Government of Nepal
Ministry of Population and Environment
Department of Hydrology and Meteorology

Observed Climate Trend Analysis of Nepal (1971-2014)

June 2017

Published by
Government of Nepal
Ministry of Population and Environment
Department of Hydrology and Meteorology
Naxal, Kathmandu
Nepal
Phone: (+977-1) 4436272, 4432409
Fax: (+977-1) 4429919, 4432136
Website: www.dhm.gov.np
E-mail: dg@dhm.gov.np

Copyright: ©Government of Nepal, Ministry of Population and Environment, Department of Hydrology and Meteorology, 2017

This Publication may be used for educational and non-profit purposes, provided acknowledgement of the source is accurately made. Use of any part of it for commercial purpose is strictly prohibited.

Supported by:

Support to Rural Livelihoods and Climate Change Adaptation in the Himalayas (Himalica), European Union, and International Centre for Integrated Mountain and Development (ICIMOD);

UK-aid, Action on Climate Today, Oxford Policy Management Limited and Practical Action

Citation: DHM, 2017. *Observed Climate Trend Analysis in the Districts and Physiographic Regions of Nepal (1971-2014)*. Department of Hydrology and Meteorology, Kathmandu

Steering Committee

Dr. Rishi Ram Sharma, Director General	Coordinator
Mr. Saraju Kumar Baidya, Deputy Director General	Member
Mr. Durga Prakash Manandhar, Deputy Director General	Member
Dr. Jagdishwor Karmacharya, Deputy Director General	Member

Technical Committee

Dr. Archana Shrestha, Senior Divisional Meteorologist	Coordinator
Ms. Pratibha Manandhar, Senior Divisional Meteorologist	Member
Mr. Bikash Nepal, Meteorologist	Member
Mr. Lasakusa Samir Shrestha, Meteorologist	Member

Government of Nepal

Ministry of Population and Environment

Ref. No:

FOREWORD

Nepal has gradually developed institutional and technical capacity to adapt to climate change. The country prepared National Adaptation Programme of Action (NAPA) in 2010 to address the most urgent and immediate adaptation needs of the country. Nepal also prepared National Framework on Local Adaptation Plans for Action (LAPA) in 2011 to implement prioritised adaptation actions at the local level and ensure integration of climate change adaptation into local and national planning processes. In 2011, Nepal formulated Climate Change Policy to streamline climate change initiatives in the country.

Climate change impacts are increasing over time, particularly in the Least Developed Countries (LDCs) like Nepal. Parties to the UN Framework Convention on Climate Change (UNFCCC) realised the urgency of expanding adaptation actions in developing countries. The Conference of the Parties to the UNFCCC at its 16th session in Cancun in 2010 established a process under the Cancun Adaptation Framework to enable LDC Parties to formulate and implement National Adaptation Plans (NAPs) to prepare for the impacts of climate change through medium and long-term adaptation measures. In Nepal, Ministry of Population and Environment (MoPE), the UNFCCC focal point, launched the NAP process in September 2015.

The NAP process has commenced the analysis of climate change trends leading to the robust projections of climate scenario in the medium- and long-run, based on which adaptation pathways could be developed. The Department of Hydrology and Meteorology (DHM) has performed a meticulous task of analyzing available climate data and produce a synthesized report containing results of climate change trend analysis. I would like to appreciate Dr. Rishi Ram Sharma, Director General of the DHM and his team for producing such a wealth of knowledge which will substantially inform the NAP process.

I would like to take this opportunity to appreciate the support provided by the Action on Climate Today (ACT), a UK-Aid funded initiative managed by Oxford Policy Management Limited and Practical Action in initiating the NAP process. I would also like to acknowledge the International Centre for Integrated Mountain Development (ICIMOD) and the experts for their support in advancing the NAP process, including on technical and scientific studies.

I do appreciate the support and contribution of all coordinators, deputy-coordinators and members of the working groups. The support from working groups in the NAP formulation process has truly helped realize the spirit of "leaving no one behind" approach adopted in the NAP process.

I am also grateful toDr. Ram Prasad Lamsal, Joint-Secretary and Chief, Climate Change Management Division; Mr. Naresh Sharma, NAP Coordinator; and NAP Team for their hard work, passion, and persistence to lay foundation for the NAP process in Nepal.

Bishwa Nath Oli, PhD
Secretary
Government of Nepal

Government of Nepal

Ministry of Population and Environment

DEPARTMENT OF HYDROLOGY & METEOROLOGY

Ref. No:

PREFACE

The global consensus on climate change as a serious threat to mankind is now stronger than ever, thanks to the ever growing body of evidence based on historical trends of climate change. Nepal is ranked as one of the most vulnerable countries in the world to climate change threats. The Government of Nepal has been actively engaged in promoting climate change activities in general, and adaptation measures in particular to help climate vulnerable communities to adapt to climate change impacts. More recently, the Government of Nepal has initiated the National Adaptation Plan (NAP) formulation process to develop medium and long-term adaptation options for the country.

In order to be effective, a plan needs to be built on a strong scientific foundation and empirical evidences. Designing adaptation plans at scale requires both the knowledge of historical climate data and the future climatic scenarios. The Department of Hydrology and Meteorology (DHM) has been supporting the NAP process to prepare the climatic trends in Nepal using the past historical data. I hope, this report will contribute to the NAP formulation process and benefit all stakeholders engaged in climate-related planning activities.

Established in 1988, the DHM is responsible to monitor all the hydrological and meteorological events in the country. The DHM regularly provides general and aviation weather forecasts, flood forecast, data dissemination and special services. As Nepal's focal point for the World Meteorological Organization (WMO), the DHM also shares the data to the global community on a regular basis. The DHM is now engaged in establishing real time meteorological and hydrological stations to cover Nepal's varied topography and landscape. This initiative will gradually help to improve climate data in developing science-based plans and programmes.

The DHM is pleased to publish this report on climate change trend analysis. I would like to thank my colleagues directly involved in the study for their hard work and dedication. I appreciate technical guidance and supervision of Mr. Saraju K. Baidya, Mr. Durga P. Manandhar and Dr. Jagdishwor Karmacharya, Deputy Director Generals at DHM. I would also appreciate Dr. Archana Shrestha and Ms. Pratibha Manandhar, Senior Divisional Meteorologists, Mr. Bikash Nepal and Mr. Lasakusa S. Shrestha, Meteorologists for their concerted effort in bringing this report in the present form. Prof. Rupak Rajbhandari is greatly appreciated for his professional inputs in carrying out trend analysis.

I would like to appreciate the support and contribution of the International Centre for Integrated Mountain Development (ICIMOD) in preparation of this report.

During the course of preparing this report, the DHM received valuable suggestions from various organizations and relevant experts in the field. I would like to take this opportunity to particularly thank Mr. Naresh Sharma, NAP Coordinator, Practical Action, and the NAP Team.

I believe that this piece of work will enhance our understanding on climate variability and change. We also reiterate our commitment to provide updated climate data for adaptation planning at different levels.

Rishi Ram Sharma, PhD
Director General, DHM

Nagpokhari, Naxal, P.O. Box: 406, Kathmandu, Nepal
Phone: 977 1 4436272, 4428532, 4441092, 4428229, 4433563
Fax: 977 1 4429919, 4426136

email: info@dhm.gov.np
Website: www.dhm.gov.np, www.mfd.gov.np
www.hydrology.gov.np

ACRONYMS

APHRODITE	Asian Precipitation Highly-Resolved Observational Data Integration Towards Evaluation
CDR	Central Development Region
CL	Confidence Level
DJF	December-January-February (Winter Season)
DHM	Department of Hydrology and Meteorology
EDR	Eastern Development Region
FMI	Finnish Meteorological Institute
FWDR	Far Western Development Region
GrADS	Grid Analysis and Display System
ICIMOD	International Centre for Integrated Mountain Development
JJAS	June-July-August-September (Monsoon Season)
LDC	Least Developed Country
LEG	Least Developed Country Expert Group
MAM	March-April-May (Pre-monsoon Season)
masl	meters above sea level
MoPE	Ministry of Population and Environment
MWDR	Mid-Western Development Region
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
PAN	Practical Action Nepal
QC	Quality Control
WDR	Western Development Region

Table of Contents

LIST OF FIGURES

EXECUTIVE SUMMARY

The Paris Agreement has a provision that adaptation action to climate change should be based on and guided by the best available science, as appropriate. One of the basic tools to understand climate change is to analyze climate change from atmospheric observations. This report is prepared by using improved methods and available climate data in Nepal as part of NAP process and provides the following key findings:

All Nepal Climate Trend

- Significant positive trends are observed in annual and seasonal All Nepal maximum temperature. All Nepal minimum temperature shows significantly positive trend only in monsoon season. No significant trend is observed in precipitation in any season.
- All Nepal annual maximum temperature trend is significantly positive (0.056^{o}C/yr). All Nepal annual minimum temperature trend is also positive (0.002^{o}C/yr) but it is insignificant.

Precipitation Trends

- At district level, pre-monsoon and monsoon precipitation shows significant trends only in few districts while winter and post-monsoon precipitation trends are insignificant in most of the districts. The significantly highest positive rainfall trend is observed in Syangja and Parbat districts in monsoon season.
- Only pre-monsoon precipitation shows significant negative trend in the High-Himalayan region. In other seasons, precipitation trends are insignificant in all physiographic regions.
- Both at district and physiographic level, three coherent but insignificant patterns are observed: 1) insignificant positive precipitation trend in the southern districts of Far Western Development Region (FWDR) in three seasons (winter, pre-monsoon and monsoon), 2) insignificant decrease in monsoon precipitation in majority of districts east of 84E longitude, and 3) insignificant highest decreasing rainfall trend in all seasons in the High Mountains and insignificant positive trend in all seasons, except in post-monsoon, in Tarai. These coherent but insignificant patterns might be associated with short term variability in atmospheric phenomena. Further analysis/longer period data is necessary to understand these patterns. Since these patterns are not significant, these results should be used very cautiously.

Maximum Temperature Trend

- The positive temperature trend is highly significant in majority of districts (more than 90% of the districts) and in all physiographic regions in all the seasons, except in majority of the Tarai districts in winter.
- At the district level, the highest significant positive trend (0.12°C/yr) is observed in Manang district in winter season.
- All five physiographic regions show significant positive trend in all seasons, except in Tarai in winter and pre-monsoon, and in Siwaliks in winter.
- In High Mountains and High Himalayas, the highest positive trend is observed in winter season and in Tarai, Siwaliks and Middle Mountains, the highest positive trend is observed in monsoon season.
- Both at district and physiographic levels, seasonal and annual maximum temperature trends demonstrate a pattern in relation to altitude with negative trend or small positive trend in lower altitude districts/regions and larger positive trend in higher altitude districts/regions

Minimum Temperature Trend

- The negative minimum temperature trend is significant in most of the northwestern districts in winter and post-monsoon seasons while positive minimum temperature trend is significant in majority of southern (Tarai to Middle Mountains) districts in Eastern Development Region (EDR), Central Development Region (CDR) and WDR in all seasons.
- Seasonal and annual minimum temperature trends, though majority are insignificant both at district and physiographic levels, show positive trends in lower elevation and negative in the higher elevation. Since these patterns are not significant, but might be associated with short term variability in atmospheric phenomena, these results should be used very cautiously.
- At the district level, significantly highest positive trend (0.046°C/yr) is observed in Dolpa district in monsoon and significantly highest negative trend (-0.076°C/yr) in Humla district in winter.
- At the physiographic level, Tarai and Siwaliks show significant increasing trend in most of the seasons. The decreasing trend is significant only in winter season in the High Himalayas.

Extreme Precipitation Trends

- Number of rainy days is increasing significantly mainly in the northwestern districts.
- Very wet days and extremely wet days are decreasing significantly, mainly in the northern districts.

- Consecutively dry days are decreasing significantly, mainly in the northwestern districts of MWDR while consecutive wet days are increasing significantly in the northern districts of MWDR and central parts of WDR and EDR.

Extreme Temperature Trends

- Trends of warm days and warm nights are significantly increasing in majority of the districts. Warm spell duration is increasing significantly in majority of the districts.
- Cool days are decreasing in majority of the districts while cool nights are increasing in few northwestern and northern districts and decreasing in few southeastern districts significantly. Cold spell duration is also increasing significantly only in the FWDR.

It is noteworthy to mention that maximum temperature trends are higher than minimum temperature trends in all seasons. The significant test shows maximum temperature trends are more robust than minimum temperature and precipitation trends.

The observed climate trends in districts and physiographic regions along with the information on significance level analyzed is presented in this report. While higher significance level provides clear signal in the trend, no clear conclusion can be drawn from insignificant trends. This report with observed climate trends with significance is, therefore, expected to provide a better guidance for adaptation planning, including the NAP process in Nepal.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) at Cancun, Mexico in 2010 realised the urgency of building adaptive capacity and resilience, and established a process to enable Least Developed Country (LDC) Parties to formulate and implement national adaptation plans (NAPs). The NAP builds on the experience in preparing and implementing National Adaptation Programme of Action (NAPAs), as a means of identifying medium- and long-term adaptation needs and developing and implementing strategies and programmes to address those needs. The Conference of the Parties to the UNFCCC at its 17th session (CoP 17) held in Durban, South Africa issued the initial guidelines for NAP formulation. As per its mandate, the LDC Expert Group (LEG) prepared the NAP Technical Guidelines to provide guidance to LDCs on the NAP formulation process. Each CoP decision provides ample opportunities to formulate NAP. Article 7 of the Paris Agreement (2015) urges each Party to, inter alia, engage in adaptation planning processes and implementation of actions, including a process to formulate and implement the NAP.

The objective of NAP process is to reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience; and facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate.

The Paris Agreement has a provision that adaptation action should be based on and guided by the best available science, as appropriate. Each Party is obliged to submit and update periodically an adaptation communication. In this pursuit, the Department of Hydrology and Meteorology (DHM), a dedicated and responsible institution of the Ministry of Population and Environment (MoPE) for climate data in Nepal, took a lead role and worked in collaboration with International Centre for Integrated Mountain Development (ICIMOD) and Practical Action to conduct a study on observed climatic trend of Nepal.

The purpose of this study is to analyse climate trend using most updated climatic data and available improved methods. Previously detailed study on historical climate trend was conducted by Practical Action Nepal (PAN) in 2009 using data from 1976 to 2005 and DHM (2015) using data from 1971 to 2012. Prior to these two studies, most studies focused either only on single climate variable (maximum temperature or precipitation or extremes only) or on All Nepal average trend or only on station level trends (Shrestha et al., 1999 and Baidya et al., 2008). Taking into consideration the results and limitations of previous studies conducted by PAN (2009) and DHM (2015), in particular trend analysis using linear regression method and with no significance tests of the trends and lack of trend analysis of extreme events, this study has considered adequately non-normal (skewed) distribution and auto-correlation present in climatic time series by using non-parametric tests for the analysis of magnitude and significance test of the trends. This study also includes extreme event trend analysis at district levels to facilitate the NAP process and adaptation planning.

This national document on climate trend analysis is a part of Nepal's NAP formulation process and would contribute to adaptation communication. The MoPE launched the NAP process in September 2015 and engaged the NAP team in May 2016. Nepal's NAP follows a process as per Decision 5/CP.17 (initial guidelines for NAP formulation) and NAP Technical Guidelines and focuses on analysing current and future climate scenarios. This technical report provides latest updates on climate trend in Nepal.

1.2 Objectives

The main objective of this study is to analyse observed seasonal and annual climate change trend in Nepal at district and physiographic regions for the NAP process.

1.3 Study Units

The climatic normal and climate trends are calculated in spatial and temporal scales. In spatial scale two types of study units were used: Districts and Physiographic regions. Figure 1.1 shows 75 districts of Nepal and their political boundaries. Nepal is divided into five physiographic zones based on elevation, topography and climate. The five regions are: Tarai (59-200 masl), Siwaliks (200-1500 masl), Middle Mountains (1000-2500 masl), High Mountains (2200-4000 masl) and High Himalayas (>4000 masl) (Figure 1.2).

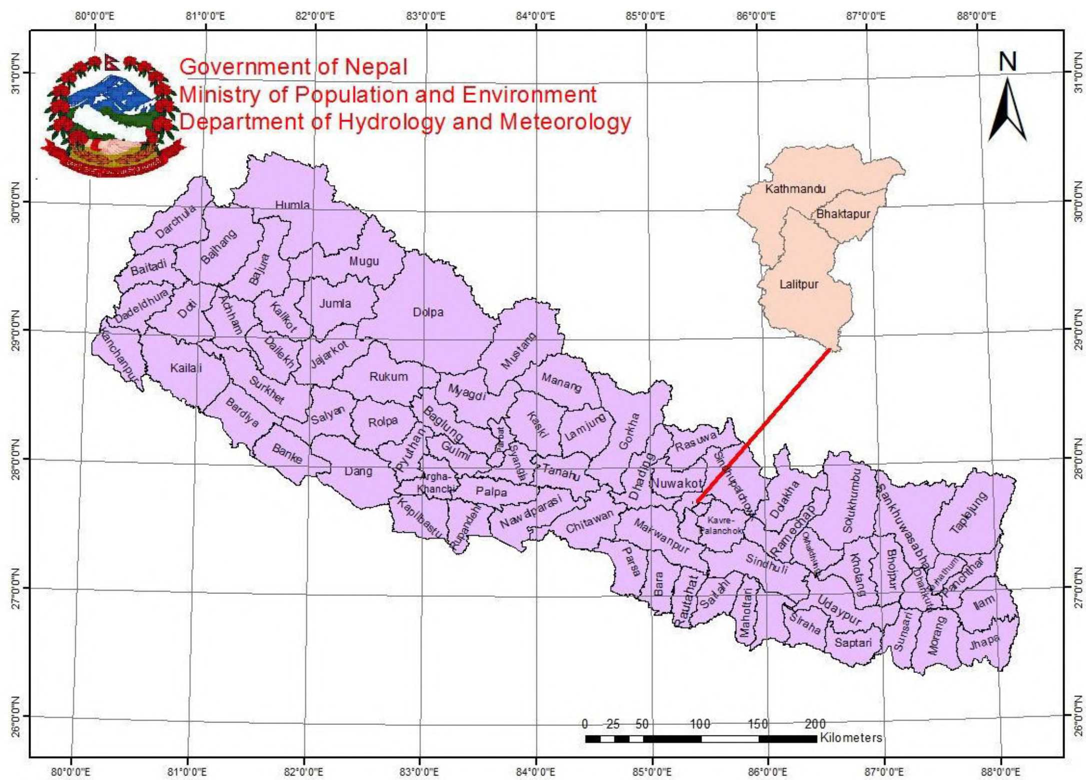

FIGURE 1. 1: DISTRICTS OF NEPAL

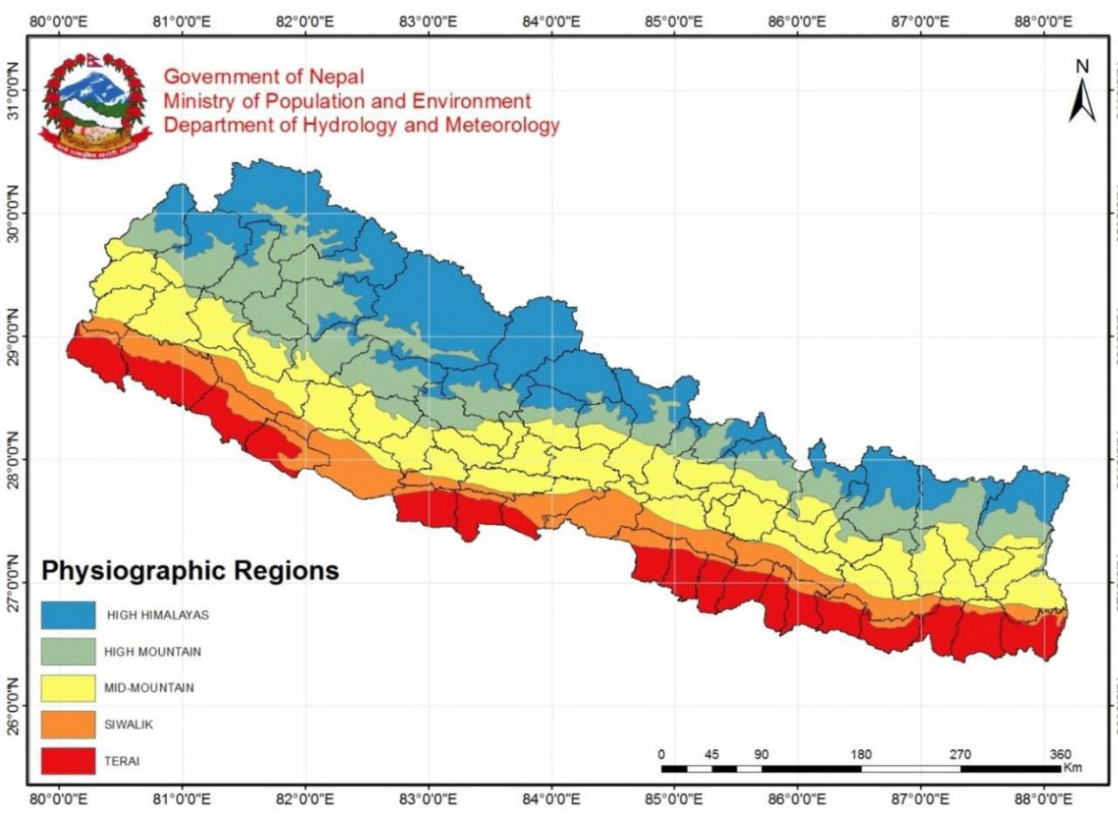

FIGURE 1.2: PHYSIOGRAPHIC REGIONS OF NEPAL

In temporal scale, annual and seasonal time scales are used in this analysis. Based on rainfall and temperature pattern, Nepal has four seasons. The climatic normal and trends are calculated for these four seasons: (i) December, January and February is winter season that is coldest and driest season; (ii) March to May is pre-monsoon season and experiences hot weather and thunderstorms; (iii) June to September is monsoon season with rainy, hot and humid weather; (iv) October and November is post-monsoon season, with pleasant weather.

1.4 THE REPORT

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

- This report is prepared on observed climate trend for Nepal using best available data and tools.
- This study is based on quality checked meteorological data in order to enhance the quality of the report and assure the best output/outcome.
- The study is based on 1km x 1km for temperature and 5km x 5km for precipitation daily gridded data set.
- This report presents All Nepal average, individual district average and individual physiographic region average of normal annual and seasonal rainfall and maximum and minimum temperatures using gridded data. This is the first study of its nature in Nepal that uses gridded data to calculate district-wise normal rainfall and temperature.
- This study calculates maximum and minimum temperature and precipitation trend for annual and four seasons for each district with significance test at 95%, 99% and 99.9 % confidence levels. Based on record, this is also the first study in Nepal that analyses climate trend at district level over whole country.
- Maps of eleven extreme climatic indices trend are prepared at district level.
- The district normal climate and climate trends are presented in the maps for annual and four seasons.
- This report uses data of only two high altitude stations (> 2800 masl uptp 5000 masl). District and physiographic trends were calculated using district average time series.

CHAPTER 2: DATA AND METHODOLOGY

2.1 DATA

Two types of data are used in this report. For temperature analysis, daily temperature data from 93 climate stations are used. Out of 93, 92 stations are established by DHM and one station, Pyramid, was established by EVK2 Project. These stations are selected based on the data length and results on quality control tests. The list of stations along with their meta-data is presented in Table A1 in the Appendix. Spatial distribution of stations and number of stations in each district (Figure 2.1a and Figure 2.1b respectively) show that majority of the districts have at least one station. The number of stations in each district varies from zero (in 13 districts) to three (in 3 districts). Other districts have 1-2 stations (Table A2 in the Appendix).

For precipitation analysis, 0.05 degree APHRODITE (Yatagai et al., 2009, 2012) daily gridded data is used. This data base for Nepal is based only on DHM rain-gauge data. APHRODITE data followed: (i) fourteen objective quality checking process for the gauged data for the errors in station metadata and serial data; and (ii) interpolation method based distance-weighted method with consideration of orographic effects on precipitation. Andermann et al (2014) concludes that APHRODITE data is best gridded data available in the Himalayan front for the temporal scale of daily or higher. The detail methodology on quality check and interpolation is illustrated in Yatagai et al. (2012). Current study uses daily data from 1971 to 2014, both for temperature and rainfall trend analysis.

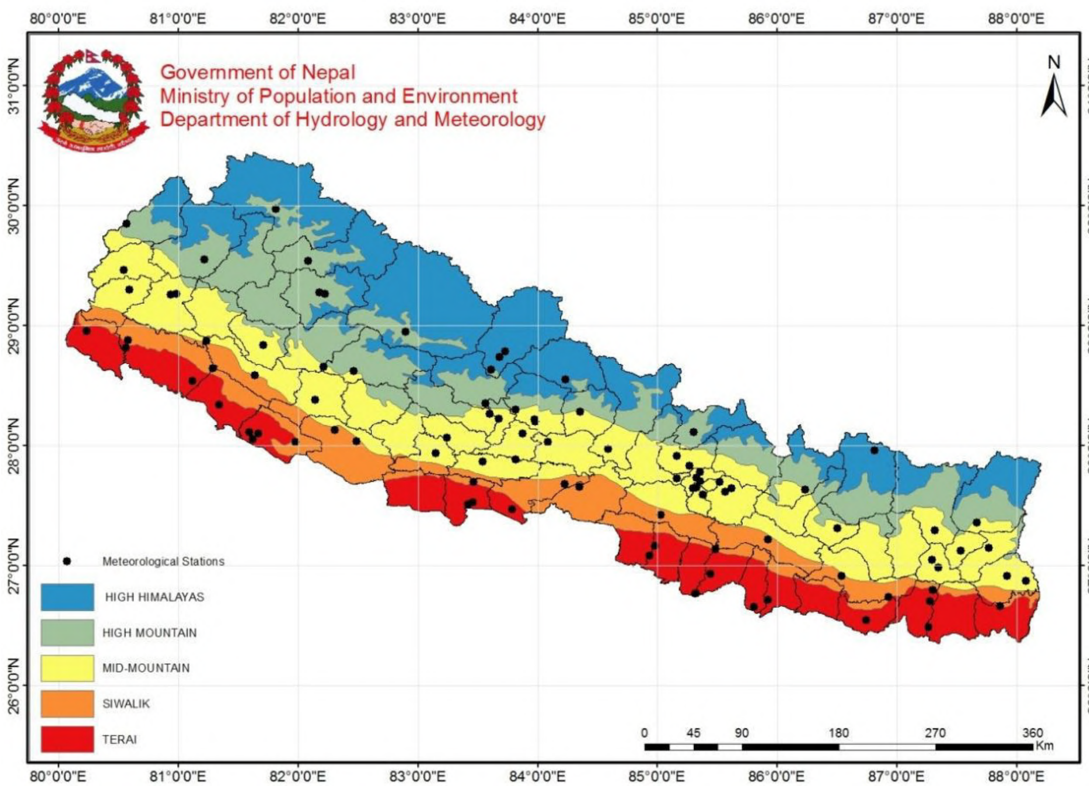

Figure 2.1a: Distribution of 93 stations used for this study

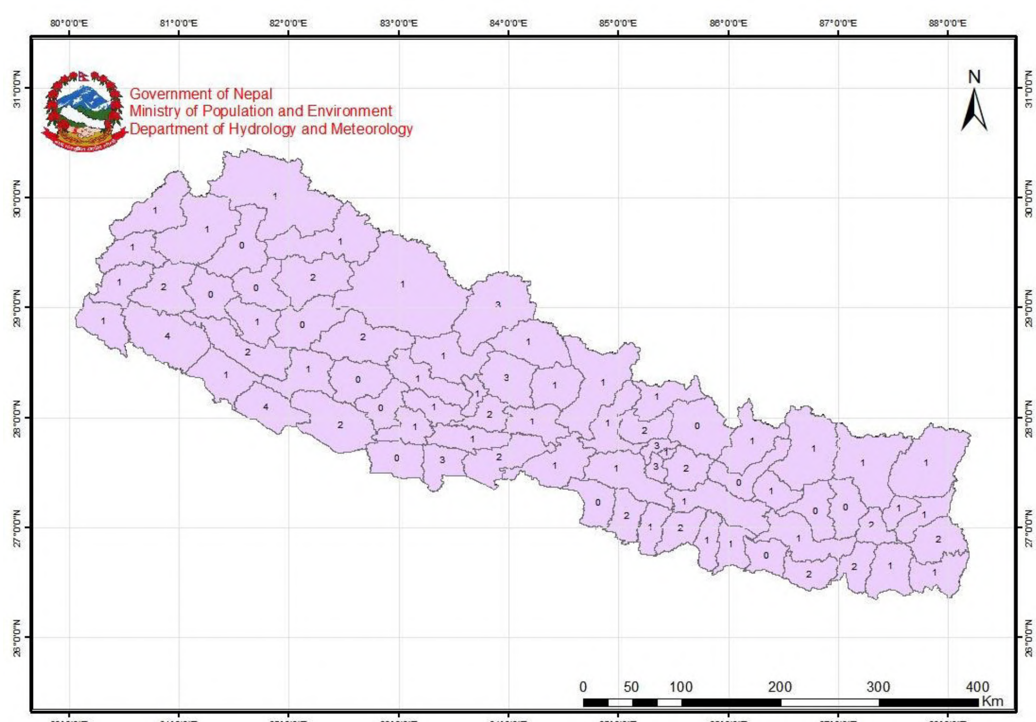

Figure 2.1b: Districtwise number of stations used in this study

2.2 METHODOLOGY

Schematic diagram of methodology used in this study is given in Figure 2.2. The detail explanation of each step is as follows:

2.2.1 TEMPERATURE DATA QUALITY CHECK

The daily temperature data of 92 DHM stations were first quality checked using RClimdex software. RClimdex is a free software which also tests quality of the meteorological data. The methods used in RClimdex quality check are discussed in Alexander et al (2006). The station data that showed outliers and unusual values were further processed. The outliers and unusual values were corrected for individual stations by replacing them by average of the value from previous day and the next day. Moreover, DHM regional offices were contacted to confirm whether station location was changed and if there were issues with the performance of instrument/observer in the stations that showed step changes in the record. No such issues were reported for those stations and thus, the step changes in the records of those stations were considered as natural and used in this analysis.

2.2.2 HIGH ALTITUDE STATION MISSING DATA FILLING

Out of 93 stations, only two stations used in this study are located in the altitude at about 3000m or above. These two stations are: Simikot (2993m) in the west in Humla District and Pyramid (5035m) in the east in Solukhumbu district. Since Simikot station was established in 1989 and Pyramid in 1993, no data were available in these high Himalayan stations prior to 1989 and 1993 respectively. When the data was interpolated using RClimdex prior to 1989 for Simikot and 1993 for Pyramid, the temperatures showed warm bias and this might lead to either no trend or negative trend. Therefore, the missing data from 1971 was first filled in both of these stations using the data from correlated neighbouring station (at lower altitude) that has data for 1971 to 1993. For Simikot, Doti station in Doti district and for Pyramid, Jiri station in Dolakha district showed best correlations. For each month, average rate of decrease of temperature from Doti to Simikot and from Jiri to Pyramid due to elevation increase was calculated. This is based on the assumption that surface air temperature decreases from low elevation to high elevation. The monthly average rates were used as a coefficient to estimate daily temperature from low elevation station to high elevation station for the missing data period. The monthly average "lapse rates" for Jiri-Pyramid and Doti-Simikot were calculated both for maximum and minimum temperature separately and are shown in Table A2 in the Appendix.

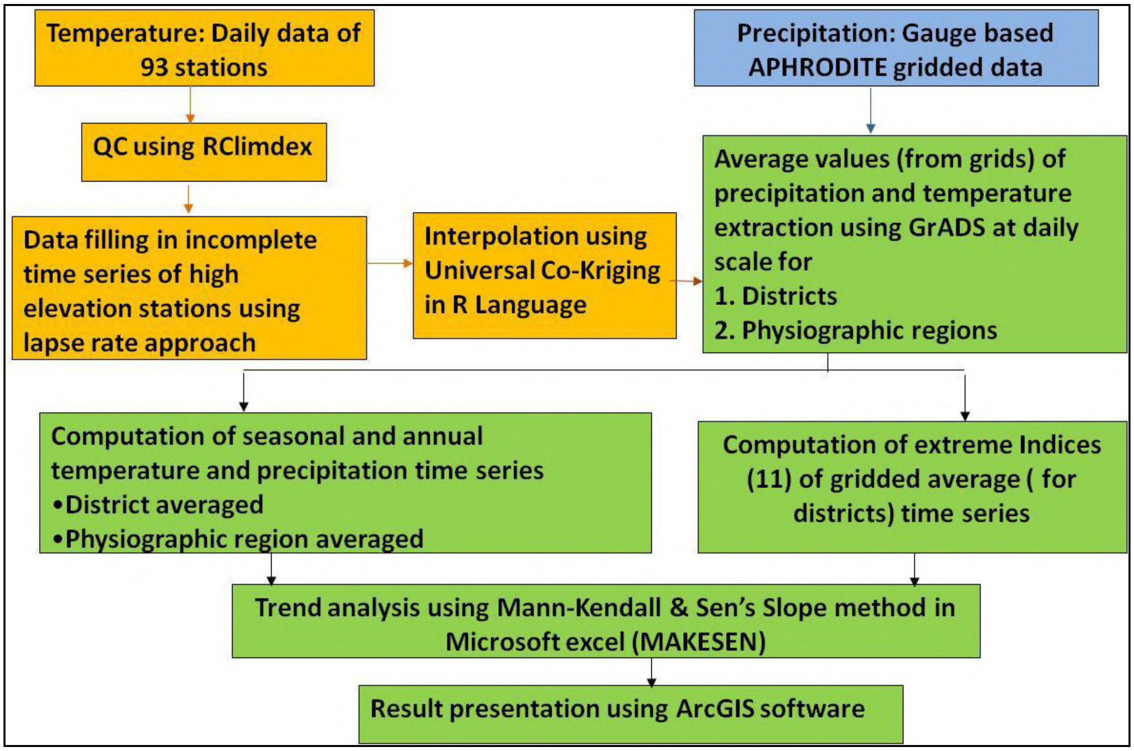

Figure 2.2: Schematic diagram of methodology

2.2.3 Gridding and Interpolation of Temperature Data

After quality check procedure and filling of high altitude missing data, the temperature daily data from 1971 to 2014 was interpolated at grid size 1x1 km using Co-Kriging (in R environment) developed in-house by DHM with the technical assistance and support from Finnish Meteorological Institute (FMI). The script considers elevation while interpolating the variables. This gridding method interpolates the temperature data where there are no stations and fills the missing data in all 92 stations.

2.2.4 District level and Physiographic Region Seasonal and Annual Time Series Calculation

Area averaged daily time series (i.e. for 75 districts and 5 physiographic regions for 1971-2014 period) of maximum temperature, minimum temperature, and precipitation were extracted from gridded data using publicly available GrADS (GRid Analysis and Display, http://cola.gmu.edu/grads/grads.php) software. From daily area averaged time series of corresponding districts and physiographic regions, monthly time series (1971-2014) were calculated for each 75 district and each five physiographic region. These precipitation, maximum temperature and minimum temperature were used to calculate seasonal and annual normal climate and to perform trend analysis.

2.2.5 TREND ANALYSIS

Combined Mann-Kendall test and Sen's Slope methods were used to analyse type, magnitude and significance of trend in climate time series data. Mann-Kendall trend test is non-parametric method that tests the presence and significance of monotonic positive or negative trend in a time series. It tests if the monotonic trend is significant or not, whereas Sen's Slope method estimates the magnitude of the linear trend (slope). In this study, MS-Excel program called MAKESENS version 1.0 developed by FMI in 2002 (Salmi et al., 2002) was used to calculate magnitude, and significance of the trend. This program incorporates both Mann-Kendall test and Sen's Slope method for trend analysis. The detail calculation method is explained by Salmi et al. (2002).

A primary goal of significant test in trend analysis is to identify "signals" in change against the 'noise' that occur internally generated fluctuation in climate system. If the 'signal' is small relative to the 'noise', trend may be observed in data by chance, purely due to random fluctuations of the 'noise'. Therefore, significance test examines if the observed trend is a 'signal' of change or simply a random fluctuation (i.e., noise). The Mann-Kendall method of significance test uses the hypothesis testing approach. It tests the null hypothesis that the monotonic trend is by chance (due to noise) in the climate data against the alternative hypothesis that there is a monotonic trend (signal) in the climate data at a certain significant level. In this study, significant tests at the level of 0.001, 0.01 and 0.05 or at confidence levels (CL) at 99.9%, 99% and 95% were used. Each significance level (0.001, 0.01, and 0.05) indicates the probability (0.1%, 1%, and 5%) that the observed trend could have occurred by chance.

Significant test at 0.001 (at 99.9% CL) means that the probability that the null hypothesis (the trend is by chance) might be true is less than 0.1%. With such low probability, the null hypothesis is likely to be incorrect and therefore the alternative hypothesis can be accepted at the confidence level of 99.9%. In other words, the trend in the data can be accepted as a real signal at the confidence level of 99.9%.

Similarly, significant test at 0.01 (at 99% CL) means the trend in data can be accepted as a real signal at the confidence level of 99%. Significant test at 0.05 (at 95% CL) means the trend in data can be accepted as a real signal at the confidence level of 95%.

In this study, significant trend represents trends with 95% or higher CL and insignificant means lower than 95% CL.

2.2.6 EXTREME INDICES ANALYSIS

These extreme indices were identified by NAP team, ICIMOD, DHM and PAN together after mapping the sectoral requirement and need for NAP. Time series of extreme indices for each district are calculated by using a programme in Fortran. Significance and slope of the trend of output indices were estimated using Mann-Kendall and Sen's slope method in MS-Excel. Time series of extreme indices were obtained from GrADS extracted area averaged data. Description of 11 extreme climate indices is shown in Table 2.

Table 2: Extreme indices and their description

Extreme Climate Indices	Descriptions
a. Number of rainy days	Annual count of days with daily precipitation > 1mm
b. Very wet days	Annual total precipitation when daily rainfall >95th percentile
c. Extremely wet days	Annual total precipitation when daily max rainfall >99th percentile
d. Consecutive wet days	Maximum number of consecutive days with daily precipitation >1mm
e. Consecutive dry days	Maximum number of consecutive days with daily precipitation <1mm
f. Warm days	Percentage of days when maximum temperature >90th percentile
g. Warm nights	Percentage of days when minimum temperature >90th percentile
h. Warm spell duration	Annual count of days with at least 6 consecutive days when maximum temperature > 90th percentile
i. Cool days	Percentage of days when maximum temperature <10th percentile
j. Cool nights	Percentage of days when minimum temperature <10th percentile
k. Cold spell duration	Annual count of days with at least 6 consecutive days when minimum temperature < 10th percentile

2.2.7 REPORT PREPARATION PROCESS

The Ministry of Population and Environment constituted a Steering Committee under the coordination of the Director General of the DHM for necessary guidance, supervision and coordination for the trend analysis and preparation of this report.

The DHM formed a Technical Committee under the coordination of Senior Divisional Meteorologist for data checking, quality control, technical supervision of the work, and finalisation of this report.

In order to best utilise the available climate data for Nepal's NAP formulation process, the Technical Committee organised consultations at regular basis with NAP Team and those engaged in supporting the NAP process, in particular ICIMOD and Practical Action for sharing on approaches, data availability and results. This report accommodates concerns and inputs of the reviewers, to the extent possible.

CHAPTER 3: CLIMATIC NORMAL

This chapter presents district and physiographic regions normals of precipitation, maximum temperature and minimum temperature. Annual and seasonal normal are calculated by averaging each time series data (for precipitation, maximum temperature and minimum temperature) for the period from 1981 to 2010. The district and physiographic regions normal climatic values are presented in the Table A3a and Table A3b in the Appendix respectively.

3.1 NORMAL PRECIPITATION FOR DISTRICTS AND PHYSIOGRAPHIC REGIONS

3.1.1 WINTER PRECIPITATION

Districts in the Far Western Development Region (FWDR) have higher normal winter rainfall than rest of the districts in the country (Figure 3.1.1a). The figure shows that the normal winter precipitation decreases from west to east in the country, with lowest rainfall in the districts of Central Development Region (CDR) and Eastern Development Region (EDR). Lowest winter precipitation is observed in Mustang, Dhankuta and few Tarai districts in EDR and CDR. Normal winter precipitation for physiographic regions is lowest over the High Himalayas and Tarai regions (Figure 3.1.1.b and Table A3b).

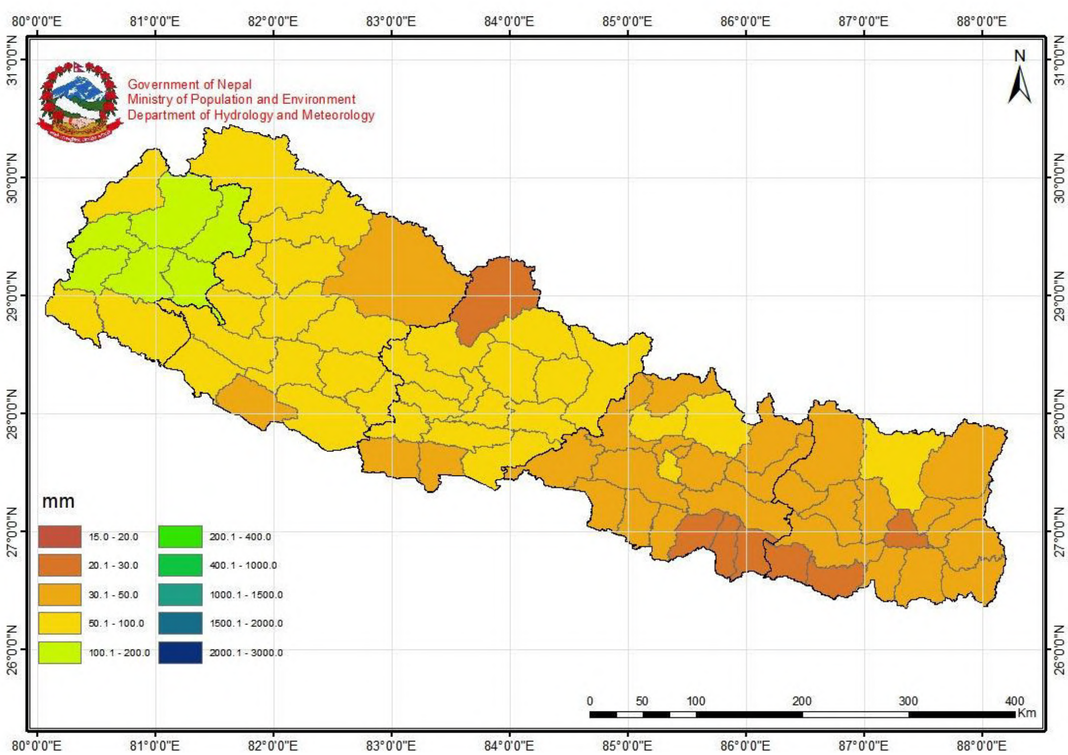

Figure 3.1.1a: Winter precipitation normal for districts

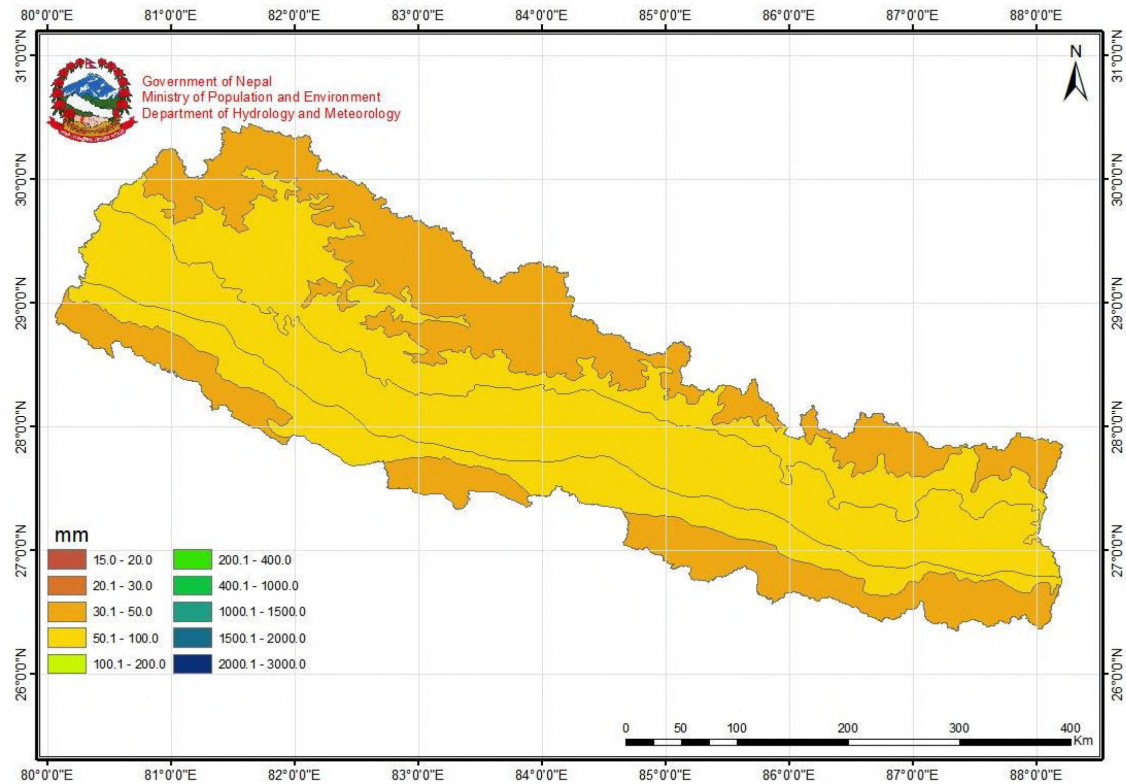

Figure 3.1.1b: Winter precipitation normal for physiographic regions

3.1.2 Pre–Monsoon Precipitation

In pre-monsoon season, lowest normal precipitation is observed in Mustang district (Figure 3.1.2a). Most districts in EDR and CDR, and Baitadi district receive highest normal rainfall during pre-monsoon. Normal pre-monsoon precipitation for physiographic regions shows higher precipitation in Middle Mountains and High Mountains than in Tarai, Siwaliks and High Himalayas (Figure 3.1.2b).

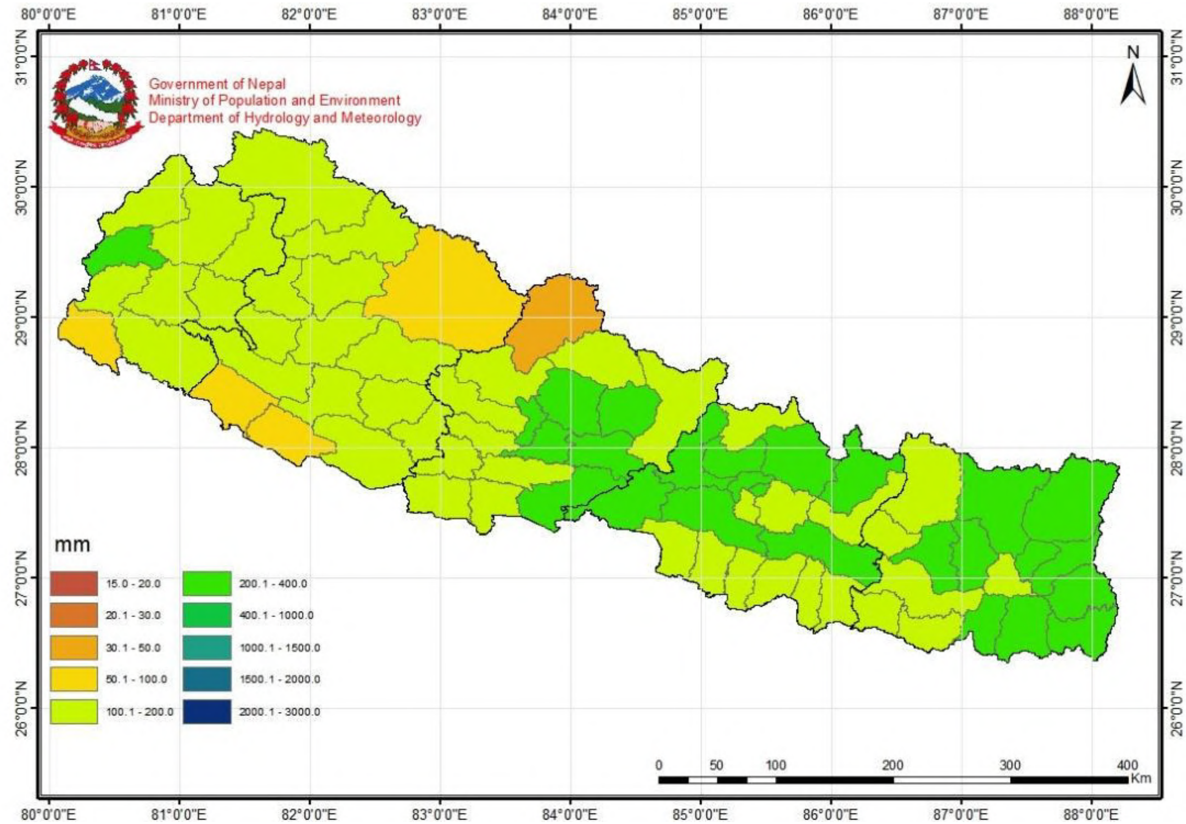

Figure 3.1.2a: Pre-monsoon precipitation normal for districts

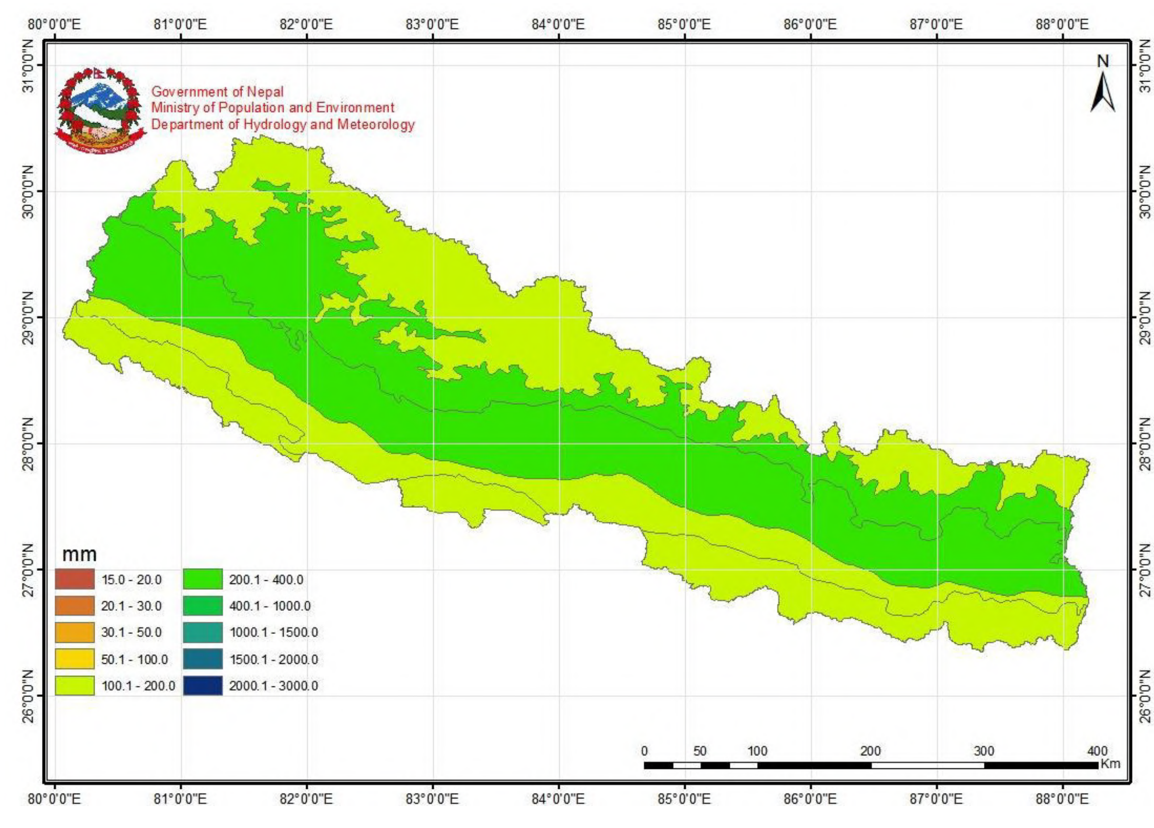

Figure 3.1.2b: Pre-monsoon precipitation normal for physiographic regions

3.1.3 MONSOON PRECIPITATION

With regard to normal monsoon precipitation in all 75 districts, northern districts of the Western Development Region (WDR) and Mid-Western Development Region (MWDR) as well as Rasuwa, Dhankuta and Tehrathum districts receive below 1000mm of rainfall (Figure 3.1.3a). Monsoon precipitation is lowest over Mustang (<200mm) and highest over Kaski and Parbat (>2000mm). The High Himalayas receive less than 1000mm while rest of the regions receive normal precipitation in monsoon season between 1000mm and 1500mm (Figure 3.1.3b).

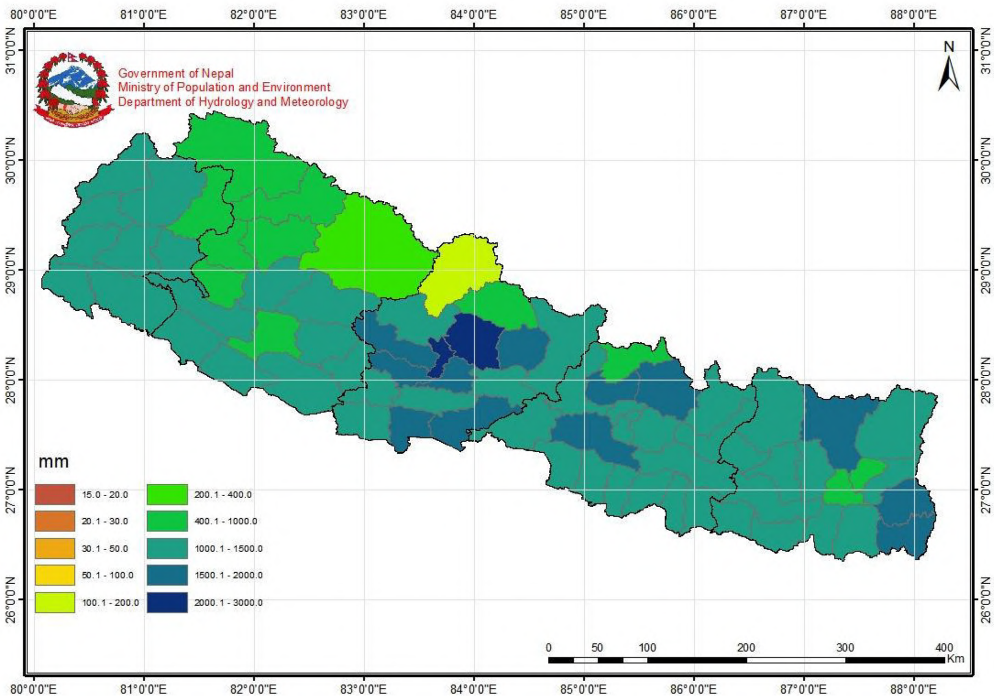

Figure 3.1.3a: Monsoon precipitation normal for districts

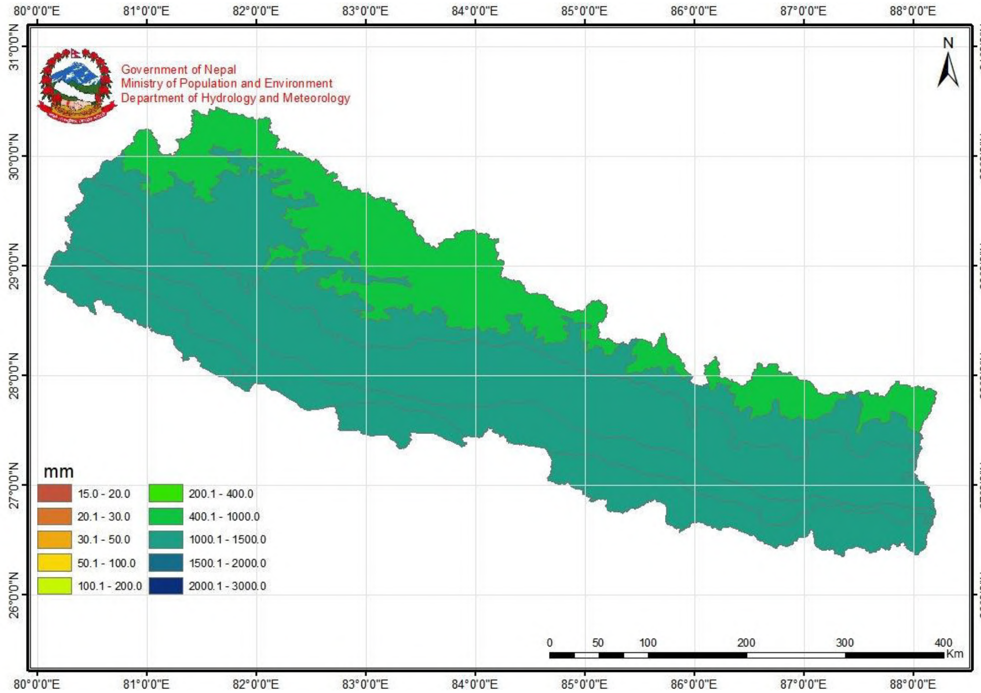

Figure 3.1.3b: Monsoon precipitation normal for physiographic regions

3.1.4 Post-Monsoon Precipitation

In post-monsoon season, only three districts in EDR and Kaski in WDR receive more than 100mm rainfall (Figure 3.1.4a). Mustang and Dolpa districts receive lowest rainfall (<20mm). Regarding normal post-monsoon precipitation for physiographic regions, High Himalayas receives below 50mm of rain whereas other physiographic regions receive between 50mm and 100mm of rainfall (Figure 3.1.4b).

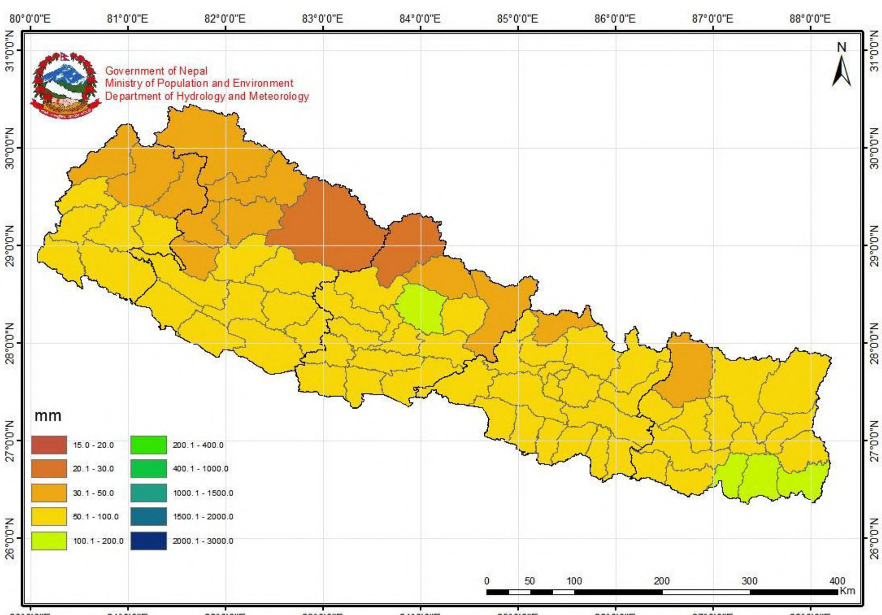

Figure 3.1.4a: Post-monsoon precipitation normal for districts

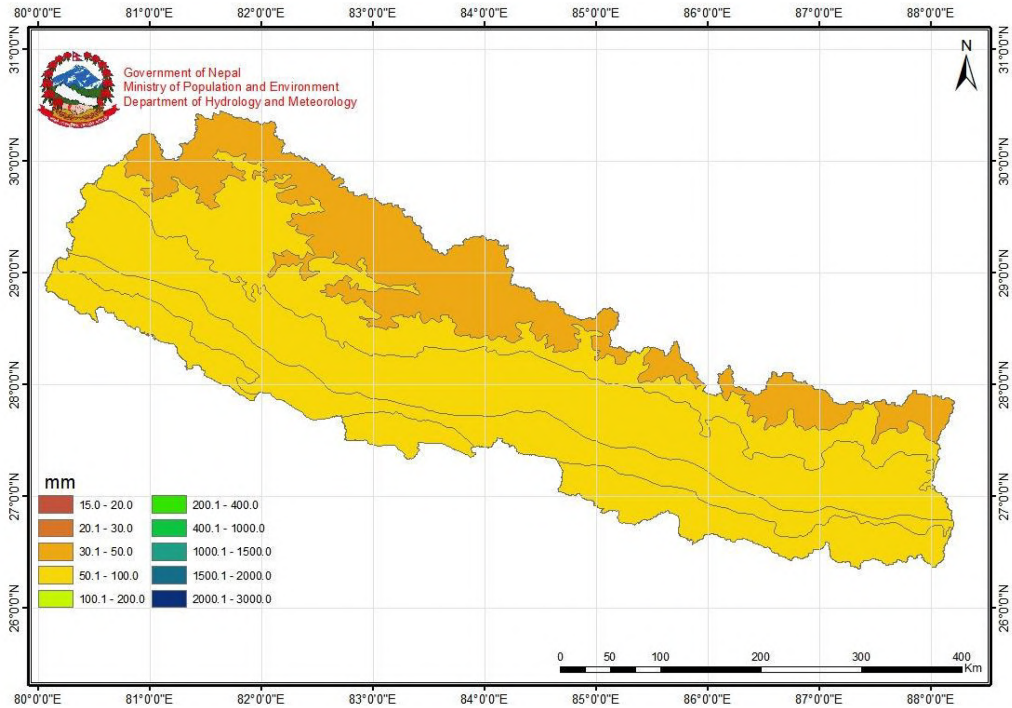

Figure 3.1.4b Post-Monsoon precipitation normal for physiographic regions

3.1.5. ANNUAL PRECIPITATION

Normal annual precipitation for all districts shows that Mustang receives the lowest rainfall (<400mm) whereas Kaski, Parbat, Tanahu, Lamjung, Nuwakot, Sindhupalchok, Sankhuwasabha, Ilam and Jhapa receive more than 2000mm of annual rain (Figure 3.1.5a). In physiographic regions, High Himalayas receives the least amount of rain (400-1000mm) and remaining regions receive higher rainfall (1500-2000mm) (Figure 3.1.5b).

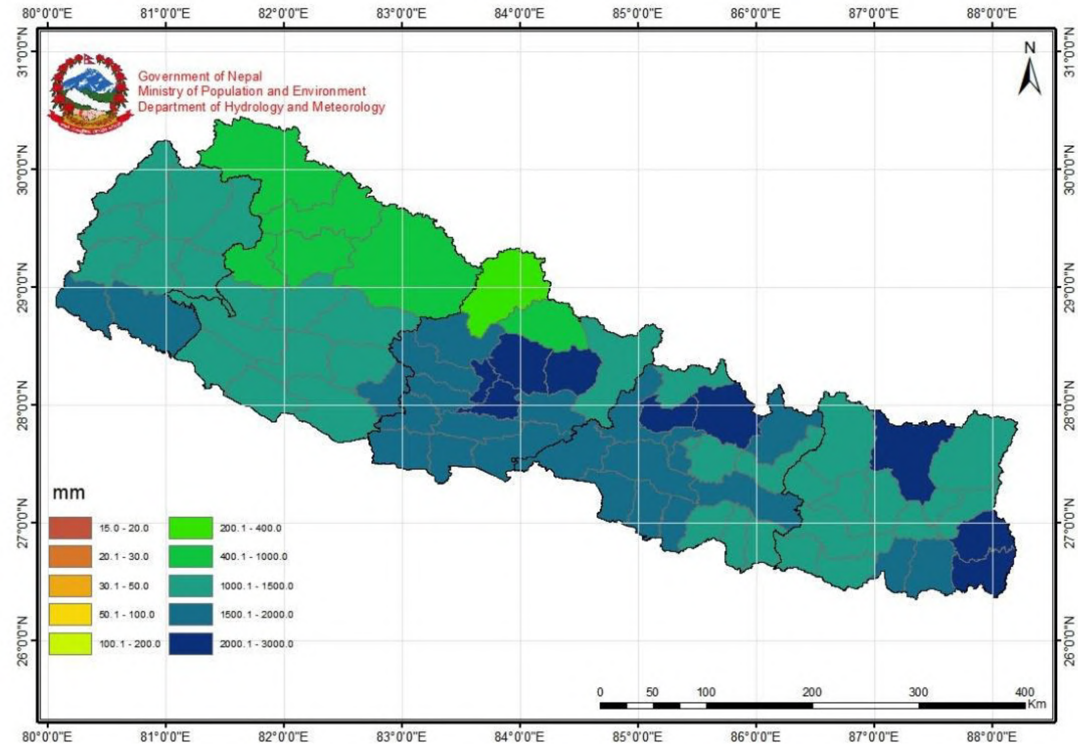

Figure 3.1.5a Annual precipitation normal for districts

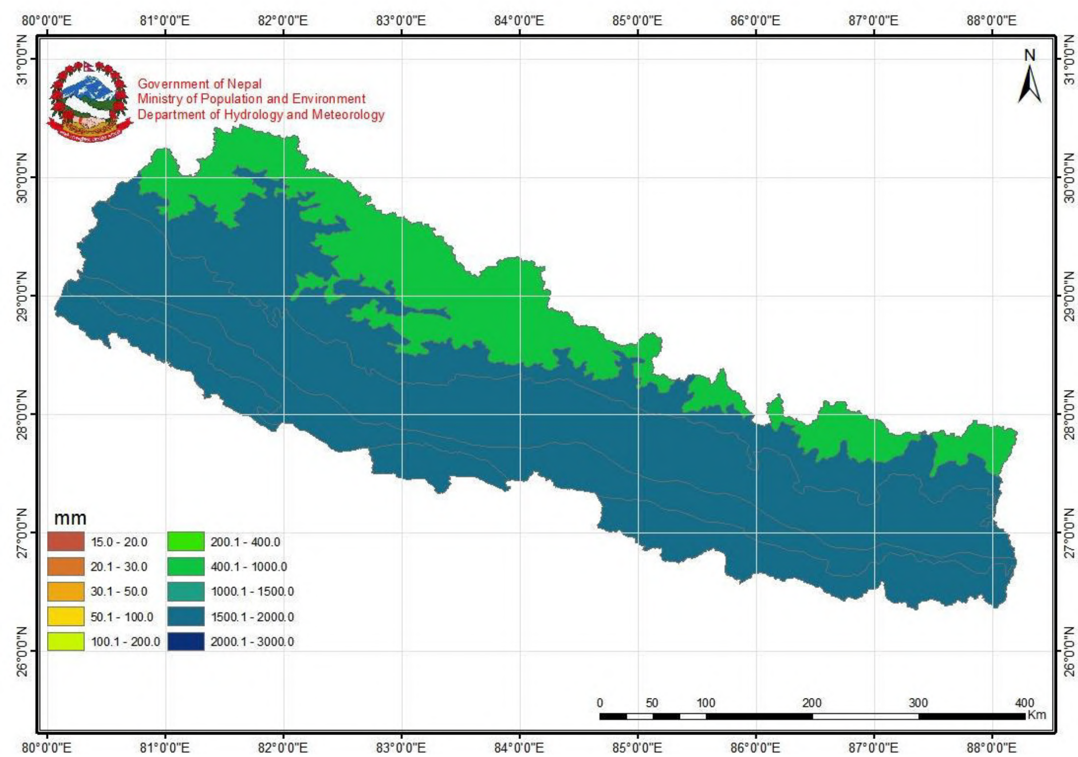

Figure 3.1.5b Annual precipitation normal for physiographic regions

3.2. NORMAL MAXIMUM TEMPERATURE

3.2.1 WINTER MAXIMUM TEMPERATURE

Manang has the lowest temperature (<0^{o}C) and all southern districts have above 20^{o}C normal winter maximum temperature (Figure 3.2.1a). In physiographic regions, High Himalayas have the lowest winter maximum temperature (5^{o}C-10^{o}C) and Siwaliks and Tarai regions have the highest winter maximum temperature (20^{o}C-25^{o}C) (Figure 3.2.1b).

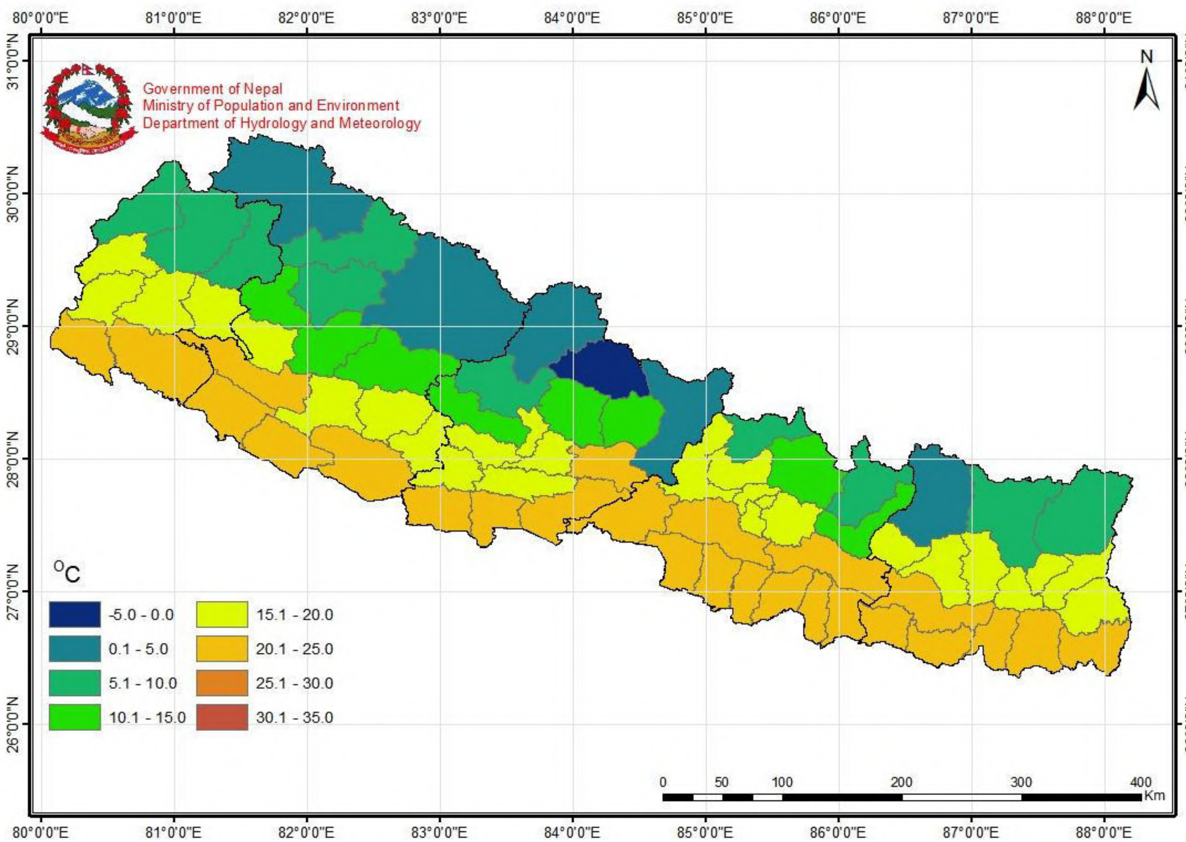

Figure 3.2.1a Winter maximum temperature normal for districts

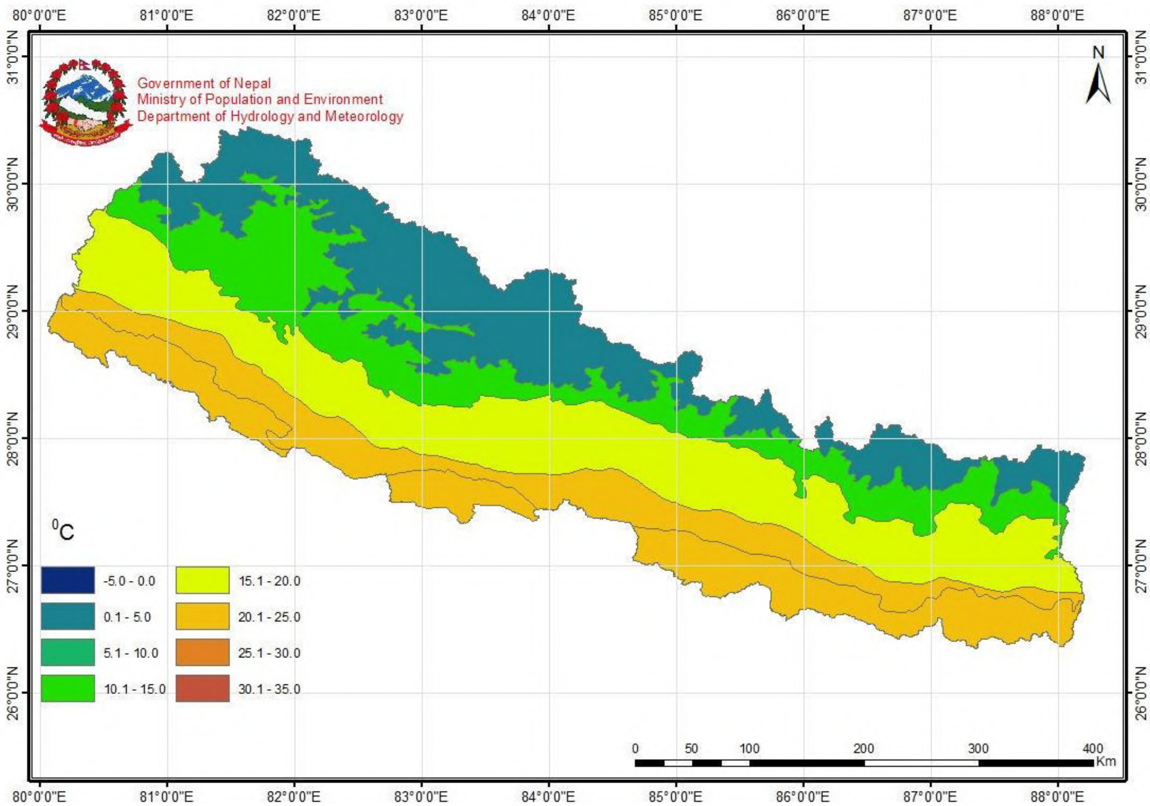

Figure 3.2.1b: Winter maximum temperature normal for physiographic regions

3.2.2. Pre–Monsoon Maximum Temperature

Three districts (Manang, Mustang and Dolpa) have the lowest temperature (<0^{o}C) whereas all Tarai districts and Surkhet, Tanahun and Udaypur have the highest (>30^{o}C) normal pre-monsoon maximum temperature (Figure 3.2.2a). The High Himalayas and High Mountains observe the lowest pre-monsoon maximum temperature (0^{o}C-5^{o}C) with highest temperature (30^{o}C-35^{o}C) in Siwaliks and Tarai physiographic regions (Figure 3.2.2b).

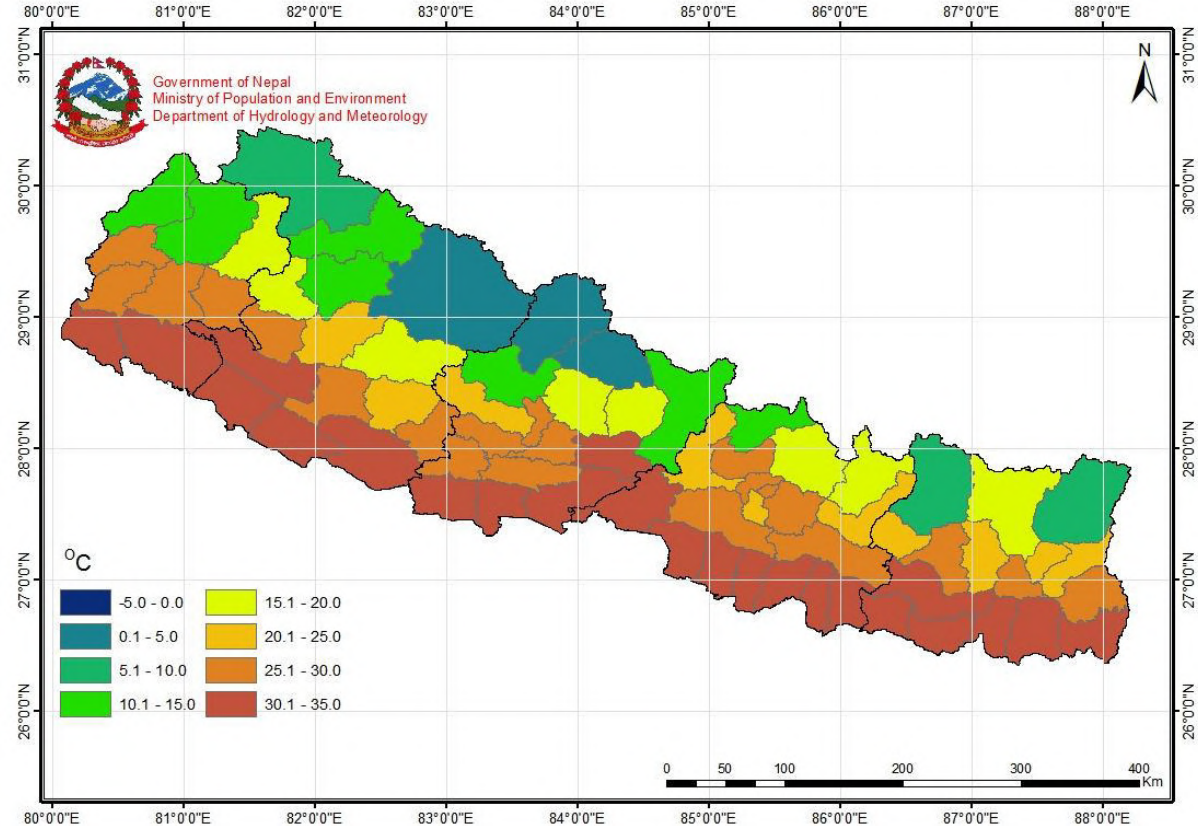

Figure 3.2.2a: Pre-Monsoon maximum temperature normal for districts

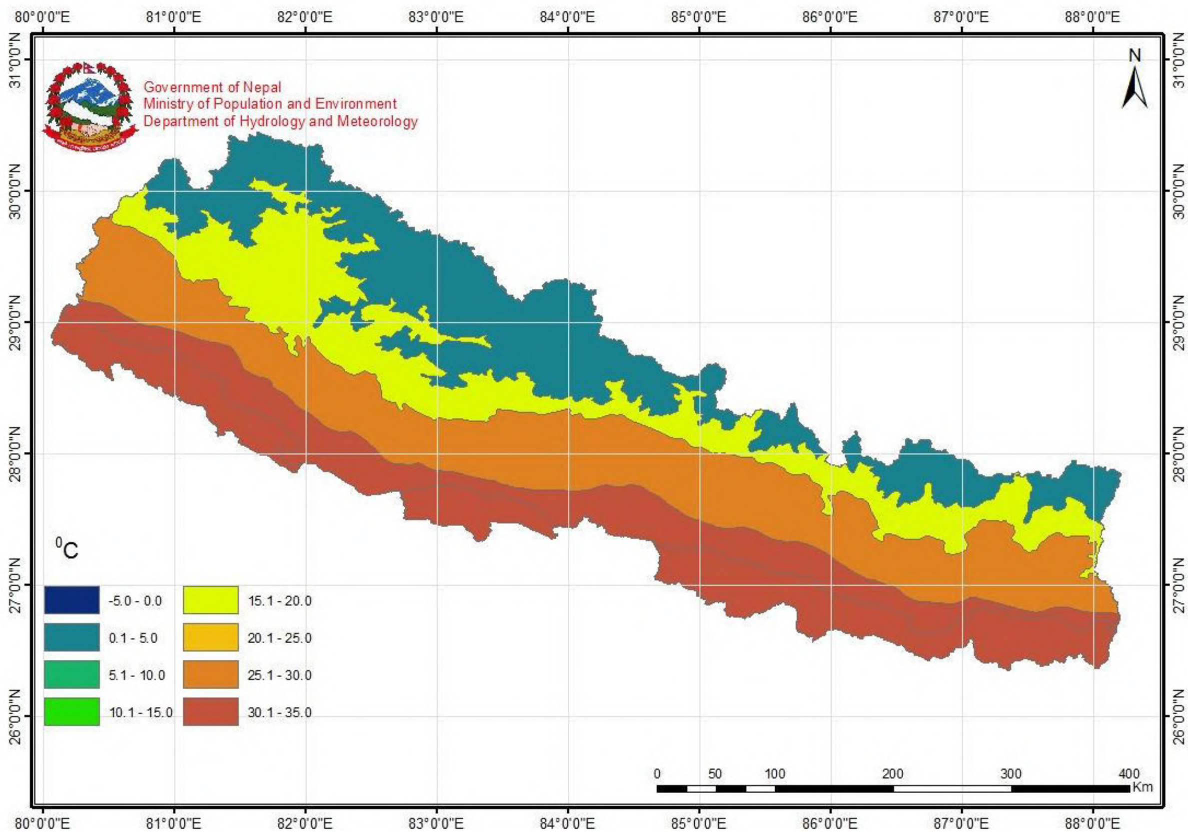

Figure 3.2.2b Pre-Monsoon maximum temperature normal for physiographic regions

3.2.3. Monsoon Maximum Temperature

Manang has the lowest (<10^{o}C) normal maximum temperature and all southern districts (Tarai) and Surkhet, Tanahun, Sindhuli and Udaypur have highest (>30^{o}C) normal maximum temperature (Figure 3.2.3a). In physiographic regions, the High Himalayas has the lowest (10^{o}C-15^{o}C) whereas the Siwaliks and the Tarai regions has the highest monsoon maximum temperature (30^{o}C-35^{o}C) (Figure 3.2.3b).

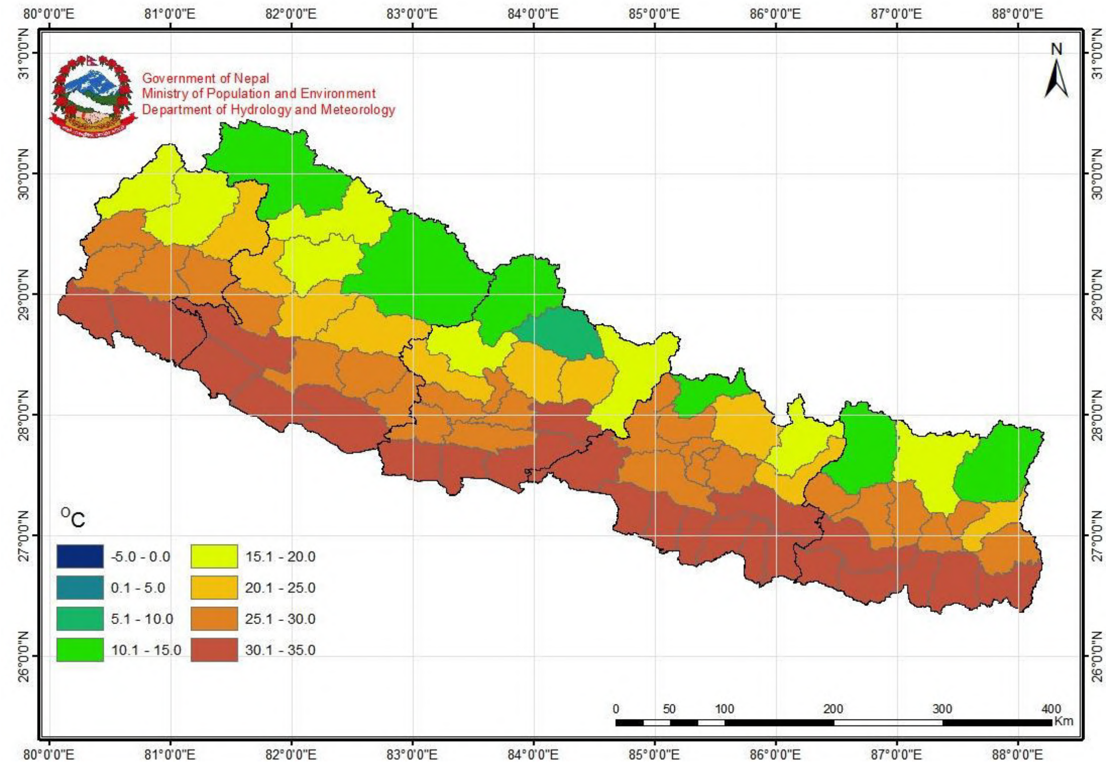

Figure 3.2.3a Monsoon maximum temperature normal for districts

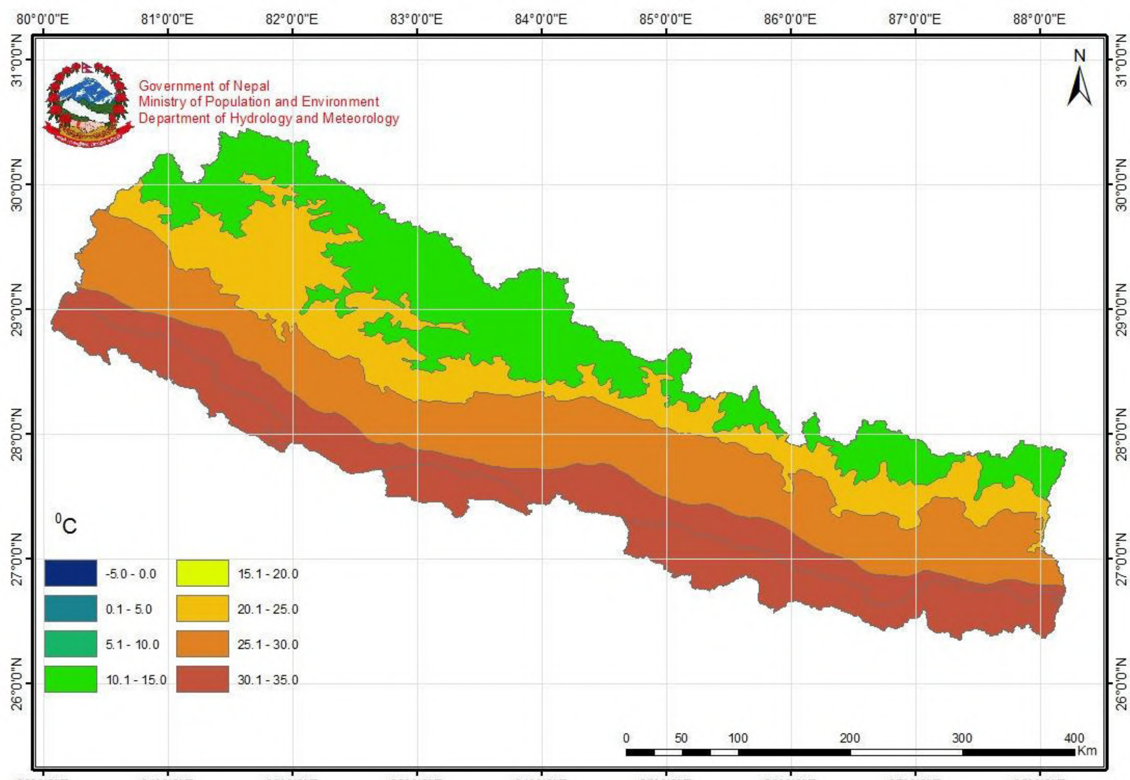

Figure 3.2.3b Monsoon maximum temperature normal for districts

3.2.4. POST-MONSOON MAXIMUM TEMPERATURE

Analysis of normal post-monsoon maximum temperature for districts shows lowest temperature (<5^{o}C) in Mustang and Manang and highest (> 30^{o}C) in majority of southern districts of EDR, CDR and WDR (Figure 3.2.4a). The High Himalayas has the lowest (0^{o}C-5^{o}C) and the Tarai region has the highest post-monsoon maximum temperature (30^{o}C-35^{o}C) (Figure 3.2.4b).

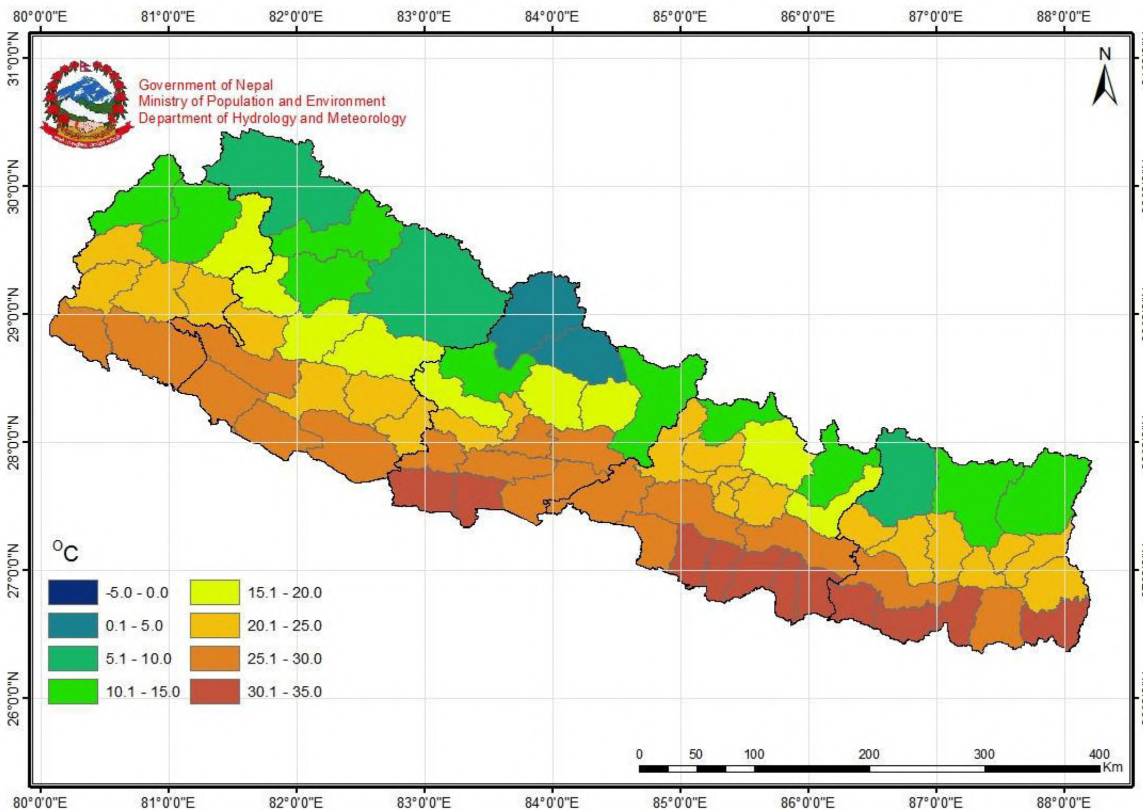

Figure 3.2.4a Post-Monsoon maximum temperature normal for districts

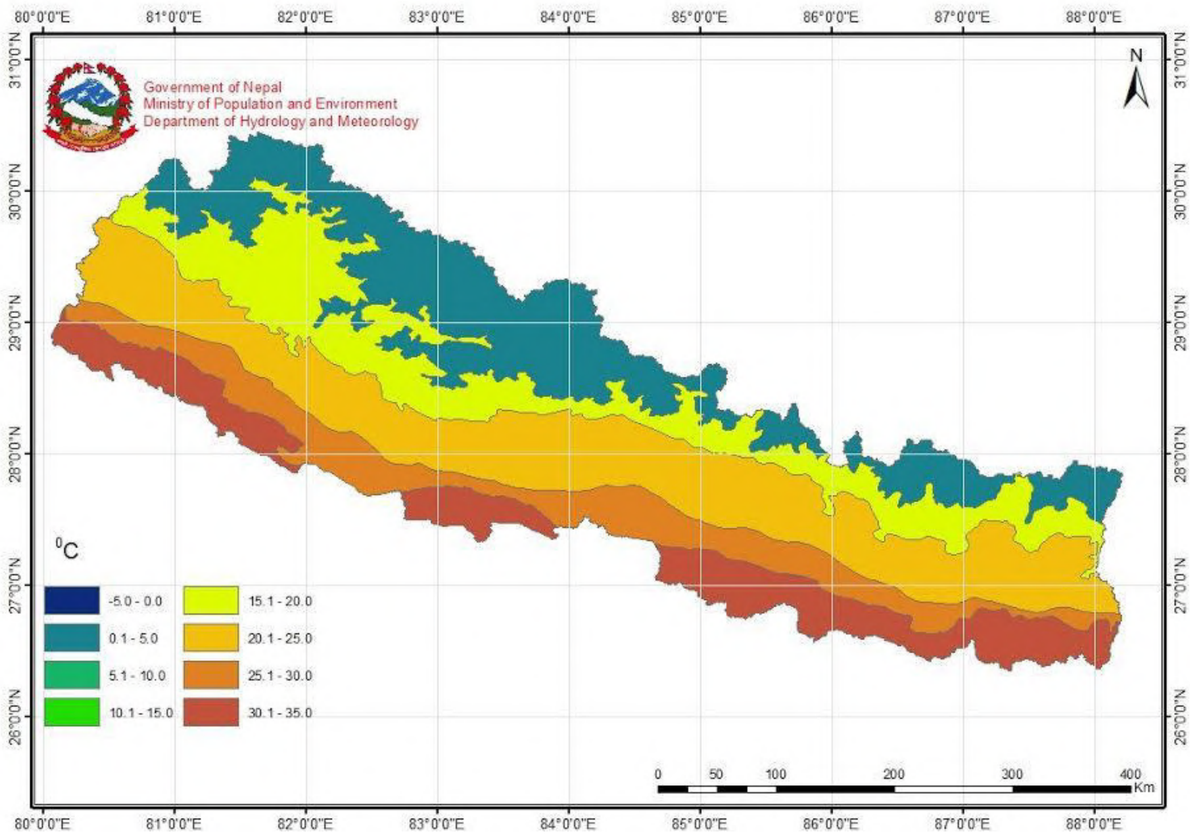

Figure 3.2.4b: Post-Monsoon maximum temperature normal for districts

3.2.5. Annual Maximum Temperature

Manang district has the lowest (<5°C) and most of the southern districts of Nepal have the highest normal annual maximum temperature above 30°C (Figure 3.2.5a). In physiographic regions, the High Himalayas has the lowest normal annual maximum temperature (5°C-10°C) whereas the Tarai region has the highest normal annual maximum temperature (>30°C) (Figure 3.2.5b).

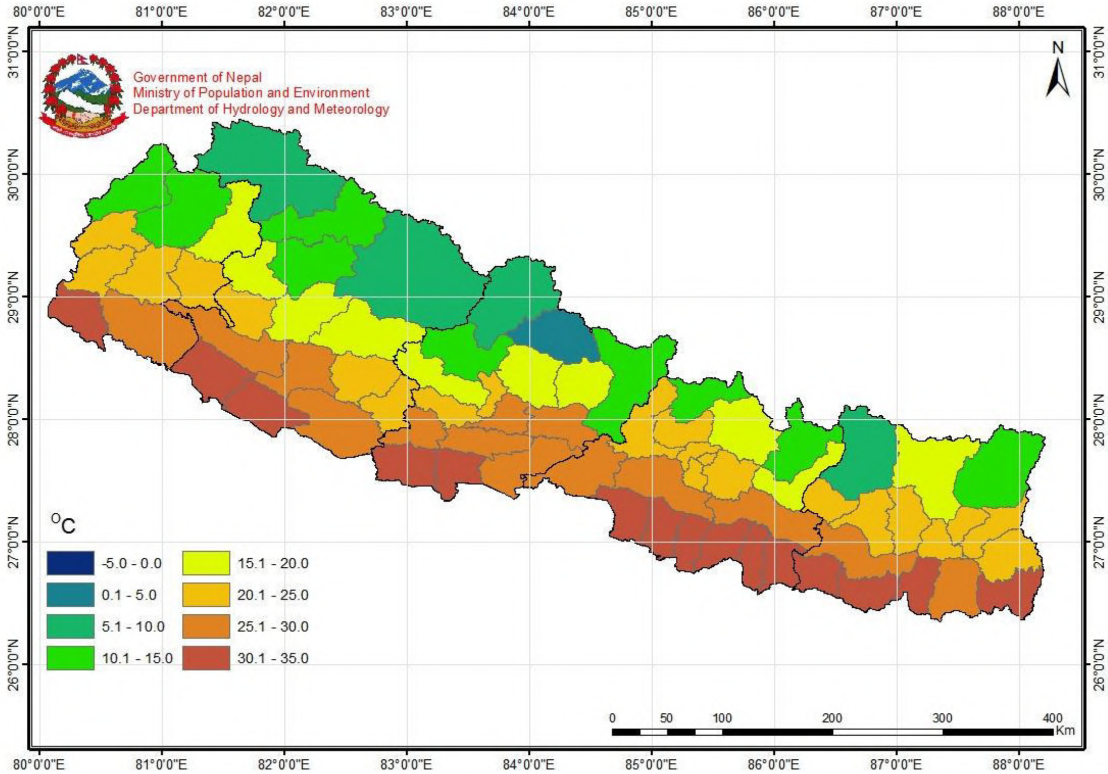

Figure 3.2.5a: Annual maximum temperature normal for districts

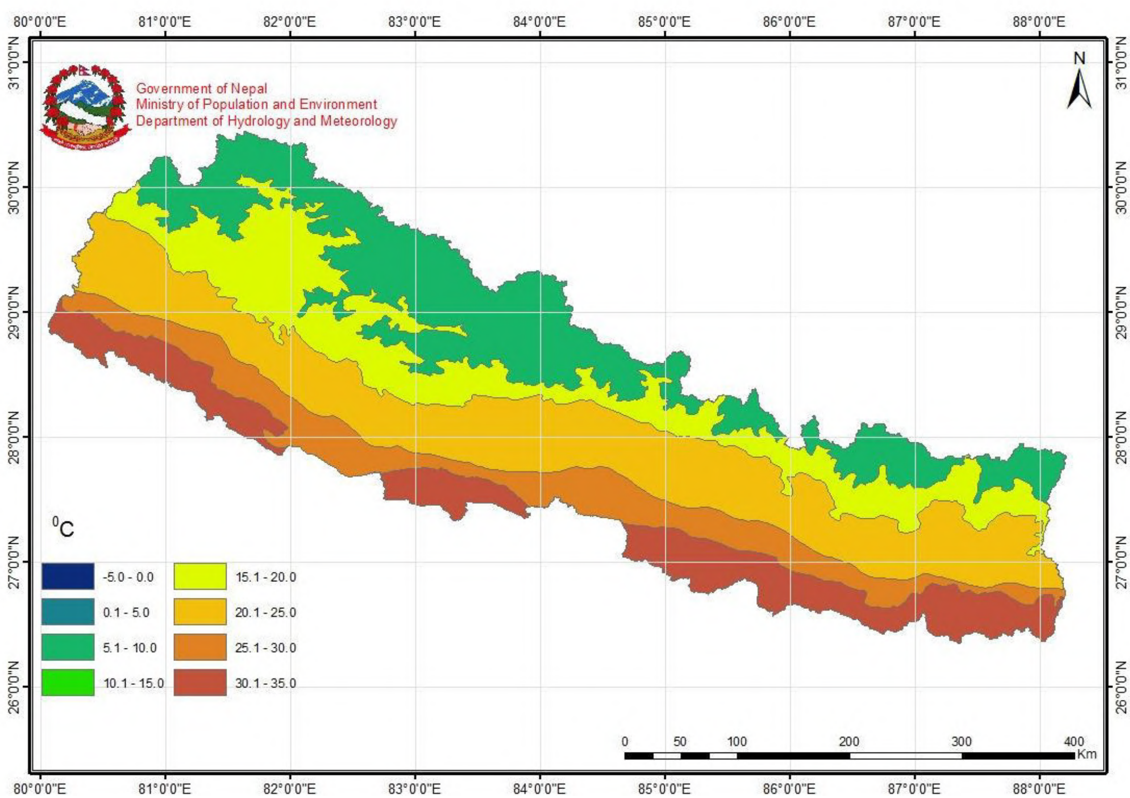

Figure 3.2.5b: Annual maximum temperature normal for physiographic regions

3.3. Normal Minimum Temperature

3.3.1 Winter Minimum Temperature

With regard to normal winter minimum temperature for the districts, northern districts of MWDR, WDR and Solukhumbu have the lowest (<-5^{o}C) whereas all southern districts of EDR, CDR and Kapilbastu and Rupandehi districts have the highest normal winter minimum temperature (10^{o}C-15^{o}C) (Figure 3.3.1a). The High Himalayas has the lowest normal winter minimum temperature (-10^{o}C to -5^{o}C) and highest normal winter minimum temperature in the Tarai region ranges from 10^{o}C to 15^{o}C (Figure 3.3.1b).

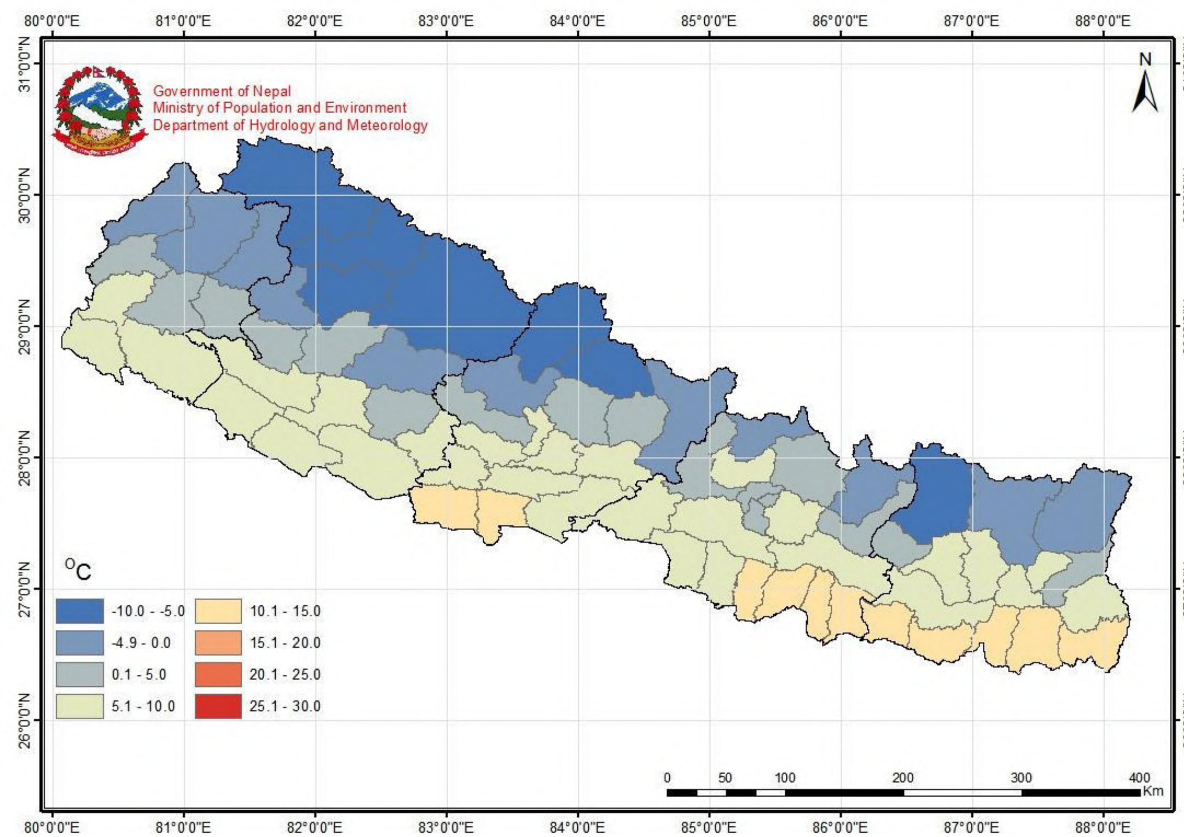

Figure 3.3.1a: Winter minimum temperature normal for districts

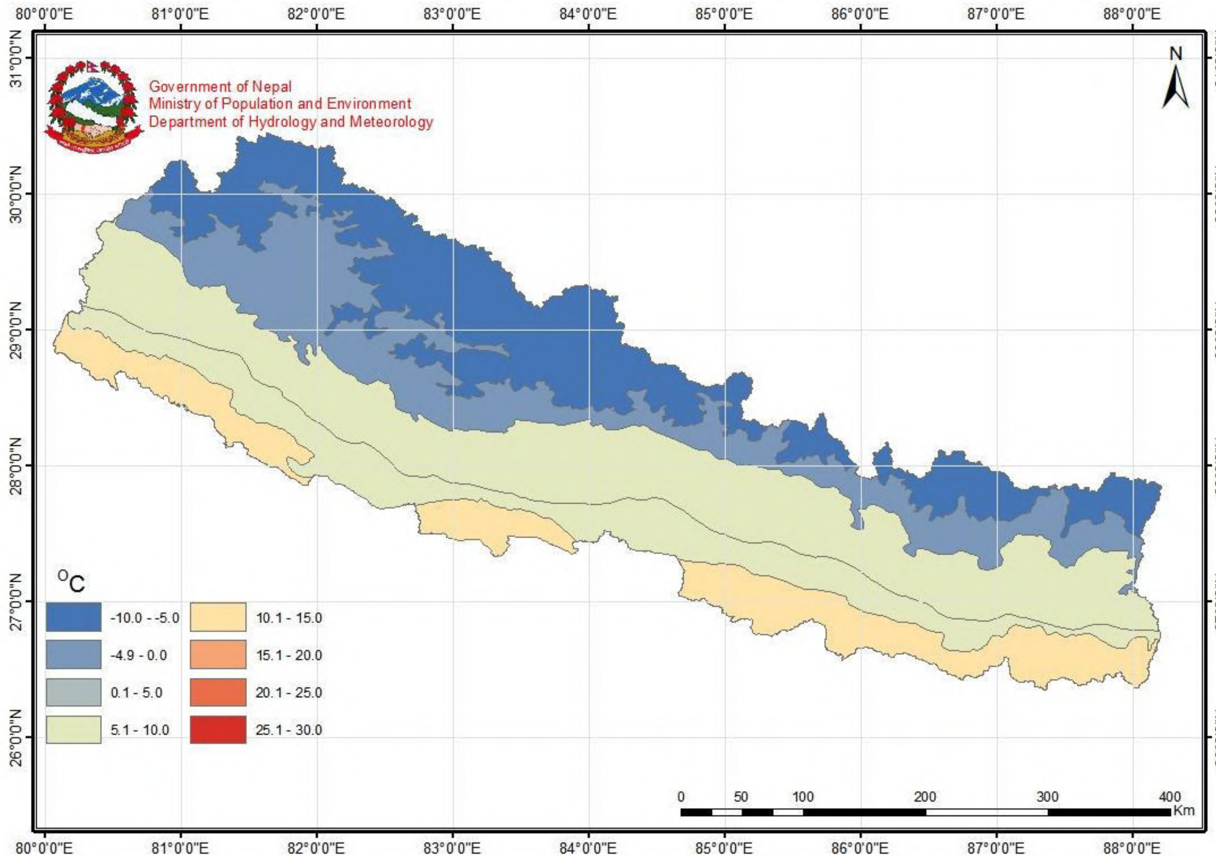

Figure 3.3.1b: Winter minimum temperature normal for physiographic regions

3.3.2 Pre–Monsoon Minimum Temperature

Manang district has the lowest (<-5°C) and all southern districts have the highest normal winter minimum temperature and it ranges between 15°C and 20°C (Figure 3.3.2a). In physiographic regions, the High Himalayas has the lowest normal pre-monsoon minimum temperature and it lies in between -5°C and 0°C. As compared to other regions, Siwaliks and Tarai have the highest normal pre-monsoon minimum temperature (15°C-20°C) (Figure 3.3.2b).

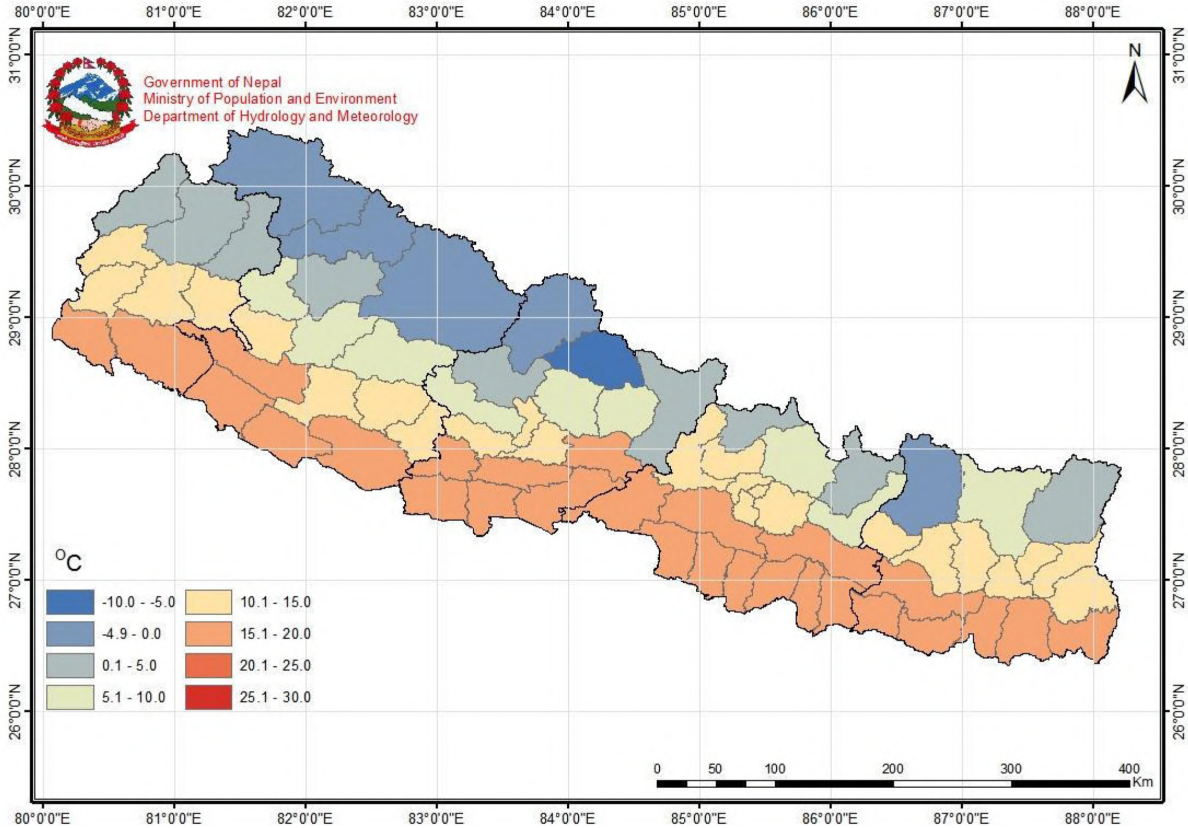

Figure 3.3.2a: Pre-Monsoon minimum temperature normal for districts

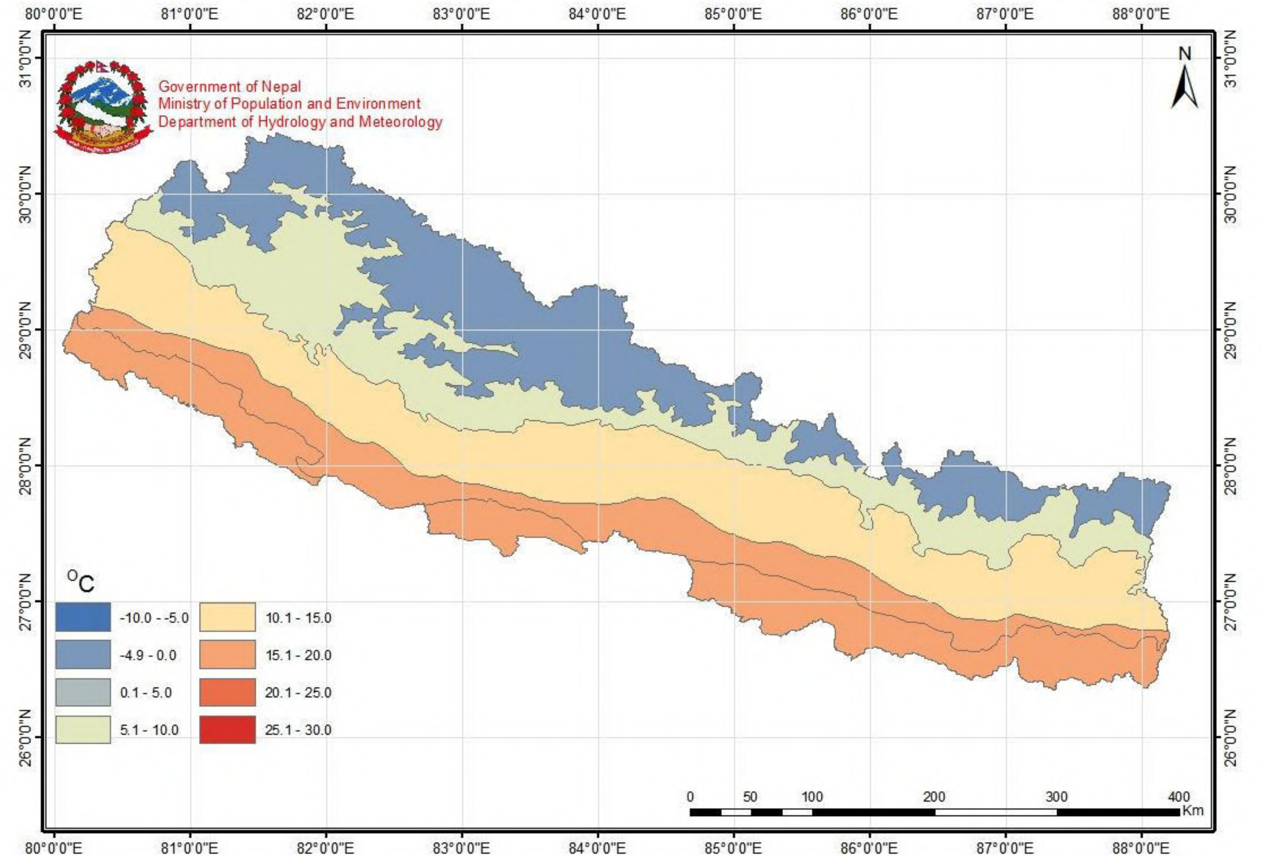

Figure 3.3.2b: Pre-Monsoon minimum temperature normal for physiographic regions

3.3.3 MONSOON MINIMUM TEMPERATURE

Humla, Dolpa, Mustang and Manang districts have the lowest (<5°C) and some of the southern districts of EDR, CDR and WDR have the highest normal monsoon minimum temperature (25°C-30°C) (Figure 3.3.3a). In physiographic regions, the High Himalayas has the lowest (0°C-5°C) and Tarai region has the highest normal monsoon minimum temperature which ranges between 25°C and 30°C (Figure 3.3.3b).

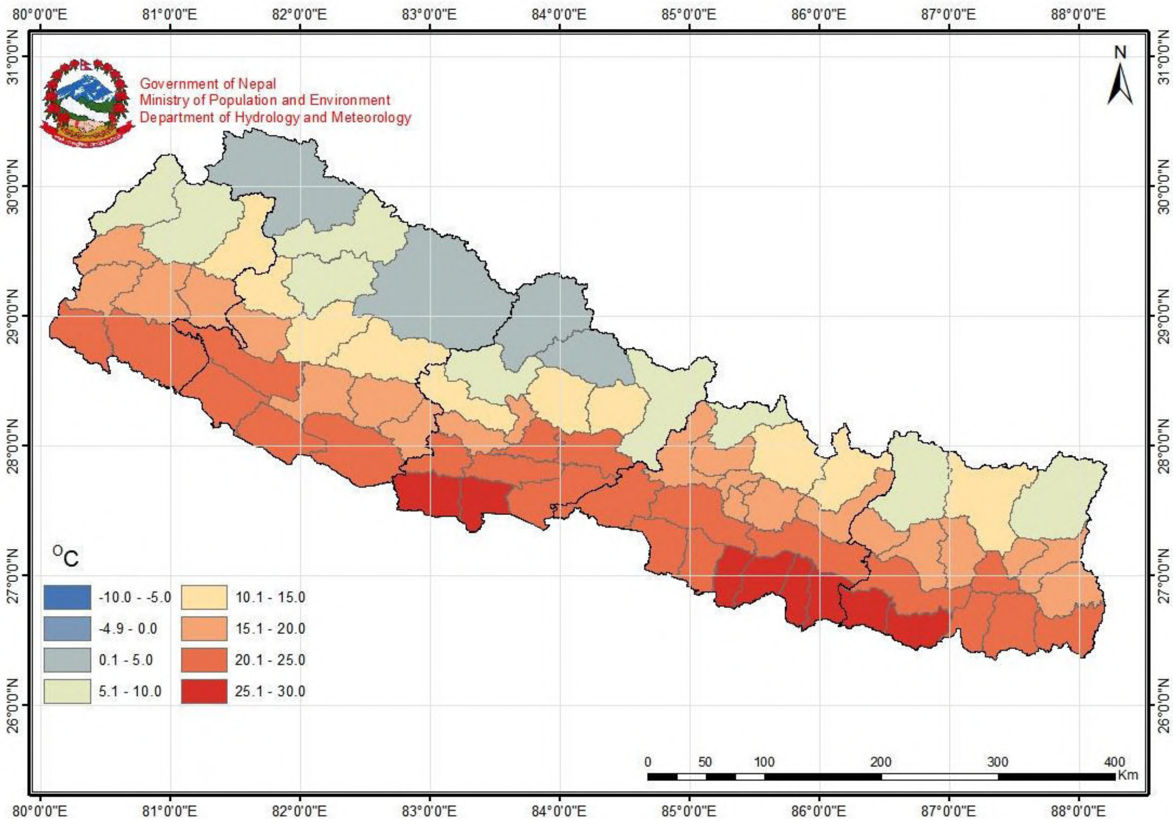

Figure 3.3.3a Monsoon minimum temperature normal for districts

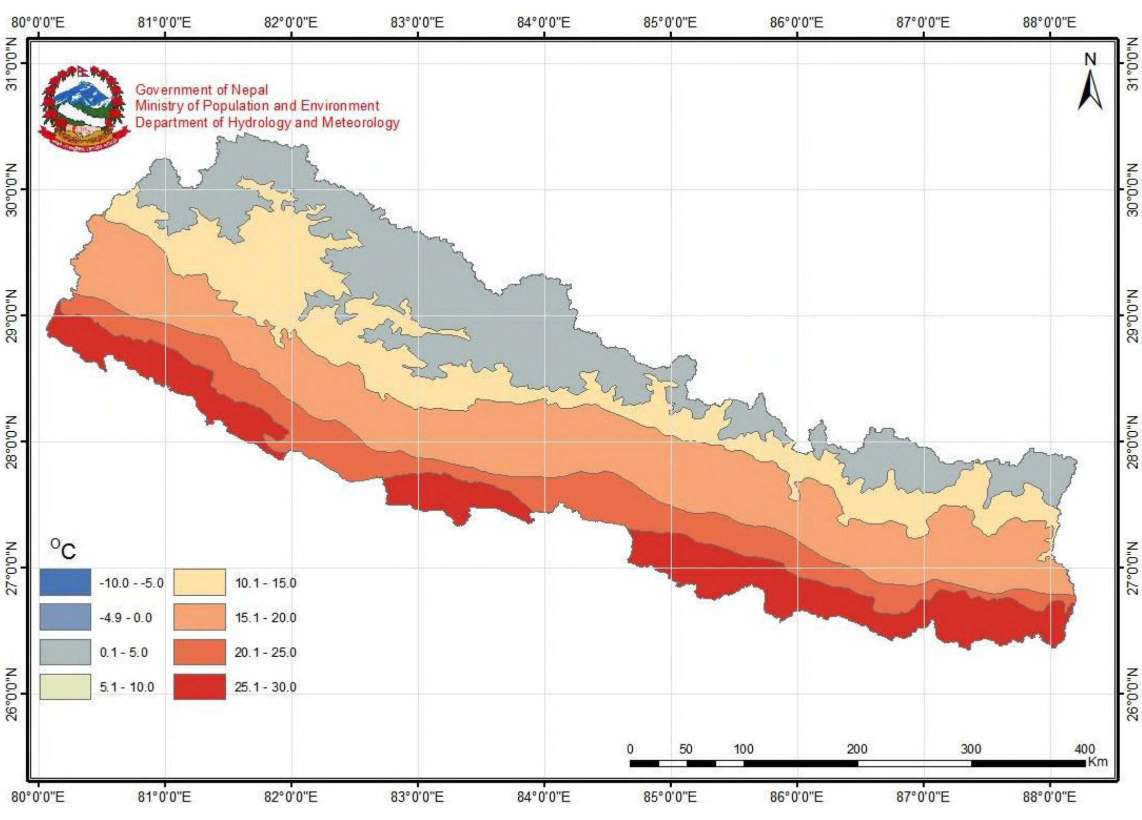

Figure 3.3.3b Monsoon minimum temperature normal for districts

3.3.4 POST-MONSOON MINIMUM TEMPERATURE

Normal post-monsoon minimum temperature for Dolpa, Mustang and Manang districts is found lowest (<-5°C) and highest (15°C-20°C) for southern districts of Nepal, except Dang (Figure 3.3.4a). The high Himalayas have the lowest normal post-monsoon minimum temperature and it ranges from -10°C to -5°C. Siwaliks and the Tarai regions have the highest normal post-monsoon minimum temperature (15°C-20°C) (Figure 3.3.4b)

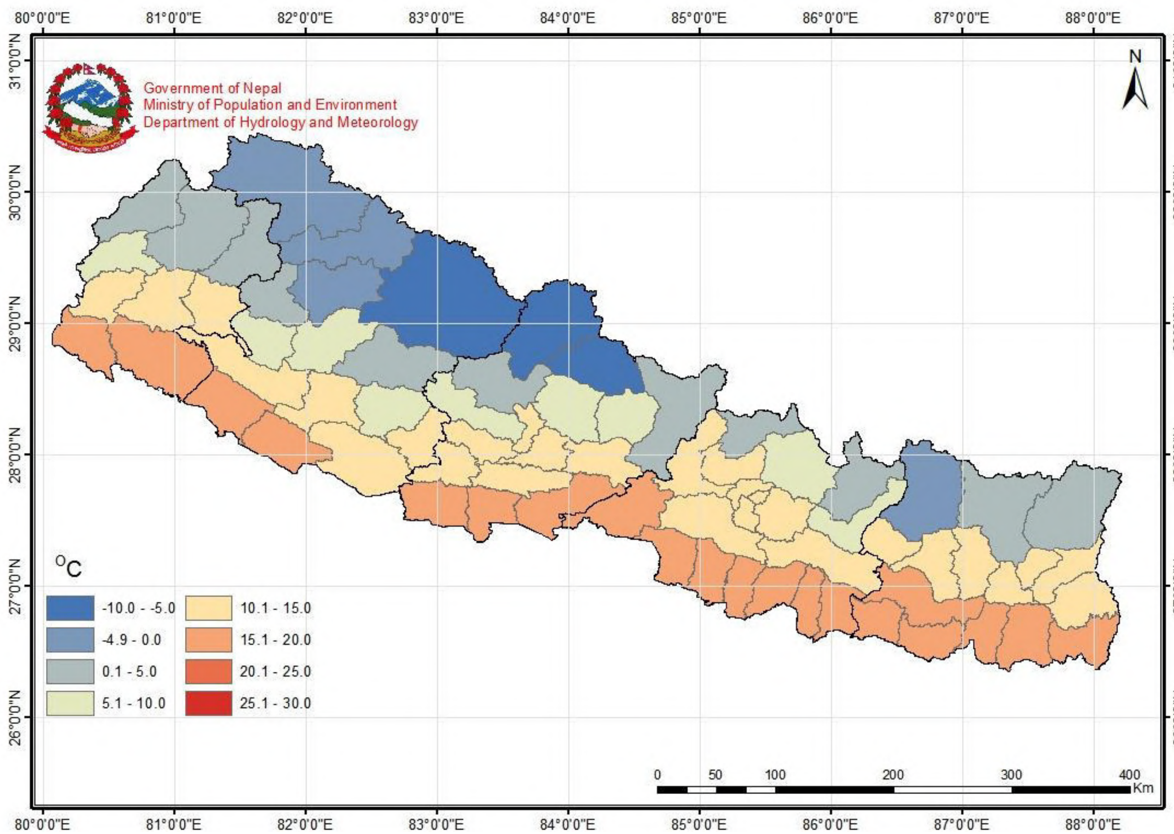

Figure 3.3.4a Post Monsoon minimum temperature normal for districts

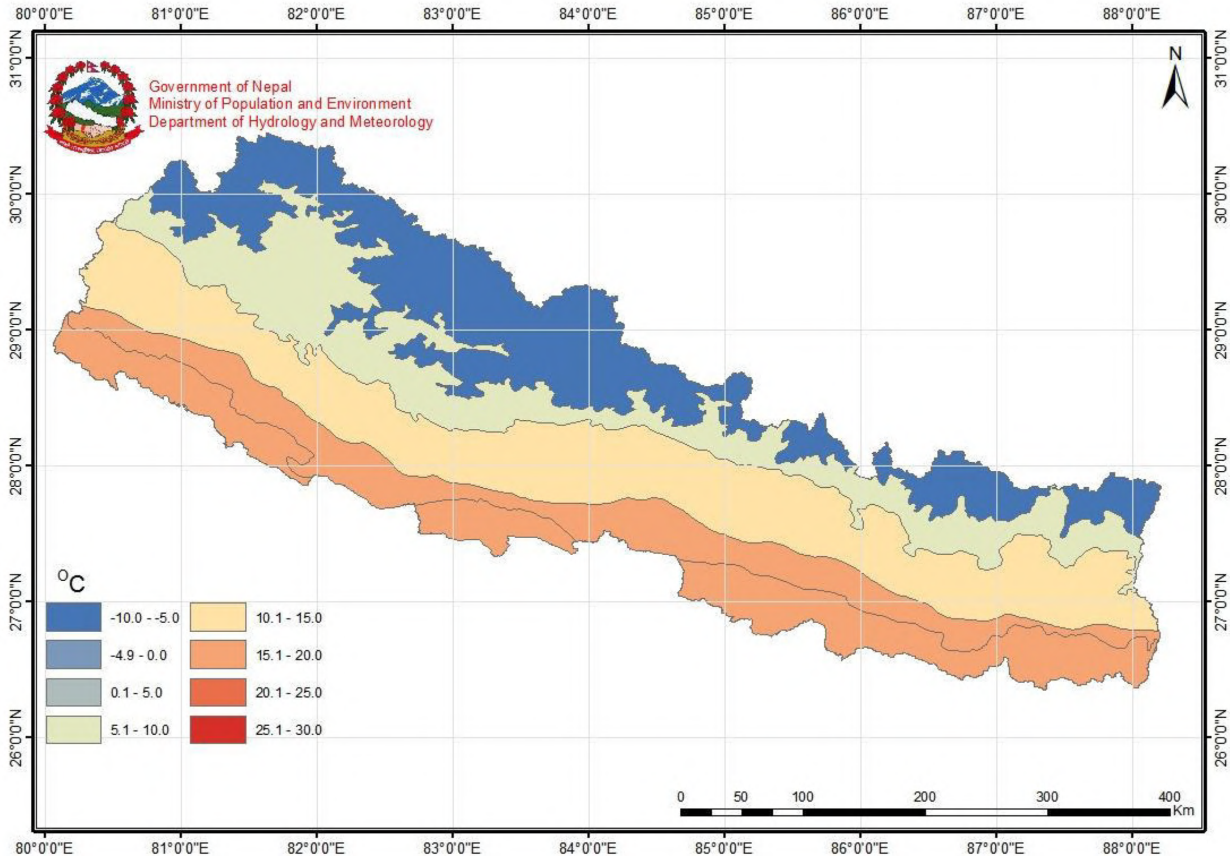

Figure 3.3.4b Post Monsoon minimum temperature normal for districts

3.3.5 ANNUAL MINIMUM TEMPERATURE

Analysis of 44 years of temperature data shows lowest (<0°C) normal annual minimum temperature for Humla, Mugu, Dolpa, Mustang and Manang districts and highest (15°C-20°C) for southern districts of Nepal including Surkhet, Tanahun, Makwanpur, Sindhuli and Udaypur (Figure 3.3.5a). The High Himalayas has the lowest normal annual minimum temperature and it ranges in between -5°C and 0°C whereas the Siwaliks and the Tarai regions have the highest normal monsoon minimum temperature and it lies in between 15°C and 20°C (Figure 3.3.5b).

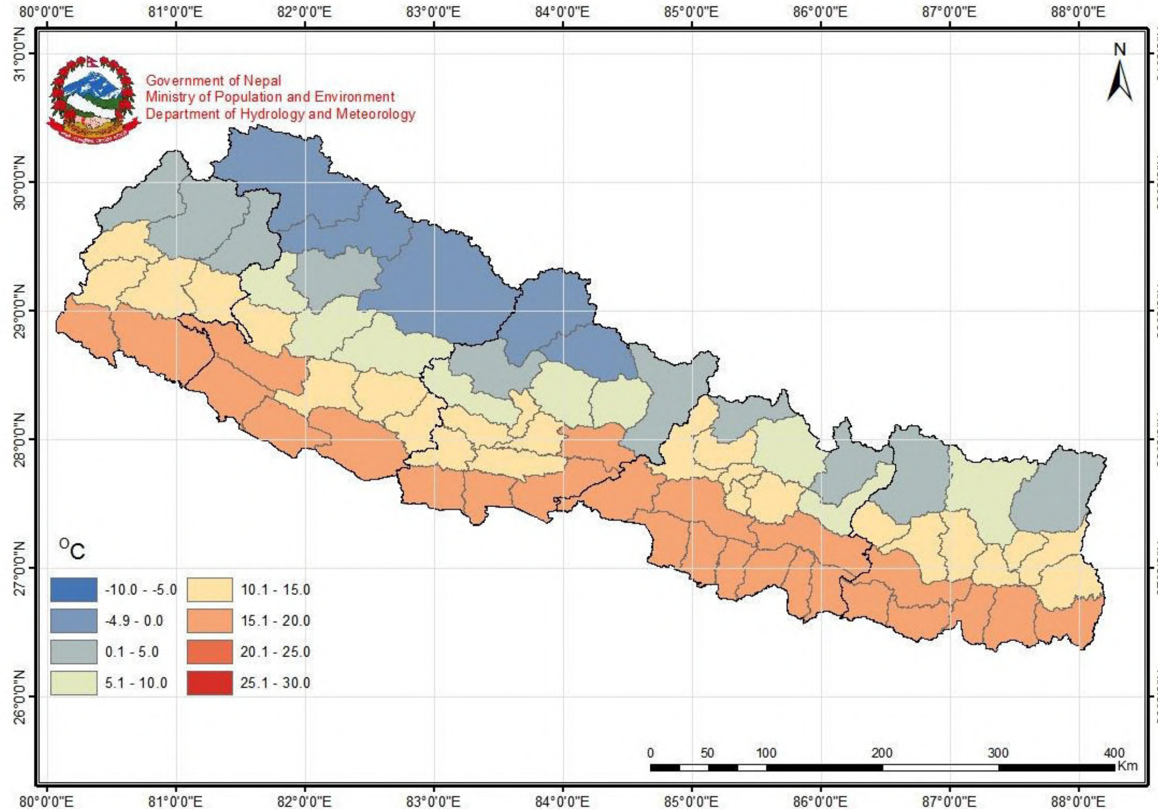

Figure 3.3.5a Annual minimum temperature normal for districts

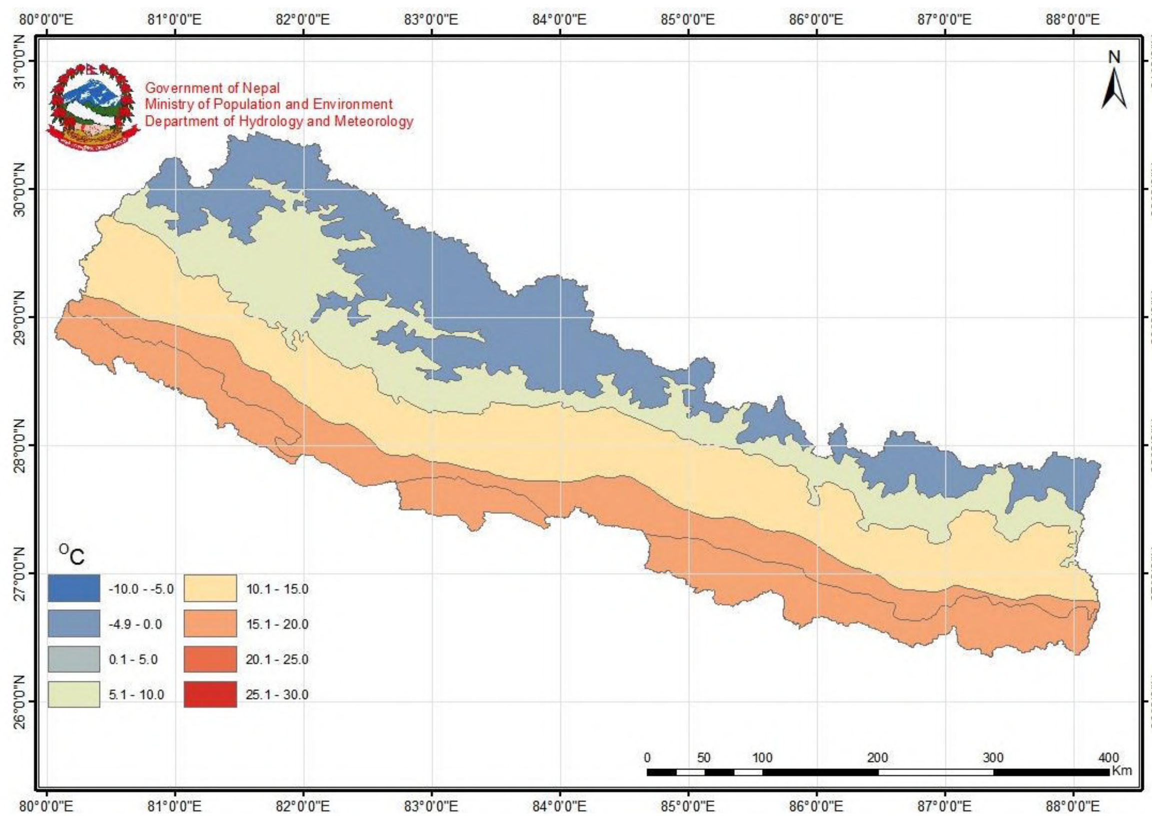

Figure 3.3.5b Annual minimum temperature normal for districts

CHAPTER 4: ALL NEPAL CLIMATIC TRENDS

Seasonal and annual climatic trends averaged for Nepal is discussed in this chapter. Nepal's average precipitation, maximum temperature and minimum temperature trends for four seasons and annually is given in Table 4.

Table 4: Climatic Trend of Nepal

Seasons	Precipitation (mm/yr)		Maximum Temperature (°C/yr)		Minimum Temperature (°C/yr)	
	α	Q	α	Q	α	Q
Winter	0	-0.072	***	0.054	0	-0.009
Pre-monsoon	0	-0.081	***	0.051	0	-0.003
Monsoon	0	-0.085	***	0.058	*	0.014
Post-monsoon	0	-0.324	***	0.056	0	-0.005
Annual	0	-1.333	***	0.056	0	0.002

Note: Significant: * 95% CL, ** 99% CL and * 99.9% CL ; insignificant at 95% CL : + , 0**

4.1 ALL NEPAL MAXIMUM TEMPERATURE TREND

All Nepal maximum temperature trend is significantly positive at 99.9% CL annually and for all seasons. The annual maximum temperature trend is 0.056^{0}C/yr. Monsoon season has the significantly highest positive trend of 0.058°C/yr and pre-monsoon has the lowest trend of 0.051°C/yr. Seasonal and annual time series of maximum temperature of Nepal shows increasing trend with inter-annual variability in all seasons (Figure 4.1).

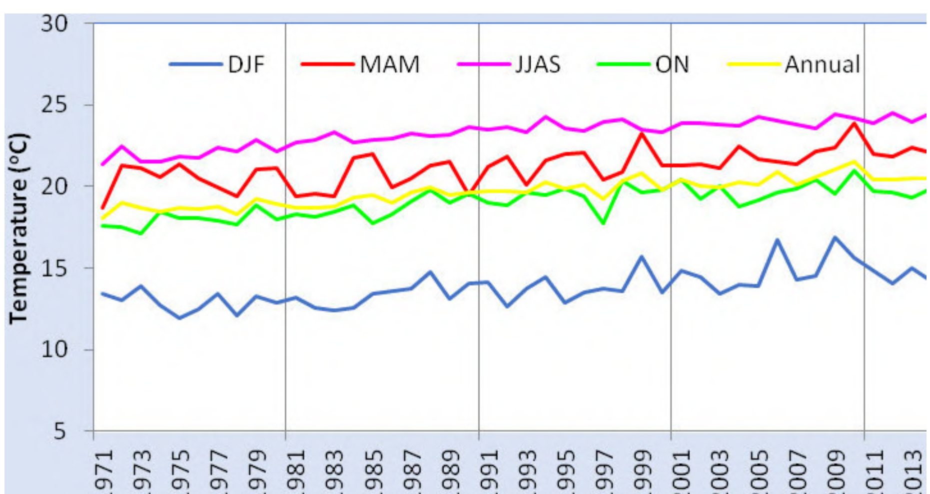

Figure 4.1: Seasonal and annual maximum temperature time series of Nepal

Note: DJF means months of December, January and February; MAM is for March, April and May; JJAS is for June, July, August and September; and ON denotes for October and November.

4.2 All Nepal Minimum Temperature Trend

All Nepal average minimum temperature trend shows increasing trend annually and in the monsoon season but only monsoon trend is significant at 95% CL (Table 4). During outher seasons minimum temperature is in decreasing trend but they are insignificant at 95% CL. Seasonal and annual time series of all Nepal averaged minimum temperature is shown in Figure 4.2.

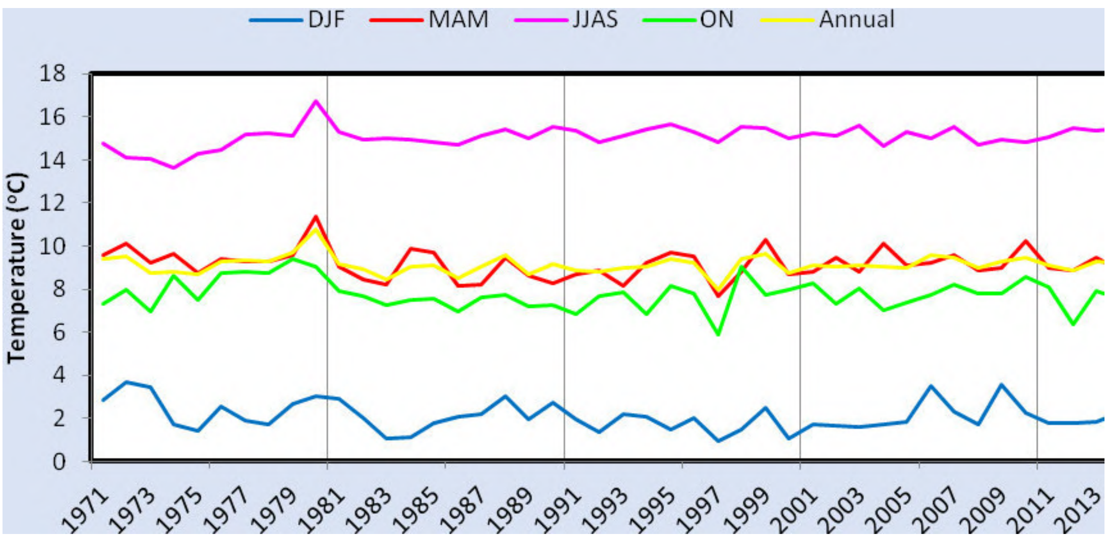

Figure 4.2: Seasonal and annual minimum temperature trend of Nepal

4.3 All Nepal Precipitation Trend

Seasonal and annual All Nepal precipitation trends show decreasing precipitation in all seasons with the highest decreasing trend (-0.3 mm/yr) in the post-monsoon season (Table 4). Annual decrease in precipitation in Nepal is 1.3 mm/yr. However, all the decreasing trends are insignificant. All Nepal average precipitation time series is shown Figure 4.3.

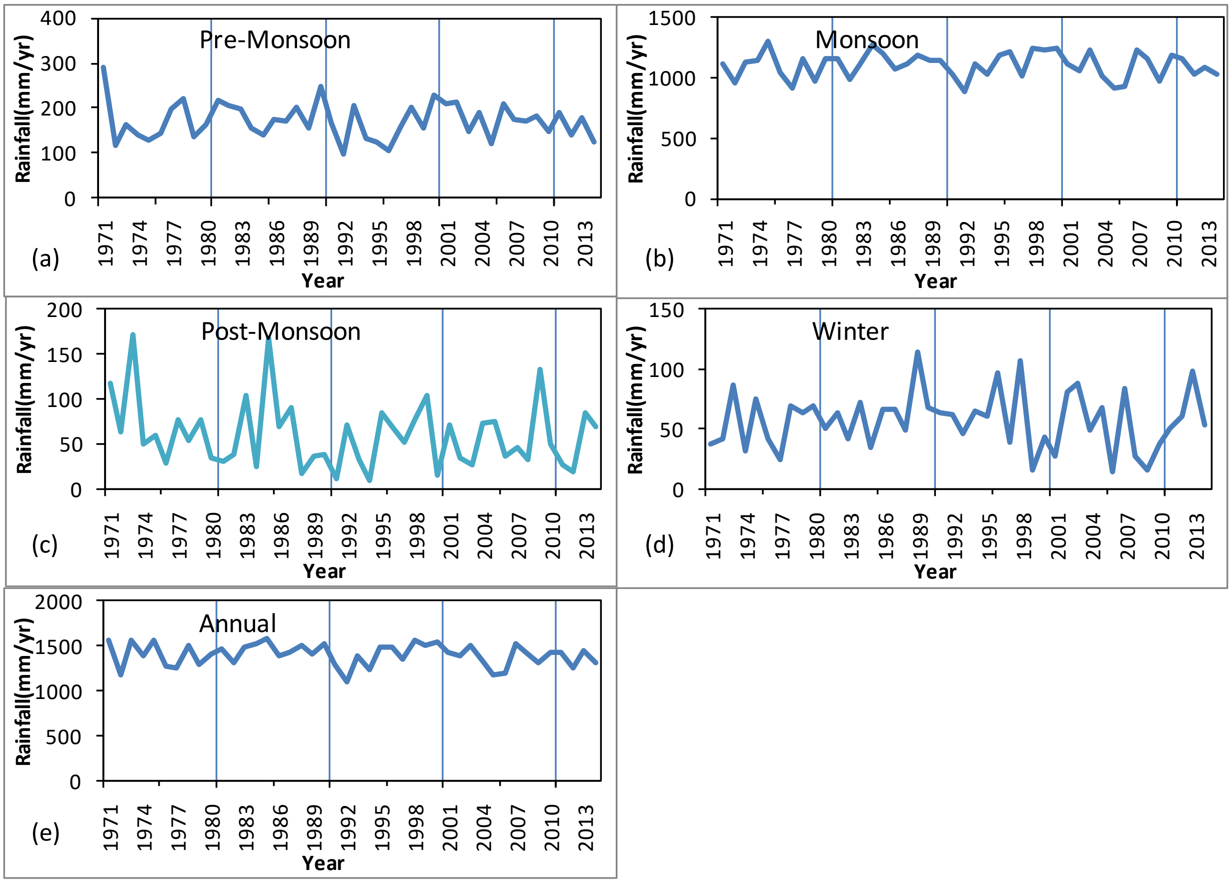

Figure 4.3 Precipitation time series of Nepal (a) Pre-Monsoon (b) Monsoon (c) Post-Monsoon (d) Winter (e) Annual

4.4 Summary of All Nepal Climate Trends

Among above three climatic trends, All Nepal maximum temperature shows significantly increasing trend annually and in all seasons. All Nepal minimum temperature shows significant positive trend only in monsoon season, while no significant trends are found for precipitation.

CHAPTER 5: PRECIPITATION TRENDS FOR DISTRICTS AND PHYSIOGRAPHIC REGIONS

The distribution of districts with positive and negative seasonal and annual precipitation trends is given in Table 5.1 and annual and seasonal precipitation trends for districts is given in Table A5 in the Appendix. Seasonal and annual precipitation trends in 5 physiographic regions are shown in Table 5.2.

Table 5.1: Distribution of districts with positive and negative seasonal and annual precipitation trends

	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
Number of districts with negative trend	42 (0)	35 (3)	47 (5)	73 (2)	47 (8)
Number of districts with positive trend	33 (0)	40 (4)	28 (2)	2(0)	28(3)

Note: Number in parenthesis indicates number of districts with significant trend at 95% or higher confidence level (Table A5 in Appendix)

Table 5.2: Seasonal and annual precipitation trends in physiographic regions of Nepal

Physiographic Regions	Winter		Pre-monsoon		Monsoon		Post-monsoon		Annual	
	α	Trend (mm/yr)	α	Trend (mm/yr)	α	Trend (mm/yr)	α	Trend (mm/yr)	α	Trend (mm/yr)
Tarai	0	0.09	+	1.24	0	0.51	0	-0.26	0	0.49
Siwaliks	0	0.08	0	0.75	0	-0.60	0	-0.38	0	-1.48
Mid Mountain	0	0.03	0	0.03	0	-0.45	0	-0.43	0	-1.58
High Mountains	0	-0.06	0	-0.82	0	-1.19	0	-0.50	+	-3.17
High Himalayas	0	-0.03	*	-0.74	0	-0.21	0	-0.32	+	-1.46

Note: Significance (α): * 95% CL, ** 99% CL and * 99.9% CL ; insignificant at 95% CL : + , 0**

5.1 WINTER PRECIPITATION TREND

Forty two districts have negative trends and 33 districts have positive trends in winter precipitation but these trends are insignificant in all districts (Table 5.1). Winter precipitation trends for the districts is shown Figure 5.1. The positive trends are observed in the southern districts of FWDR, northern and southern districts of MWDR and WDR and northern districts of EDR (Figure 5.1). Rest of the districts, mainly southern districts in CDR and EDR have negative trends in winter precipitation. The trend values of each district along with significance level are given in Table A5 in the Appendix. Though insignificant, the highest increasing trend (0.51mm/yr) is observed in Humla and highest decreasing trend (-0.60mm/yr) is detected in Rasuwa (Table A5 in Appendix).

Winter precipitation trends in 5 physiographic regions (Table 5.2) show insignificant trends (at 95% CL). Tarai, Siwaliks and Middle Mountains show slightly increasing winter precipitation trend. The High Mountains and High Himalayas show slightly decreasing winter precipitation. It is noteworthy that both negative and positive trend values are less than 0.1mm/yr. Though insignificant, the highest positive trend is observed in Tarai and the highest negative trend in High Mountains (Table 5.2).

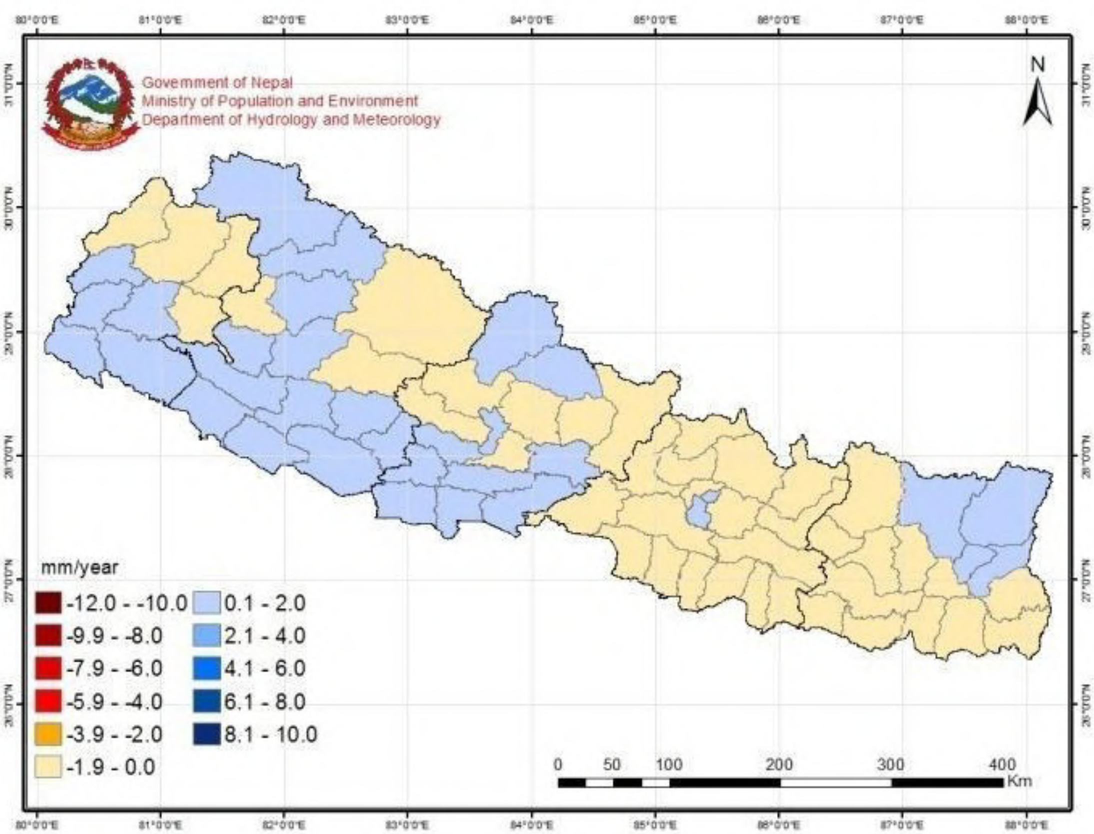

Figure 5.1a: Winter precipitation trend for districts.

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

5.2 PRE-MONSOON PRECIPITATION TREND

In pre-monsoon season, 40 districts show positive precipitation trend with significant only in 4 districts and 35 districts have negative precipitation trend with significant only in 3 districts at 95% or higher CL (Table 5.1). Four districts with significantly positive trends are Morang, Sunsari, Saptari and Mahottari in the Tarai region of EDR and CDR (Figure 5.2). The significant negative districts are Humla, Rasuwa and Ramechhap (Figure 5.2). The significantly highest increasing trend (2.2mm/yr) is observed in Sunsari and the significantly highest negative trend (-1.3mm/yr) is observed in Rasuwa (Table A5 in Appendix)

Increasing trend of pre-monsoon precipitation is observed in Tarai, Siwaliks and Middle Mountains, while decreasing trend is observed in High Mountains and High Himalayas physiographic regions (Table 5.2). These trends are insignificant, except in the High Himalayan region (significant negative trend at 95% CL). Though insignificant, the highest positive trend value (1.24mm/yr) is found in Tarai and it is noteworthy to mention that pre-monsoon precipitation is increasing in lower elevation and decreasing at higher elevation, with highest decrease in High Mountains (Table 5.2).

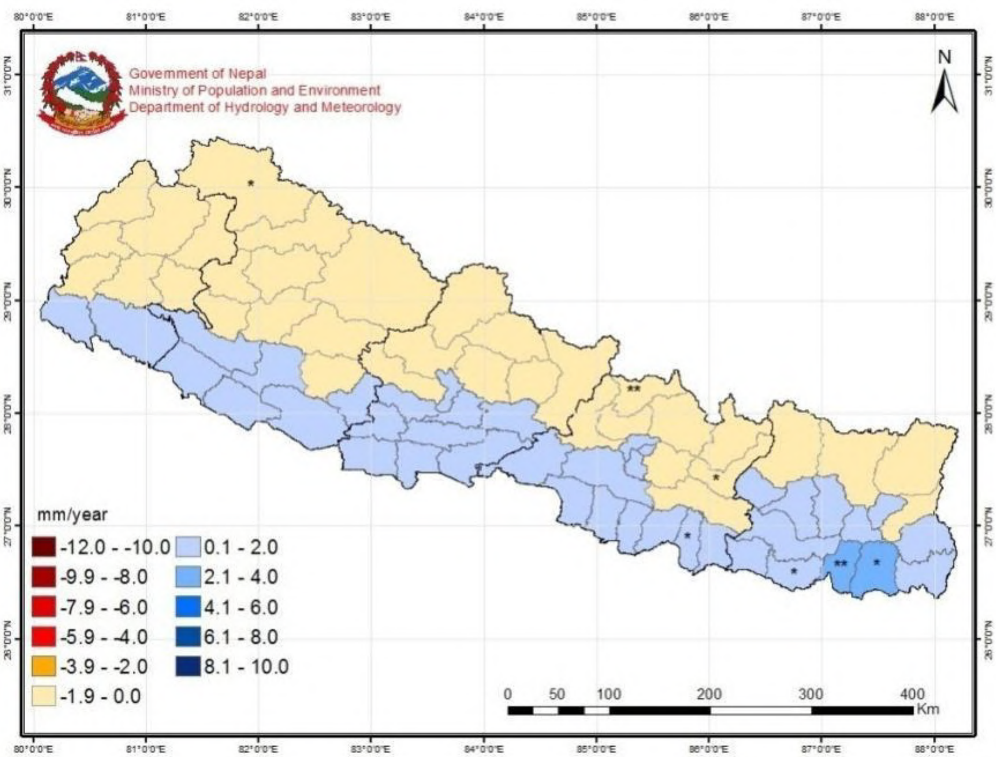

Figure 5.2a: Pre-Monsoon precipitation trend for districts.

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

5.3 Monsoon Precipitation Trend

Monsoon precipitation trends are positive in 28 districts, out of which only two districts have significant trends (Table 5.1). Parbat and Syangja of WDR showed positive trends significance at 95% CL (Figure 5.3). Precipitation trends are negative in 47 districts during monsoon season, and of them, 5 districts have significant trend (Table 5.1). Manang, Dolakha, Ramechhap, Sindhuli and Ilam are 5 districts that show significance at 95% or higher CL.

Monsoon precipitation trend is in increasing order in all districts of FWDR and southwestern and northeastern districts in MWDR and central districts in WDR (Figure 5.3). Decreasing monsoon precipitation is observed in large parts of EDR, CDR and northern part of WDR. The southern districts of FWDR have insignificant positive precipitation trend, which is also observed in winter (Figure 5.1) and pre-monsoon (Figure 5.2) seasons.

The highest significant increasing trend (9.04 mm/yr) and decreasing trend value (-7.5 mm/yr) are observed in Syangja and Ilam districts respectively (Table A5 in the appendix).

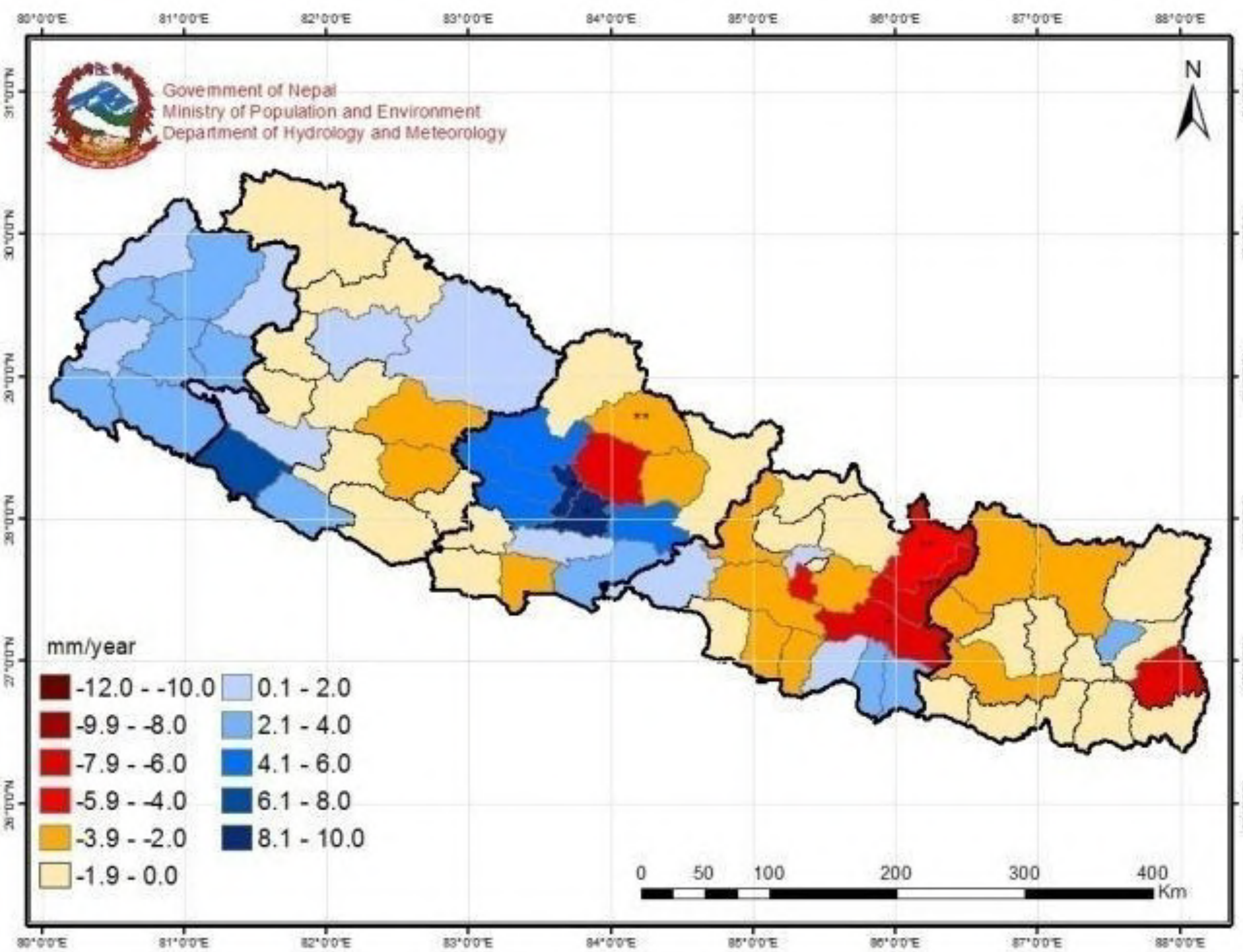

Figure 5.3a Monsoon Precipitation trend for districts.

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

In physiographic regions, Tarai has insignificant increasing trend in monsoon precipitation while the rest of the physiographic regions have insignificant decreasing trend (Table 5.2). Though insignificant, monsoon precipitation trend is positive in Tarai region and and negative in higher elevations, with highest decreasing trend in High Mountains (Table 5.2). This pattern is similar to winter and pre-monsoon precipitation trends (Table 5.2).

5.4 POST-MONSOON PRECIPITATION TREND

Only two districts (Humla and Mugu) show positive trend while rest of 73 districts show negative trends in post-monsoon precipitation (Figure 5.4 and Table 5.1). All positive trends are insignificant. Among the districts with negative trends, only two districts (Rasuwa and Solukhumbu) show significance at 95% or higher CL. The post-monsoon precipitation trend pattern is totally different from previous three seasons (Table 5.1). The district-wise trend values are presented in Table A5 in the Appendix.

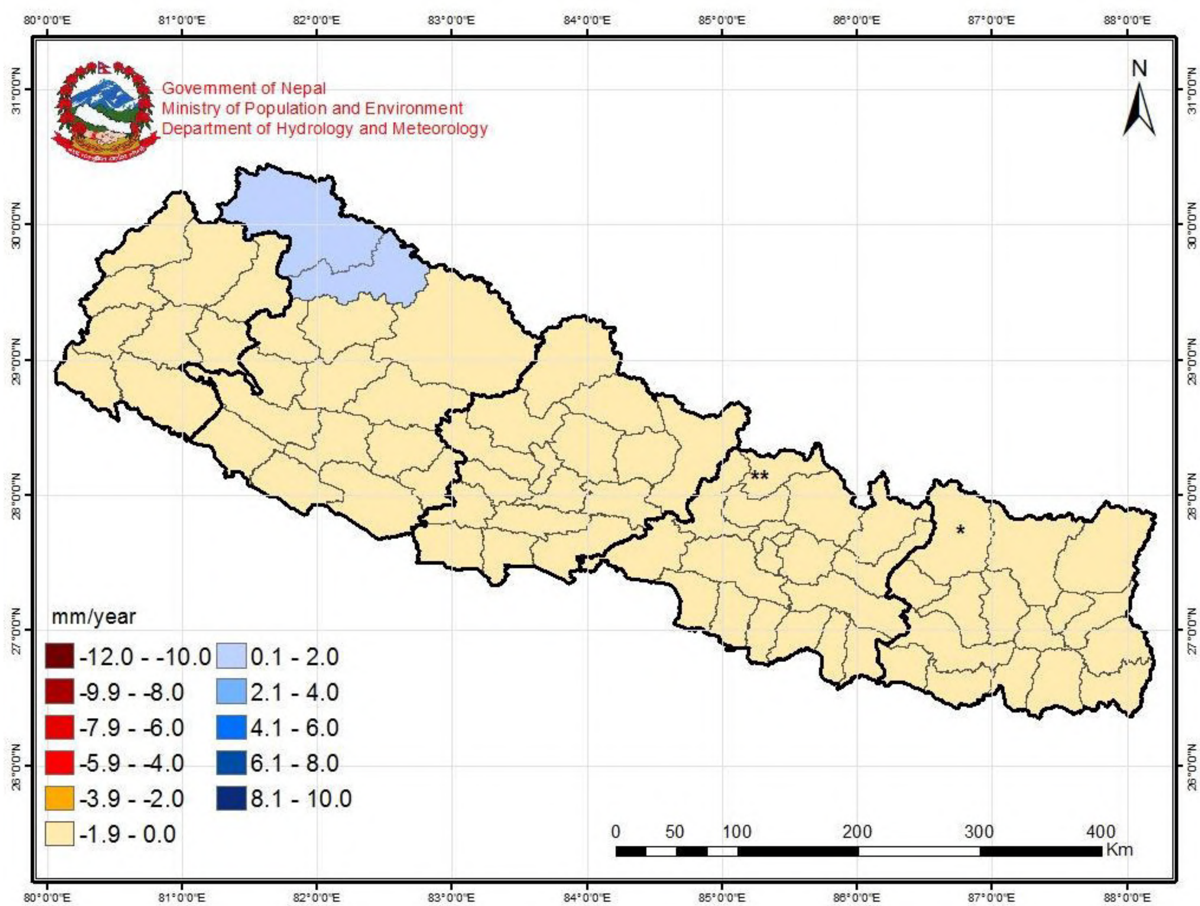

Figure 5.4a Post-Monsoon Precipitation trend for districts.

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

Post-monsoon precipitation trend shows insignificant decreasing trend in all five physiographic regions (Table 5.2). Though insignificant, highest decreasing trend is found in High Mountains (Table 5.2).

5.5 ANNUAL PRECIPITATION

Out of 75 districts, 28 districts show increasing annual precipitation trend and 47 districts show decreasing trend (Table 5.1). Annual precipitation trend pattern is almost similar to the monsoon season (Figure 5.5). Most of the districts in EDR and CDR and northern parts of WDR show decreasing annual precipitation whereas most of districts in the FWDR and central districts of WDR show increasing precipitation trend.

The district-wise trend values of annual precipitation show significantly highest decreasing trend in Kaski and significantly highest increasing trend (9.0mm/yr) in Syangja (Table A5 in the Appendix).

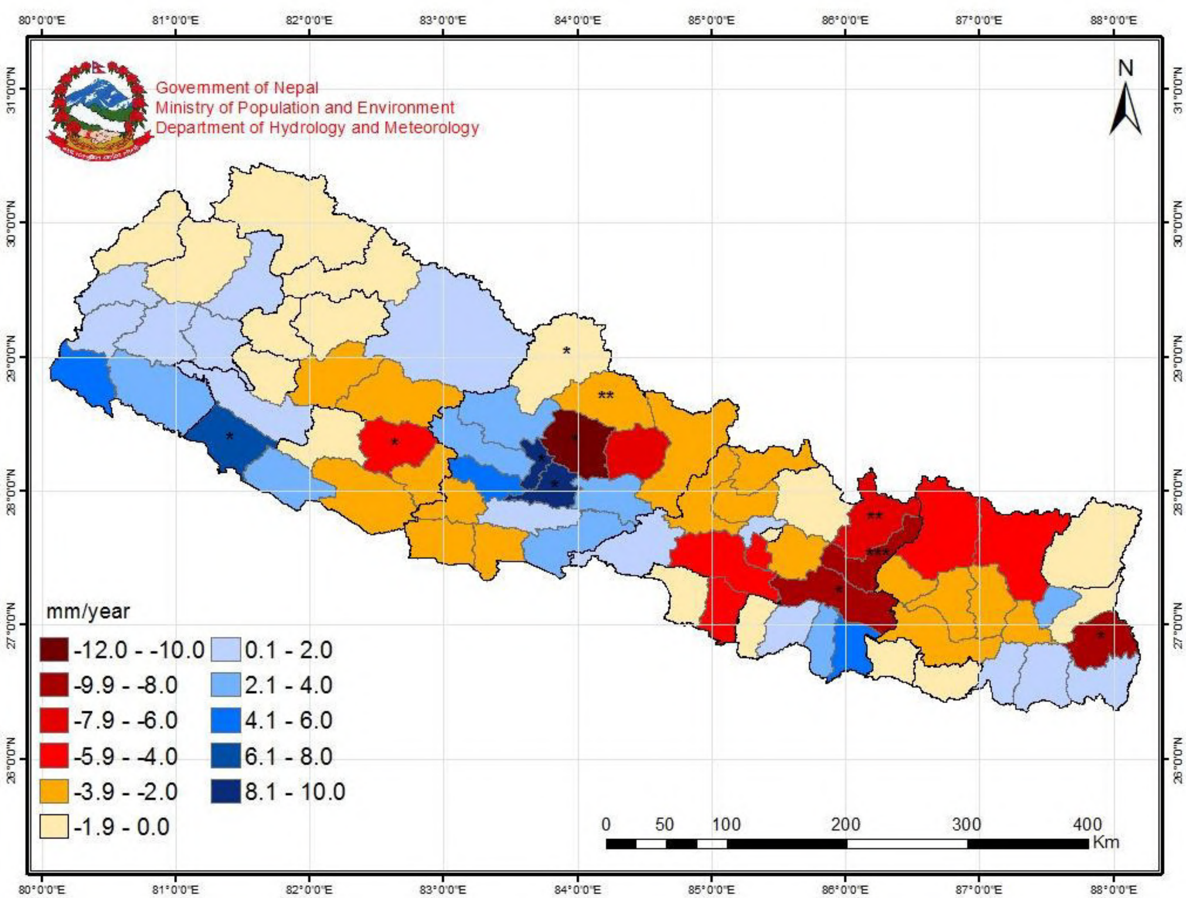

Figure 5.5a Annual Precipitation trend for districts.

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

In case of annual precipitation trend, all physiographic regions, except Tarai, show decreasing trend (Figure 5.2). As in seasonal precipitation trends, highest negative trend (-3.17 mm/yr) is observed in High Mountain region. The pattern of decreasing rainfall trend with elevation is also found in annual precipitation.

5.6 SUMMARY OF PRECIPITATION TREND

Significant precipitation trends are observed only in few districts in pre-monsoon (Humla, Rasuwa, Ramechhap, Mahottari, Saptari, Sunsari and Morang in Figure 5.2) and in monsoon (Syangja, Parbat, Manang in Figure 5.3). Winter and post-monsoon precipitation trends are insignificant in majority of the districts (Figure 5.1 and Figure 5.4). The highest significant positive rainfall trend is observed in Syangja and Parbat districts in monsoon season.

In physiographic regions, only pre-monsoon precipitation shows significant positive trend in the High-Himalayan region. In other seasons precipitation trends are insignificant in all physiographic regions.

Both at district and physiographic level, three coherent but insignificant patterns are noteworthy. For example, the southern districts of FWDR shows positive but insignificant precipitation trend persistent in three seasons: winter, pre-monsoon and monsoon. Similarly, it is noteworthy that monsoon precipitation is increasing in all districts in FWDR and central part of WDR and is decreasing in majority of districts east of 84E longitude. The High Mountain region shows insignificant highest decreasing rainfall trend among all seasons and Tarai region shows insignificant positive trend in all seasons, except in post-monsoon.

These coherent but insignificant patterns might be associated with short term variability in atmospheric phenomena. Further analysis is necessary to understand these patterns. Since these patterns are not significant, these results should be used very cautiously.

CHAPTER 6: MAXIMUM TEMPERATURE TREND FOR DISTRICTS AND PHYSIOGRAPHIC REGIONS

Summary of district distribution with positive and negative trends annually and seasonally is given in Table 6.1. Annual and seasonal maximum temperature trends for districts along with significance levels are annexed (Table A6 in the Appendix). Seasonal and annual maximum temperature trends in physiographic regions are given Tables 6.2

Table 6.1: Distribution of districts with positive and negative seasonal and annual maximum temperature trends

	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
Number of districts with negative trend	11(0)	(0)	0 (0)	0 (0)	0 (0)
Number of districts with positive trend	64(59)	75(62)	75 (75)	75 (71)	75 (72)
Note: Number in parenthesis indicates number of districts with significant trend at 95% or higher confidence level (Table A6 in Appendix)					

Table 6.2: Seasonal and annual maximum temperature trends in the Physiographic Regions

Physiographic Regions	Winter		Pre-monsoon		Monsoon		Post-monsoon		Annual	
	α	Trend (°C/yr)	α	Trend (°C/yr)	α	Trend (°C/yr)	α	Trend (°C/yr)	α	Trend (°C/yr)
Tarai	0	-0.004	0	0.018	***	0.036	**	0.028	***	0.021
Siwaliks	0	0.010	*	0.031	***	0.040	***	0.033	***	0.030
Mid Mountain	***	0.046	***	0.049	***	0.055	***	0.052	***	0.052
High Mountains	***	0.070	***	0.062	***	0.064	***	0.064	***	0.068
High Himalayas	***	0.101	***	0.076	***	0.072	***	0.085	***	0.086
Note: Significant: * 95% CL, ** 99% CL and * 99.9% CL ; insignificant at 95% CL : + , 0**										

6.1 WINTER MAXIMUM TEMPERATURE TREND

Winter maximum temperature is increasing significantly at 99% or higher CL in majority of the districts, except in the Tarai districts (Figure 6.1). The Tarai districts, west of Mahottari show slightly decreasing trend, but they are insignificant. Eastern districts including Mohottari show increasing winter maximum temperature trend, among which only three districts (Jhapa, Morang and Sunsari) have significant positive trend at 95% or higher CL. The negative trends of Tarai districts might be due to the long episode of fog events in winter since the last decade. Moreover, the magnitude of winter maximum temperature trend is either negative or slightly positive in Tarai districts. Positive significant maximum temperature trends increases from southern districts (Taria region) towards northern districts (Himalayan region).

It is interesting to note that 59 districts show significant positive trend at 95% or higher CL (Table 6.1). The highest positive trend (0.118°C/yr) is observed in Manang district and lowest positive trend (0.016°C/yr) is found in Makwanpur district (Table A6 in the Appendix).

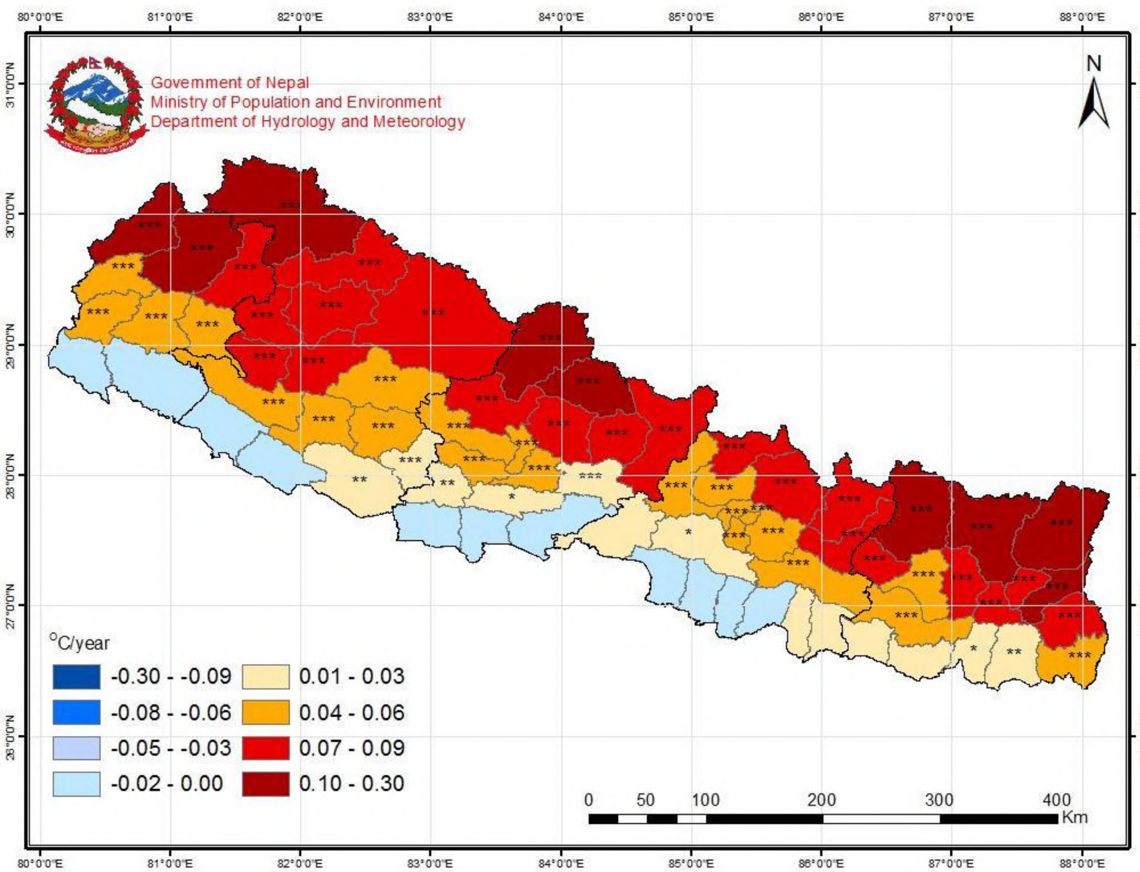

Figure 6.1a Winter Maximum Temperature trend for districts

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

Winter maximum temperature shows significant positive trend at 99.9% CL in Middle Mountain, High Mountain and High Himalayan regions (Table 6.2). The significantly highest positive trend (0.101°C/yr) is observed in High Himalayas and the lowest positive trend (0.010°C/yr) in the Siwaliks (Table 6.2). This depicts a pattern in winter maximum temperature trend with altitude (negative trend in Tarai and lowest positive trend in the Siwaliks and then positive trend increases in altitude regions.

6.2 PRE-MONSOON MAXIMUM TEMPERATURE TREND

Maximum temperature in pre-monsoon maximum temperature is in increasing trend in all the districts (Figure 6.2 and Table 6.1). Except in majority of Tarai districts, 62 districts (Table 6.1) with positive trend show significance at 95% or higher CL. Positive trends in Tarai districts are significant only in four districts (Jhapa, Morang, Sunsari and Siraha) of EDR at 95% CL. Positive temperature trend increases from southern districts (Taria) towards northern districts (Himalayan regions). The pre-monsoon maximum temperature trend values are listed in Table A6 in the Appendix. Significantly highest positive trend (0.086°C/yr) is observed in Darchula district and lowest (0.024°C/yr) in Siraha district (Table 6A in the Appendix).

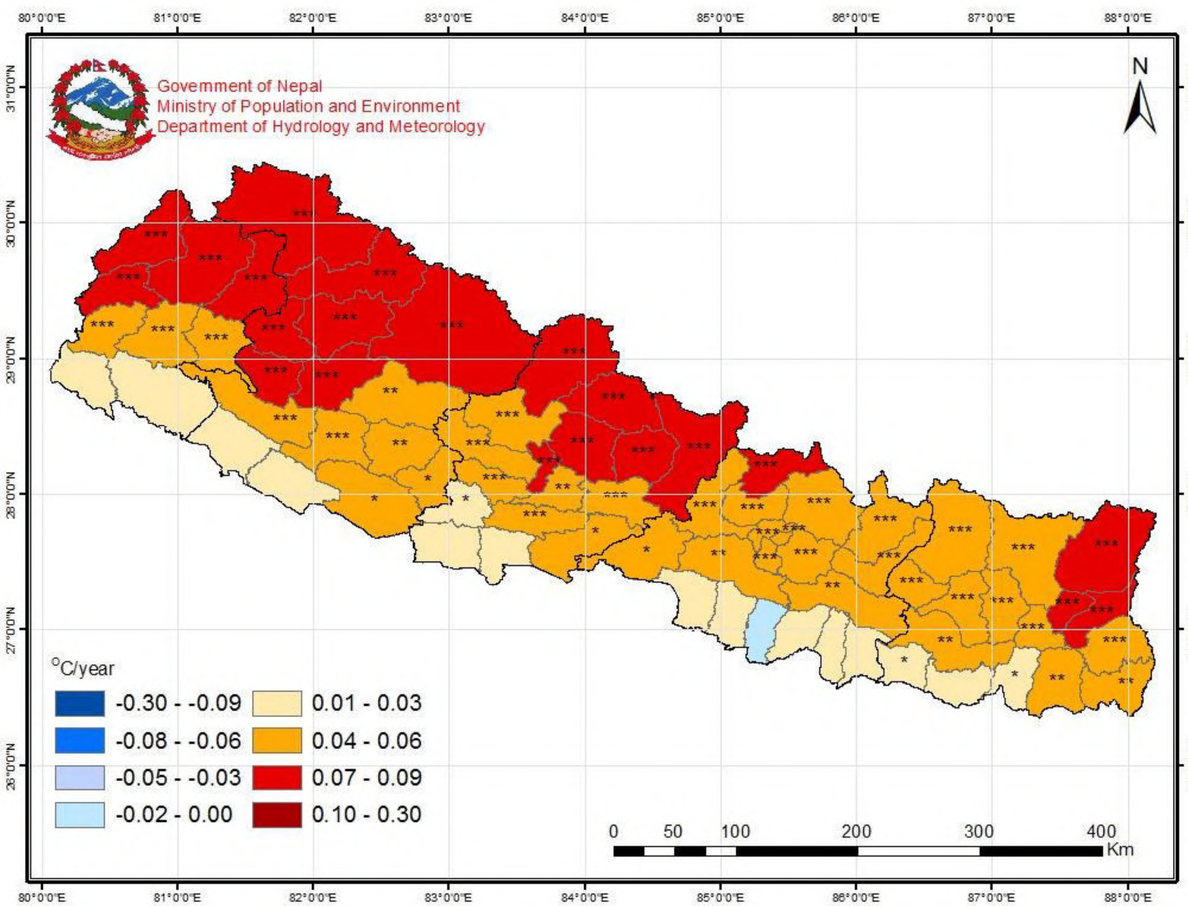

Figure 6.2aPre-Monsoon Maximum Temperature trend for districts

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

In all physiographic regions, monsoon maximum temperature trend shows significant positive trend at 99.9% CL (Table 6.2). The Tarai has lowest positive trend (0.036°C/yr) and the High Himalayas has the highest positive trend (0.072°C/yr) (Table 6.2). This also demonstrate an increase in maximum temperature trend with elevation as in winter and pre-monsoon seasons (Table 6.2).

6.3 MONSOON MAXIMUM TEMPERATURE TREND

In monsoon season, maximum temperature shows positive trend significant at 99.9% CL in all districts (Figure 6.3). Majority of the districts show positive trends higher than 0.04°C/yr. The highest positive maximum temperature trend (0.090°C/yr) is observed in Dolpa district and the lowest positive trend (0.026°C/yr) in Rautahat district (Table A6 in the Appendix).

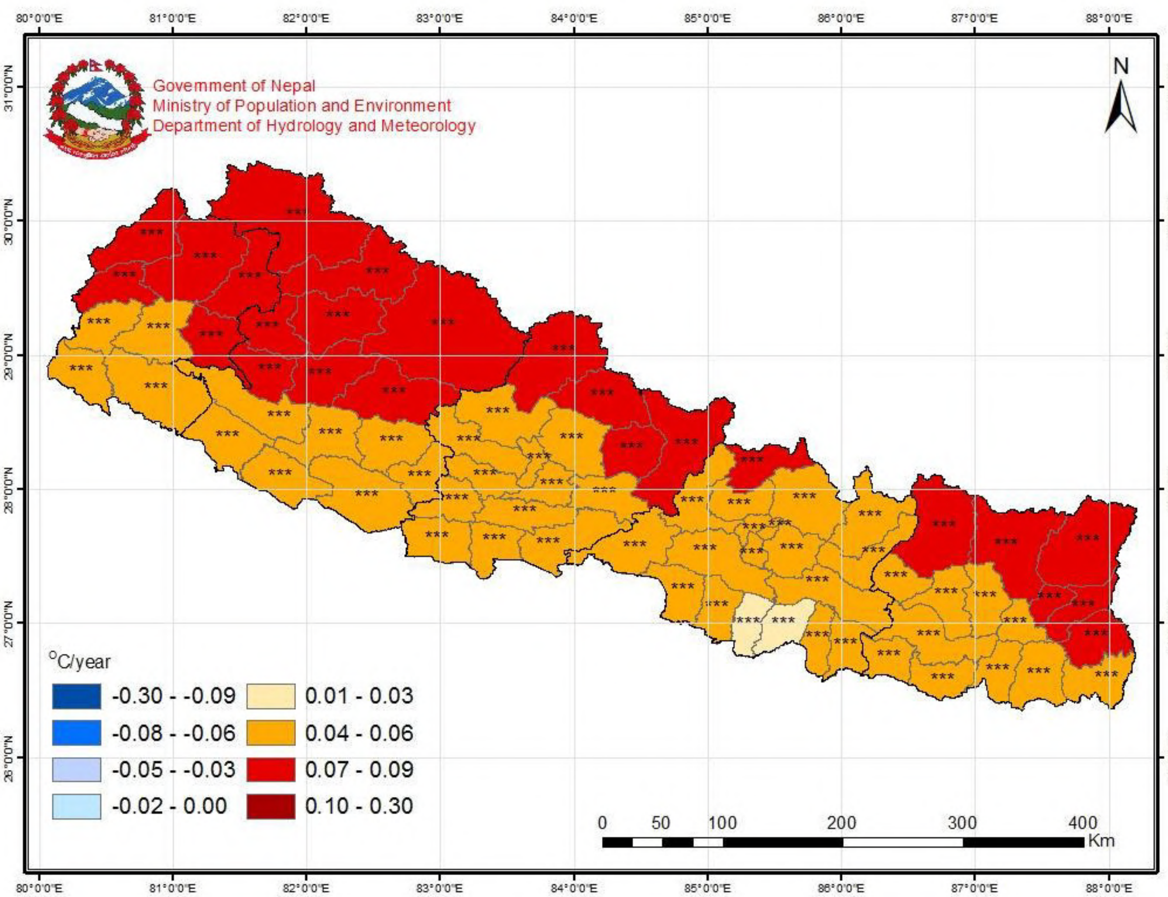

Figure 6.3a Monsoon Maximum Temperature trend for districts

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

In all physiographic regions, monsoon maximum temperature trend shows significant positive trend at 99.9% CL (Figure 6.2). The Tarai has lowest positive trend (0.036°C/yr) and the High Himalayas has the highest positive trend (0.072°C/yr) (Table 6.2). This also demonstrate an increase in maximum temperature trend with elevation as in winter and pre-monsoon seasons (Table 6.2).

6.4 POST-MONSOON MAXIMUM TEMPERATURE TREND

In post-monsoon season, maximum temperature shows significantly increasing trend at 95% or higher CL in most of the districts, except Nawalparasi, Bara, Rautahat and Sarlahi (Figure

6.4). The magnitude of the positive temperature trend increases from southern districts (Taria) towards northern districts (Himalayan regions).

The trend values of post-monsoon maximum temperature are shown in Table A6 in the Appendix. It shows that the highest positive trend (0.094°C/yr) is observed in Taplejung district and lowest positive trend (0.021°C/yr) is observed in Parsa district with significance higher than 95% CL.

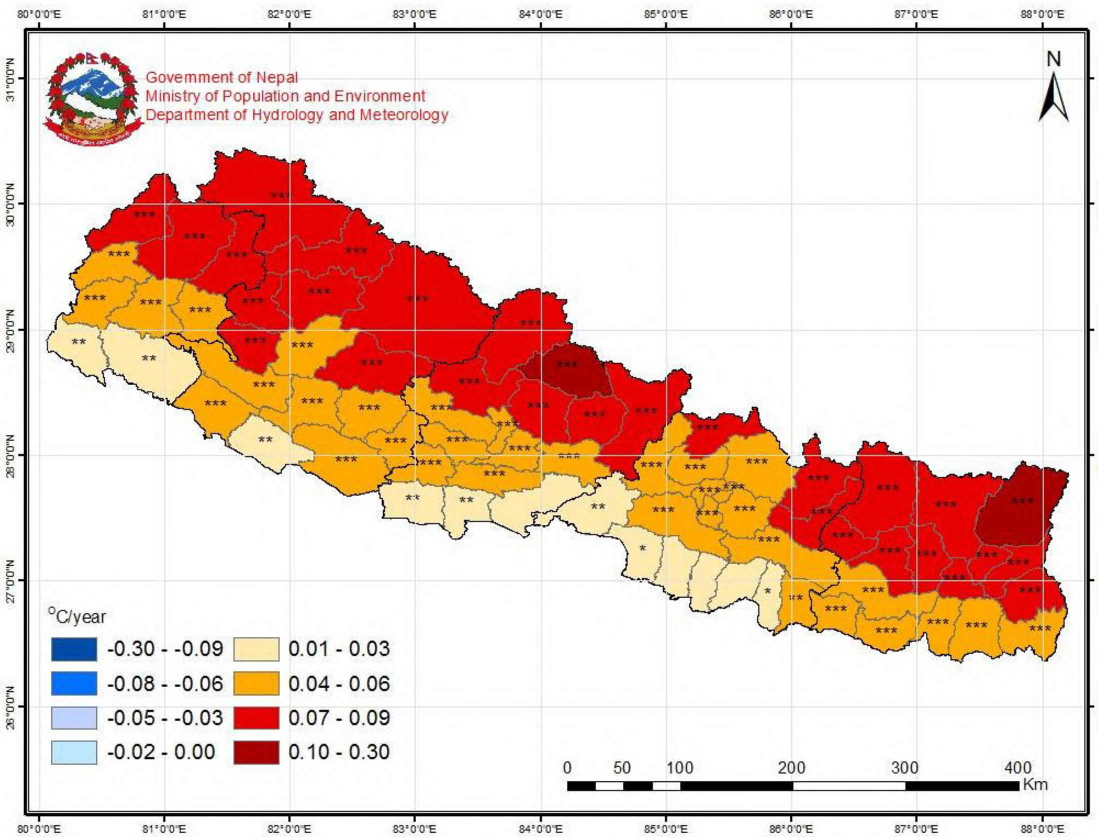

Figure 6.4aPost-Monsoon Maximum Temperature trend for districts

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

Post-monsoon maximum temperature trend shows significant positive temperature trend at 99% or higher CL in all physiographic regions (Table 6.2). The lowest positive trend (0.028°C/yr) is observed in Tarai and the highest positive trend (0.085°C/yr) in the High Himalayas. There is an increase in temperature trend with the elevation from south to north which is consistent with the distribution of post-monsoon maximum temperature trend in the districts.

6.5 Annual Maximum Temperature Trend

Annual maximum temperature in districts show significantly increasing trend at 99% or higher CL in all districts, with insignificant positive trends in Bara, Rautahat and Sarlahi districts (Figure 6.5). The Figure shows positive temperature trend increases from southern districts (Taria) towards northern districts (Himalayan regions). This pattern is consistent with the seasonal maximum temperature trend.

The annual maximum temperature trend values are listed in Table A6 in the Appendix. The highest significant positive trend (0.092^{o}C/yr) is observed in Manang and lowest positive trend (0.017^{o}C/yr) is observed in Parsa district.

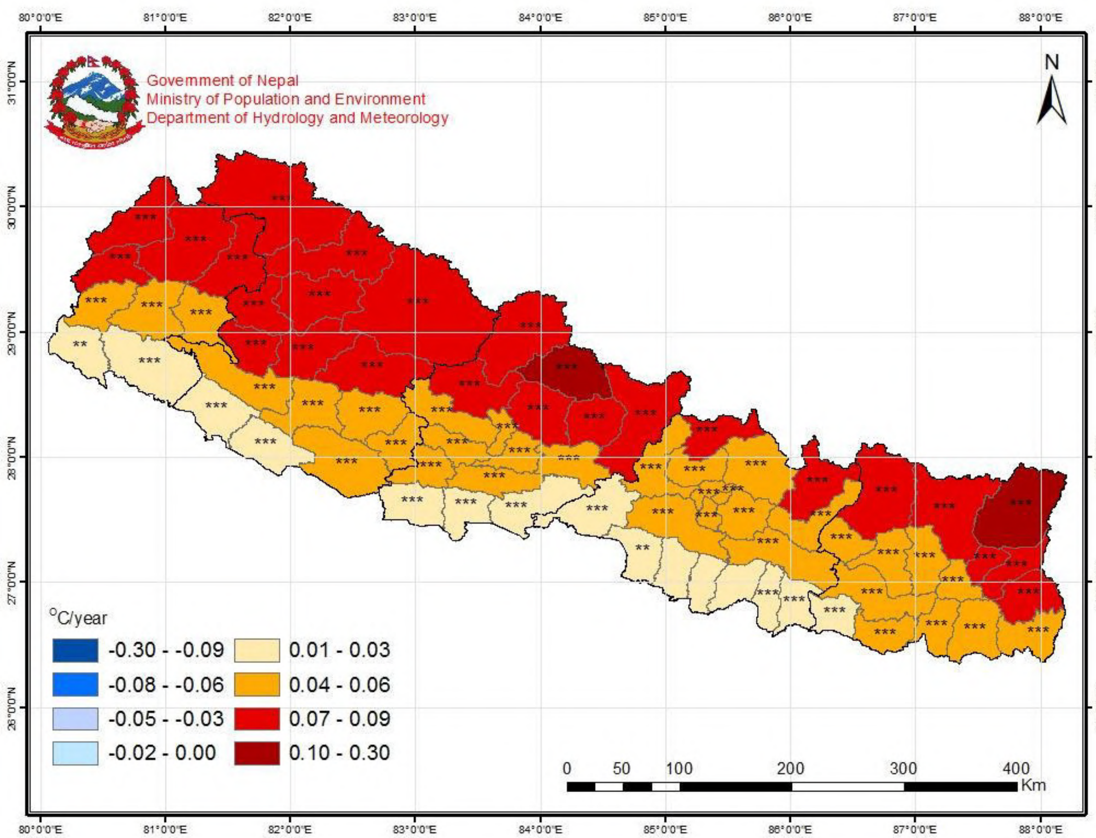

Figure 6.5a Annual Maximum Temperature trend for districts.

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

Annual maximum temperature trend in five physiographic regions is shown in Table 6.2. It shows positive temperature trend significant at 99.9% CL in all five regions. The temperature trend increases northward with elevation. Tarai has the lowest positive trend (0.021^{o}C/yr) while High Himalayan region has the highest increasing trend (0.086^{o}C/yr). This pattern is consistent with the distribution of annual maximum temperature trend in physiographic regions in other seasons.

6.6 Summary of Maximum Temperature Trend

At the District level, maximum temperature trend in most of the districts are significantly positive for all seasons, except in Tarai districts in winter season. The highest significant positive trend (0.12^{o}C/yr) is found in winter season in Manang district.

At Physiographic level, all five regions show significant positive trend in all seasons, except in Tarai in winter and pre-monsoon and in Siwaliks in winter. In High Mountains and High Himalayas, the highest positive trend is observed in winter season and in Tarai, Siwaliks and Mid Mountains, the highest positive trend is observed in monsoon season (Table 6.2).

Both at district and physiographic levels, seasonal and annual maximum temperature trends show a pattern in relation to altitude (Negative trend or slightly positive trends in lower altitude districts/regions and larger positive trends in higher altitude districts/regions).

CHAPTER 7: MINIMUM TEMPERATURE TREND FOR DISTRICTS AND PHYSIOGRAPHIC REGIONS

The annual and seasonal minimum temperature trends for the districts are listed in Table A7 in the Appendix. Summary of districts with positive and negative trends for seasonal and annual minimum temperature trends is given in Table 7.1. Seasonal and annual minimum temperature trends in five physiographic regions are in Table 7.2.

Table 7.1 Distribution of districts with positive and negative seasonal and annual minimum temperature trends

Trend types	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
Districts with negative trend	33(14)	30(0)	8(0)	28 (7)	23 (3)
Districts with positive trend	42(21)	45(19)	67(50)	47 (17)	52 (33)

Note: Number in parenthesis indicates number of districts with significant trend at 95% or higher confidence level (Table A7 in Appendix)

Table 7.2 Seasonal and annual minimum temperature trends in the physiographic regions

Physiographic Regions	Winter		Pre-monsoon		monsoon		Post-monsoon		Annual	
	α	Trend (oC/yr)	α	Trend (oC/yr)	α	Trend (oC/yr)	α	Trend (oC/yr)	α	Trend (oC/yr)
Tarai	**	0.025	*	0.015	***	0.015	0	0.013	***	0.018
Siwaliks	*	0.016	*	0.013	***	0.015	0	0.013	***	0.016
Mid Mountain	0	0.004	0	0.004	**	0.014	0	0.006	*	0.010
High Mountains	+	-0.018	0	-0.011	*	0.013	0	-0.013	0	-0.005
High Himalayas	**	-0.056	+	-0.021	0	0.013	+	-0.025	+	-0.015

*Note: Significant: * 95% CL, ** 99% CL and *** 99.9% CL; insignificant at 95% CL : + , 0*

7.1 WINTER MINIMUM TEMPERATURE TREND

Winter minimum temperature shows positive trend in 42 districts (southern and southeastern districts) and negative trend in 33 districts, in particular northern and northwestern districts (Table 7.1 and Figure 7.1). Out of these 42 districts, 21 districts show significant positive trend at 95% higher CL and these districts are located in the southern part of EDR, CDR and WDR.

Out of the 33 districts, 14 districts (northwestern parts of the FWDR and MWDR and northern parts of WDR and EDR) show significantly negative trend at 95% CL. In contrast to winter maximum temperature pattern, the low elevation districts have positive trend and high altitude districts have negative trend.

The winter minimum temperature trend values are presented in Table A7 in the Appendix. The significant positive trend ranges from lowest (0.015°C/yr) in Kathmandu district to highest (0.039°C/yr) in Mahottari district. The significant highest negative trend (-0.076°C/yr) is observed in Humla district and lowest negative trend (-0.015°C/yr) is observed in Doti district.

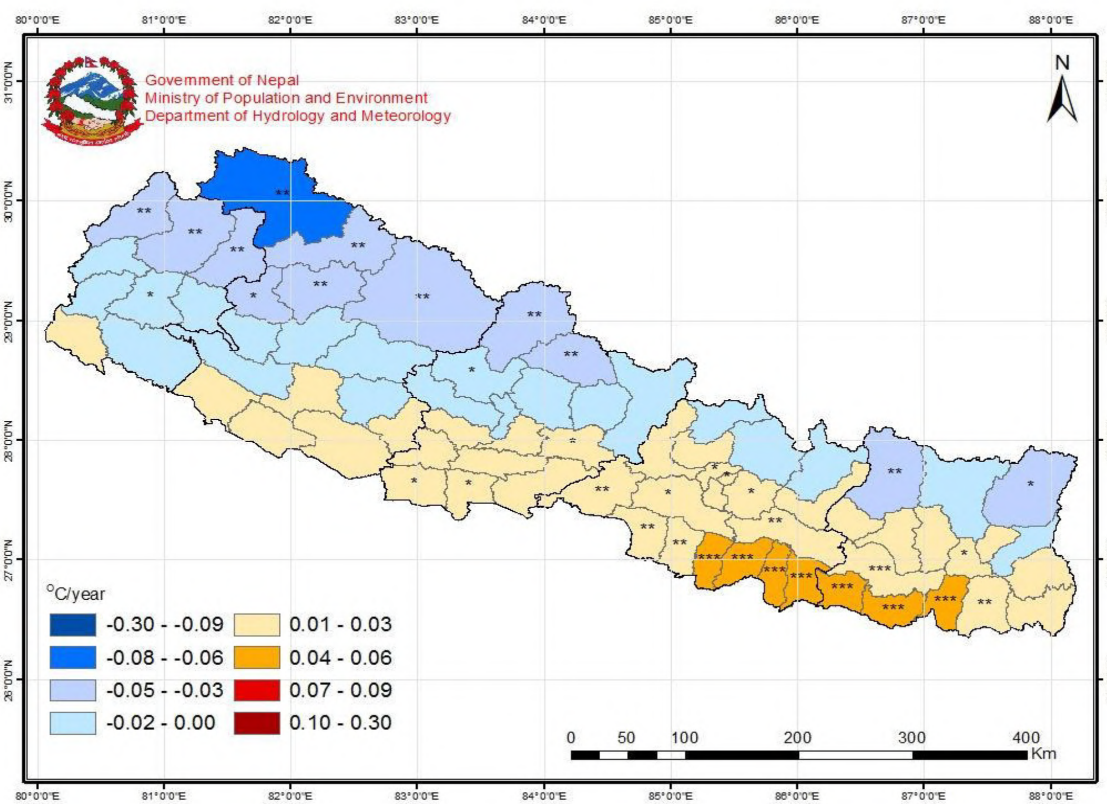

Figure 7.1a Winter Minimum Temperature trend for districts.

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

Winter minimum temperature trend is significant and positive at 99% CL in Tarai and at 95% CL in Siwaliks (Table 7.2). It shows significant negative trend in the High Himalayas, insignificant positive trend in Middle Mountains and insignificant negative trends in High Mountains. The winter minimum temperature trend show highest positive trend (0.025°C/yr, significant) in Tarai (Table 7.2). The highest negative trend (-0.056°C/yr, significant) is observed in the High Himalayas. The trend pattern shows a relation with altitude, with positive minimum temperature trend in low altitude which decreases with altitude becoming negative at High Mountains and Himalayas.

7.2 PRE-MONSOON MINIMUM TEMPERATURE TREND

Pre-monsoon minimum temperature show positive trend in 47 districts and negative trend in 30 districts (Table 7.1 and Figure 7.2). The increasing trends are significant at 95% or higher CL in 19 districts (southern parts of EDR, CDR and WDR). Insignificant negative trends are found in most of districts in FWDR and MWDR and northern districts of WDR and EDR. The pre-monsoon minimum trends for districts are listed in Table A7 in the Appendix. The highest significant positive trend (0.031°C/yr) is observed in Mahottari district.

In physiographic regions, pre-monsoon minimum temperature trend is significant and positive at 95% CL in Tarai and Siwaliks and insignificant in Middle Mountains (Table 7.2). In High Mountains and High Himalayas, the trend is negative but insignificant. The positive trend is highest (0.015°C/yr) in Tarai while negative trend is highest (-0.021°C/yr) in High Himalayas (Table 7.2).

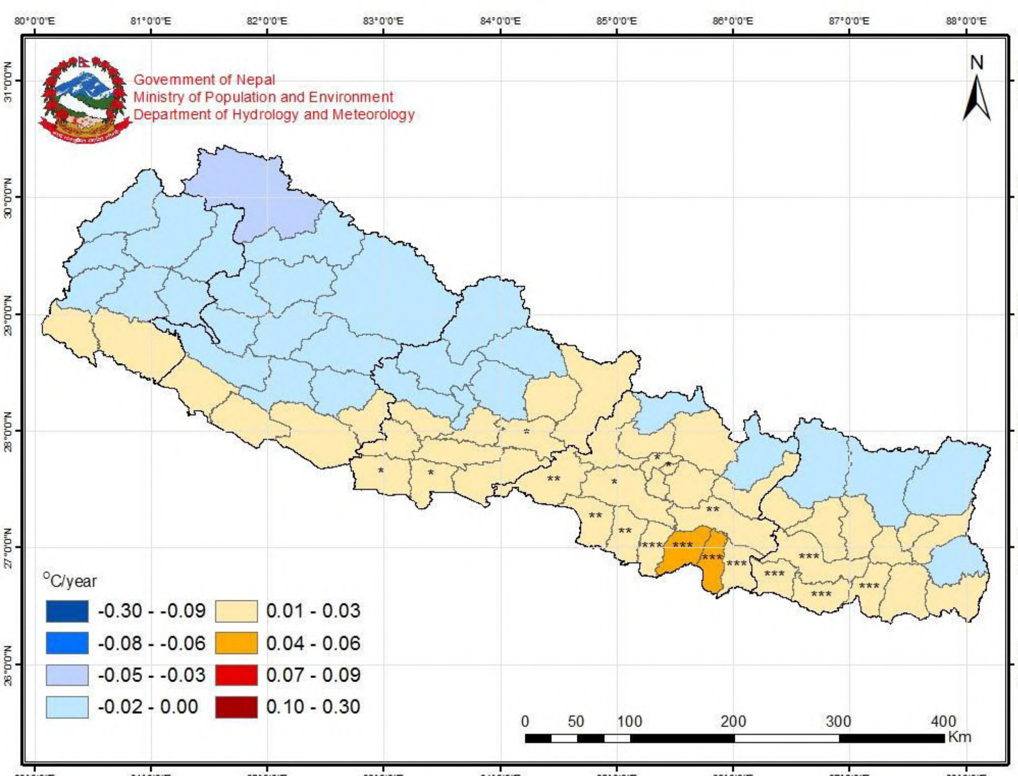

Figure 7.2a Pre- Monsoon Minimum Temperature trend for districts.

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

7.3 Monsoon Minimum Temperature Trend

Monsoon minimum temperature is in positive trend in majority of districts (67 districts), and negative trends in 8 districts (northwestern part of the country and Manang) (Table 7.1and Figure 7.3). Positive trends are significant in 50 districts. All of the 8 districts with negative trend show insignificant result. The monsoon minimum temperature trends are listed in Table A7 in the Annex. It depicts significantly highest positive trend (0.046°C/yr) in Dolpa district and lowest positive trend (0.010°C/yr) in Morang district.

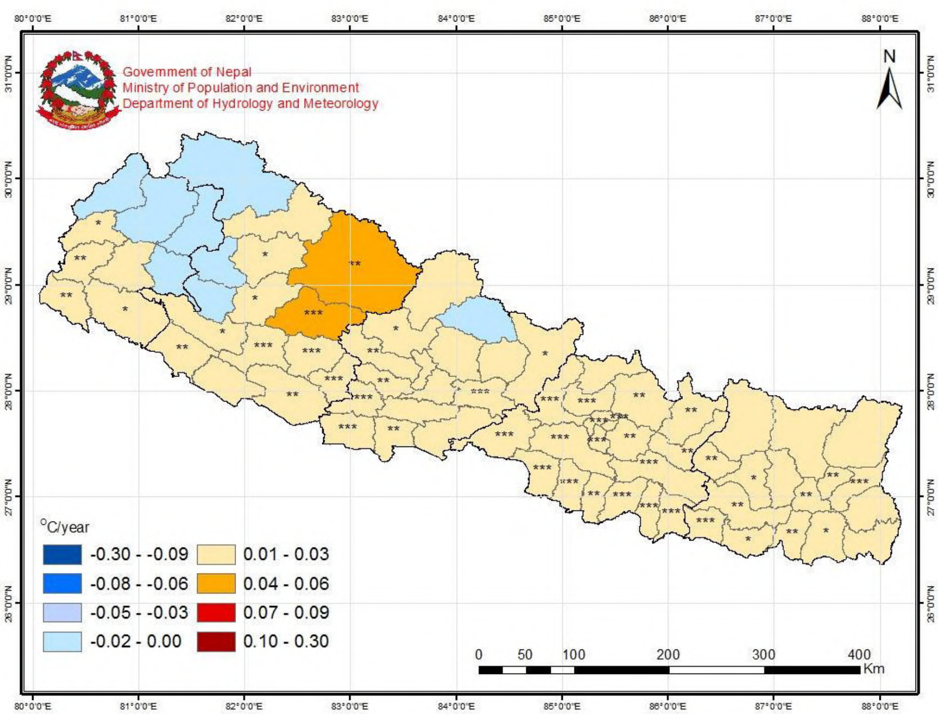

Figure 7.3a Monsoon Minimum Temperature trend for districts.

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

Monsoon minimum temperature trend in the five physiographic regions is significant and positive at 99.9% CL in Tarai and Siwaliks and at 99% CL in Middle Mountains and at 95% CL in High Mountains, while insignificant positive trend is observed in High Himalayas (Table 7.2). Tarai shows the highest positive trend (0.015°C/yr) while High Himalayan and High Mountain regions show the lowest increasing trend (0.013°C/yr) in case of monsoon minimum temperature (Table 7.2).

7.4 Post-monsoon Minimum Temperature Trend

The pattern of minimum temperature trend in post-monsoon (Figure 7.4) has similarity with that in pre-monsoon season (Figure 7.1). A total of 27 districts (the northwestern districts of FDR, MWDR and WDR and northeastern districts of EDR) show negative trend (Table 7.1 and

Figure 7.4). Out of 27 districts only 7 districts show significant negative trend at 95% CL (Figure 7.4). Post-monsoon minimum temperature trend is positive in 47 districts, among which 17 districts (CDR and EDR) show significant positive trend at 95% or higher CL (Table 7.1 and Figure 7.4).

Taking into the magnitudes of trend values (Table A7 in the Appendix), the significantly highest positive trend (0.028^{o}C/yr) is observed in Siraha districts. The significantly highest negative trend (-0.037^{o}C/yr) is found in Humla district.

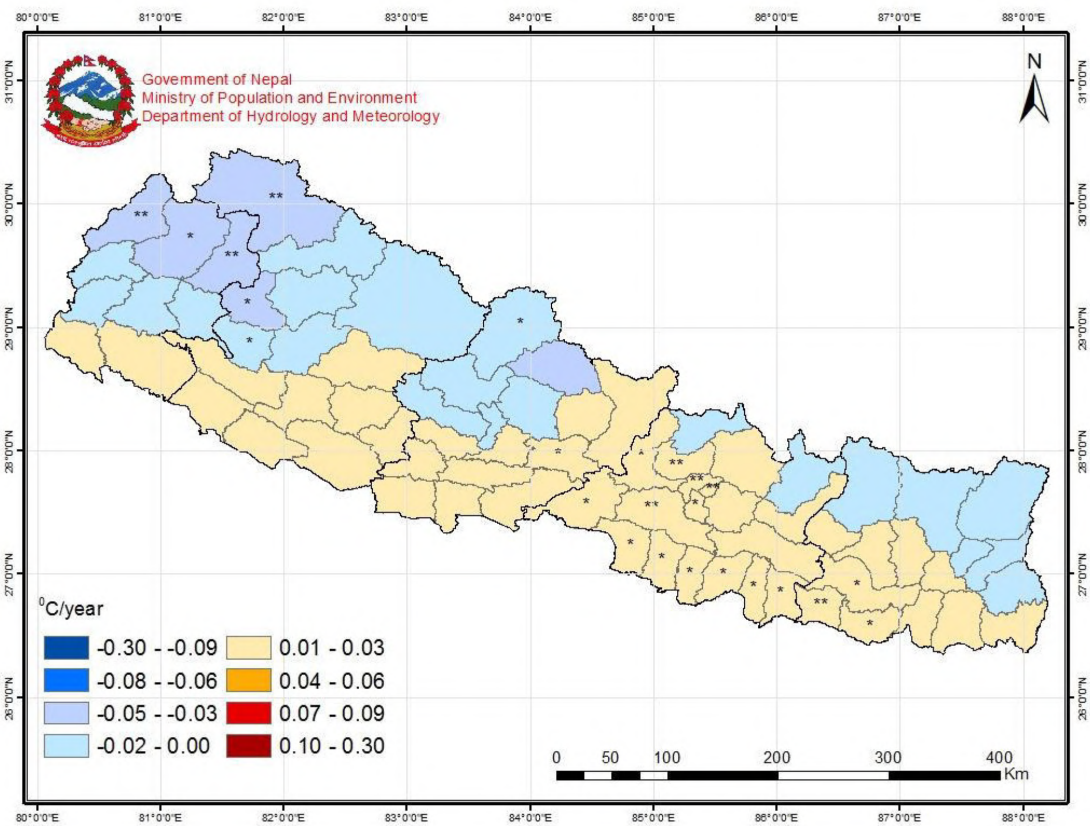

Figure 7.4a Post-Monsoon Minimum Temperature trend for districts

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

Positive (but insignificant) temperature trend is observed in Tarai, Siwaliks and Middle Mountains and negative trend (but insignificant) in the High Mountains and High Himalayas (Table 7.2). This pattern of minimum temperature trend in relation to altitude is consistent with the patterns in other 3 seasons.

7.5 ANNUAL MINIMUM TEMPERATURE TREND

Annual minimum temperature trend in 75 districts and number of districts with positive and negative trends are given in Figure 7.5 and Table 7.1. Fifty two districts (southern parts of the

FWDR, MWDR, WDR, EDR and most of the districts of CDR) show positive annual minimum trend while 23 districts (northwestern parts of FWDR, MWDR and WDR, northern part of CDR and northeastern parts of EDR) show negative annual minimum temperature trend (Figure 7.5 and Table 7.1). Among the districts with positive trend, 33 districts show significant at 95% or higher CL and only three districts (Manang, Humla and Kalikot) show significant negative trend at 95% or higher CL. The pattern of annual minimum temperature trend also shows positive trend in low elevation districts and negative trend in high elevation districts as in all the seasons.

The trend values of annual minimum temperature are shown in Table A7 in the Appendix. The significantly highest positive trend (0.029°C/yr) is found in Dhanusa district and significantly highest negative trend (-0.030°C/yr) is observed in Manang district.

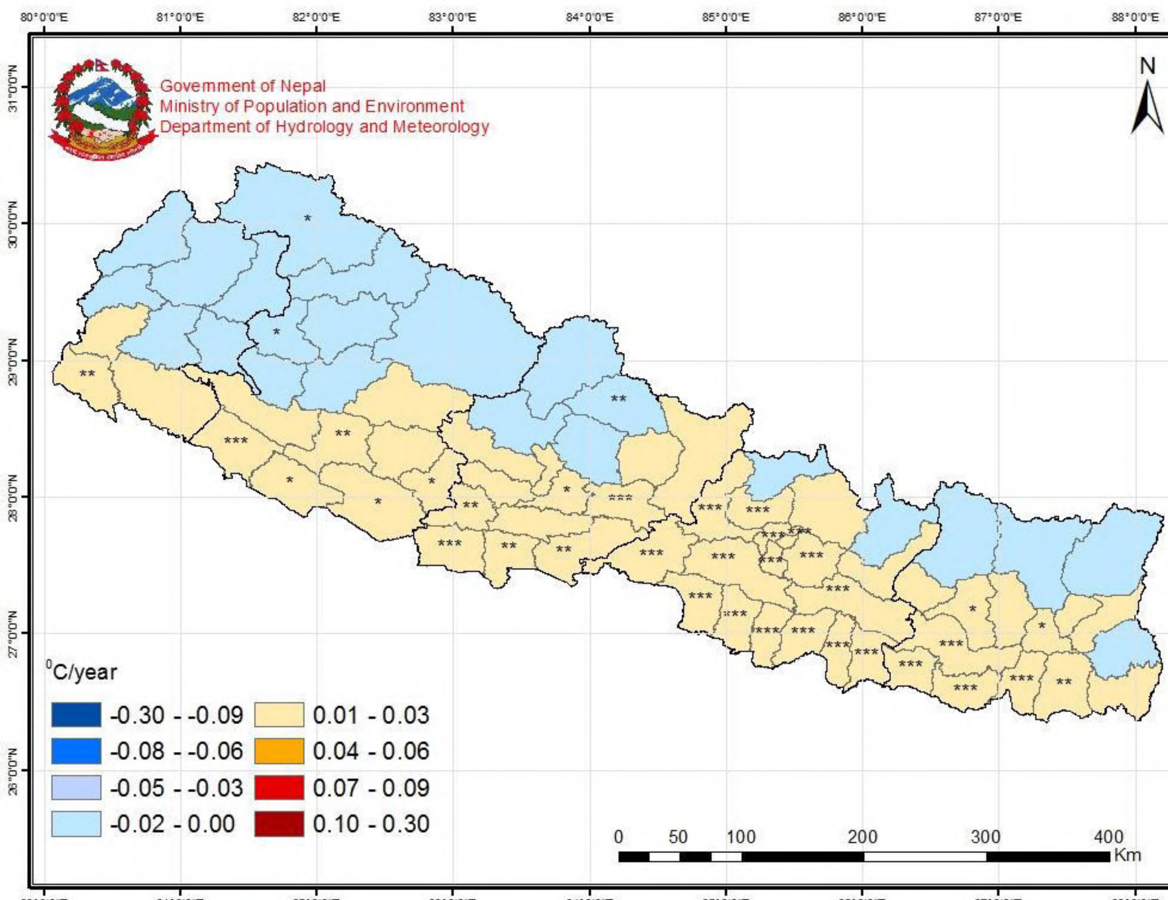

Figure 7.5a Annual Minimum Temperature trend for districts.

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

Annual minimum temperature trend of five physiographic regions show positive temperature trend significant at 99.9% CL in Tarai and Siwaliks while at 95% CL in the Mid-mountains (Table 7.2). High mountains and High Himalayas did not show significant trend.

7.6 SUMMARY OF MINIMUM TEMPERATURE TRENDS

Results of minimum temperature trends shows that some northwestern districts show significantly decreasing trends in pre-monsoon and post-monsoon seasons, while most of the Tarai districts in Western, Central and Eastern Development Regions show significantly increasing trends in all seasons. Significantly highest positive trend (0.046^{o}C/yr) is found in Dolpa district in monsoon and the highest negative trend (-0.076^{o}C/yr) is found in Humla district in winter season.

At physiographic level, Tarai and Siwaliks show significant increasing trend in most of the seasons. High Mountain and High Himalayan regions show decreasing trend in all seasons, except in monsoon. The negative trend is significant only in winter season in the High Himalayas.

Seasonal and annual minimum temperature trends show a pattern in relation to the elevation (trends are positive in lower elevation districts and negative in higher elevation districts). This pattern is opposite to the pattern in maximum temperature trends in relation to elevation. Since the trends, specifically, negative trends are insignificant, this result should be used cautiously.

CHAPTER 8: EXTREME EVENT TRENDS

Results of trend analysis of eleven extreme climate indices for 75 districts of Nepal are presented in this chapter. The district trend values with significance levels for each climate index are shown in Table A8 in the Appendix.

8.1 NUMBER OF RAINY DAYS

Number of annual rainy days (rainfall greater than 1mm in a day) shows positive trend in all districts, except in Rasuwa, Nuwakot, Sunsari and Morang districts (Figure 8.1). However, only 12 districts (Humla, Mugu, Bajura, Jumla, Jajarkot, Rukum, Dolpa, Syangja, Khotang, Bhojpur, Dhankuta and Terhathum) show significant positive trend at 95% or higher CL and only three districts (Rasuwa, Sunsari and Morang) show significant negative trend.

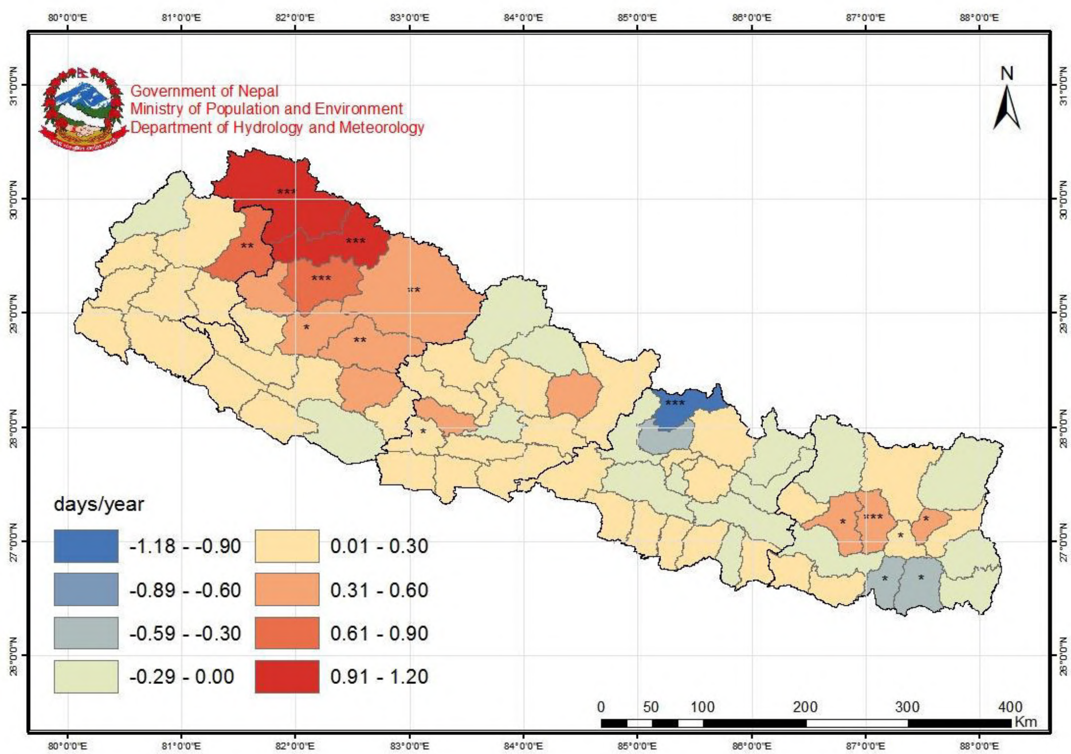

Figure 8.1 District level number of rainy days trend.

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

8.2 VERY WET DAYS

District level trends of very wet days (days with annual daily rainfall >95th percentile) shows decreasing trend in most of the districts, with 17 districts significant negative trend at 95% or higher CL (Figure 8.2). Only two districts (Bardiya and Syangja) have significant increasing trend at 95% CL.

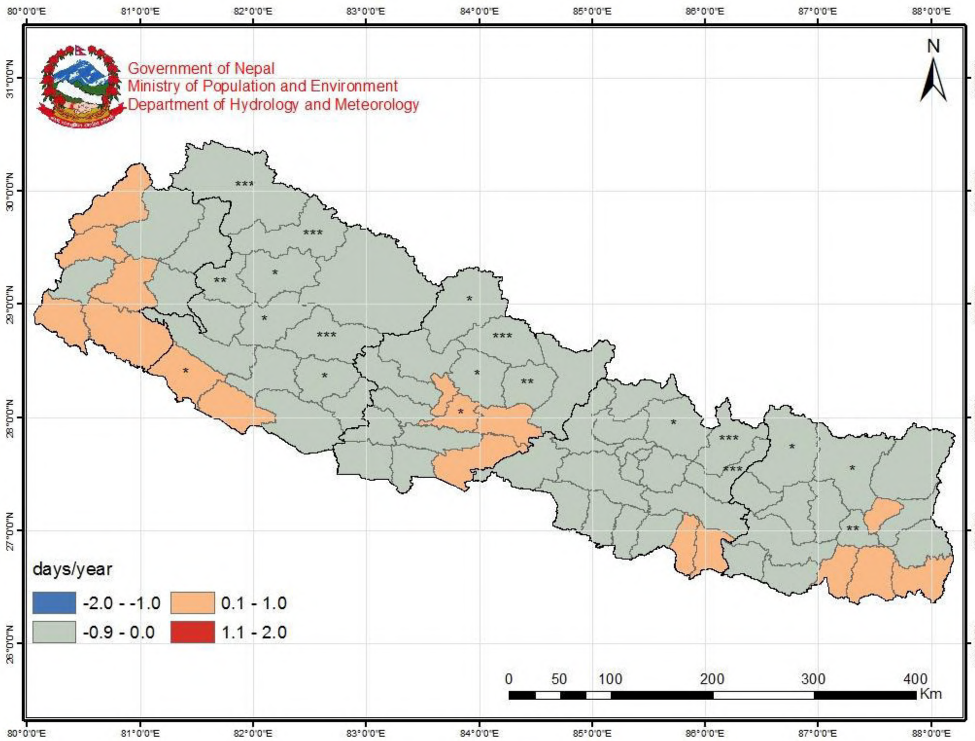

Figure 8.2 District level Very Wet Days (R95P) trend.

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

8.3 Extremely Wet Days

The trend of extremely wet days (days with daily rainfall >99percentile) shows that most of the districts (68 districts) have negative trends, out of which 22 districts show 95% or higher CL significance (Figure 8.3). Interestingly, only one district, Syangja in WDR, shows significant positive trend of extremely wet days at 95% CL.

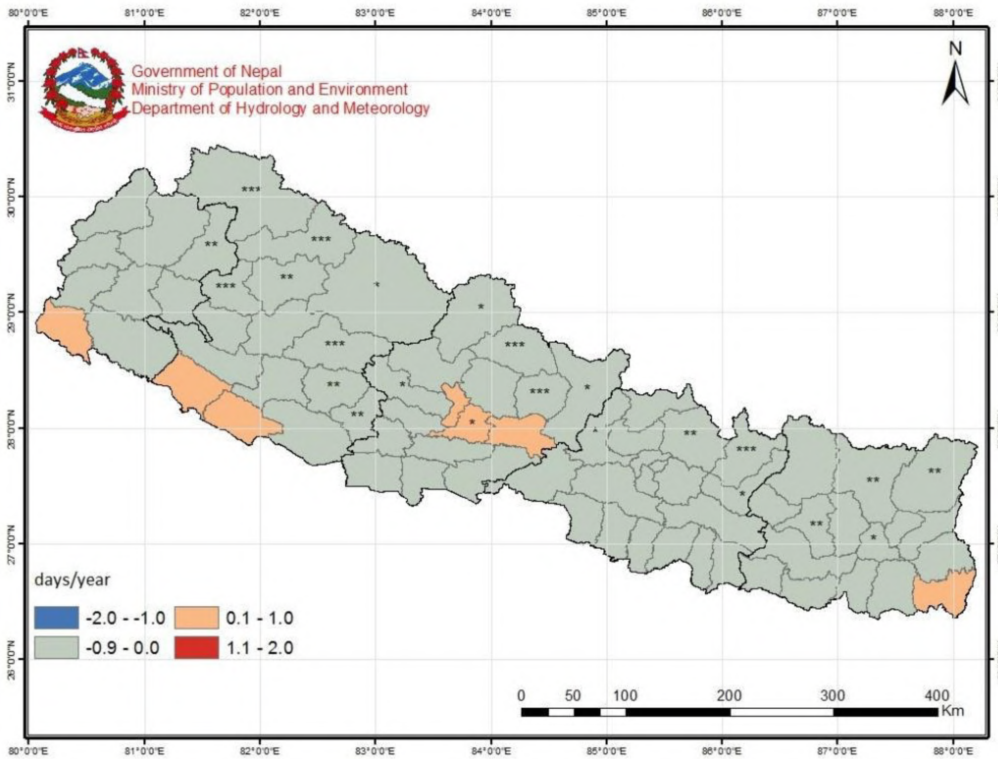

Figure 8.3 District level Extremely Wet Days (R99P) trend.

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

8.4 CONSECUTIVE DRY DAYS

The trend of consecutive wet days (maximum number of consecutive days with daily rainfall <1mm) shows significantly negative trend at 95% or higher CL in four districts (Humla, Mugu, Jumla and Bajura) (Figure 8.4) and significantly positive trend at 99% or higher CL in only two districts (Rasuwa and Nuwakot).

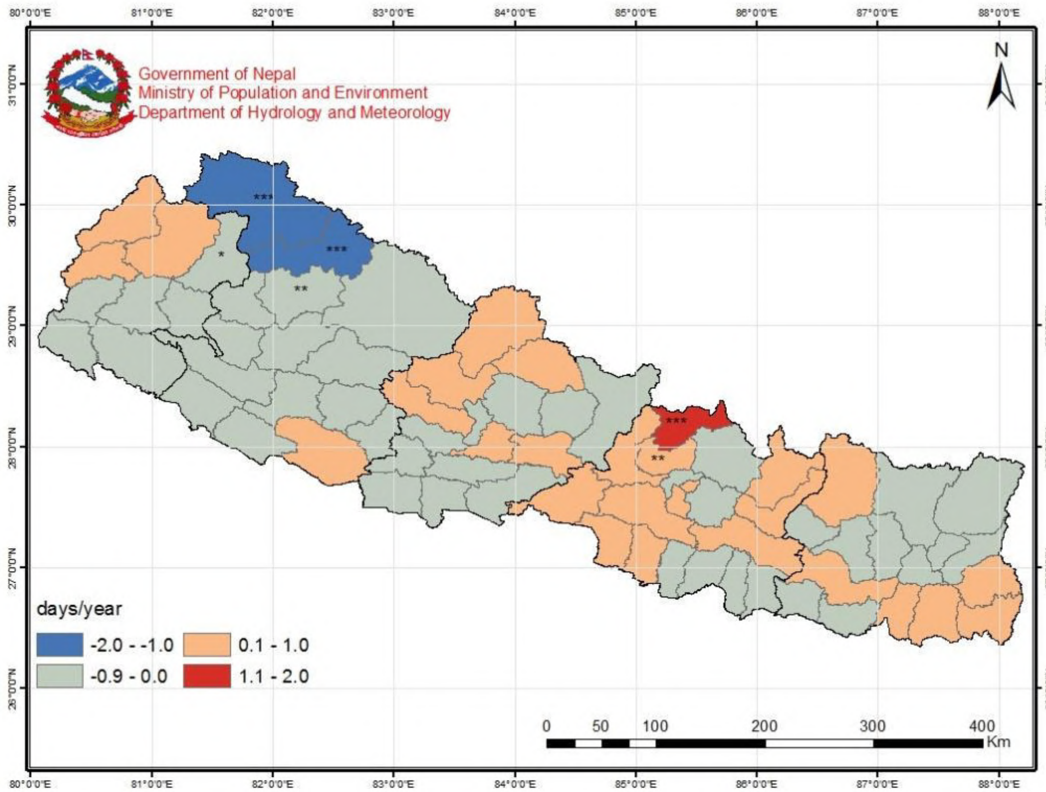

Figure 8.4 District level Consecutive Dry Days (CDD) trend.

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

8.5 CONSECUTIVE WET DAYS

The trend of consecutive wet days (maximum number of consecutive days with daily rainfall >1mm) is in increasing trend in most of the districts, among which, 20 districts show significant trend at 95% or higher level (Figure 8.5). Only three districts (Rasuwa, Sunsari, and Morang) show significant negative trend at 95% or higher CL.

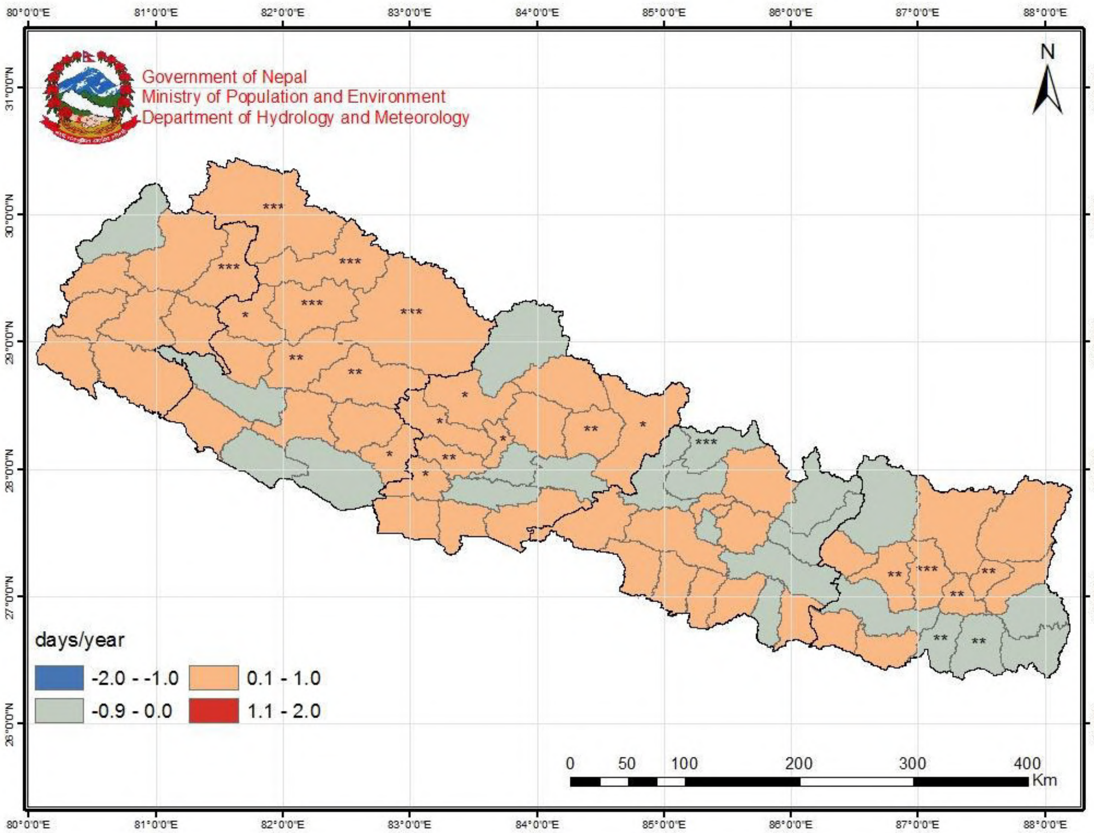

Figure 8.5 District Level Consecutive Wet Days (CWD) trend.

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

8.6 Cool Days

Annual cool days (percentage of days when maximum temperature <10th percentile) are in decreasing trend in most of the districts, except in Nawalparasi, Parsa, Bara, Rautahat and Sarlahi districts (Figure 8.6). Out of 70 districts with negative trends, 61 show significant trends at 95% or higher CL. Significant decrease of cool days is most prominent in High Mountain and High Himalayan districts.

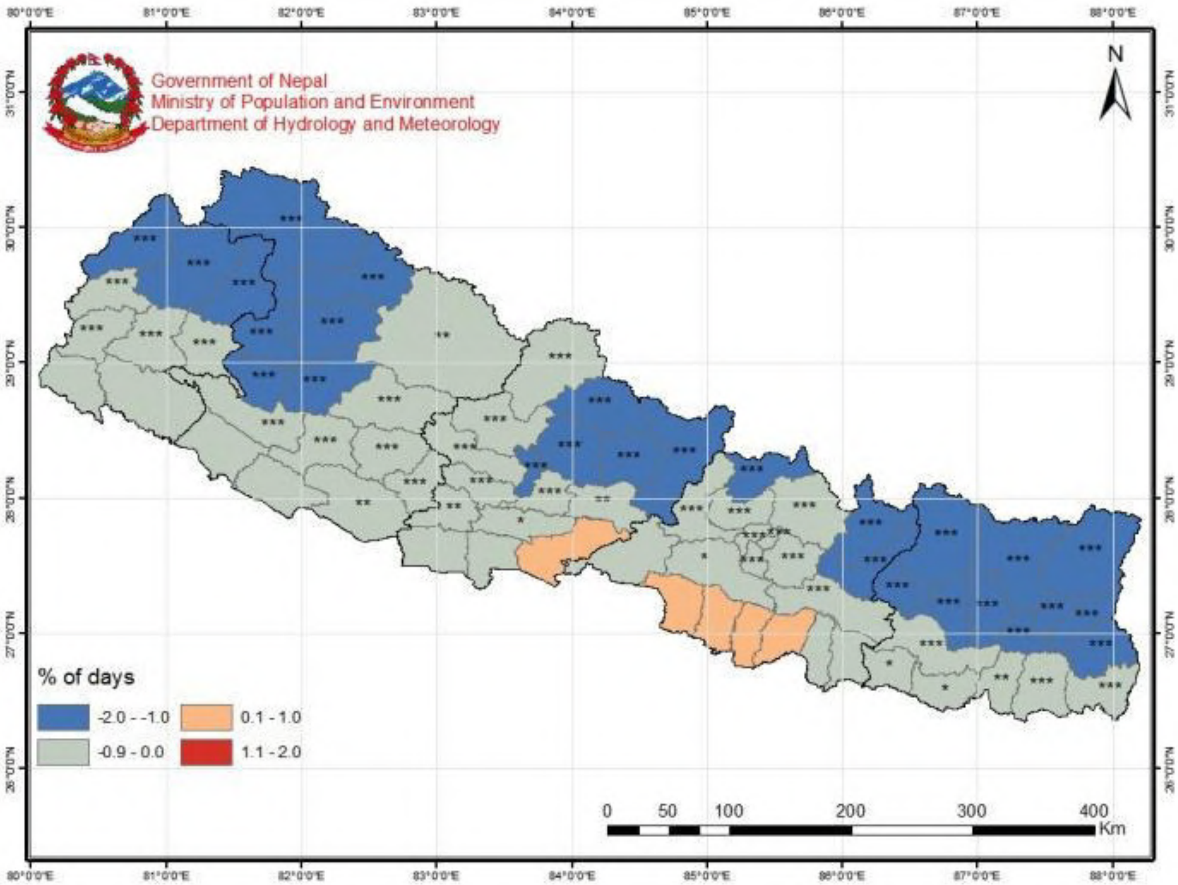

Figure 8.6 District level Cool Days trend.

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

8.7 Cool Nights

Cool nights (percentage of days when minimum temperature <10th percentile) are in negative trend in southern and southeastern districts whereas positive trend in northern and northwestern districts of Nepal (Figure 8.7). This result is consistent with the significant negative trend of minimum temperature in the northwestern districts of Nepal (Figures 7.1, 7.2, 7.3 and 7.4). Out of the districts with negative trend, 17 districts show significance at 95% or higher CL. Similarly, out of the districts with positive trend, 9 districts show 95% or higher CL significance.

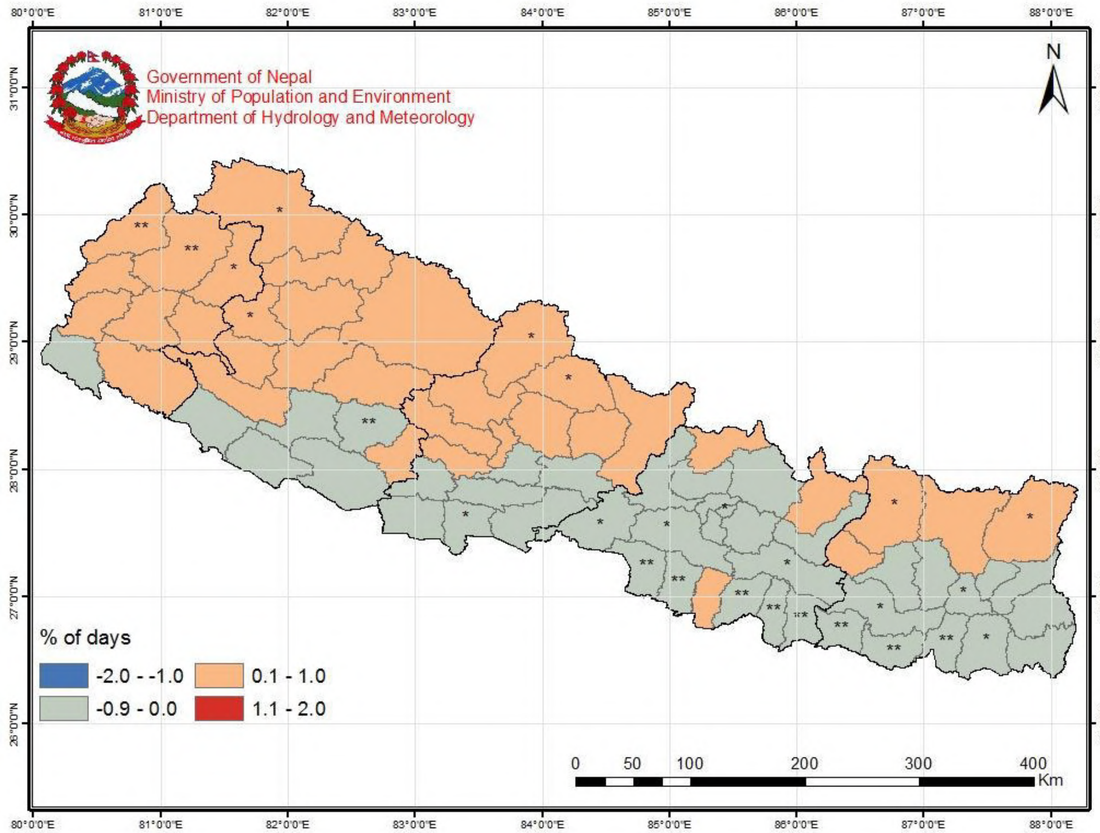

Figure 8.7 District level Cool Nights trend.

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

8.8 WARM NIGHTS

Warm nights (percentage of days when minimum temperature exceeds 90th percentile) are in increasing trend in most of the districts, out of which 42 districts have significant trend at 95% or higher CL (Figure 8.8). This result is consistent with the significant positive trend of minimum temperature in southern districts of Nepal (Figures 7.1, 7.2, 7.3 and 7.4).

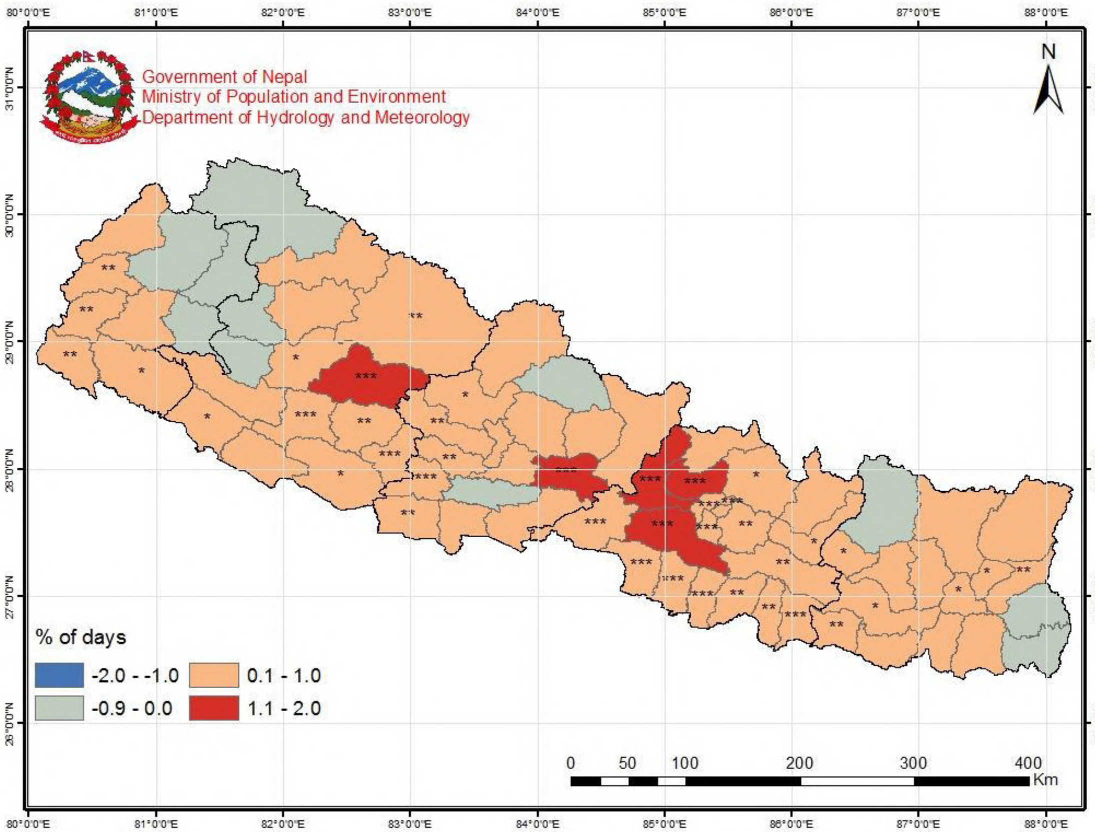

Figure 8.8 District level Warm Nights trend.

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

8.9 WARM DAYS

Increasing trend in warm days (percentage of days when maximum temperature is greater than 90th percentile) is significant in all districts except in 13 districts of Tarai (Figure 8.9). All districts that has positive trend are significant at 99% or higher CL, except three districts (Surkhet, Rupandehi and Saptari) which have positive significant trend at at 95% CL. This result is consistent with the significant positive trend of maximum temperature in majority of districts of Nepal (Figures 6.1, 6.2, 6.3 and 6.4).

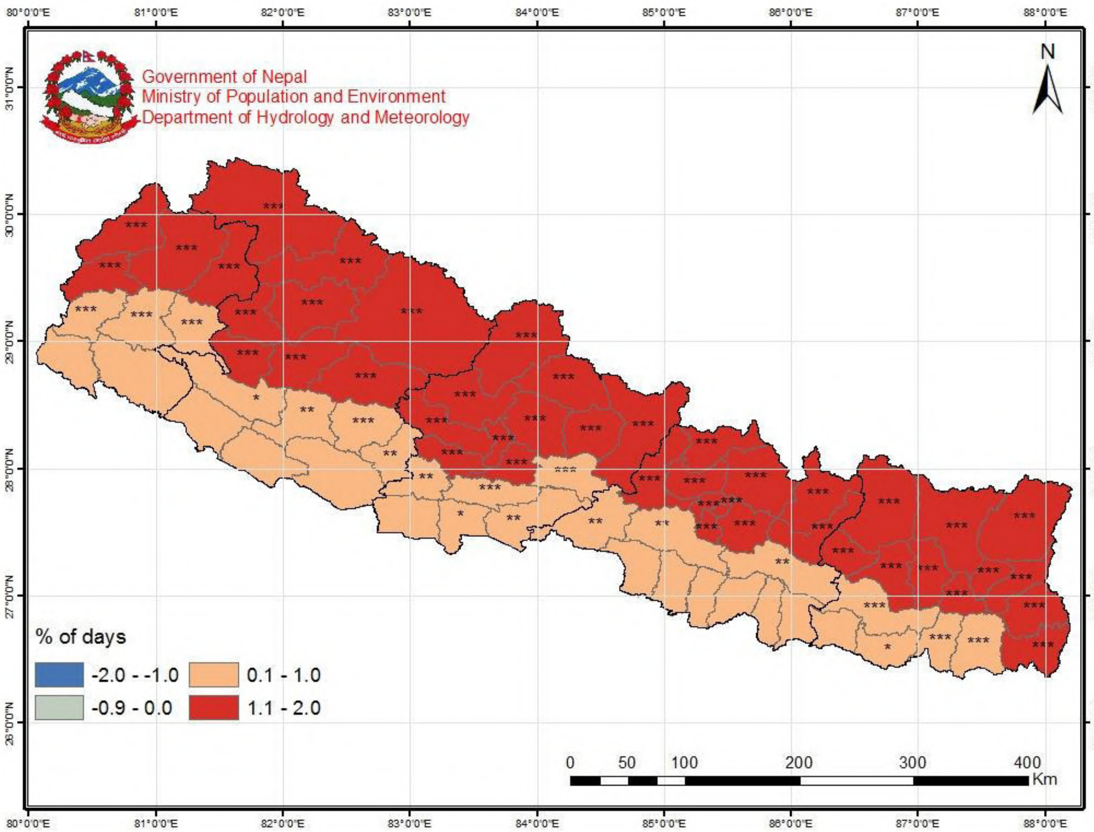

Figure 8.9 District level Warm Days trend.

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

8.10 Warm Spell Duration

District level trend of warm spell duration (annual count of days with at least 6 consecutive days when maximum temperature >90th percentile) is positive in most of the districts (72 districts), out of which 51 show significance at 95% or higher CL (Figure 8.10). Three districts (Rautahat, Sarlahi and Mahottari) show insignificant negative trend.

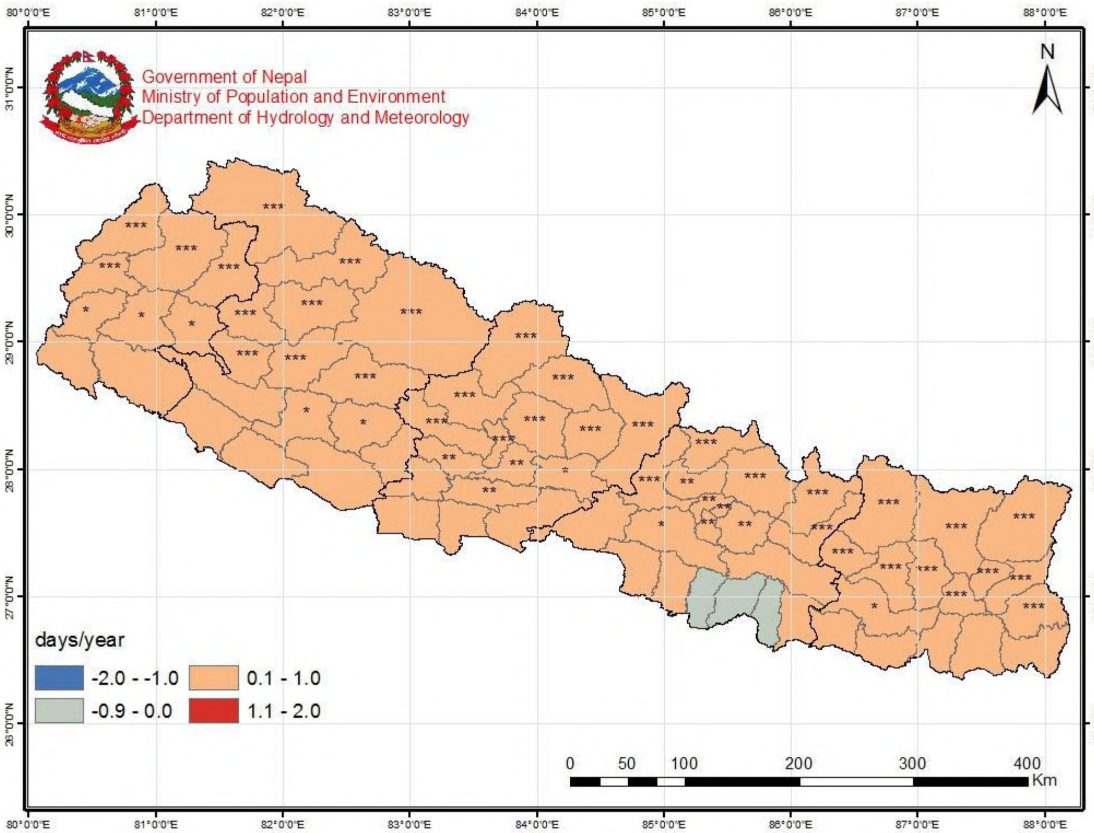

Figure 8.10 District level Warm Spell duration trend.

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

8.11 Cold Spell Duration

District level cold spell duration (annual count of days with at least 6 consecutive days when minimum temperature <10thpercentile) is in positive trend in western and northern districts and is in decreasing trend in southeastern districts of Nepal (Figure 8.11). Significant positive trends are observed mainly in FDR while negatives are not significant.

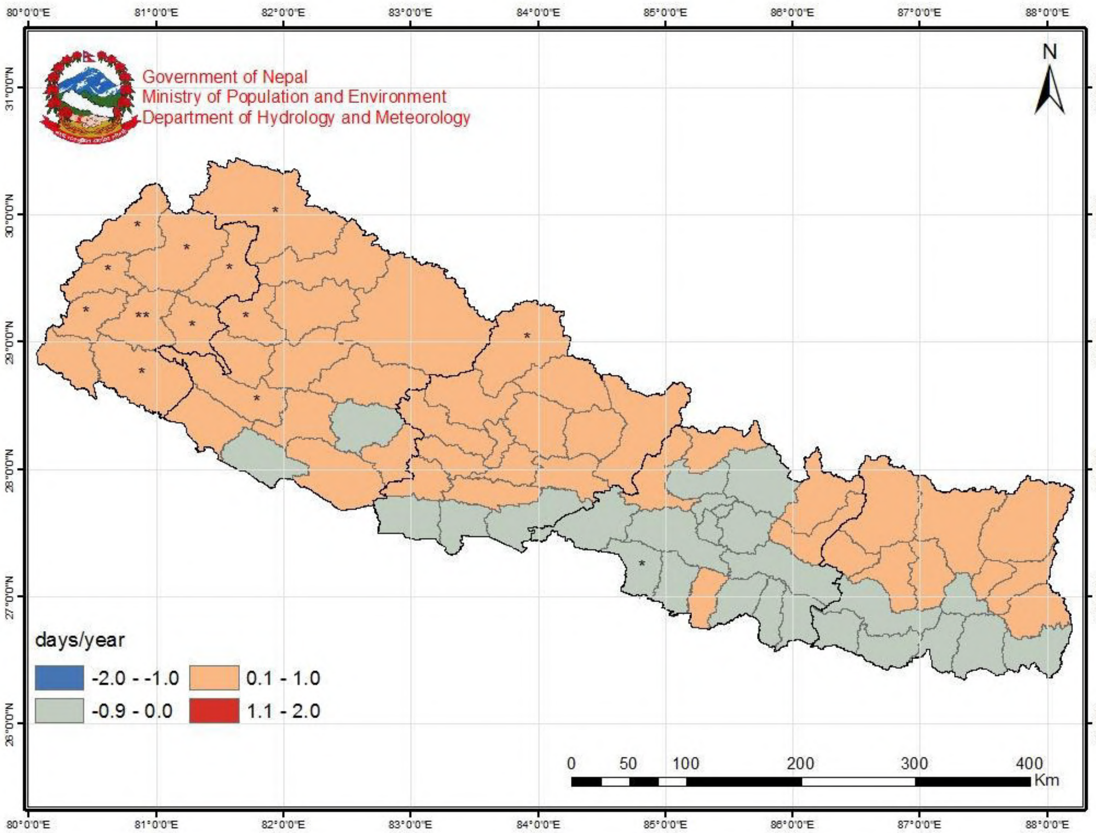

Figure 8.11 District level Cold Spell Duration Trend.

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

8.12 SUMMARY: EXTREME CLIMATE TRENDS

Extreme precipitation trends show significant trends in northwestern and northern districts Number of rainy days is increasing significantly mainly in northwestern districts. Very wet days and extremely wet days are also decreasing significantly, mainly in the northern districts. Consecutive wet days are increasing significantly in the northern districts of MWDR, and central parts of WDR and EDR while consecutively dry days are decreasing significantly, mainly in the northwestern districts.

Extreme temperature show significant trends in the majority of the districts. Warm days and warm nights are in increasing trend significantly in majority of the districts. Warm spell duration is increasing in majority of the districts and cold spell duration is increasing only in the FWDR significantly. Cool days are decreasing in majority of the districts significantly while cool nights are increasing significantly in few districts in the northern and northwestern parts and decreasing significantly in the southeastern districts.

Table 8 Summary of extreme climate indices trend

Extreme Climate Indices	Trend pattern/regions
a. Number of rainy days	Increasing significantly, mainly in the northwestern districts and trends are insignificant in other districts
b. Very wet days and	Decreasing significantly, mainly in the northern districts and trends are insignificant in other districts
c. Extremely wet days	
d. Consecutive wet days	Increasing significantly in the northern districts of MWDR, central part of WDR and EDR and trends are insignificant in other districts
e. Consecutive dry days	Decreasing significantly, mainly in the northwestern districts and trends are insignificant in other districts
f. Warm days	Increasing significantly in majority of the districts
g. Warm nights	Increasing significantly in majority of the districts
h. Warm spell duration	Increasing in majority of the districts
i. Cool days	Decreasing in majority of the districts
j. Cool nights	Increasing in the northwestern significantly & decreasing in the southeast significantly
k. Cold spell duration	Increasing significantly only in the FWDR districts and trends are insignificant in other districts

CHAPTER 9: LINKING WITH PREVIOUS RESULTS

This chapter links the results of this study with previous studies in Nepal. This study is based on gridded station data while almost all previous studies (e.g. Baidya et al., 2008; PAN, 2009; DHM, 2015) on climate trend analysis in Nepal were based on the trend analysis of station data. This study has longer data period than previous studies. This study has used largest number of stations as compared to previous studies. This study went through extensive quality control of temperature data, in which inconsistent records were corrected before using them for analysis. In previous studies data/stations with inconsistent records were excluded, which led to fewer stations for analysis (e.g. Baidya et al., 2008; DHM, 2015). This study has applied non-parametric method, Mann-Kendal–Sen Slope's Method for trend analysis while previous studies have used linear regression method that is more suitable for normally distributed and independent time series. Considering methodology and data period in this study, different results are expected. However, it is important to point out the differences and similarities in the results with previous results on trend analysis in Nepal.

This study shows higher annual positive trends in Nepal average maximum temperature than in minimum temperature. This pattern is consistent with previous studies (e.g. Shrestha et al., 1999; PAN, 2009; DHM, 2015). This study shows All Nepal average annual maximum temperature trend is increasing at 0.056°C/yr, which is lower than result of Shrestha et al. (1999) (0.059°C/yr) and higher than DHM (2015) study (0.04°C/yr). Similarly, in this report minimum temperature trend is increasing at 0.002°C/yr while DHM (2015) and PAN (2009) showed 0.01°C/yr and 0.03°C/yr increase in minimum temperature respectively. Minimum temperature trend is lower in magnitude than those from the previous studies.

This study shows that significant warming trend (at greater than 95% CL) in maximum temperature is greater in higher altitude districts and regions. This result confirms similar findings of previous studies in Nepal (e.g. Shrestha et al., 1999; PAN, 2009; DHM 2015; Shrestha and Devkota, 2010). This study finds negative minimum temperature trend annually and seasonally (except in post-monsoon) in high altitude districts/regions and positive trend in lower elevation districts/regions, which is opposite of the maximum temperature trend variation with altitude. Similar results in minimum temperature trends were reported in PAN (2009) and DHM (2015).

Seasonal and annual precipitation trends in this study show different pattern than the previous studies in most parts of the country, mainly in winter and monsoon (PAN, 2009; DHM, 2015). In pre-monsoon and post-monsoon seasons, the rainfall trend matches with findings of DHM (2015) to some extent, while in winter and monsoon seasons, the rainfall trend is different than PAN (2009) and DHM (2015). This might be due to two reasons: (i) this study used gridded Aphrodite data (in which missing data were filled) whereas previous studies conducted trend analysis only on available data; and (ii) this study used non-parametric test while previous studies used linear regression method for trend analysis.

The findings that show decreasing trend in the cool days and cold nights and increasing trend in warm days and warm nights in Nepal are also reported in Baidya et al (2007) and Shrestha et al (2016). This study found significant trends in extreme precipitation indices in certain districts, while previous studies reported no clear trend in most of precipitation extremes (Baidya et al 2007; Shrestha et al, 2016). The different results in current study could be due to the fact that it used APHRODITE data that provides long term time series data compare to previous studies that used station data.

CHAPTER 10: CONCLUSION

This study was conducted to provide information on observed climate trends in Nepal for the NAP process. The observed climate trend analysis was performed using gridded temperature and precipitation data for the period from 1971 to 2014. The non-parametric Mann-Kendall and Sen's Slope method was used to calculate the trends and to test the significance of trends for districts and physiographic regions for four seasons and annually.

All Nepal trend analysis shows a significant positive trend in annual and seasonal maximum temperature. Significant positive trend in all Nepal minimum temperature is observed only in monsoon. No significant trend is found annually or seasonally in All Nepal precipitation trend.

District level trend analysis shows a robust positive trend (significant at 99.9% confidence level) in maximum temperature in all districts for all seasons, except in Tarai districts in winter season. The significance of minimum temperature and in precipitation are only limited to few districts and seasons.

Extreme events (indices) associated with precipitation show significant trends (positive and negative) specifically in northwestern or northern districts. In contrary the extreme warm temperature indices showed significantly increasing trends in majority of districts. The extreme cool temperature indices are increasing significantly, mainly in the northwestern parts of the country.

The results on significance test from this study allows identifying the real clear trend various spatial and temporal scales. Nonetheless, a number of insignificant but coherent patterns are noted in the precipitation and temperature trends. It is important to note such patterns, as it could be related to the short term climate variability. Further study is necessary to understand the underlying atmospheric phenomena associated with respective climatic trends and patterns.

This study provides the district level climate trends and their level of significance. While using these results for vulnerability and risk assessment and adaptation planning for NAP process, level of significance of the climate trends should be considered. Therefore, further discussion with each thematic group is necessary for better implication of the results in NAP process.

References

Alexander, L.V., Zhang, X., Peterson, T.C., Caesar, J., Gleason, B., Klein Tank, A.M.G., Haylock, M., Collins, D., Trewin, B., Rahimzadeh, F., Tagipour, A., Rupa Kumar, K., Revadekar, J., Griffiths, G., Vincent, L., Stephenson, D.B., Burn, J., Aguilar, E., Brunet, M., Taylor, M., New, M., Zhai, P., Rusticucci, M., Vazquez-Aguirre, J.L., (2006) Global observed changes in daily climate extremes of temperature and precipitation. *J. Geophys. Res. Atmos*. 111, D05109. doi:10.1029/2005JD006290.

Andermann, C., Bonnet, S., and Gloaguen, R. (2014) Evaluation of precipitation data sets along the Himalayan front. Geochemistry, Geophysics, Geosystems, AGU and the Geochemical Society, 2011, 12 (7), pp. Q07023. .

Baidya S.K.; Shrestha M.L; Srikh M. M. (2008) Trends in daily climatic extremes of temperature and precipitation in Nepal. *Journal of Hydrology and Meteorology*, 5(1)

DHM (2015) Study of Climate and climatic variation over Nepal. Department of Hydrology and Meteorology, Ministry of Population and Environment, Nepal

PAN (2009) *Temporal and Spatial Variability of Climate Change over Nepal* (1976-2005). Practical Action Nepal, Kathmandu.

Salmi, T., Määttä, A., Anttila, P., Ruoho-Airola, T., Amnell, T. (2002) Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates – the Excel template application MAKESENS. Finnish Meteorological Institute, Helsinki.

Shrestha, A. B., C. P. Wake, P. A. Mayewski, and J. E. Dibb, (1999) Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94. *Journal of Climate*, 12, 2775-2787.

Shrestha A. B. and Devekota L. P. (2010) Climate Change in the Eastern Himalayas: Observed Trends and Model Projections. Climate Change Impact and Vulnerability in the Eastern Himalayas - Technical Report 1. ICIMOD, Kathmandu

Shrestha A.B.; Bajracharya S.; Sharma A.R.; Duo C.; Kulkarni A (2016) Observed trends and changes in daily temperature and precipitation extremes over the Koshi river basin 1975–2010. J. Climatology DOI: 10.1002/joc.4761

Yatagai, A., Arakawa, O., Kamiguchi, K., Kawamoto, H., Nodzu, M.I., Hamada, A., (2009). A 44-year daily gridded precipitation dataset for Asia based on a dense network of rain gauges. *Sci. Online Lett. Atmos*. 5, 137–140.

Yatagai A, Kamiguchi K, Arakawa O, Hamada A, Yasutomi N, Kitoh A (2012) APHRODITE: Constructing a long-term daily gridded precipitation dataset for Asia based on a dense network of rain gauges. *Bulletin of the American Meteorological Society* 93:1401–1

APPENDIX

Table A1: List of Stations with Meta Data

S.N.	Station Index No.	Station Name	Districts	Lon (degrees)	Lat (degrees)	Elevation (m)	Establish Year
1	103	Patan (West)	Baitadi	80.5	29.5	1292	1984
2	104	Dadeldhura	Dadeldhura	80.6	29.3	1879	1979
3	105	Mahendra Nagar	Kanchanpur	80.2	29.0	197	1976
4	107	Darchula	Darchula	80.6	29.9	1097	1989
5	202	Chainpur (West)	Bajhang	81.2	29.6	1304	1980
6	203	Silgadhi Doti	Doti	81.0	29.3	1309	1977
7	207	Tikapur	Kailali	81.1	28.5	149	1979
8	209	Dhangadhi(Attariya)	Kaliali	80.6	28.8	184	1977
9	215	Godavari(West)	Kailali	80.6	28.9	280	1981
10	218	Dipayal (Doti)	Doti	80.9	29.3	563	1983
11	303	Jumla	Jumla	82.2	29.3	2363	1977
12	307	Rara	Mugu	82.1	29.5	2980	1979
13	310	Dipal Gaun	Jumla	82.2	29.3	2422	1985
14	311	Simikot	Humla	81.8	30.0	2993	1978
15	312	Dunai	Dolpa	82.9	29.0	2098	1989
16	401	Pusma Camp	Surkhet	81.2	28.9	987	1971
17	402	Dailekh	Dailekh	81.7	28.8	1394	1973
18	405	Chisapani(Karnali)	Bardiya	81.3	28.6	201	1971
19	406	Surkhet (Birendra Nagar)	Surkhet	81.6	28.6	720	1975
20	409	Khajura (Nepalganj)	Banke	81.6	28.1	129	1972
21	416	Nepalgunj(Reg.Off.)	Banke	81.6	28.1	141	1977
22	417	Rani Jaruwa Nursery	Bardiya	81.3	28.3	145	1976
23	419	Sikta	Banke	82.0	28.0	162	1979
24	420	Nepalgunj Airport	Banke	81.7	28.1	165	1996
25	508	Tulsipur	Dang	82.3	28.1	683	1974
26	511	Salyan Bazar	Salyan	82.1	28.4	1557	1971
27	513	Chaurjhari Tar	Rukum	82.2	28.7	863	1979
28	514	Musikot(Rukumkot)	Rukum	82.5	28.6	1412	1986
29	515	Ghorai (Dang)	Dang	82.5	28.0	663	1989
30	601	Jomsom	Mustang	83.7	28.8	2744	1978
31	604	Thakmarpha	Mustang	83.7	28.7	2655	1971
32	605	Baglung	Baglung	83.6	28.3	964	1978
33	607	Lete	Mustang	83.6	28.6	2490	1998
34	609	Beni Bazar	Myagdi	83.6	28.4	835	1989
35	614	Kushma	Parbat	83.7	28.2	900	1989
36	702	Tansen	Palpa	83.5	27.9	1183	1971
37	703	Butwal	Rupandehi	83.5	27.7	180	1971
38	705	Bhairahawa Airport	Rupandehi	83.4	27.5	108	1971
39	706	Dumkauli	Nawalparasi	84.2	27.7	183	1978
40	707	Bhairahawa (Agric)	Rupandehi	83.5	27.5	112	1973
41	715	Khanchikot	Arghakhanchi	83.2	27.9	1760	1979
42	725	Tamghas	Gulmi	83.2	28.1	1547	1981
43	728	Semari	Nawalparasi	83.8	27.5	110	1981

44	802	Khudi Bazar	Lamjung	84.4	28.3	838	1971
45	804	Pokhara Airport	Kaski	84.0	28.2	827	1971
46	805	Syangja	Syangia	83.9	28.1	871	1980
47	809	Gorkha	Gorkha	84.6	28.0	724	1973
48	810	Chapkot	Syangja	83.8	27.9	460	1981
49	811	Malepatan (Pokhara)	Kaski	84.0	28.2	859	1971
50	814	Lumle	Kaski	83.8	28.3	1738	1971
51	815	Khairini Tar	Tanahun	84.1	28.0	515	1972
52	816	Chame	Manang	84.2	28.6	2680	1978
53	902	Rampur	Chitawan	84.4	27.7	189	1972
54	906	Hetaunda N.F.I.	Makwanpur	85.0	27.4	452	1972
55	909	Simara Airport	Bara	85.0	27.2	137	1972
56	911	Parwanipur	Bara	84.9	27.1	87	1972
57	922	Gaur	Routahat	85.3	26.8	77	1989
58	1004	Nuwakot	Nuwakot	85.2	27.9	966	1983
59	1007	Kakani	Nuwakot	85.3	27.8	2034	1972
60	1022	Godavari	Lalitpur	85.4	27.6	1527	1972
61	1024	Dhulikhel	Kabhre	85.6	27.6	1543	1986
62	1029	Khumaltar	Lalitpur	85.3	27.7	1334	1971
63	1030	Kathmandu Airport	Kathmandu	85.4	27.7	1337	1971
64	1036	Panchkhal	Kabhre	85.6	27.6	857	1979
65	1038	Dhunibesi	Dhading	85.2	27.7	991	1973
66	1039	Panipokhari(Kathmandu)	Kathmandu	85.3	27.7	1329	1974
67	1043	Nagarkot	Bhaktapur	85.5	27.7	2147	1977
68	1055	Dhunche	Rasuwa	85.3	28.1	1993	1989
69	1071	Buddhanilakantha	Kathmandu	85.4	27.8	1428	1987
70	1073	Khokana	Lalitpur	85.3	27.6	1309	1998
71	1103	Jiri	Dolkha	86.2	27.6	1877	1971
72	1107	Sindhuli Madhi	Sindhuli	85.9	27.2	556	1989
73	1111	Janakpur Airport	Dhanusa	85.9	26.7	76	1971
74	1118	Manusmara	Sarlahi	85.4	26.9	90	1987
75	1121	Karmaiya	Sarlahi	85.5	27.1	139	1985
76	1122	Jalesore	Mahottari	85.8	26.7	68	1989
77	1206	Okhaldhunga	Okhaldhunga	86.5	27.3	1731	1971
78	1212	Phatepur	Saptari	86.9	26.7	83	1982
79	1213	Udayapur Gadhi	Udayapur	86.5	26.9	469	1989
80	1223	Rajbiraj	Saptari	86.7	26.5	68	1985
81	1303	Chainpur (East)	Sankhuwasabha	87.3	27.3	1277	1987
82	1304	Pakhribas	Dhankuta	87.3	27.0	1720	1987
83	1307	Dhankuta	Dhankuta	87.3	27.0	1192	1976
84	1311	Dharan Bazar	Sunsari	87.3	26.8	310	1998
85	1314	Terhathum	Terhathum	87.5	27.1	1525	1989
86	1319	Biratnagar Airport	Morang	87.3	26.5	72	1972
87	1320	Tarahara	Sunsari	87.3	26.7	120	1987
88	1405	Taplejung	Taplejung	87.7	27.4	1744	1971
89	1407	Ilam Tea Estate	Ilam	87.9	26.9	1208	1972
90	1416	Kanyam Tea Estate	Ilam	88.1	26.9	1570	1973
91	1419	Phidim (Panchther)	Panchther	87.8	27.1	1157	1973
92	1421	Gaida (Kankai)	Jhapa	87.9	26.7	107	1985
93	2000	Pyramid	Solukhumbu	86.8	28.0	5035	1992

Table A2: Maximum temperature coefficient (lapse rate) (^{o}C/km)

Months	Maximum temperature coefficient "lapse rate"		Minimum temperature coefficient "lapse rate"	
	Doti : Simikot	Jiri: Pyramid	Doti : Simikot	Jiri: Pyramid
Jan	-5.45	-5.81	-7.57	-3.20
Feb	-6.71	-6.41	-8.67	-3.99
Mar	-7.47	-6.77	-8.07	-4.34
Apr	-6.87	-6.87	-5.96	-4.58
May	-6.74	-6.36	-5.80	-4.81
Jun	-5.76	-5.73	-6.01	-4.97
Jul	-4.65	-5.59	-5.10	-4.97
Aug	-4.92	-5.71	-5.04	-5.00
Sep	-4.93	-6.01	-5.46	-5.06
Oct	-4.92	-6.26	-6.56	-4.74
Nov	-4.83	-5.75	-6.47	-3.66
Dec	-3.90	-5.36	-7.87	-2.90

Table A3a: Seasonal and Annual Climatic Normals for 75 Districts

	Precipitaton (mm)					Maximum Temperature (^{o}C)					Minimum Temperature (^{o}C)				
	Winter	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Annual**	**Winter**	**Pre-monsoon**	**monsoon**	**Post-monsoon**	**Annual**	**Winter**	**Pre-monsoon**	**monsoon**	**Post-monsoon**	**Annual**
Achham	109.9	166.7	1051.4	51.4	1379.0	17.7	27.0	28.2	23.3	24.5	5.0	13.1	18.9	10.9	12.6
Arghakhanchi	57.5	141.7	1367.0	61.4	1627.7	19.6	28.4	28.9	25.3	25.8	7.2	15.5	20.9	13.6	14.9
Baglung	62.4	186.6	1610.4	59.0	1918.5	13.2	20.0	22.6	18.2	18.9	5.0	8.1	14.2	6.8	8.3
Baitadi	107.1	203.5	1110.1	51.9	1472.4	16.9	25.5	27.1	22.4	23.4	4.1	11.8	18.0	9.9	11.6
Bajhang	103.0	162.3	1012.5	46.6	1323.9	7.6	13.8	17.9	12.6	13.4	-3.8	2.3	8.8	0.7	2.6
Bajura	100.3	148.1	728.9	46.8	1023.8	9.9	16.6	20.3	15.2	15.9	-2.4	4.2	10.8	2.6	4.5
Banke	49.7	85.9	1024.7	50.6	1210.8	23.3	34.4	33.5	29.5	30.5	9.3	18.7	24.6	16.4	17.9
Bara	34.9	171.8	1419.2	66.4	1692.3	24.0	33.6	33.3	30.1	30.5	9.8	19.0	25.0	17.3	18.4
Bardiya	64.8	94.0	1252.8	54.7	1466.3	22.8	33.9	33.2	29.1	30.1	9.3	18.6	24.7	16.4	17.9
Bhaktapur	43.3	202.1	1173.8	54.2	1473.2	17.9	25.6	26.8	23.0	23.7	4.7	12.3	18.6	11.0	12.3
Bhojpur	33.8	241.2	1091.0	69.6	1435.5	17.9	25.0	26.3	23.1	23.3	5.8	13.2	18.6	12.0	12.9
Chitawan	44.5	211.1	1460.7	67.4	1783.7	23.0	32.6	32.5	28.8	29.5	9.2	18.0	23.8	16.3	17.4
Dadeldhura	108.5	164.9	1151.6	52.8	1477.5	17.1	26.4	27.5	22.6	23.8	4.3	12.3	17.8	10.0	11.7
Dailekh	82.1	141.2	952.8	43.2	1219.3	22.0	31.8	31.4	27.6	28.5	8.1	17.2	22.7	14.8	16.4
Dang	52.7	114.8	1230.9	59.6	1457.9	8.1	14.6	18.5	13.2	14.1	-3.1	3.1	9.5	1.5	3.4
Darchula	96.1	180.8	1079.9	46.9	1403.4	18.0	27.2	28.2	23.8	24.7	5.4	13.5	19.5	11.5	13.1
Dhading	48.3	217.8	1366.2	51.7	1683.9	17.0	24.7	26.2	22.1	22.8	4.7	12.0	17.7	10.7	11.8
Dhankuta	29.4	185.9	847.8	57.8	1120.8	19.5	26.7	27.7	24.8	24.9	7.3	15.0	20.2	13.6	14.6
Dhanusa	24.7	151.6	1075.8	59.7	1311.8	24.4	33.4	33.1	30.2	30.5	10.4	19.5	25.2	18.1	18.9
Dolakha	39.6	200.8	1253.0	60.0	1553.3	9.6	15.3	18.5	14.4	14.8	-1.5	4.4	11.0	3.5	5.0
Dolpa	37.8	68.3	352.8	28.1	487.0	0.7	4.9	11.2	5.4	6.1	-9.0	-4.5	3.0	-5.2	-3.3
Doti	107.9	161.5	1093.8	52.5	1415.4	17.1	26.1	27.4	22.7	23.7	4.5	12.4	18.5	10.4	12.1
Gorkha	52.0	196.9	1016.1	47.4	1312.3	0.1	14.8	18.3	13.8	12.1	-1.4	4.3	9.9	3.2	4.6
Gulmi	63.5	199.0	1512.9	52.0	1827.4	18.3	26.5	27.6	23.7	24.4	5.9	13.7	19.2	12.0	13.3
Humla	75.8	119.3	421.5	39.4	655.7	2.0	6.7	12.4	7.1	7.5	-8.8	-3.5	3.5	-4.5	-2.7
Ilam	36.1	259.9	1677.8	96.1	2069.9	19.0	26.0	27.4	24.6	24.5	7.1	14.8	19.9	13.5	14.4
Jajarkot	84.3	141.1	1088.3	58.2	1372.0	13.7	21.5	23.9	18.8	19.9	0.5	7.7	14.2	5.8	7.8
Jhapa	30.8	262.0	1936.3	117.5	2346.6	24.4	32.6	32.7	30.2	30.2	10.7	19.5	24.5	17.8	18.7
Jumla	80.6	138.8	598.2	43.6	861.4	7.4	13.1	17.6	12.3	13.0	-5.4	0.5	8.0	-1.0	1.3
Kailali	83.4	109.8	1472.3	53.8	1719.0	18.0	25.9	27.1	23.2	23.9	5.0	12.6	18.9	11.4	12.6
Kalikot	89.8	142.1	557.1	41.9	830.9	21.8	32.8	32.3	28.1	29.1	8.8	17.9	23.8	15.7	17.2
Kanchanpur	74.8	94.0	1430.9	55.3	1655.0	11.5	18.9	21.9	16.7	17.7	-1.0	5.8	12.1	3.9	5.9
Kapilbastu	43.8	100.2	1331.1	56.9	1532.0	23.0	33.9	33.5	29.5	30.3	9.4	18.7	24.7	16.5	18.0
Kaski	78.4	356.5	2173.2	102.5	2710.5	23.9	34.2	33.5	30.1	30.7	10.4	19.7	25.1	17.5	18.8
Kathmandu	46.9	217.2	1345.6	57.1	1666.6	11.4	17.6	20.8	16.3	16.9	0.3	6.3	12.2	5.3	6.6
Kavrepalanchok	39.2	171.0	1046.7	54.5	1311.3	17.4	25.0	26.3	22.4	23.1	4.4	11.8	18.1	10.6	11.9
Khotang	35.2	201.6	1104.5	60.9	1402.2	18.1	25.2	26.4	23.3	23.5	5.8	13.3	18.8	12.1	13.1
Lalitpur	50.7	195.2	1297.2	61.0	1603.9	17.3	24.9	26.3	22.4	23.0	4.3	11.9	18.2	10.6	11.9
Lamjung	69.6	311.0	1695.7	76.4	2152.6	13.2	19.9	22.5	18.1	18.8	1.7	8.1	13.6	6.9	8.2
Mahottari	27.1	150.7	1071.6	59.5	1308.9	24.2	33.4	33.1	30.1	30.4	10.2	19.4	25.1	17.9	18.7
Makwanpur	45.2	217.0	1622.7	76.6	1961.4	20.6	29.2	29.7	26.0	26.7	7.1	15.4	21.3	13.9	15.1
Manang	56.5	107.1	406.2	42.4	612.0	-0.7	3.1	8.9	3.8	4.2	-9.3	-5.4	0.3	-6.2	-4.6
Morang	33.4	237.5	1491.7	101.3	1863.9	23.8	31.7	31.9	29.4	29.4	10.1	18.8	24.1	17.3	18.1
Mugu	74.4	131.6	554.0	41.1	801.0	5.3	10.4	15.6	10.3	10.8	-6.6	-1.0	6.4	-2.2	-0.1
Mustang	25.6	44.7	166.6	21.0	257.8	0.2	4.3	10.2	4.7	5.3	-8.9	-4.8	1.9	-5.5	-3.7
Myagdi	59.8	176.7	1247.5	62.2	1546.2	7.0	12.4	16.7	11.8	12.4	-3.4	1.9	8.3	0.9	2.5
Nawalparasi	51.4	205.4	1622.8	73.2	1952.8	22.8	32.7	32.7	28.8	29.6	9.3	18.1	23.9	16.3	17.5

Nuwakot	54.4	243.7	1820.1	67.8	2185.9	17.8	25.5	26.8	22.8	23.6	5.1	12.5	18.4	11.3	12.4
Okhaldhunga	32.5	185.2	1107.0	60.1	1384.8	17.0	24.1	25.4	22.1	22.4	4.7	12.0	17.9	10.9	12.0
Palpa	51.4	169.7	1399.7	59.6	1680.5	19.7	28.6	29.2	25.4	26.1	7.2	15.2	20.7	13.6	14.8
Panchthar	41.1	271.4	1087.0	69.3	1468.8	16.3	22.8	24.7	21.6	21.6	5.0	12.0	17.4	10.8	11.8
Parbat	64.1	274.9	2169.5	80.2	2588.7	17.9	25.5	27.0	23.0	23.7	5.2	12.4	18.2	11.1	12.3
Parsa	34.8	159.4	1308.8	62.7	1565.6	23.7	33.4	33.1	29.7	30.3	9.6	18.7	24.6	17.0	18.1
Pyuthan	60.3	152.2	1264.5	54.4	1531.6	18.3	26.7	27.7	23.7	24.4	5.6	13.7	19.3	11.8	13.2
Ramechhap	33.4	175.2	1037.8	53.0	1299.4	14.2	20.9	23.0	19.3	19.7	2.2	9.0	15.3	8.0	9.2
Rasuwa	42.8	125.3	860.7	46.0	1074.7	5.5	10.5	14.6	10.1	10.6	-4.2	0.9	6.9	0.1	1.5
Rautahat	30.7	154.9	1285.5	66.8	1537.8	15.8	23.6	25.2	20.8	21.7	3.1	10.7	16.7	8.9	10.5
Rolpa	71.7	157.8	1171.5	57.2	1458.2	24.2	33.8	33.6	30.4	30.8	10.2	19.4	25.3	17.8	18.8
Rukum	65.6	139.7	1031.1	55.6	1292.1	11.2	17.9	21.2	16.1	17.1	-0.8	5.7	12.5	4.4	6.1
Rupandehi	47.0	121.5	1502.7	74.3	1745.4	23.8	34.3	33.6	30.2	30.7	10.4	19.7	25.2	17.7	18.9
Salyan	64.8	110.3	935.1	52.7	1162.9	19.2	28.4	28.7	24.4	25.5	5.6	13.9	19.8	11.8	13.4
Sankhuwasabha	50.9	385.4	1513.6	99.5	2049.4	25.0	33.4	33.1	30.7	30.7	10.6	19.7	25.0	18.2	18.9
Saptari	27.7	166.0	1140.2	68.2	1402.0	24.2	33.6	33.4	30.2	30.6	10.2	19.4	25.2	17.9	18.8
Sarlahi	29.2	152.7	1221.4	69.9	1473.2	10.0	15.7	18.8	14.9	15.2	-0.1	5.7	11.4	4.7	6.0
Sindhuli	36.2	205.4	1376.3	80.9	1698.8	21.3	29.6	30.0	26.8	27.2	7.8	16.1	22.0	14.8	15.8
Sindhupalchok	51.9	218.4	1687.8	77.0	2034.9	11.9	18.3	21.0	16.8	17.4	0.3	6.7	13.0	5.7	7.0
Siraha	26.3	151.0	1047.1	61.4	1285.7	24.6	33.4	33.1	30.4	30.6	10.5	19.6	25.1	18.2	19.0
Solukhumbu	30.5	138.1	1040.8	48.8	1257.9	3.6	8.1	12.5	8.3	8.5	-5.4	-0.7	5.6	-1.3	0.1
Sunsari	32.8	226.9	1433.6	101.1	1794.3	24.5	32.6	32.5	30.1	30.1	10.4	19.3	24.7	17.8	18.6
Surkhet	77.8	115.1	1148.1	51.1	1391.9	20.1	30.3	30.4	25.9	27.0	7.0	15.7	21.5	13.4	15.1
Syangja	54.5	268.5	1729.9	65.2	2118.4	20.0	28.3	29.3	25.3	26.0	7.1	14.7	20.5	13.4	14.5
Tanahu	56.4	330.7	1472.4	65.7	1925.2	21.5	30.3	30.9	27.0	27.8	8.2	16.3	22.1	14.9	16.0
Taplejung	40.6	271.4	1087.0	69.3	1468.4	5.2	9.8	14.3	10.1	10.2	-3.5	1.5	7.3	0.7	2.0
Terhathum	34.6	244.5	846.4	53.9	1179.4	17.4	24.1	25.8	22.7	22.8	5.8	13.0	18.2	11.7	12.7
Udayapur	30.7	177.0	1076.0	65.5	1349.3	22.5	30.4	30.6	27.9	28.1	8.9	17.3	22.8	16.1	16.8

Table A3b: Seasonal and Annual Climatic Normals for Physiographic Region

	Precipitation (mm)					Maximum Temperature (^oC)					Minimum Temperature (^oC)				
	Winter	**Pre-monsoon**	**monsoon**	**Post-monsoon**	**Annual**	**Winter**	**Pre-monsoon**	**monsoon**	**Post-monsoon**	**Annual**	**Winter**	**Pre-monsoon**	**monsoon**	**Post-monsoon**	**Annual**
High Himalayas	49.6	105.4	502.9	36.5	694.2	11.8	18.5	21.5	16.9	17.6	-9.1	-4.8	2.0	-5.5	-3.8
High Mountains	72.6	202.7	1189.8	62.9	1527.9	11.8	18.5	21.5	16.9	17.6	-0.2	6.4	12.8	5.0	6.6
Mid Mountain	60.2	212.9	1292.7	61.7	1627.4	18.6	26.8	27.8	23.9	24.6	5.8	13.6	19.4	12.0	13.3
Siwaliks	52.0	160.9	1426.3	69.4	1708.5	22.6	32.5	32.4	28.5	29.3	8.9	17.7	23.5	15.9	17.1
Terai	41.7	149.5	1339.1	70.2	1600.4	23.9	34.1	33.9	30.3	30.8	10.3	19.5	25.2	17.7	18.8

Table A5a: District Precipitation Trends with Corresponding Significance Levels

S.N.	Districts	Winter		Pre-monsoon		Monsoon		Post-monsoon		Annual	
		α	Trend	α	Trend	α	Trend	α	Trend	α	Trend
1	Achham	0	-0.16	0	-0.61111	0	2.38	0	-0.45	0	1.628571
2	Arghakhanchi	0	0.14	0	1.073317	0	-1.53	0	-0.56	0	-3.0477
3	Baglung	0	-0.22	0	-0.19858	0	4.53	0	-0.62	0	2.38447
4	Baitadi	0	0.01	0	-0.68915	0	2.21	0	-0.23	0	1.302564
5	Bajhang	0	-0.20	0	-1.26754	0	2.67	0	-0.28	0	-0.49
6	Bajura	0	-0.18	0	-0.82333	0	1.91	0	-0.05	0	0.935453
7	Banke	0	0.23	+	0.812944	0	3.94	0	-0.11	0	3.752963
8	Bara	0	-0.15	0	0.052421	0	-2.72	0	-0.62	0	-4.64427
9	Bardiya	0	0.41	0	0.6734	+	6.56	0	-0.18	*	7.864615
10	Bhaktapur	0	0.02	0	0.56125	0	-0.20	0	-0.31	0	-0.09457
11	Bhojpur	0	-0.16	0	0.085484	0	-0.47	0	-0.79	0	-2.18021
12	Chitawan	0	-0.12	+	1.708489	0	0.17	0	-0.33	0	1.319968
13	Dadeldhura	0	0.08	0	-0.50238	0	0.44	0	-0.17	0	0.643
14	Dailekh	0	0.05	0	-0.41769	0	-0.12	0	-0.36	0	-1.18278
15	Dang	0	0.14	0	0.672059	0	-1.28	0	-0.62	0	-2.27303
16	Darchula	0	-0.28	0	-0.86389	0	1.13	0	-0.38	0	-1.03459
17	Dhading	0	-0.19	0	-0.144	0	-2.94	0	-0.77	+	-3.86083
18	Dhankuta	0	-0.09	0	0.023846	0	-1.91	0	-0.53	0	-2.76092
19	Dhanusa	0	-0.20	+	1.467619	0	3.60	0	-0.40	0	4.135667
20	Dolakha	0	-0.26	+	-1.52972	**	-5.63	0	-0.45	**	-7.72086
21	Dolpa	0	0.00	0	-0.45936	0	1.19	0	-0.13	0	0.210714
22	Doti	0	0.29	0	-0.44273	0	3.47	0	-0.33	0	1.948684
23	Gorkha	0	-0.19	0	-0.7214	0	-1.38	0	-0.45	0	-3.35296
24	Gulmi	0	0.15	0	0.917148	0	5.40	0	-0.73	0	5.11581
25	Humla	0	0.51	*	-1.3	0	-0.19	0	0.03	0	-0.7395
26	Ilam	0	-0.20	0	0.450877	*	-7.50	0	-0.60	*	-9.56731
27	Jajarkot	0	0.10	0	-0.5075	0	-0.34	0	-0.65	0	-2.945
28	Jhapa	0	-0.04	+	1.606224	0	-0.21	0	-0.23	0	1.495135
29	Jumla	0	0.09	0	-0.64776	0	0.30	0	-0.08	0	-0.57946
30	Kailali	0	0.48	0	0.469982	0	3.04	0	-0.22	0	3.443212
31	Kalikot	0	-0.48	0	-0.76944	0	-0.06	0	-0.25	0	-1.82952
32	Kanchanpur	0	0.45	0	0.358333	0	3.96	0	-0.26	0	5.23
33	Kapilbastu	0	0.19	0	0.672222	0	-1.86	0	-0.59	0	-2.17636
34	Kaski	0	-0.10	0	-1.37321	+	-7.59	0	-1.30	*	-11.4408
35	Kathmandu	0	-0.02	0	0.437647	0	0.83	0	-0.38	0	1.000962
36	Kavrepalanchok	0	-0.09	0	-0.03929	0	-2.44	0	-0.18	0	-2.45481
37	Khotang	0	-0.15	0	0.736667	0	-1.94	0	-0.59	0	-3.04
38	Lalitpur	0	0.118333	0	0.21	0	-4.94	0	-0.24	+	-4.95
39	Lamjung	0	-0.02926	0	-0.81	0	-3.99	0	-0.76	+	-6.47

40	Mahottari	0	-0.07906	*	1.36	0	2.23	0	-0.50	0	2.79
41	Makwanpur	0	-0.13284	0	0.07	0	-3.96	0	-0.44	0	-5.13
42	Manang	0	0.240783	+	-0.70	**	-2.76	+	-0.52	**	-3.88
43	Morang	0	-0.0375	*	2.00	0	-0.67	0	-0.57	0	0.04
44	Mugu	0	0.238889	0	-0.62	0	-1.15	0	0.01	0	-1.84
45	Mustang	0	0.120606	0	-0.23	+	-0.94	0	-0.20	*	-1.16
46	Myagdi	0	-0.04308	0	-0.33	0	4.14	0	-0.60	0	2.18
47	Nawalparasi	0	0.088429	0	1.58	0	2.64	0	-0.30	0	3.72
48	Nuwakot	0	-0.13843	0	-0.09	0	-1.97	+	-0.99	0	-2.74
49	Okhaldhunga	0	-0.12804	0	0.12	0	-2.24	0	-0.47	0	-2.69
50	Palpa	0	0.005124	0	1.04	0	0.77	0	-0.51	0	0.81
51	Panchthar	0	0.227083	0	-0.33	0	-0.43	0	-0.70	0	-1.39
52	Parbat	0	0.021637	0	0.98	*	8.65	0	-0.52	*	8.80
53	Parsa	0	-0.19125	0	0.50	0	-1.53	0	-0.43	0	-1.43
54	Pyuthan	0	0.087302	0	0.21	0	-1.88	0	-0.68	0	-3.69
55	Ramechhap	0	-0.21996	*	-1.19	***	-6.67	+	-0.73	***	-9.22
56	Rasuwa	0	-0.58578	**	-1.31	0	-0.07	**	-1.04	+	-2.60
57	Rautahat	0	-0.1265	0	0.21	0	-2.16	0	-0.39	0	-1.79
58	Rolpa	0	0.031067	0	-0.48	0	-3.92	0	-0.40	*	-5.19
59	Rukum	0	-0.12381	0	-0.70	0	-2.50	0	-0.37	0	-3.80
60	Rupandehi	0	0.176389	0	0.89	0	-2.70	0	-0.42	0	-3.28
61	Salyan	0	0.083283	0	0.00	0	-0.51	0	-0.22	0	-1.04
62	Sankhuwasabha	0	0.003472	0	-1.14	0	-3.22	0	-0.91	0	-4.68
63	Saptari	0	-0.196	*	1.44	0	-0.92	0	-0.26	0	-0.24
64	Sarlahi	0	-0.00757	0	1.04	0	1.13	0	-0.28	0	1.23
65	Sindhuli	0	-0.2151	0	-0.37	*	-6.82	0	-0.98	*	-8.14
66	Sindhupalchok	0	-0.05833	0	-0.10	0	-0.54	0	-0.06	0	-0.19
67	Siraha	0	-0.20185	0	0.71	0	-1.76	0	-0.44	0	-1.62
68	Solukhumbu	0	-0.35813	0	-0.15	0	-3.03	*	-0.94	0	-4.36
69	Sunsari	0	-0.09722	**	2.19	0	-0.79	0	-0.20	0	0.72
70	Surkhet	0	0.203613	0	0.04	0	0.72	0	-0.41	0	0.28
71	Syangja	0	-0.10683	0	0.69	*	9.04	0	-0.53	*	8.99
72	Tanahu	0	0.030075	0	0.10	0	4.77	0	-0.18	0	3.76
73	Taplejung	0	0.248437	0	-0.33	0	-0.43	0	-0.70	0	-1.36
74	Terhathum	0	0.213393	0	0.03	0	2.54	0	-0.40	0	2.99
75	Udayapur	0	-0.21514	0	0.80	0	-3.81	0	-0.68	0	-3.35

Note: * 95%, ** 99% and * 99.9% Significant; '+' & '0': Insignificant**

Table A6a: District maximum temperature trends with corresponding significance levels

S.N.	Districts	Winter		Pre-monsoon		Monsoon		Post-monsoon		Annual	
		α	Trend	α	Trend	α	Trend	α	Trend	α	Trend
1	Achham	***	0.047	***	0.057	***	0.063	***	0.047	***	0.056052
2	Arghakhanchi	**	0.019	*	0.029	***	0.043	***	0.034	***	0.034
3	Baglung	***	0.050	***	0.047	***	0.055	***	0.057	***	0.055
4	Baitadi	***	0.056	***	0.061	***	0.066	***	0.053	***	0.062
5	Bajhang	***	0.103	***	0.077	***	0.072	***	0.072	***	0.084
6	Bajura	***	0.086	***	0.072	***	0.065	***	0.066	***	0.077
7	Banke	0	-0.005	+	0.024	***	0.034	**	0.025	***	0.020
8	Bara	+	-0.021	0	0.007	***	0.030	0	0.016	0	0.010
9	Bardiya	0	-0.003	0	0.020	***	0.036	***	0.032	***	0.024
10	Bhaktapur	***	0.043	***	0.042	***	0.043	***	0.046	***	0.044
11	Bhojpur	***	0.062	***	0.057	***	0.053	***	0.064	***	0.057
12	Chitawan	0	0.002	*	0.034	***	0.048	**	0.029	***	0.027
13	Dadeldhura	***	0.036	***	0.045	***	0.053	***	0.046	***	0.047
14	Dailekh	***	0.064	***	0.081	***	0.078	***	0.061	***	0.072
15	Dang	**	0.017	*	0.032	***	0.037	***	0.032	***	0.031
16	Darchula	***	0.096	***	0.086	***	0.081	***	0.073	***	0.087
17	Dhading	***	0.047	***	0.055	***	0.059	***	0.050	***	0.052
18	Dhankuta	***	0.063	***	0.055	***	0.056	***	0.065	***	0.059
19	Dhanusa	0	0.007	+	0.022	***	0.032	**	0.033	***	0.024
20	Dolakha	***	0.078	***	0.050	***	0.059	***	0.067	***	0.063
21	Dolpa	***	0.078	***	0.065	***	0.090	***	0.078	***	0.078
22	Doti	***	0.048	***	0.051	***	0.058	***	0.046	***	0.052
23	Gorkha	***	0.083	***	0.070	***	0.072	***	0.072	***	0.076
24	Gulmi	***	0.034	***	0.046	***	0.051	***	0.043	***	0.045
25	Humla	***	0.104	***	0.083	***	0.068	***	0.077	***	0.085
26	Ilam	***	0.068	***	0.058	***	0.067	***	0.070	***	0.067
27	Jajarkot	***	0.066	***	0.070	***	0.071	***	0.060	***	0.072
28	Jhapa	***	0.035	**	0.034	***	0.053	***	0.052	***	0.044
29	Jumla	***	0.090	***	0.078	***	0.071	***	0.080	***	0.086
30	Kailali	0	-0.005	+	0.023	***	0.038	**	0.028	***	0.023
31	Kalikot	***	0.089	***	0.085	***	0.075	***	0.071	***	0.082
32	Kanchanpur	0	-0.012	+	0.020	***	0.033	**	0.023	**	0.018
33	Kapilbastu	0	-0.003	0	0.020	***	0.035	**	0.022	***	0.021
34	Kaski	***	0.074	***	0.060	***	0.058	***	0.069	***	0.067
35	Kathmandu	***	0.044	***	0.045	***	0.045	***	0.047	***	0.044
36	Kavrepalanchok	***	0.037	***	0.039	***	0.043	***	0.043	***	0.042
37	Khotang	***	0.060	***	0.052	***	0.052	***	0.066	***	0.057

38	Lalitpur	***	0.043	***	0.045	***	0.046	***	0.049	***	0.045
39	Lamjung	***	0.078	***	0.065	***	0.065	***	0.071	***	0.070
40	Mahottari	0	0.001	0	0.013	***	0.031	*	0.026	***	0.019
41	Makwanpur	*	0.016	**	0.038	***	0.045	***	0.034	***	0.034
42	Manang	***	0.118	***	0.086	***	0.071	***	0.090	***	0.092
43	Morang	**	0.028	**	0.034	***	0.046	***	0.051	***	0.040
44	Mugu	***	0.085	***	0.070	***	0.068	***	0.075	***	0.080
45	Mustang	***	0.092	***	0.069	***	0.065	***	0.080	***	0.080
46	Myagdi	***	0.068	***	0.052	***	0.059	***	0.070	***	0.065
47	Nawalparasi	0	-0.009	*	0.033	***	0.049	+	0.018	***	0.026
48	Nuwakot	***	0.038	***	0.045	***	0.050	***	0.041	***	0.045
49	Okhaldhunga	***	0.063	***	0.052	***	0.053	***	0.067	***	0.057
50	Palpa	*	0.020	***	0.045	***	0.056	***	0.039	***	0.043
51	Panchthar	***	0.093	***	0.073	***	0.074	***	0.085	***	0.082
52	Parbat	***	0.059	***	0.063	***	0.057	***	0.056	***	0.059
53	Parsa	0	-0.014	+	0.023	***	0.036	*	0.021	**	0.017
54	Pyuthan	***	0.028	*	0.031	***	0.045	***	0.038	***	0.040
55	Ramechhap	***	0.067	***	0.047	***	0.053	***	0.065	***	0.056
56	Rasuwa	***	0.077	***	0.061	***	0.063	***	0.068	***	0.069
57	Rautahat	+	-0.019	0	0.004	***	0.026	0	0.018	0	0.009
58	Rolpa	***	0.047	**	0.039	***	0.051	***	0.048	***	0.048
59	Rukum	***	0.056	**	0.042	***	0.068	***	0.060	***	0.064
60	Rupandehi	0	-0.012	+	0.025	***	0.043	**	0.022	***	0.021
61	Salyan	***	0.047	***	0.052	***	0.051	***	0.044	***	0.051
62	Sankhuwasabha	***	0.091	***	0.056	***	0.066	***	0.078	***	0.072
63	Saptari	0	0.017	+	0.025	***	0.036	***	0.044	***	0.030
64	Sarlahi	0	-0.010	0	0.002	***	0.029	+	0.019	+	0.013
65	Sindhuli	***	0.032	**	0.035	***	0.039	***	0.043	***	0.037
66	Sindhupalchok	***	0.063	***	0.049	***	0.053	***	0.056	***	0.055
67	Siraha	0	0.015	*	0.024	***	0.034	***	0.039	***	0.029
68	Solukhumbu	***	0.100	***	0.056	***	0.068	***	0.084	***	0.076
69	Sunsari	*	0.020	*	0.029	***	0.040	***	0.045	***	0.033
70	Surkhet	***	0.032	***	0.049	***	0.052	***	0.042	***	0.044
71	Syangja	***	0.036	**	0.046	***	0.052	***	0.043	***	0.047
72	Tanahu	***	0.028	***	0.044	***	0.050	***	0.038	***	0.042
73	Taplejung	***	0.113	***	0.072	***	0.077	***	0.094	***	0.091
74	Terhathum	***	0.088	***	0.068	***	0.070	***	0.082	***	0.077
75	Udayapur	***	0.036	**	0.038	***	0.043	***	0.056	***	0.043

Note: Significance (α): * 95% CL, ** 99% CL and * 99.9% CL ; insignificant at 95% CL : + , 0**

Table A7a: District minimum temperature trends with corresponding significance levels

S.N.	Districts	Winter		Pre-monsoon		Monsoon		Post-monsoon		Annual	
		α	Trend	α	Trend	α	Trend	α	Trend	α	Trend
1	Achham	+	-0.018	0	-0.012	0	-0.001	+	-0.016	0	-0.0043
2	Arghakhanchi	0	0.009	0	0.011	***	0.018	0	0.004	**	0.013
3	Baglung	0	-0.013	0	-0.006	**	0.019	0	-0.005	0	0.003
4	Baitadi	0	-0.016	0	-0.007	*	0.015	+	-0.018	0	0.000
5	Bajhang	**	-0.048	+	-0.028	0	-0.003	*	-0.032	+	-0.018
6	Bajura	**	-0.044	+	-0.025	0	-0.005	**	-0.034	+	-0.019
7	Banke	+	0.015	0	0.005	0	0.010	0	0.009	*	0.009
8	Bara	**	0.030	**	0.023	***	0.017	*	0.018	***	0.023
9	Bardiya	+	0.012	0	0.009	**	0.017	0	0.013	***	0.012
10	Bhaktapur	*	0.018	*	0.016	***	0.021	**	0.016	***	0.020
11	Bhojpur	0	0.009	0	0.004	0	0.008	0	0.002	0	0.007
12	Chitawan	**	0.022	**	0.018	***	0.022	*	0.028	***	0.025
13	Dadeldhura	0	-0.012	0	-0.002	**	0.016	0	-0.011	0	0.003
14	Dailekh	0	-0.012	0	-0.011	0	-0.009	*	-0.021	+	-0.010
15	Dang	0	0.005	0	0.006	**	0.014	0	0.001	*	0.008
16	Darchula	**	-0.045	+	-0.024	0	-0.001	**	-0.035	+	-0.016
17	Dhading	0	0.002	+	0.013	***	0.027	*	0.019	***	0.017
18	Dhankuta	*	0.018	0	0.011	**	0.014	0	0.006	*	0.014
19	Dhanusa	***	0.038	**	0.029	***	0.022	*	0.026	***	0.029
20	Dolakha	0	-0.013	0	-0.006	**	0.013	0	-0.007	0	-0.002
21	Dolpa	**	-0.052	0	-0.016	**	0.046	0	-0.017	0	0.000
22	Doti	*	-0.019	0	-0.013	0	0.007	0	-0.013	0	-0.003
23	Gorkha	+	-0.019	0	0.005	*	0.018	0	0.000	0	0.002
24	Gulmi	0	0.002	0	0.005	**	0.013	0	0.003	0	0.007
25	Humla	**	-0.076	+	-0.032	0	-0.005	**	-0.037	*	-0.028
26	Ilam	0	0.001	0	-0.004	0	0.004	0	-0.010	0	-0.001
27	Jajarkot	0	-0.014	0	-0.010	*	0.016	0	-0.011	0	0.000
28	Jhapa	+	0.014	0	0.003	0	0.001	0	0.002	0	0.005
29	Jumla	**	-0.051	0	-0.017	*	0.016	+	-0.028	0	-0.012
30	Kailali	*	0.017	+	0.012	**	0.017	+	0.012	***	0.016
31	Kalikot	0	0.000	0	0.005	*	0.015	0	0.004	+	0.011
32	Kanchanpur	*	-0.035	+	-0.020	0	-0.008	*	-0.033	*	-0.018
33	Kapilbastu	0	0.009	0	0.014	**	0.018	0	0.004	**	0.016
34	Kaski	*	0.022	**	0.018	***	0.018	0	0.006	***	0.018
35	Kathmandu	0	-0.014	0	-0.004	0	0.005	0	-0.003	0	-0.002
36	Kavrepalanchok	*	0.015	*	0.016	***	0.023	**	0.017	***	0.020
37	Khotang	0	0.008	0	0.004	*	0.011	0	0.007	*	0.010

38	Lalitpur	+	0.014	+	0.013	***	0.019	*	0.013	***	0.017
39	Lamjung	0	-0.009	0	0.007	+	0.015	0	0.009	0	0.008
40	Mahottari	***	0.039	**	0.031	***	0.019	*	0.023	***	0.027
41	Makwanpur	*	0.021	**	0.018	***	0.023	**	0.024	***	0.023
42	Manang	**	-0.050	0	-0.019	0	-0.017	+	-0.030	**	-0.030
43	Morang	**	0.024	+	0.013	*	0.010	0	0.007	**	0.014
44	Mugu	**	-0.055	0	-0.019	0	0.013	+	-0.030	0	-0.011
45	Mustang	**	-0.043	0	-0.016	0	0.013	*	-0.027	+	-0.014
46	Myagdi	*	-0.029	0	-0.015	*	0.016	0	-0.014	0	-0.004
47	Nawalparasi	+	0.017	+	0.015	0	0.009	0	0.010	**	0.015
48	Nuwakot	0	0.009	*	0.016	***	0.024	**	0.022	***	0.021
49	Okhaldhunga	0	0.002	0	0.001	**	0.014	0	0.002	+	0.008
50	Palpa	0	0.004	0	0.005	0	0.002	0	0.001	0	0.004
51	Panchthar	0	-0.001	0	0.001	***	0.018	0	-0.006	0	0.007
52	Parbat	0	-0.002	0	-0.003	0	0.008	0	-0.001	0	0.003
53	Parsa	**	0.026	**	0.018	***	0.020	*	0.022	***	0.023
54	Pyuthan	0	0.003	0	0.007	***	0.019	0	0.003	*	0.009
55	Ramechhap	0	0.001	0	0.001	**	0.014	0	0.001	0	0.005
56	Rasuwa	+	-0.020	0	-0.001	+	0.015	0	-0.005	0	-0.001
57	Rautahat	0	-0.004	0	-0.001	***	0.021	0	0.001	+	0.008
58	Rolpa	***	0.033	***	0.028	**	0.026	*	0.019	0	0.025
59	Rukum	+	-0.019	0	-0.007	***	0.038	0	0.002	0	0.008
60	Rupandehi	*	0.021	*	0.014	**	0.013	0	0.007	**	0.017
61	Salyan	0	0.003	0	-0.001	***	0.019	0	0.011	**	0.012
62	Sankhuwasabha	+	-0.017	0	-0.010	0	0.005	0	-0.012	0	-0.007
63	Saptari	***	0.035	**	0.022	*	0.011	*	0.020	***	0.023
64	Sarlahi	***	0.037	***	0.031	***	0.019	*	0.021	***	0.027
65	Sindhuli	**	0.027	**	0.019	***	0.017	+	0.018	***	0.021
66	Sindhupalchok	0	-0.004	0	0.003	**	0.014	0	0.004	0	0.006
67	Siraha	***	0.039	**	0.026	***	0.019	**	0.028	***	0.029
68	Solukhumbu	**	-0.037	0	-0.016	0	0.007	0	-0.017	0	-0.010
69	Sunsari	***	0.032	*	0.019	**	0.010	0	0.015	***	0.019
70	Surkhet	0	-0.004	0	0.000	*	0.011	0	0.004	0	0.006
71	Syangja	0	0.006	0	0.005	+	0.008	0	0.007	*	0.009
72	Tanahu	*	0.018	*	0.016	***	0.026	*	0.025	***	0.023
73	Taplejung	*	-0.034	0	-0.014	0	0.008	+	-0.023	0	-0.010
74	Terhathum	0	0.007	0	0.007	**	0.014	0	-0.003	+	0.009
75	Udayapur	***	0.028	*	0.019	**	0.013	*	0.020	***	0.020

Note: Significance (α): * 95% CL, ** 99% CL and *** 99.9% CL; insignificant at 95% CL: +,

Table A8: District trends for extreme climate indices

Districts	Rainy Days		Consecutive dry days		Consecutive wet days		Very wet days		Extremely wet days		Warm days		Cool days		Warm spell duration		Warm nights		Cool nights		Cold spell duration	
	α	Trend	α	Trend	α	Trend	α	Trend	α	Trend	α	Trend	α	Trend	α	Trend	α	Trend	α	Trend	α	Trend
Achham	0	0.2	0	-0.2	0	0.2	0	0.0	0	0.0	***	0.8	***	-0.8	*	0.3	0	-0.1	0	0.3	*	0.3
Arghakhanchi	*	0.3	0	-0.2	*	0.3	0	-0.1	0	0.0	**	0.7	**	-0.4	0	0.2	***	0.8	0	0.0	0	0.2
Baglung	0	0.2	0	0.1	*	0.5	0	0.0	*	-0.1	***	1.4	***	-0.9	***	0.4	**	0.9	0	0.2	0	0.2
Baitadi	0	0.1	0	0.0	0	0.1	0	0.1	0	0.0	***	1.2	***	-1.0	***	0.4	**	0.7	0	0.3	*	0.3
Bajhang	0	0.1	0	0.1	+	0.2	0	0.0	0	0.0	***	1.6	***	-1.2	***	0.3	0	0.0	**	0.6	*	0.3
Bajura	**	0.7	*	-0.6	***	0.7	0	-0.1	**	-0.1	***	1.4	***	-1.1	***	0.4	0	-0.1	*	0.6	*	0.3
Banke	0	0.1	0	-0.1	0	-0.1	0	0.1	0	0.0	0	0.3	0	-0.1	0	0.2	0	0.2	0	-0.1	0	0.0
Bara	0	0.2	0	0.1	0	0.3	0	-0.1	0	0.0	0	0.2	0	0.2	0	0.0	***	0.6	**	-0.5	+	-0.2
Bardiya	0	0.1	0	-0.2	0	0.1	*	0.2	0	0.0	0	0.2	0	-0.1	0	0.2	*	0.5	0	-0.1	0	0.1
Bhaktapur	0	0.1	0	0.1	0	0.1	0	0.0	0	0.0	***	1.0	***	-0.9	**	0.3	***	0.9	*	-0.3	0	-0.1
Bhojpur	***	0.5	0	-0.2	***	0.8	0	-0.1	0	0.0	***	1.4	***	-1.1	***	0.3	0	0.2	0	-0.1	0	0.0
Chitawan	0	0.0	0	0.1	0	0.1	0	0.0	0	0.0	**	0.6	0	-0.2	0	0.2	***	1.0	*	-0.3	0	0.0
Dadeldhura	0	0.1	0	-0.1	0	0.0	0	0.0	0	0.0	***	0.7	***	-0.6	*	0.3	**	0.8	0	0.3	*	0.3
Dailekh	0	0.1	0	-0.1	0	0.2	0	-0.1	0	0.0	***	1.0	***	-1.0	***	0.4	0	-0.2	0	0.2	+	0.2
Dang	0	-0.1	0	0.1	0	-0.1	0	0.0	0	0.0	+	0.4	**	-0.4	0	0.2	*	0.5	0	0.0	+	0.2
Darchula	0	-0.1	+	0.3	0	0.0	0	0.0	0	0.0	***	1.7	***	-1.1	***	0.4	0	0.1	**	0.6	*	0.2
Dhading	0	-0.3	+	0.4	0	-0.3	0	-0.1	*	-0.1	***	1.3	***	-0.8	***	0.3	***	1.2	0	-0.1	0	0.0
Dhankuta	*	0.3	0	-0.2	**	0.4	**	-0.1	*	-0.1	***	1.5	***	-1.1	***	0.3	*	0.6	*	-0.3	0	-0.1
Dhanusa	+	0.3	0	-0.2	+	0.3	0	0.1	0	0.0	0	0.4	0	-0.2	0	0.1	***	0.7	**	-0.5	0	-0.2
Dolakha	0	-0.2	0	0.2	0	-0.2	***	-0.3	***	-0.1	***	1.5	***	-1.1	***	0.3	+	0.5	0	0.1	0	0.2
Dolpa	**	0.5	0	-0.3	***	0.7	+	-0.2	*	-0.1	***	1.5	**	-0.7	***	0.2	**	1.0	+	0.4	+	0.2
Doti	0	0.1	0	-0.1	0	0.2	0	0.0	0	0.0	***	0.8	***	-0.7	*	0.3	0	0.3	+	0.3	**	0.3
Gorkha	0	0.2	0	-0.1	*	0.3	0	-0.1	*	-0.1	***	1.6	***	-1.1	***	0.4	0	0.2	0	0.2	0	0.1
Gulmi	+	0.3	0	-0.2	**	0.5	0	0.0	0	0.0	***	1.0	***	-0.7	**	0.3	**	0.6	0	0.1	+	0.2

Humla	***	1.0	***	-1.0	***	0.9	***	-0.3	***	-0.1	***	1.5	***	-1.1	***	0.2	0	-0.1	*	0.7	*	0.2
Ilam	0	0.0	0	0.1	0	-0.1	0	-0.1	+	0.0	***	1.6	***	-1.2	***	0.3	0	0.0	0	0.0	0	0.2
Jajarkot	*	0.5	0	-0.4	**	0.5	*	-0.2	0	0.0	***	1.3	***	-1.1	***	0.4	*	0.6	0	0.2	0	0.2
Jhapa	0	-0.1	0	0.1	0	-0.2	0	0.1	0	0.0	***	1.0	***	-0.7	+	0.1	0	-0.2	0	-0.3	0	-0.1
Jumla	***	0.7	**	-0.8	***	0.8	*	-0.1	**	-0.1	***	1.3	***	-1.2	***	0.3	+	0.5	+	0.4	0	0.1
Kavrepalanchok	0	0.1	0	0.0	0	0.2	0	-0.1	0	0.0	***	1.0	***	-0.7	**	0.3	**	0.8	0	-0.3	0	-0.1
Kailali	+	0.3	0	-0.1	0	0.1	0	0.1	0	0.0	0	0.3	0	-0.1	0	0.1	*	0.6	0	0.1	*	0.2
Kalikot	0	0.0	0	-0.2	*	0.4	**	-0.2	***	-0.1	***	1.4	***	-1.2	***	0.4	0	-0.1	*	0.5	*	0.3
Kanchanpur	0	0.2	0	0.0	0	0.0	0	0.1	0	0.0	+	0.2	0	0.0	0	0.2	**	0.7	0	-0.1	0	0.1
Kapilbastu	0	0.2	0	0.0	0	0.3	0	-0.1	0	0.0	0	0.4	0	-0.1	0	0.1	**	0.6	+	-0.3	0	0.0
Kaski	0	0.1	0	0.0	0	0.1	*	-0.2	0	0.0	***	1.5	***	-1.1	***	0.3	0	0.0	0	0.3	0	0.1
Kathmandu	0	0.1	0	0.0	0	0.1	0	0.0	0	0.0	***	1.1	***	-0.9	**	0.3	***	1.0	0	-0.2	0	0.0
Khotang	*	0.4	0	-0.3	**	0.5	0	-0.1	**	-0.1	***	1.2	***	-1.0	***	0.3	0	0.4	0	0.0	0	0.1
Lalitpur	0	0.0	0	0.2	0	-0.1	0	-0.1	0	0.0	***	1.1	***	-0.8	**	0.3	***	1.0	0	-0.2	0	0.0
Lamjung	+	0.3	+	-0.3	**	0.5	**	-0.2	***	-0.1	***	1.6	***	-1.2	***	0.3	0	0.3	0	0.1	0	0.1
Mahottari	0	0.0	0	0.0	0	0.0	0	0.1	0	0.0	0	0.3	0	-0.1	0	0.0	**	0.6	**	-0.6	0	-0.1
Makwanpur	0	0.0	0	0.0	0	0.0	+	-0.1	0	0.0	**	0.8	*	-0.3	*	0.2	***	1.1	*	-0.3	0	0.0
Manang	0	-0.1	0	0.3	0	0.1	***	-0.3	***	-0.1	***	1.6	***	-1.3	***	0.3	0	-0.4	*	0.5	+	0.2
Morang	*	-0.3	0	0.2	**	-0.5	0	0.1	0	0.0	***	1.0	***	-0.6	0	0.1	0	0.3	*	-0.4	0	-0.1
Mugu	***	0.9	***	-1.0	***	0.8	***	-0.3	***	-0.1	***	1.3	***	-1.0	***	0.3	0	0.5	+	0.6	+	0.2
Mustang	0	-0.2	0	0.3	0	-0.1	*	-0.2	*	-0.1	***	1.5	***	-1.0	***	0.2	0	0.2	*	0.4	*	0.2
Myagdi	0	0.2	0	0.0	*	0.4	0	0.0	0	0.0	***	1.4	***	-0.9	***	0.3	*	0.5	0	0.3	0	0.1
Nawalparasi	0	0.2	0	-0.1	0	0.2	0	0.1	0	0.0	**	0.7	0	0.0	+	0.2	+	0.4	0	-0.3	0	0.0
Nuwakot	+	-0.3	**	0.6	0	-0.2	0	-0.1	0	0.0	***	1.0	***	-0.8	**	0.3	***	1.1	0	-0.2	0	0.0
Okhaldhunga	0	0.2	0	-0.1	0	0.2	0	-0.1	0	0.0	***	1.4	***	-1.1	***	0.3	*	0.5	0	0.0	0	0.1
Palpa	0	0.2	0	-0.2	0	0.0	0	0.0	0	0.0	***	1.0	*	-0.4	**	0.3	0	0.0	0	0.0	+	0.2
Panchthar	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	***	1.9	***	-1.4	***	0.3	**	0.7	0	0.0	0	0.2
Parbat	+	0.3	0	0.0	*	0.4	+	0.1	0	0.0	***	1.4	***	-1.1	***	0.3	0	0.3	0	0.1	0	0.2
Parsa	0	0.2	0	0.0	0	0.2	0	0.0	0	0.0	+	0.4	0	0.1	0	0.1	***	0.8	**	-0.4	*	-0.2

Pyuthan	0	0.2	0	-0.2	*	0.4	+	-0.1	**	-0.1	**	0.7	***	-0.6	+	0.2	***	0.9	0	0.1	0	0.1
Ramechhap	0	-0.3	0	0.3	0	-0.3	***	-0.3	*	-0.1	***	1.3	***	-1.0	***	0.3	*	0.5	0	0.0	0	0.1
Rasuwa	***	-1.2	***	1.6	***	-0.8	0	0.0	0	0.0	***	1.6	***	-1.1	***	0.4	0	0.2	0	0.1	0	0.1
Rautahat	0	0.3	0	0.0	+	0.4	+	-0.1	0	0.0	0	0.0	0	0.2	0	-0.1	***	0.9	0	0.1	0	0.2
Rolpa	0	0.4	+	-0.4	+	0.3	*	-0.2	**	-0.1	***	0.8	***	-0.9	*	0.3	**	0.6	**	-0.5	+	-0.2
Rukum	**	0.5	+	-0.4	**	0.7	***	-0.4	***	-0.1	***	1.3	***	-0.8	***	0.3	***	1.1	0	0.2	0	0.2
Rupandehi	0	0.3	0	-0.2	0	0.2	0	-0.1	0	0.0	*	0.5	0	0.0	0	0.2	+	0.4	*	-0.3	0	0.0
Salyan	0	0.2	0	-0.2	0	0.2	0	0.0	0	0.0	**	0.6	***	-0.9	*	0.3	***	0.7	0	0.0	0	0.1
Sankhuwasabha	0	0.2	0	-0.2	0	0.1	*	-0.2	**	-0.1	***	1.7	***	-1.2	***	0.4	0	0.0	0	0.3	0	0.1
Saptari	0	0.1	0	0.0	0	0.2	0	0.0	0	0.0	*	0.5	*	-0.4	0	0.1	0	0.3	**	-0.5	0	-0.2
Sarlahi	0	0.3	0	-0.1	0	0.2	0	-0.1	0	0.0	0	0.1	0	0.0	0	0.0	**	0.6	**	-0.6	+	-0.2
Sindhuli	0	0.0	0	0.2	0	0.0	*	-0.2	0	0.0	**	0.7	***	-0.5	+	0.2	**	0.7	*	-0.4	0	-0.1
Sindhupalchok	0	0.2	0	0.0	0	0.3	0	-0.1	**	-0.1	***	1.3	***	-1.0	***	0.4	*	0.5	0	0.0	0	0.0
Siraha	0	0.2	0	-0.1	0	0.3	0	0.0	0	0.0	+	0.5	*	-0.3	0	0.2	**	0.6	**	-0.5	0	-0.2
Solukhumbu	0	-0.1	0	0.2	0	0.0	*	-0.2	0	0.0	***	1.6	***	-1.2	***	0.3	0	0.0	*	0.4	+	0.1
Sunsari	*	-0.4	0	0.2	**	-0.6	0	0.1	0	0.0	***	0.8	**	-0.4	0	0.1	0	0.3	**	-0.5	0	-0.2
Surkhet	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	*	0.5	***	-0.6	+	0.3	0	0.3	0	0.1	*	0.2
Syangja	0	-0.1	0	0.2	0	-0.2	*	0.2	*	0.1	***	1.2	***	-0.7	**	0.2	+	0.4	0	0.0	0	0.1
Tanahu	0	0.0	0	0.0	0	-0.1	0	0.0	+	0.0	***	1.0	**	-0.5	*	0.2	***	1.2	0	-0.2	0	0.1
Taplejung	0	0.0	0	0.0	0	0.2	0	-0.1	**	-0.1	***	1.9	***	-1.5	***	0.4	0	0.1	*	0.5	+	0.2
Terhathum	*	0.4	0	-0.3	**	0.4	0	0.1	0	0.0	***	1.9	***	-1.4	***	0.4	*	0.5	0	-0.1	0	0.1
Udayapur	0	-0.1	0	0.1	0	-0.1	0	0.0	0	0.0	***	0.9	***	-0.6	*	0.2	*	0.4	*	-0.4	0	0.0

Note: Significance (α): * 95% CL, ** 99% CL and * 99.9% CL ; insignificant at 95% CL : + , 0**