NAP formulation process. It has proposed a framework for vulnerability and risk assessment (VRA) using IPCC-AR5 as the foundation. The IPCC framework considers risk as a function of hazard, exposure, and vulnerability. The proposed framework unpacks the elements of risk and customizes them to needs and applicability in the national context. The framework assumes that the risk of climate related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the exposure and vulnerability of human and natural systems. Changes in the climate system (trends and scenarios), biophysical system, and socioeconomic processes (including governance and adaptation and mitigation actions) are drivers of hazards, exposure, and vulnerability.

4.1.4 Strategies and Frameworks

In relation to climate change and vulnerability, Nepal has developed some strategies and frameworks. Followings are the major highlights of the strategies and frameworks:

Low Carbon Economic Development Strategy 2015

- Aims at identifying the key approaches and interventions that will allow Nepal to maximize its resilience and low carbon growth potential without compromising the overall growth potential of all development sectors. The major sectors include energy, forestry, agriculture, industry, transport, building & waste) and cross cutting issues (policy, financing, GESI & institution).
- Aims to create an enabling environment to promote private sector investments and foreign direct investments in low carbon (energy efficiency and renewable energy) technologies; develop electrical rail network in the low lands of Nepal; control drivers of deforestation and forest degradation to enhance carbon sequestration; provide better price from carbon markets to ensure an equitable benefit sharing mechanisms and maximize benefits at the local level to help sustainable management of forests; etc. The strategy is under endorsement from the council of ministers, Government of Nepal.

National REDD Strategy

- Initiatives to further contribute to promoting sustainable management of forests, carbon sequestration and adaptation co-benefits.

- Envisioned to optimize carbon and non-carbon benefits of forest ecosystems for the prosperity of the Nepali people, and has objectives of, inter alia, reducing carbon emission, and enhancing carbon sequestration and climate resilience.

Table 4.1: Climate change policies with its responses, potential impact areas and level of governance

Policies/Plans and Regulations	**Response**		**Potential impact areas**				**Level of Governance**		
	Mitigation	Adaptation	Agriculture	Water Resources	Forest	Disaster	Federal	Provincial	Local
Regulatory Frameworks									
Water Resource Act, 1992			*	*	*	*	*		*
Forest Act, 1993					*	*	*		*
Environment Protection Act, 1996 and its Rules 1997				*	*	*	*		*
Local Government Operation Act (LGOA), 2017	*	*	*	*	*	*	*	*	*
Disaster Risk Reduction and Management Act, 2017	*	*				*	*	*	*
Policies/plans and Strategies									
Ninth Plan (1997-2002)	*	*				*	*		
National Conservation Strategy (NCS) 1998	*	*	*	*	*		*		
Nepal Biodiversity Strategy, 2002	*	*				*	*		
Tenth Plan (2002-2007)	*	*				*	*		
National Water Resources Strategy, 2002	*	*							
National Agriculture Policy, 2004	*	*	*	*	*		*		
National Water Plan (2005)	*	*		*		*	*		
Water Induced Disaster Management Policy, 2006	*	*		*		*	*		
Three Year Interim Plan (2007/08-2009/10)	*	*				*	*		
National Strategy for Disaster Risk Management in Nepal	*	*				*	*		
National Adaptation Programme of Action (NAPA), 2010		*	*	*	*	*	*		
Twelve Three Year Plan (2010/11-2013/14)	*	*	*	*	*	*	*		
Climate Change Policy ,2011	*	*	*	*	*	*	*		
Local Adaptation Plan for Action (LAPA) 2011		*	*	*	*	*	*		*
Climate Resilient Planning Tool, 2011	*	*	*	*	*	*	*		
Climate Change Adaptation and Disaster Risk Management in Agriculture: Priority Framework for Action 2011–2020		*	*				*		
Local Disaster Risk Management Planning Guidelines (LDRMP), 2012		*				*			*
Thirteenth Plan (2013/14-2015/16)	*	*	*	*	*	*			
Irrigation Policy, 2014		*	*	*	*	*	*		
Water Induced Disaster Management Policy, 2015		*				*	*		
Forest Policy, 2015	*	*				*	*		
National Adaptation Plans (NAPs) 2015		*	*	*	*	*	*		
National Land Use Policy, 2015	*		*		*		*		
Agriculture Development Strategy (20152035)		*	*				*		
Fourteenth Periodic Plan (2016/17-2018/19)	*	*	*	*	*	*	*		
Forestry Sector Strategy (FSS), (2016-2025)	*	*	*	*	*	*	*		
National REDD+ Strategy	*	*				*	*		
National Ramsar Strategy and Action Plan, Nepal (2018-2024)	*	*		*	*		*	*	*

Source: Nepal (2019)

Agriculture Development Strategy (2015-2035)

- Sets forth priorities to move toward self- reliant, sustainable, competitive, and inclusive agriculture sector that drives economic growth and contributes to improving livelihood, food and nutrition security leading to food sovereignty
- Includes strategies for poverty reduction, agricultural trade competitiveness, and establishing higher and more equitable income and rights for farmers
- Includes various measures targeted at the most disadvantaged rural population including poor households, women, indigenous peoples, Dalits and other marginalized communities, especially with a focus on improved food security.

Nepal's Nationally Determined Contributions (2016)

- Provides impacts of climate change across sectors including water resource management (stressing reduced water availability and increased droughts and floods), agriculture, food security and renewable energy
- Prioritizes climate-resilient sustainable land and forest management, ecosystem rehabilitation and restoration, strengthening community-based NRM, and improving agricultural techniques
- References the legitimate rights of all Nepali people, including disadvantaged social groups over biological resources

Water Resource Strategy (2002)

- Recognizes the connection between human activities, natural factors, and risks of severe flooding and environmental deterioration, economic loss, and displacement of people and that this calls for improved holistic watershed management
- Provides roadmap to strengthen institutional capacities, implement watershed and aquatic ecosystem programmes, and meet long-term requirements for social and ecological sustainability

Climate Change Adaptation and DRM in Agriculture Priority Framework for Action (2011-2020)

- Addresses five priority action areas: (i) institutional and technical capacity for climate change adaptation and disaster risk management in agriculture, (ii) assessment and monitoring of climate risks, vulnerabilities and enhancing early warning systems, (iii) improving knowledge management, awareness raising and education on climate change, adaptation and disaster risk management, (iv) reducing climate related risks and underlying vulnerabilities by implementing technical interventions in agriculture and livestock, (v) strengthening capacities and procedures for effective disaster preparedness, response and rehabilitation
- Identifies gaps in existing plans and strategies and provides a list of actions relevant to climate change adaption, NAPA and national strategies for disaster risk management

Environment-friendly Local Government Framework (2013)

- Aims to establish environmental governance and create a sustainable environment-friendly society at multiple levels from the household to village to municipality to district
- Contributes to mainstreaming environment, climate adaptation and disaster management issues into local planning and encourages the coordination and cooperation between environment and development
- Increases local ownership and recognizes the leadership roles of local institutions and the importance of positive competition for motivating environmental management

Nepal Country Report on Sustainable Development Goals 2016-2030

- Gives update on Nepal's status on reaching the SDG targets
- Provides breakdown of GHG emissions, including in relation to agriculture sector, and the projected changes expected until 2030

4.2 Activities

4.2.1 Ratification of the Paris Agreement

The Paris Agreement on Climate Change that was adopted in Paris in December 2015 and signed by leaders from 177 countries in New York during the high-level Signature ceremony will enter into force 30 days after ratification by at least 55 countries and by countries representing at least 55% of global emissions. Even though, Nepal emission is negligible, its ratification will show positive signal and helps to contribute in reaching minimum countries requirement (at least 55 countries). The representative of Nepal in the High-Level Signature Ceremony of the Paris Agreement has stated, "Nepal intends to submit the instrument of ratification at the earliest".

4.2.2 National Framework on LAPA (2011)

Realizing the climate change as a major agenda under the UNFCCC convention regime, the GoN has approved the national framework on Local Adaptation Plans for Action (LAPA) to address the internalize and prioritize the climate change adaptation action from local level to national level. The framework provides a way to integrate the specific needs of local people for climate change adaptation and resilience into local-to-national level planning. It also helps ensure that the process of integrating climate change resilience into planning is a bottom-up, inclusive, responsive and flexible process. As the goal set out in Nepal's Climate Change Policy (2011) to improve the people's livelihoods through climate change impact mitigation and adaptation activities of the GoN in implementing the policy and the NAPA, and to support other initiatives, including coordination mechanism as well as delivering climate adaptation results at the local level. NAPA has identified and prioritized the adaptation options, and implemented "Increasing community-based adaptation through integrated management of agriculture, water, forests and biodiversity" in the name of NCCSP.

UK Aid/DFID and European Union are the funding organizations with a total contribution of 14.6 million pound. Approximately 80% of the fund allocated for the implementation by the government is being used for local level activities. The remaining 20% is allocated for institutional capacity building and coordination at the national level. The 100 Local Adaptation Plan of Actions (LAPAs) developed by the local communities at VDC level are being implemented. The goal of the NCCSP is to contribute towards enhancing the adaptation capacity of the poorest and most vulnerable communities in Nepal. The programme has a key objective to enhance capacity of the Government, particularly, MoPE and Ministry of Federal Affairs and Local Development (MoFALD) and non-governmental (NGOs, CBOs, private Sector and Communities) institutions to implement the Climate Change Policy (2011) and most urgent and immediate adaptation actions to increase the resilience of the climate vulnerable poor people.

Through NCCSP, the LAPAs are being implemented in 14 districts: Achham, Bajura, Kailali in the Far Western region and Bardiya, Dolpa, Humla, Jumla, Mugu, Dailekh, Jajarkot, Kalikot, Dang, Rolpa and Rukum in the mid-western region. The target area has an approximate population of

three million. The primary beneficiaries of the programme are the poorest and most climate vulnerable people, particularly poor women and men from disadvantaged and marginalized groups. Other stakeholders include the district line agencies, community-based organizations, non-government organizations, indigenous, groups, MoSTE, the Climate Change Council, Ministry of Finance, MoFALD.

4.2.3 Promoting Ecosystem-Based Adaptation (EbA)

The EbA concept was introduced and the term coined at the UNFCCC COP 14 in Poznan in 2008. Since then, the concept has successfully been promoted into broader negotiations, policies, strategies and action plans. EbA has been suggested as an appropriate adaptation effort to minimize climate risks to society, economy and ecosystems. In Nepal, the government line agencies are implementing the EbA programmes in partnership with national and international organizations such as IUCN, UNEP, UNDP, and TMI. Academic institutions and research NGOs are taking part in generating EbA knowledge. In 2013, Nepal undertook the first pilot project of mountain EbA in Panchase covering three districts Syangja, Kaski, and Parbat. Alongside the Panchase, EbA South project was implemented covering central part of Nepal. In further impetus, the programme of "Scaling Up Mountain EbA Building Evidence, Replicating Success and Informing Policy" was taken up in 2017. At present, an urban EbA project focusing in Kathmandu valley is in progress.

4.2.4 Nationally-Determined Contributions (NDC)

Government of Nepal prepared and communicated its Nationally Determined Contributions (NDC) to the UNFCCC Secretariat in February 2016, which realizes the importance of reducing the impact of climate change and seeks to implement climate adaptation actions to protect life and life-support systems as well as improve the livelihoods of climate vulnerable communities. The cumulative impacts of NDCs would greatly contribute to limiting the rise in temperature to safe levels. Nepal will implement its NDC and contribute to the global efforts of reducing GHGs emissions and helping life and life-support systems to adapt and build resilience to climate change impacts. However, Nepal requires bilateral and multilateral support to meet both qualitative and quantitative targets. Nepal has to formulate and implement NAP and implement NAPA and LAPAs; conduct research and studies on loss and damage associated with climate change impacts and develop and implement measures to reduce climate vulnerabilities.

5. Adaptation Action Plans

Based on the level of vulnerability, adaptation action plans for major sectors have been prepared. The adaptation actions were prioritized based on approach paper of central and provincial planning commission, sectoral policies and plans of government of Nepal, NAPs, climate change budget code, and adaptation measures identified by thematic experts. The project team conducted consultation meetings with relevant government officials in all seven provincial capitals including Kathmandu. Time frame is divided into short (<5 years), medium (<10 years) and long term (>15 years). Similarly, budget size of actions is also categorized into small (USD < 1 million), medium (USD <9 million) and large scale (USD >10 million).

Table 5.1 presents a list of action plans for the sectors. The plans have been prepared based on the approach papers and programme-budget of the Federal as well as Provincial Governments. Consultation meetings were held with officials at Federal as well as Provincial levels to discuss on the extent of vulnerability and adaptation priorities.

Table 5.1: Adaptation action plans

Sector	Main Objective/Goal	Actions	Monitoring and Assessment Indicators	Time Frame	Budget Size	Implementing/Responsible Entities
1. Agriculture and Food Security						
1.1	To ensure food security through increasing agriculture production and productivity with sustainable farming and reducing climate change impacts	Coordination among central, province and local government and enhancement of the capacity of key institutions involved in Agriculture Development Strategy implementation	Well-coordinated, number of trainings, reports	Short term	Small	National Planning Commission (NPC), Ministry of Agriculture, Livestock Development (MoALD)
1.2		Securing food and nutrition of disadvantaged groups and rights to food by implementing land use policy	Number of household access to food, available of food in months, enhanced storage capacity	Short term	Small	MoALD
1.3		Strengthen research capacity of institutions and expanded it into provincial level and make responsive to aware farmers and agro enterprises	Established research institutions in province and set of mechanism to disseminate at local level	Medium term	Medium	DOA
1.4		Providing bio-fertilizers and promoting organic production	Number of households used bi-fertilizers, and quantity of production	Short term	Small	MoALD
1.5		Improving animal breeds appropriate for the Nepal farming systems conditions	Number of animal breeds, reports	Short term	Small	MoALD
1.6		Enhancement of resilient capacity of farmers to climate change, disasters, price volatility and other shocks	Number of farmers enhanced their capacity	Short term	Small	MoALD
1.7		Encouraging investment for agriculture commercialization by adopting modern technology with considering climate change scenarios	Amount of investment and number of new technologies in agriculture commercialization	Medium term	Medium	MOALD, Ministry of Finance (MoF)

1.8		Strengthening information system like agricultural production and market access to farmers and consumers	Progress reports	Short term	Small	Agriculture and Livestock Business Promotion Division (ALBPD)
2. Water Resources and Energy						
2.1	To protect, conserve and manage water sources, produce clean energy and promote alternative energy	Development of watershed management policy and plan with considering climate change adaptations	Developed policy and plan and approved	Short term	Small	Ministry of Energy, Water Resources and Irrigation (MoEWRI)
2.2		Restoration of ponds, conservation of wetlands, and promotion of rain water harvesting technique to cope with water resources scarcity	Number of ponds, wetlands, rain water harvesting schemes	Medium	Medium	Province government, Municipalities
2.3		Establishing the research stations to monitor the GLOF, river basins and other climate induced disasters	Functional research units	Medium	Medium	Department of Hydrology and Meteorology (DHM), Water and Energy Commission Secretariat (WECS)
2.4		Adoption of SMART irrigation systems and expanded equitably and viably and improved irrigation efficiently management	Number of SMART irrigation schemes	Medium	Medium	MoEWRI
2.5		Promotion of nonconventional energy sources (such as biogas, solar energy, and hydropower), and fuel-efficient technologies (such as bio-briquettes, improved cooking stoves) to reduce demand of firewood.	Number of schemes	Long term	Large	AEPC, WECS
2.6		Development of multipurpose including disaster resilient and cost-effective energy production and storage projects	Number of projects	Long term	Large	MoEWRI, Nepal Electricity Authority (NEA)

2.7		Extension of hydrological and meteorological networks of DHM in all districts and municipalities and informed to communities timely during climate induced disasters.	Number of DHM units at local level, information sharing mechanism	Medium	Medium	DHM
3. Forests and Biodiversity						
3.1	To maintain balance in environment and sustainable development through participatory forest, biodiversity and watershed conservation and share benefits of productions	Formulation and execution of policy and plans (Climate change policy, NAPs)	Approval of climate change policy 2019, NAPs	Short	Small	Ministry of Forest and Environment (MoFE)
3.2		Establishing mechanism of payment for REDD as national and Payment of Ecosystem Services (PES) for community income generation to sustain forest resources	Established mechanisms and number of houses benefitted under PES	Long term	Large	MoFE
3.3		Strengthen participatory and inclusive forest management and biodiversity conservation practices to enhance the resilient capacity of forest resources dependent communities	Number of households benefitted, reports	Short term	Small	Department of Forest Soil Conservation (DoFSC)
3.4		Establishment of research stations in range land, forest areas and protected areas to assess the status and trend of changes over time	Number of research stations, published research articles, reports	Medium	Medium	Department of National Park and Wildlife Conservation (DNPWC), Department of Forest Research and Survey (DFRC)
3.5		Promoting natural based solution activities (EbA and clean energy)	Number of projects and benefitted households	Medium	Medium	MoFE, Alternative Energy Promotion Centre (AEPC)
4. Public Health and Water, Sanitation and Hygiene						
4.1	To reduce vulnerability on human health	Strengthen surveillance on climate induced vectors, water and food borne diseases and scale up of diseases control programmes	Reports, publications	Medium term	Medium	Ministry of Health and Population (MoHP)

4.2	through enhancing adaptive capacity	Preparation of sanitation and hygiene plan in climate induced disasters areas or extreme weather conditions and implement it	Prepared plan, number of households benefitted	Short term	Small	DWSS
4.3		Formation of immediate emergency/response Team for disaster from climate change	Functioning of information centre, provided equipment.	Long term	Large	Province government, Municipalities
4.4		Introduce/ update climate change and health related modules into school and university curriculum and informal education system	Updated curriculum, run class, reported	Medium	Medium	MoHP in collaboration with Curriculum Development Centre (CDC) of schools and universities
4.5		Establishment of knowledge centre and strengthen research capacity of institutions with information sharing mechanism to communities on health and climate change	Established centre, provided equipment, human resources, report	Long term	Large	Management Division/HMIS and HOs, Nepal Health Research Council
4.6		Developing climate resilient water safety plan and strengthening water quality surveillance	Developed water safety plan, report	Short term	Small	Ministry of Water Supply (MoWS), Department of Water Supply and Sewerage (DWSS)
5. Tourism, Natural and Cultural Heritage						
5.1	To develop safe, quality and tourism friendly attractive touristic centres in Nepal	Construction of eco-cultural circuit and trekking trails	Construction completion reports and Annual progress report	Medium term	Medium size	Ministry of Culture, Tourism and Civil Aviation, Department of Tourism
5.2		Establishment of digital tourist information centre	Functioning of information centre	Short term	Small	Ministry of Culture, Tourism and Civil Aviation, Department of Tourism
5.3		Application of early warning system in disaster prone area and weather information system to alert visitors about predicted weather status including weather extremities	Established coordination between Ministry of and DHM and functioning of information system	Short term	Small	Ministry of Communication and Information Technology, DHM

5.4		Enhancement of efficiency of emergency preparedness and rescue team for immediate action in the climate related events of disasters	Number of trainings and participants, post training report	Short term	Small	Ministry of Home Affair, Ministry of Culture, Tourism and Civil Aviation, Department of Tourism
5.5		Identification of climate sensitive areas and conservation of the naturally, culturally, religiously and historically important monuments	Conserved monuments and heritages, reports	Long term	Large	Ministry of Culture, Tourism and Civil Aviation, Department of Archaeology
5.6		Promotion of ecosystem-based tourism practices	Established home stays in rural areas, promotions materials	Short term	Small	Ministry of Culture, Tourism and Civil Aviation, Department of Tourism, Municipalities
6. Infrastructure and Urban Settlements						
6.1	To develop climate resilient infrastructures, make liveable city and sustain services	Amendments or reformulating the existing building code, infrastructure design guidelines and policies to integrate the climate change adaptation options in the policies and plans at central, province and local level	Revised policies and plans	Medium	Medium	Ministry of Urban Development, Relevant Ministry of Province, and Municipalities
6.2		Revitalization or development of cities with approach of green infrastructure through the preservation and including green space such as agriculture, parks and water holes and rivers to reducing the urban heat island.	Developed new safe and resilient cities	Long term	Large	MoUD, Department of Urban Development and Building Construction (DUDBC)
6.3		Encouragement for using renewable energy in housing, electric vehicle, and solar energy	Number of houses and persons used alternative energy	Short term	Small	MoUD, MOEWRI, AEPC
6.4		Awareness to people and communities living in climate induced disaster-prone areas and relocation of risky settlements in safe area.	Number of people awared and relocated their houses	Short term	Small	Municipalities

7. Climate Induced Disasters						
7.1	To prepare for reducing effect of climate induced disasters and effectively response it	Supporting to develop local level disaster risk reduction plan and implement it effectively	Developed DRR plans at local level, reports	Short term	Medium	Province Government, Municipalities
7.2		Establishing the research stations to monitor the GLOF, river basins and other climate induced disasters	Functional research units	Medium term	Medium	DHM, WECS
7.3		Strengthen the capacity of disaster response team with well-equipped and trained in each provinces and municipality	Strengthen capacity, functional unit, report	Medium term	Medium	MoHA, Provinces and Municipalities
8. Gender and Social Inclusion						
8.1	To operationalize gender sensitive climate efforts to promoting gender equality and inclusion in Nepal	Ensuring equal representation of women in decision making at climate change policy, programme, strategies and project	Number of women in decision making position	Short term	Small	Ministry of Women, Children and Senior Citizen (MoWCSC)
8.2		Developing and delivering special livelihood enhancement skills training in the areas of agriculture, forestry, livestock, micro enterprise, health, etc to the marginalized, poor and disadvantaged families	No of women benefitted and involved in trainings, reports	Long term	Large	MOFE, MoALD
8.3		Creating trust fund for women and climate change specific activities and initiatives	Trust fund for women specific activities and initiatives	Short term	Small	MoFE
8.4		Strengthen research capacity of women to identify disease patterns for new and emerging diseases and raise awareness through women groups	Disease patterns mapped, no of responses & early warning installed	Medium term	Medium	Research institutions, including academic institutions

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