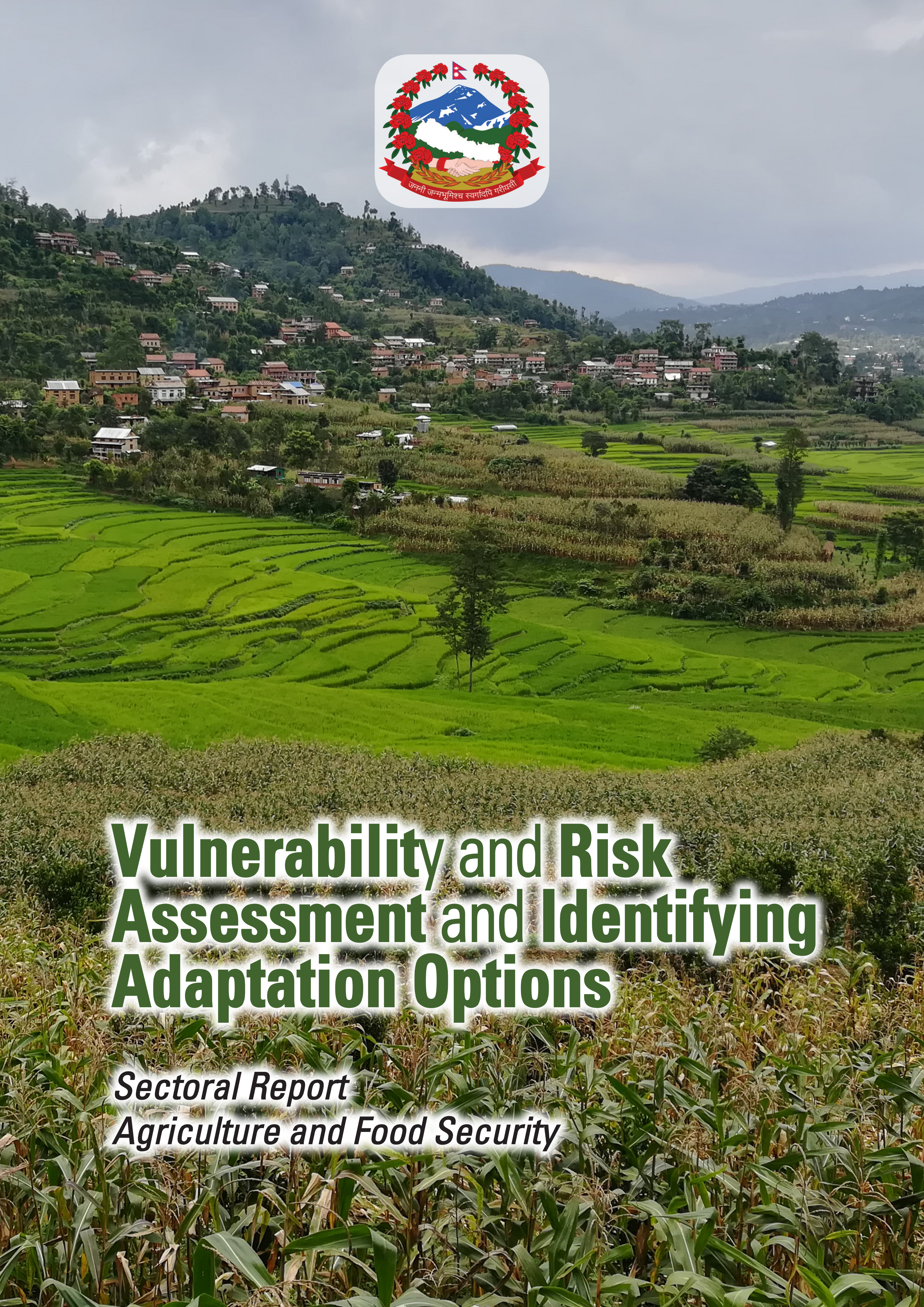

Vulnerability and Risk Assessment and Identifying Adaptation Options

Sectoral Report

Agriculture and Food Security

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Foreword

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

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

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

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

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

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

Acknowledgment

The National Climate Change Policy (2019) identifies eight thematic areas and four cross-cutting areas which will be impacted by climate change. As such, there is a pressing need to understand how public and private investments might be impacted. Without adequate information on risks and vulnerability, it will be difficult to translate policy into action. To plan and implement a successful adaptation strategy, it is vital to understand the likely impacts of climate change on different sectors and communities, and, in particular, how these may evolve in the future.

A National Adaptation Plan (NAP) needs to be developed based on a strong scientific foundation and reliable evidence. This includes data and information about how the climate has evolved in the recent past and how it may further change in the future. To realize this, the MoFE has carried out detailed Vulnerability and Risk Assessments (VRAs) of the thematic areas identified by the National Climate Change Policy at the municipal, district, and regional scales. The VRA framework and methodology presented in the report are based on the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and the NAP technical guidelines of the UNFCCC.

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

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

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

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

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

List of Acronyms

ADS	Agriculture Development Strategy
AFS	Agriculture and Food Security
AHP	Analytical Hierarchy Process
AR	Assessment Report
CBA	Cost-benefit Analysis
CBS	Center Bureau of Statistics
CCA	Climate Change Adaptation
CEA	Cost-Effectiveness Analysis
CSA	Climate Smart Agriculture
CSB	Community Seed Bank
CSV	Climate Smart Village
DHM	Department of Hydrology and Meteorology
DoE	Department of Education
DoI	Department of Irrigation
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GAP	Good Agriculture Practices
GDP	Gross Domestic Product
GESI	Gender Equity and Social Inclusion
GHG	Greenhouse Gas
GIS	Geographic Information System
GO	Government Organization
GoN	Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
INGO	International NGOs
IPCC	Intergovernmental Panel on Climate Change
LAPA	Local Adaptation Plan for Action
LI-BIRD	Local Initiatives for Biodiversity, Research, and Development
MCA	Multi-criteria Analysis
MoAD	Ministry of Agricultural Development
MoALD	Ministry of Agriculture and Livestock Development
MoF	Ministry of Finance
MoFE	Ministry of Forests and Environment

MoPE	Ministry of Population and Environment
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NARC	Nepal Agriculture Research Council
NDC	Nationally Determined Contribution
NGO	Non-government Organization
NPC	National Planning Commission
NUS	Neglected and Underutilized Species
OPM	Oxford Policy Management
PCI	Participatory Crop Improvement
PIF	Policy and Institutions Facility
PMAMP	Prime Minister Agricultural Modernization Project
PPB	Participatory Plant Breeding
PVS	Participatory Variety Selection
RCP	Representative Concentration Pathways
SRI	System of Rice Intensification
TC	Technical Committee
ToR	Terms of Reference
TWG	Technical Working Group
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VRA	Vulnerability and Risk Assessment
ZHC	Zero Hunger Challenge

Executive Summary

Agriculture plays an important role in the livelihood security and socio-economic development of Nepal. However, several socio-economic and political issues hamper the overall agricultural growth and development, and these challenges are further worsened by climate change. The agriculture sector is exposed to temperature and precipitation change, extreme events, and climate-induced hazards. The exposure is higher because a large number of people depend on agriculture and a large tract of land is under agriculture. Subsistence farming practices, small farm sizes, low crop, and livestock productivity, and inherent poverty make farming communities highly sensitive to climate change. Farmers' capacity to adapt to climate-induced risks is also low, which, combined with the high sensitivity, makes them highly vulnerable to climate change impacts. The high incidences of hazards and extreme events, high exposure, and high vulnerability all contribute to the high risk to the sector.

As a commitment to the United Nations Framework Convention on Climate Change (UNFCCC), Nepal is formulating a National Adaptation Plan (NAP) to address climate risks through appropriate adaptation options. The National Climate Change Policy (2019) has identified agriculture and food security as key climate-sensitive sectors. Besides, climate change is identified as a major challenge in other agriculture-related policy documents such as Agriculture Development Strategy (2015-2035), Nepal Agriculture Research Council (NARC) Strategic Vision for Agricultural Research (2011-2030), and Zero Hunger Challenge (ZHC) 2025.

Conducting Vulnerability and Risk Assessment (VRA) is one of the major activities of the NAP. This report presents the findings of a VRA for the Agriculture and Food Security sector. The goal of the VRA was to enhance the adaptive capacity and build the resilience of climate-vulnerable people and communities, geographical areas, physical infrastructure, and ecosystems. Adhering to this goal, this study (i) assessed the vulnerability of climate change to agriculture and food security and ranked/categorized associated climate risks and vulnerabilities, and (ii) identified adaptation options to address priority climate vulnerabilities and risks in agriculture and food security sector. The study aided in setting strategic priorities - where to invest, what to invest in, and how to invest – to make adaptation actions more effective, efficient, and impactful.

The VRA work adopted the country-specific framework, which is aligned with the framework suggested by IPCC's Fifth Assessment Report (AR5). Slight modifications, however, were made to tailor it to the country's needs and priorities. The major approaches taken during the VRA include consultations for seeking feedback from Technical Committee (TC) and Technical Working Group (TWG); integration of GESI as a cross-cutting theme in all steps; field consultations for sharing results, seeking inputs, and endorsing the decisions; a combination of qualitative and quantitative indicators for wider coverage of issues, and adoption top-down and bottom-up approaches for data collection. The process also involved inter-sectoral consultations, consultations at the province and local levels, and feedback collection through weekly progress review meetings, technical meetings, and bilateral and peer consultations.

The study followed nine key steps as part of the VRA framework proposed by the government, which included: i) unpacking AR-5 key concepts and terminologies; ii) developing VA and RA frameworks; iii) identifying key indicators for hazard, exposure, vulnerability (sensitivity and adaptive capacity) for different themes; iv) exploring data sources, nature, and character; v) undertaking data collection, tabulation, filtering, and normalization; vi) carrying out weightage and composite value calculation; vii) analyzing data; viii) identifying climate change impacts and risks, and ix) identifying and appraising adaptation options. For identifying indicators, validation and consolidation, relevant literature was reviewed. OPM-PIF's experts and members from the Technical Committee (TC) and Technical Working Group (TWG) reviewed the indicators and provided feedback to ensure the quality of the indicators. Data were normalized to make indicators coherent and comparable to each other and ease the computation of indices. The normalized data were then multiplied by the weight for the specific indicators to produce indices for different vulnerability and risk parameters.

The weight was calculated for each indicator for which a survey was done among selected technical experts in the agriculture, and food security sector. The experts were asked to score the indicators based on their subjective judgment. Then, hazard index, exposure index, sensitivity index, and adaptive capacity index were calculated for each district by multiplying the individual normalized value with the respective weight and finally adding all the products of multiplication. The vulnerability index was calculated by deducting the adaptive capacity index from the sensitivity index of the respective district. Finally, the risk index was calculated for each district by multiplying the hazard index, exposure index, and vulnerability index of the district. The districts were then grouped into five categories based on the indices: very high, high, moderate, low, and very low. This was done for hazard, exposure, sensitivity, adaptive capacity, vulnerability, and risks; and maps were produced accordingly.

Scenario analysis was also carried out for extreme events and risks using two Representative Concentration Pathways - RCP 4.5 and RCP 8.5 - for the medium-term (2030) and longer-term (2050). Additionally, impact assessment and implications were documented using literature review, field consultations, and experts' own past experiences, which was followed by identification of adaptation options from reports maintained by government organizations, NGOs, INGOs, UN organizations, regional organizations, and other relevant institutions. The adaptation options were shared with the provincial and local stakeholders and feedback was sought from them to ensure that they were realistic, relevant, and locally viable.

The results of this VRA are presented briefly below.

Climate change, hazards, and exposure - trends and scenarios: A report published by the Department of Hydrology and Meteorology on Observed Climate Trend Analysis (1971–2014) in Nepal states that maximum temperature trends were higher than minimum trends in all seasons; maximum temperature trends were more robust than minimum temperature and precipitation trends; significant positive trends existed in annual and seasonal maximum temperature and minimum temperature; a significantly positive trend existed only in monsoon season in all Nepal but no significant trend existed in precipitation in any season; all Nepal annual maximum temperature trend was significantly positive (0.056°C/yr); and the annual minimum temperature trend was positive (0.002°C/yr) but not at the significant level.

Various climate models predict an increase in temperature, a decrease in post-monsoon and winter precipitation, an increase in heavy precipitation events, and an increase in the average number of consecutive dry days in Nepal. Similarly, summer and winter temperatures, the number of hot days, and extremely hot days in the pre-monsoon, monsoon, post-monsoon and winter seasons are likely to increase in the coming decades. Average annual temperatures could increase by 1.3-3.8°C by 2060, and 1.8-5.8°C by 2090 compared to a reference period of 1986-2005, and the frequency of hot days could increase by about 16% by the 2060s compared to 1970-1999. Some models under both RCP 4.5 and 8.5 scenarios predict a decline in average winter precipitation by around 10% for the period 2021-2050 compared to 1961-1990.

The major hazards occurring in Nepal include floods, droughts, hailstorms, heatwaves, cold waves, diseases, and insects. The past trends show several changes in all types of hazards. The current analysis was done using RCP 4.5 and RCP 8.5 emissions pathways shows that the districts under very high hazard category and very high risk category will likely increase under both scenarios while the number of districts for high, moderate, low, and very low categories will likely decline under both scenarios in the considered time scales.

Climate change impacts, key issues, and challenges: The long-term impact of climate change on agriculture and food security is inevitable, which will have disproportionately bigger impacts among women, Dalit, Janajatis, and other marginalized communities. The literature review suggests that climate change has caused a multitude of impacts in the agriculture sector and its dependent population. About 90% of crop loss in Nepal can be attributed to weather or meteorological events, increased temperature, and hazards such as erratic rainfall, droughts, and floods triggered by them. When crops, livestock, and fisheries are combined, climate change induces losses in production equivalent to 10% to 30%. Drought is the most critical hazard. Between 1971 and 2007 droughts accounted for 38.9% and floods for 23.2% of all loss caused by weather and climate-related events. Floods rank second in terms of dangerous hazards, with their recurrent impacts in the form of crop loss, wash away of land, and livestock casualties. Insects and disease pests, hailstorms, cold waves, and heatwaves also adversely affect crop yield.

The rising temperature negatively affects weight gain, reproduction, breeding pattern, feed intake, and conversion efficiency of animals. It increases heat stress, morbidity, vector-borne diseases (such as ticks and flies), parasitic diseases (such as liver fluke and nematodes), new skin diseases, and ectoparasite infestation in animals. Climate-induced water loss in ponds and water reservoirs also decreases the productivity of the pasture and has negative impacts on the fisheries sector. The rise in temperature and deterioration in the quality of water induces stresses and new diseases in fish, degrade fishery habitat, cause a decline of fishery stocks, reduce the productivity of freshwater aquaculture and cause a decline of local species, thus affecting the economy and livelihood of fishing communities. The impacts of climate change in the sector have several social and cultural implications as well, such as loss of jobs, migration, changing gender roles, food insecurity, poverty, and family economy. The direct economic cost of current climate variability in the agriculture sector is equivalent to 1.5% to 2% of the country's GDP, and a 2–4% annual drop in GDP by climate change will require USD 2.4 billion for adaptation by 2030. Women, Dalits, Janajatis, small-holder farmers, farmers relying on rainfed agriculture, and other marginalized communities are the hardest hit by climate change.

Climate Change Vulnerability and Risk: The majority of the districts (53%) have either a low or very low level of exposure, while the Terai districts are more exposed due to the relatively larger sizes of agricultural lands, greater populations of livestock and poultry, and more fishery activities. Several of the districts in Province 1, Province 2, and Bagmati Province are more exposed than the other provinces, and all the districts under Karnali Province have very low or low exposure. Similarly, the majority of the eastern mountain and hilly districts have lower exposure which is largely influenced by the areas of agricultural land and population.

The large majority of districts (>70%) have moderate to very high sensitivity, while the rest have either low or very low sensitivity. The analysis shows the districts in Gandaki, Lumbini and Karnali Provinces fall under the very high sensitivity category. Whereas the highly sensitive districts are spread across the mid-hill and high-hill regions from east to west, the majority of districts in Karnali Province fall under the high sensitivity category. The Terai districts have either low or very low sensitivity. Similarly, over 60% of districts have high or very high adaptive capacity. All the districts, except Surkhet and Western Rukum in Karnali Province and the majority of the districts in Sudurpaschim, fall under the very low adaptive capacity category. Moreover, the majority of districts in the mid-hill and high-hill regions are either in very low or low adaptive capacity categories. The majority of the districts in the Terai have either high or very high adaptive capacity.

The vulnerability analysis showed that the large majority of districts (45) have moderate to very high levels of vulnerability. Several districts in Gandaki, Lumbini, Karnali, and Sudurpaschim Provinces fall under the very high vulnerability category. Those falling under the high vulnerability category are either in mid-hill or high-hill regions, whereas all the districts in Terai, except Parasi, fall under the very low vulnerability category irrespective of the province. The Karnali and Sudurpaschim provinces are highly sensitive and have the poor adaptive capacity, which makes them highly vulnerable.

The risk analysis under the RCP 4.5 and RCP 8.5 emissions pathways show that the districts with very high risk will likely increase in number under both scenarios, while the number of districts for all other categories will likely decline in 2030 and 2050. At baseline, Dhading, Makawanpur, Gorkha, Tanahu, Udayapur, Sindhuli, Morang, and Jhapa are at very high risk. Under the RCP 4.5 scenario, Khotang, Mahottari, Sindupalchowk, Syangja, Baglung, and Dang will be added to the very high risk category in 2030 and three additional districts (Nawalpur, Sarlahi, and Nuwakot) will be added to this category in 2050. Similarly, under the RCP 8.5 scenario, Dang, Baglung, Syangja, Nawalpur, and Mahotari will move to a very high risk category in 2030 and six additional districts (Khotang, Udayapur, Sankhuwasabha, Sarlahi, Saptari, and Nuwakot) will move to this category in 2050.

Climate change adaptation is a priority of the agriculture sector. High-impact adaptation results are possible by adopting various sustainable, climate-resilient, low-input, and energy-efficient technologies and practices such as conservation agriculture, climate-smart agriculture, and organic agriculture, to name a few. A large number of, short-, medium- and long-term adaptation options are available for the agriculture and food security sectors to be practiced by the government and non-government organizations in the country. Such technologies and practices can be tailored to local needs and priorities, while duly considering GESI issues when local level VRA and adaptation planning are being done.

There were some limitations of this VRA study. High-quality, consistent and up-to-date data is in short supply in the agriculture sector. The maintained databases are difficult to transform into usable forms, as they are aggregated and not consistent across time and space. Therefore, appropriate data management and sharing mechanisms must be developed to benefit future studies like this. Such data management is especially important for livestock, poultry, and fisheries, for which data is scantier. Besides, conducting a local Palika level VRA would be worthwhile in the future once all Palikas start keeping relevant information because that would help identify local problems and even more context-specific adaptation options and strategies.

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Chapter 1

Background and Sectoral Context

1.1 Background

Agriculture is the vehicle for socio-economic development and the mainstay of livelihood for most people in Nepal. The agriculture sector underpins food security, poverty reduction, export earnings, and income of the poorest households in Nepal, which means poor agriculture results in poverty and food insecurity (Gauchan, 2008). The sector employs over two-thirds of the country's total population which is significantly higher than other South Asian neighbors (World Bank, 2008). Among the female population, nearly 70% are employed by agriculture (CBS, 2014). Agriculture contributes about 27% of Nepal's Gross Domestic Product (GDP) and accounts for 13% of total foreign trade (MoF, 2019[1]), and agriculture-based GDP growth is about two times more effective in reducing poverty than non-agricultural GDP growth (World Bank, 2008; Gauchan, 2008). In 2015, the crop sector accounted for almost half, livestock for one-quarter, whereas vegetables, forestry, fruits, and spices such as ginger and cardamom covered 10%, 8%, and 7% respectively of all agricultural GDP (Karki, 2015; FAO, 2019).

Agriculture also plays an important role in enhancing social welfare functions in developing countries since it can serve as a buffer, safety net, and economic stabilizer (Gauchan, 2008). Poverty and food insecurity rates are higher in hills, more so in the western hills and mountains than in the Terai due to the limited availability of arable land and low agricultural productivity in the former. The human development and empowerment indices are also better in the Terai region than hills and mountains since the former has relatively better infrastructure, productive agriculture, access to markets, and opportunities for non-agricultural activities in the former (CBS, 2011; UNDP, 2014). Within an about 200-km north-south span, a variety of crops representing sub-tropical to temperate regions are grown and a variety of livestock, poultry, and fish are raised owing to the high range of temperature along the altitudinal gradients as discussed below.

1 https://mof.gov.np/uploads/document/file/compiled%20economic%20Survey%20english%207-25_20191111101758.pdf

Farming: Crops, vegetables, and fruits play a pivotal role in the household economy, family diet, and livelihoods. Cereal crops such as rice, maize, wheat, millet, and barley are the main source of diet for most people in Nepal. Cereal crops cover 76 percent of the total cultivated land, cash crops about 10 percent, and pulses about 7 percent. Cereal constitutes about one-third of the weightage of the total agro-products in the country, and paddy is the most important cereal crop, followed by maize and wheat, both in terms of cultivated area and in terms of production (Gauchan, 2008).

Among cereals, rice contributes 67% of total cereal consumption, 23% of protein intake, and 32% of daily energy intake (28% energy intake for maize and wheat combined) (Joshi et al., 2020). The importance of several local crops including neglected and underutilized (NUS) crops—which are also known to be Himalayan superfoods, such as barley, buckwheat, finger millet, foxtail millet, proso millet, and amaranths—is also high, particularly in the high mountains[2]. A variety of vegetable crops and fruits are also grown for family diet and income. Lentil, potato, sugarcane, and tea have been important cash crops for years, and coffee, ginger, cardamom, banana, and potato have received popular markets in the recent decades (MoF, 2016; Dhital, 2017). Out of more than 500 edible plant species, only 200 are cultivated (NBS, 2002), so about 35% of all vegetables consumed are collected from forests and bushes during food deficit periods particularly during natural hazards (Thapa, 2013).

Livestock: Livestock is an integral part of Nepalese agriculture, contributing to family nutrition, manure, energy (e.g., biogas), cooking fuel from dung (CBS, 2014). The sector alone contributes 14% of the total protein requirement and contributes more to GDP than fishery and agricultural cash crops combined (Bhujel et al., 2008). Cattle, buffalo, goat, sheep, pig, mule, horse, fowl, duck, and dove are commonly raised animals and birds either for consumption or the household economy or both. There are 7.17 million cattle (including Yak and Chauri), 4.68 million buffaloes, 0.8 million sheep, 8.47 million goats, 1.04 million pigs, 24.48 million poultry, and 0.38 million ducks in the country (MoAD, 2019a), and 12% cattle and 36% buffaloes are crossbred. Seven indigenous breeds of cattle, three buffaloes, four goats, four sheep, three pigs, and three chicken indigenous breeds are reported in Nepal (Joshi et al., 2017). Now different new birds such as turkey, wildfowl, and quail are commercially raised, and their popularity is growing. As per the 2011 Census of Agriculture, there is 22.4 million small and large livestock. There has been a significant increase in the number of goats (up by 59 percent), pigs (30 percent), and sheep (29 percent), poultry (49 percent), and ducks (9 percent) (CBS, 2014). Protein from livestock sources was 15.92 percent in 2012/13 (CBS, 2014), and demand is increasing by 8-10 percent annually (MoAD, 2014a), partly due to rising incomes, which is also contributing to the increase in the import of livestock (ADS, 2014).

Fisheries and aquaculture: The interest in aquaculture in Nepal began in the early 1980s. Since then, aquaculture has been developed as a viable agricultural sector contributing to 0.5 percent of the total agricultural GDP in 2013/14, mainly based in the Terai plains that are home to 94 percent of fishponds (MoAD, 2014b). According to Pant and colleagues (2012), fisheries and aquaculture have contributed to household income, food, and nutrition security, livelihoods, women's empowerment. Fish accounts for only 1.7% of the total protein supply while fisheries employ 700 thousand people (53 percent women) and contributes more than 1.32% of the GDP (US$ 154 million) of the country (KC, 2014). Aquaculture is among the fastest-growing food sectors in the country with the demand for aquaculture and fisheries likely increasing from 46,000 metric tons in 2008[3] to 3,64,000 metric tons by 2032, with 94% coming from aquaculture and 6% from capture fisheries (Mishra, 2014).

2 http://himalayancrops.org/wp-content/uploads/2016/08/LCP-Himalayan-Superfoods-Poster-logos-at-bottom.jpg

3 http://pubs.iclarm.net/resource_centre/WF_3543.pdf

The number and area of fishponds have increased substantially in the last few years because of the government's subsidy on new fish pond construction and fish raising. A total of 232 fish species are reported in the country, and the natural capture fisheries employ more than 0.425 million people representing over 18 marginalized ethnic communities. The common capture fish species include grass carp, silver carp, common carp, bighead carp, and rohu. In recent years, tilapia and catfish are gradually becoming popular. Very few farmers also practice rice-cum-fish and rice-cum-duck farming.

Agrobiodiversity: Nepal is rich in agrobiodiversity due to its climatic, ecological, socioeconomic, and cultural diversity. Agricultural biodiversity is higher in the mid-hills since it is a transitional zone. The mountain region, however, is home to endemic, climate stress-tolerant, or resilient, nutrient-rich indigenous crops. They are also known as 'Himalayan super food' and 'future smart crops' (Gauchan, 2020). The temperate and tropical climates in Province 1, Bagmati, Lumbini, and Sudurpaschim Provinces allow more diversity while the predominantly sub-tropical climate in Province 2 gives little opportunity to diversify the agroecosystems. Similarly, the Gandaki and Karnali Provinces have a large tract of the area with a temperate climate that houses less diversity than other provinces. While Province 1 is well known for tea, cardamom, vegetables, and dairy products, Province 2 and the Lumbini Province are favourable for cereal and pulse. Bagmati Province is good for citrus, vegetables, maize, and coffee, whereas Gandaki Province's climate favors apple, citrus, coffee, ginger, corn, and vegetables. The Lumbini Province is known for citrus, coffee, ginger, and pulses. Karnali Province is dominant in apple, walnut, and medicinal and aromatic plants. And Sudurpaschim Province's climate is favourable for wheat and vegetables[4]. Based on the significance of crops, livestock, and fisheries, the GoN has designated different super zones and zones under the Prime Minister Agricultural Modernization Project (PMAMP)[5]. The zones and respective crops, vegetables, fruit trees, and livestock are presented below (see Table 1).

Table 1: List of districts under zones and super zones for different crops, vegetables, and fishery

Province*	Super zone	Zone (crop)	Zone (Livestock)
Province 1	Jhapa (rice)	Jhapa (rubber, betel nut, maize), Ilam (kiwi), Panchthar (cardamom), Taplejung (cardamom), Morang (rice, fish), Sunsari (ginger-turmeric, fish, rice, vegetable), Bhojpur (cardamom), Dhankuta (vegetable), Sankhuwasabha (cardamom), Udaypur (orange, ginger-turmeric), Khotang (maize), Okhaldhunga (potato), Solukhumbu (orange, ginger-turmeric, kiwi)	Ilam (cattle), Sunsari (pig)
Province 2	Dhanusa (fish), Bara (fish)	Saptari (mango), Siraha (rice, mango), Dhanusa (rice), Sarlahi (rice), Rautahat (vegetable, rice seed), Parsa (vegetable)	Saptari (buffalo)
Bagmati Province	Sindhuli (sweet organge), Kavre (potato)	Dolakha (kiwi), Sindhupalchok (maize), Makwanpur (vegetable), Bhaktapur (potato), Nuwakot (vegetable, potato), Dhading (vegetable, maize), Chitwan (vegetable, bee, banana, rice)	Ramechhap (goat)
Gandaki Province	Kaski (vegetable), Syanga (orange)	Gorkha (orange, rice), Tanahu (vegetable), Lamjung (cardamom), Syangja (spice crops), Parbat (rice), Nawalpur (orange, vegetable), Palpa (vegetable), Mustang (orange), Manang (orange), Parbat (maize), Myagdi (orange), Baglung (potato), Eastern Rukum (walnut)	Myagdi (pig)

4 http://www.doanepal.gov.np/downloadfile/Final%20Report%20Inter-Provincial%20Dependency%20on%20Agriculture%20-%20DVN%202018_1548834926.pdf

5 The PMAMP has laid out a structure comprised of super zones (commercial areas of more than 1,000 ha), zones (areas over 500 ha), blocks (over 50 ha) and pockets (over 10 ha). These are defined areas across the country that receive government support to produce certain crops intensively.

Province*	Super zone	Zone (crop)	Zone (Livestock)
Lumbini Province	Dang (maize), Kapilbastu (rice), Gulmi (coffee), Bardiya (rice)	Dang (mustard, bee), Kapilbastu (rice, vegetable), Gulmi (maize, orange), Pyuthan (rice), Arghakhanchi (vegetable), Rupandehi (fish), Rolpa (maize), Western Rukum (vegetable), Banke (maize)	Arghakhanchi (goat)
Karnali Province	Jumla (apple)	Salyan (ginger-turmeric, rice), Jajarkot (orange, bee), Dailekh (orange, potato), Kalikot (apple), Surkhet (ginger-turmeric, vegetable)	Dailekh (goat)
Sudurpaschim Province	Kailali (wheat), Dadeldhura (potato)	Achham (potato), Bajura (olive), Baitadi (maize), Darchula (apple), Kanchanpur (rice), Dadeldhura (soybean)	Achham (goat)

1.2 Major challenges in the AFS sector

Nepal is a poor and food-deficit country with about 4.6 million food-insecure people. Nearly 20% of people are mildly food-insecure, 22% moderately food-insecure and 10% severely food insecure (NDHS 2016). Similarly, 8.1% are undernourished while wasting, mortality, and stunting among children younger than 5 years account for 11.3%, 3.6%, and 36% respectively (MoH, New ERA, and ICF, 2017). These problems are attributable to, inter alia, poor and underdeveloped agriculture that is manifested in low production and low productivity, fragmented land and scattered production, subsistence farming, and population pressure, food habit change, low irrigated land, high costs of production, and soaring food prices; transportation and distribution problems, inadequate food buffer stocks; and inadequate access to food diversity (MoALMC, 2018). These challenges, along with a few others, are listed below.

- About 21% of Nepal's land is cultivated, with a landholding size of 0.68 ha per household, and over 50% of farmers cultivating land less than 0.5 ha. Only 54% of the land is irrigated while the rest is rain-fed with poor-quality soils, high fragility, and climate sensitivity (CBS, 2014).
- The indiscriminate use of fertilizer and pesticides along with modern varieties and hybrids is further degrading soil quality and the environment. The high cost of such inputs along with labor and machinery use are substantially increasing the cost of production, but the marginal income is too little to cushion or compensate for the increased cost.
- The importance of diversified agriculture as a sustainable approach to address food and nutrition security is undervalued. There is poor access to modern varieties and breeds and poor adaptation of valuable genetic resources in harsh environments of the mountain region, whereas the Terai region has lost much of its agrobiodiversity to genetically uniform modern varieties and breeds.
- Reduced/losing interest of a large majority of youth in agriculture and their migration is leading to low investment and consequently low yield and poor profit. Policy failure to attract youth, ensure regular supply of input at a reasonable price, regulate seed, machinery, and product marketing is also attributable to poor agricultural growth.
- There are capacity gaps and needs for different types of institutions in Nepal, which include: poor awareness and capacity on appropriate crop and livestock management, resource mobilization, income generation, adoption of new technologies and practices, enterprise development, market networking, and accessing credit, among others (FAO, 2014). The MoALD sees capacity gaps in financing, institutional policies, and subsequent technology adoption, coupled with poor collaboration and cooperation among the stakeholders, which presents as a challenge (MoALD, 2019a).

These existing challenges in the agriculture sector are further exacerbated by climate change, with its disproportionately high impact on poor and vulnerable households and communities, particularly women and girls (Mearns & Norton, 2010). In the future too, climate change will have significant negative impacts on the basic survival of people and ecosystem integrity, and agriculture will remain the hardest hit among all sectors (World Bank, 2016).

Local knowledge and practices on adaptation, along with modern technologies, are crucial to sustain agriculture in the future and inherit a food secure world to our posterity. However, despite various efforts to support farmers to adapt to climate change, several challenges and barriers continue to limit the ability of farmers, particularly women and marginalized communities, to adapt to climate change and build resilience (UNDP, 2009b). These challenges are presented below:

- The new technologies and practices—such as disease-resistant and climate stress-tolerant crop varieties, new machinery, and new livestock and poultry breeds—are being introduced to farmers but they are still inadequate to tackle emerging climate change problems partly due to ad-hoc adaptation efforts. The slow rate of scaling up new climate-resilient tools and practices is also contributing to low productivity.
- Farmers have poor access to weather and climate-related information, knowledge, and services since agrometeorological information is poorly accessible at a wide scale, and seasonal forecasts and market information is poorly established. The number of manual stations and automatic surface observation systems is small, so it hinders the generation of high-quality, reliable data for weather forecasting and projections for the medium- and long-term time scale.
- The research on climate change in the agriculture sector is inadequate. For example, understanding the climate thresholds and their implications for the growth and production of major crops is poor for different agricultural systems.
- Financial resources are key to promoting impactful adaptation options but with GoN's financial and technical constraints, farmers have poor access to them (Regmi & Bhandari, 2013). Moreover, the foreign investment in the agriculture sector is almost negligible, i.e., less than 1% of the country's total foreign investment. The agriculture line ministry needs additional human resources and institutional setup for effective implementation of policies, plans, strategies, and frameworks and to fill the gaps in institutional arrangements, capacity, and mechanisms to implement them (Chhetri et al., 2011; Maharjan & Maharjan, 2017).
- Besides the several sector-specific challenges in the agriculture sector, gender inequality is a prevalent issue throughout the country, with Province 2 and Karnali Province ranking at the top. Climate change magnifies pre-existing gender inequalities such as limited access to resources and information, poor ownership of resources (land, capital, credit, water, technology), and exclusion from the decision-making process (FAO, 2019; Mainlay et al., 2012; WWF, 2013). Climate change impacts men and women differently with women being more adversely affected (UN Women, 2014. For instance, lack of assets and limited access to financial capital limit women from being able to diversify their livelihoods (Skinner, 2011). Although women and girls can play a crucial role in adaptation owing to their distinctive knowledge of natural resources management, they remain poorly incorporated in international and national climate change policies (UNDP, 2009a). The focus on the incorporation of GESI issues into the development and implementation of climate change, particularly in the laws and legislation of Nepal, is still poor despite the fact some plans and policies recognize it, as shown in Annex 1 (Mainlay et al., 2012; FAO, 2019). Climate change and disasters also make women vulnerable to sexual and gender-related violence (FAO, 2019).

Chapter 2

Objectives and Scope of the Study

2.1 Objectives and rationale of the study

The agriculture sector plays a pivotal role in employment generation, food and nutrition security, poverty alleviation, and economic growth of a huge population in Nepal. Hence, without agricultural growth, the overall development of the country is out of the question. However, the agriculture sector faces a multitude of social, economic, cultural, institutional, and political problems. The sector is highly sensitive to climate change, which further exacerbates existing challenges. Recently, these challenges have been further worsened by the current COVID-19-led crisis. Agricultural activities, crop growth and development, livestock, and fisheries health and productivity may bear a big impact even with a marginal change in temperature, precipitation, humidity, and sunlight. The agriculture sector is likely to be more severely impacted with its implications on the economy, food security, livelihoods, social capital, and policy landscape.

The ultimate goal of the VRA study is to enhance the adaptive capacity and build the resilience of climate-vulnerable people and communities, geographical areas, physical infrastructure, and ecosystems. The overall objective is to conduct a climate vulnerability and risk assessment (VRA) and identify adaptation options in the Agriculture and Food Security sector. The specific objectives are to:

- Assess vulnerability to climate change of the agriculture and food security sector through applicable frameworks and ranking/categorizing associated climate risks and vulnerabilities.
- Identify and prioritize adaptation options to these risks to address priority climate risks and vulnerabilities of the agriculture and food security sector.

The results are useful for decision-makers, policymakers, and planners. The actors and agencies can prioritize geographic areas and adaptation actions for future investment and implementation of adaptation practices. Specifically, the results of this study will help strategize as to where what and how to invest, so that adaptation actions become effective, efficient, and impactful. Also, the findings are useful for formulating new policies and revising existing policies. Besides, the adaptation options identified by the study will be useful for local Palikas and farming communities.

2.2 Scope of the study including limitations

This study assessed the climate vulnerability and risks in the agriculture sector of Nepal. Since climate change directly impacts agricultural activities or indirectly by affecting the working environments of the sector-dependent population, the study took into account and identified indicators for both parameters or components. The district was considered as the basic unit for data gathering since most of the relevant data were available for districts. The data was then aggregated for provinces and geographic regions within these provinces. Case studies included in the study are also drawn from secondary literature. The study relied on secondary information since primary data collection was not possible within the scope of the study. The study adopted feedback collection, data and report validation, and decision-endorsement strategies, including workshops and meetings. Due to the COVID-19 pandemic, some of the meetings were held virtually. The lockdown and travel restrictions imposed by the government also restricted movements for field consultations in the early stages.

Chapter 3

Methodology

3.1 Framework

Vulnerability, risk, and impact assessment is an important step mentioned under Element B (Preparatory elements) out of the four elements of the NAP guideline (UNFCCC, 2012). Several methods and tools, such as predictive models, empirical studies, expert judgment, and experimentation, have been used to assess climate change exposure, vulnerability, and risk in the past (Plummer et al., 2012). The tools are either quantitative or qualitative. The study also involves participatory and secondary data-based analyses, including the use of GIS and remote sensing[2].

Among several tools, the Intergovernmental Panel on Climate Change (IPCC)'s Assessment Report-5 (AR5) provides the most comprehensive and widely accepted framework for such assessments. The National Adaptation Plan (NAP) technical guidelines and NAP VRA framework 2017 for Nepal (MoPE, 2017 suggest a country-specific framework by adopting the IPCC AR5 framework. This study used the framework proposed by MoPE, 2017 **(Figure 1)**.

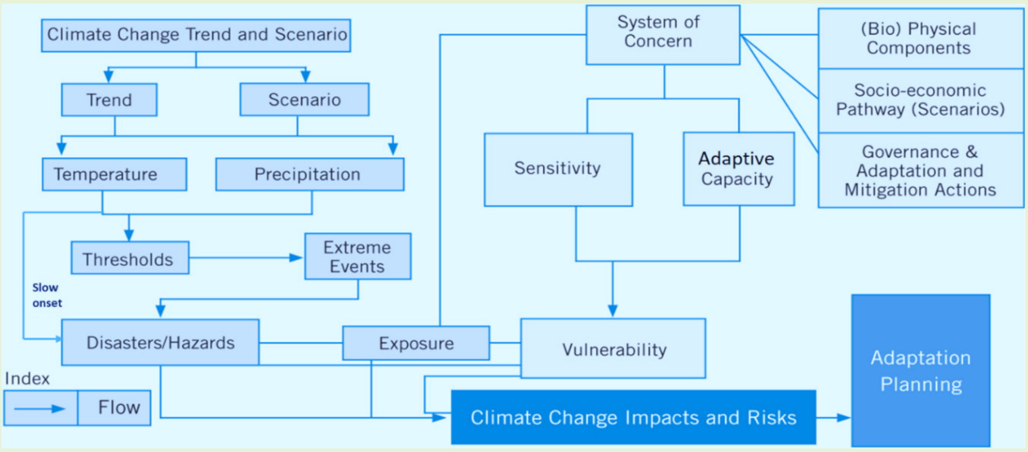


Figure 1: VRA framework proposed by MoPE, 2017

This framework has also been endorsed by the Ministry of Agriculture and Livestock Development (MoALD) by including it in the Ministry's handbook and training manual on climate change adaptation (CCA) for the planning of the agriculture sector of Nepal (MoALD, 2019a). In this framework, Risk is defined as the function of hazard, exposure to hazard, and vulnerability to hazard. It is taken as the ultimate factor measuring climate change threat or impact on human lives. Vulnerability is considered as the function of sensitivity and adaptive capacity. These are explained by using the following equations.

$$R = H \times E \times V$$

$$V = S - AC$$

Where,
R = risk, H = hazard, E = exposure, V = vulnerability, S = sensitivity and AC = adaptive capacity

3.2 Approach

The study was grounded in consultations, which allowed for seeking feedback from Technical Committee (TC), Thematic Working Group (TWG), provincial governments, and Palikas. This also allowed for sharing findings and endorsing certain decisions. The study put maximum effort to integrate and harmonize the methodology, results, and findings among sectors, which involved inter-sectoral consultation and feedback collection through weekly progress review meetings, technical meetings, and bilateral/peer-wise consultations. Data was gathered using quantitative and qualitative approaches for which both types of indicators were included. The data collection, feedback collection, and result analysis undertook both top-down and bottom-up approaches. Gender equality and social inclusion (GESI) was duly considered as a cross-cutting theme in all steps of the study.

3.3 Methodological steps

The methodology involved nine key steps. The steps are taken, along with the GESI integration strategy in the relevant step, are shown in Figure 2 below. Some of the steps, particularly after step 2, are also briefly described below. Steps 1 and 2 are briefly elaborated in section 3.1 and the rest are described below.

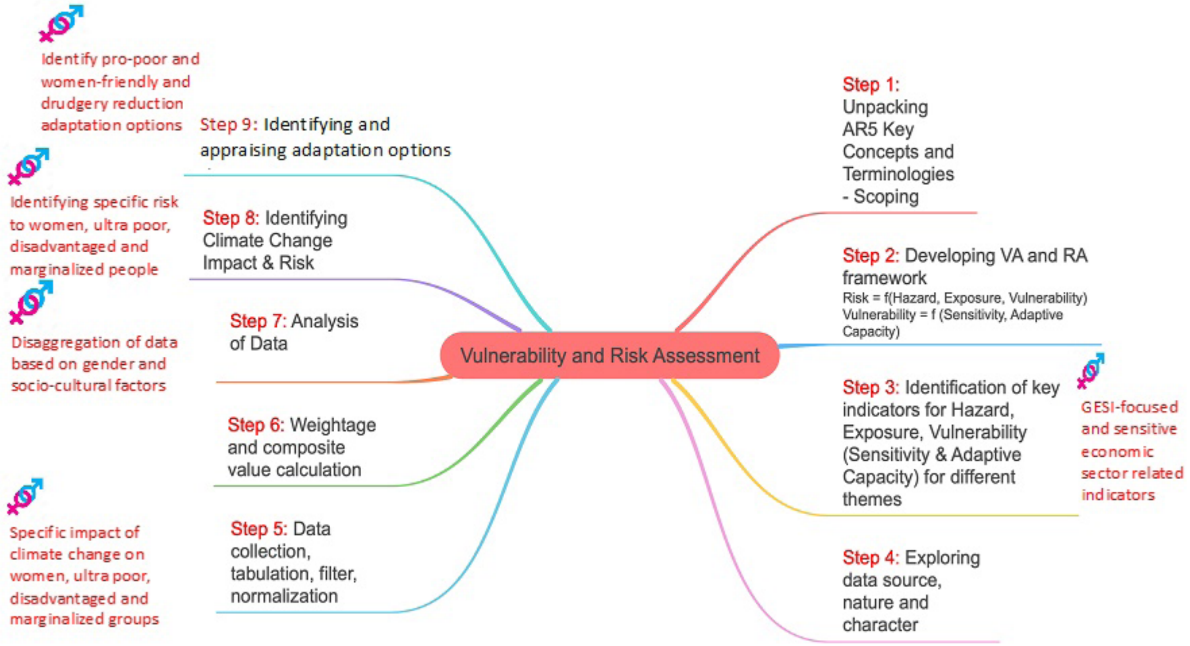


Figure 2: Steps followed in VRA and strategy to integrate GESI issues

3.3.1 Exploring Data Sources, Nature and Character

The study gathered authentic and robust, up-to-date, quantitative, and qualitative data from various secondary sources such as government documents, periodic reports, profiles, policy documents, and documents released by line ministries and departments. Priority has been given to government data and published reports, which, inter alia, included data from the Department of Hydrology and Meteorology (DHM), Central Bureau of Statistics (CBS), MoALD database, and reports. The nature and character of data varied with the source of data. They were available in Excel, word, Comma-separated value (CSV), Geographic Information System (GIS) shapefile, and grid formats. Wherever feasible, the data was validated through different data sources.

3.3.2 Indicators, weightage, and analysis

An indicator-based vulnerability assessment is among the most common and practical climate vulnerability assessment methods, allowing to mathematically combine indicators into a single composite index (Adger et al., 2004; Luers et al., 2003; Tonmoy et al., 2014). This study employed an indicator-based vulnerability assessment method where indicators were identified for hazards, exposure, sensitivity, and adaptive capacity, as presented in **Table 2** below. The NAP document is the main source of indicators (MoPE, 2017) but other indicators were also added based on the review of relevant documents (MoE, 2010; NPC, 2010; GoN, 2011; GoN, 2014). The indicators were then validated and revised based on the availability of required data in essential forms, country priority, and local feasibility, after soliciting input from other thematic and cross-cutting working group members, OPM-PIF team, TWG members, and TC members. The lists of participants of the TWG and TC meeting are presented in Annex 2 and 3 respectively.

Weight was calculated for each indicator for which a survey was conducted among technical experts to collect their opinions on the relative importance of each indicator. We used modified AHP to adjust the prioritization of a long list of indicators. This involved asking experts to give a numerical value using Saaty's nine-point scale based on how important they considered each indicator (Hossain et al., 2014; Likert, 1932; Saaty, 1984; Song & Kang, 2016) since a pairwise comparison was not practical due to the long list of indicators. The opinions of 14 respondents, including members of the TWG, government experts, I/NGOs, and the private sector, were assessed. Based on this, the weight of each indicator was computed, then group judgments were computed using their geometrical average. Then, exposure index, sensitivity index, and adaptive capacity index were calculated by multiplying the individual normalized value with the respective weight and finally adding all the products of multiplication. The vulnerability index was calculated by deducting the adaptive capacity index from the sensitivity index of the respective district. Finally, the risk index was calculated for each district by multiplying the hazard index, exposure index, and vulnerability index. Districts were then grouped based on indices into five categories (based on Jenks natural break method): very high, high, moderate, low, and very low, and the levels of hazard, exposure, sensitivity, adaptive capacity, vulnerability, and risks were categorized and maps were produced accordingly.

3.3.3. Data Collection, Tabulation, Filtering, and Normalization

Data was collected from various secondary sources as shown in step 4 making sure they were grounded in specific ecosystems, human settlements, and critical infrastructure at risk. The spatial data was available in vector and raster formats, while non-spatial data were available in a tabular format. Both spatial/non-spatial data were then tabulated into the uniform format. The data was compiled in Excel according to hazard, sensitivity, and adaptive capacity indicators for different ecological zones, districts, and provinces. Data filtering was done by ranking, clustering (grouping), imputing (substituting some values for missing data), and sorting data (mainly categorical and nominal data) for individual variables by different responses (e.g., gender). Where appropriate, the transformation of data was done.

All quantitative data were normalized using the following formula to make them consistent and comparable, where all the values were converted to the value ranging between 0-1.

$$Z_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

where,
Z_i is the i^{th} normalized data
X_i is the original value of ith data that is being transformed
X_{max} is the maximum value in that category/indicator
X_{min} is the minimum value in the indicator

3.3.4 Identifying Climate Change Impact and Risk

Impacts were identified using a literature review while the risk index was calculated from the function of hazard, exposure, and vulnerability indicators. Each risk index was converted to five classes (very high, high, moderate, low, and very low) as per the natural break method. These classes helped identify climate-vulnerable hotspots in terms of geography, province, district, and possible climatic zone/agroecology. A scenario analysis of climate extreme events and risk was done using the two Representative Concentration Pathway (RCP) scenarios – RCP 4.5 and RCP 8.5 – to project possible changes by 2030 and 2050.

3.3.5 Identifying and Appraising Adaptation Options

There are no one-size-fits-all options for addressing climate change challenges, so the emphasis was given on place- and context-specific adaption options (IPCC, 2014), making sure that the options meet one of these states: no-regrets, low-regrets (or limited regrets), and win-win (UKCIP, 2018). The options included the following broader topics: (i) management and operational strategies; (ii) critical infrastructure changes; (iii) climate change integration in sectoral policies, strategies, and work plans; (iv) investment portfolio priorities; and/or, (v) capacity-building. The GESI perspective was taken into account to understand if certain hazards and risk factors are more common among certain vulnerable and marginalized people - women, youth, and the physically deprived (e.g., people with disabilities).

The criteria suggested by UKCIP (2018) such as effectiveness, efficiency, equity, flexibility, sustainability, impacts and side-effects, acceptability, urgency, external and internal coherence, robustness, dependencies, deliverability, and feasibility were also considered. Adaptation options were identified and prioritized by reviewing various published and unpublished documents[6].

Table 2: Indicators for exposure, sensitivity, and adaptive capacity and their weights for calculating indices

Exposure	Weightage	Sensitivity	Weightage	Adaptive capacity	Weightage
Agricultural land area	0.07	Land under temporary crops	0.113	Average productivity of major crops	0.073
Area under cereal crops	0.066	Land under temporary fallow	0.131	Land under permanent crops	0.069
Area under horticultural crops	0.066	Rainfed area	0.156	Rangeland per capita livestock	0.063
Area under meadows and pasture	0.049	Man-livestock ratio	0.1	Access to water-efficient agri-tools (rower/dhiki pump, pumping set/motors)	0.068
Potential irrigable land (km^2)	0.075	Man-poultry ratio	0.1	Holdings for shallow tube wells	0.065
River length (km)	0.075	Population below 15 and above 60 years of age	0.025	Holdings for deep tube well	0.061
Total livestock	0.041	Women-headed HHs	0.03	Meat yield	0.1
Number of livestock keeping buildings	0.034	Number of Janajatis and Dalits	0.031	Milk yield	0.1
Total poultry population	0.036	Average family size	0.028	Average land holding	0.1
Number of poultry farm	0.03	Seasonal out-migration	0.027	Labor productivity (NPR)	0.103
Fish farms and ponds (number)	0.03	HPI	0.032	Women's share in income (proportion)	0.098

6 NAPA document lists adaptation options by hazard; NAP suggests strategy of 'leaving no one behind', linking national and sub-national adaptation planning; CDKN, LI-BIRD and CCAFS used criteria and indicators for identifying over 100 CSAs and prioritizing 13 champion CSA technologies and practices for three ecological zones

Exposure	Weightage	Sensitivity	Weightage	Adaptive capacity	Weightage
Fish farms and ponds (area)	0.029	GDI	0.031	Road density	0.018
Number of holdings with agriculture as the main source of income	0.121	Holdings with agriculture credit	0.03	Access to the radio (no. of household)	0.02
Number of livestock raising households	0.089	Land ownership-land tenure (landless families)	0.034	Access to television (no. of household)	0.02
Number of poultry-keeping households	0.089	Food insufficiency	0.032	Number of farmer cooperative	0.022
Road length (km)	0.017	Geography of land (slope)	0.1	NGOs/CBOs working in district	0.02
Agroecosystems (number)	0.02				
Mountain area (ha)	0.021				
Mid-hills area (ha)	0.021				
Terai area (ha)	0.021				

Chapter 4

Observed Climate Change Impacts in the Sector

4.1 Observed and perceived impacts in the sector and sub-sectors

Climate change is univocal and widespread in Nepal with its multitude of impacts on the country's agriculture sector. It has a direct impact on agricultural yield and productivity through changes in temperature, precipitation, and carbon dioxide concentration (Kim et al., 2008). It also has an indirect impact on agriculture, through crop conversion, change in farmland utilization, adjustment of input application (Kim et al., 2008; Calvin & Fisher-Vanden, 2017), price-induced changes in input, and planting decisions, and technological innovations (Calvin & Fisher-Vanden, 2017). Both historical and projected impacts of climate change on crop productivity in Nepal have a mixed outlook. For instance, some studies show potential for wheat, maize, and rice yield declines (Palazzoli et al., 2015), while others project yield improvements due to improvement of the condition in highland production areas (NPC, 2018).

Crop post-harvest activities are also affected by climate-induced disasters, particularly in storage due to dampening or excessive heat or cold, depending on season and location. Some crops experience early maturity (Chaudhary & Bawa, 2011; Chaudhary et al., 2011) but sustain poor fruit and grain setting due to the hastened and unnatural maturity. One of the poorly appreciated impacts of climate change on agricultural production is its impact on the health and productivity of farmers. Dunne et al. (2013) suggest that currently a drop of 10% global labor productivity occurs during peak months as a result of warming and that a decline of up to 20% might be expected by the 2050s under the highest emissions pathway (RCP 8.5). Poor and marginalized farmers practicing subsistence rainfed agriculture, forest-based enterprises, fishing, and pastoralism are highly sensitive to climate change (Gentle et al., 2014). Below, perceived impacts, along with observed past trends and future scenarios of impacts are presented for the agricultural sub-sectors.

4.1.1 Perceived impacts

The major perceived impacts in agricultural sub-sectors include dying off of crops; inundation and wash away of cropland; increased weed infestation; increased insect and disease infestations; early crop maturity; early flowering of fruit trees such as rhododendron, peach, pear, and cherry; adoption of new crops in higher altitudes; change in heat period and breeding cycle in animals; reduced yield of fodder and grasslands; and damage of fish ponds (Bhatta et al., 2016; Chaudhary et al., 2011; Chaudhary & Aryal, 2009; Chaudhary & Bawa, 2011; ICIMOD, 2015; Regmi & Pandit, 2016; Walker et al., 2019).

The Climate Survey carried out by CBS in 2017 reveals that 60.25 percent of households observed the emergence of new diseases and 66.09 percent observed the appearance of new insects/ pests in crops, while 45.98 percent of households observed the appearance of new diseases in livestock. The survey revealed that Marne rog (Sheath blight), Gobre (Borer), Woilaune (Wilting), and Dadhuwa (Blight) are commonly reported crop diseases in Nepal. Similarly, Laai (Aphids) is less common in the tropical and temperate zone, while Madhuwa (Plant hopper) is reported in the subtropical zone[7]. These diseases and insects are likely to be triggered by extreme climatic events. Other impacts are presented in Table 3. Field consultations also helped identify climate change impacts on different agricultural sub-sectors, which are presented in Annex 4.

Table 3: Perceived impacts caused by different hazards in the agricultural sub-sectors

Hazards	Nature and intensity	Impact on crops, fruits, and grazing lands	Impacts on livestock, poultry, and fishery
Droughts	Increasing in frequency and intensity across the country	Drying up of water sources; crops dying off; increased weed infestation; early maturity leading to poor grain formation; evaporation and evapotranspiration leading to the high amount of water loss; fruit cracking due to heavy rainfall after a long drought	An increasing number of bugs and mosquitoes affecting animals and birds; new respiratory diseases; water scarcity; low yield of grasslands and fodder; suffocation and death of fish due to low water depth in ponds
Floods	Increasing in trend; more high-intensity floods occur	Inundation of cropland; washing away of crops, lands	Inundation of grazing lands affecting grazing; damaging and wash away of sheds; flooding of fishponds; damaging ponds
Hailstorms	Making pockets in certain eco-geography with high intensity and frequency of hailstorm; an untimely occurrence of an event	Crops, vegetables, and fruits are beaten by hailstones thus reducing the yield	Killing of animals and birds when hit by hailstones; damaging sheds; shattering fodder trees and grasses
Cold waves	Increasing in some regions while others are getting better, moving toward low and mid-hills	Winter crops are affected, particularly solanaceous crops such as potato, tomato, chilly due to late blight, aphids and other diseases and insects	The killing of animals, birds, and fish due to cold; slow growth of livestock and fish
Thunderstorms	Higher occurrence and with increased casualties	Due to decreased activity of people, farm activities are not performed in time; sometimes occur during crop harvest time, so delayed harvest causes yield loss	Livestock and birds are killed due to lightning and shock caused by it
Diseases	New insects and diseases are seen triggered by climate change	Changing climate triggers the occurrence and growth of insects and diseases; reduced yield of crops due to damages caused by insects and diseases	Killing livestock and fishes due to different types of diseases

7 CBS. 2017. National Climate Change Impact Survey. National Planning commission.

Changes in snowfall pattern	Change in time, duration, and quantity of snowfall	Depleting ecosystems; altering flowering and fruiting of plants	Dwindling quantity and quality of rangelands impacting fodder productivity for livestock

Source: Bhatta et al., 2016; Chaudhary et al., 2011; Chaudhary & Aryal, 2009; ICIMOD, 2015; Ishaq et al., 2017; Regmi & Pandit, 2016; Walker et al., 2019[8]

4.1.2 Past observed trends

Crop, horticulture, and grazing land: The key extreme events and hazards impacting the agriculture sector include droughts, floods, hailstorms, cold waves, heat waves, thunderstorms, and insect and disease pests. Climate-related extreme events and hazards induced by the events impact large tracts of agricultural land in different crop-growing seasons. For instance, between 2002 and 2009, a large area of some major crops was affected in the country as shown in Table 4. The largest area affected was rice followed by maize, and the biggest impact was experienced in 2002, followed by 2006 and 2004 (IFAD, 2013).

Table 4: Area (in hectares) of crops affected by climate-related extreme events in Nepal

Crops	Year							
	2002	2003	2004	2005	2006	2007	2008	2009
Paddy	115,000	6,967	116,506	3,585	120,000	88,800	30,873	92,000
Maize	4,435	954	1,293	20	47	4,271	549	1,700
Millet	-	-	500	419	-	1,451	3	-
Others	2,067	611	-	-	-	-	324	-
Total	121,502	8,532	118,299	4,024	120,047	94,522	31,749	93,700

Source: IFAD, 2013

Among all hydro-meteorological hazards in Nepal, drought—a slow onset, widespread disaster[9]—ranks at the top in terms of severity of impacts on crops. Drought and slow onset of monsoon delay planting (Bhatta et al., 2016; Chaudhary & Aryal, 2009), which leads to poor crop germination, flowering and grain, and fruiting, and eventually decline in productivity. There were 16 major drought events recorded between 1972 and 2016 in different parts of the country, which caused crop loss ranging from 56,000 metric tons in 2013 to 917,260 metric tons in 1992 (Adhikari, 2018) (Table 5). Between 1971 and 2007, nearly 850,000 ha of crops were affected by weather- and climate-related events, where droughts contributed to 38.9% of the lost crops, and floods to 23.2% (UNDP, 2009a). In 2006, droughts contributed to the loss of 11% rice yield and 7% wheat yield in Nepal.

Table 5: Major crop loss caused by drought between 1972-2016

S.N.	Drought year	Causes of drought	Major crop loss (in Metric tonne)	Affected regions
1	1972	Late onset of monsoon/rainfall	333,380	Eastern and Central
2	1976	Poor distribution of rainfall	218,480	Western
3	1977	Late onset of rainfall	322,320	Eastern and Central
4	1979	Late onset of rainfall	544,820	Western

8 The information presented in the table is also an outcome of stakeholder consultations at Province level conducted by PIF/OPM NAP-VRA team; Thematic expert's field observations and interactions with local people at different times; and personal communications with professionals specialized in the subject matter.

9 https://www.wri.org/our-work/project/world-resources-report/climate-change-nepal-impacts-and-adaptive-strategies

S.N.	Drought year	Causes of drought	Major crop loss (in Metric tonne)	Affected regions
5	1982	Late onset of rainfall	727,460	Eastern
6	1986	Poor distribution of rainfall during August and September	377,410	Western
7	1992	Late onset of rainfall	917,260	Eastern
8	1994	Poor distribution of rainfall	595,976	All regions
9	1997	Poor distribution of rainfall	69,790	Eastern
10	2002	Poor distribution of rainfall	83,965	Eastern and Central
11	2008	Poor distribution of rainfall during November 2008 to February 2009	56,926	All regions
12	2009	Late-onset of monsoon	499,870	Eastern and Central
13	2012	Summer monsoon late-onset and long dry spell	797,629	Eastern and Central
14	2013	Inadequate rainfall that affected rice plantation	56,000	Eastern and Central Terai districts
15	2015	Delayed monsoon and weak at the onset, which delayed paddy transplantation	Not available	Eastern Terai
16	Mid-November 2015 to Mid-March 2016	Poor monsoon and drought	300,000 people highly insecure	Mid- and Far-Western hills and mountains

Source: Adhikari, 2018, who drew the information from Joshi, 2018 and UNDP, 2013

Every year, monsoon floods inundate and wash away lands and deposit sand, silt, and debris, resulting in the desertification of cultivable lands mostly in foothills and Terai belts of Nepal. When rivers change course following flood and landslide events, croplands are loaded with sand or turn into riverbeds. According to the Post Flood Recovery Need Assessment Report (NPC, 2017), the incessant rainfall between August 11 and 14, 2017 flooded 35 districts of the country (with 18 districts severely affected) and inundated about 80 percent of the land along the Terai region. The report claims that about 58% of the total loss and damage by the flood accounted for agriculture, livestock, and irrigation infrastructure. The human casualties reported were 134 (44 female) and the number of people affected was about 1.7 million (866,993 males and 821,480 females) in the 18 most-affected districts. The flood completely or partially destroyed more than 190,000 houses (NPC, 2017).

Hailstorms, cold waves, and heat waves adversely affect crop yield mainly in the mid-hills and the Terai region of Nepal. The hailstorms damage cereal crops, vegetables, and fruits at all stages, thus causing a yield decline. Cold waves affect crops particularly belonging to the solanaceous family such as potato, tomato, and chilies. Insects and disease pests are also major hazards affecting agriculture. Between 1971 and 2007, 847,648 hectares of land sustained crop loss due to different climate-related extreme events, of which drought alone accounted for 329,332 hectares (40% of total loss) (Table 6). Walker and colleagues (2019) report that 1.5, 4.3, 2.1 and 4.1 percent of households experienced losses in their crops due to pests, plant diseases, and post-harvest losses combined in 2015, 2016, 2017, and 2018 respectively. The 1998 winter cold wave drastically reduced crop yields such as chickpea by 38%, lentil by 37.6%, leaf mustard by 36.5%, potato by 27.8%, and mustard seed by 11.2% (NARC, 2010; Poudel, 2016).

Table 6: Loss of agricultural land and crops as a result of climate-related extreme events in Nepal (1971-2007)

Events	Loss (in hectares)
Droughts	329,332
Floods	196,977
Hailstorms	117,518
Rains	54,895
Strong winds	23,239
Cold waves	21,794
Others (forest fires, epidemics, snowstorms, fires, storms, etc.)	83,336

Source: IFAD, 2013; MoPE, 2016; NSET, 2009

Agrobiodiversity and crop adaptation: Climate change has also impacted agricultural biodiversity (Regmi et al., 2009; Regmi and Paudyal, 2018). Depending on their nature, extent, and intensity, sometimes whole crops, varieties, or genes are wiped out from a locality. Several times, farmers cannot harvest anything at all when droughts affect growth and reproduction, floods inundate entire land for days, insect and disease damage crops, and weeds outperform crops. Contrarily, some positive impacts have been seen in the higher altitude regions. Some new crops, vegetables, and fruit trees such as maize, tomato, chilly, mango, litchi, etc., have been introduced by high-hill farmers in their locality, which was not possible around four to five years earlier (Chaudhary & Aryal, 2009; Chaudhary & Bawa, 2011). This will have a positive impact on local agrobiodiversity, and it needs to be taken into account when adaptation plans are developed and implemented.

Additionally, several farmers also alter cropping patterns when they find one or more crops unprofitable, or when all crops are lost due to a hazard (Regmi & Pandit, 2016). Due to floods and long dry spells, a large chunk of the country's land also goes unattended or remains fallow. In 2005, droughts caused about 10 percent of agricultural land to become fallow in some areas, while in the mid-western Terai, heavy rains along with floods reduced crop production by 30% (Regmi, 2007). Therefore, such decisions have impacts on land use patterns.

Livestock and animal husbandry: The available literature on livestock, poultry, and fishery claims that the rising temperature negatively affects weight gain, reproduction, breeding patterns, feed intake, and conversion efficiency, heat stress, morbidity, vector (such as ticks and flies) borne diseases, parasitic diseases (liver fluke and nematodes), ectoparasite infestation, and new skin diseases in animals (KC, 2014). Fatigue, foot and mouth diseases, cough, and cold are also reported as some of the consequences triggered by climate change (Chaudhary & Aryal, 2009; Chaudhary et al., 2011). Other anecdotal studies also report that poor fertility and inceptions, abortion, early puberty, irregular menstrual cycles are also partly attributable to climate change. Unpredictable weather patterns, coupled with climate-induced water loss in ponds and water reservoirs in pastures, also have a direct effect on livestock production and the livelihoods of the people (FAO, 2014).

Livestock productivity is affected when various management activities such as the timing of herd movement, and fodder and forage productivity are influenced by weather and climate change (Pokhrel & Pandey, 2011; Sherpa & Kayastha, 2009). For instance, the winter drought in 2008 damaged 105,350 ha of forestland, leading to the death of livestock (MoHP, 2012).

The population of indigenous livestock breeds is rapidly declining mainly because of disease outbreaks linked to climate change, although it should be noted that breeds of goats and yaks are more resilient to water, fodder, and forage shortages in some regions (Koirala & Bhandari, 2019).

There are six major impacts of climate change on livestock which include increasing incidence of disease pests; depleting grass and feed; stress due to heat; appetite loss; and, as a result, decreasing milk production; and death of an animal (Shrestha & Baral, 2018) (**Figure 3**). The incidence of diseases and external parasites in animals, heat stress, infertility, water scarcity, loss of forages and fodders, a decline in milk yield, and lactation period (Dhakal et al., 2013). These changes cause negative impacts on livestock production, growth performance, and reproductive functions (Koirala & Bhandari, 2019).

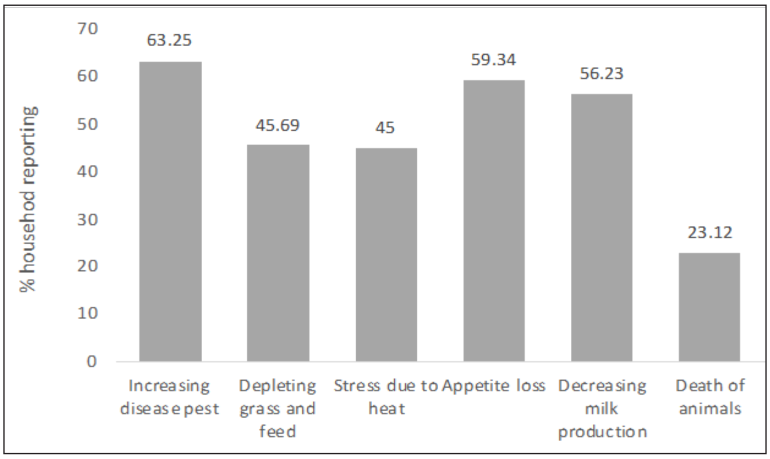


Figure 3: Impact of climate change on livestock and animal husbandry in Nepal
Source: Shrestha & Baral, 2018

Fishery and aquaculture: The impact of climate change on the fisheries sector is also alarming. Some of these impacts are: the rise in temperature and deterioration in the quality of water; stresses and new diseases in fish, degradation of fishery habitats, declining of fishery stocks, reduction in the productivity of freshwater aquaculture; and decline of local species with impacts on the economy and livelihood of fishing communities (Wagle, 2011) are some of the impacts of climate change. Wagle further describes the following impact of climate change on aquaculture: "By 2020, freshwater availability in Southeast Asia, particularly in larger river basins is projected to decrease (IPCC, 2007); changes in hydrological regime is likely to bring about changes that could impact fisheries and aquaculture activities in both lentic and lotic water; an attitudinal shift in agro-ecological zones due to increased temperatures which may lead to mobility of certain fish species to higher altitudes; and an increased exposure to diseases in aquaculture due to temperature increase". Flooding is one of the main causes of fish productivity decline. Findings from the Chitwan district about the damage caused by the 2017 flood in fishponds are presented as a case study below (Storming, 2017).

Case study of the 2017 flood impact in the fishery in Chitwan, Nepal				
Name of farmer	**Sex**	**Nature and extent of damage**	**Economic impact (USD)**	**Remark**
HPG	M	1.2 tons of fish due to oxygenation	2,000	-
PB	F	Wash away of pond spread over 8.4 acres and 4,000 fish fries (fingerlings)	-	-
LK	M	Wash away 50% of the pond along with fish	-	-
MRC	M	Partial damage of fishpond	10,000	-
RP	M	10 fishponds and 2,200,000 fish fries in 4 nurseries	35,000	Took 2-3 years to recover the loss
RR	F	All fish her family had raised	-	-

Source: Adapted from Storming, 2017; Names of farmers have been presented as abbreviations to keep their actual identity confidential

The NARC Strategic Vision for Agricultural Research (2011-2030) identifies the following climate change impacts on agriculture: the altitude boundaries for agro-ecological zones may shift and lead to movement of certain crops, livestock, and fish species shifting to higher altitudes; changes to and losses of agro-biodiversity due to limited adaptability; impact on shrinking habitats and fewer shelters in livestock and fisheries sub-sector; less irrigation water due to uncertain rainfall patterns; increased land degradation and soil erosion; a shift in the cycle of existing weeds, diseases and pests and possible invasions of new weeds, diseases and pests; and lower quantity and quality of some crops and animal products (NARC, 2010).

Our analysis revealed that the changes in maximum temperature, minimum temperature, and precipitation have a direct contribution to the yield of major crops. For fishery, only precipitation plays a significant role while the other two climate parameters have a non-significant level of contribution. The changes in minimum temperature have more role to play in crop productivity than maximum temperature. For livestock and poultry production, they don't play a significant role. Moreover, when we did a separate analysis for three highly drought-prone districts in three ecological zones (Sarlahi, Ramechhap, and Humla), similar patterns were found **(Table 7 and 8)**.

Table 7: Contribution of climate change parameters in yields of major crops and fishery

Agricultural Commodity	T-Max	T-Min	Precipitation	R^2
Aggregate production – Annual	2.150**	-	1.194*	0.186
Aggregate production – Pre-monsoon	-	2.202**	1.843*	0.189
Aggregate production – Monsoon	-	2.001**	2.373**	0.212
Paddy productivity (Monsoon)	-	2.065**	5.206***	0.44
Wheat productivity	-	2.568**	2.557**	0.264
Maize productivity	-	1.752*	3.612***	0.295
Fisheries productivity	-	-	4.883***	0.241

*Significant at 10% level; **Significant at 5% level; ***Significant at 1% level

Table 8: Relationship between climate parameters with yields of major crops based on regression analysis

District	R-value		
	Max Temp vs Yield	Min Temp vs Yield	Precipitation vs Yield
Sarlahi	0.0282ns	0.2579*	-0.0967ns
Ramechhap	0.2842*	0.1702ns	-0.0702ns
Humla	-0.454***	0.1744ns	-0.0018ns

*Significant at 10% level; **Significant at 5% level; ***Significant at 1% level

4.1.3 Future Projections of climate change impacts

The existing literature on projection and scenario analysis shows that climate change will have a substantive impact on crop yield and production. An IFAD report shows a 6.77% decline in rice yield and a 5.66% increase in wheat yield by 2050, and a 12.90% decline in rice yield and a 9.77% decline in wheat yield by 2080, in comparison to 2011, due to changing temperature and precipitation (MoPE, 2016) (**Table 9 and 10)**.

Table 9: Change in rice production due to changes in temperature and precipitation

S.N.	Parameter	Season	Production change (metric tons)			Production change (as % to 2011 production)		
			2020s	2050s	2080s	2020s	2050s	2080s
1	Max temp	JJAS	-240,638	-505,340	-794,106	-7.53	-15.81	-24.85
2	Min temp	JJAS	0	0	0	0.00	0.00	0.00
3	Precipitation	JJAS	-170	1,364	3,409	-0.01	0.04	0.11
4	Min temp	ON	189,282	287,708	378,564	5.92	9.00	11.85
	Net change		-51,527	-216,268	-412,133	-1.61	-6.77	-12.90

Source: MoPE, 2016

Table 10: Change in wheat production due to changes in temperature and precipitation

S.N.	Parameter	Season	Production change (metric tons)			Production change (as % to 2011 production)		
			2020s	2050s	2080s	2020s	2050s	2080s
1	Max. temperature	DJF	14,059	26,243	41,239	1.24	2.31	3.62
2	Min. temperature	DJF	0	0	0	0.00	0.00	0.00
3	Precipitation	DJF	-190,554	38,111	-152,443	-16.74	3.35	-13.40
	Net change		-176495	64354	-111204	-15.51	5.66	-9.77

Source: MoPE, 2016

Rice and wheat yields will decline across the Terai, while maize yields will increase in Sunsari and decrease in Nepalgunj and Rupandehi (Devkota et al., 2017). In the hills region, there will be a decline in rice, maize, and wheat yields in 2070 compared to 2030. In the mountains, there will be yield gain in rice in Jumla and Mustang, and a decline in Solukhumbu, and maize yields will decline in 2070 compared to 2030. Moreover, wheat yields will increase in Jumla but decline in Mustang and Solukhumbu districts **(Figure 4)**.

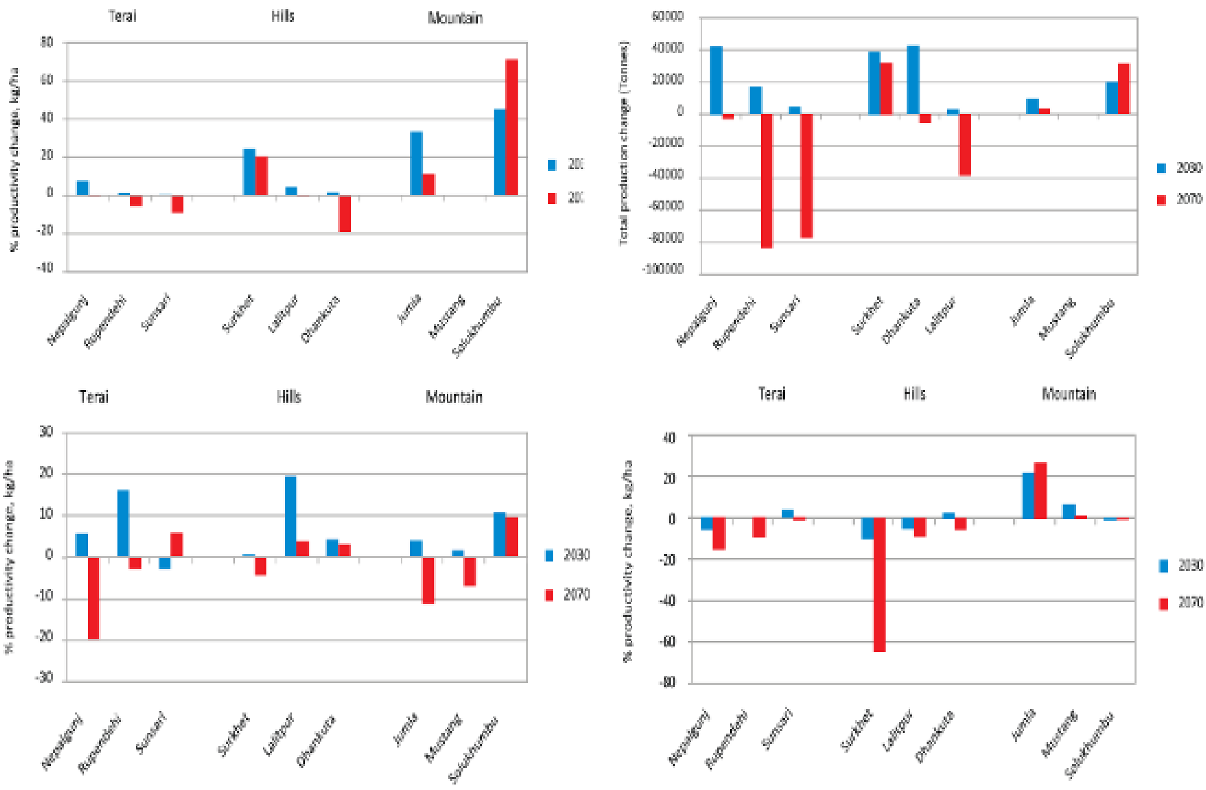


Figure 4: Rice and wheat yields change from climate change

Top two: Percentage change in rice yields from climate change, relative to the baseline period (Left) and a total change in rice yields from climate change (based on production area), relative to baseline (Right); Bottom two: Percentage change in maize yields (Left) and wheat yields (Right) relative to the baseline period (Source: Devkota et al., 2017)

4.2 Livelihoods and socio-economic dimensions of the impact of climate change

The impacts discussed earlier have several implications on social, economic, and livelihood fronts (Regmi et al 2015). The decline of yield and production results in poor availability and access to food, which leads to food insecurity and poverty. Food insecurity and poverty will have a further impact on children's nutrition and health in highly affected areas, although the country has made substantive progress in improving children's health in all indicators (WHO & MoHP, 2015).

Several families are forced to migrate and take refuge as a strategy to cope with climate change-induced disasters, most often floods10. Every year floods displace and render many people homeless and food insecure, so they have no choice but to seek temporary settlement and employment (NPC, 2017). The hardest hit by this are indigenous peoples, Dalits, and marginalized communities (e.g., Majhi, Malah, and other fisher folks) since they live near the rivers and traditionally rely on fishing for their survival. They also have poor adaptive capacity to tackle climate change risk and build resilience (UNDP, 2009b).

10 Accessed from: https://www.wri.org/our-work/project/world-resources-report/climate-change-nepal-impacts-and-adaptive-strategies

When people take temporary shelters, it further makes them vulnerable and puts them at risk from wild animals, heavy downpours, and cold. Several families shift their livelihood strategies, change occupation, and borrow money and food to respond to the climate change crisis. Because men tend to migrate to cities and abroad, the traditional work division in agriculture is also altering with women taking more burden in agriculture and household chores, which is resulting in the feminization of agriculture. Women labour population in agriculture has increased from 36% in 1981, to 45% in 1991, 48.1% in 2001 and 49.8% in 2011 (JVS/GWP, 2015). This is adding more work burden on women and also inviting more health complications (Paudel et al., 2020; Regmi et al 2015; UNDP, 2009b).

Migration also leads to land abandonment which contributes to low crop yield (Paudel et al., 2020; Regmi et al 2015; UNDP, 2009b). However, due to poor access to agricultural inputs, including loans owing to their lack of ownership of property that they could use as collateral, the financial crisis further pushes women, Dalit, Janajatis, and other marginalized communities to the edge (Mainlay et al., 2012; WWF, 2013). The lack of assets and limited access to financial capital limit women from being able to diversify their livelihoods (Skinner, 2011). When droughts strike, women have to walk longer to manage water for household chores, livestock feeding, and irrigating crops. Droughts also have a disproportionate impact on small-scale farmers and herders (Jones, 2010) because they own small and marginal lands and move around to graze their animals. When disease and insect pests damage crops, women have a hard time managing labour since most of the men are either away or busy managing their crops. Recently women have been taking up a new role of spraying chemicals on crops. Further, climate change and disasters also make women vulnerable to sexual and gender-related violence (FAO, 2019). These challenges in agriculture lead to poor yield and productivity of agricultural lands, livestock, poultry, and fishery (FAO, 2019).

Climate change also has implications for the economy. The direct economic cost of current climate variability in the agriculture sector is equivalent to 1.5% to 2% of the country's GDP on average (approximately USD 270 million in 2013 prices) (MoALD, 2019). In 2008, a flood displaced over 60 thousand people in the Terai region (FAO, 2014). The direct economic cost of the 2006 and 2009 droughts equated to USD 336,420,000 and USD 65,148,000, respectively (Devkota et al., 2017). A recent GoN report estimates a 2–4% drop in current GDP per year due to climate change, with the need for USD 2.4 billion to be invested in adaptation efforts by 2030. Additionally, 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 annually (UNDP, 2013). The total value of crops exposed to the climate, as of 2012, is estimated at USD 1.5 billion (UNDP, 2013). The 2017 floods resulted in an estimated economic loss of about 69.5 million USD in agriculture (11.9%), 102.7 million USD in livestock (17.6%), and 168.1 million USD in irrigation (28.8%) (NPC, 2017).

Chapter 5

Observed and Projected Climate Change Hazards and Exposure in the Sector

5.1. Climate change Trend and Scenario

5.1.1 Climate change trends

The following facts are reported in DHM (2017) and MoFE (2019).

Temperature trend: The Observed Climate Trend Analysis of Nepal, published by the Department of Hydrology and Meteorology (2017), shows significant annual increasing trends (0.056^0 C/yr) in maximum temperature and non-significant increasing trends in annual minimum temperature (0.002^{0}C/yr) in the period between 1971 and 2014. However, the minimum temperature has significantly increased in the monsoon season. The maximum temperature has increased at a higher rate than the minimum temperature in all seasons.

Precipitation trend: The major findings include a non-significant positive precipitation trend in the southern districts of Sudurpaschim Province in winter, pre-monsoon, and monsoon. Besides, they also show a non-significant decrease in monsoon precipitation in most districts east of 84E longitude. There is also an all-season non-significant highest decreasing rainfall trend in the high mountains but the Terai experienced a non-significant positive trend in all seasons, except post-monsoon. At the district level, Dolpa district observed a significantly highest positive trend (0.046°C/yr) in the monsoon season and Humla observed a significantly highest negative trend (-0.076°C/yr) in winter. At the physiographic level, there was a significant increasing trend in most seasons in Terai and Siwaliks. There has been an annual decrease at the rate of 1.3 mm/yr at a significant level.

Extreme temperature trend: In most districts across the country, the trends of warm days and warm nights are increasing significantly. Cool days are decreasing, and warm spell duration is increasing significantly in most districts. Likewise, cool nights are decreasing in a few southeastern districts and increasing significantly in a few northwestern and northern districts. Cold spell duration is increasing significantly only in the Sudurpaschim Province.

Extreme precipitation trend: In the northwestern districts specifically, the number of rainy days is increasing significantly. Extremely wet days and very wet days significantly are decreasing, mainly in the mountains. Consecutive wet days are increasing significantly in the northern districts of Karnali Province and central parts of Gandaki and Lumbini Provinces, and Province 1. Likewise, consecutive dry days are decreasing significantly, mainly in the northwestern districts of Karnali Province.

5.1.2 Climate change scenarios

Temperature: Average annual temperatures could increase by 1.3-3.8°C by 2060, and 1.8-5.8°C by 2090 compared to a reference period of 1986-2005, and the frequency of hot days could increase about 16% by the 2060s compared to 1970-1999 (Rajbhandari et al., 2017; World Bank Climate Change Knowledge Portal, 2018). The Organization for Economic Cooperative and Development (OECD) revealed that mean annual temperature will increase by an average of 1.2°C by 2030, 1.7°C by 2050, and 3°C by 2100, based on General Circulation Models (GCM) run with the SRES B2 scenario. The GCM and Regional Circulation Models-based study by NCVST (2009) projected that the mean annual temperature will increase by 1.4°C but mostly at the non-significant level both at district and physiographic levels by 2030, 2.8°C by 2060, and 4.7°C by 2090. In terms of spatial distribution, a higher increment in temperature over western and central Nepal compared to eastern Nepal for the years 2030, 2060, and 2090, with projections for western Nepal being the greatest. The frequencies of hot days and nights for 2060 and 2090 also show similar trends. The overall seasonal maximum temperature is found to be the largest increase of 4.5˚C in spring and smallest increase of 3.3˚C in summer, whereas minimum temperature is found to be the largest increase of 5.4˚C in winter and smallest increase of 3.4˚C in summer by the end of the 21st century (MoSTE, 2014).

Precipitation: Some models under both RCP 4.5 and RCP 8.5 scenarios predict a decline of average winter precipitation by around ten percent for the period 2021-2050 compared to 1961-1990 (ICIMOD, 2015). The OECD-GCM model projected up to a 5-10 percent increase in precipitation in eastern Nepal but almost no change in precipitation in western Nepal. The projection depicted an increase in precipitation across the country in the range of 15-20 percent for the summer. The NCVST (2009) study projected both an increase and a decrease in mean annual precipitation, but no clear trends have been observed. Regarding spatial distribution, a higher rate of increase in monsoon rainfall is observed in eastern and central Nepal as compared to western Nepal. The projection indicated an increase in the intensity of rainfall, a decrease in winter precipitation, and an increase in monsoon and post-monsoon rainfall. The temporal scale analysis showed a change in precipitation by 8-12 percent in the long term. It also showed a precipitation increase in the western region. Overall a two percent decrease in annual precipitation in the country is observed by the 2020s, compared to the baseline. However, it increases by six and 12 percent of the baseline by 2050s and 2080s respectively (MoSTE, 2014). These may adversely affect the agricultural system and food security (MoSTE, 2014). A summary of climate change projections is presented in **Table 11.**

Table 11: Projection of maximum-minimum temperature and precipitation over the various season in Nepal

Season	OBS (˚C)	Baseline (˚C)	Bias (˚C)	2020s (˚C)	2050s (˚C)	2080s (˚C)
Maximum Temperature						
DJF	17.8	9.5	8.3	1.5	2.8	4.4
MAM	26.0	21.7	4.3	1.1	2.6	4.5
JJAS	27.3	21.6	5.7	1.0	2.1	3.3
ON	23.3	14.7	8.6	1.2	2.7	3.8
ANNUAL	23.6	16.9	6.7	1.2	2.6	4.0
Minimum Temperature						
DJF	4.7	-5.6	10.2	2.3	3.9	5.4
MAM	12.5	7.0	5.4	1.2	2.9	4.2
JJAS	18.5	15.3	3.3	1.2	2.4	3.4
ON	10.8	2.9	7.8	2.5	3.8	5.0
ANNUAL	11.6	4.9	6.7	1.8	3.3	4.5
Precipitation						
DJF	71	163	-130	-15	3	-12
MAM	211	319	-51	4	10	-3
JJAS	1330	1190	11	-1	8	20
ON	72	220	-206	-4	-5	3
ANNUAL	1683	1892	-12	-2	6	12

Source: MoSTE, 2014

Box 2. Climate future scenario in Nepal.

- Average annual mean temperature is likely to rise. Mean temperature could increase by 0.9–1.1 degrees Celsius (°C) in the medium-term period and 1.3–1.8 °C in the long-term period.
- Both the average annual mean temperature and the average annual precipitation are projected to increase until the end of the century. Precipitation could increase by 11–23%, and mean temperature might increase by 1.7–3.6 °C by 2100.
- The temperature is projected to increase for all seasons. The highest rates of mean temperature increase are expected for the post-monsoon season (1.3–1.4 °C in the medium-term period, and 1.8–2.4 °C in the long-term period) and the winter season (1.0–1.2 °C in the medium-term period, and 1.5–2.0 °C in the long-term period).
- Average annual precipitation is likely to increase in both the medium-term and long-term periods. Average annual precipitation is likely to increase by 2–6% in the medium-term period and by 8–12% in the long-term period
- Precipitation is projected to increase, barring the pre-monsoon season. Precipitation will increase in all seasons, except the pre-monsoon season, which is likely to see a decrease of 4–5% in the medium-term period. The post-monsoon season might have the highest increase in precipitation with respect to the reference period, possibly going up by 6–19% in the medium-term and 19–20% in the long-term.
- Projections about precipitation in the future have a large degree of uncertainty, even more than temperature projections.. Agreement between different climate models is larger for temperature, as compared to precipitation. Collectively, these results suggest that projections regarding temperature-related changes are more certain than the projected changes in precipitation.
- Intense precipitation events are likely to increase in frequency, with extremely wet days expected to increase at a higher rate than very wet days.
- The number of rainy days is likely to decrease in the future. This, in combination with the increase in precipitation intensity, is likely to create more water-related hazards in the future.
- Future changes in consecutive dry days (CDD) and consecutive wet days (CWD) varies with the RCP scenarios. The RCP 4.5 scenario projects a likely increase in CDD, while the extreme scenario RCP 8.5 projects a likely decrease. In agreement with this trend, CWD is projected to decrease under the RCP 4.5scenario and is likely to increase under RCP 8.5.

- Both warm days and warm nights are likely to increase in the future. The number of warm days will rise sharply, from 36 days to 60 days a year in the medium-term, and to 68 days a year in the long- term period, under the RCP 4.5 scenario. This is in concurrence with increasing temperature trends in the future.
- Both cold days and cold nights are likely to decrease in future. The number of cold days decline by 42–53% under the RCP 4.5 scenario over the two periods in this study. This too is in concurrence with increasing temperature trends.

(Source: MoFE, 2019)

- The duration of warm spells, of at least six days of high maximum temperatures, are likely

A recent projection or scenario analysis by the Ministry of Forest and Environment (MoFE) has also revealed several facts about potential future scenarios (MoFE, 2019). They are presented in the box below.

5.2 Climate change stressors/hazards in the sector and sub-sectors

5.2.1. Climatic hazard and extreme event trends

Farmers in Nepal are facing the problems of temperature and precipitation changes, extreme events, and climate-induced hazards with varying nature and intensity at temporal and spatial scales. Major climate-induced hazards impacting agriculture in Nepal include droughts, floods, hailstorms, lightning and thunderstorms, diseases, and insect pests. According to Karki and colleagues (2017), the following changes in hazards and extreme events have been observed in Nepal.

- Average precipitation during the post-monsoon and winter seasons decreased between 1970 and 2012. It further exacerbated the challenges facing local farmers and communities during the dry season.
- The recent analysis of data from weather stations across Nepal observed decreasing winter precipitation at 68% of stations from 1981-2010 and decreasing post-monsoon precipitation at 92% of stations in the same period.
- Over the past 40 years, the average number of consecutive dry days has increased across the country. About 80% of analysed stations in Nepal exhibit a significant increase in consecutive dry days over the period 1970-2012.

The trends of different extreme events and hazards between 1971-2020 based on current data analysis are shown in **Figure 5**, which indicates that the majority of hazards are in increasing trends particularly after the 1990s. Most of the extreme events and hazards started becoming unusual with the drastic increase in numbers since the 2000s. High fluctuations are seen in landslides, floods, heavy rainfall, thunderbolt, and windstorm.

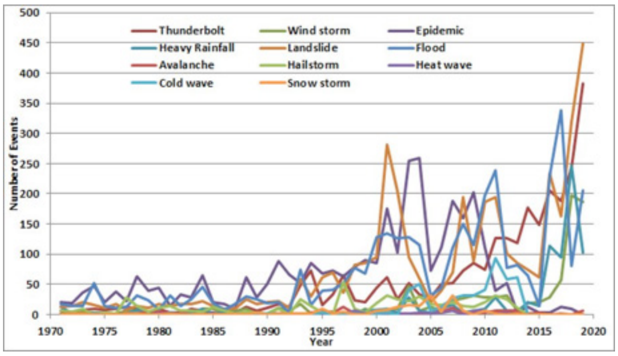
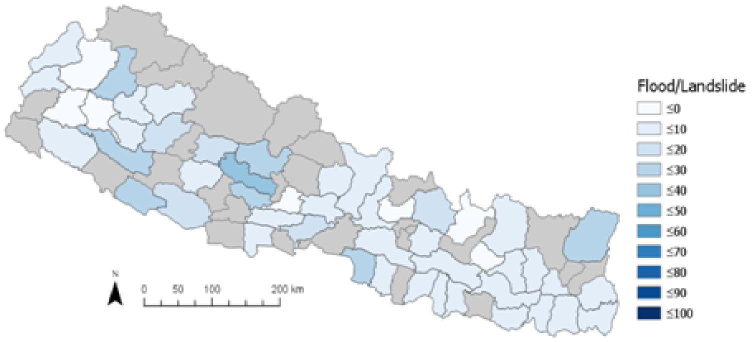


Figure 5: Trends of different hazards and extreme events in Nepal (1971-2020)

The figures below (Figure 6, Figure 7, Figure 8, and Figure 9) show the frequency of different hazards that occurred between 2015 and 2018 in Nepal and different ecological and geographic regions reported by Walker and colleagues (2019). The authors revealed the following findings:

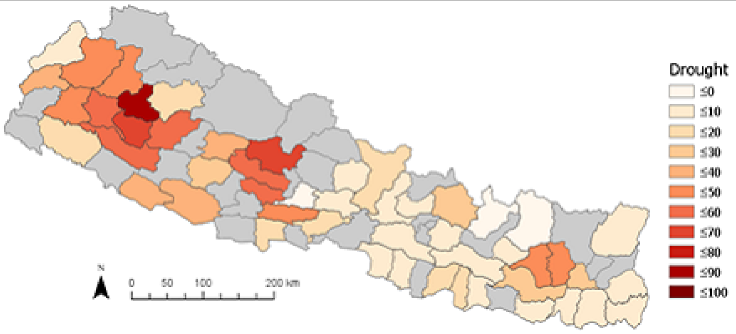
- Floods and landslides were prevalent in Surkhet, Baglung, and Myagdi in 2014-15, affecting 20 to 25 percent of households. One in five households was affected in Bajura and Taplejung in 2015-16.
- The drought was a widespread event in 2015-16, with significant proportions of households in the western, mid-western, and far-western regions affected. There were also isolated reports of drought in the western hill region in 2014-15 (Myagdi, Baglung, and Gulmi) and in the mountain region in 2016-17 (Bajura and Bajhang).
- Fire, hail, and lightning were generally infrequent, but there was significant regional variation. In 2015-16, the only district reporting high rates of fire, hail, and lightning was Taplejung (38 percent of households). In 2016-17 there were frequent reports in the mountain, far western hill, and mid-western hill regions. In Bajhang, 60 percent of households in the sample reported fire, hail, or lightning. This was concurrent with a high number of drought reports in the district. In 2017-18 the shock was concentrated in the far western and mid-western hill regions.
- Pests, plant disease, and post-harvest loss were infrequent overall, but households in the mid-western and western hill regions experienced these shocks with greater frequency (Table 4.5). The incidence of pests, plant disease, and post-harvest loss rose nationwide in 2015-16 and 2017-18. Specific districts were disproportionately affected, such as Gulmi and Jajarkot in 2015-16, Rukum in 2016-17, and Gorkha, Lamjung, and Tanahun in 2017-18.



Region	2015	2016	2017	2018
Mountain	2.8	5.3	1.5	0.5
Far Western Hill	-	0.4	-	0.4
Mid Western Hill	6.3	7.5	3.1	0.2
Western Hill	7.1	3.1	3.3	0.3
Central Hill	0.8	1.1	0.1	0.3
Eastern Hill	0.9	1.9	0.3	0.3
Far Western Terai	2.6	1.9	1.1	0.4
Mid Western Terai	6.4	7.2	5.6	2.9
Western Terai	0.2	3.2	0.4	2.9
Central Terai	0.3	1.1	-	8.1
Eastern Terai	1.5	0.7	0.4	2.1
Nepal	2.6	2.7	1.3	2.3

Figure 6: Frequency of flood and landslide reports (2015-18)

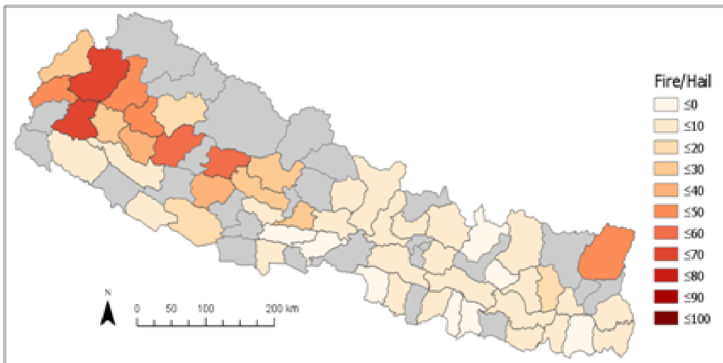
Figure: percentage of households that reported at least one instance of the shock between 2014 and 2018. Grey indicates non-sample areas; Table: Frequency of flood and landslide by region (percentage of households)
Source: Walker et al., 2019



Region	2015	2016	2017	2018
Mountain	-	21.7	7.3	2.2
Far Western Hill	-	35.6	18.5	1.8
Mid Western Hill	0.2	40.2	14.2	7.7
Western Hill	12.6	17.6	0.8	0.1
Central Hill	0.1	1.7	2.8	1.2
Eastern Hill	12.0	14.0	0.5	2.2
Far Western Terai	0.4	17.8	-	-
Mid Western Terai	-	30.3	5.0	1.1
Western Terai	0.2	15.0	1.9	0.2
Central Terai	0.3	7.5	0.3	-
Eastern Terai	1.1	2.4	-	0.1
Nepal	2.9	15.1	3.3	1.2

Figure 7: Frequency of drought reports (2015-18)

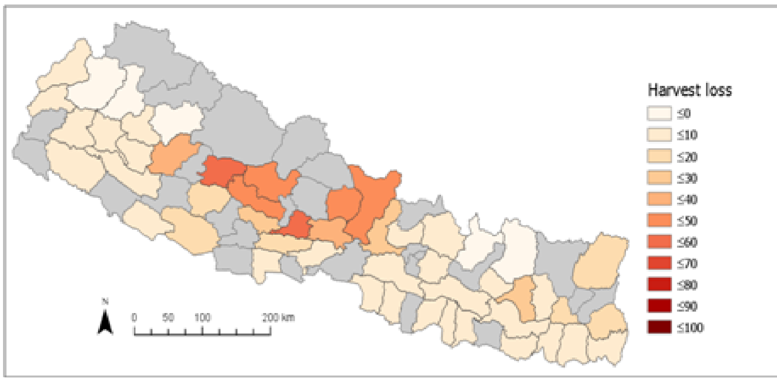
Figure: percentage of households that reported at least one instance of the shock between 2014 and 2018. Grey indicates non-sample areas; Table: Frequency of drought by region (percentage of households)
Source: Walker et al., 2019



Region	2015	2016	2017	2018
Mountain	0.5	6.2	18.7	-
Far Western Hill	-	0.7	36.9	10.7
Mid Western Hill	1.6	6.3	30.6	6.7
Western Hill	1.4	3.9	0.8	5.2
Central Hill	0.3	0.7	0.8	1.4
Eastern Hill	0.9	4.3	0.5	0.2
Far Western Terai	0.4	5.6	-	1.5
Mid Western Terai	-	6.1	0.3	0.3
Western Terai	-	0.8	0.4	-
Central Terai	-	0.1	-	0.4
Eastern Terai	0.4	1.0	0.6	-
Nepal	0.5	2.8	5.6	1.9

Figure 8: Frequency of fire, hail, and lightning reports (2015-18)

Figure: percentage of households that reported at least one instance of the shock between 2014 and 2018. Grey indicates non-sample areas; Table: Frequency of fire, hail, and lightning by region (percentage of households)
Source: Walker et al., 2019



Region	2015	2016	2017	2018
Mountain	0.2	0.7	1.3	1.2
Far Western Hill	-	0.7	2.6	3.7
Mid Western Hill	0.6	9.8	13.3	0.8
Western Hill	7.6	8.3	2.1	21.5
Central Hill	0.4	1.4	2.4	4.7
Eastern Hill	1.4	6.0	0.5	3.2
Far Western Terai	1.9	6.7	0.4	1.8
Mid Western Terai	0.3	5.6	2.2	1.1
Western Terai	-	3.6	1.5	1.1
Central Terai	0.3	2.5	0.3	0.4
Eastern Terai	1.1	3.2	0.4	-
Nepal	1.5	4.3	2.1	4.1

Figure 9: Frequency of pests, plant diseases, and post-harvest loss, 2015-2018

Figure: percentage of households that reported at least one instance of the shock between 2014 and 2018. Grey indicates non-sample areas. Table: Frequency of pests, plant disease, and post-harvest loss by region (percentage of households)

Source: Walker et al., 2019

As a part of this study, the analysis of hazard risk of floods, droughts, hailstorms, and cold waves for the period between 1971 and 2019 also shows a variation in terms of geographic and political regions with high hazard risk (**Figure 10**). The Terai region is more prone to floods, hailstorms, and cold waves, while the hills and mountains are more prone to droughts. Among the Terai districts, Jhapa, Morang, Sunsari, and Kailali are at very high flood risk; Bara and Banke are at very high hailstorm risk; and Saptari, Mahottari, and Rautahat are at very high cold wave risk. Drought hazard risk is particularly high in western mountains. Dolpa and Humla in Karnali Province and Gorkha in Gandaki Province are at very high risk. The eastern mountain districts also have a high drought risk.

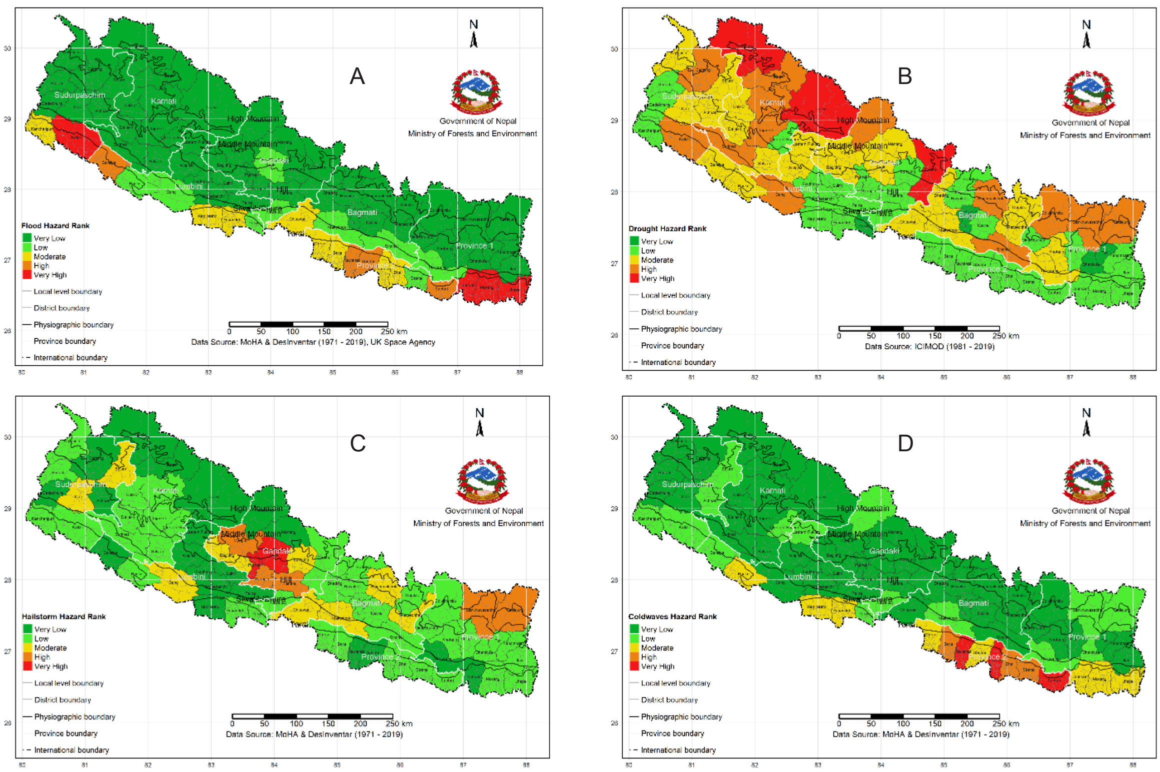


Figure 10: Past trend of flood hazard, drought hazard, hailstorm hazard, and cold wave hazard risks in Nepal (1971-2019)

A trends analysis was done for the top-most drought-prone districts in the country (Dolpa, Gorkha, and Humla) and three top-most districts in the Terai region (Surkhet, Dang, and Kailali). The number of drought events and areas impacted by the drought events between 1981 and 2019 in these districts are shown in **Figure 11** below. The analysis shows that drought events fluctuate over the years, but the districts considered for the analysis show that there are variations in the number of events and areas impacted over the years. All three districts in the Terai region show similar trends which may be because they fall in the same region. The drought trends in other regions may vary among districts. The trends of flood and landslides are separately shown in **Figure 12**.

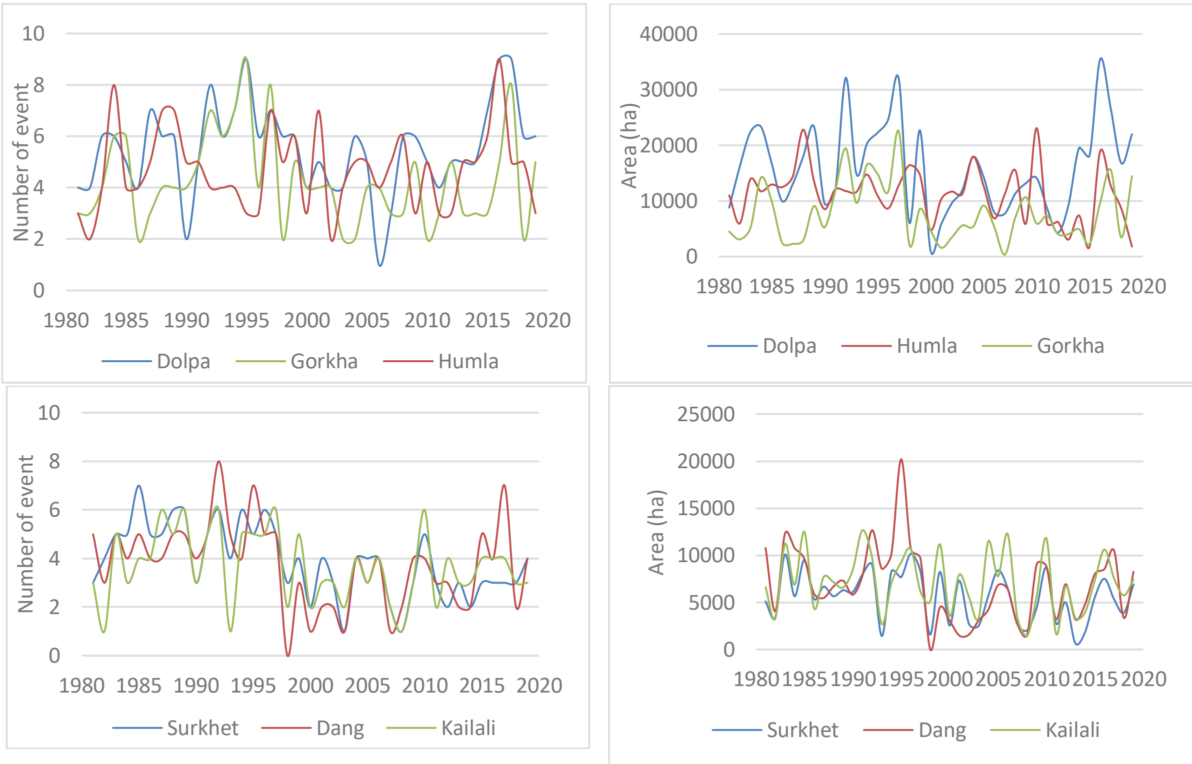


Figure 11: Past trend of drought event and area impacted by event for top-most highly impacted districts in the country (top) and for top-most highly impacted districts in Terai (bottom) (1981-2019)

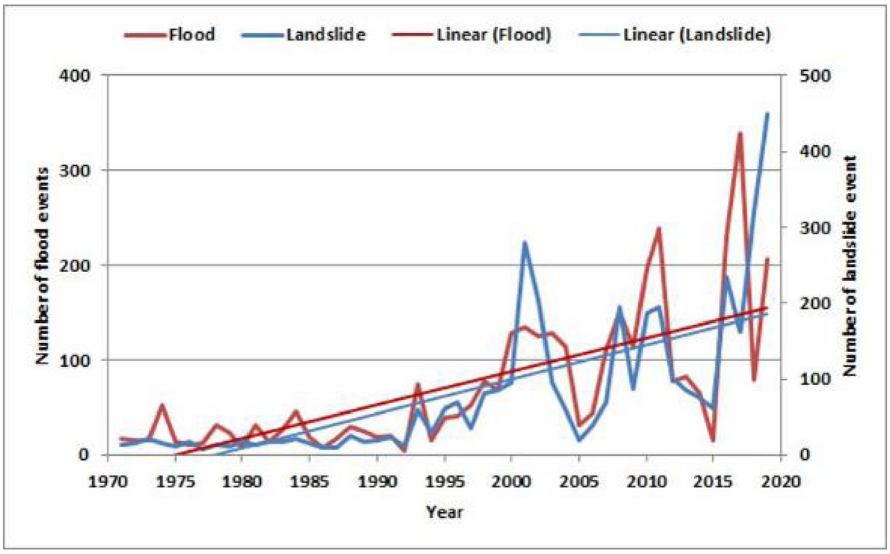


Figure 12: Trends of flood and landslide events in Nepal (1971-2020)

5.2.2 Extreme Climatic Events Scenarios

The current analysis revealed that extreme events will have differential patterns in 2030 and 2050 under both RCP 4.5 and RCP 8.5 compared to the baseline (**Figures 13)**. From the analysis, the changes are not visible between 2030 and 2050 both under RCP 4.5 and RCP 8.5. But when individual hazards or extreme climatic events are analysed, visible patterns are likely, which is clear from the past trends described earlier in section 5.1.2. Similarly, if categorical classes are assigned, that may also show visible and comparable patterns. Various studies have shown some change patterns. For instance, based on the Global Climate Models (GCMs), NCVST (2009) reports as follows:

- Extremely hot days will likely increase by up to 55% by the 2060s and up to 70% by the 2090s.
- Extremely hot nights are projected to increase by up to 77% by the 2060s and 93% by the 2090s.
- There will likely be an increase in precipitation by 40% by the 2030s and from a decrease of 52% to an increase of 135% by the 2090s.

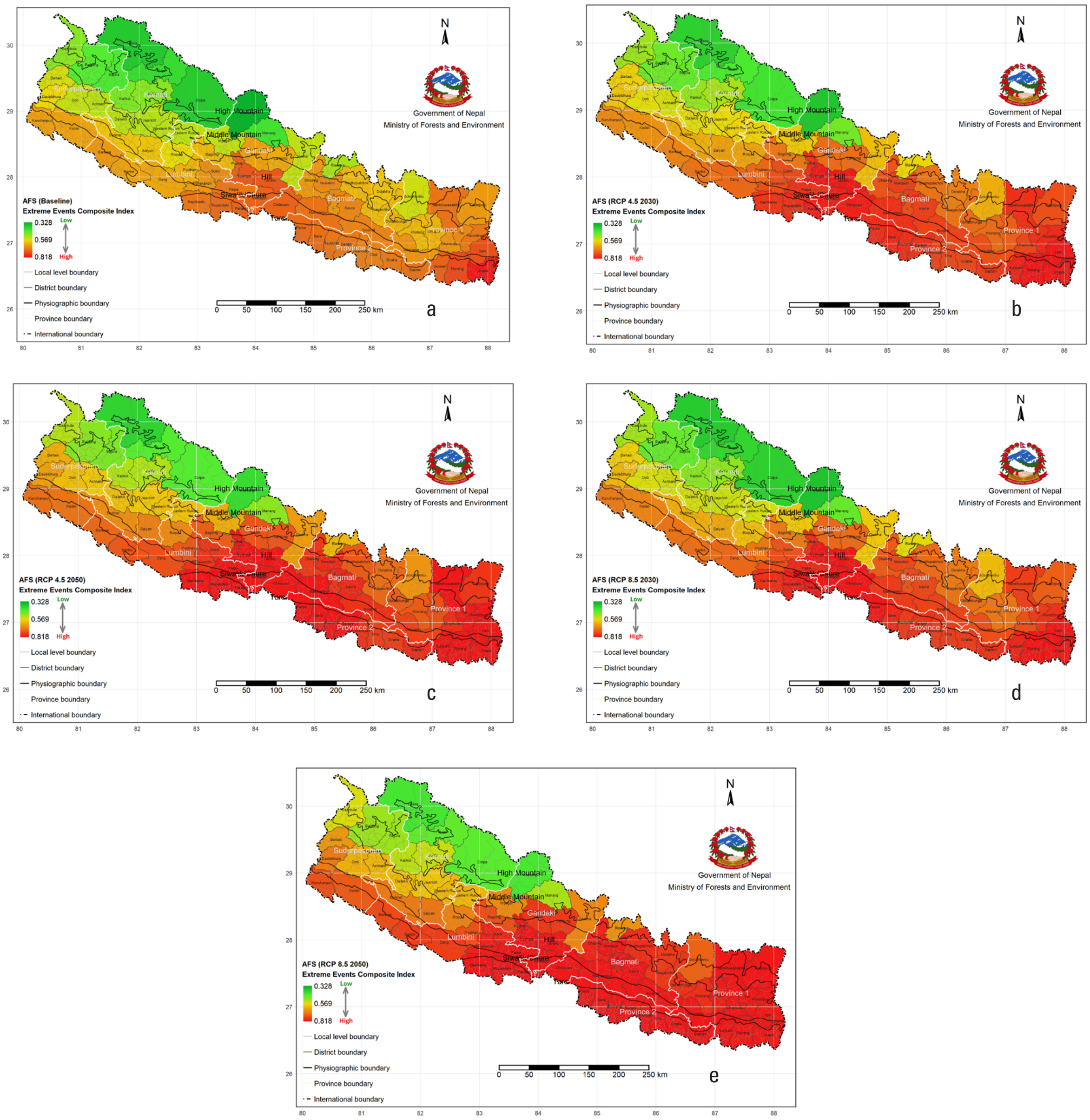


Figure 13: Scenario analysis of multiple extreme events affecting agriculture using two emission scenarios for 2030 and 2050 in Nepal: A: Baseline, B: RCP 4.5, 2030, C: RCP 4.5, 2050, D: RCP 8.5, 2030, and E: RCP 8.5, 2050.

5.3 Climate Change exposure in the sector and sub-sectors

Exposure is defined as the presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructures, or economic, social, or cultural assets in places and settings that could be adversely affected by climate change (IPCC, 2014, p. 5). In this assessment, agriculture land area, livestock population, fisheries population, agriculture-related resources and infrastructure, and most importantly, the people dependent on agriculture are considered as indicators of exposure.

The analysis of exposure revealed that a majority of districts (53%) have a low or very low level of exposure to climate-induced hazards. The Terai districts are more exposed than other regions due to the relatively larger sizes of agricultural lands, the number of livestock, poultry, and fishery activities. The Terai region also has larger irrigable land, and larger population dependent on agriculture, and more and bigger infrastructure thus making it more exposed. In terms of the province, the larger number of districts in Province 1, Province 2, and Bagmati Province are more exposed than the other provinces, since the districts in these provinces are the food baskets of the country with larger arable land and livestock and fishery populations. On the contrary, all the districts under Karnali Province have very low or low exposure due to predominantly subsistent agriculture involving small arable land, and few livestock and fishery activities. The majority of the eastern mountain and hilly districts are exposed less than the Terai districts for similar reasons. The districts falling in different exposure categories are presented by provinces in **Table 12** and **Figure 14.** The index matrices for individual districts for exposure, sensitivity, adaptive capacity, and vulnerability are presented in **Annex 5.**

The Rupandehi and Kailali districts have high exposure in Western Terai, while all other districts have either moderate or low exposure. This is mainly because of higher **land area under cereal crops** in these two districts compared to other neighboring Terai districts: Rupandehi (93,480ha), Kailali (110,285ha), Banke (61,172ha), Bardiya (69,580ha), Kanchanpur (82,464ha), Kapilbastu (95,749ha), Nawalpur (34,902ha) and Parasi (33,868ha). The total land area exposed to climate change is also higher in Rupandehi and Kailali, which consequently plays a critical role in land area under cereal crops. Besides, the number of holdings with agriculture as the main source of income is also higher in these two districts: Rupandehi (104,174), Kailali (111,662), Banke (61,433), Bardiya (68,063), Kanchanpur (70,573), Kapilbastu (74,770), Nawalpur (42,391) and Parasi (45,924).

Table 12: Grouping of districts in different exposure categories

Exposure categories	Districts under different Provinces	Number of districts
Very high	Province 1: Jhapa, Morang, Sunsari Lumbini Province: Rupandehi Sudurpaschim Province: Kailali	5
High	Province 1: Ilam Province 2: Saptari, Siraha, Dhanusa, Sarlahi, Bara Bagmati Province: Chitwan Lumbini Province: Kapilbastu, Dang	9

Exposure categories	Districts under different Provinces	Number of districts
Moderate	Province 1: Bhojpur, Udaypur, Khotang Province 2: Mahottari, Rautahat, Parsa Bagmati Province: Sindhuli, Kavre, Singhupalchok, Nuwakot, Makwanpur. Dhading Gandaki Province: Gorkha, Tanahu, Kaski, Syangja, Baglung, Nawalpur Lumbini Province: Banke, Bardiya, Gulmi Karnali Province: Surkhet Sudurpaschim Province: Kanchanpur	22
Low	Province 1: Taplejung, Panchthar, Terhathum, Dhankuta, Sankhuwasabha, Solukhumbu, Okhaldhunga Bagmati Province: Dolakha, Ramechhap, Kathmandu, Lalitpur Gandaki Province: Lamjung, Myagdi, Parbat Lumbini Province: Parasi, Palpa, Arghakhanchi, Pyuthan, Rolpa Karnali Province: Dolpa, Western Rukum, Salyan, Jajarkot, Dailekh Sudurpaschim Province: Achham, Bajhang, Darchula, Doti, Baitadi, Dadeldhura	31
Very low	Bagmati Province: Rasuwa, Bhaktapur Gandaki Province: Manang, Mustang Lumbini Province: Eastern Rukum Karnali Province: Mugu, Kalikot, Humla Sudurpaschim Province: Bajura	10

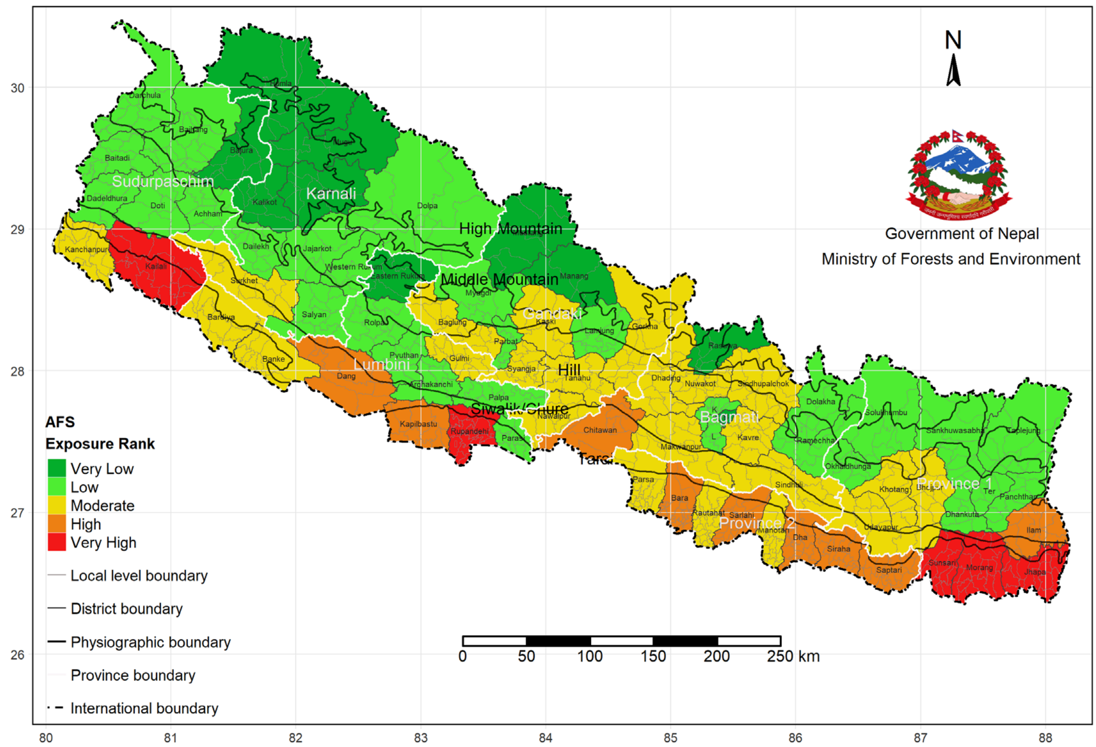


Figure 14: Exposure of agriculture sector in different districts, provinces, and ecological regions

Chapter 6

Observed Climate Change Vulnerability in the Sector

6.1 Sensitivity in the sectors

Sensitivity in this assessment refers to the degree to which a system or crop is affected, either adversely or positively by climate variability or change. The sensitivity indicators are mostly related to the characteristics of agriculture-dependent population, the fragility of the system, the condition and status of the crops, livestock, and fisheries, and socio-economic parameters.

The analysis shows that a large majority of districts (>70%) have moderate to very high sensitivity while the rest have either low or very low sensitivity. The major indicators contributing to high or low sensitivity include small landholding population, dependent population, population density, seasonal outmigration, Human Poverty Index (HPI), Gender Inequality Index (GII), the holding of credit, and land tenure. Some districts in Gandaki, Lumbini and Karnali Provinces fall under the very high sensitivity category, while there are none in the other provinces. The highly sensitive districts are spread across the mid-hill and high-hill regions from east to west, but the majority of districts in Karnali and Sudurpaschim Provinces fall under the high sensitivity category because land in those provinces is less productive, population density is higher with the dominance of Dalits and indigenous peoples, and HDI is lower than the other provinces. The Terai districts have either low or very low sensitivity despite their high exposure to climatic hazards because of better land ownership and accessibility is relatively better due to good road access than the other provinces. Districts falling in different categories are presented by provinces in **Table 13** and **Figure 15**.

The sensitivity is high in Manang and low in Mustang, although they might look similar due to proximity. The difference is because of the following reasons:

- Manang is highly sensitive because of the higher proportion of rainfed land (66.81% in Manang and 8.12% in Mustang), man-livestock ratio (0.75 in Manang and 0.17 in Mustang), indigenous and Dalit population (92%

in Manang and 87% in Mustang), average slope (29.196 degrees in Manang and 23.858 degrees in Mustang) as compared to Mustang.

- Manang is reported as a more sensitive district than Mustang even in NAPA (2010) and AFS stock-taking report (2016).

The sensitivity of Nawalpur and Parasi districts have different sensitivity, although values for several indicators were supposed to be the same because new data has not been generated yet. The following factors can be attributed to these differences:

- Land under temporary fallow: Nawalpur (36.78%), Parasi (20.50%)
- Man-livestock ratio: Nawalpur (0.64), Parasi (0.43)
- Janajatis and Dalits: Nawalpur (76%), Parasi (37%)
- Mean slope: Nawalpur (13.67 degrees), Parasi (5.097 degrees)

Table 13: Grouping of districts in different sensitivity categories

Sensitivity categories	Districts under different Provinces	Number of districts
Very high	Province 1: Khotang Bagmati Province: Ramechhap, Dolakha Gandaki Province: Gorkha, Tanahu, Baglung Lumbini Province: Palpa, Gulmi, Pyuthan, Rolpa, Eastern Rukum	11
High	Province 1: Jhapa, Panchthar, Bhojpur, Sankhuwasabha, Solukhumbu, Okhaldhunga Bagmati Province: Dhading, Sindupalchok, Kathmandu, Makwanpur Gandaki Province: Manang, Myagdi, Syanga, Nawalpur Lumbini Province: Arghakhachi, Kapilbastu Karnali Province: Dailekh, Jajarkot, Western Rukum Sudurpaschim Province: Bajhang, Achham, Doti	22
Moderate	Province 1: Taplejung, Terhathum, Dhankuta, Morang, Udaypur Province 2: Siraha, Mahotari Bagmati Province: Sindhuli, Kavre, Nuwakot, Rasuwa Gandaki Province: Lamjung, Kaski, Parbat Lumbini Province: Dang Karnali Province: Mugu, Kalikot, Salyan, Surkhet Sudurpaschim Province: Dadeldhura, Baitadi, Darchula, Bajura	23
Low	Province 1: Ilam, Sunsari Province 2: Saptari, Dhanusa, Sarlahi Bagmati Province: Lalitpur, Chitwan Gandaki Province: Mustang Lumbini Province: Parasi, Rupandeshi, Banke, Bardiya Karnali Province: Humla, Jumla, Dolpa Sudurpaschim Province: Kailali	16
Very low	Province 2: Rautahat, Bara, Parsa Bagmati Province: Bhaktapur Sudurpaschim Province: Kanchanpur	5

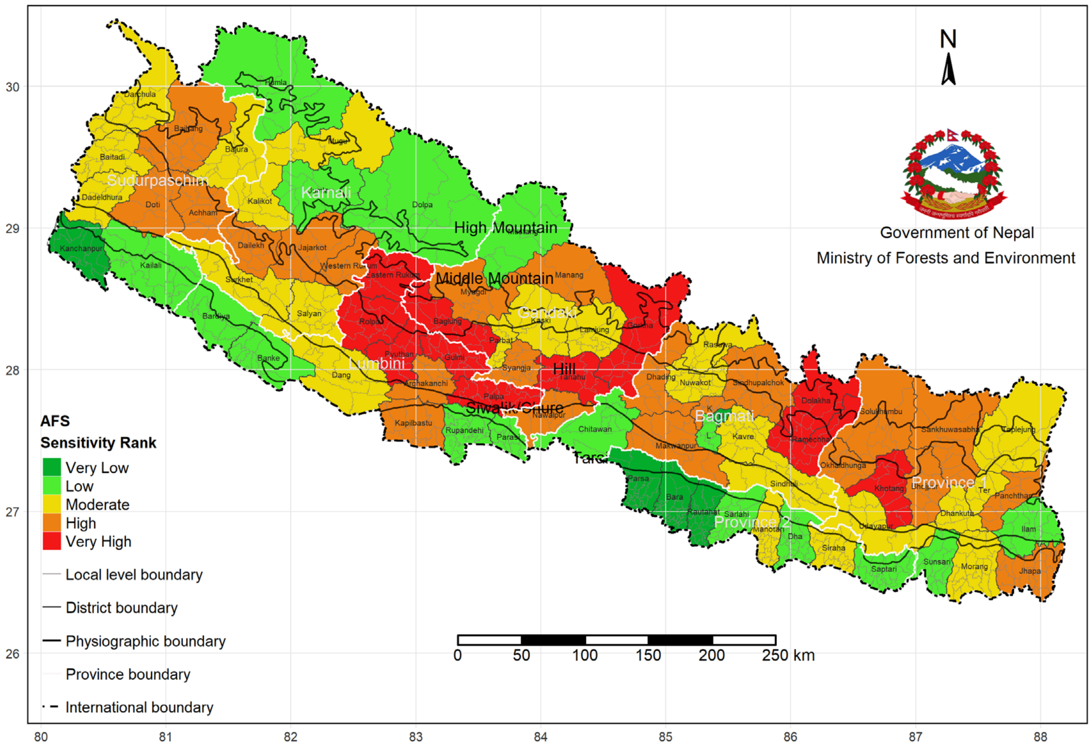


Figure 15: The sensitivity of the agriculture sector in different districts, Provinces, and ecological regions

6.2 Adaptive capacity in the sectors

Adaptive capacity in this sector is interpreted as the ability of systems and institutions, in terms of strategies, plans, programs, practices, and mechanisms, and human resources mobilized in the management that is supportive for the sector, to adjust to potential damage of climate change as well as that facilitate the sector related system to take advantage of opportunities and to respond to consequences of climate change.

The levels of adaptive capacity also vary across the country. A total of 30 districts have moderate to very low adaptive capacity, whereas 31 districts have high and 16 districts have very high adaptive capacity. Overall, over 60% of districts have a high or very high adaptive capacity. All the districts, except Surkhet and Western Rukum in Karnali Province and the majority of the districts in Sudurpaschim Province, fall under the very low adaptive capacity category, particularly because of the high incidence of poverty and food insecurity, low HDI, poor access to shallow and deep tube wells, poor access to radio and television, and low use of modern and efficient agri-tools and implements in the region. Those provinces are also highly sensitive as discussed in the earlier section. Moreover, the majority of districts in the mid-hill and high-hill regions are either in very low or low adaptive capacity categories because of similar reasons. Despite being highly exposed to climate hazards, the majority of the districts in the Terai have either high or very high adaptive capacity mainly because of high per capita land holding, good access to resources and services, high crop and livestock productivity, high labour productivity, the use of modern and efficient agri-tools, and holding of shallow and deep tube wells. Wealth generally provides access to markets, technology, and other resources that can be used to adapt to climate variability and change (Brenkert & Malone, 2005).

The Prime Minister Agricultural Modernization Program of Nepal is promoting several agricultural technologies. The program has designated Super zones, Zones, Blocks, and Pockets in different districts. Wherever those designated areas exist, the farmers have better adaptive capacity due to the adoption of new climate-resilient technologies. Community Seed Banks (CSBs) help repatriate local crop variety seeds when drought and other hazards impact grain and seed production (Chaudhary, 2013; Shrestha et al., 2013; Vernooy et al., 2019). Neglected and Underutilized Species (NUS) are tolerant to various types of droughts due to their inherent genetic diversity and ability to coexist with the local micro-environment. Crop diversity decreases the vulnerability of agriculture to climate change (Chaudhary et al., 2020; Kandji et al., 2006; Reidsma & Ewert, 2008). Moreover, the higher the population density, the more the chance of a larger number of people to be affected. This is a proxy indicator. More rural population density means less land holding per capita (Gbetibouo et al., 2010). However, due to a lack of data in the required format, these indicators were not included in the VRA analysis.

Women's adaptive capacity is poor. Women perform up to 92% of forage collection activity but their participation in improved forage farming groups has been about 36% (Paudel et al., 2009). **Table 14** and **Figure 16** shows districts falling in different adaptive capacity categories.

Dang has moderate adaptive although the adjoining districts are mostly higher. Sindhuli district has the very low adaptive capacity, even though the surrounding districts are better off. Nawalpur and Parasi have low adaptive capacity while the majority of western and far-western Terai have high adaptive capacity. These differences can be attributed to the following:

- **Access to water efficient tools:** Nawalpur (317,605 HH), Parasi (16,251), Banke (21,584), Bardiya (11,576), Dang (1,763), Kailali (52,738), Kanchanpur (36,310), Kapilbastu (34,035) and Rupandehi (57,354)
- **Shallow tube well:** Nawalpur (1,698 HH), Parasi (1,567), Banke (13,683), Bardiya (12,866), Dang (1,563), Kailali (21,540), Kanchanpur (32,216), Kapilbastu (4,867) and Rupandehi (19,538)
- **Deep tube well:** Nawalpur (469 HH), Parasi (378), Banke (11,838), Bardiya (4,481), Dang (841), Kailali (13,752), Kanchanpur (4,530), Kapilbastu (5,878), Rupandehi (8,599)
- **Labour productivity:** Nawalpur (97,731 NPR), Parasi (97,731), Banke (133,048), Bardiya (100,882), Dang (109,337), Kailali (98,420), Kanchanpur (100,042), Kapilbastu (110,694), Rupandehi (126,222)

Table 14: Grouping of districts in different adaptive capacity categories

Adaptive capacity categories	Districts under different Provinces	Number of districts
Very low	Bagmati Province: Sindhuli Gandaki Province: Mustang Karnali Province: Dolpa, Mugu, Humla, Jumla, Jajarkot, Salyan, Kalikot, Dailekh Sudurpaschim Province: Bajura, Bajhang, Achham, Doti, Baitadi, Dadeldhura	16
Low	Province 1: Taplejung, Panchthar, Terhathum, Sankhuwasabha, Dhankuta, Bhojpur, Solukhumbu, Khotang, Udaypur Bagmati Province: Dolakha, Ramechhap, Sindhupalchok, Rasuwa, Nuwakot, Dhading, Makwanpur Gandaki Province: Gorkha, Lamjung, Tanahu, Nawalpur, Manang, Myagdi, Baglung, Parbat Lumbini Province: Parasi, Eastern Rukum, Rolpa, Pyuthan Karnali Province: Western Rukum, Surkhet Sudurpaschim Province: Darchula	31
Moderate	Province 1: Ilam, Okhaldhunga Province 2: Saptari, Mahottari, Sarlahi, Rautaha Bagmati Province: Kavre, Lalitpur Gandaki Province: Kaski, Syangja Lumbini Province: Palpa, Gulmi, Arghakhanchi, Dang	14
High	Province 1: Jhapa, Morang, Sunsari Province 2: Siraha, Dhanusa, Parsa Bagmati Province: Kathmandu, Bhaktapur Lumbini Province: Kapilbastu, Banke, Bardiya Sudurpaschim Province: Kailali, Kanchanpur	13
Very high	Province 2: Bara Bagmati Province: Chitwan Lumbini Province: Rupandehi	3

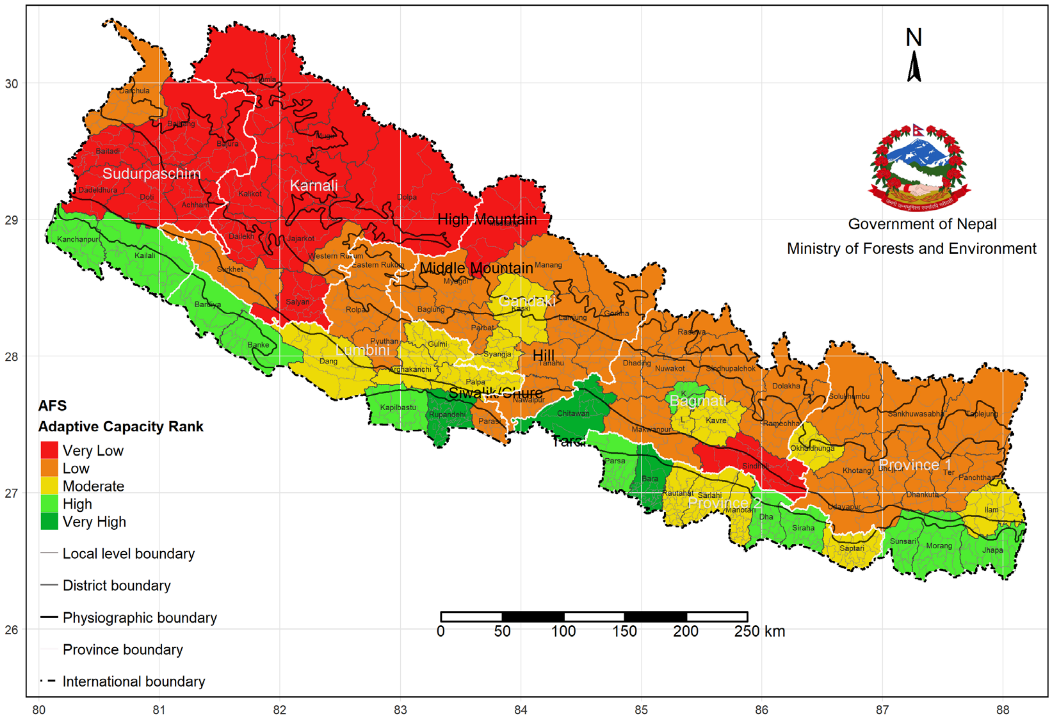


Figure 16: The adaptive capacity of the agriculture sector in different districts, Provinces, and ecological regions

6.3 Vulnerability in the sectors

Vulnerability in this sector is understood as the propensity or predisposition of agriculture and food security systems to be adversely affected by climate change. In this assessment, the vulnerability has been measured as the difference between the sensitivity and adaptive capacity associated with the sector.

Vulnerability analysis showed that the majority of districts (45 districts) have moderate to very high levels of vulnerability. Similar to adaptive capacity, several districts in Gandaki, Lumbini, Karnali, and Sudurpaschim Provinces fall under a very high vulnerability category mainly because their sensitivity is moderate to high and adaptive capacity low to moderate. Those falling under the high vulnerability category are either in the mid-hill or high-hill regions which is because they are sensitive due to poor agricultural resources while their adaptive capacity is poor mainly due to poor access to resources and services such as modern efficient agri-tools and implements and deep and shallow tube wells. In contrast, all the districts in the Terai region, except Parasi, fall under the low vulnerability category irrespective of the province mainly because those districts are less sensitive due to better quality land and have better adaptive capacity due to access to resources and better production systems than other regions. The Karnali and Sudurpaschim Provinces are highly sensitive and have poor adaptive capacity, which makes the region highly vulnerable. Nawalpur and Parasi, have low and moderate vulnerability respectively. **Table 15** and **Figure 17** shows districts falling in different vulnerability categories.

Table 15: Grouping of districts in different vulnerability categories

Vulnerability categories	Districts under different Provinces	Number of districts
Very high	**Gandaki Province:** Myagdi, Baglung Gorkha, Tanahu **Lumbini Province:** Pyuthan **Karnali Province:** Dailekh **Sudurpaschim Province:** Bajura, Bajhang, Achham, Doti, Baitadi	11
High	**Province 1:** Khotang **Bagmati Province:** Dolakha, Ramechhap, Sindhuli, Dhading **Lumbini Province:** Rolpa, Eastern Rukum **Karnali Province:** R, Salyan, Western Rukum, Jajarkot, Kalikot, Jumla **Sudurpaschim Province:** Dadeldhura	12
Moderate	**Province 1:** Taplejung, Panchthar, Dhankuta, Bhojpur, Udaypur, Okhaldhunga, Sankhuwasabha **Bagmati Province:** Sindhupalchok, Rasuwa, Nuwakot, Makwanpur **Gandaki Province:** Mustang, Manang, Lamjung, Nawalpur, Syangja, Parbat **Karnali Province:** Surkhet, Dolpa, Mugu, Humla **Sudurpaschim Province:** Darchula	22
Low	**Province 1:** Terhathum **Province 2:** Mahotari **Gandaki Province:** Kaski **Lumbini Province:** Palpa, Gulmi, Arghakhanchi, Parasi	7
Very low	**Province 1:** Ilam, Jhapa, Morang, Sunsari **Province 2:** Saptari, Siraha, Dhanusa, Sarlahi, Rautahat, Bara, Parsa **Bagmati Province:** Chitwan, Kathmandu, Bhaktapur, Lalitpur, Kavre **Lumbini Province:** Rupandehi, Kapilbastu, Dang, Banke, Bardiya **Sudurpaschim Province:** Kailali, Kanchanpur	23

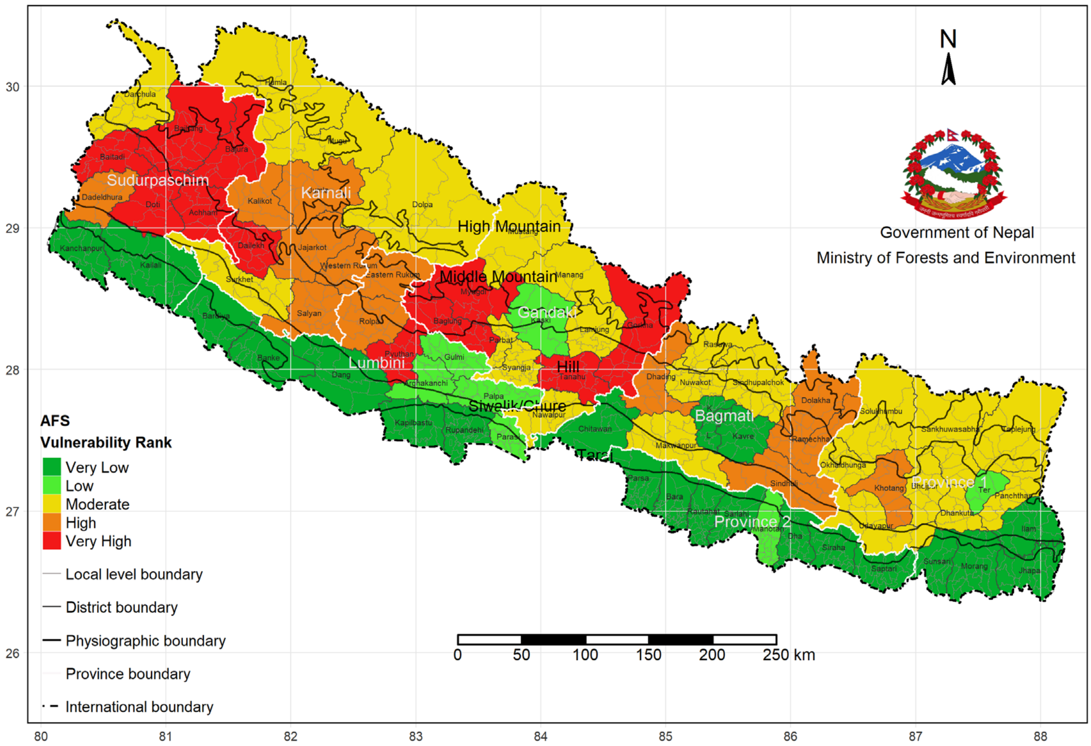


Figure 17: The vulnerability of the agriculture sector in Nepal

The analysis by province also shows variations among different districts within the provinces, except for Province 2. In all the provinces, except Province 2, for the most part, all five categories (very low to very high) of vulnerability exist. Other details are listed below and the numbers of districts under different vulnerability categories are presented in **Table 16**. The maps of the seven provinces with districts falling in different vulnerability categories are shown below (**Figure 18**).

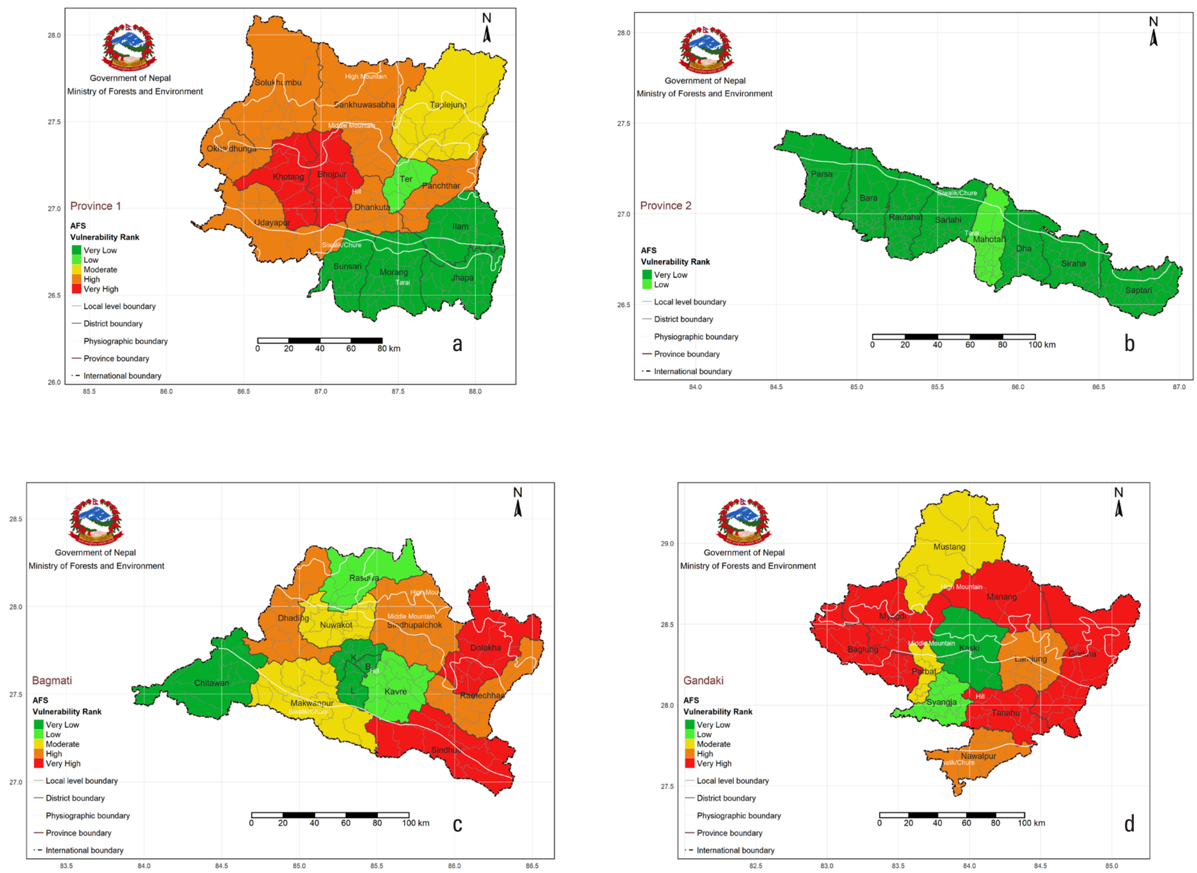
The highest number of very highly vulnerable districts are in Gandaki Province, followed by Sudurpaschim Province. Additionally, the highest number of highly vulnerable districts are in Karnali Province. In contrast, the largest number of districts with very low vulnerability is in Province 2, followed by Lumbini Province. Presented below is a breakdown of these rankings.

- **Province 1**: One district (Khotang) has a high vulnerability, while eight districts have moderate (Taplejung, Panchthar, Dhankuta, Bhojpur, Udayapur, Okhaldhunga, Solukhumbu, and Sankhuwasabha) and one district has low (Terhathum) vulnerability and four districts (Ilam, Jhapa, Morang and Sunsari) have very low vulnerability.
- **Province 2:** Only two categories, very low (Saptari, Siraha, Dhanusa, Sarlahi, Rautahat, Bara, Parsa) and low (Mahottari) exist.
- **Bagmati Province:** Four districts (Dhading, Dolakha, Ramechhap, and Sindhuli) have high, four districts (Sindhupalchok, Rasuwa, Nuwakot, and Makwanpur) have moderate, and four districts (Kathmandu, Lalitpur, Bhaktapur, and Chitwan) have very low vulnerability.
- **Gandaki Province:** Four districts (Gorkha, Tanahu, Myagdi, and Baglung) have very high, six districts (Mustang, Manang, Lamjung, Nawalpur, Syangja, and Parbat) have moderate, and one district (Kaski) has a low vulnerability.

- **Lumbini Province:** One district (Pyuthan) has very high, two districts (Rolpa and Eastern Rukum) have high, four districts (Parasi, Palpa, Arghakhanchi, and Gulmi) have low, and five districts (Rupandehi, Kapilbastu, Dang, Banke, and Bardiya) have very low vulnerability.
- **Karnali Province:** One district (Dailekh) has very high, five districts (Western Rukum, Salyan, Jajarkot, Kalikot, and Jumla) have high, and four districts (Humla, Mugu, Dolpa, and Jumla) have moderate vulnerability.
- **Sudurpaschim Province:** Five districts (Bajura, Bajhang, Baitadi, Achham, and Doti) have very high, one district (Dadeldhura) has high, one district (Darchula) has moderate, and two districts (Kailali and Kanchanpur) have very low vulnerability.

Table 16. Number of districts under different vulnerability categories in different provinces

Province	Vulnerability category					
	Very high	High	Moderate	Low	Very low	Total
Province 1	0	1	8	1	4	14
Province 2	0	0	0	1	7	8
Bagmati Province	0	4	4	0	5	13
Gandaki Province	4	0	6	1	0	11
Lumbini Province	1	2	0	4	5	12
Karnali Province	1	5	4	0	0	10
Sudurpaschim Province	5	1	1	0	2	9
Total	17	16	9	10	25	77



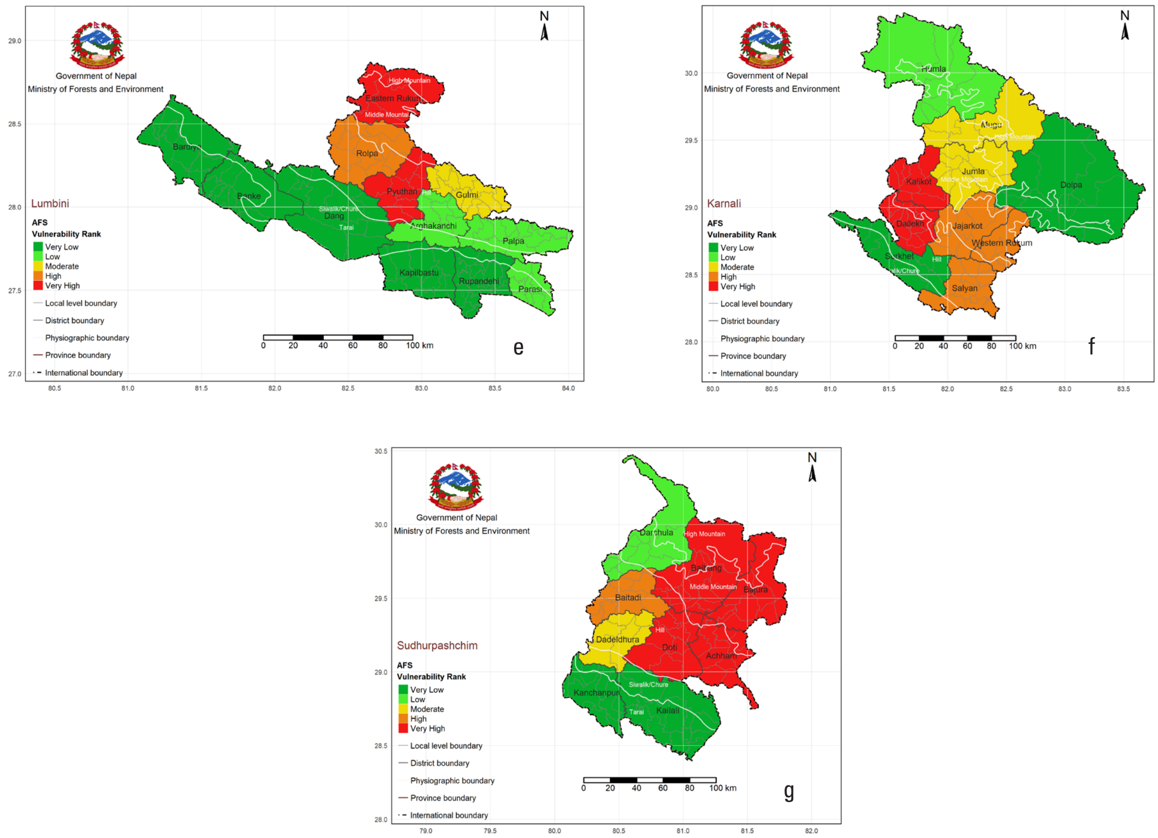


Figure 18: The vulnerability of the agriculture sector in different districts of a give in province

Chapter 7

Projected Climate Change Risks and Potential Adaptation Options in the Sector

7.1 Future climate change risks in the sector and sub-sectors

The risk of climate change impact for this sector is interpreted as the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as a probability of occurrence of hazardous events or trends multiplied by the impacts of these events. Risk results from the interaction of vulnerability, exposure, and hazard.

The scenario analysis was done using the RCP 4.5 and RCP 8.5 scenarios. The risk of climate change impact for this sector is interpreted as the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk results from the interaction of vulnerability, exposure, and hazard. The findings show that the districts under the very high risk category will likely increase under both scenarios, while the number of districts for all other categories will likely decline in the considered time scales. This is likely because the temperature is likely to increase over time, which, combined with droughts and extreme precipitation trends, will make several districts more exposed to those events. The vulnerability is likely to increase because of the increased rate of migration, population growth leading to high density, the incidence of a new disease, and insect pests, among other reasons.

Under the RCP 4.5, the districts with the very high-risk category are likely to increase from eight in baseline to 14 in 2030 and 17 in 2050. Similarly, under the RCP 8.5, the districts with the very high risk category will likely increase from eight in baseline to 14 in 2030 and 20 in 2050. The number of districts falling under the high-risk category will shift from 13 to 17 and further to 16 under the RCP 4.5 2030 and 2050 respectively. While the districts will shift to 16 each under the RCP 8.5 2030 and RCP 8.5 2050. Figure 19 below illustrates further details.

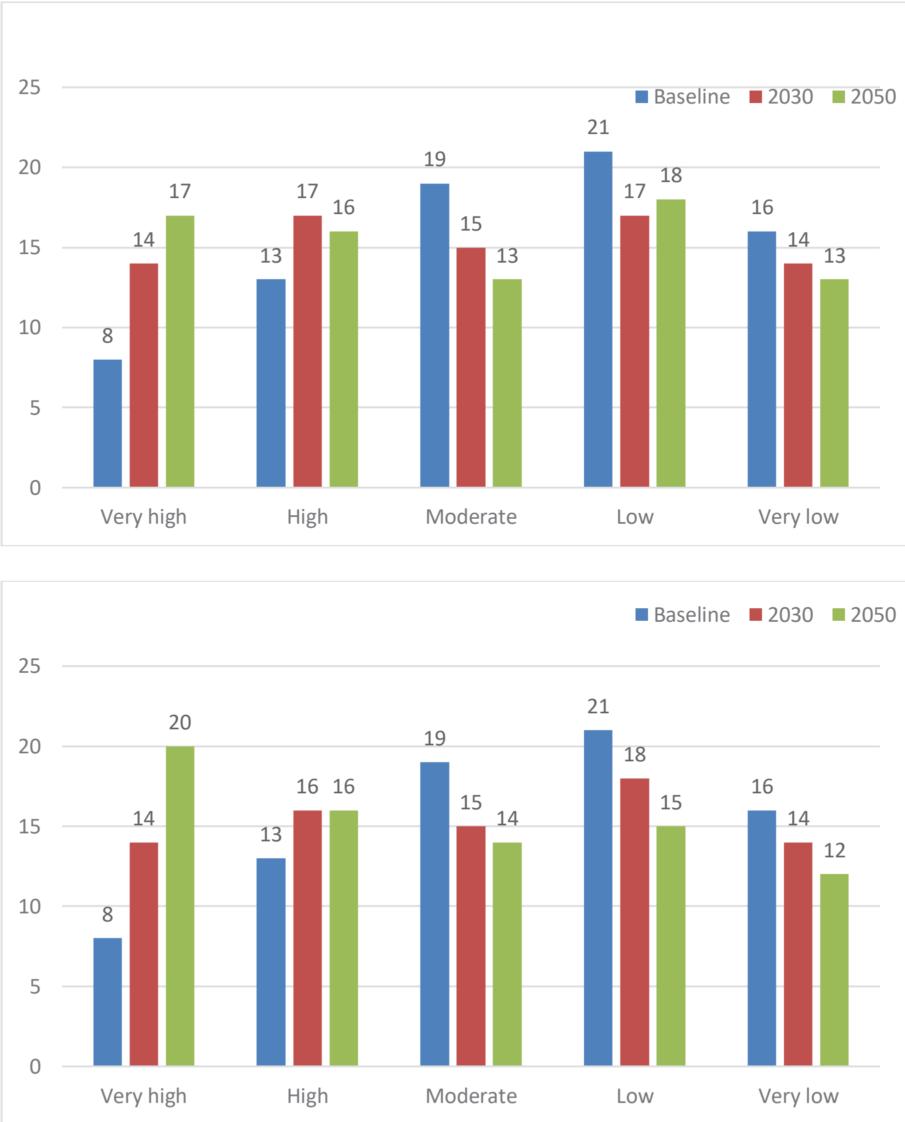


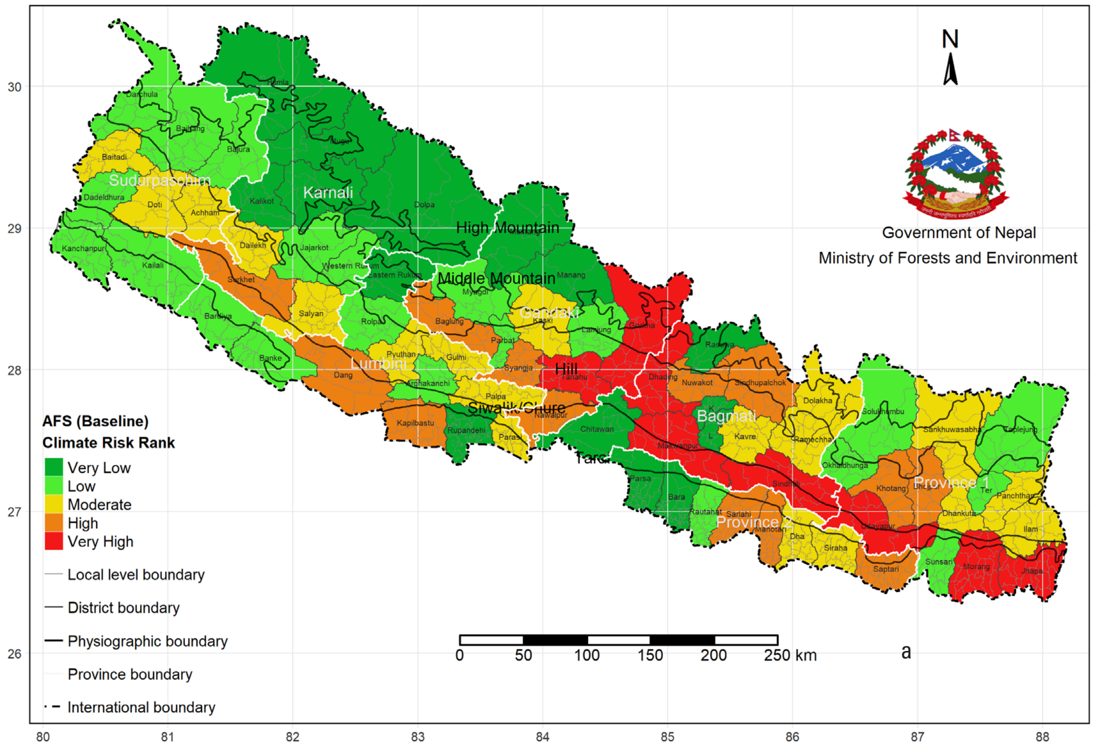
Figure 19: Number of districts falling under different risk categories in three-time scales (baseline, 2030 and 2050) under RCP 4.5 (Top) and RCP 8.5 (Bottom)

At baseline, three districts in Province 1 (Jhapa, Morang, and Udaypur), three districts in Bagmati Province (Sindhuli and, Dhading), and two districts in Gandaki Province (Gorkha and Tanahu) are at a very high risk category. The reason behind this is the combination of high exposure, low sensitivity, and poor adaptive capacity. For one district, one of the three indices (exposure, sensitivity, and adaptive capacity) is higher while in other districts, some other indices are higher. Not a single district in Province 2, Lumbini Province, Karnali Province, and Sudurpaschim Province is in that category.

Under the RCP 4.5 scenario, four districts in Province 1 (Khotang, Udayapur, Morang, and Jhapa), one district in Province 2 (Mahottari), four districts in Bagmati Province (Sindhuli, Makwanpur, Dhading, and Sindupalchok), further four districts each in Gandaki (Gorkha, Tanahu, Syangja, and Baglung) and one district in Lumbini (Dang) Provinces will be in the very high risk category. Similarly, three additional districts (Sarlahi, Nuwakot, Nawalpur) will be added to the very high risk category in 2050, compared to 2030.

Under the RCP 8.5 scenario, three districts in Province 1 (Jhapa, Morang, and Udayapur), one district in Province 2 (Mahottari), four districts in Bagmati Province (Sindhuli, Makwanpur, Dhading, and Sindupalchok), five districts in Gandaki Province (Nawalpur, Tanahu, Syangja, Baglung, and Gorkha), one district in Lumbini Province (Dang) and one district in Karnali Province (Surkhet) will be in the high risk category. In 2050, six additional districts—Khotang, Bhojpur, and Sankhuwasabha in Province 1, Sarlahi in Province 2, Nuwakot in Bagmati—will move to the very high risk category compared to RCP 8.5 2030. Additional details can be seen in **Figure 20** and **Annex 6.**

Overall, several districts in all three ecological regions in Province 1, four districts in Province 2 (Saptari, Siraha, Mahottari, and Sarlahi), the hill and mountain districts in Bagmati Province, and some mid and high-hill districts in Gandaki Province are likely going to be at higher risk in the future under both the scenarios. A few Terai (particularly in Lumbini Province) and mid-hill districts in Lumbini, Karnali, and Sudurpaschim Provinces are going to face a higher risk in the future. High-hill and mountain districts in both Karnali and Sudurpaschim Provinces are likely to have a low or very low risk of climate change in the future under both scenarios.



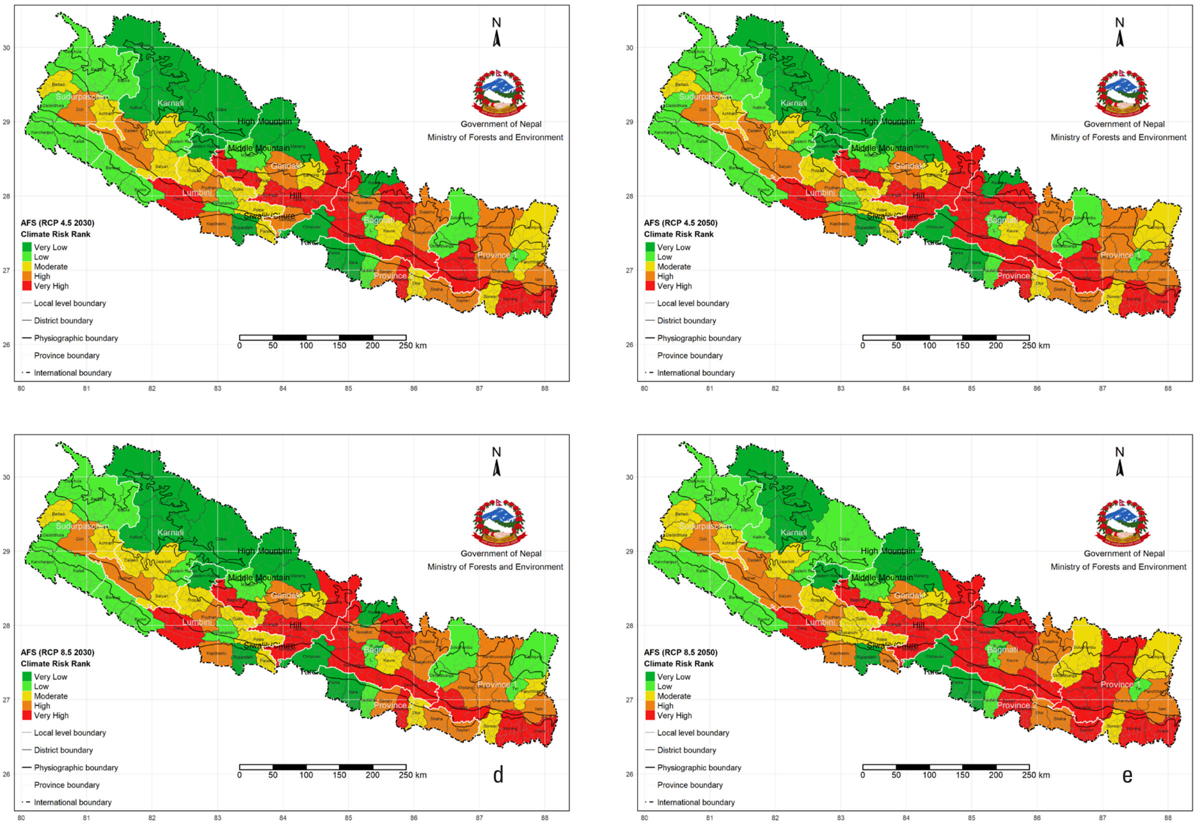


Figure 20: Scenario analysis of climate risk affecting agriculture using two emission scenarios for 2030 and 2050 in Nepal: A: Baseline, B: RCP 4.5, 2030, C: RCP 4.5, 2050, D: RCP 8.5, 2030, and E: RCP 8.5, 2050.

Other studies conducted in Nepal also project the influence of climate change on agricultural production. Dunne et al. (2013) suggest that there is a drop of 10% in global labor productivity during peak months due to warming. A decline of up to 20% is projected by the 2050s under the highest emissions pathway (RCP 8.5). These lowland areas of the country will be impacted more where extreme high heat will increasingly be experienced.

Besides, a decline of crop yield by eight percent by 2050, 16% for maize, and 11% for sorghum are projected in South Asia under climate change. The study conducted on hydrology and productivity of rain-fed crops (wheat, maize, rice) in the Indrawati river basin shows that Maize yield would largely decrease (2.8% on average in 2050 and 3.5% on average in 2100), with however large variability (–15.0% to +4.7%, and –17% to +4.0%, respectively). Wheat would be impacted most (–3.6% on average in 2050 and –0.1% on average in 2100), but both spread (–35.6% to +13.2%, and –25.1% to +18.0%, respectively), and Coefficient of Variance (CV) in all simulations vary largely (Palazzoli et al., 2015).

7.2 Opportunities of adaptation in the sector

The vulnerability and risk assessment allows identifying adaptation options suitable for given geographic areas and sectors. It is important to tailor adaptation technologies and practices to local risks, needs, priorities, and available resources. Different organizations have adopted different techniques to identify and group adaptation options in the past; for instance, the NAPA undertook a hazard-based approach. Several recent undertakings focus on underlying causes of vulnerability such as informational, capacity, financial, institutional, and technological needs. The adaptation actions are organized into three categories: i) structural and physical, ii) social, and iii) institutional. The structural and physical adaptation options are discreet structural and engineering options and have clear outputs and outcomes. The social options target specific vulnerabilities of disadvantaged groups such as social inequities. The institutional options include adaptation actions that enhance the ability of institutions responsible for climate action. This study used the framework embedding the above-mentioned three categories to organize the adaptation options identified via different sources. Both incremental adaptation options and transformative adaptation options are identified for the agriculture sector. To ensure a bottom-up approach, the engagement of local governments, NGOs, and civil society organizations, communities, and households in responding to climate risks and vulnerabilities is key. Since some communities, households, and individuals (e.g., women, marginalized groups, and other socially excluded groups) are more vulnerable than others owing to their differing social, economic, and cultural backgrounds, the Gender Equality and Social Inclusion (GESI) approach has been employed in identifying, implementing, and evaluating adaptation options. This approach helps identify targeted activities for the most vulnerable communities. Below sub-sector-wise adaptation options are described.

7.3 Sub- sector-wise adaptation options

The Agriculture Development Strategy 2015 includes research and knowledge generation related to climate change. It prioritizes research on stress-tolerant varieties and breeds of crops, livestock and fish, and the development of climate-resilient agriculture. Nepal has initiated several activities to reduce the risks and vulnerabilities of climate change on its people, property, and natural resources (MoPE, 2016). The Climate-Smart Agriculture (CSA) Country Profile of Nepal has identified the top three adaptation practices for eight crops, cattle, and poultry in Nepal (CIAT, World Bank, CCAFS, and LI-BIRD, 2017). Several other adaptation practices can be found in the literature (Khatri-Chhetri et al., 2017; Poudel et al., 2017; MoALD, 2019a; UNDP, 2004). Some specific examples include using plastic tunnels and climate tolerant crop varieties; promoting Zaid crops (e.g. watermelon, cucumber, pumpkin, and gourds); using botanical pesticides combined with integrated pest management; introducing and promoting pest- and disease-resistant varieties; promoting mulching; improving existing gravity irrigation systems; diversifying the farming system; cultivating drought-resistant crops; adjusting planting dates and locations; improving land management; constructing water harvesting structures and river training structures like gabion wire filled with boulders, dykes, and river dams to divert canals and control floods; and harvesting rainwater in plastic ponds to irrigate crops. The adaptation options identified through the stakeholder committee and literature review are presented in **Table 17** below.

However, adaptation is strongly influenced by factors including institutional, technological, informational, and economic factors, and there can be barriers (restrictions that can be addressed) and limits to all these factors. Several barriers to the adaptation of agriculture and food security systems have been raised, including inadequate information on the climate and climate impacts and the risks and benefits of the adaptation options; lack of adaptive capacity; inadequate extension; institutional inertia; cultural unacceptability; financial constraints including lack of access to credit; insufficient fertile land; poor infrastructure; and lack of functioning markets and insurance systems. Given these barriers, adaptation in the agriculture sector has to be incremental and transformative and based on strong evidence and research findings.

Table 17: Adaptation options by sectors for Agriculture, Food Security, and Nutrition

Key risks and vulnerabilities	Priority adaptation options	Short Term (5)	Medium-term (2030)	Long term (2050)
Negative impacts of climate trends have been more common than positive ones. Positive trends are evident in some mountainous regions because of the favourable temperature for crops and vegetables Reduced crop productivity associated with heat and drought stress, risk of crop failure, risk of limited food access and quality. Crops, pasture, and husbandry are susceptible to drought and extreme precipitation For example, rice, a major crop in Nepal, requires sufficient irrigation and temperature for proper growth and production. And delay in the onset of monsoon possibly led to a delay in the sowing of rice, affecting the growth of maize, along with reducing the recharge of the underground aquifer.	**Improved technologies and practices**			
	Introduce precision input application practices by applying leaf colour chart, nutrition experts, laser labeler, green seeker			
	Promote drought-resilient agricultural practices such as home garden, agroforestry, System Rice Intensification (SRI), Alternate Wetting and Drying, direct seeding			
	Introduce technology: early sowing is being facilitated by improvements in machinery and by the use of techniques such as dry sowing, seedling transplanting, and seed priming			
	Promote cultivation practices that reduce water loss such as direct-seeded rice, zero/minimum tillage, auto-seeder, jab planter, other mechanization to preserve soil moisture			
	Promote the adoption of sustainable farming methods such as organic farming, bio-pesticides, and bio-manure, Integrated Pest Management, Integrated Nutrient Management			
	Adopt Participatory Crop Improvement (PCI): Participatory Plant Breeding (PPB), Participatory Variety Selection (PVS), Grassroots Breeding with the inclusion of local varieties as a parent			
	Promote conservation agriculture practices (e.g., cover crop, mixed cropping, crop rotation, mulching, legume integration) to preserve water moisture in the soil and increase yield			
	Promote the plastic house combined with drip irrigation for vegetable production, linking with markets			
	Introduce double transplantation of rice (Kharuhan in eastern Terai)			
	Support farmers to shift crop calendars to skip adverse weather during critical growth stages of major staple crops			
	Protect vegetables from hailstorms and insects with technologies such as netting			
	Introduce furrow irrigated bed planting and drainage management			
	Promote dry bed nursery (mainly rice) and raised bed nursery (for vegetables) management			
	Improve gene conservation; promote seed bank and access to extensive gene banks; seed banks could facilitate the conservation of rare and threatened varieties and species and the development of cultivars with appropriate thermal time and thermal tolerance characteristics			
People highly dependent on rainfed agriculture are particularly at risk	**Irrigation and soil and water management**			
	Ensure the irrigation system for rainfed system, or provide alternative farming options to deal with climate adversities			
	Promote enhanced storage and access to irrigation water, more efficient water delivery systems, improved irrigation technologies such as deficit irrigation, more effective water harvesting, agronomy that increases soil water retention through practices such as minimum tillage and canopy management, agroforestry, increase in soil carbon, and more effective decision support			

	Promote solar-based irrigation system combined with micro-irrigation techniques			
	Introduce micro-irrigation (drip irrigation, sprinkler irrigation), Bursha propeller pump			
	Promote water tapping and multiple-use water system: grey/ wastewater ponds in kitchen gardens, plastic ponds, maintenance of traditional ponds and water sources, groundwater trenching, rainwater harvest			
Agricultural wage laborers, small-scale farmers in areas with multidimensional poverty and economic marginalization, children in urban slums, and the elderly are particularly susceptible	**Crop and variety change**			
	Promote improving cultivar tolerance to high temperature for almost all crops and environments as high temperatures are known to reduce both yield and quality. Introduce short-duration and drought-tolerant crops and varieties to avoid drought during maturity time			
	Introduce altering crop varieties (flood-tolerant, drought-tolerant, diseases resistant), agricultural diversification, and shifting agriculture/ crop calendar			
	Promote planting of climate-resilient and genetically diverse local crops and varieties, including neglected and underutilized species (NUS)			
	Promote Himalayan Super Food and Future Smart Crop approaches to conserving genetically diverse and nutrient-rich local crops			
	Introduce altering of crop varieties (adoption of flood-tolerant varieties such as Swarna-Sub1), targeting the flood-prone areas. Also, introduce insect- and disease-resistant crop varieties			
	Promote new crops, varieties, and seeds/seedlings along with short-duration crops to avoid weather-related damage			
	Strengthening agricultural support system			
	Implement ICT-based agro-advisory services targeting weather-based and impact-based forecasting system			
	Promote the adoption of approaches that integrate climate forecasts at a range of scales, which in some cases can better inform crop risk management			
	Promote seed cleaning, drying, and storing machines for proper seed management to keep their viability			
	Promote the use of grain storage bags, protecting seeds and grains from fungal diseases triggered by moist and humid weather			
	Establish a vegetable collection center to regulate sales during extreme events			
	Infrastructure development for risk reduction and effective response			
	Promote the establishment of gene banks, seed banks, nurseries, orchards, research stations, laboratories in all the provinces.			
	Construct embankment of river channels and tree plantation along the banks to protect farmlands			
	Establish a cold storage system for storage of farmers products and provide incentives to farmers			
	Construct check dam to protect irrigation sources and potential damage to agricultural land			
	Assess the Loss and Damage (L&D) from climate extreme events and climate-induced disasters in the agriculture and food security sector.			

Risk of irreversible harm due to short time for recovery between droughts, approaching a tipping point in the rainfed farming system, and/or pastoralism Risk of the loss of livelihoods and harm as drought may take several years; in terraced agriculture	**Livestock and animal husbandry**			
	Ensure matching of stocking rates with pasture production, and adjust herd and watering point management to altered seasonal and spatial patterns of forage production			
	Promote managing of diet quality (using diet supplements, legumes, choice of introduced pasture species, and pasture fertility management)			
	Promote more effective use of silage urea molasses mineral block, prophylaxis and area-specific mineral block, crop residue treatment, precision feeding, pasture spelling, and rotation			
	Promote fire management to control woody thickening			
	Support practices such as using more suitable livestock breeds or species; migratory pastoralist activities; and a wide range of biosecurity activities to monitor and manage the spread of pests, weeds, and diseases			
	Promote local breeds, species, improved breeds with desired traits through artificial insemination, wallow and bath tolerant (for various hazard risks)			
	Increase shade provision through trees or cost-effective structures to substantially reduce the incidence of high heat stress days, reduce animal stress, and increase productivity, with spraying being a less effective option			
	Enhance fodder management through plantation and agroforestry practice			
	Introduce cattle/goat/poultry shed improvement and climate-smart housing			
Changes in the intensity, frequency, and seasonality of climate patterns and extreme events, glacier melting, and changes in precipitation with associated changes in groundwater and river flows are expected to result in significant changes across a wide range of freshwater ecosystem types with consequences for fisheries and aquaculture in many places	**Fishery and aquaculture**			
	Adopt complementary adaptive responses including occupational flexibility, changing target species and fishing operations, protecting key functional groups, and establishing insurance schemes			
	Promote a range of adaptations including developing early warning systems for extreme events, providing hard defenses against flooding and surges, ensuring infrastructure such as ports and landing sites are protected, ensuring effective disaster response mechanisms, and others			
	Adopt adaptive responses in aquaculture by including the use of improved feeds and selective breeding for higher temperature tolerance strains to cope with increasing temperatures and shifting to more tolerant strains of mollusks to cope with increased acidification			
	Ensure better planning and improved site selection to adapt to expected changes in water availability and quality; use integrated water use planning that takes into account the water requirements and human benefits of fisheries and aquaculture in addition to other sectors, and improving the efficiency of water use in aquaculture operations are some of the other adaptation options			
	Promote practices of the growth of local fish species and adoption of climate resilient and stress-tolerant local fish species. Also, promote plantation of trees and shrubs and cover crops along with fishponds			

Risk of policy and governance failures, resulting in the ineffectiveness of coping and adaptation responses, leading to maladaptation practices, which further increase the risks and vulnerabilities	**Policy and Institutional strengthening, capacity building, and finance**			
	Develop climate change strategy and action plan for the agriculture and food security sector, mostly focused on addressing key climate change impact on crops, livestock and fisheries sector			
	Promote the risk transfer mechanisms guidelines and mechanisms such as crop, livestock, and fisheries insurance covering mostly the marginalized and small holder farmers			
	Develop and promote research on climate change to understand how climate change is altering the farming and cropping system, including the best available breeds and varieties to suit the changing contexts			
	Develop technology and strategies to promote both indigenous and improved technologies for climate-smart agriculture			
	Decentralize climate-smart agriculture, target the 753 palikas and mobilize cooperatives, private sectors, and farmers groups			
	Integrate the provisions of the Environment Protection Act, National CC policy, other documents in the agriculture sector policies and plans and ensure its effective implementation			
	Organize capacity developing activities targeting the agriculture sector practitioners, local and provincial governments and cooperatives, and farmers			
	Strengthen the local agriculture groups and promote climate field school approaches to enhance exchange and knowledge and information among farmers to collectively deal with climate and weather extremities			
	Identify and target the most vulnerable households, women households, and smallholder farmers in terms of adaptation options. Design specific adaptation packages for these groups to help them to better adopt and cope with climate change impacts			
	Incentivize the private sector for leveraging climate financing and ensure their investment in research and development of adaptation technology and practices; for example, green enterprise promotion			
	Scale up the climate-smart village and climate-smart technologies and practices in different areas of Nepal, particularly to the vulnerable districts, palikas, and provinces			
	Document and promote local knowledge and practices that are successful in helping the farmers cope with and adapt to climate change hazards			
	Introduce and promote improved agriculture land zoning and management practices to address the core issues of fallow land, degradation of agricultural land, land fragmentation, etc.			
	Integrate research and development activities in the planning and budgeting process. Allocate sufficient funds for climate change research			
	Integrate climate resilience in planning and budgeting process of agriculture and food security sector, including other things such as academic curriculums, research works, etc.			
	Support in organizing innovation fairs to document and promote technology and practices, including local knowledge			
	Develop priority bankable adaptation and resilience projects targeting the most vulnerable sectors, sub-sectors, communities, commodities, and geographical areas			

Case study: Solar-pumped irrigation improves crop yield and livelihoods in drylands

The productivity in irrigated land is estimated to be about three times higher than inrainfed land (Foster & Cota, 2014). In Nepal, a large chunk of agricultural land (nearly half of the cultivable land) is rainfed, so there is low crop yield and consequently high poverty and food insecurity. Groundwater is extracted using solar-, diesel-, and grid-operated electric pumps across the country and the government is pushing hard to promote renewable energy-based irrigation to improve agricultural production and productivity. Solar-based irrigation is emerging as a viable renewable energy-based irrigation system partly because the country has good solar energy potential due to over 300 sunny days per year and average solar radiation of 4.4 kWh/m2/day to 5.5 kWh/m2/day (World Bank Group-ESMAP, 2017). The government has already supported 200 solar pumped irrigation systems, and several others are supported by non-government organizations (NGOs) across the country, with further scaling-up potential.

Solar irrigation is a climate-smart agriculture technology since it helps irrigate crops when rainwater is not enoughmainly in rainfed agriculture (adaptation goal), which increases crop yield (productivity goal) and reduces greenhouse gas emissions when it replaces the diesel-operated irrigation pump (mitigation goal). Hence, it is gradually replacing diesel-operated water pumping in agriculture. Thapa and colleagues (2019) revealed that 50% of the farmers relying on rain-fed irrigation in Saptari have drastically reduced diesel pump-based irrigation. It has also enhanced crop intensity three times and increased crop productivity by 15% after using the solar pump for irrigation. Another study in the same district shows that the family income from agriculture increased from NPR103,258 to NPR 195,847, which indicates solar pumps have the potential of saving NPR 2,185 million per year or equivalent to NPR 436,000 per household per year (Raut et al., 2017).

Bhusal et al. (forthcoming) have also found an increase in cropping intensity from 160% to 200%, annual household production from 586 kg to 1499 kg, and the number of crops cultivated per year from 3 to 7, thus culminating in the increased family income by NPR 7680 per year. Solar-based irrigation has been proven very useful for smallholders, indigenous people, Dalits, and other marginalized communities when they are organized as a group. For instance, it has transformed the Mushar communities living in the Siraha district by making water available for their leased lands and improving food security (Jati et al.,2018). Solar-based irrigation's contribution to reducingGHG emission is often poorly reported or remained unclaimed, so if it is assessed in economic terms, more of its importance will become evident.

Solar-based irrigation is thus a viable option in the areas where electricity is far-fetched particularly when farmlands are away from houses. However, so far it has a slow scaling up rate mainly due to the high initial cost, so sustainable financing mechanisms including government subsidies are key to its promotion (Mukherji et al., 2017). In addition, an effective supply chain network, easy access to repairing service, promotion of high-value crops, incorporation of micro-irrigation techniques, increased access to technology, and subsidized pricing could contribute to scaling up and sustainable management of solar irrigation pumps. Appropriate policies need to be in place to ensure the extraction of groundwater resources is sustainable irrespective of any means of water pumping.

Chapter 8

Conclusion and Recommendations

8.1 Conclusion

Agriculture has always been and will remain an integral part of human life, but the sector is facing various climatic and non-climatic challenges. Among climate stressors, temperature rise, drought, altered precipitation, other extreme events, and disasters triggered by them have reduced the yield of crops, livestock, and fisheries, causing considerable economic loss and pushing many poor farmers to food and nutrition insecurity in Nepal. The future projections also show that the long-term effects of slow-onset disasters will have serious impacts on agriculture and food security, requiring careful planning and implementation of adaptation options.

A Vulnerability and Risk Assessment (VRA) was conducted, adhering to the framework suggested by the IPCC Fifth Assessment Report and adopted by the government of Nepal, to identify current and future risks, pinpoint climate hotspots, and identify currently adopted and potential adaptation options suitable for short, medium, and long-term using available data, published and unpublished literature, and stakeholders and community consultations.

The past trend and future scenario analysis of climate change show a grim picture. A report published by the Department of Hydrology and Meteorology on Observed Climate Trend Analysis (1971–2014) in Nepal states that maximum temperature trends were higher than minimum trends in all seasons; maximum temperature trends were more robust than minimum temperature and precipitation trends; significant positive trends existed in annual and seasonal maximum temperature and minimum temperature; a significantly positive trend existed only in monsoon season in all Nepal but no significant trend existed in precipitation in any season; all Nepal annual maximum temperature trend was significantly positive (0.056°C/yr); and the annual minimum temperature trend was positive (0.002°C/yr) but not at the significant level.

Various climate models predict an increase in temperature, a decrease in post-monsoon and winter precipitation, an increase in heavy precipitation events, and an increase in the average number of consecutive dry days in Nepal. Similarly, summer and winter temperatures, the number of hot days, and extremely hot days in the pre-monsoon, monsoon, post-monsoon and winter seasons are likely to increase in the coming decades. Average annual temperatures could increase by 1.3-3.8°C by 2060, and 1.8-5.8°C by 2090 compared to a reference period of 1986-2005, and the frequency of hot days could increase by about 16% by the 2060s compared to 1970-1999. Some models under both RCP 4.5 and 8.5 scenarios predict a decline in average winter precipitation by around 10% for the period 2021-2050 compared to 1961-1990.

Climate-induced hazards are having a major impact on agriculture production and food security in Nepal. The major hazards impacting agriculture include droughts, floods, hailstorms, diseases, lightning, and thunderstorms. Extreme climatic events affecting agriculture include consecutive wet days, extreme wet days, the number of rainy days, warm nights, cold days, consecutive dry days, and warm spell duration. These climate events are causing a huge impact on agriculture with various social, economic, cultural, and political implications. Some events such as floods, landslides, and droughts are on the rise over time and will likely continue to rise. Past climatic extreme events and triggered hazards have harmed crops, livestock, poultry, and fishery, and will likely cause more impacts in the future if the current trends of such events continue. The analysis using RCP 4.5 and RCP 8.5 emissions pathways show that the districts under the very high hazard category and very high-risk category will likely increase under both scenarios, while the number of districts for high, moderate, low, and very low categories will likely decline under both scenarios in the considered time scales.

The climate exposure in the country varies with location and time. The majority of the districts (53%) have a low or very low level of exposure, with the Terai districts being more exposed due to the relatively larger sizes of agricultural lands, the higher number of livestock, poultry, and fishery activities. A larger number of districts in Province 1, Province 2, and Bagmati Province are more exposed than in other provinces, and all districts under Karnali Province have very low or low exposure. Additionally, the majority of the eastern mountain and hilly districts are less exposed. The districts with very high exposure include Jhapa, Morang, Sunsari, Rupandehi, Kailali, while the districts with high exposure were Ilam, Saptari, Siraha, Dhanusa, Sarlahi, Bara, Chitwan, Kapilbastu, and Dang.

The large majority of districts (>70%) have moderate to very high sensitivity, while the rest have either low or very low sensitivity. The analysis shows the districts in Gandaki, Lumbini and Karnali Provinces fall under the very high sensitivity category. Whereas the highly sensitive districts are spread across the mid-hill and high-hill regions from east to west, the majority of districts in Karnali Province fall under the high sensitivity category. The Terai districts have either low or very low sensitivity. Districts with very high sensitivity include Khotang, Ramechhap, Dolakha, Gorkha, Tanahu, Baglung, Palpa, Gulmi, Pyuthan, Rolpa, and Eastern Rukum and those with high sensitivity include Jhapa, Panchthar, Bhojpur, Solukhumbu, Okhaldhunga, Kathmandu, Makwanpur, Sindupalchok, Dhading, Nawalpur, Syanga, Manang, Myagdi, Kapilbastu, Arghakhachi, Western Rukum, Jajarkot, Dailekh, Bajhang, Achham and, Doti. The rest of the districts are ranked as either moderate, low, or very low in terms of sensitivity.

The adaptive capacity in Nepal is relatively good but varies with places. Overall, over 60% of districts have high or very high adaptive capacity. All the districts, except Surkhet and Western Rukum in Karnali Province and the majority of the districts in Sudurpaschim, fall under the very low adaptive capacity category. Moreover, the majority of districts in the mid-hill and high-hill regions are either in very low or low adaptive capacity categories. The majority of the districts in the Terai have either high or very high adaptive capacity. Districts with very low adaptive capacity include Sindhuli, Mustang, Dolpa, Mugu, Humla, Jumla, Jajarkot, Salyan, Kalikot, Dailekh, Bajura, Bajhang, Achham, Doti, Baitadi, Dadeldhura and those with low adaptive capacity include Taplejung, Panchthar, Terhathum, Sankhuwasabha, Dhankuta, Bhojpur, Solukhumbu, Khotang, Udaypur, Dolakha, Ramechhap, Sindhupalchok, Rasuwa, Nuwakot, Dhading, Makwanpur, Gorkha, Lamjung, Tanahu, Nawalpur, Manang, Myagdi, Baglung, Parbat, Parasi, Eastern Rukum, Rolpa, Pyuthan, Western Rukum, Surkhet, and Darchula.

The vulnerability analysis showed that the large majority of districts (45) have moderate to very high levels of vulnerability. Several districts in Gandaki, Lumbini, Karnali, and Sudurpaschim Provinces fall under the very high vulnerability category. Those falling under the high vulnerability category are either in mid-hill or high-hill regions, whereas all the districts in Terai, except Parasi, fall under the very low vulnerability category irrespective of the province. The Karnali and Sudurpaschim provinces are highly sensitive and have poor adaptive capacity, which makes them highly vulnerable. Districts with very high vulnerability include Myagdi, Baglung, Gorkha, Tanahu, Dailekh, Pyuthan, Achham, Baitadi, Doti, Bajura, and Bajhangand, and those with high vulnerability include Dhading, Rolpa, Dolakha, Western Rukum, Sindhuli, Salyan, Eastern Rukum, Khotang, Kalikot, Jajarkot, Jumla, Ramechhap, and Dadeldhura.

The risk analysis under the RCP 4.5 and RCP 8.5 emissions pathways show that the districts with very high risk will likely increase in number under both scenarios, while the number of districts for all other categories will likely decline in 2030 and 2050. At baseline, Dhading, Makawanpur, Gorkha, Tanahu, Udayapur, Sindhuli, Morang, and Jhapa are at very high risk. Under the RCP 4.5 scenario, Khotang, Mahottari, Sindupalchowk, Syangja, Baglung, and Dang will be added to the very high risk category in 2030 and three additional districts (Nawalpur, Sarlahi, and Nuwakot) will be added to this category in 2050. Similarly, under the RCP 8.5 scenario, Dang, Baglung, Syangja, Nawalpur, and Mahotari will move to a very high risk category in 2030 and six additional districts (Khotang, Udayapur, Sankhuwasabha, Sarlahi, Saptari, and Nuwakot) will move to this category in 2050.

Nepal has initiated several adaptation activities to reduce the risks and vulnerabilities of climate change on its people, property, and natural resources. Different organizations have adopted different techniques to identify and group adaptation options in the past. Several recent undertakings focus on underlying causes of vulnerability such as informational, capacity, financial, institutional, and technological needs. Some specific examples include using plastic tunnels and climate tolerant crop varieties; promoting Zaid crops (e.g. watermelon, cucumber, pumpkin, and gourds); using botanical pesticides combined with integrated pest management; introducing and promoting pest- and disease-resistant varieties; promoting mulching; improving existing gravity irrigation systems; diversifying the farming system; cultivating drought-resistant crops; adjusting planting dates and locations; improving land management; constructing water harvesting structures and river training structures like gabion wire filled with boulders, dykes and river dams to divert canals and control floods; and harvesting snow and rainwater in plastic ponds to irrigate crops and drink.

Various Climate Smart Agriculture Practices (CSAs), such as System of Rice Intensification (SRI), drip irrigation, sprinkler irrigation, alternate wetting and drying, zero or minimum tillage, mulching, and adoption of drought-tolerant crops and varieties can reduce the use of irrigation and thus reduce fuel burning in the area where pump sets are used. If pump sets are substituted by solar irrigation pumps, that will also reduce emissions from the burning of fuel. Agroforestry practices can also help to sequester carbon and thus lower the chances of global warming. Since some communities, households, and individuals (e.g., women, marginalized groups, and other socially excluded groups) are more vulnerable than others owing to their differing social, economic, and cultural backgrounds, the Gender Equality and Social Inclusion (GESI) approach was employed to identify the adaptation options. This approach helped identify activities suitable for the most vulnerable communities.

Government organizations and partners are supporting farmers to adapt to climate change risks but several social, economic, financial, institutional and policy gaps in addressing risks still prevail. This situation calls for an effective strategy to tackle potential climate change risks in agriculture in the future, which should include smart investment plans, policies, collaboration, and implementation mechanisms. Priority should be given to the adaptation options that address multiple risks, and a combination of different adaptation options can give better results as they address multiple risks. Therefore, the selection of adaptation options accordingly may make action efficient and effective.

8.2 Recommendations

A large number of issues have emerged from this study. These need to be duly considered in the future to appropriately interpret and use the study findings, develop conducive policies, and consequently obtain desired results in climate change adaptation.

- **Quality data management and sharing:** High quality, consistent and up-to-date data are in short supply in the agriculture sector. Databases maintained by the ministries and their departments are not frequently updated. The maintained databases are difficult to transform into usable forms, as they are aggregated, incompatible, and not consistent across time and space. Moreover, data is not easily available online. Time-series data is also lacking, which makes analysis of trends and scenarios difficult. Therefore, appropriate data management mechanisms, preferably online, should be developed to keep and share up-to-date data with people as and when required. Database management is especially critical for livestock, poultry, and fisheries, for which data is scantier.
- **Local-level consultations for adaptation options:** It is important to engage local communities and provincial and local governments in identifying adaptation options. Before the consultation, a portfolio of adaptation options through a literature review can be prepared to facilitate discussions during local level consultations. The inclusion of women, Dalits, Janajatis, and other vulnerable and marginalized communities is crucial.
- **Gender equity and social inclusion:** It is important to involve women, Dalits, Janajatis, vulnerable, and other marginalized communities in VRA and identification of adaptation options to ensure their challenges are understood and needs and priorities addressed by plans. Their involvement is also extremely important during the implementation, monitoring, and evaluation of adaptation actions.

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Annexes

Annex 1: Gender references in agriculture and rural development-related policies and strategies

Agriculture-related policies	GESI issues integrated
Agriculture Development Strategy (2015-2035), MoAD	• Addresses food and nutrition security of the most disadvantaged rural populations, including pregnant and lactating women • Contains a 10-year Plan of Action, which includes the development of a GESI strategy in agriculture
Gender Equity and Social Inclusion Strategy Framework (2016), MoAD and UN Women	• An overarching strategy to operationalize GESI in agriculture • Promotes capacity building of the GESI target groups for their meaningful participation in decision-making processes
National Seed Vision (2013-2025)	• Supports equal rights and access to information, skills, and services on seed use, irrespective of gender, caste, and ethnicity, across geographical regions
National Agriculture Policy (2004), MoAD	• Encourages 50 percent participation of women in every possible agricultural activity for gender equality • Conducts mobile training programs to reach villages and homesteads to ensure women's participation and access to information • Identifies and classifies small farmers with fewer resources and lands to provide possible facilities • Provides particular programs to targeted groups/resources for poor landholders (less than 4 ha), and deprived groups (Dalit and Janajati) in the development of commercial and competitive agricultural systems • Enhances management capacity of women in women's cooperatives and farmers' groups
Agribusiness Promotion Policy (2007), MoAD	• Ensures special programs for the poor, women, and Dalits for establishing agricultural entrepreneurs
Agro-biodiversity Policy (2007) (first revision, 2014), MoAD	• Organizes special programs for the poor, women, and Dalits for the establishment and development of agro-enterprises • Explores, promotes, and utilizes indigenous knowledge in agriculture by including women, indigenous people, and the poor • Implements sustainable agro-biodiversity promotion and income-generation programs
Gender Mainstreaming Strategy (2006), MoAD	• Commits to achieving 50/50 women-men participation in all administrative mechanisms, including MoAD divisions, programs, committees and boards • Commits to increasing women's skills in commercial agriculture, women's economic empowerment, and institutionalization of gender issues at all levels focusing on women's participation in commercial agriculture
Agriculture Mechanization Promotion Policy (2014), MoAD	• Aims to attract youth and women producers in mechanized agriculture and increase their productivity • Identifies and promotes the adoption of women and environment-friendly technologies and machines to reduce the drudgery of women's work through agricultural mechanization
Irrigation Policy (2014) and Water Induced Disaster Management Policy (2016)	• Emphasizes 33 percent of disadvantaged people engaged in water users' associations • Encourages participation of backward and disadvantaged groups in users' group for management
Climate Change Policy (2011, 2019), NDC. (2020), Mainlay & Tan. (2012)	• Ensures the participation of poor people, Dalits, marginalized indigenous communities, women, children, and youth in the implementation of climate adaptation and climate change-related programs • Provides capacity-building for local bodies and ensures the implementation of local-level activities

Source: FAO, 2019

Annex 2: List of participants taking part in TWG meeting

S.N.	Name	Designation	Sex
1	Dr Hari Bahadur KC	Joint Secretary- MoALD	Male
2	Ms. Srijana Shrestha	Under Secretary, MoFE	Female
3	Dr Bimal Raj Regmi	Team Lead PIF/OPM	Male
4	Mr. Shree Krishna Neupane	Plant Protection Officer, and Member Secretary of TWG, MoALD	Male
5	Dr Pashupati Chaudhary	Thematic Expert, PIF/OPM	Male
6	Dr Nilhari Neupane	Thematic Expert, PIF/OPM	Male
7	Mr. Pabitra Gurung	Thematic Expert, PIF/OPM	Male
8	Dr Pashupati Nepal	Coordinator, VRA-PIF	Male
9	Mr. Gyanendra Karki	Project Coordinator, UNEP/NAP	Male
10	Dr Bhogendra Mishra	GIS Expert, PIF	Male
11	Ms. Kabita Mandal	Communications Consultant, UNEP	Female
12	Dr Hari Sharma Neupane	Chief Executive Officer, Agro-Enterprise Centre	Male
13	Dr Shree Bhagwan Thakur	Consultant, UNEP	Male
14	Mr. Manoj Pokhrel	Plant Protection Officer, Plant Quarantine and Pesticide Management Center	Male
15	Ms. Meena Pokhrel	Expert	Female
16	Mr. Ashaswi Devkota	Expert	Male
17	Mr. Mohan Krishna Maharjan	Member, DFTQC	Male
18	Mr. Anil Kumar Acharya	Program Coordinator, CEAPRED	Male
19	Mr. Rudra BhatTerai	GM/Member, NACCFL	Male
20	Dr Krishna Kumar Mishra	Chief, Genebank, NARC	Male
21	Ms. Binaya Parajuli	Assistant Gender Affairs and M&E Officer, UNEP	Female
22	Dr Shalu Adhikari	Expert	Female
23	Mr. Dal Prasad Pudasainy	Specialist/Member, NFC	Male
24	Mr. Bishnu Hari Devkota	Chief, Deputy-coordinator, Agricultural Biodiversity, and Environment Division, MoALD	Male
25	Saroj Kant Adhikari	Senior Agriculture Extension Officer, Agriculture Extension and Training Centre	Male
26	Dr Kishor Dahal	Dean, IAAS, TU	Male
27	Ms. Basana Sapkota	GESI Expert	Female
28	Dr Keshab Gautam	Under Secretary, CCMD-MoFE	Male
29	Mr. Sujan Shrestha	Program Management Assistant, UNEP	Male
30	Mr. Saroj Kanta Adhikari	Specialist/Expert, AITC	Male
31	Mr. Pratik Ghimire	Logistics Support, PIF/OPM	Male

Annex 3: List of participants of Technical Committee meeting

Name	Organization
Dr Radha Wagle	MoFE, CCMD
Dr Arun Bhatta	MoFE, CCMD
Srijana Shrestha	MoFE, CCMD
Srijana Bhusal	MoFE, CCMD
Raju Sapkota	MoFE, CCMD
Hari Krishna Laudari	MoFE, CCMD
Yam Nath Pokhrel	MoFE, CCMD
Ram P. Awasthi	MoFE, CCMD
Muna Neupane	MoFE, CCMD
Khemraj Kafle	MoFE, CCMD
Surendra Pant	MoFE, CCMD
Somnath Gautam	MoFE, CCMD
Indira Kandel	DHM
Gyanendra Karki	NAP-UNEP
Basanta Paudel	NAP-UNEP
Dr Ram P Lamsal	PIF
Dr Pashupati Nepal	PIF
Dr Pashupati Chaudhary	PIF
Pabitra Gurung	PIF
Dr Nilhari Neupane	PIF
Dr Eak Rana	PIF
Dr Kalyan Gauli	PIF
Regan Sapkota	PIF
Basana Sapkota	PIF
Dr Shiba Banskota	PIF
Smriti Shah	PIF
Gita GC	PIF
Dr Yadav Joshi	PIF
Dr Bhogendra Mishra	PIF
Dr Dilip Gautam	PIF
Pratik Ghimire	PIF
Rojy Joshi	PIF
Dinanath Bhandari	PIF
Bamshi Acharya	PIF
Dr Bimal Raj Regmi	PIF

Annex 4: The outcomes of provincial stakeholder consultation meetings

Province 1

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Mountain					
Temperature rise Zone shifting The emergence of a new disease in livestock Infertility in livestock Loss in forage and fodder production	Increasing	Occupation shift: change in livelihood patterns; for example, labour migration to cities and abroad Migration: migration of communities due to scarcity of water, declining productivity, and food security issues Insufficient access to goods and services due to damage of infrastructure by disasters	Poor, marginalized, indigenous farmers	Invest in increasing infrastructure facilities Introduce new and stress resistance varieties Provide subsidy package in value chain e.g., Insurance of livestock for loss and damage due to climate change Ensure species-specific production packaging and ensure the marketing	Increase the access to the storage facility Introduce post-harvesting technologies Implement conservation activities and establish a gene bank Increase access to goods and services
Hills					
Average temperature rise Rainfall variability Production decline The emergence of pests and diseases Loss of species	Increase in temperature and changes in precipitation Increase in the impact of extreme events	The rise in temperature leading to an increase in new pests and diseases Declining livestock yield due to loss of pasture and access to high-quality fodder Low quality of food products such as honey New diseases in livestock such as SD (lumpy skin disease) A decline in the number of fisheries due to flooding and water pollution	Herders, farmers, fisherfolks Women-headed households	Promote mechanization cultivation Promote strict quarantine and quality control measures Promote pre-information system (temperature, humidity), weather broadcast	Establish cold stores, grain stores, and community seed banks Promote agro-biodiversity management practices such as crop diversity, conservation of rare and threatened species

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Terai					
Flood Fluctuating rainfall patterns Changes in cropping patterns Flood	Increasing trend Loss and damage are huge in the agriculture sector	Production and productivity of crop, livestock, and fisheries is low due to negative impact of climate change The emergence of new pests and diseases including new weeds leading to crop failure Degradation of agriculture land soil fertility loss due to erosion and flooding The livestock population is impacted due to loss and damage and lack of access to feed Due to temperature rise, the development of the grain of maize is a problem Early and late monsoon has impacted the rainfed lands and thus yield	Women-headed households have to work hard on the farm to manage adversaries and crop failure and losses Smallholder and marginalized farmers have issues with food security and nutrition due to the loss of crops and grains The rice growers are mostly impacted due to a lack of water for irrigation	Promote flood early warning system Promote community-based adaptation practices that help farmers to access stress-tolerant varieties and methods of farming Provide information and knowledge to smallholder and women farmers about the extreme weather events and advisories	Establish community seed banks to conserve seeds during the crisis Establish gene bank to conserve important traits of local and indigenous crops Promote climate-smart agriculture practices such as those who help manage the crops, soil, and nutrients, and water more efficiently Promote conservation of local varieties and crops Conserve water resources and promote water conservation technologies such as drip irrigation Provide alternative livelihood opportunities for poor and marginalized farmers

Province 2

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Rainfall: extreme variation i.e., too much and too less leading to flood and landslide Temperature rise Increase in drought-prone areas An outbreak of insect and pests and disease Drying of water sources Declining agriculture productivity and land fragmentation issues Invasive species Extinction of local crops and varieties	Rainfall is less: heavy rainfall in a short duration Massive temperature increase- minimum is increasing Increased incidence of pest and diseases The water table is low production of cereal crops is declining The emergence of new species	Soil quality is degraded; production is declining, migration issues, loss of properties The insect population is increasing due to the rise in temperature which is a cause for crop failure Production losses of legume species Lack of water and heavy irrigation cost Job switching, brain drain, unemployment problem Issues with the sustainability of crop yield Declining crop diversity Impact on the food chain and availability	Landless, marginalized, and smallholder farmers Those who live near disaster-prone areas e.g., sloppy land, degraded land, riverbank	Provide awareness and training to farmers and local government officials about climate change and adaptation Develop agriculture adaptation plans at the local and provincial level Promote climate field schools targeting farmers	Promote early warning systems and agro advisories for farmers Introduce stress-tolerant varieties for flood and drought including disease and pest resistant varieties Implement climate-smart agriculture practices that reduce the crop losses, declining yield Promote water-efficient irrigation technologies Manage degraded and barren riverbank land for livelihood opportunities Promote organic farming Implement improved practices such as crop rotation, mixed farming, home gardening, seed banks

Bagmati Province

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Mountain					
Extinction of indigenous and local breeds and crops Increase in the evidence of natural calamities (sudden flood, landslides) Food insecurity Poverty	Temperature is increasing rapidly in mountain areas Rainfall is also increasing in the mountain areas Extreme climatic events increasing: GLOF, avalanches, snowstorms, landslides	Shifting of snowline Decrease of transhumance system (livestock farming negatively impacted) Shifting of agro-ecological zone A decrease in the availability of feed, forage, and pasture	Small and marginal farmers Financially weak and poor farmers	Promote rainwater harvesting and plastic pond Promote cultivation inside protected structure, e.g., naturally ventilated greenhouse, net house Promote climate resilient livestock sheds Promote urban and terrace farming Promote agroforestry interventions Promote cultivation of insect/pests resistant, drought-resistant, and flood-resistant varieties (SWARNA SUB) Establishment of indigenous species resource center Conduct awareness and training	Development and adoption of climate-smart agriculture practices Development of new and high yielding pest resistant/ drought and flood resistance varieties Promote early warning system and agro-advisories Establishment of the community seed bank and gene bank Development climate-resilient practices for livestock and fisheries
Hills and Terai Malnutrition Impact on food availability Increase in vulnerability index	Increase in temperature A variation on rainfall (early, late, too much in a short period) Flood, landslide increasing Pest and disease outbreak	Drying off of water resources Increase in incidence of pest and disease (parasites and vector-borne) Pest emergence and pest resurgence A decline in production and productivity of major crops Loss of top fertile soil Change in the reproductive behavior of animals (in terms so heat period and fertility) Lack of water for crops	Marginalized, smallholder farmers with limited landholding size Women-headed households with no access to services and no land rights		

Gandaki Province

Challenges	Trends	Impact	Adaptation Options
Productivity decline Loss of crops Degradation of agriculture and pastureland including fishponds Declining pasture lands New weeds, pest, and diseases	Increasing trend	Loss of agriculture production and productivity The gradual decline in promotion of local, landraces in agriculture and horticulture Women are increasing leading the agriculture labour jobs and cases are reported on maternal health Loss of livelihood opportunities in poor and marginalized households Loss of crops due to unseasonal hailstones The appearance of various pest and disease as well invasive alien species Changes in weather cycle impacting agriculture cycle Use of intense pesticides instead of biocides, leading towards loss of production Issues of storage of agriculture and horticulture products	Promote organic farming Promote conservation of local biodiversity Promote technology for off-season farming Promote use of modern equipment Create income-generating activities, targeting the poor and marginalized communities Promote use of organic fertilizer, nano fertilizer, effective micro-organisms Establish an early warning system with access to rural communities Prioritize income-generating activities to ensure youth are employed in such activities

Lumbini Province

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Terai					
Change in the rainfall pattern Extreme events Extreme changes in temperature Flooding and inundation Pest, diseases, and weeds Issues with food security	The monsoon rain has shifted 1 month – late A gradual increase in temperature Too much and too little rainfall being the trend New insects such as the Salaha insect and the American army insect A decline in production and quality of yield	Production decline due to lack of water for cereal crops Issues of lack of grain in maize Changes in the flowering time of fruits A decline in livestock production Damages to agriculture crops and land from floods; damage in the fishponds Problems in all the crops Impacts on children, women, and elderly	Small scale and marginalized farmers practicing subsistence agriculture Farmers are dependent on agriculture for their livelihood Farmers in the Terai region are dependent on agriculture-mostly smallholders Poor farmers Children, the elderly, pregnant women	Facilitate change in cropping technology and practices (e.g., DSR, raised nursery) Adopt protected agriculture practice Develop ventilated sheds for livestock Managing water through irrigation and proper drainage Implement program targeted for insect pest control – integrated pest management Enhance storage systems	Develop stress-tolerant crop varieties that can withstand droughts and floods Promote water-efficient technologies Promote multistorey farming system Promote agroforestry practices and riverbank protection activities; plantation Promote submerge tolerant varieties Promote IPM, ICM, IPNM Promote organic farming practices Promote resistant varieties Establish cold storage Develop a scientific package of practices
Hills					
Changes in agro-ecosystem (shifting of crop pattern) Chilling hours lacking for apples, pears, etc Hailstone issues	The trend of having mangos in areas where there used to be oranges Oranges found in the place where apples used to grow Early flowering Change in shape of hailstones and their arrival time	Decline in productivity Increase in cost of farming Investments not yielding proper returns Total damage to crops	Smallholder farmers	Change cropping pattern Invest in research and development to develop and identify varieties that can grow in the changing climate Promote protected agriculture	Invest in technology development Develop new varieties Improve extension system Develop insurance system Provide loans to farmers

Karnali Province

Physiography	Climate-related major events	The sectoral impact from climate-related events	Adaptation options	
			Medium term	Long term
Himal/Pahad	Temperature increase Extreme weather event Off seasonal snowfall More rainfall Drought Intense rainfall	Increase in snowmelt rate Change in crop phenology Increase in geo-hazards Increase in GLOF Increase in avalanches Increase in disease, pests, and insects Depletion of water sources Increase in landslides and floods	Carry out plantation of suitable plants Conduct research, development, and training at the local level Promote bio-fencing, organic agricultural technology, multi-purpose water management, lift/ alternative irrigation facilities, drought resistance cropping, dike construction, and tree plantation	Carry out adaptation capacity development Develop long term policy and programs Promote alternative sources of livelihood, and insect, pest, and disease-resistant crops Protect and develop local crop varieties Expand the agro-forestry Identify vulnerable areas and deploy the adaptation program

Sudurpaschim Province

Physiography	Climate-related major events	The sectoral impact from climate-related events	Adaptation option	
			Medium term	Long term
Mountain/Hill	Increase in avalanches Increase in floods and landslides Land degradation Thunderbolts	Decrease in productivity (in agriculturally based industries) Disruption of the phenological cycle – some species of birds and animals disappear Increase in invasive species of plants Decrease in the attractiveness of the region Unplanned roads due to bulldozers Drying up of springs Destruction of bridges, roads, canals, etc.	Carry out public awareness program Identify the industrial sites only after detailed study, research, public consultation, and reporting Update the policy, laws, and acts to include climate change issues Operate electric-buses Upgrades the roads Avoid the use of plastics and promote paper bags.	Promote organic farming Develop own brands and promote them Increase electricity production

Annex 5: Vulnerability, Hazard and Risk Index for all 77 districts

District	Exposure	Sensitivity	Adaptive capacity	Vulnerability	Baseline context of climate extreme events	RCP 4.5 2030 of climate extreme events	RCP 4.5 2050 of climate extreme events	RCP 8.5 2030 of climate extreme events	RCP 8.5 2050 of climate extreme events	Baseline Risk	RCP 4.5 2030 Risk	RCP 4.5 2050 Risk	RCP 8.5 2030 Risk	RCP 8.5 2050 Risk
Achham	0.325	0.84	0.276	0.961	0.527	0.552	0.588	0.547	0.605	0.444	0.465	0.495	0.461	0.51
Arghakhanchi	0.29	0.843	0.658	0.098	0.638	0.736	0.774	0.736	0.801	0.29	0.335	0.352	0.335	0.365
Baglung	0.392	0.925	0.39	0.864	0.603	0.675	0.709	0.666	0.736	0.587	0.658	0.69	0.648	0.717
Baitadi	0.313	0.733	0.262	0.791	0.55	0.578	0.615	0.58	0.638	0.411	0.433	0.461	0.434	0.478
Bajhang	0.259	0.775	0.205	1	0.433	0.46	0.48	0.452	0.502	0.297	0.315	0.329	0.31	0.344
Bajura	0.187	0.74	0.23	0.876	0.426	0.452	0.47	0.451	0.501	0.198	0.211	0.219	0.21	0.234
Banke	0.49	0.647	0.729	0	0.625	0.678	0.722	0.689	0.76	0.286	0.311	0.331	0.316	0.348
Bara	0.665	0.42	0.819	0	0.688	0.791	0.838	0.791	0.857	0.082	0.094	0.099	0.094	0.102
Bardiya	0.538	0.554	0.72	0	0.635	0.66	0.699	0.683	0.741	0.256	0.266	0.282	0.275	0.299
Bhaktapur	0.114	0.502	0.68	0	0.656	0.767	0.794	0.745	0.827	0.055	0.065	0.067	0.063	0.07
Bhojpur	0.401	0.792	0.389	0.613	0.611	0.712	0.736	0.68	0.806	0.535	0.624	0.645	0.596	0.706
Chitawan	0.713	0.616	1	0	0.704	0.803	0.85	0.819	0.897	0.064	0.074	0.078	0.075	0.082
Dadeldhura	0.26	0.706	0.317	0.614	0.569	0.591	0.628	0.606	0.666	0.323	0.335	0.356	0.344	0.378
Dailekh	0.366	0.811	0.278	0.902	0.53	0.56	0.594	0.548	0.6	0.491	0.519	0.55	0.507	0.555
Dang	0.737	0.711	0.628	0	0.622	0.701	0.738	0.696	0.762	0.62	0.698	0.736	0.694	0.759
Darchula	0.237	0.712	0.344	0.564	0.479	0.499	0.524	0.504	0.553	0.241	0.251	0.264	0.254	0.279
Dhading	0.507	0.855	0.417	0.668	0.636	0.73	0.769	0.72	0.798	0.725	0.832	0.877	0.821	0.91
Dhankuta	0.345	0.763	0.404	0.524	0.64	0.75	0.784	0.736	0.847	0.459	0.538	0.563	0.528	0.608
Dhanusha	0.695	0.652	0.724	0	0.661	0.746	0.762	0.763	0.842	0.44	0.497	0.508	0.508	0.561
Dolakha	0.341	0.886	0.392	0.785	0.591	0.663	0.686	0.666	0.766	0.482	0.54	0.559	0.543	0.624
Dolpa	0.221	0.587	0.264	0.51	0.375	0.414	0.434	0.384	0.439	0.171	0.188	0.197	0.175	0.2
Doti	0.361	0.831	0.27	0.956	0.532	0.559	0.596	0.557	0.615	0.498	0.523	0.557	0.521	0.575
Eastern Rukum	0.115	0.959	0.476	0.73	0.529	0.575	0.593	0.552	0.607	0.142	0.154	0.159	0.148	0.163
Gorkha	0.492	0.904	0.382	0.84	0.535	0.597	0.632	0.587	0.657	0.646	0.72	0.763	0.708	0.794
Gulmi	0.382	0.88	0.65	0.187	0.647	0.739	0.775	0.731	0.794	0.414	0.472	0.495	0.467	0.508
Humla	0.151	0.651	0.3	0.549	0.372	0.384	0.39	0.376	0.419	0.118	0.122	0.124	0.12	0.134
Ilam	0.567	0.574	0.59	0	0.734	0.85	0.882	0.849	0.957	0.477	0.553	0.574	0.552	0.622
Jajarkot	0.282	0.801	0.328	0.769	0.525	0.564	0.587	0.54	0.591	0.351	0.376	0.392	0.36	0.394
Jhapa	0.9	0.803	0.816	0	0.818	0.931	0.957	0.915	1	0.772	0.878	0.904	0.864	0.944
Jumla	0.149	0.65	0.229	0.707	0.483	0.51	0.519	0.488	0.537	0.165	0.175	0.178	0.167	0.184
Kailali	0.812	0.517	0.755	0	0.624	0.643	0.678	0.661	0.718	0.289	0.297	0.314	0.306	0.332
Kalikot	0.162	0.739	0.276	0.77	0.467	0.497	0.519	0.479	0.526	0.18	0.191	0.2	0.184	0.203

District	Exposure	Sensitivity	Adaptive capacity	Vulnerability	Baseline context of climate extreme events	RCP 4.5 2030 of climate extreme events	RCP 4.5 2050 of climate extreme events	RCP 8.5 2030 of climate extreme events	RCP 8.5 2050 of climate extreme events	Baseline Risk	RCP 4.5 2030 Risk	RCP 4.5 2050 Risk	RCP 8.5 2030 Risk	RCP 8.5 2050 Risk
Kanchanpur	0.504	0.458	0.662	0	0.627	0.65	0.688	0.668	0.734	0.218	0.226	0.239	0.232	0.255
Kapilbastu	0.624	0.806	0.758	0	0.677	0.773	0.818	0.781	0.847	0.514	0.586	0.621	0.593	0.643
Kaski	0.454	0.766	0.555	0.188	0.628	0.693	0.728	0.7	0.772	0.477	0.527	0.553	0.532	0.587
Kathmandu	0.239	0.788	0.747	0	0.657	0.769	0.795	0.742	0.82	0.188	0.221	0.228	0.213	0.235
Kavrepalanchok	0.44	0.75	0.614	0.022	0.654	0.758	0.788	0.748	0.833	0.425	0.493	0.513	0.487	0.542
Khotang	0.41	0.88	0.408	0.738	0.602	0.693	0.715	0.674	0.785	0.576	0.663	0.684	0.645	0.751
Lalitpur	0.231	0.604	0.598	0	0.637	0.738	0.773	0.727	0.811	0.176	0.204	0.213	0.201	0.224
Lamjung	0.283	0.756	0.416	0.482	0.616	0.685	0.726	0.693	0.769	0.353	0.392	0.416	0.397	0.441
Mahottari	0.557	0.69	0.524	0.113	0.663	0.754	0.78	0.764	0.838	0.586	0.667	0.69	0.676	0.741
Makawanpur	0.476	0.847	0.459	0.557	0.681	0.781	0.829	0.764	0.843	0.686	0.787	0.835	0.77	0.849
Manang	0.051	0.821	0.424	0.588	0.415	0.462	0.488	0.454	0.514	0.045	0.05	0.053	0.049	0.056
Morang	1	0.687	0.738	0	0.739	0.842	0.87	0.832	0.916	0.739	0.842	0.87	0.832	0.916
Mugu	0.129	0.659	0.279	0.613	0.402	0.426	0.433	0.395	0.444	0.114	0.12	0.122	0.112	0.125
Mustang	0.079	0.574	0.287	0.433	0.328	0.369	0.401	0.365	0.422	0.051	0.058	0.063	0.057	0.066
Myagdi	0.22	0.861	0.353	0.826	0.531	0.585	0.614	0.586	0.651	0.284	0.314	0.329	0.314	0.349
Nawalpur	0.368	0.804	0.416	0.574	0.702	0.8	0.841	0.834	0.91	0.551	0.628	0.661	0.655	0.714
Nuwakot	0.404	0.751	0.413	0.481	0.651	0.758	0.793	0.746	0.822	0.533	0.62	0.649	0.61	0.672
Okhaldhunga	0.259	0.827	0.51	0.405	0.606	0.69	0.708	0.684	0.779	0.303	0.346	0.355	0.343	0.39
Palpa	0.322	0.863	0.642	0.173	0.675	0.779	0.817	0.789	0.859	0.36	0.416	0.436	0.421	0.458
Panchthar	0.302	0.788	0.429	0.514	0.672	0.793	0.826	0.781	0.903	0.418	0.494	0.515	0.486	0.563
Parasi	0.341	0.556	0.384	0.178	0.702	0.8	0.841	0.834	0.91	0.398	0.454	0.477	0.473	0.516
Parbat	0.24	0.737	0.42	0.438	0.702	0.787	0.824	0.787	0.855	0.332	0.372	0.39	0.372	0.404
Parsa	0.474	0.402	0.738	0	0.694	0.786	0.837	0.829	0.894	0.118	0.133	0.142	0.141	0.152
Pyuthan	0.314	1	0.446	0.876	0.61	0.696	0.723	0.675	0.737	0.478	0.545	0.567	0.529	0.577
Ramechhap	0.344	0.884	0.441	0.668	0.603	0.683	0.701	0.68	0.774	0.467	0.529	0.543	0.527	0.599
Rasuwa	0.114	0.693	0.385	0.437	0.51	0.569	0.604	0.562	0.645	0.115	0.128	0.136	0.126	0.145
Rautahat	0.483	0.418	0.601	0	0.677	0.787	0.831	0.769	0.836	0.25	0.291	0.307	0.284	0.309
Rolpa	0.288	0.907	0.477	0.63	0.566	0.626	0.651	0.596	0.658	0.359	0.398	0.414	0.378	0.418
Rupandehi	0.81	0.544	0.968	0	0.691	0.78	0.821	0.8	0.87	0.031	0.035	0.037	0.036	0.039
Salyan	0.338	0.753	0.306	0.729	0.59	0.629	0.664	0.62	0.675	0.464	0.494	0.521	0.487	0.53
Sankhuwasabha	0.355	0.806	0.429	0.547	0.681	0.78	0.814	0.758	0.886	0.508	0.582	0.607	0.566	0.661
Saptari	0.693	0.651	0.646	0	0.679	0.764	0.782	0.78	0.848	0.55	0.619	0.633	0.632	0.687
Sarlahi	0.625	0.628	0.584	0	0.675	0.778	0.813	0.776	0.845	0.542	0.624	0.652	0.622	0.678
Sindhuli	0.441	0.761	0.336	0.674	0.661	0.756	0.778	0.754	0.833	0.657	0.752	0.774	0.75	0.829
Sindhupalchok	0.444	0.826	0.418	0.611	0.602	0.683	0.719	0.695	0.786	0.583	0.662	0.697	0.674	0.761

District	Exposure	Sensitivity	Adaptive capacity	Vulnerability	Baseline context of climate extreme events	RCP 4.5 2030 of climate extreme events	RCP 4.5 2050 of climate extreme events	RCP 8.5 2030 of climate extreme events	RCP 8.5 2050 of climate extreme events	Baseline Risk	RCP 4.5 2030 Risk	RCP 4.5 2050 Risk	RCP 8.5 2030 Risk	RCP 8.5 2050 Risk
Siraha	0.655	0.752	0.754	0	0.665	0.746	0.757	0.766	0.834	0.48	0.538	0.547	0.553	0.602
Solukhumbu	0.255	0.785	0.413	0.545	0.547	0.615	0.641	0.603	0.702	0.293	0.329	0.343	0.323	0.376
Sunsari	0.748	0.546	0.75	0	0.702	0.799	0.821	0.798	0.878	0.342	0.389	0.4	0.389	0.428
Surkhet	0.455	0.767	0.397	0.547	0.59	0.613	0.648	0.614	0.67	0.565	0.587	0.621	0.588	0.642
Syangja	0.461	0.813	0.537	0.315	0.723	0.82	0.86	0.819	0.883	0.609	0.691	0.724	0.69	0.744
Tanahu	0.462	0.907	0.396	0.816	0.724	0.828	0.873	0.829	0.892	0.811	0.929	0.978	0.93	1
Taplejung	0.26	0.767	0.469	0.385	0.636	0.736	0.774	0.71	0.84	0.316	0.366	0.384	0.353	0.417
Terhathum	0.223	0.725	0.496	0.244	0.652	0.776	0.808	0.764	0.885	0.254	0.302	0.314	0.297	0.344
Udayapur	0.523	0.743	0.383	0.533	0.639	0.733	0.752	0.738	0.822	0.697	0.801	0.821	0.806	0.898
Western Rukum	0.188	0.846	0.367	0.765	0.529	0.575	0.593	0.552	0.607	0.235	0.255	0.263	0.245	0.269

Annex 6: Grouping of districts under different risk categories in 2030 and 2050 in different scenarios

Scenario	Risk categories	District		
		Baseline	2030	2050
RCP 4.5	Very high	Dhading, Makawanpur, Gorkha, Tanahu, Udayapur, Sindhuli, Morang, Jhapa	Dhading, Makawanpur, Baglung, Sindhupalchok, Gorkha, Tanahu, Udayapur, Syangja, Sindhuli, Morang, Khotang, Dang, Jhapa, Mahottari	Dhading, Makawanpur, Nuwakot, Baglung, Sindhupalchok, Gorkha, Tanahu, Udayapur, Syangja, Sindhuli, Morang, Khotang, Dang, Nawalpur, Jhapa, Sarlahi, Mahottari
	High	Kapilbastu, Nuwakot, Baglung, Sindhupalchok, Syangja, Surkhet, Bhojpur, Khotang, Dang, Nawalpur, Sarlahi, Mahottari, Saptari	Kapilbastu, Dolakha, Dhankuta, Nuwakot, Sankhuwasabha, Dailekh, Pyuthan, Surkhet, Siraha, Bhojpur, Doti, Nawalpur, Kaski, Sarlahi, Ramechhap, Saptari, Ilam	Kapilbastu, Dolakha, Dhankuta, Sankhuwasabha, Dailekh, Pyuthan, Surkhet, Siraha, Bhojpur, Salyan, Doti, Kaski, Panchthar, Ramechhap, Saptari, Ilam
	Moderate	Dolakha, Dhankuta, Sankhuwasabha, Kavrepalanchok, Dailekh, Pyuthan, Achham, Siraha, Baitadi, Palpa, Salyan, Doti, Dhanusha, Kaski, Panchthar, Parasi, Gulmi, Ramechhap, Ilam	Rolpa, Lamjung, Sunsari, Kavrepalanchok, Parbat, Achham, Baitadi, Palpa, Salyan, Dhanusha, Taplejung, Panchthar, Jajarkot, Parasi, Gulmi	Rolpa, Lamjung, Sunsari, Kavrepalanchok, Parbat, Achham, Baitadi, Palpa, Dhanusha, Taplejung, Jajarkot, Parasi, Gulmi
	Low	Rolpa, Myagdi, Lamjung, Sunsari, Terhathum, Rautahat, Western Rukum, Bardiya, Solukhumbu, Parbat, Darchula, Banke, Kailali, Arghakhanchi, Okhaldhunga, Bajura, Kanchanpur, Taplejung, Jajarkot, Bajhang, Dadeldhura	Myagdi, Terhathum, Rautahat, Western Rukum, Bardiya, Solukhumbu, Lalitpur, Darchula, Banke, Kailali, Arghakhanchi, Okhaldhunga, Bajura, Kanchanpur, Bajhang, Kathmandu, Dadeldhura	Myagdi, Terhathum, Rautahat, Western Rukum, Bardiya, Solukhumbu, Lalitpur, Darchula, Banke, Kailali, Arghakhanchi, Okhaldhunga, Bajura, Kalikot, Kanchanpur, Bajhang, Kathmandu, Dadeldhura
	Very low	Humla, Mugu, Rasuwa, Lalitpur, Bhaktapur, Dolpa, Rupandehi, Mustang, Bara, Manang, Eastern Rukum, Chitawan, Kalikot, Jumla, Parsa, Kathmandu	Humla, Mugu, Rasuwa, Bhaktapur, Dolpa, Rupandehi, Mustang, Bara, Manang, Eastern Rukum, Chitawan, Kalikot, Jumla, Parsa	Humla, Mugu, Rasuwa, Bhaktapur, Dolpa, Rupandehi, Mustang, Bara, Manang, Eastern Rukum, Chitawan, Jumla, Parsa

Scenario	Risk categories	District		
		Baseline	2030	2050
RCP 8.5	Very high	Dhading, Makawanpur, Gorkha, Tanahu, Udayapur, Sindhuli, Morang, Jhapa	Dhading, Makawanpur, Baglung, Sindhupalchok, Gorkha, Tanahu, Udayapur, Syangja, Sindhuli, Morang, Dang, Nawalpur, Jhapa, Mahottari	Dhading, Makawanpur, Nuwakot, Sankhuwasabha, Baglung, Sindhupalchok, Gorkha, Tanahu, Udayapur, Syangja, Bhojpur, Sindhuli, Morang, Khotang, Dang, Nawalpur, Jhapa, Sarlahi, Mahottari, Saptari
	High	Kapilbastu, Nuwakot, Baglung, Sindhupalchok, Syangja, Surkhet, Bhojpur, Khotang, Dang, Nawalpur, Sarlahi, Mahottari, Saptari	Kapilbastu, Dolakha, Dhankuta, Nuwakot, Sankhuwasabha, Pyuthan, Surkhet, Siraha, Bhojpur, Doti, Khotang, Kaski, Sarlahi, Ramechhap, Saptari, Ilam	Kapilbastu, Dolakha, Dhankuta, Kavrepalanchok, Dailekh, Pyuthan, Surkhet, Siraha, Salyan, Doti, Dhanusha, Kaski, Panchthar, Parasi, Ramechhap, Ilam
	Moderate	Dolakha, Dhankuta, Sankhuwasabha, Kavrepalanchok, Dailekh, Pyuthan, Achham, Siraha, Baitadi, Palpa, Salyan, Doti, Dhanusha, Kaski, Panchthar, Parasi, Gulmi, Ramechhap, Ilam	Rolpa, Lamjung, Sunsari, Kavrepalanchok, Dailekh, Parbat, Achham, Baitadi, Palpa, Salyan, Dhanusha, Panchthar, Jajarkot, Parasi, Gulmi	Rolpa, Lamjung, Sunsari, Solukhumbu, Parbat, Achham, Arghakhanchi, Baitadi, Palpa, Okhaldhunga, Taplejung, Jajarkot, Gulmi, Dadeldhura
	Low	Rolpa, Myagdi, Lamjung, Sunsari, Terhathum, Rautahat, Western Rukum, Bardiya, Solukhumbu, Parbat, Darchula, Banke, Kailali, Arghakhanchi, Okhaldhunga, Bajura, Kanchanpur, Taplejung, Jajarkot, Bajhang, Dadeldhura	Myagdi, Terhathum, Rautahat, Western Rukum, Bardiya, Solukhumbu, Lalitpur, Darchula, Banke, Kailali, Arghakhanchi, Okhaldhunga, Bajura, Kanchanpur, Taplejung, Bajhang, Kathmandu, Dadeldhura	Myagdi, Terhathum, Rautahat, Western Rukum, Bardiya, Lalitpur, Darchula, Banke, Dolpa, Kailali, Bajura, Kalikot, Kanchanpur, Bajhang, Kathmandu
	Very low	Humla, Mugu, Rasuwa, Lalitpur, Bhaktapur, Dolpa, Rupandehi, Mustang, Bara, Manang, Eastern Rukum, Chitawan, Kalikot, Jumla, Parsa, Kathmandu	Humla, Mugu, Rasuwa, Bhaktapur, Dolpa, Rupandehi, Mustang, Bara, Manang, Eastern Rukum, Chitawan, Kalikot, Jumla, Parsa	Humla, Mugu, Rasuwa, Bhaktapur, Rupandehi, Mustang, Bara, Manang, Eastern Rukum, Chitawan, Jumla, Parsa