Final Report on
Assessment of Effects of Climate Factors on Diarrheal Diseases at National and Sub-national Levels in Nepal

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Final Report on

Assessment of Effects of Climate Factors on Diarrheal Diseases at National and Sub-national Levels in Nepal

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EXECUTIVE SUMMARY

Global climate change is expected to increase the risk of diarrheal diseases. This study aims to assess the effects of climate factors on the incidence of diarrheal diseases of under five children in Nepal. Retrospective in nature, the study utilized climatic data from 1970 to 2014, diarrheal data between 2002 and 2014 and water supply and sanitation coverage data for the period 2001 and 2015. Trend analysis of climatic data was done using Surfer software. Statistical modeling was carried out mainly to associate weather related variables and seasonal effects on diarrheal cases. The association between incidence of diarrhea and water supply and sanitation coverage was explored using graphical plots and spatio-temporal maps. The ethical approval to conduct this study was taken from Ethical Review Board of the Nepal Health Research Council (NHRC).

General warming trend of annual maximum and minimum air temperature was observed in all five physiographic regions; Terai, Siwaliks, Middle Mountain, High Mountain and High Himalaya. The warming rate was found higher in highlands (mountains) compared to lowlands (Terai and Siwaliks). The country's annual maximum and minimum warming trend was 0.0368°C and 0.0146°C per year respectively. The annual precipitation trend was declining at -2.5458mm per year in all physiographic regions except High Himalayas and in all seasons except pre-monsoon.

For this study, Nepal was divided into 15 Eco-Developmental regions or clusters. The eco-development-wise percent rise in diarrheal cases in under-five year children per 1°C increase in average temperature ranged between 0.85% to 5.05% with highest rise detected in Western Mountain and minimum in Central Terai. The eco-belt-wise effects was observed higher in Mountain (3.42%). The overall effect of temperature for Nepal was found to be 4.39% rise in diarrheal cases.

The eco-development-wise percent rise in diarrheal cases in under-five year children per 1 cm increase in rainfall ranged between 0.40% to 0.80% with highest rise detected in Western Mountain and minimum in Central Mountain region. The eco-belt-wise effects was observed higher in Mountain (0.48%) whereas statistically insignificant in Terai. The overall effect of rainfall for Nepal was found to be 0.28% rise in diarrheal cases.

Diarrheal cases were found substantially higher in summer in ten out of the fifteen eco-development regions or clusters with 22.94% to 64.94%.. The highest rise was detected in Far-Western Mountain and lowest in Western Terai. Spring season was negatively associated in Central Hill, Mid-western Terai and Far-western Terai. The overall effects in Nepal due to seasonal effects were found to be 11.63% rise in summer and 14.5% less in spring compared to winter and autumn seasons as reference season combined.

It is found that 0.94% to 3.50% increase in diarrheal cases in under-five children per thousand increases in the target population. The highest increase detected in Mid-western Hill and the least in Central Hill. Eco-belt-wise effects were much higher in the Mountain region (4.12%) and least in Hill (0.97%). The overall effect of population in Nepal was found to be 1.53% rise in diarrheal cases.

Eco-development domain analysis disclosed that 5.98% to 20.82% increase in diarrheal cases annually with maximum found in Far-western Terai and minimum in Far-western Hill and. Eco-belt-wise effects were highest in Mountain (16.39%) and least in Terai (12.54%). The overall effect in Nepal was found to be 13.86% annual increment.

The trend of the incidence of diarrhoeal disease among under-five children is increasing in all the 15 geographical clusters across the country over the last 10 years from 2003 to 2013. The monthly diarrheal data analysis of the past 10 years (2003-2013) shows that the incidence of the diarrheal diseases has occurred across all months during the year. However, in the entire geographical clusters about 60% of the diarrheal incidence took place from the months of May through October. The year 2009 has recorded the highest incidence of diarrheal disease followed by 2012 and 2013.

The drinking water coverage over the past 15 years across different geographical clusters in the country was in increasing trend. However this trend was not consistent in all the clusters. The overall drinking water coverage at national level was 86%. About 14% of the drinking water sources were still unsafe for consumption but those sources were used by the people for the consumption. The computed correlation coefficient values of water coverage and incidence of diarrheal disease was found very weak indicating the increased water coverage could not reduce the trend of under five diarrheal disease incidence.

Over the past 15 years, the sanitation coverage has been increased from the average of 17.7% to 90.6% from 2001 to 2015 respectively. The sanitation coverage at household level has been rapidly increased from 2012 onwards. However, the sanitation coverage in the central Tarai and eastern Tarai regions is still below the average national sanitation coverage. The correlation coefficient between the sanitation coverage and diarrhea disease incidence of the under-five children shows very low positive value, indicating increased sanitation coverage has not lowered down the diarrheal disease incidence among the under-5 children population.

The coverage of sanitation does not reflect the use of toilet and other behaviour aspects of total sanitation. Still there is no 100% sanitation coverage; whatever gap exist in the sanitation coverage is adequate to contaminate the overall nearby water bodies especially during first rain flush. The weather variability especially the increase in temperature favours the growth of pathogens in the contaminated water. Consumption of such contaminated water without any point of use treatment increases the incidence of diarrheal disease.

Our analysis shows significant effect of air temperature and rainfall on incidence of diarrhea with wide variation across eco-development regions. The effects of climatic parameters on incidence of diarrhea are more pronounced in Mountain and Hill regions compared to Terai region. Hence, existing diarrhea control program should be designed and updated from climate change adaptation perspective to reduce burden of diarrheal diseases among under five years children in Nepal.

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LIST OF Abbreviation and ACRONYMS

β	Parameter coefficient
C	Celsius
CH	Central Hill
CI	Confidence Interval
CM	Central Mountain
CT	Central Terai
CV	Coefficient of Variation
Df	Degrees of freedom
DfID	Department for International Development
DoHS	Department of Health Services
DWSS	Department of Water Supply and Sewerage
EH	Eastern Hill
EM	Eastern Mountain
ET	Eastern Terai
FWH	Far-Western Hill
FWM	Far-Western Mountain
FWT	Far-Western Terai
GHG	Greenhouse Gas
GLOF	Glacial Lake Outburst Flood
GLM	Generalized Linear Model
HHR	High Himalaya Region
HMIS	Health Management Information System
HMR	High Mountain Region
HSIS	Health Sector Information System
IPCC	Intergovernmental Panel on Climate Change
LAPA	Local Adaptation Plans for Action
MAX	Maximum
MIN	Minimum
MoPE	Ministry of Population and Environment
MMR	Middle Mountain Region
MWH	Mid-Western Hill
MWM	Mid-Western Mountain
MWT	Mid-Western Terai
NAPA	National Adaptation Programmes of Action
NB	Negative Binomial
NBD	Negative Binomial Distribution
RH	Relative Humidity
RR	Relative Risk
Sig	Significant
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
SWR	Siwalik Region
TAR	Terai Region
UNFCC	United Nations Framework Convention on Climate Change
VIF	Variance Inflation Factor
WH	Western Hill

WM	Western Mountain
WT	Western Terai
WHO	World Health Organization

1. BACKGROUND

Climate change has become a global concern in recent years. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*" [1]. This definition differs from that of Intergovernmental Panel on Climate Change (IPCC) which refers climate change as *"a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer"* [2]. The Fourth Assessment Report by IPCC has asserted that anthropogenic activities are primarily responsible for global greenhouse gas (GHG) emissions [3]. Increasing GHGs emissions result in greenhouse gas effect which leads to global warming and ultimately causes changes in climate. Since humans are accountable for climate change, they are the ones to endure its consequences. The World Health Organization (WHO) has reported that climate change induced extreme weather events such as intense storms, heat waves, drought and flood have dramatic impacts on human health [4]. Human health is affected directly or indirectly by climate change, with direct effects occurring due to changes in temperature and precipitation and occurrence of heat waves, floods, droughts and fires whereas indirect effects are due to ecological disruptions like crop failures, shifting patterns of disease vectors, etc. [5]. The projected impacts of climate change on human health include increasing burden from malnutrition, diarrheal, cardio-respiratory and infectious diseases, increased morbidity and mortality from heat waves, floods and droughts, changed distribution of some disease vectors and substantial burden on health services. One of the prominent effects of climate change is on diarrheal diseases [3]. Global climate change is expected to increase the risk of diarrhoeal diseases, a leading cause of childhood mortality in developing countries [6].

1.1. Climate change in Nepal

Nepal is highly vulnerable to climate change impacts. More than 1.9 million people are climate vulnerable, 10 million are increasingly at risk and this figure is likely to increase significantly in the future [7]. Nepal's greenhouse gas emission is around 0.027 percent of total global emissions [8]. Although, Nepal is least responsible for global GHGs emission, it is most susceptible to the impacts of climate change [9]. Observed data indicates consistent warming and rise in the maximum temperature at an annual rate of 0.04 – 0.06°C [7]. Practical Action Nepal (2009) has also reported that there is an increasing trend in temperature over Nepal, with maximum temperature rising at a greater rate (0.05°C/year) than the minimum temperature (0.03°C/year) [10]. Similarly, the annual increase in temperature is at the rate of 0.06°C to 0.12°C in Middle Mountain and Himalayan regions, while less than 0.03°C in the Siwalik and Terai (southern plains) regions based on the data from 1971 to 1994 [11]. The warming trends are higher in the mountainous regions than in the plains, indicating that the trends are spatially variable in Nepal. This rapid rate of warming is resulting in the melting of glaciers and the likelihoods of Glacial Lake Outburst Floods (GLOFs). The average glacial retreat is more than 30m per year [12]. So far, fourteen GLOF events have been recorded in Nepal and there are six potentially dangerous glacial lakes which are on the risk of outbursts [13]. A number of studies have indicated that the Himalayan glaciers are melting rapidly. Recent studies have revealed surface area loss, an upward shift in snow-line altitude (SLA) and an increase in debris coverage of the glaciers in the Everest region [14, 15]. Also, the glaciers in the Everest region are highly sensitive to changes in temperature and projected increases in precipitation are insufficient to offset the increased glacier melt [16]. Hence, the mountain region of Nepal is on high risk due to the impacts of climate change.

Despite having negligible share in greenhouse gas emission globally, Nepal is experiencing the impacts of climate change in several sectors such as water resources, agriculture, biodiversity, and health. Glacial retreat, decrease in river discharge during low-flow season and increase in runoff due to melting of snow are some of the observed impacts of climate change on water resources in Nepal. A study by Practical Action Nepal has revealed that the water sources in the middle hills of Nepal have been affected due to droughts and drying up of spring sources [17]. Analysis of precipitation data in Nepal has revealed changes in precipitation patterns i.e. decreasing number of annual rainy days, increasing number of extreme precipitation events [18]. Areas receiving high rainfall have experienced floods and landslides whereas areas with less rainfall are having droughts and water scarcity. Such events are making water unsafe due to contamination which can cause different water borne diseases, leading to loss of lives and property. Based on the fourth assessment report by IPCC, Nepal will experience 15 to 20% increase in summer precipitation and 5 to 10% increase in winter precipitation in eastern part while almost no change in precipitation in western part of Nepal [18]. Such changes in precipitation pattern have impacts on agricultural production. For instance, a study on the impact of climate change on rice production in Nepal showed that increase in temperature beyond the critical threshold of 29.9°C decreased the rice yields [19]. The observed climate change impacts on vegetation are shifting of forest towards the higher altitude, change in their composition, and extinction of species [18]. The impacts of climate change on human health in Nepal are still not much known, but there are indications of direct and indirect impacts[17]. Department of Health Services in 2007 and 2009 has reported the increasing incidence of water and food-borne diseases such as diarrhea, dysentery, typhoid, etc and vector-borne diseases such as malaria, Kalazar and Japanese Encephalitis with the rise in temperature [18]. Local communities in Nepal have experience increase in disease vector like mosquitoes in higher altitudes, increasing skin diseases and other diseases like Japanese encephalitis [17]. The implications of climate change are group into 1) Cardio-respiratory diseases 2) Injuries 3) Nutritional deficiencies /malnutrition 4) Diarrhoeal diseases 5) Vector-borne disease and 6. Psychological stress/diseases in Nepal [20].

The impacts of climate change are inevitable. Appropriate adaptation and mitigation measures are required to deal with these impacts. Since, Nepal is highly climate vulnerable, Government of Nepal has made several efforts to cope with the impacts of climate change. It has highly prioritized climate change agenda and actively involved in establishing legal and institutional arrangements such as enforcement of Climate Change Policy 2011, establishment of Climate Change Council chaired by Right Hourbale Prime Minister, formation of Multi stakeholder Climate Change Initiatives Coordination Committee (MCCICC) chaired by secretary of Ministry of Environment establishment of Climate Change Management Division in Ministry of Environment and implementation of Climate Change Budget Code [21]. Similarly, National Adaptation Programmes of Action (NAPA) and Local Adaptation Programmes of Action (LAPA) has been prepared and implemented. Particularly in health sector, NAPA has prioritized the following adaptation options [7]:

- Strengthening health system
- Awareness raising and capacity building
- Promotion of appropriate local adaptive knowledge
- Coordination among concerned stakeholders

- Integration of health impacts of climate change into broader development plans and related activities
- Research on climate change and health for evidence based policy and planning including health national adaptation plan formulation process

1.2. Climate change and diarrheal diseases

Globally, there are nearly 1.7 billion cases of diarrheal disease with around 760,000 deaths of children under five years old every year [22]. Climate change is expected to increase the risk of diarrheal diseases, a leading cause of childhood mortality [6]. Number of studies has found association between temperature and the occurrence of diarrheal disease [6, 23-25]. These studies found that the increasing temperature lead to greater incidence of diarrhea. A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases showed that increase in ambient temperature was generally associated with increase in all-cause and bacterial diarrhoea [6]. Both low and high temperatures had significant impact on childhood diarrhoea [25]. A study conducted in Peru showed that ambient temperature rise of 1^{o}C could lead to 8% increase in the incidence of diarrhoea [23]. Similarly, another study conducted in Pacific Island showed that rise of 1°C could lead to 3% increase in the incidence of diarrhoea [26]. An association was observed between increase in maximum and minimum temperature, and increasing rate at which diarrhoea affected children under the age of five years old in the Cape Town Metropolitan Area [24].

Effects of climate change are evident in public health of Nepalese. Department of Health Service Annual report show the increasing incidence of water and food-borne diseases such as diarrhea, dysentery, typhoid, etc [27] with the rise in temperature. Temperature related illness and death from cold and heat waves have been increasing in recent years [18].

1.3. Rationale of the study

Diarrhea accounted for 3.6% of the global disease burden in 2010, with much of this burden concentrated in poor regions [23]. Around 760,000 deaths of children under-five years occur every year due to diarrhoea [22], indicating children under-five years are more vulnerable to diarrheal diseases. Although, Government of Nepal makes huge investment on water, sanitation and hygiene to reduce burden of diarrheal diseases, the cases of diarrheal diseases is still high and frequent epidemics of diarrhea and cholera are reported every year [27]. In some districts, incidence of diarrheal disease is on increasing trend. Information on the interaction between climate change and health is very limited in Nepal. Few studies have been done to assess the effects of climatic factors on diarrheal diseases in selected districts of Nepal. A study on the status and trends of diarrheal diseases with respect to observed temperature and rainfall variability in the three ecological zones in Nepal; the Terai, Hills and Mountains showed decreasing trend in all three geographic regions with highest diarrheal incidences in the Mountains, followed by the Hills and Terai [28]. The study period was restricted to 14 years (1994/95-2007/08) because of the constraints to data availability and only 17 districts were chosen for the study. The trend was not found uniform across the country. The study had carried out only general trend of study variables without considering rigorous analysis of climatic factors and diarrheal incidence together. Hence, there was an urgent need to carry out national study using latest data to generate evidence for further planning and DfID funded project supported to fulfill this knowledge gap through scientific studies.

The present study includes all 75 districts of Nepal and incorporated the monthly rainfall and temperature data from 1971-2014, and monthly diarrheal data from 2002-2014. Hence, utilizing long term climate data and considering diarrheal cases from 75 districts, this study aims to identify the effects of climate factors on incidence of diarrheal diseases and provide spatio-temporal distribution of diarrheal diseases incidence in Nepal.

1.4. Objectives of the study

The main objective of this study is to estimate effects of climatic factors on the incidence of diarrheal diseases in Nepal. The specific objectives of this study are as follows:

- To analyse trend of temperature and precipitation data of Nepal
- To analyse trend of diarrheal diseases in Nepal
- To analyse trend of sanitation and water supply coverage data of Nepal
- To explore relationship between incidence of diarrheal and climatic factors using time series data

- To explore effect of water and sanitation coverage on the diarrheal incidence
- To explore spatial pattern of diarrheal incidence in Nepal
- To generate spatio-temporal maps of diarrheal incidence in Nepal

2. METHODOLOGY

2.1. Formation of study team

A multidisciplinary team consisting of Environmental Health Expert with specialization in climate change and health, climatologist or meteorologist, public health expert, epidemiologist, WASH Expert, Bio-statistician/modeling expert and data management expert was formed. The multidisciplinary team held series of meetings to develop the concepts and collect the relevant data. Environmental Health Expert coordinated the team and bridge knowledge of different experts. Public Health and Environmental Science Graduates were recruited as a Research Assistants to support Experts mainly to data management for analysis and report drafting.

2.2. Study design

The study was quantitative in nature which aimed to explore relationship of climatic factors and WASH intervention on diarrheal diseases incidence in Nepal. Time series log-linear regression analysis was done to assess the relationship between climatic factors and diarrheal incidence. The study was retrospective using data of different time period depending on their availability.

2.3. Study sites

This study was carried out taking all 75 districts from 15 eco-development regions; Eastern Terai (ET), Eastern Hill (EH), Eastern Mountain (ET), Central Terai (CT), Central Hill (CT), Central Mountain (CM), Western Terai (WT), Western Hill (WH), Western Mountain (WM), Mid-Western Terai (MWT), Mid-Western Hill (MWH), Mid-Western Mountain (MWM), Far-Western Terai (FWT), Far-Western Hill (FWH), Far-Western Mountain (FWM) which represents three ecological regions (Terai, Hill and Mountain) and five development regions

(Eastern, Central, Western, Mid-Western and Far-Western development regions) as shown in Figure 1.

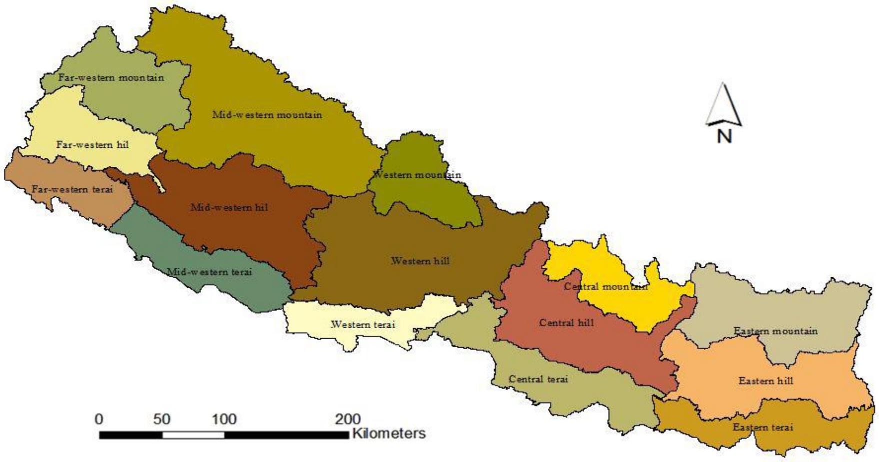


Figure 1: Eco-development region or cluster for study units

2.4. Data collection

Climatic data were procured from Department of Hydrology and Meteorology, Government of Nepal. Monthly temperature (maximum and minimum) from 1971 to 2014 and precipitation data (1970-2014) were available in the digital formats. The elevation of Nepal ranges from 60 m MSL (meter Mean Sea Level) in the Terai to 8848 m MSL in the High Himalaya with five different physiographic regions. In this study, five physiographic regions defined by Land Resource Mapping Project (LRMP) 1986 are used. According to this Terai Range (TAR) from 60 m to 200 m MSL, Siwalik Range (SWR) from 200 m to 1500 m MSL, Middle Mountain Range (MMR) from 1500 m to 2500 m MSL, High Mountain Range (HMR) from 2000 m to 4000 m MSL and High Himalaya Range (HHR) from 4000 m to 8848 m MSL were considered [29]. According to this elevation range, the climatic (temperature and precipitation) data were collected.

The data on the monthly diarrheal disease at district level were obtained from Health Management Information System (HMIS), Department of Health Service (DoHS) for the years from 2002 to 2014. However, the diarrhea disease incidence has been computed from the complete data of the years 2003 and 2013. The yearly data on water and sanitation at district level was obtained from the population censuses 2001 and 2011 (CBS) and the DWSS sources 2012, 2013, 2014 and 2015. The monthly and yearly trend analysis of diarrheal disease for 12 years from 2002 to 2014 has been analysed and interpreted at the 15 cluster level (5 development region*3 ecological regions). The spatial analysis of the diarrheal disease has been carried out at the district level for the same 12 years and the spatial co-relationships of the diarrheal disease with the water coverage change and sanitation coverage at district level have also been analysed.

2.5. Ethical approval

The ethical approval for this study was taken from Ethical Review Board (ERB) of the Nepal Health Research Council (NHRC).

2.6. Data management and analysis

Collected data were entered developing standard format in Microsoft EXCEL and analyzed in SPSS software. Before analyzing data, data cleaning and editing were done independently by two team members. Data were analyzed using statistical modelling approach. Spatial and temporal pattern of data were presented using GIS software.

Monthly, seasonal and annual statistics of air temperature and precipitation data were calculated by using PIVOT table in EXCEL for all selected station (Precipitation 237 and Temperature 67). The air temperature and precipitation trend of individual station were also calculated using slope function. Missing temperature and precipitation data for the period of 1971 to 2014 was filled without applying interpolation method. Data was arranged into seasonal and annual scale and it's formatted in the Surfer programs input. Temporal and spatial variations were plotted using Surfer.

All the 75 districts are covered with 12 years of monthly data (144) for each district resulting to a total of 10799 (one month missing) data points for analysis. District-wise monthly data of diarrheal cases and meteorological parameters were collected for 12 consecutive years (2002/2003-2013/2014). Meteorological parameters were maximum temperature, minimum temperature, rainfall, relative humidity (morning & evening). Missing meteorological data from different stations were replaced by nearest stations within a domain (eco-development region).

2.7. Statistical modelling

Ecological time series modelling of spatially dispersed district level data based upon monthly aggregates was done. Estimates of variables associated with change in monthly diarrheal cases of under five years of age children were obtained separately for 15 eco-development regions (domains/clusters) and a pooled estimate of overall effects in Nepal. Statistical modelling was carried out mainly to associate weather related variables and seasonal effects on diarrheal cases in under 5 year children of Nepal with the negative binomial model (NB) also known as the Poisson-gamma model with NB2 variance function. It is the generalized linear model (GLM) with log link function suitable for over-dispersed count data. The model is used basically to account the over-dispersed nature of monthly reported diarrheal cases. In the model, the dependent variable was assumed distributed as negative binomial distribution (NBD) which is a mixture of Poisson and gamma distributions. It has log link function with additional multiplicative random effect parameter distributed as gamma distribution to address the unknown heterogeneity. The model is specified as follows:

$$\begin{aligned}\log\left(\lambda_i\right) &= \beta_0 + \beta_1 x_{i1} + ..\beta_k x_{ik} + \varepsilon_i \\ &= \beta_0 + \sum_{i=1}^{k} \beta_k x_{ik} + \varepsilon_i\end{aligned}$$

where β_i s are the unknown parameters, x_{ik} are the values of the predictor variables, λ_i is the mean of the dependent variable, $\beta_0 + \varepsilon_i$ is the random intercept in the model. Also, the model can be expressed as where $\mu_i = e^{\sum_{i=1}^{k}\beta_k x_{ik}}$ and $e^{\beta_0+\varepsilon_i}$ is the random intercept term. In the NB2 model, the variance function which allows over-dispersion is $\mu_i + \alpha\mu_i^2$ where α is a scalar parameter. Predictors with p values less than 0.25 are retained in the fitted models basically to capture all the relevant predictors under consideration so that important variables are not left out even though statistically insignificant at 95% confidence level. Several model adequacy tests are employed to check goodness of fit, multicollinearity, heteroscedasticity, autocorrelations and over dispersion. Statistical software used for data modelling was SPSS version 20.

3. RESULTS

3.1. Descriptive analysis of climatic data

In this study, available climatic data were divided into five physiographical regions: TAR, SWR, MMR, HMR and HHR. With the purpose of representing all five physiographic region of the country, 67 temperature stations and 237 precipitation stations over different physiographic regions were selected in this study. Among them, records of temperature (maximum and minimum) from 67 stations (TAR- 15 stations, SWR- 12 stations, MMR- 29 stations, HMR- 4 stations and HHR- 7 stations) were considered. The longest records (45 years) were available since 1971 to 2014 in three stations (Jiri, Pokhara Airport, and Kathmandu Airport) and the shortest records (17 years) were available in Makalu station. Most of the stations had data available for over (30 year) data (Appendix, Table 7).

The precipitation data were also available for over (30 Years) in : TAR-51 stations, SWR- 41 stations, MMR- 100 stations, HMR-36 stations and HHR-9 stations (Appendix, Table 8).

3.2. Seasonal and annual temperature trends

The observed seasonal and annual maximum temperature trend from Table 1 shows

a) **Winter season:** The highest increasing trend of maximum temperature (0.106^0C/year) was found in HHR and maximum temperature decreasing trend of - 0.023^0C/year was observed in TAR, among all five regions during the winter season.

b) **Pre -monsoon season:** The highest trend of maximum temperature (0.060^0C/year) was found in MMR and the lowest trend of maximum temperature (0.019^0C/year) was obtained in TAR, among all five regions during pre-monsoon season.

c) **Monsoon season:** The highest maximum temperature with increasing trend of 0.052^0C/year found in MMR and the lowest maximum temperature increasing trend of 0.018^0C/year obtained in HMR, among all five regions during monsoon season.

d) **Post-monsoon season:** The highest maximum temperature with increasing trend of 0.052^0C/year found in MMR and the lowest maximum temperature trend 0.015 ^{0}C/year obtained in TAR, among all five regions during post-monsoon season.

Table 1 Seasonal and annual trend of maximum temperature (1971-2014)

Region	**Winter**	**Pre-monsoon**	**Monsoon**	**Post-Monsoon**	**Annual**
Terai	-0.023	0.019	0.028	0.015	0.008
Siwallik	0.005	0.025	0.032	0.018	0.020
Middle Mountain	0.065	0.060	0.052	0.052	0.058
High Mountain	0.041	0.023	0.018	0.023	0.028
High Himalaya	0.106	0.047	0.034	0.032	0.021
Country	0.0294	0.0368	0.0399	0.0384	0.0368

The annual maximum temperature with highest increasing trend of 0.058^0C/year was observed in MMR and the lowest increasing trend of 0.008^0C/year in TAR, among all five regions.

The annual maximum temperature of increasing trend over Nepal was observed to be 0.0368^0C/year whereas the seasonal highest maximum temperature increasing trend of 0.0399^0C/ year in monsoon season and the seasonal lowest maximum temperature increasing trend of 0.0294^0C/year in winter season.

Table 2 Seasonal and Annual Trend of Minimum Temperature (1971-2014)

Region	Winter	Pre-monsoon	Monsoon	Post-Monsoon	Annual
Terai	0.023	0.010	0.010	0.005	0.003
Siwallik	0.018	0.011	0.012	0.012	0.010
Middle Mountain	0.020	0.020	0.028	0.015	0.020
High Mountain	0.043	0.021	0.029	0.013	0.035
High Himalaya	0.053	0.013	0.001	0.043	0.025
Country	0.0225	0.0113	0.0203	0.0120	0.0146

The observed seasonal and annual minimum temperature trend from Table 2 shows

a) **Winter season:** The highest minimum temperature with increasing trend of 0.053^{0}C/year was observed in HHR and the lowest minimum temperature trend of 0.018^{0}C/year is obtained in Siwalik region, among all five regions during winter season.

b) **Pre-monsoon season:** The highest minimum temperature with increasing trend of 0.021^{0}C/year found in HMR and the lowest minimum temperature trend of 0.010^{0}C/year obtained in TAR, among all five regions during pre-monsoon season.

c) **Monsoon season:** The highest minimum temperature with increasing trend of 0.029^{0}C/year found in HMR and the lowest minimum temperature trend of 0.001^{0}C/year was obtained in HHR among all five regions during monsoon season.

d) ~~d)~~ **Post-monsoon season:** The highest minimum temperature with increasing trend of 0.043^{0}C/year found in HHR and the lowest minimum temperature increasing trend of 0.005^{0}C/year was obtained in TAR, among all five regions during post-monsoon season.

The annual minimum temperature with highest increasing trend of 0.035^{0}C/year was observed in HMR and lowest increasing trend of 0.003^{0}C/year in TAR, among all five regions (Chainpur East one station was omitted for temperature trend analysis due to the inconsistent data).

The annual minimum temperature of increasing trend over Nepal was observed to be 0.0146^{0}C/year whereas the seasonal highest minimum temperature increasing trend of 0.0255^{0}C/year in winter season and the seasonal lowest minimum temperature increasing trend of 0.0113^{0}C/year in pre-monsoon season.

3.3. Seasonal and annual precipitation trends

The observed seasonal and annual precipitation trend from Table 3 shows

a) **Winter season:** The highest precipitation with increasing trend of 0.100 mm/year found in TAR and the lowest precipitation trend of decreasing trend of -0.660 mm/year found in HHR, among all five regions during winter season.
b) **Pre-monsoon season:** The highest precipitation with increasing trend of 4.26 mm/year found in HHR and the lowest precipitation increasing trend of 0.690 mm/year found in MMR, among all five regions during pre-monsoon season.
c) **Monsoon season:** The highest precipitation with increasing trend of 21.72 mm/year found in HHR and the lowest precipitation decreasing trend of -3.3140 mm/year found in MMR, among all five regions during monsoon season.
d) **Post-monsoon season:** The highest precipitation with increasing trend of 0.970 mm/year found in HHR and the lowest precipitation decreasing trend of -0.380 mm/year found in MMR, among all five regions during post-monsoon season.

Table 3 Annual and seasonal Precipitation Trend (1970-2014)

Region	**Winter**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Annual**
Terai	0.100	1.320	-0.870	0.300	-0.810
Siwallik	-0.030	1.390	-1.850	-0.190	-2.440
Middle Mountain	-0.060	0.690	-3.140	-0.380	-5.340
High Mountain	-0.280	0.780	-0.370	-0.150	-3.160
High Himalaya	-0.660	4.260	21.720	0.970	6.970
Country	-0.0076	0.8598	-1.2652	-0.1449	-2.5458

The annual precipitation increasing trend of 6.970 mm/year found in HHR and the precipitation decreasing trend of -5.340 mm/year observed in MMR, among all five regions and four season. Over the whole country, the monsoon precipitation decreasing trend of -1.2652 mm/year and pre-monsoon precipitation increasing trend of 0.8598 mm/year was observed, whereas annual precipitation decreasing trend over Nepal of -2.5458mm/year was observed during 1970 to 2014 (Annapurna and Makalu from HHR, two stations were omitted for precipitation trend analysis due to the very short - 5 year data period).

3.4. Temporal and spatial variations in temperature

The annual and seasonal time series of surface maximum and minimum temperature trend over the country for the period 1971-2014 were analyzed and plotted as shown in Figure 2 to Figure 11. The trends, in general, were found higher in maximum than in minimum temperature. The linear trend analysis in this report was considered as a monotonic increase or decrease in the average value of the parameter that was observed between the beginning and end of the period (1971-2014). However, due to the fact that most stations had missing values in their dataset for the period 1971-2014, and thus did not provide a continuous time series; the discussion of the trend analysis would be limited to a few locations. Furthermore, stations with unusually high or low (Outlier) trend were further analyzed and were not considered for spatial analysis after homogeneity testing and identification of shift of station with some significant change in observation. The examples of these stations were Dhankuta, Chame, Dunai, Dailekh etc.

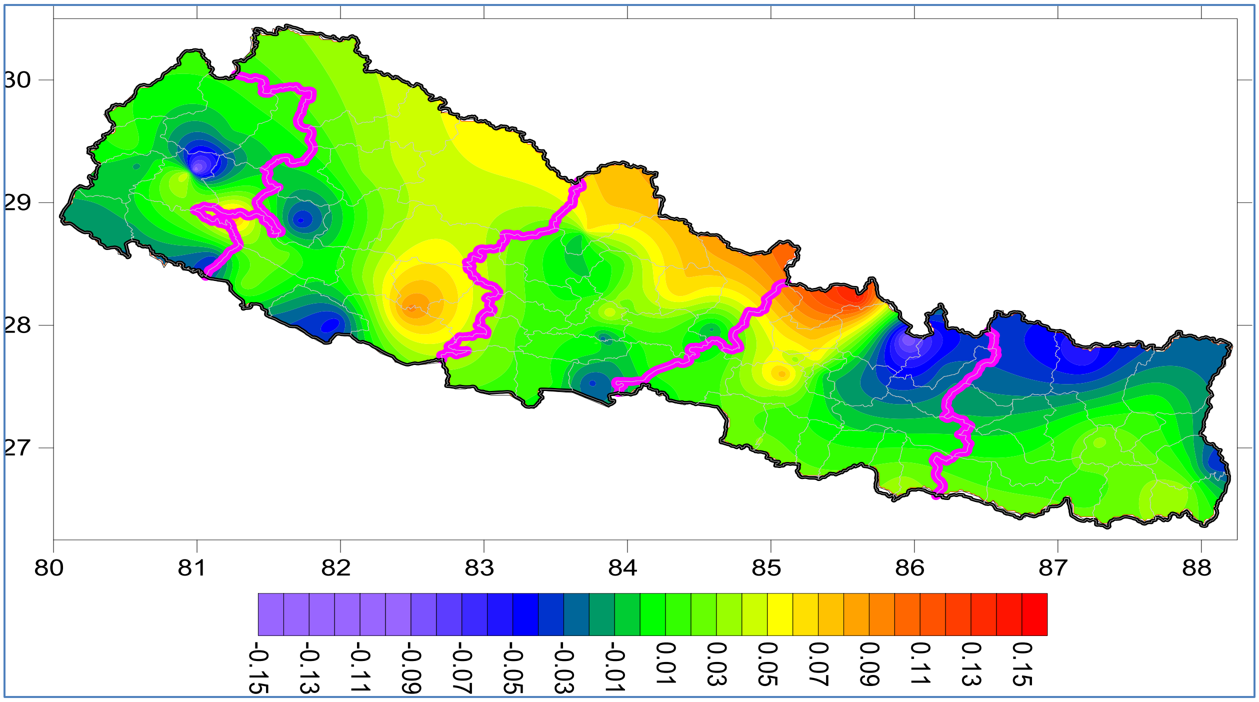


Figure 2 Annual Minimum temperature trend (1971-2014)

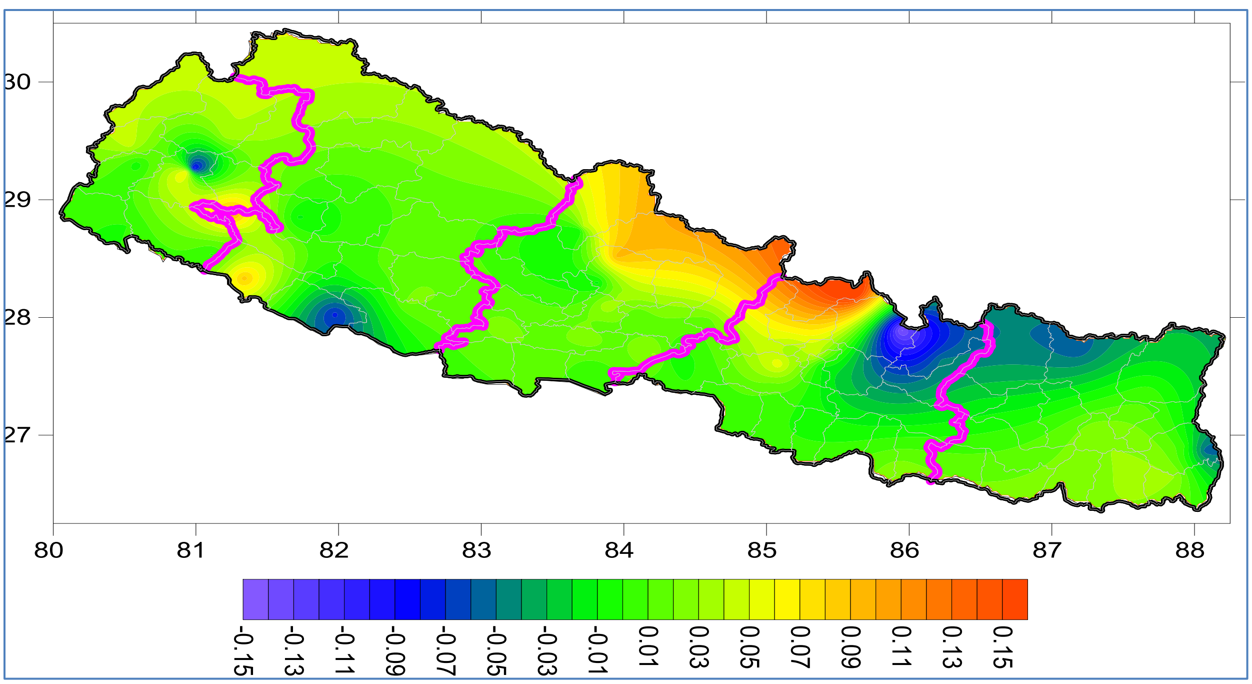


Figure 3 Pre-monsoon minimum temperature trend (1971-2014)

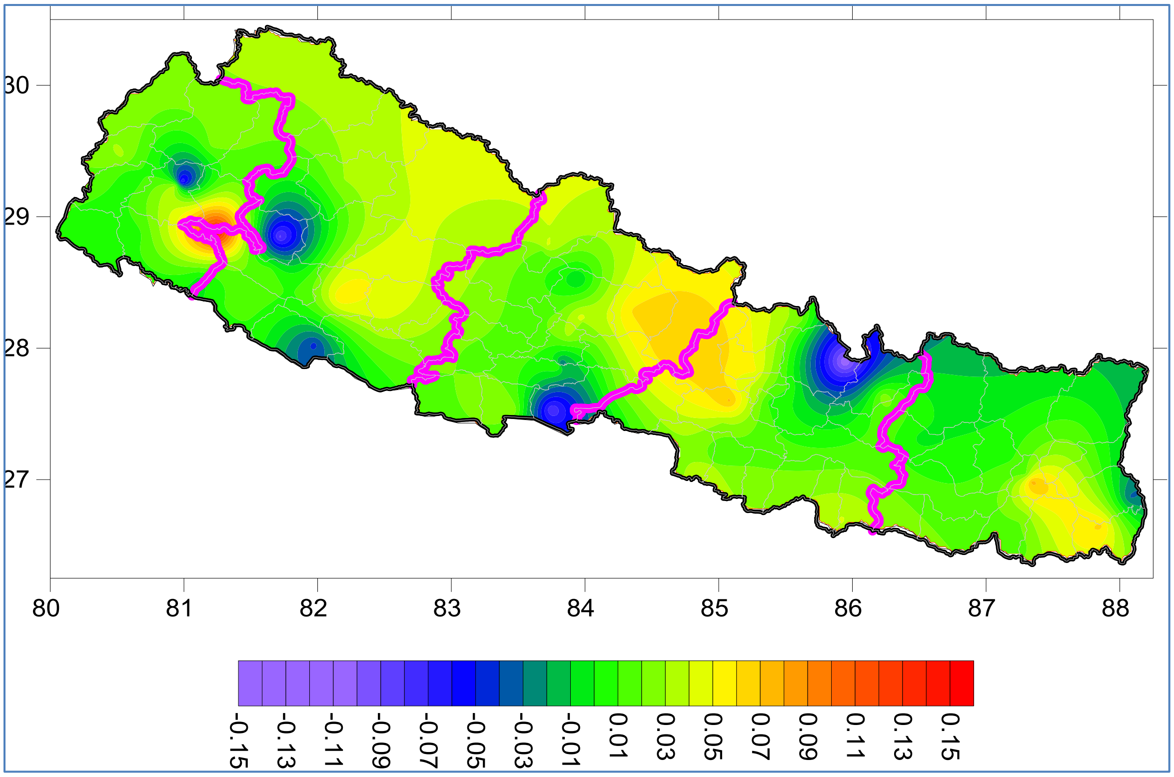


Figure 4 Monsoon minimum temperature trend (1971-2014)

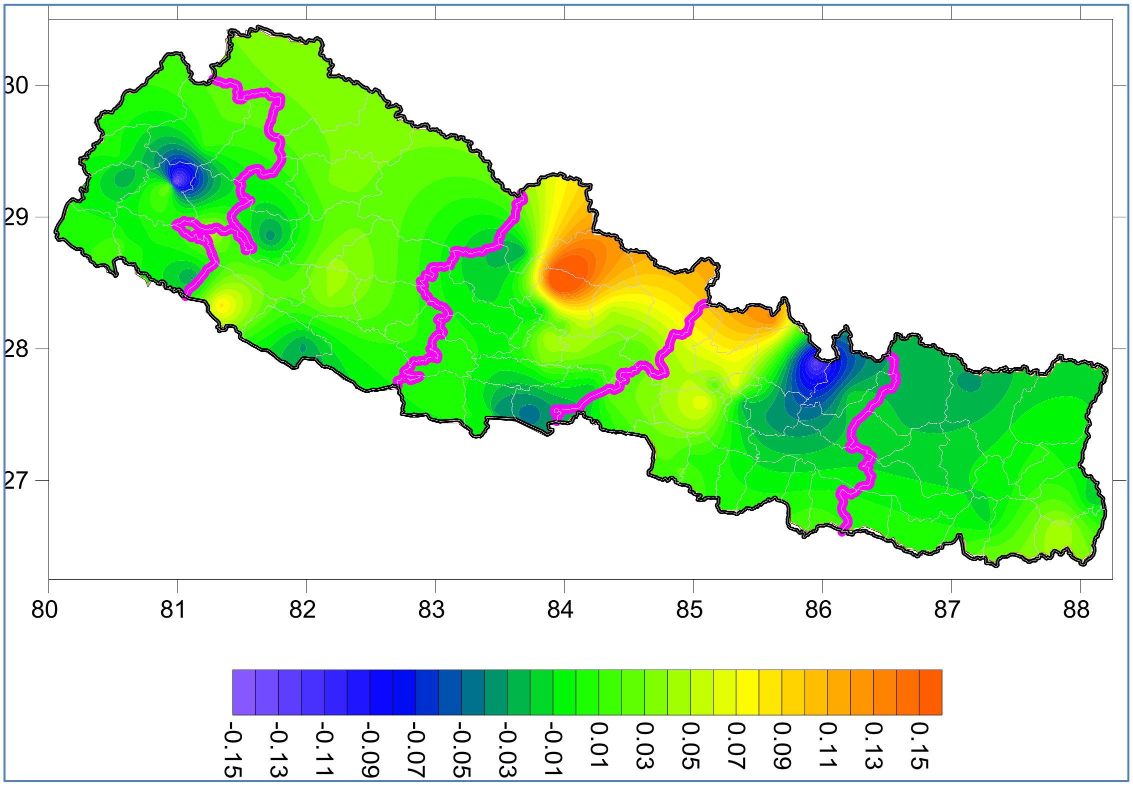


Figure 5 Post-monsoon minimum temperature trend (1971-2014)

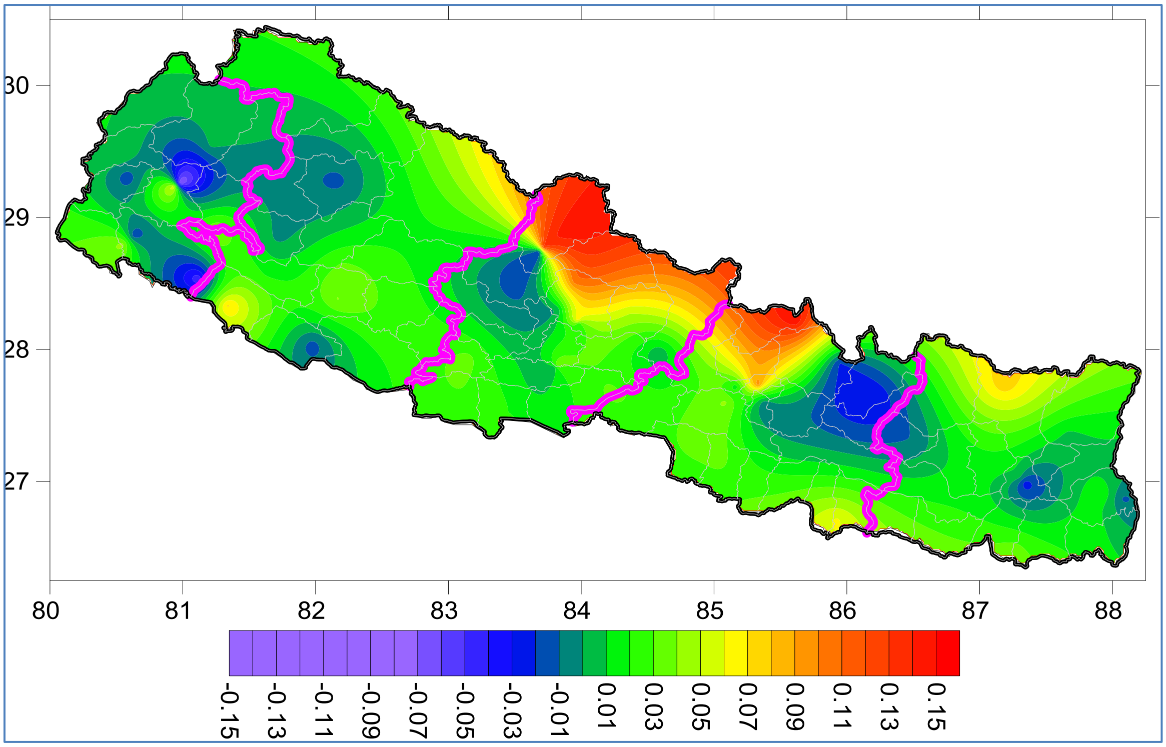


Figure 6 Winter minimum temperature trend (1971-2014)

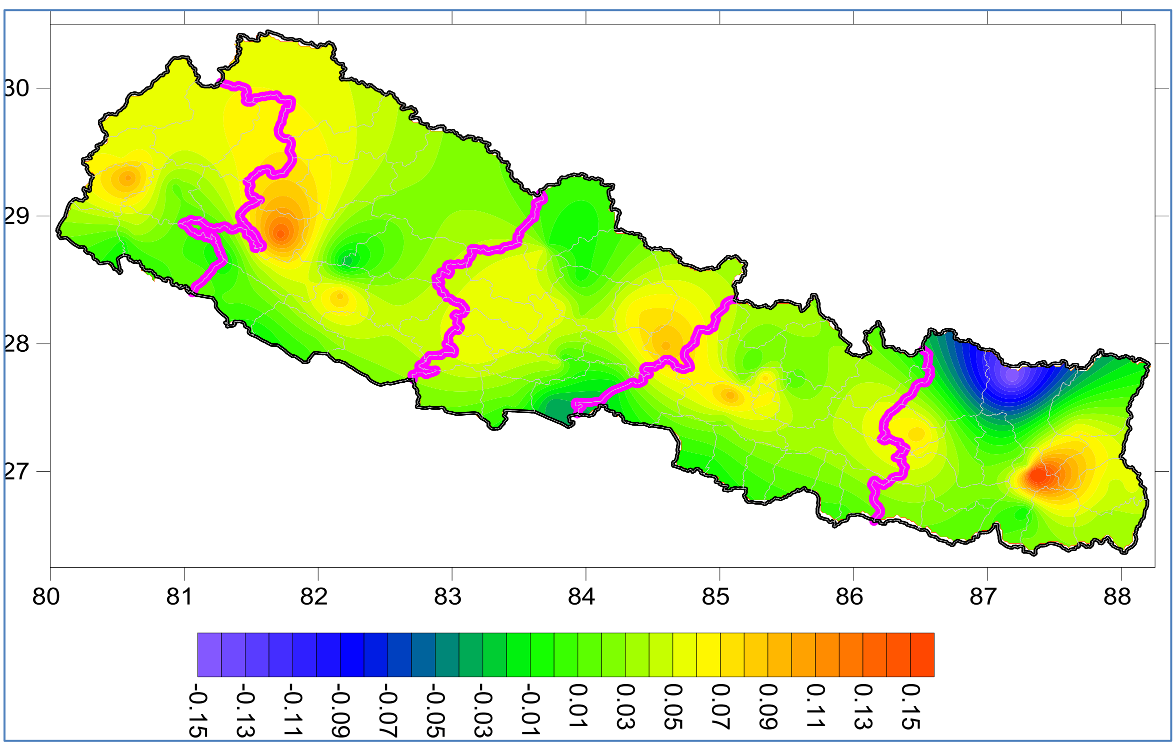


Figure 7 Annual maximum temperature trend (1971-2014)

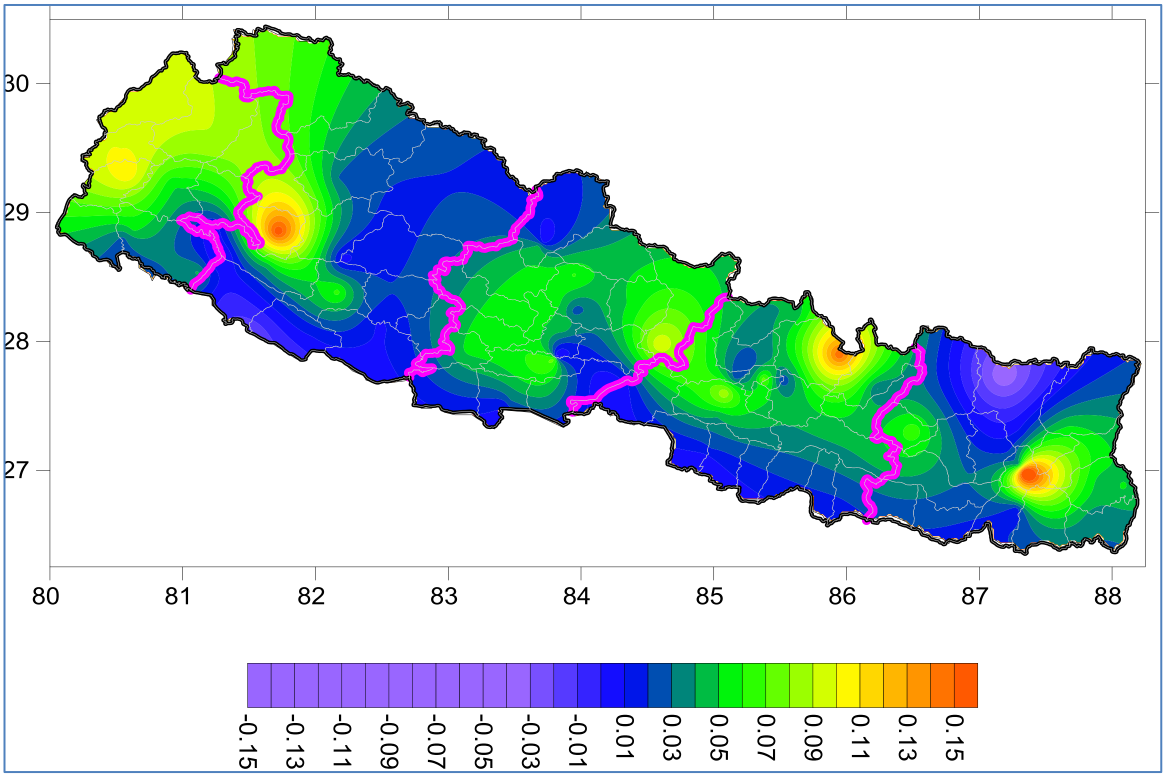


Figure 8 Pre-monsoon maximum temperature trend (1971-2014)

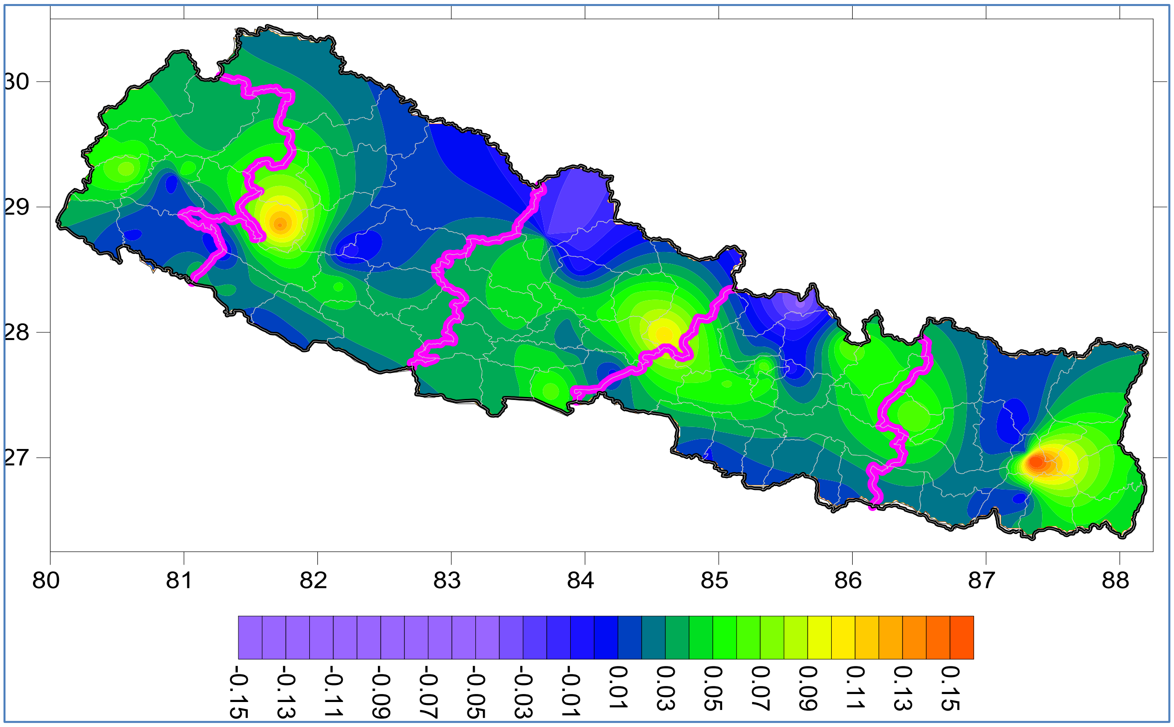


Figure 9 Monsoon maximum temperature trend (1971-2014)

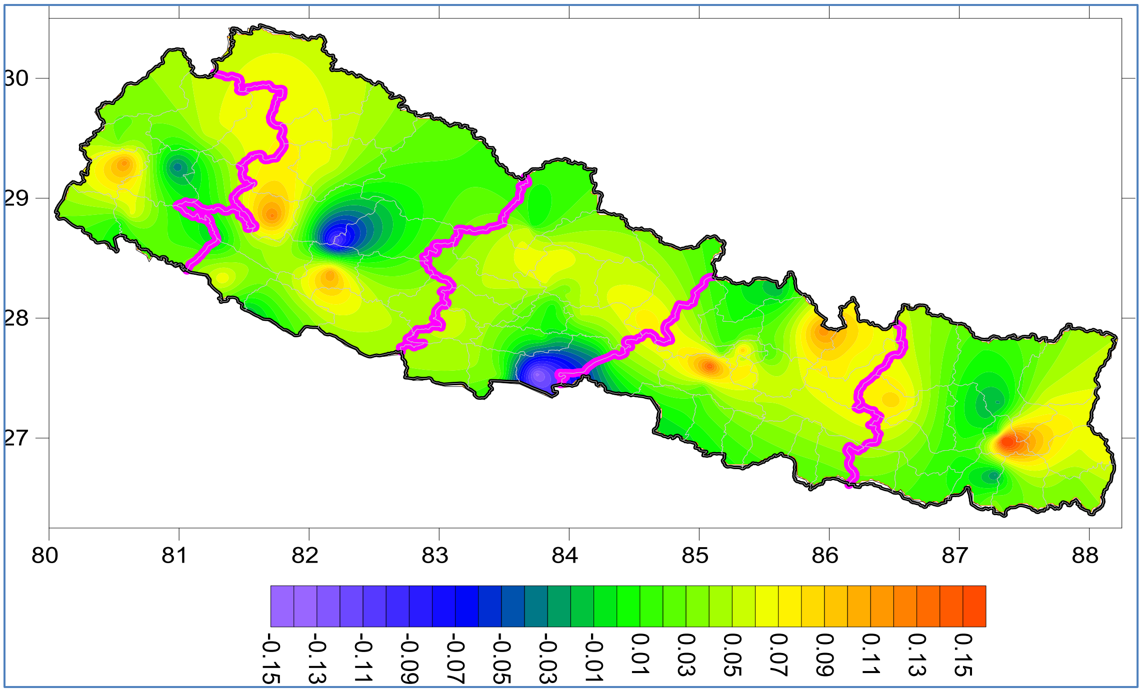


Figure 10 Post-monsoon maximum temperature trend (1971-2014)

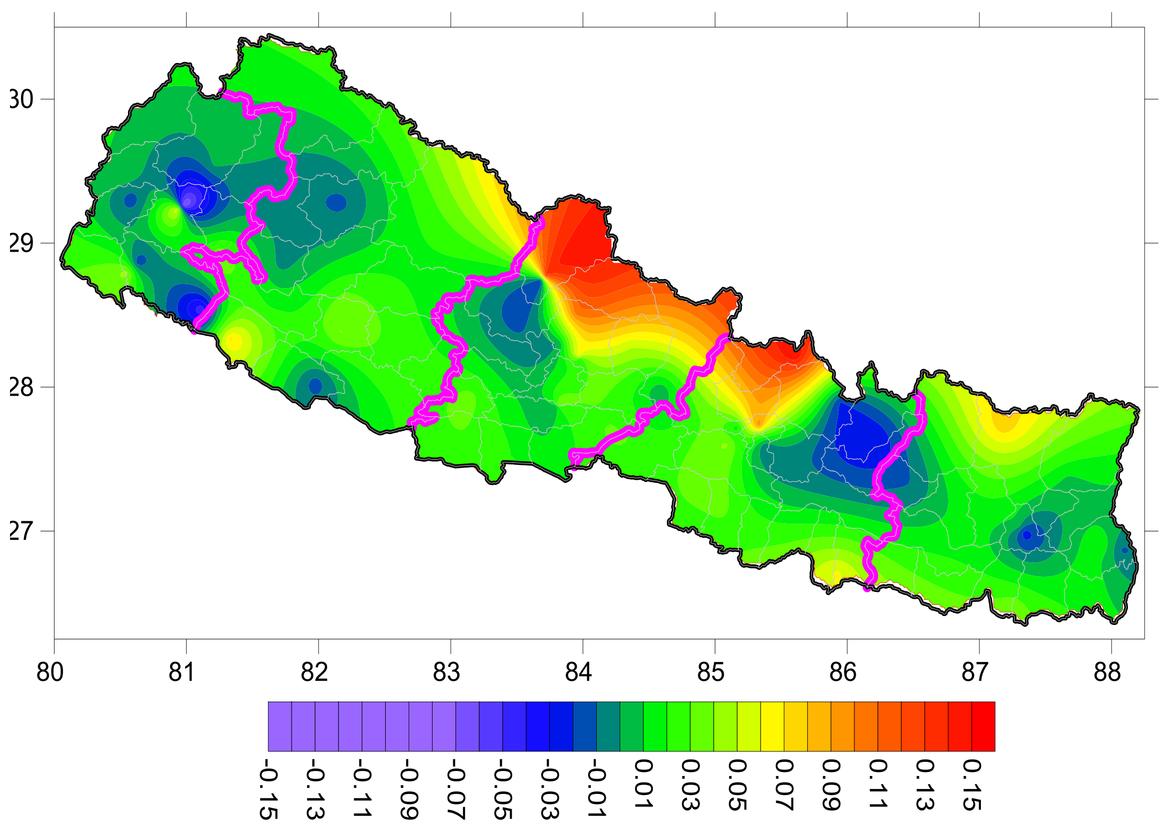


Figure 11Winter maximum temperature trend (1971-2014)

3.5. Temporal and spatial variations in precipitation

Annual Precipitation trend: Annual precipitation trend was calculated and plotted based on data from 1970-2014 in surfer program as shown in Figure 12. The positive trends were found in Annapurna western region, Makalu and Phatepur (Saptari) eastern region, Myagdi (Darbanga) western region areas over 30 mm/year and the decreasing trend of 60 mm/year found in Rangkhani (Baglung), Melung (Dolakha), Thokarpha (Sindhupalchok) areas. Most of the mid-western development region showed decreasing annual precipitation trend.

Monsoon Precipitation Trend: The positive trends were found in Tark Ghyang (Sindhupalchok): Central region, Annapurna: western region, Makalu: Eastern region areas over 30 mm/year and the decreasing trend of 60 mm/year found in Melung (Dolakha) eastern and other small areas of Rukumkot (Rukum) in mid-western development regions.

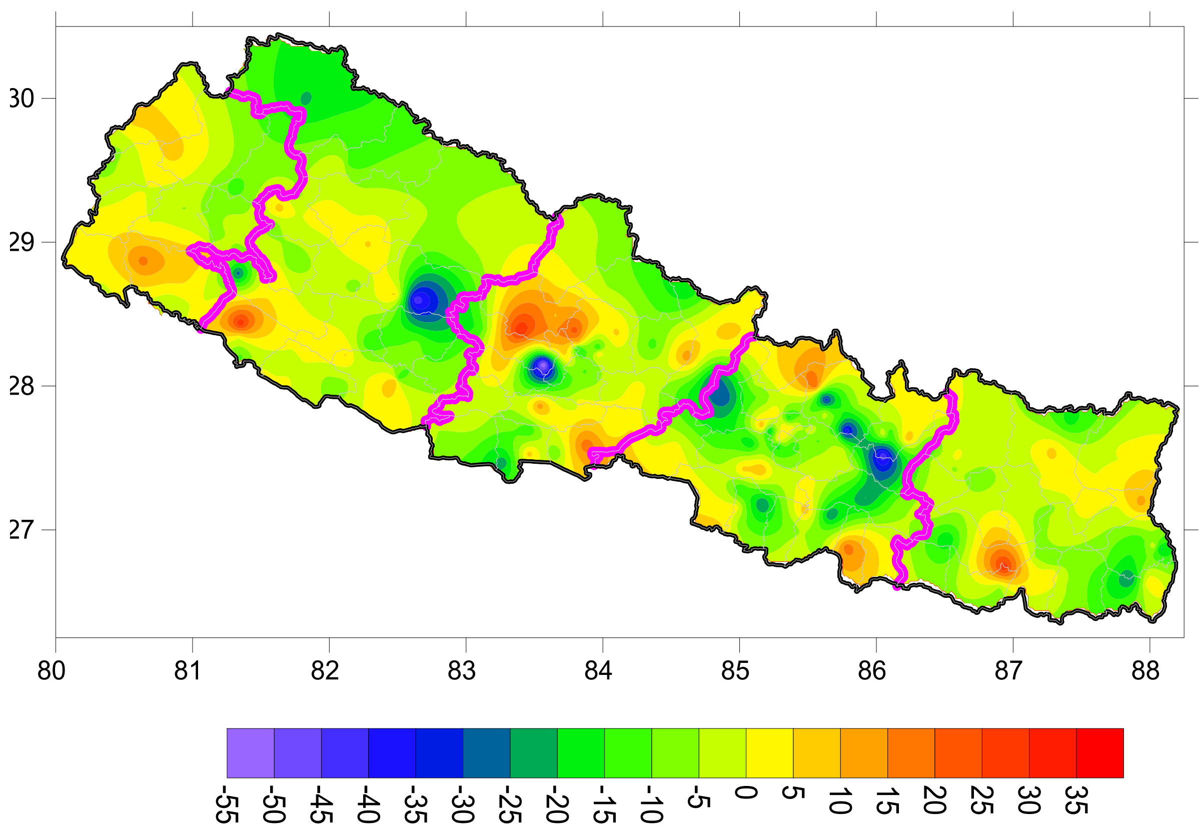


Figure 12 Annual rainfall trend (1970-2014)

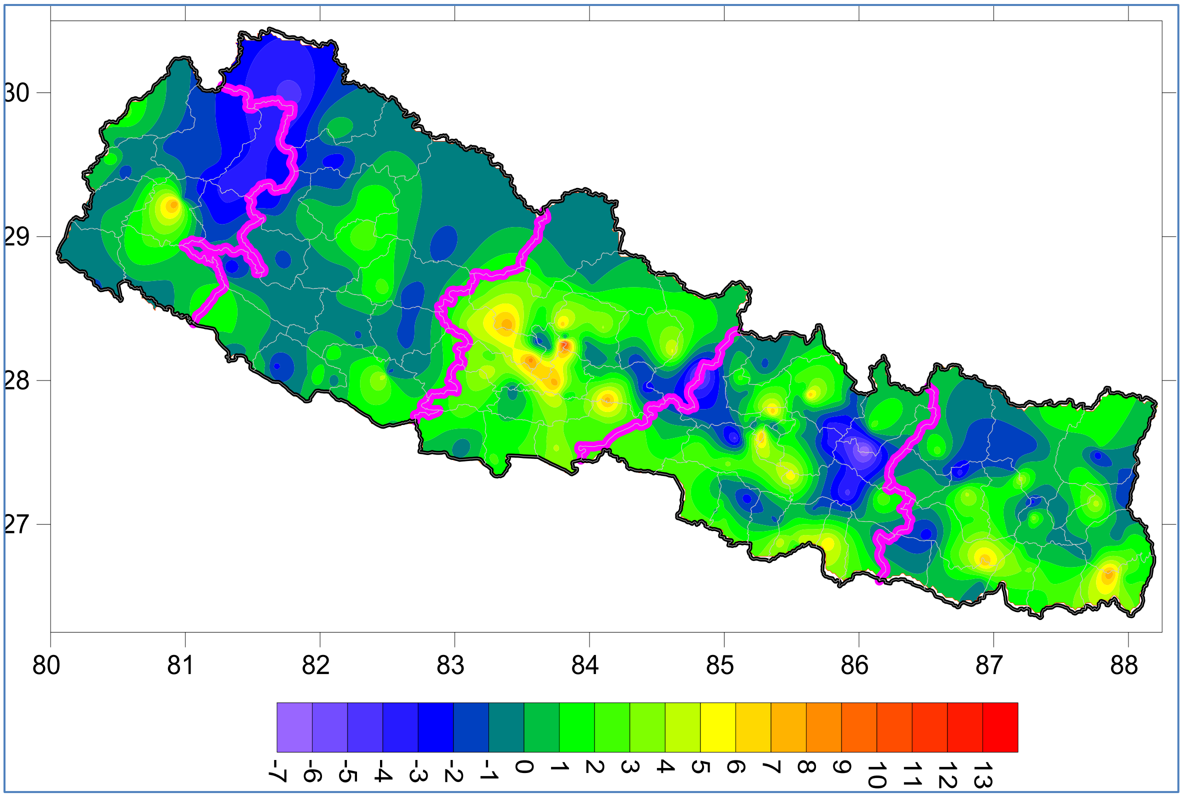


Figure 13 Pre-monsoon Rainfall Trend (1970-2014)

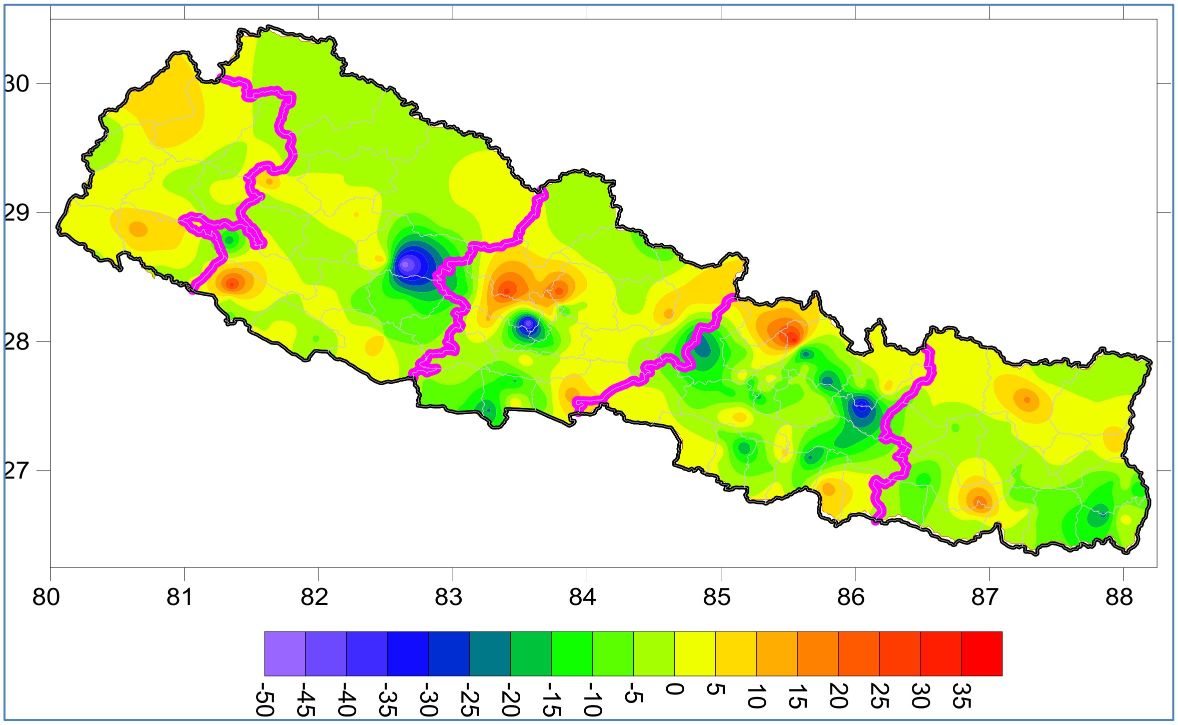


Figure 14 Monsoon Rainfall Trend (1970-2014)

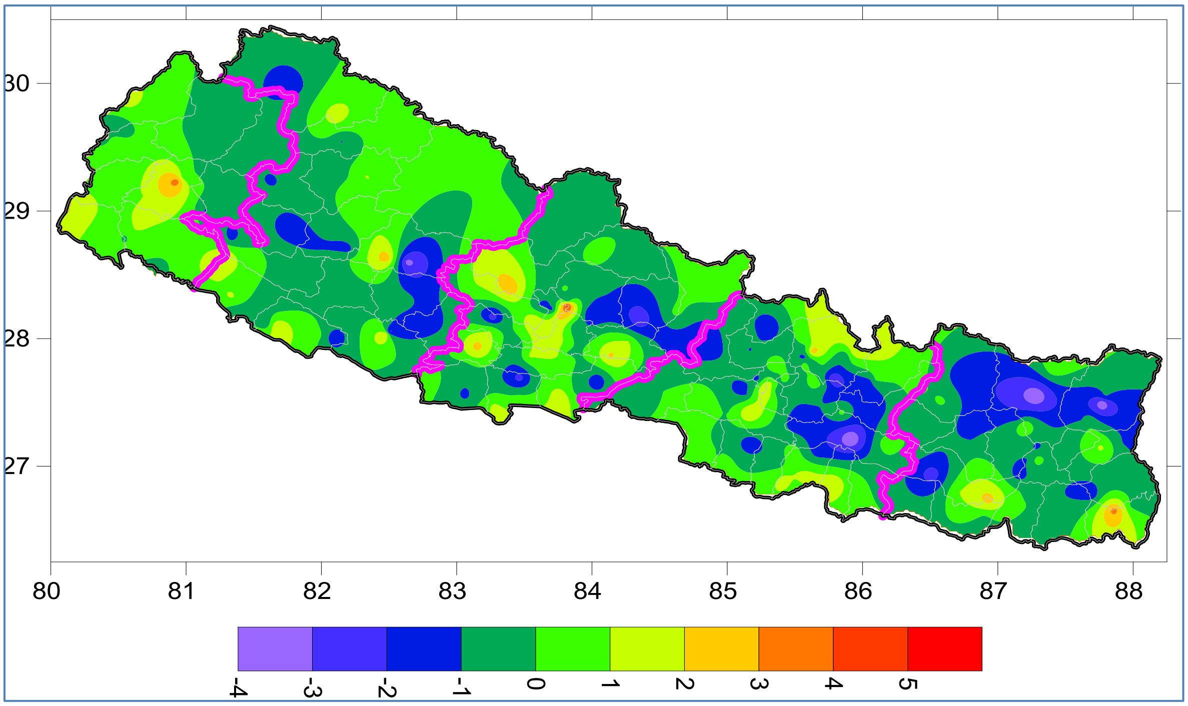


Figure 15 Post monsoon Rainfall Trend (1970-2014)

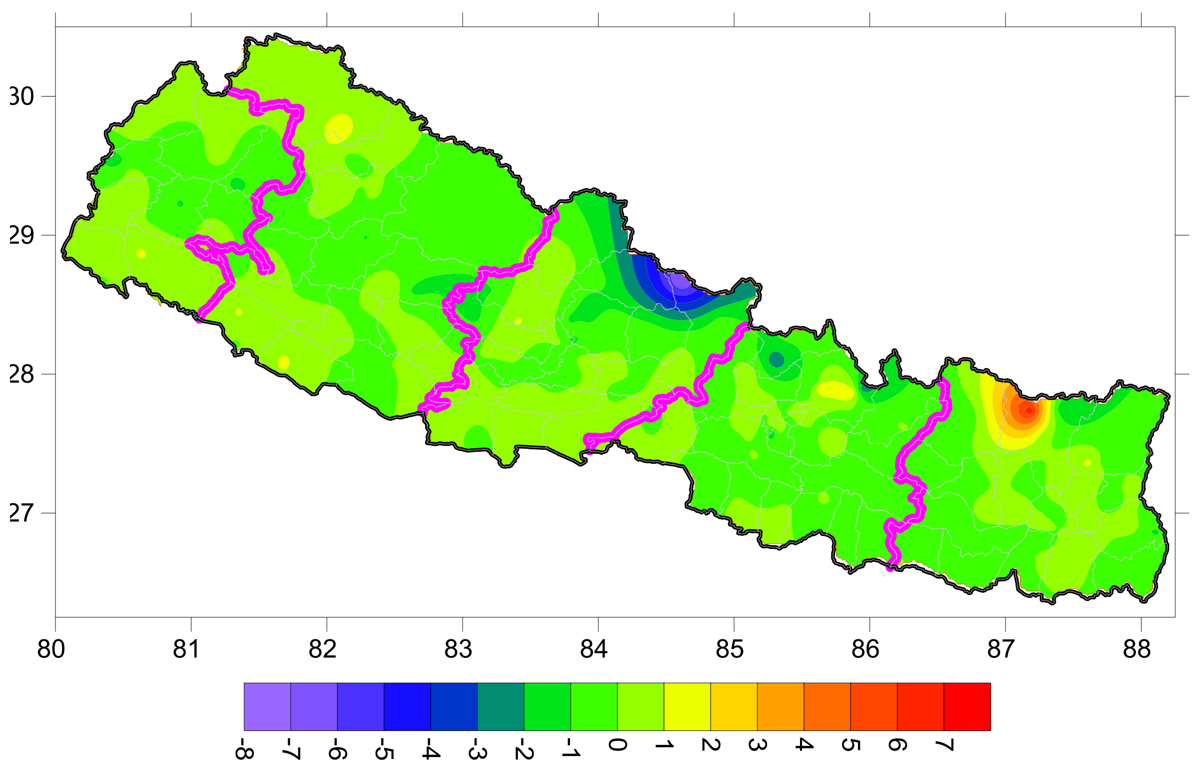


Figure 16 Winter Rainfall Trend (1970-2014)

3.6. Annual temporal trend of temperature and rainfall

The annual maximum and minimum temperature with increasing trend of 0.0368 ^{0}C/year and 0.0146^{0}C/year was obtained in over Nepal (1971-2014) shown respectively in Figure 17 and18. The annual rainfall with decreasing trend of -2.4598 mm/year was found in over Nepal (1970-2014) which is shown in Figure 19.

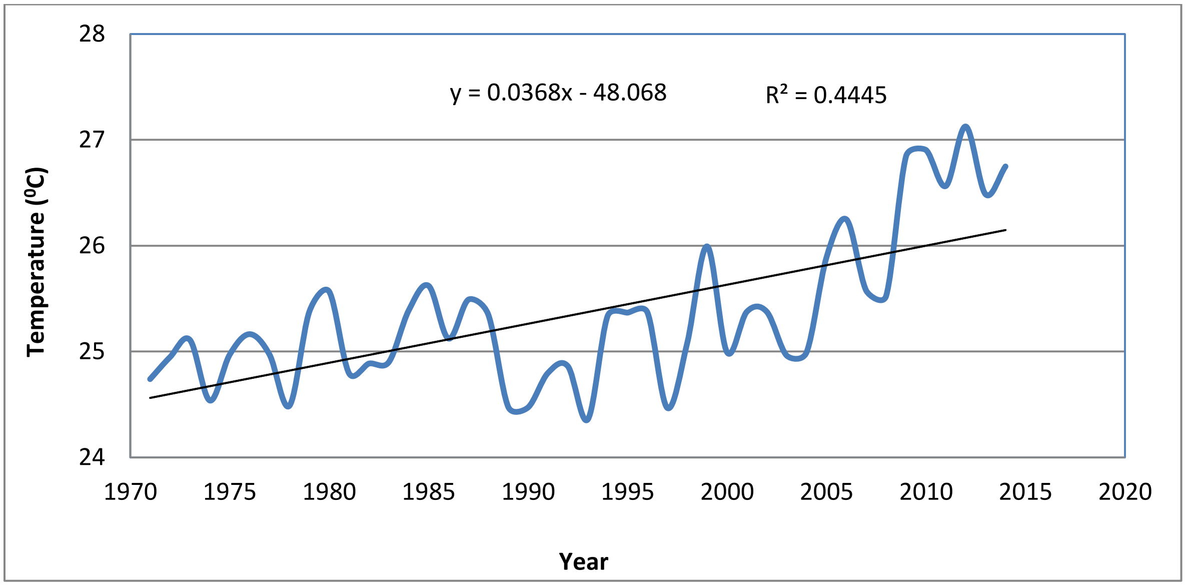


Figure 17 Annual maximum temperature trend over Nepal (1971-2014)

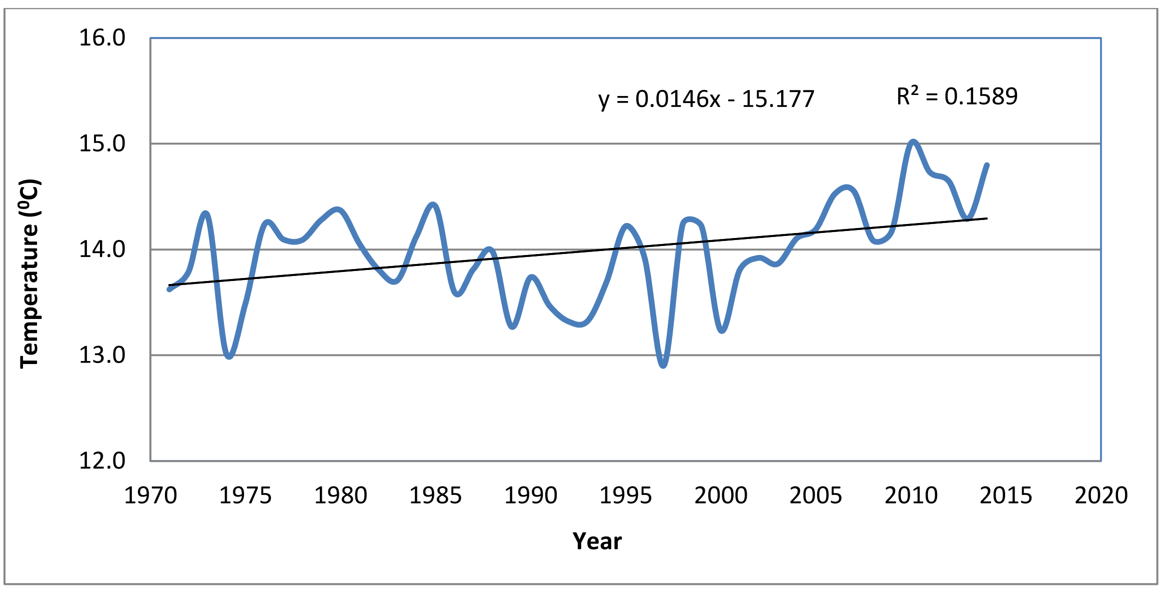


Figure 18 Annual minimum temperatures over Nepal (1971-2014)

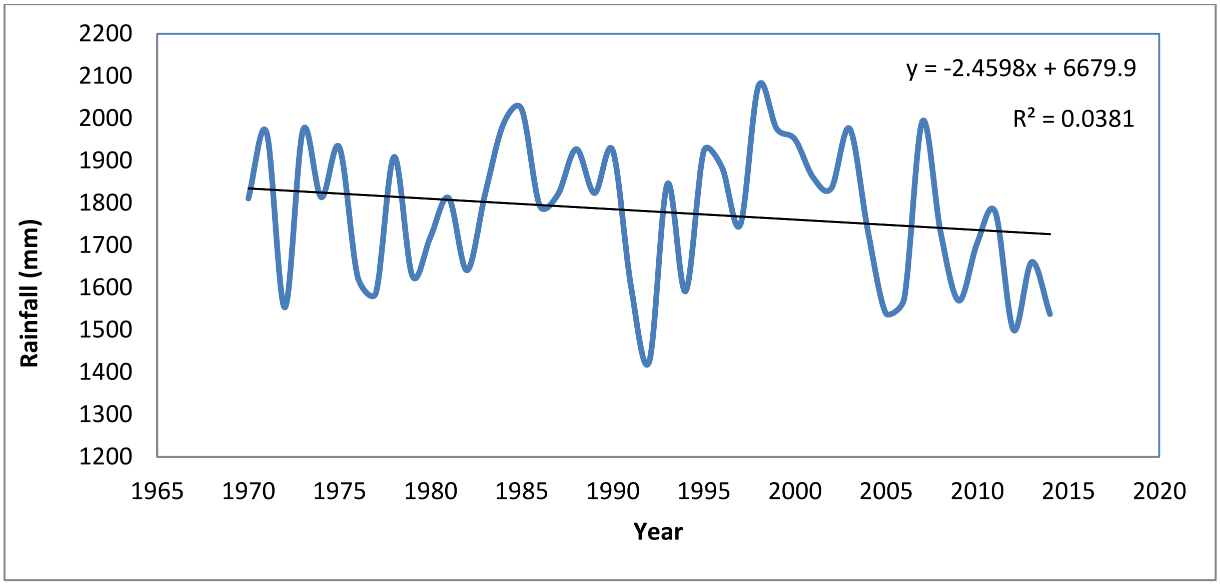
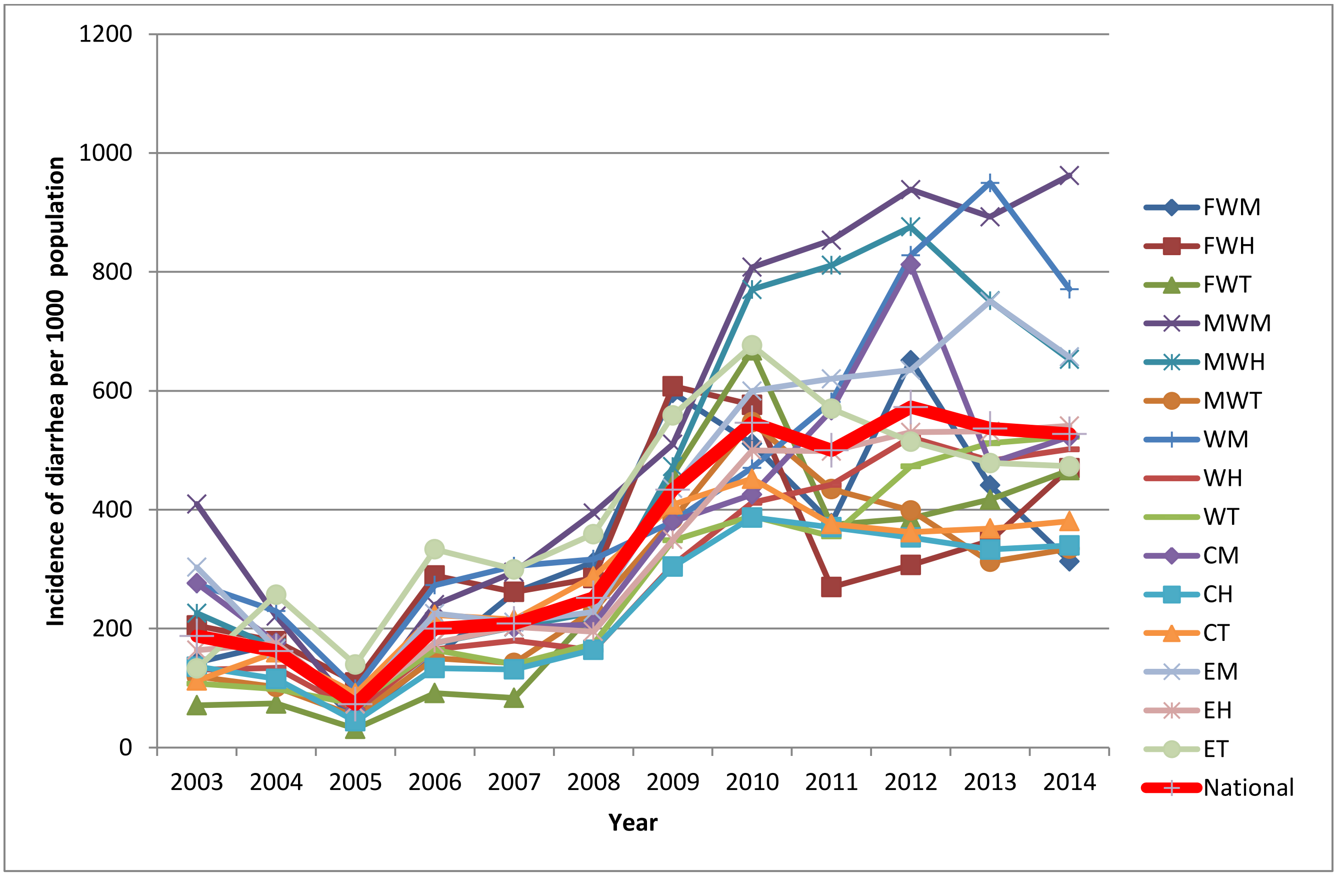


Figure 19 Annual rainfall trends over Nepal (1970-2014)

Results of statistical modelling are expressed separately for different eco-development regions and for Nepal as a whole. The predictor variables used are meteorological parameters (average, maximum and minimum temperatures, rainfall and relative humidity) and other variables such as seasonal dummies to account seasonal effects, annual trend and under-five target population. Effects are presented separately for different predictor variables as follows.

3.7. Diarrheal incidence in under-five children by eco-development regions

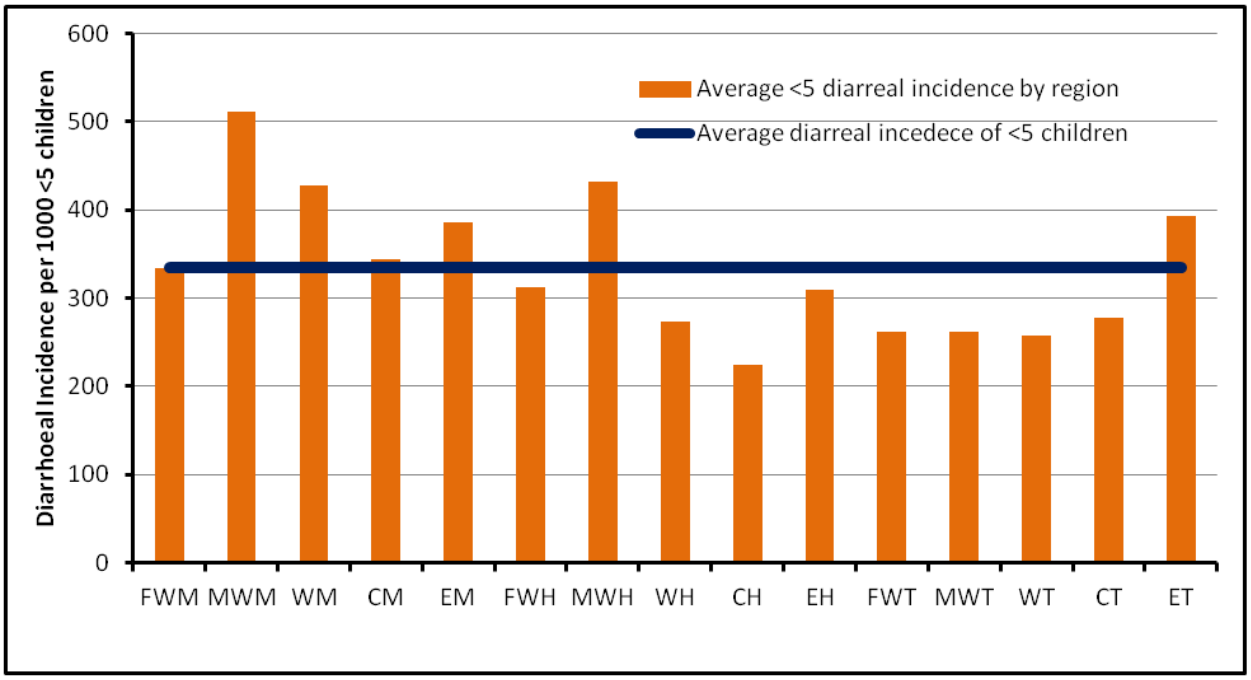
There was an increasing trend of diarrheal disease incidence in the under five children per 1000 population in all 15 eco-development regions across the country over the last 10 years from July 2003 to June 2013 as shown in figure 31. However, the trend showed fluctuation. Likewise, the average values of the diarrhea incidence had increased considerably by year, but not consistently. For instance, the average value of the diarrheal incidence was 187 per 1000 population of the under-five children in 2003 that increased to average incidence of 546 per 1000 population in 2012, the highest value. The thick red line shows national incidence of diarrheal diseases.



(Source: HMIS Data, 2003 – 2013)

Figure 20: Trend of diarrheal disease by eco-development regions

In 2005, the average value with 73 per 1000 population was the lowest. There was also remarkable variation in the diarrheal incidence in each year by eco-development regions. For example, the minimum value of diarrheal disease incidence was 71 per 1000 in 2003 which was in FWT region, whereas the maximum value was 410 in the same year which was observed in MWM region. In the year 2005, the average incidence of diarrheal disease with 73 was the lowest, while the minimum and maximum values were 32 in FWT region and 139 in ET region respectively in the same year. The year 2012 marked the highest average value of incidence of diarrheal disease with 572 per 1000 population while during the same year the minimum value was 307 in FWH region and maximum value was 939 per 1000 population in MWM region (Figure 20).



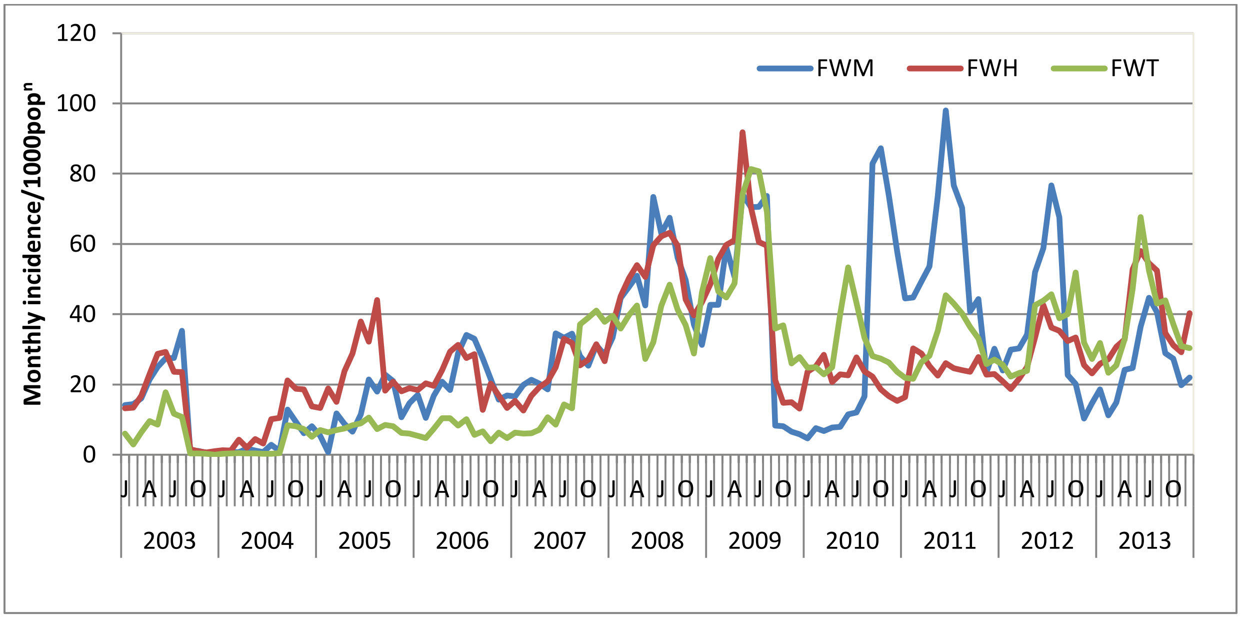
(Source: HMIS Data, 2003 – 2013)

Figure 21 : Average decadal diarrheal incidence in under-five children by eco-development region

Figure 20 shows the changing scenario of incidence of diarrheal disease by eco-development regions during the past decade. Within the past 10 years, the diarrheal disease incidence had increased from average of 187 (95% CI= 136-239) to 572 (95% CI =457-688) per 1000 under five children. With reference to the national average incidence of diarrhea of children 334 (blue horizontal line) per 1000 under five population, higher diarrheal incidence was found in all four mountain regions such as mid west, western, central and eastern except far western region. There was also higher diarrheal incidence in two other regions, including the mid-western hill and eastern Terai region than the national average. It means that all other nine eco-development regions have average diarrheal incidence values below the national average.

3.8. Monthly diarrheal disease incidences by development regions

3.8.1. Far-Western development region



(Source: HMIS Data, 2003 – 2013)

Figure 22 Monthly diarrheal incidences in under five children in Far-Western development region

a. Far-Western Mountain

While compared to average monthly diarrheal incidence of 29/1000 under-five children during the past 10 years, the diarrheal incidence was found higher in five months from May through September in the far western mountain region. The monthly incidence of diarrhea showed higher values ranging from 98/1000 in June to 70/1000 in August 2011. In 2010, even in the cold months of October and November the values ranged from 87 to 74.From the months of May through September of the same year, there was about 60% of diarrheal incidence occurred among the under-five children (Figure 22).

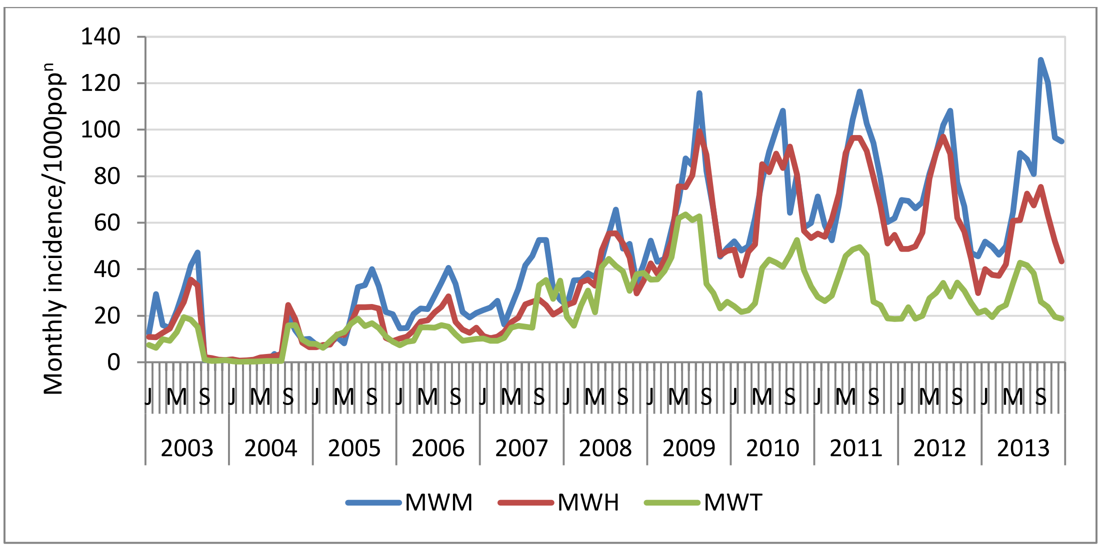
b. Far-Western Hill

In the far western hill region, the diarrheal incidence of 10 years showed a distinct pattern happening mainly during the summer months from April through August. But in the years: 2004, 2007, 2012 and 2013 the incidence of diarrhea even during the winter months was recorded above the mean. In 2009 and 2010, the incidence of diarrhea in the months of January through August was recorded above the mean. Overall, about 60% of diarrheal incidence occurred during the months of April through September which is shown in figure 22.

c. Far-Western Terai

In the far western Terai, the average yearly diarrheal incidence among the under five children was found increasing from the months of May through September. But in the years: 2007 and 2008, the incidence of diarrheal disease even during the winter months was found higher than the average diarrheal incidence value of the region as shown in figure 22.

3.8.2. Mid-Western development region



(Source: HMIS Data, 2003 – 2013)

Figure 23 Monthly diarrheal disease incidence in under five children in Midwestern development region

a. Mid Western Mountain (MWM)

More than 50% diarrheal incidence occurred from May to September. Winter diarrhea was also recorded above mean in 2012 as shown in figure 23.

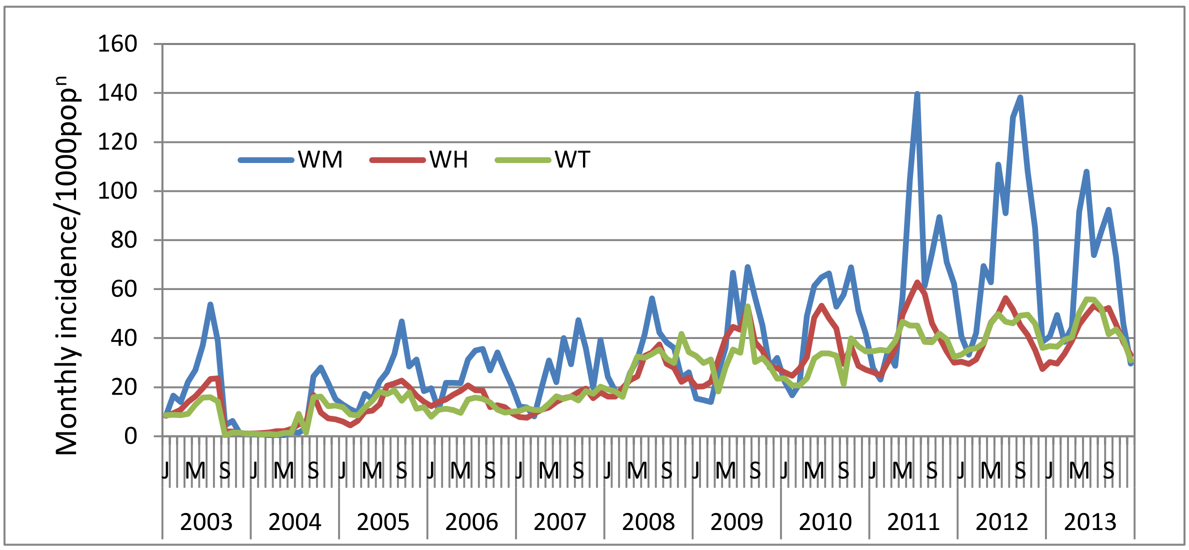
b. Mid Western Hill

About 64% of diarrheal incident took place from the months of May through October. The highest diarrheal diseases incidence was recorded in 2009 which is shown in figure 23.

c. Mid Western Terai

Almost 60% diarrhoeal incidences occurred during the months from May through October. The highest diarrheal diseases incidence was recorded in 2009 which is shown in figure 23.

3.8.3. Western development region



(Source: HMIS Data, 2003 – 2013)

Figure 24 Monthly diarrheal incidence in under five children in Western development region

a. Western Mountain

In the western mountain region, the incidence of the diarrheal disease occurred at 67% during the months of May through October. The highest diarrheal disease incidence was occurred in 2011 and 2012 as shown in figure 24.

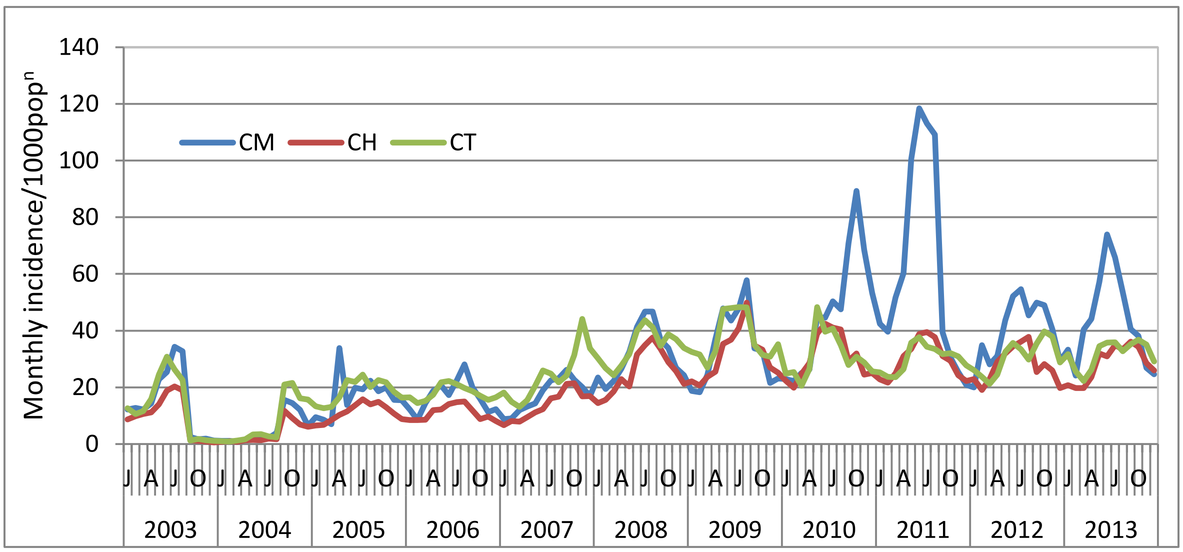
b. Western Hill

More than 61% of diarrhoeal incidence occurred during the months of May through September. Of the past 10 years (2003 to 2013) data, the highest diarrheal incidence was occurred in 2013 as shown in figure 24.

c. Western Terai

In the western Terai, more than 62% of diarrhoeal disease incidence occurred during the months of May through October. The highest diarrheal disease incidence was occurred in 2011 as in figure 24.

3.8.4. Central development region



(Source: HMIS Data, 2003 – 2013)

Figure 25 Monthly diarrheal incidences in under-five children in Central development region

a. Central Mountain

In the central mountain region, about 64% of diarrheal disease occurred during the months of May through October. The highest diarrheal incidence was occurred during the year 2011 as shown in figure 25.

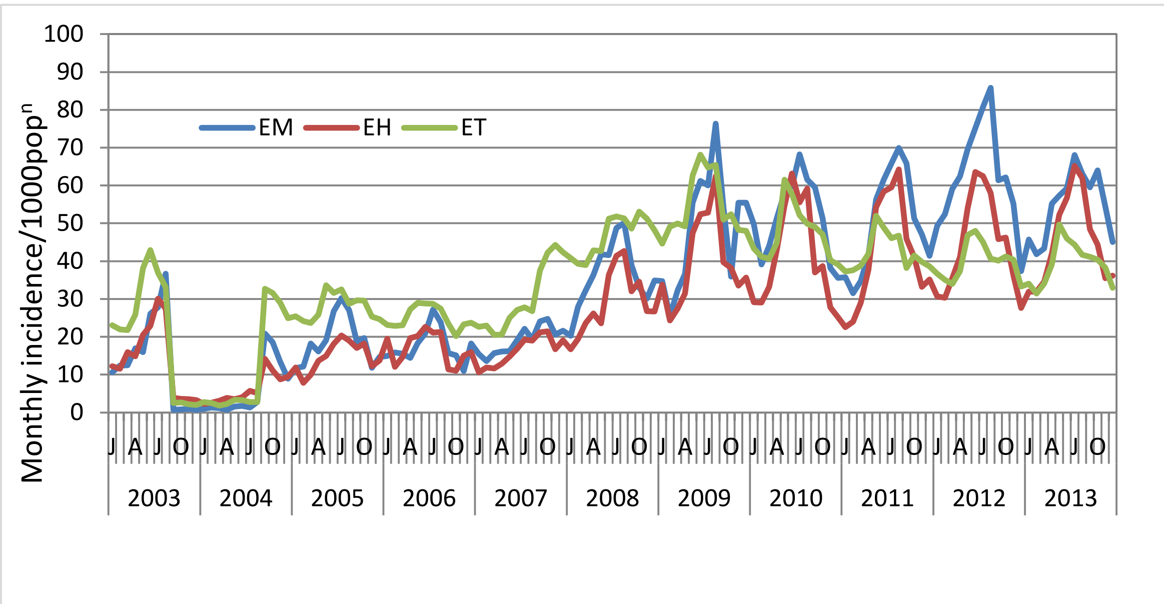
b. Central Hill

About 57% of diarrheal disease incidence occurred during the months of May through October. In this region, the highest diarrheal disease incidence was occurred in 2009 as shown in figure 25.

c. Central Terai

About 59% of overall diarrheal disease incidence occurred in the central Terai region during the months of May through October. In this cluster, the highest diarrheal disease incidence was occurred in 2009 followed by 2010 as shown in figure 25.

3.8.5. Eastern development region



(Source: HMIS Data, 2003 – 2013)

Figure 26 Monthly diarrheal incidence in under-five children in Eastern region

a. Eastern Mountain

Of the overall diarrheal disease incidence, about 58% occurred in the eastern mountain cluster during the months of May through October. There was highest diarrheal disease incidence in the eastern mountain cluster in 2012 as shown in figure 26.

b. Eastern Hill

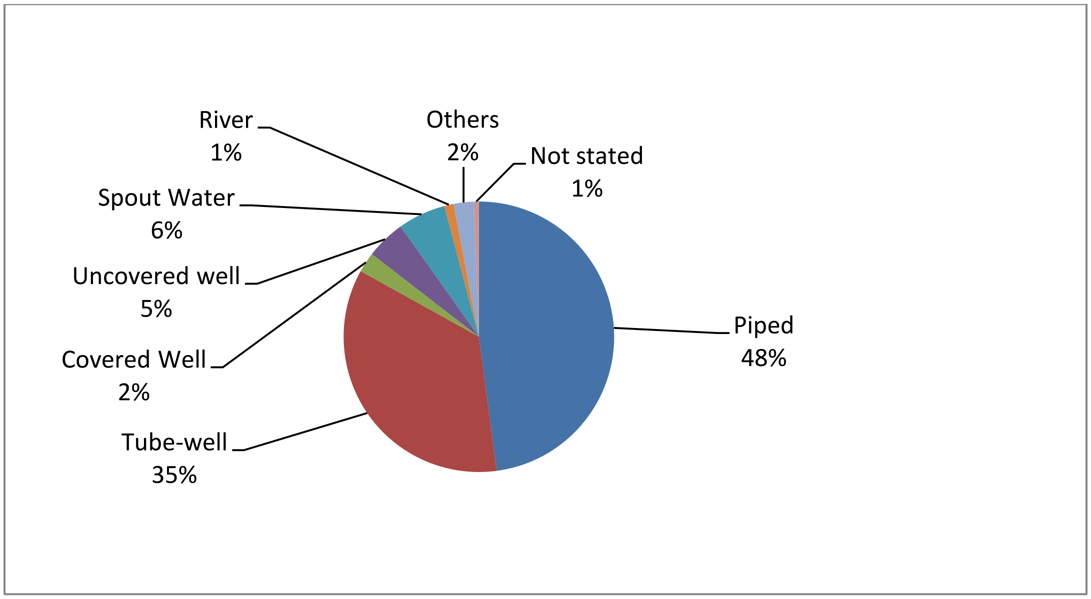
In the eastern hill cluster, the diarrheal incidence was highest, i.e. 58% during the summer rainy months of May through October. The highest diarrheal disease incidence was occurred in the eastern hill in 2013 as shown in figure 26.

c. Eastern Terai

The analysis of one decade's diarrheal disease incidence shows that about 60% of diarrheal incidence occurred during the months of May through October. The highest diarrheal disease was occurred in the eastern Terai cluster in 2009 as shown in figure 26.

3.9. Drinking water supply coverage and the incidence of diarrheal diseases

There is direct link between drinking water supply and diarrheal disease. There are several proximal and distal factors causing diarrheal disease. One of the major causes can be related to the water supply and sanitation coverage situation in the region. Figure 27 depicts the drinking water sources and consumption status. About 85% of the water sources which are defined as safe sources are being supplied from piped water, tube well and covered wells. The remaining 15% are from the unsafe sources, which are still used by the people for consumption (DWSS 2011).



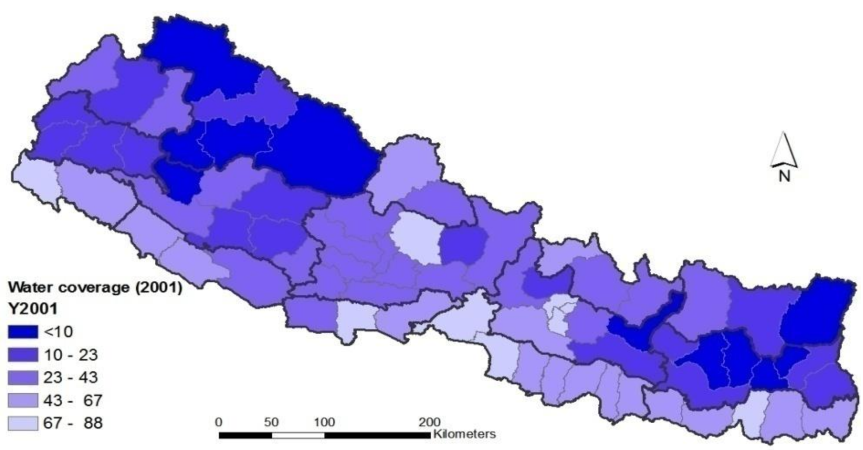
(Source: CBS 2014)

Figure 27 Sources of water used for drinking purpose

As shown in Figures 28 to 30, there has been increased in the overall water coverage over the past 15 years across different eco-development regions in the country. However there is no consistency in the increasing trend of the drinking water coverage among these regions. For instance, there were fluctuations in the water coverage distribution among the eco-development regions in 2001, while in the later years; the distribution of water coverage has been less fluctuating among these regions. Though, there has been an increasing trend of water coverage during the past 15 years.

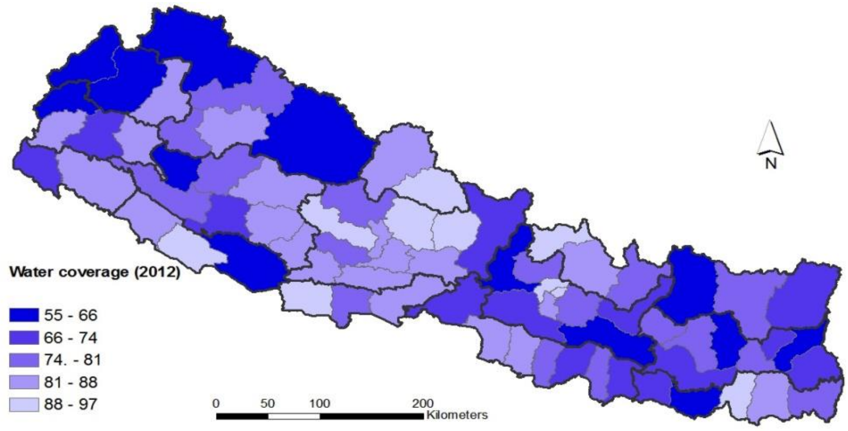
3.10. Spatial distribution of drinking water coverage

The spatial distribution of diarrheal disease incidence is linked to drinking water coverage. The spatial drinking water coverage for the last 15 years i.e. 2001, 2011 and 2015 are depicted in figure 28, 29 and 30 respectively.



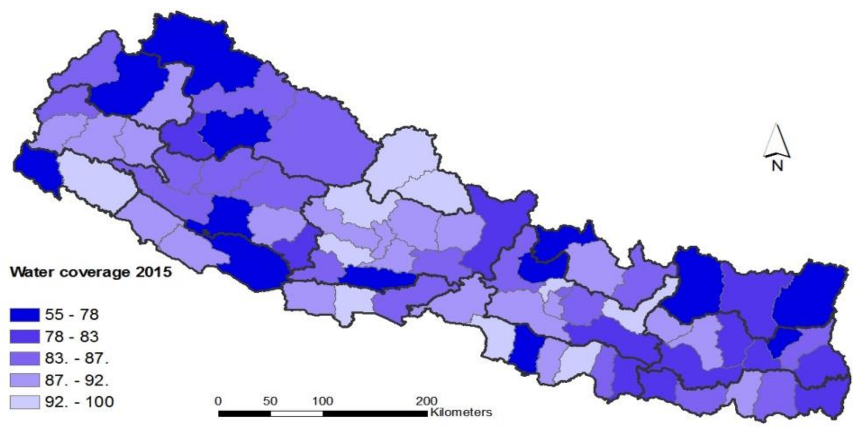
(Source: CBS, 2001)

Figure 28 Drinking water coverage in 2001



(Source: CBS, 2011& DWSS, 2012)

Figure 29 Drinking water coverage in 2011-2012



(Source: DWSS, 2015)

Figure 30 Drinking water coverage in 2015

The drinking water coverage has been increasing for the last 15years from 2001 to 2015. It is found that the Mid-Western Hill and Mountain districts had very low drinking water coverage i.e. below 20 percent in 2001 which improved to 75 percent in 2011 and went up to 80 percent in 2015. Higher coverage of drinking water districts were very much scattered up to 2011 in the Western and Central Hills and Terai regions. But in 2015, higher percentage (>80%) water coverage in all regions were common (Figure 30). The government effort is to provide safe source of drinking water (basic water coverage) to 100% household (DWSS 2011)

Figure 31 describes the sharing of drinking water by different sources coverage at household level as defined by government of Nepal[1].

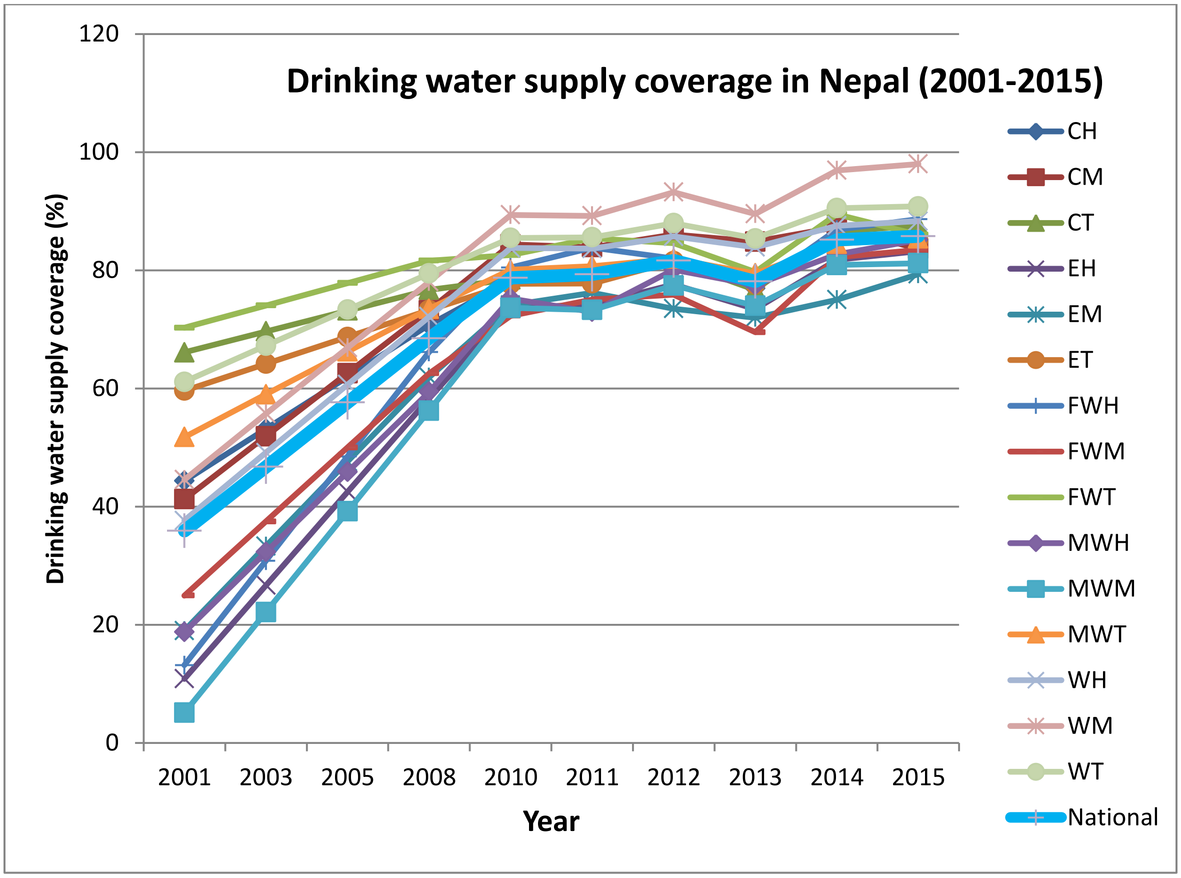


Figure 31 Trends of household drinking water coverage by the eco-development region

It is generally assumed that increasing drinking water coverage affects to decrease in diarrheal disease at household level and vice versa (decreasing drinking water coverage indicates increasing diarrheal disease). In other words, there is an inverse relationship between the water coverage and diarrheal disease. During the last 15 years, the water coverage has been found

1The drinking water coverage households refer to those households which are located within the water sources of 50 m vertical and 250m horizontal distances (WECS 2002, water resource strategy Nepal 2002).

increasing from the average household coverage of 38% (95% CI=27-49) in 2001 to 86% (95% CI=84-89) in 2015 (Figure 31). While computing the correlation coefficient (r value) of water coverage and incidence of diarrheal disease, it was found negative with r=-0.02 in 2003. But in other years such as 2010, 2012 and 2013 the correlation values were found positive 0.26, 0.08, and 0.29 respectively. This indicates that the diarrheal disease incidence has increased despite increase in drinking water coverage. The drinking water coverage is still relatively low in case of Far Western and Mid Western Mountain and Central and Eastern Terai as in figure 31.

3.11. Sanitation coverage and the incidence of diarrheal diseases

Like drinking water coverage, the sanitation coverage is also related to diarrheal disease. So, increasing sanitation coverage means decreasing in diarrheal disease at household level and vice versa (decreasing sanitation coverage indicates increasing diarrheal disease). In other words, there is an inverse relationship between the sanitation coverage and diarrheal disease.

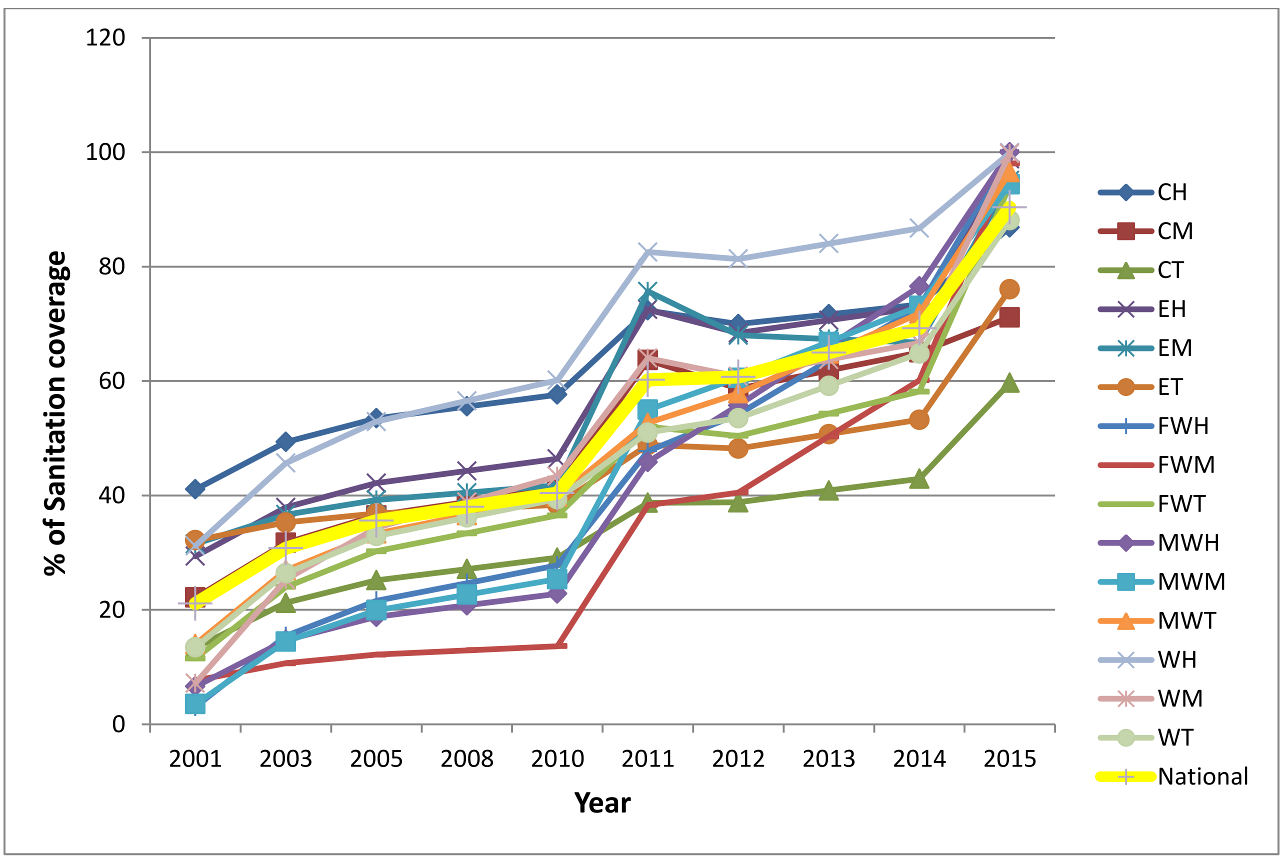


Figure 32 Trend of household sanitation coverage by eco-development region

Sanitation as per the definition of DWSS (2011) is considered as household toilet coverage. In the past one and half decades, the sanitation analysis shows that its coverage has increased from the average of 17.7 (95% CI = 11-24) in 2001 to 90.6 (95% CI = 83-97) in 2015. The sanitation coverage has gradually increased over the years. For instance, the maximum household coverage of sanitation in 2001 was 41% while it was 100% in 2015. The progress sanitation coverage at household level has been rapidly increased from 2011 onwards. It might be due to the government efforts to declare 100% sanitation coverage by 2017 (DWSS 2011). However, the sanitation coverage in the central Terai and eastern Terai regions is still below the average national sanitation coverage as shown in figure 31. The thick bold yellow line represents national sanitation coverage.

While computing the correlation coefficient between the sanitation coverage and diarrheal disease incidence of the under-five children, the value was found negative i.e. -0.65, indicating the reverse relationship between those two indicators. It means that higher sanitation coverage resulting in less diarrheal disease. Similarly, there were also negative correlation coefficient values such as r=-0.02 and -0.07 in 2010 and 2012 respectively. However these inverse relationships seem very weak. But in 2013 the value of r=0.253 between those two indicators was positive. Though the relationship between them seems to be weak, it indicates increased sanitation coverage has not lowered down the diarrheal disease incidence among the under-five children population.

3.12. Spatial Distribution of Sanitation Coverage

The spatial sanitation coverage for the last 15 years i.e. 2001, 2011 and 2015 are depicted in Figure 33,34 and 35 respectively. The sanitation coverage has been increasing for the last 15years from 2001 to 2015. Some improvements, particularly in the districts of the Western half of the country have appeared in 2011. Rapid increase in the sanitation coverage has occurred from 2011 onward. The record of the sanitation coverage of 2015 showed that the majority of the regions were with above 80% toilet coverage except in the Central Terai and the Mid-Western Hills and Mountains (Figure 35)

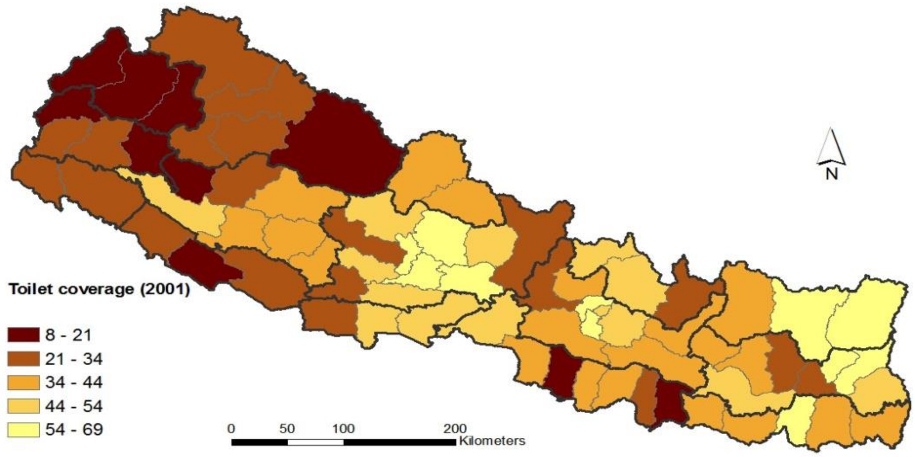


Figure 33 Sanitation coverage of 2001

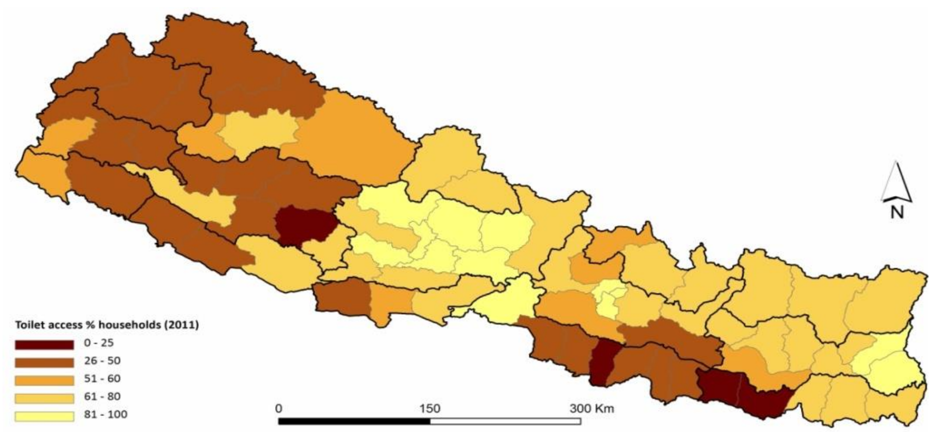


Figure 34 Sanitation coverage of 2011

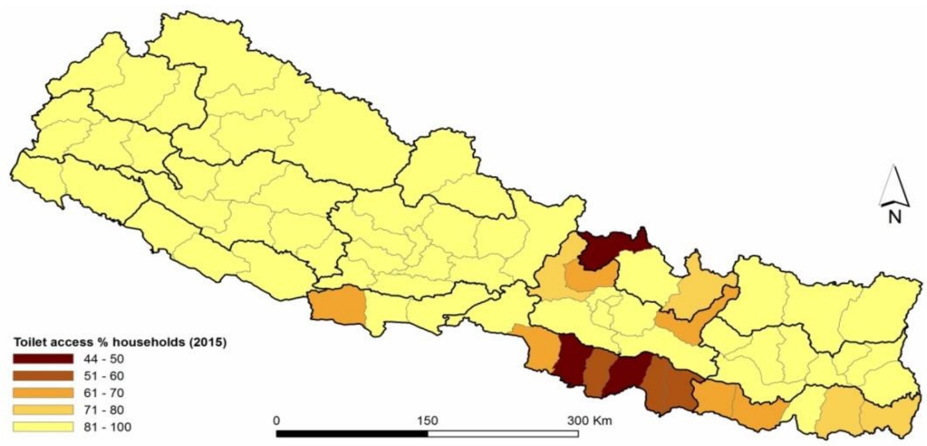


Figure 35 Sanitation coverage of 2015

Over the past one and half decades i.e. from 2001 to 2015, the data on both drinking water coverage and sanitary coverage at household level shows increasing trend as shown in figure 36. In both cases, the Government of Nepal has set an objective of making them 100% coverage, which means the entire households at national level should get drinking water and sanitation facility.

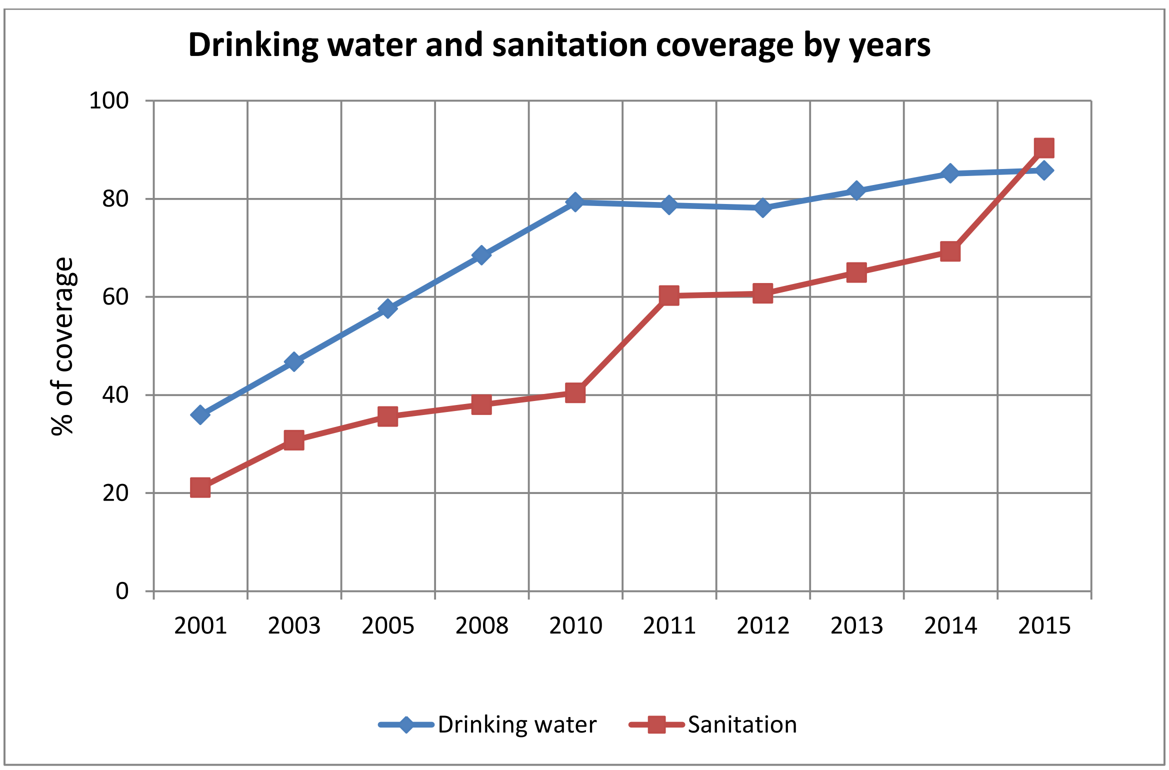


Figure 36 Trends of drinking water and sanitation coverage

3.13. Spatial distribution of diarrheal incidence among under-five children, and drinking water and sanitation coverage by district

The correlation analysis of the diarrheal diseases incidence with the water and sanitation coverage at the district level for the year 2003 was negative, indicating an increase in coverage of water and sanitation decreased diarrheal diseases incidence. The co-relationship value between diarrheal diseases with both water and sanitation coverage was statistically significant with $p<0.05$ ($p = 0.006$).

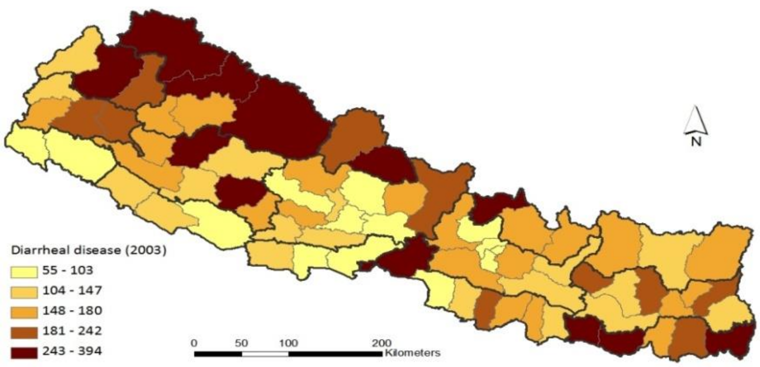


Figure 37 Diarrheal disease incidence in 2003

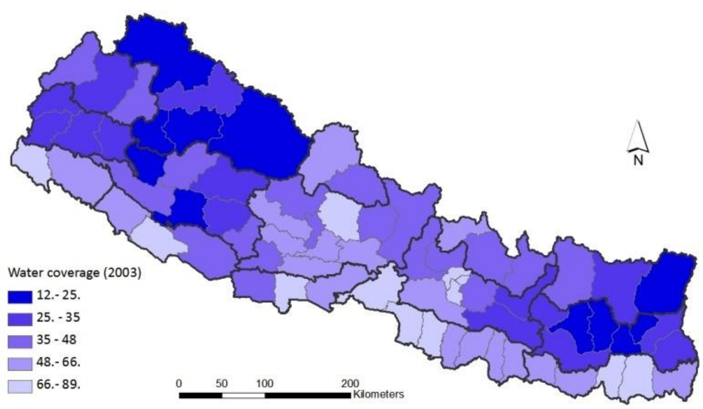


Figure 38 Water coverage in 2003

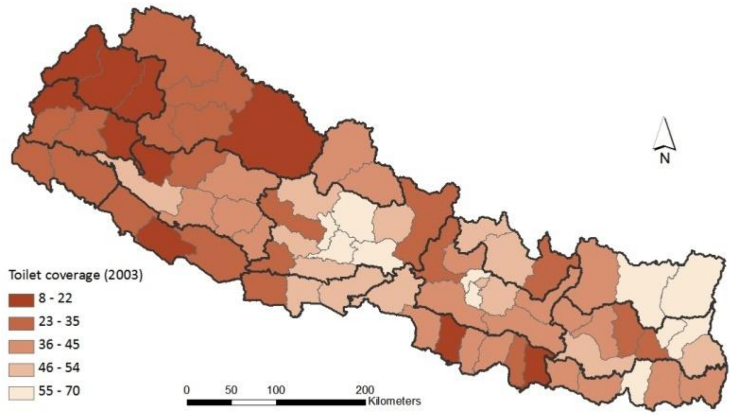


Figure 39 Sanitation coverage in 2003

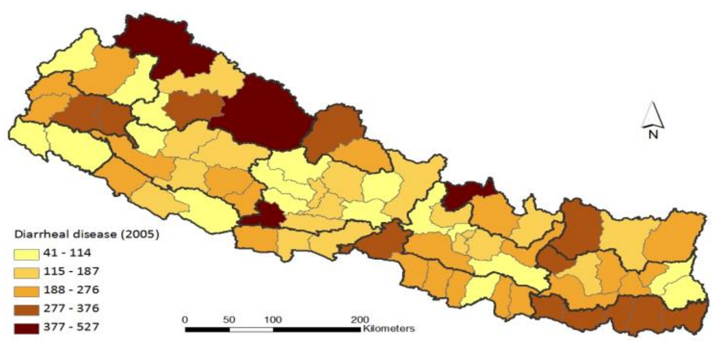


Figure 40 Diarrheal disease incidence in 2005

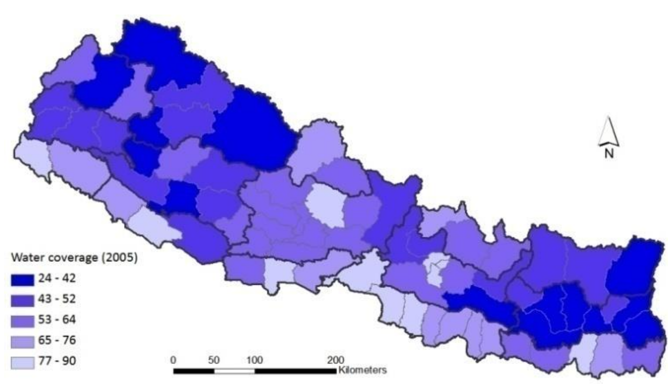


Figure 41 Water coverage in 2005

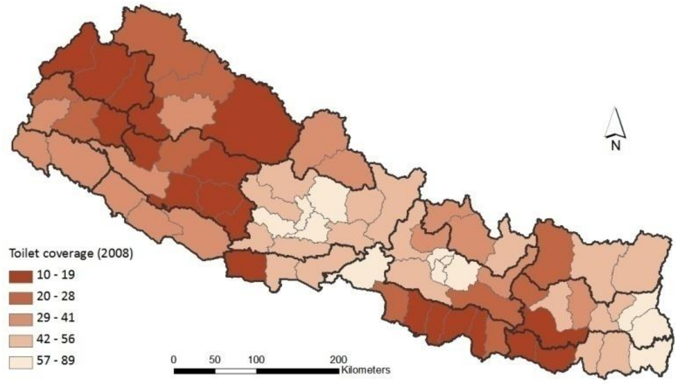


Figure 42 Sanitation coverage in 2005

In 2005, the correlation coefficient values of diarrheal disease incidence with the coverage of water and sanitation were *r =-0.192 and r =– 0.067* respectively. Though there were negative correlations between the incidence of diarrheal disease and both water and sanitation coverage, the level of statistical significant varied, showing the *p* values for the water coverage at >0.5 while that for the sanitation coverage at $p<0.5$.

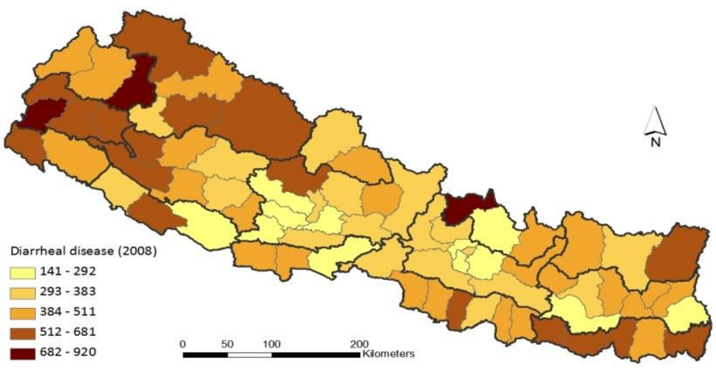


Figure 43 Diarrheal disease incidence in 2008

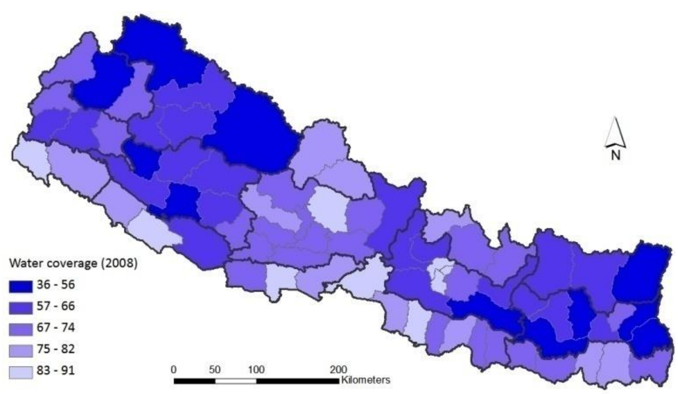


Figure 44 Water coverage in 2008

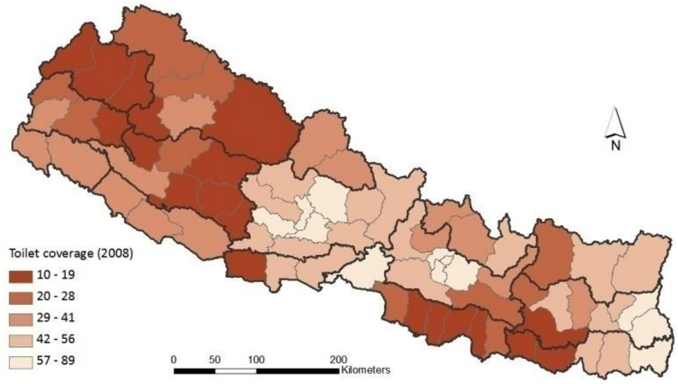


Figure 45 Sanitation coverage in 2008

In 2008, the statistical correlation values between the diarrheal incidence and the water coverage were at $r=-0.155$, $p = 0.092$ and those with the sanitation coverage were at $r = -0.433$, $p = <0.05$. These mean that the correlation between diarrheal diseases incidence and the water coverage was very poor and not statistically significant, while the correlation between diarrheal disease incidence and the sanitation coverage was relatively strong and statistically significant.

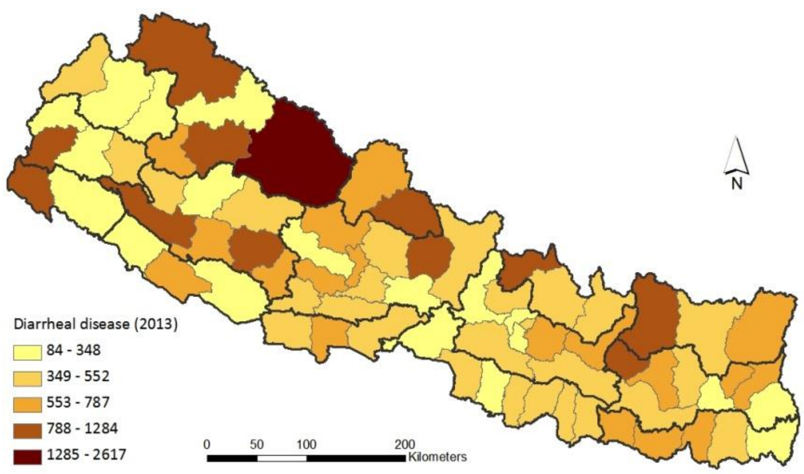


Figure 46 Diarrheal disease incidence in 2013

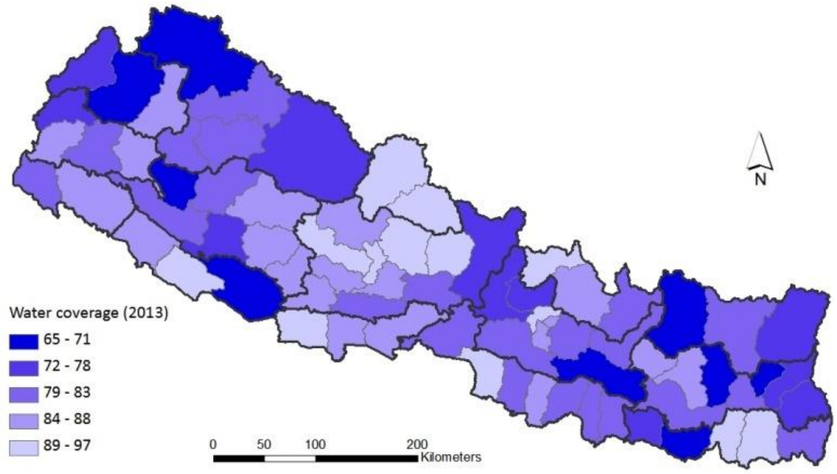


Figure 47 Water coverage in 2013

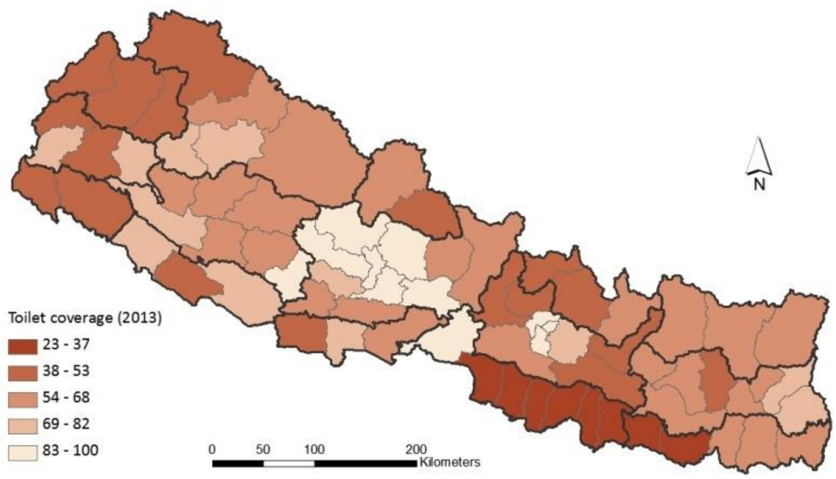


Figure 48 Sanitation coverage in 2013

In 2013, the correlation values between the diarrheal incidence and the both water and sanitation coverage were at -0.029 and -0.031 respectively, indicating negative but weak correlation. The statistical significance at 95% confidence level showed the value of *p* in both cases at $p>0.05$, indicating statistically not significant.

3.14. Effects of temperature

Effects of temperature on occurrence of diarrheal cases were assessed separately for average, maximum and minimum temperatures. The eco-development-wise percent rise in diarrheal cases per 1^0C increase in average temperature varied substantially between domains and ranged between 0.85% to 5.05% with minimum increase detected in CT region and highest found in WM. The eco-belt-wise effects ranged between 1.46% (Terai) to 3.42% (Mountain). The overall effect for Nepal was found to be 4.39% (95% CI: 3.95-4.85). Regions with relatively less increase in diarrheal cases in under five children were found to be CT, ET, WT, WH and FWM with less than 1.7% increase per 1^0C increase in average temperature. Domains which showed highest effects were CH, MWT and WM with more than 4.5% increase for the same (Figure 49).

The percent rise in diarrheal cases per 1^0C increase in maximum temperature also varied substantially between domains and ranged between 0.74% to 5.22% with minimum increase detected in western hill region and highest found in mid-western Terai. The overall effect for Nepal was found to be 3.87% (95% CI: 3.44-4.31). Regions with relatively less increase in diarrheal cases in under five children were WH, WT and CT with less than 1.3% increase per 1^0C increase in maximum temperature. Domains which showed highest effects were CH, FWT and MWT with more than 4.2% increase for the same (Figure 50).

The percent rise in diarrheal cases per 1^0C increase in minimum temperature also varied substantially between domains and ranged between 1.31% to 7.87% with minimum increase detected in ET region and highest found in WM. The overall effect for Nepal was found to be 3.79% (95% CI: 3.39-4.19). Regions with relatively less increase in diarrheal cases in under five children were ET, WT and FWM with less than 1.8% increase per 1^0C increase in minimum temperature. Domains which showed highest effects were CH, MWT and WM with more than 3.8% increase for the same (Figure 51).

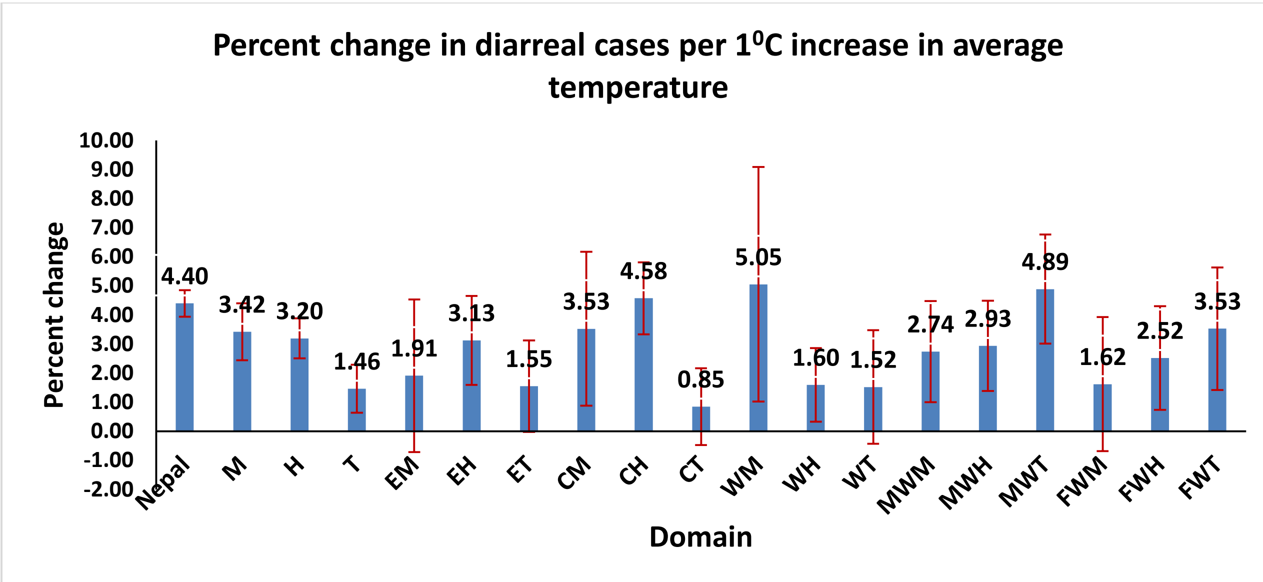


Figure 49 Percentage increase in diarrheal cases per 1°C increase in average temperature

[Note: The vertical lines in the figures represent the 95% confidence interval (CI)]

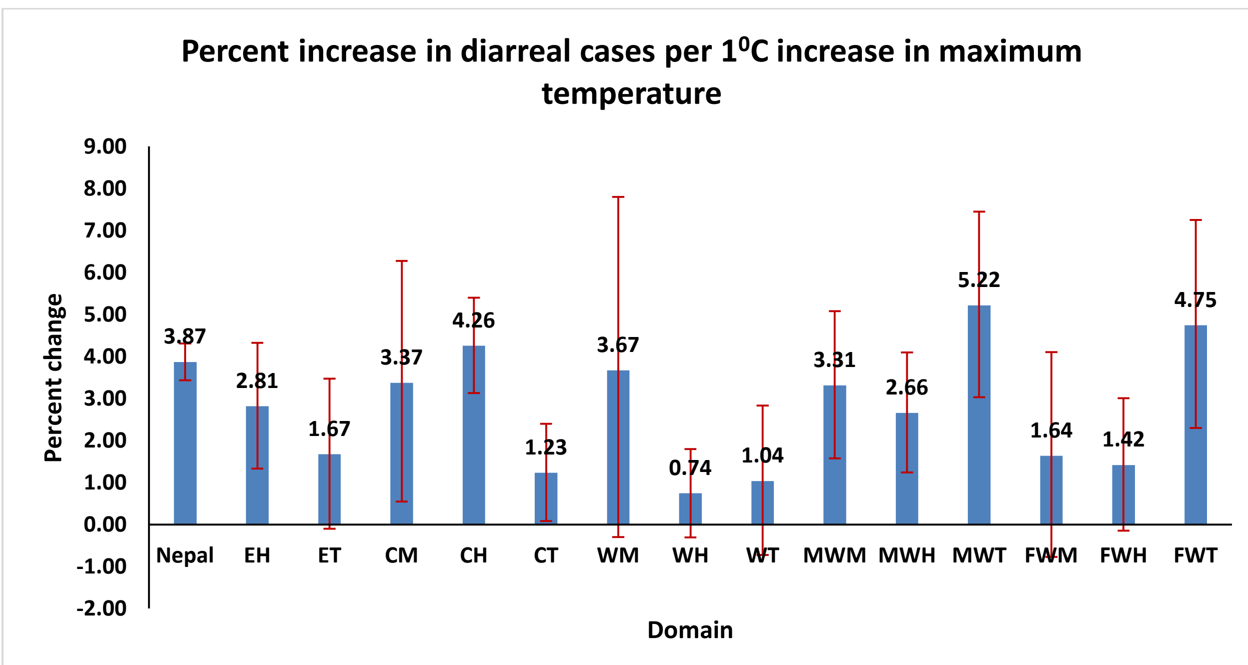


Figure 50 Percentage increase in diarrheal cases per 1°C increase in maximum temperature

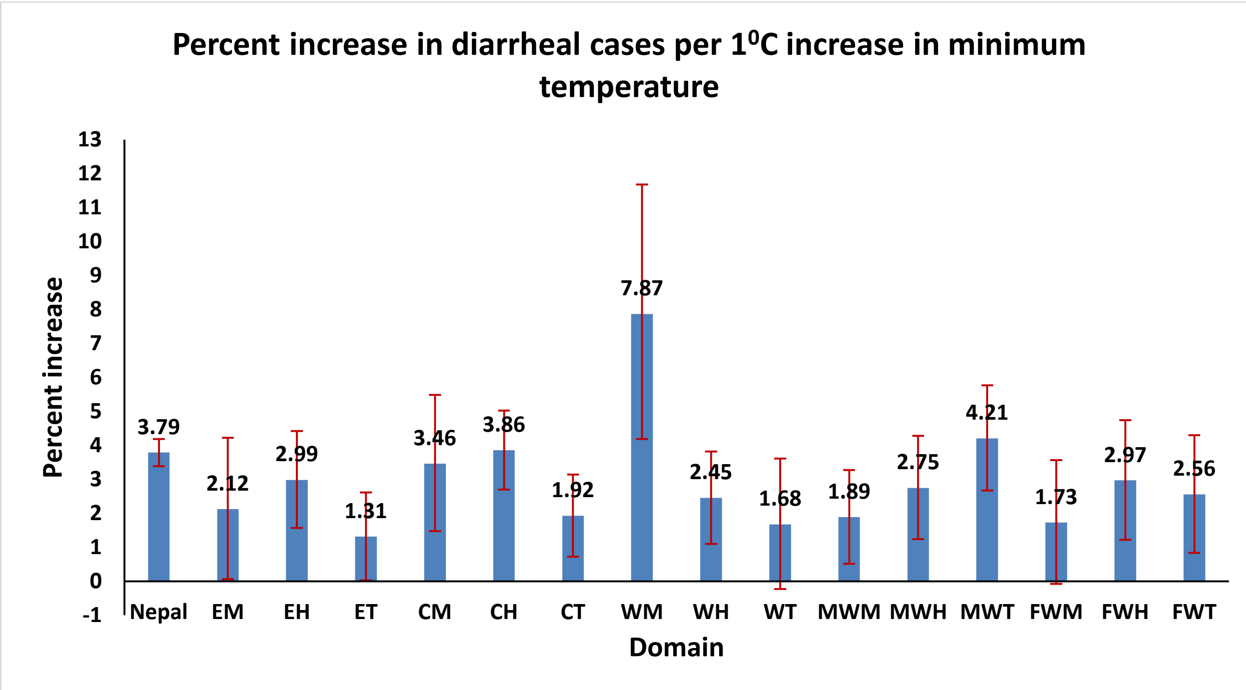


Figure 51 Percentage increase in diarrheal cases per 1°C increase in minimum temperature

3.15. Effects of rainfall

Studies have found that heavy rainfall accompanied by flooding are usually associated with outbreak of water-borne diseases especially in an underdeveloped country like Nepal. In this context, statistical modelling of diarrheal incidences is also modelled using rainfall as one of the main predictor variables. Results of modelling showed that the percent rise in diarrheal cases in under five years children was significantly associated with occurrence of rainfall in many eco-development regions (6) of Nepal. Increase in 1 cm rainfall was associated with 0.40% to 0.80% increase in diarrheal cases with minimum increase detected in CM region and highest found in MWH. The overall effect for Nepal was found to be 0.28% (95% CI: 0.15-0.41) (Figure 52). It is notable that rainfall was found highly insignificant ($p>0.25$) in Terai region and far western development region of Nepal.

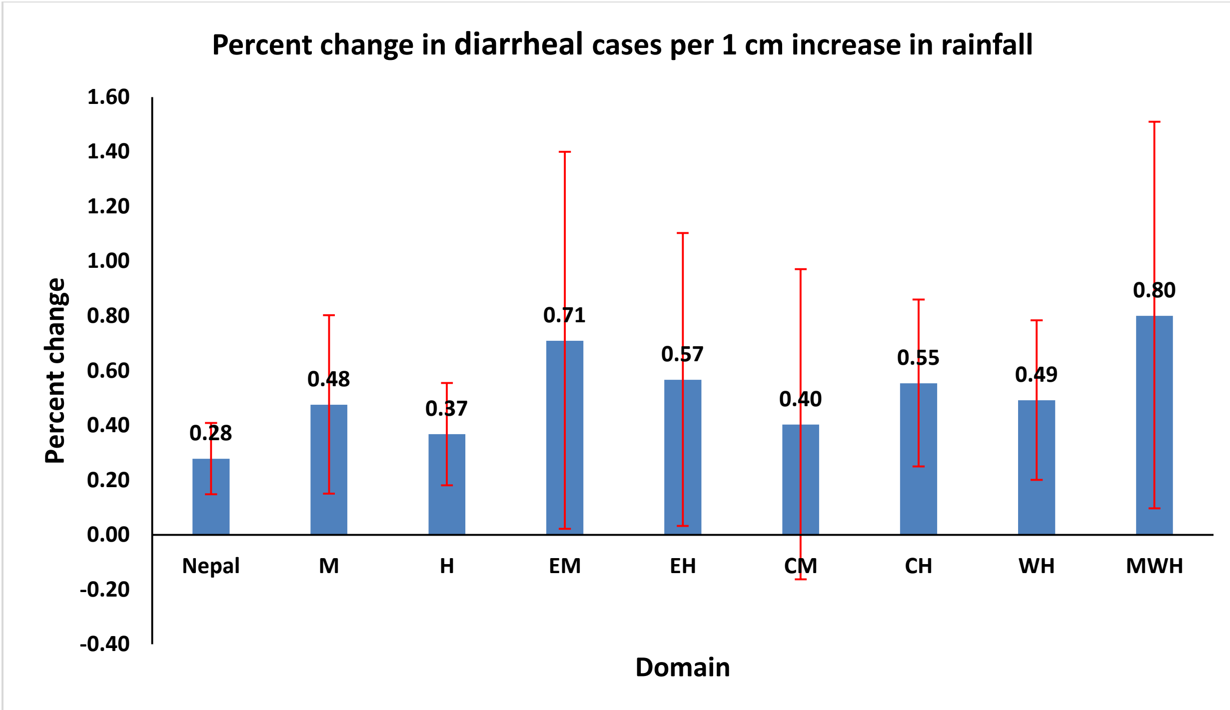


Figure 52 Percentage change in diarrheal cases per 1 cm increase in rainfall

3.16. Effects of relative humidity

Relative humidity is another important meteorological parameter which can affect diarrheal incidence. However, inclusion of this variable in models revealed statistically significant associations in only three eco-development regions and the effects were also contrasting with minus.071% to 0.49% change in diarrheal cases in under five years children per 1% increase in relative humidity. Additionally, it is found that relative humidity was statistically significant only in Hill eco-belt (-0.17%) and insignificant considering overall effect in Nepal. The results pointed out that relative humidity is not a dominant predictor as temperature or rainfall in predicting diarrheal cases in the sub-population of Nepal (Figure 53)

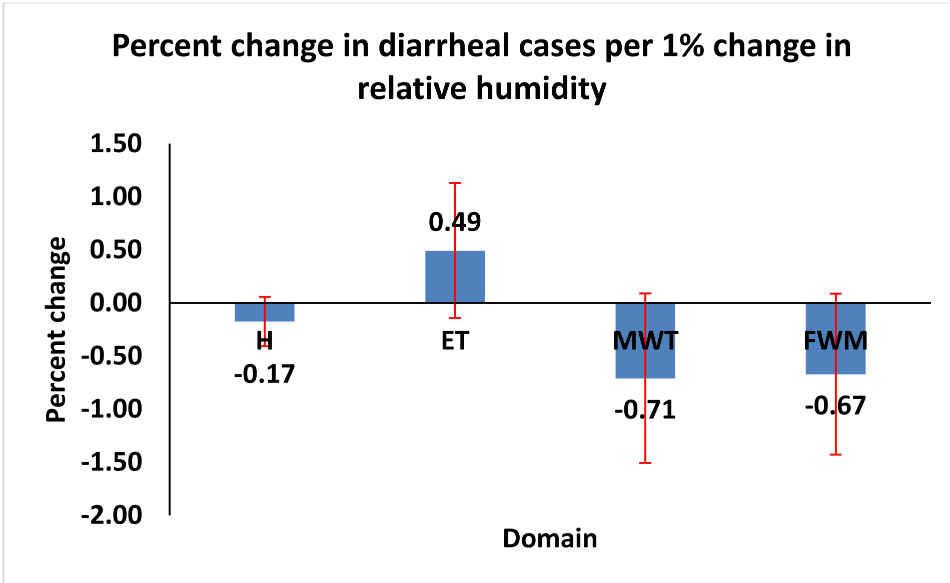


Figure 53 Percentage change in diarrheal cases per 1% increase in relative humidity

3.17. Seasonal effects

Seasonal effects are important predictors in diarrheal incidence particularly in children as children and elderly people are more prone to seasonal effects. Results revealed that diarrheal cases were found substantially higher in summer in ten out of the fifteen eco-development regions with 22.94% to 64.94% rise in diarrheal cases. The lowest increase was detected in WT and highest in FWM. Eco-belt-wise effects showed that the percent increase in summer is highest in Hill (35.22%) and lowest in Mountain (25.7%). However, the overall effect in Nepal is found to be 11.63% (95% CI: 4.17-19.61) rise in summer (Figure 54).

Similarly, spring season was found to be associated negatively in three eco-development regions, namely CH, MWT and FWT with lowest decrease detected in CH (15%) and highest decrease in MWT (36.2%). Other domains were found highly insignificant regarding this season including all the mountain, eastern and western domains. The overall effect in Nepal was found to be 14.5% decrease in spring. Lastly, autumn season was found statistically associated with diarrheal cases in only four domains which are WM, WH, MWH and FWH with effects ranging between -13.44% (FWH) and 52.27% (WM) which excludes all the Terai, eastern and central domains of

Nepal. Eco-belt-wise effects reveal that the effect was minimum in Mountain (9.97%) and maximum in Terai (16.8%). The overall effects in Nepal due to seasonal effects was found to be 11.63% rise in summer (95% CI: 4.17-19.61), 14.5% less in spring (95% CI: -18.81 to -10.02) compared to winter and autumn seasons as reference season combined (Figure 54). It is to be noted that even though seasonal effects are compared basically with winter as the reference season for modelling, the actual reference season varied and was either winter or combined season including winter and other excluded season(s)) in a particular model.

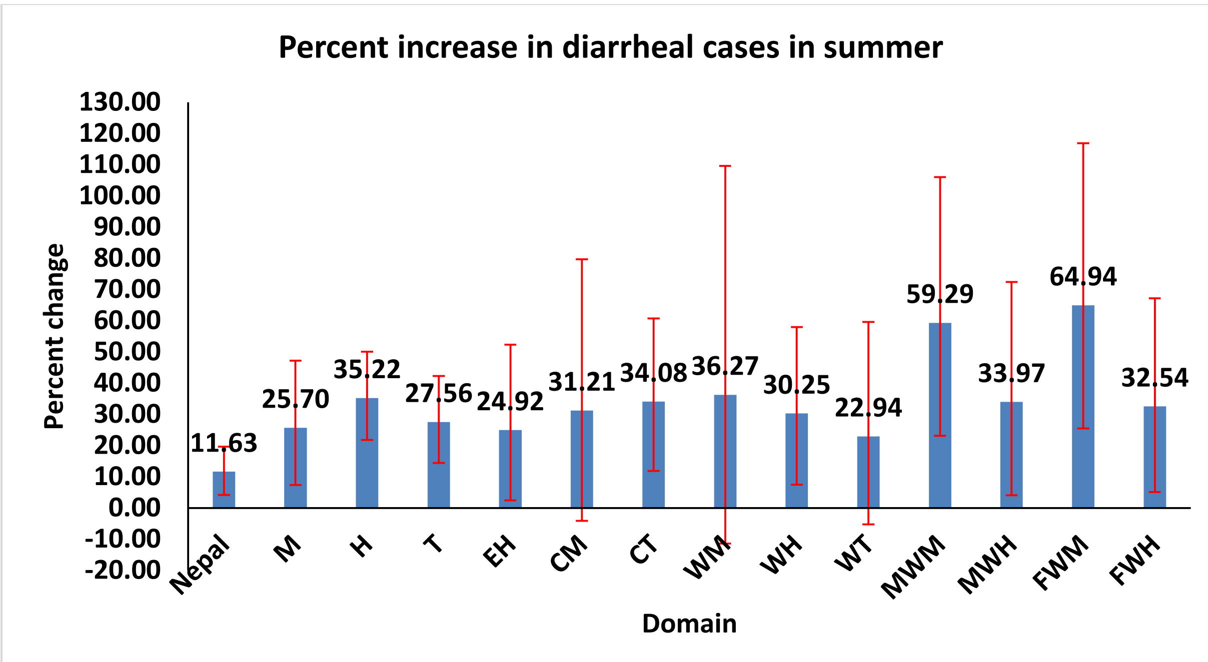


Figure 54 Percentage increase in diarrheal cases in summer season

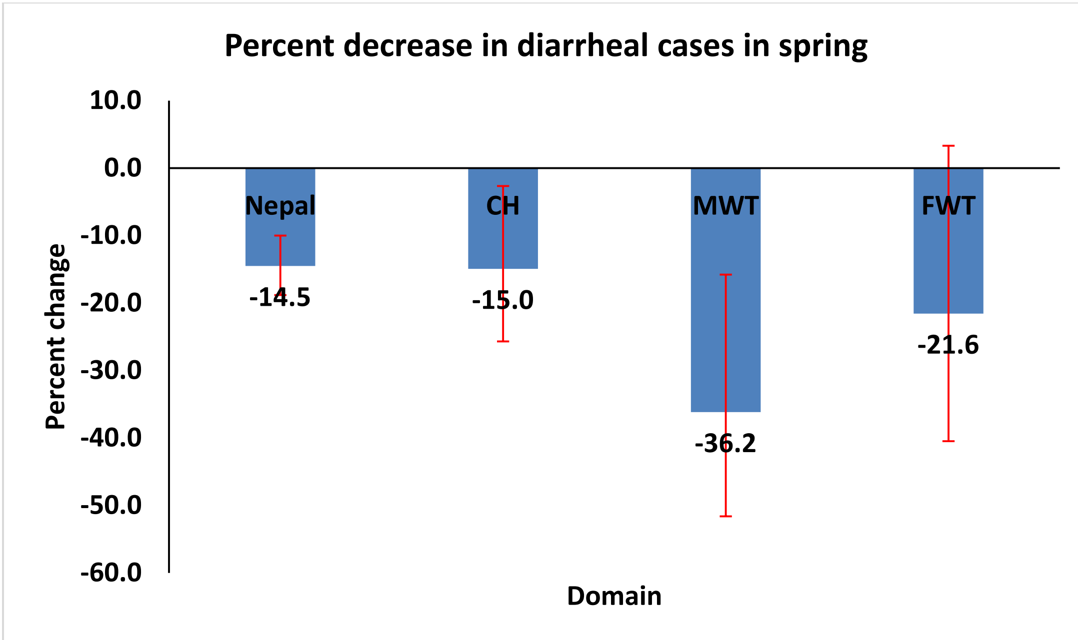


Figure 55 Percentage decrease in diarrheal cases in spring season

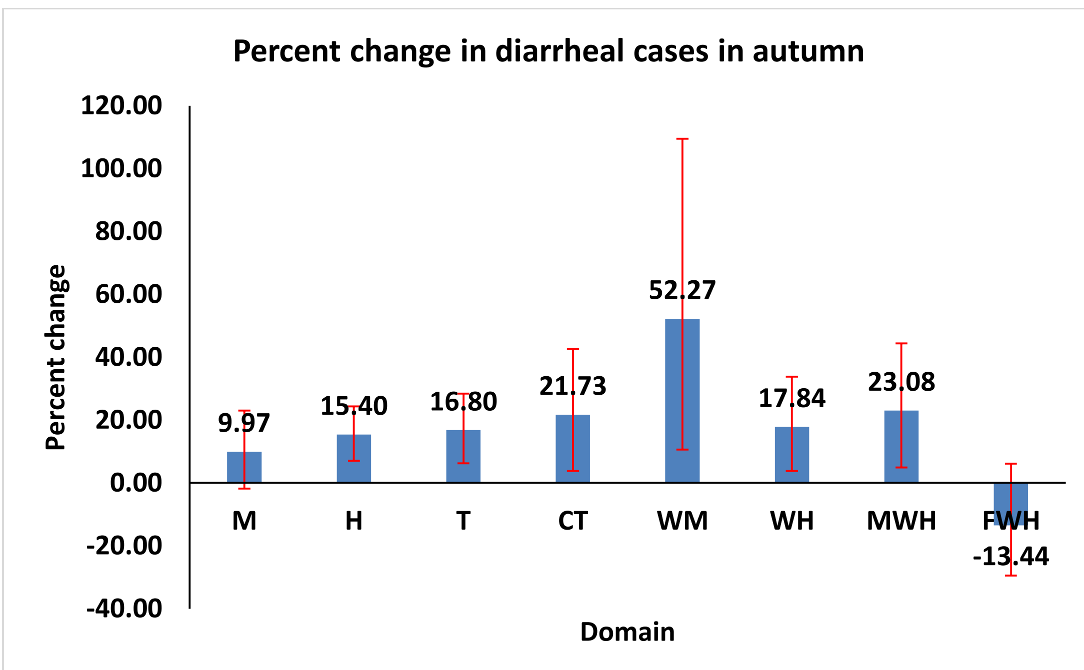


Figure 56 Percentage change in diarrheal cases in autumn season

3.18. Effects of under five target population size

It is expected that in the absence of reasonable socio-economic, health facilities and infrastructure development in an underdeveloped country like Nepal, population growth would naturally induce more diarrheal cases in children as well. To examine whether this is true or not, the target population of under five year children are also included as a predictor variable in built statistical models. Results showed that this is in fact true in nine models out of the fifteen statistical models built separately for different domains and also for Nepal as a whole. Eco-development-wise results revealed 0.94% to 3.50% increase in diarrheal cases in under five children per thousand increase in target population. The least increase was found in CH and the highest increase was detected in MWH. Higher effects were found mostly in Mountain regions (2.21% - 2.63%) except in MWH (3.5%). The regions where the effects were not found statistically significant were ET, MWT, FWT, FWH, EM and WM regions. Considering eco-belt-wise effects, it was detected that the effect was much higher in the Mountain region (4.12%) and least in Hill (0.97%). The overall effect in Nepal was found to be 1.53% (95% CI: 1.45-1.61) rise in the cases (Figure 57)

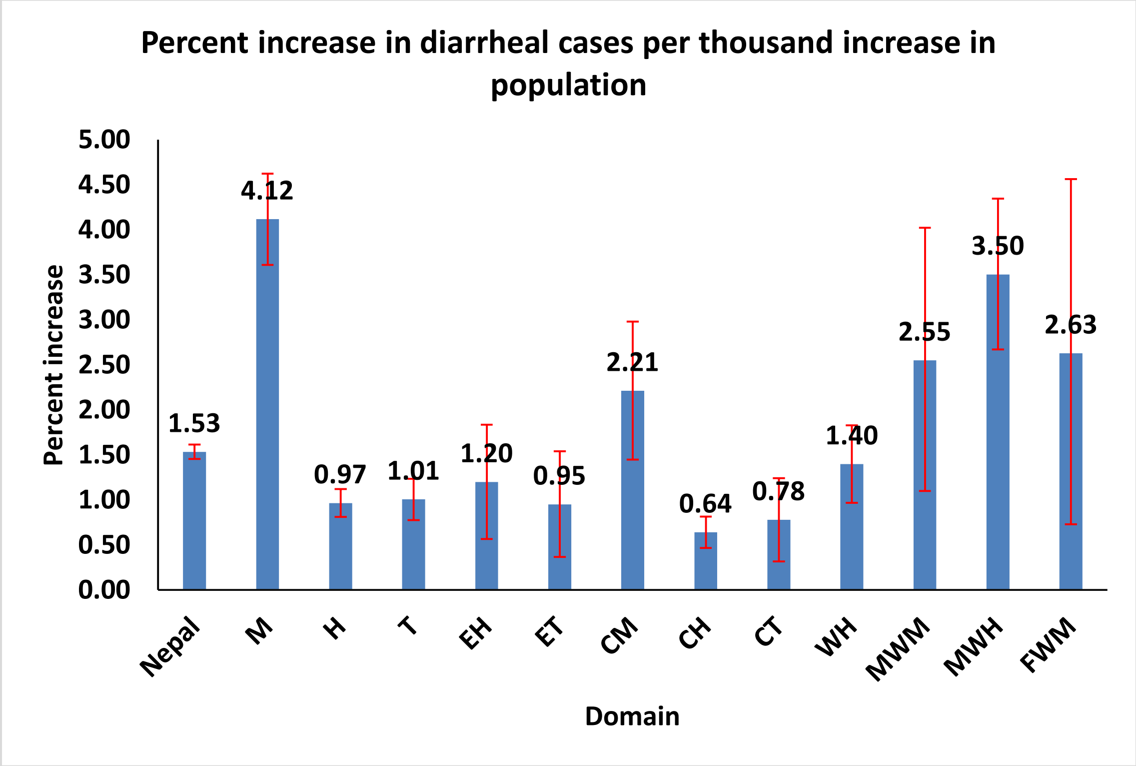


Figure 57 Percentage increase in diarrheal cases per thousand increase in target population

3.19. Effects of trend

Time series data analysis requires adjustments of long term trend effects in the presence of effects due to main weather related variables and seasonal effects. This is addressed by inclusion of a trend variable as year. Results of eco-development domain analysis disclosed that 5.98% to 20.82% increases in diarrheal cases were estimated annually with minimum found in FWH and maximum in FWT. Considering eco-belt-wise effects, it was found that the effect was highest in Mountain (16.39%) and least in Terai (12.54%).The overall effect in Nepal was found to be 13.86% (95% CI: 13.22-14.5) annual increment. The low and high increases were spread across all the three eco-belts of Nepal. The most vulnerable regions regarding annual growth of diarrheal cases were found to be WT, MWM, MWH and FWT (18.21%-20.82%) which excluded eastern and central regions (Figure 58).

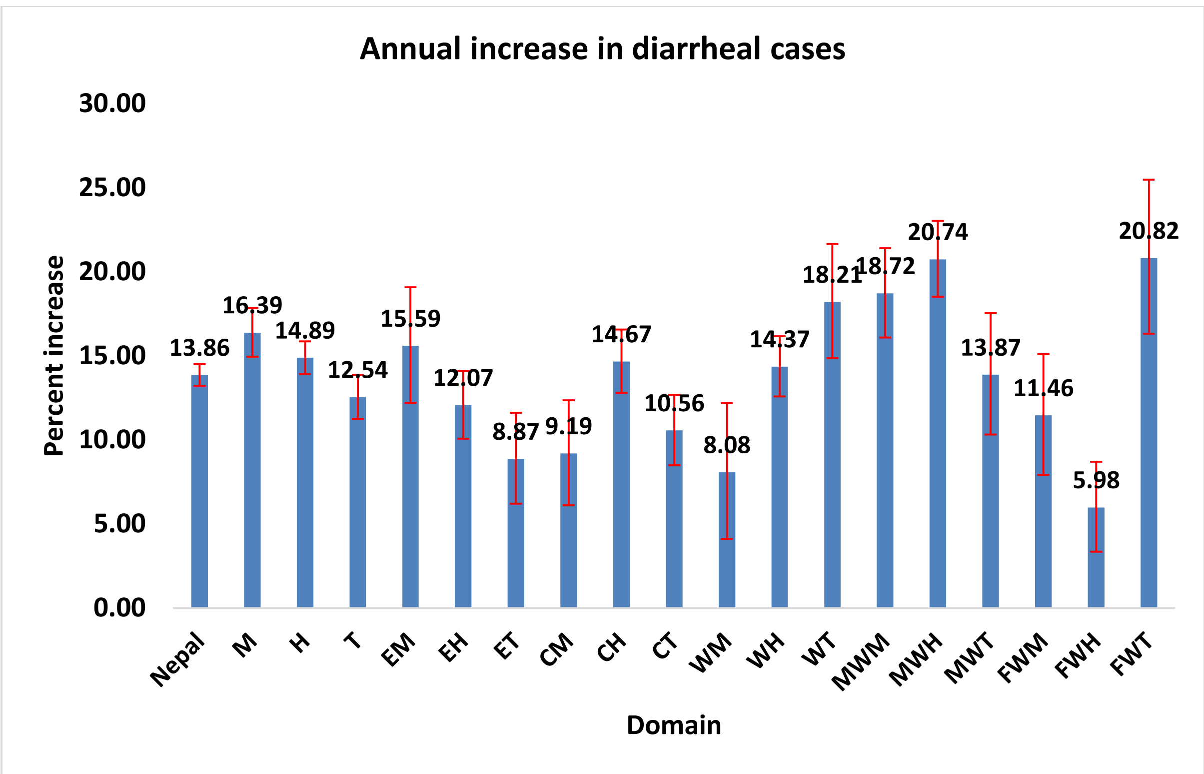


Figure 58 Percentage annual increase in diarrheal cases

3.20. Model adequacy tests

Model adequacy tests are assessed by the following criteria as mentioned below.

- Goodness of fit (Omnibus test)
- Multicollinearity (Variance inflation factors)
- Heteroscedasticity (Residual plot)
- Autocorrelation (residual plots)
- Outliers (residual plot)
- Oversdispersion

Omnibus test is found highly significant with *p* values less than 0.0001 for all the models built which indicates that data fits well to NB model. Multicollinearity assessed by Variance inflation factors (VIFs) revealed that its values are less than 3 for all the models built (mostly less than 2.5) which verifies absence of multicollinearity problem. There were few outliers (around 4 regarding standardized person residuals) in most of the models. These are deleted while obtaining the final estimates. Examination of residual plots after deletion of outliers showed at least fairly constant pattern with randomly scattered residuals in all the models built. Since the monthly data of diarrheal cases were highly over dispersed, NB model was used to overcome the problem of over dispersion. The estimated values in fitted NB models showed dispersion parameter less than 1. However, there was existence of significant autocorrelations (which could be mainly due to using monthly data instead of daily and large sample size) in the models built which was tried to be minimized by adjusting the models through inclusion of lagged dependent variables but did not work effectively. Moreover, inclusion of such lagged dependent variables substantially distorted the estimates. Additionally, the scatter plot of the time series residuals showed residuals randomly distributed without visible patterns which is a positive indication despite the presence of significant autocorrelations. Moreover, data consists of spatially distributed district aggregates along with temporal data which suggested that the computed significant correlations would not be accurate compared to estimates obtained from temporal data only. Consequently, the issue of presence of autocorrelations was ignored. A couple of residual plots are displayed below in the figure 29 and 30 for visual assessment.

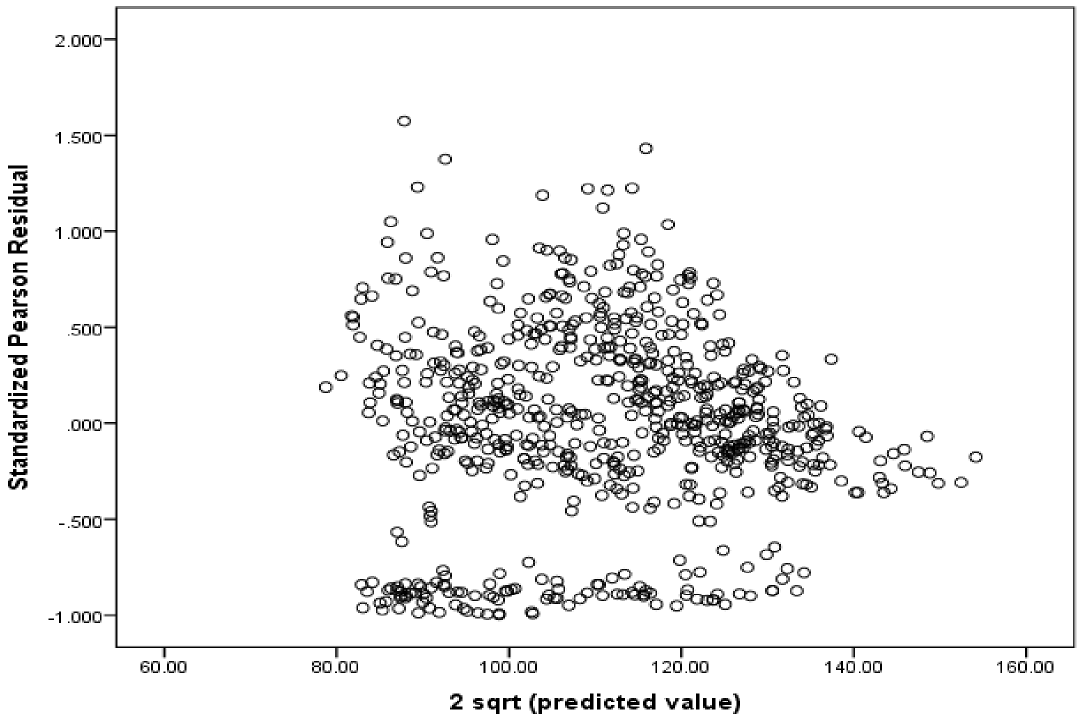


Figure 59 Standardized Pearson Residual Plots

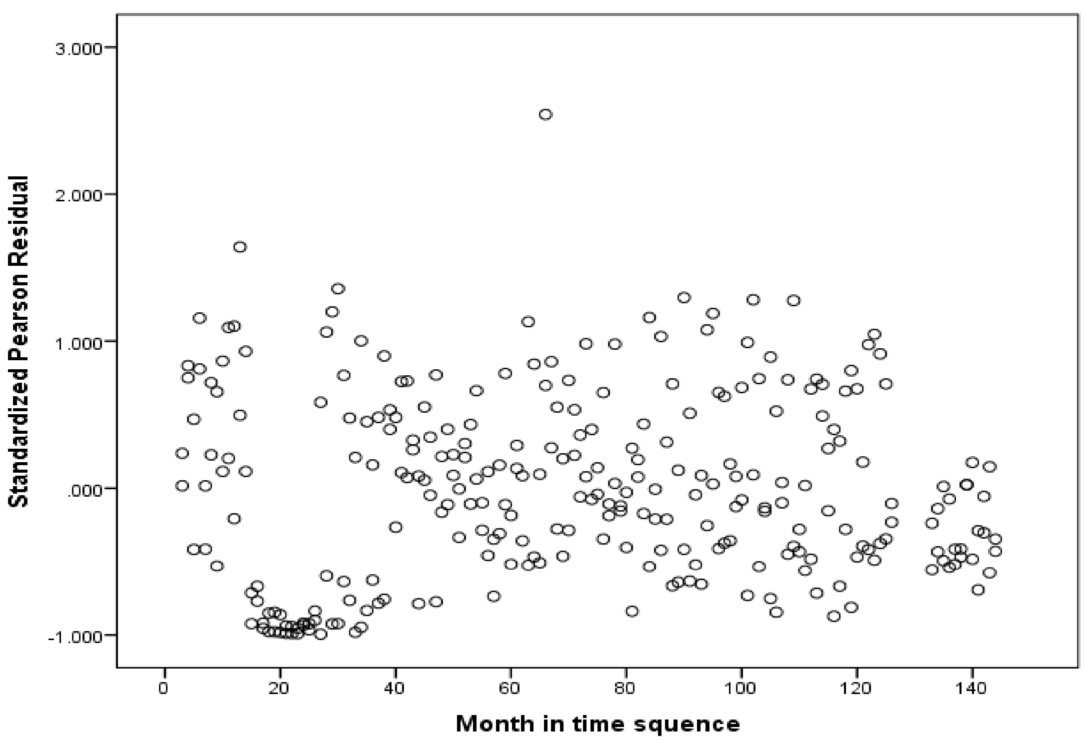


Figure 60 Standardized Pearson Residual Plots after deletion of outliers

3.21. Descriptive analysis of climatic and diarrhoeal data

An overall descriptive analysis was done to examine and assess how the percentage changes in diarrheal cases differed across the domains, eco-belts and development regions considering all the parameters. The results are displayed in the following tables. The domain-wise effects of parameters varied substantially with coefficient of variation (CV) ranging between 24.62% and 229.74%. The minimum variation was obtained for rainfall effects on under 5 diarrheal cases where the parameter is retained in the models. The maximum variation was detected for relative humidity though only three domains retained the parameter (Table 4). The monthly time series plot of diarrheal incidence, rainfall and average temperature is shown in Figure 61.

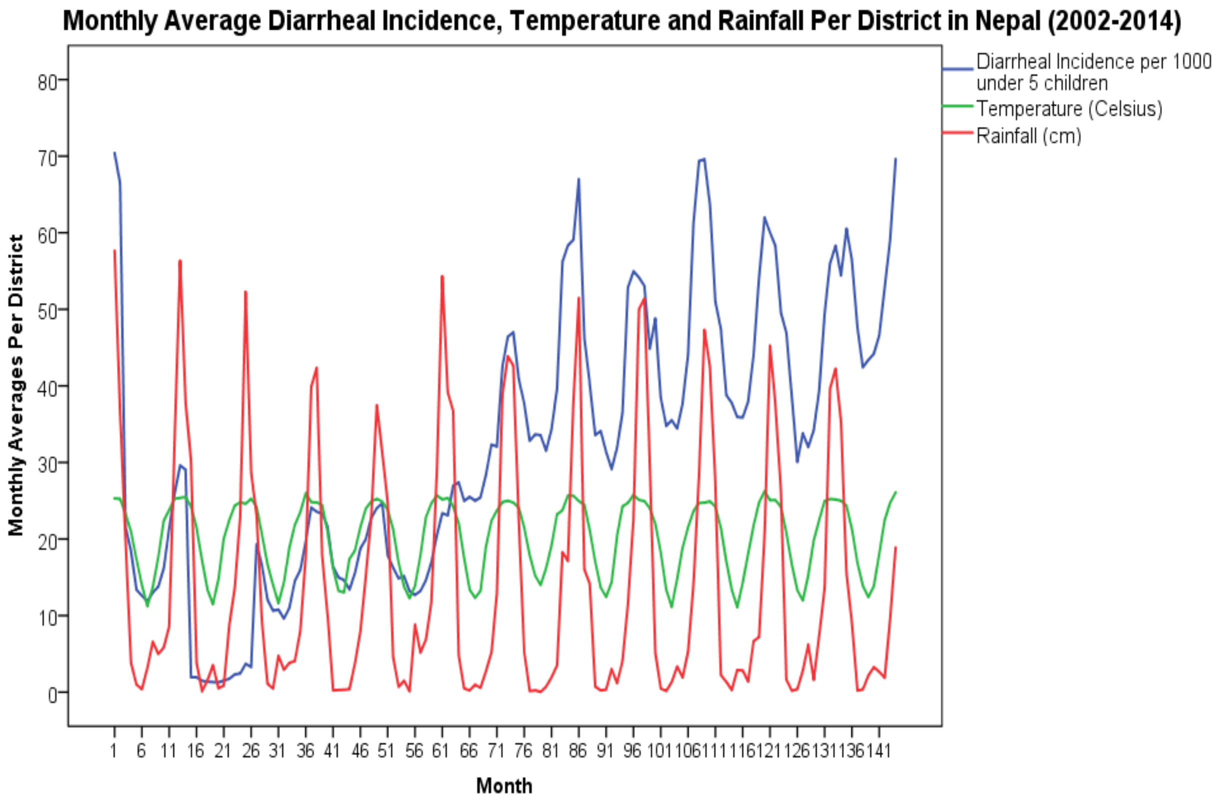


Figure 61: Monthly time series plot of climatic variables and diarrheal incidence (2002-2014)

Note: 1=July 2002; 2=August 2002; so on; 144= June 2014.

Examination of ecobelt-wise effects showed that effects due to average temperature varied substantially and ranged between 1.46% and 3.46%, maximum temperature ranged between 0.96% and 2.89% and minimum temperature ranged between 1.7% and 2.89%. The temperature effects were found highest in Mountain and lowest in Terai. This indicates that people residing in Mountain are more susceptible to diarrheal incidence due to higher temperature rise compared to other eco-belts of Nepal. Considering the variability in the effects between eco-belts, it showed that CV ranged between 26.99% and 48.82% with lowest found for minimum temperature and highest for maximum temperature. Effect due to rainfall was found insignificant in Terai and ranged between 0.37% (Hill) to 0.48% (Mountain). Relative humidity was retained only in Hill showing negative effects with 0.17% decrease in diarrheal cases per 1% rise in relative humidity. Summer and autumn seasons were found to have higher incidence in diarrheal cases compared to winter/spring seasons as the reference in all the three eco-belts of Nepal. The percent rise in diarrheal cases between eco-belts ranged between 25.70% to 35.22% in summer with 17.1% variation in CV and 9.97% to 16.8% in autumn with higher variation of 25.68% in CV. The effect of target population size is detected in all the three eco-belts with percent rise in diarrheal cases per one thousand increase in under five target population was found to range between 0.97% (Hill) to 4.12% (Mountain). This suggests that development process and other factors have restricted the increase in diarrheal incidence in Hill more than other eco-belts of Nepal despite population growth. Visibly, in this regard, the Mountain region has fared the worst scenario. Lastly, considering the annual increment of diarrheal cases, it was found that it ranged between 12.54% (Terai) to 16.39% (Mountain) which again verifies that diarrheal incidence is increasing in higher rate in Mountain compared to Hill and Terai regions of Nepal (Table 5).

Table 4 Descriptive statistics of domain-wise effects

Parameter	**N**	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Temperature	15	.85	5.05	2.80	1.32	47.31
MAX TEMP	14	.74	5.22	2.70	1.45	53.71
MIN TEMP	15	1.31	7.87	2.92	1.60	54.96
Rainfall	6	.40	.80	.59	.14	24.62
RH	3	-.71	.49	-.30	.68	229.74
Summer	10	22.94	64.94	37.04	13.90	37.52
Spring	3	-36.20	-15.00	-24.27	10.85	44.71

Autumn	5	-13.44	52.27	20.30	23.32	114.91
Population	9	.64	3.50	1.76	1.00	56.52
Year	15	5.98	20.82	13.55	4.65	34.33

Table 5 Ecobelt-wise effects on under five years children diarrheal cases

Parameter	**N**	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Temperature	3	1.46	3.42	2.69	1.07	39.74
Max. Temperature	3	0.96	2.89	2.20	1.07	48.82
Min. Temperature	3	1.70	2.97	2.39	0.64	26.99
Rainfall	2	0.37	0.48	0.42	0.08	18.06
Relative Humidity	1	-0.17	-0.17	-0.17		
Summer	3	25.70	35.22	29.49	5.04	17.10
Autumn	3	9.97	16.80	14.05	3.61	25.68
Year	3	12.54	16.39	14.61	1.94	13.26
Target Population	3	0.97	4.12	2.03	1.81	89.08

Note: Shaded regions indicate the parameters cannot be computed.

4. DISCUSSION

This study assessed the effects of climate factors on the incidence of diarrheal diseases at national and sub-national level in Nepal. The analysis of temperature data from 1971 to 2014 showed a general increasing temperature trend in Nepal. The maximum temperature was rising at the rate of 0.0368°C per year while the minimum temperature was increasing at 0.0146°C per year. Similar trends were observed in other studies. The temporal and spatial analysis of temperature data from 1976-2005 revealed an increasing maximum temperature at a greater rate of 0.05°C per year than the minimum temperature trend of 0.03°C per year [10]. Consistent warming and rise in the maximum temperature at an annual rate of 0.04 – 0.06°C observed in Nepal [7]. However, the warming rate was relatively at lower in present study than previous studies. This may be due to consideration of more temperature stations and longer time duration (1971 to 2014) for temperature data in this study.

Analysis of maximum temperature for the period 1971–94 revealed warming trends ranging from 0.06° to 0.12°C per year in most of the Middle Mountain and Himalayan regions, while less than 0.03°C per year in the Siwalik and Terai regions [11]. Equivalent trends were observed in this study as well. Increasing temperature was found to be higher in highlands (mountains) compared to lowlands (Terai and Siwaliks). The decreasing maximum temperature trend over the TAR may be due to the frequent development of cold wave episodes during winter seasons in the recent decades [30]. Increasing temperature in higher regions is attributed to the sensitivity of the mountainous regions to climate change.

Annual precipitation trend was declining in all physiographic regions except High Himalayas and in all seasons except pre-monsoon. It was decreasing at -2.5458 mm per year in most of the mid-western development region. However, positive trends were found in parts of western and eastern regions. A study by Practical Action Nepal revealed similar trends; positive trend in annual precipitation in eastern, central, western and far-western development regions while decreasing trend in most of mid-western development region [10]. The hills and mountains in the north showed positive trends in precipitation trend while the plains in the south experienced negative trends in a report by Ministry of Population and Environment [9]. However, in this study, only High Himalayas showed positive trends in precipitation (6.970 mm per year). The declining annual precipitation trend in this study may be due to higher rate of decrease in Monsoon precipitation (-1.2655 mm per year) as the annual precipitation pattern of Nepal which is dominated by Monsoon [10].

Results from statistical modelling suggest that occurrence of diarrheal cases are sensitive to temperature variation with higher temperature associated with relatively higher incidence of diarrheal cases in Nepal. Similar results were obtained in other studies [6], [23] and [24] , rise in temperature lead to increase in diarrheal cases. In this study, an overall increasing trend of 4.39% in diarrheal cases in under-five children per 1°C rise in average temperature was observed. The highest effect was seen in Mountains and lowest effects in Terai. An overall decreasing trend was observed in all three geographic regions; Terai, Hills and Mountain with higher diarrheal incidences in the Mountains, followed by the Hills and Terai in a small scale study [28]. This may be due to the data consideration; this study is based on data from 1971 to 2014 whereas the other study was based on 14 years data (1994/95-2007/08) of selected districts.

Eco-belt-wise effects due to temperature, rainfall and target population were found highest in the Mountain in comparison to other eco-belts of Nepal; 3.42% increase in diarrheal cases per 1°C rise in average temperature, 0.48% increase per 1 cm increase in rainfall and 4.12% increase per thousand increase in target population (under five years). Also, the annual increment of diarrheal cases was highest in Mountain (16.39%). Furthermore, trend analysis showed that temperature as well as precipitation was higher in Mountains than other eco-belts, indicating that people residing in Mountain are more susceptible to diarrheal incidence due to increasing temperature, precipitation and target population effects.

Over the past 15 years, the drinking water coverage has increased from the average household coverage of 38% to 86% and sanitation coverage from 17.7% to 90.6%. However, the diarrheal incidence in under-five children is also found to be increasing in this study. A positive relationship existed between drinking water coverage and diarrheal cases which may be due to water coverage not being consistent across the country. Also, the drinking water quality may be of concern as it has been reported by Department of Water Supply and Sewerage that about 14% of the drinking water sources, which are unsafe for consumption, are still being used [31]. Increasing occurrence diarrheal cases can be related to non-treatment of water before drinking. Despite the sanitation coverage of 90.6%, the rising trend in diarrheal incidence in under-five children may be associated with poor hygiene. Since this study does not encompass the hygiene standards in the study area, the percentage increase in diarrheal cases could have been affected by it. Also, the coverage does not reflect the use of toilet and other behaviour aspects of total sanitation. Still there is no 100% water supply and sanitation coverage. As a result, there are still sources for contamination of water sources and supply of contaminated drinking water.

The positive correlation between water supply coverage and incidence of diarrheal disease except in 2003 indicates that the diarrheal disease incidence has increased despite increase in drinking water coverage which may be associated with quantity and quality of drinking water supplied and household level hygienic behaviour. The negative correlation coefficient (-0.65) between the sanitation coverage and diarrhea disease incidence of the under five children in 2003, indicates the reverse relationship between the two indicators that is increasing sanitation coverage decreased diarrhea incidence. But in the later years, the correlation coefficient between sanitation coverage and diarrhea disease showed very low positive value, indicating increased sanitation coverage has not lowered down the diarrheal disease.

From the statistical results, it is concluded that there is lack of pattern discernable of the spatial distribution of the diarrhea disease incidence, water coverage and toilet coverage among the districts across the country. In other words, the patterns show change neither from the south to the north nor from east to west. Rather the patterns are related to the spatial location features of the districts with remoteness and urban centres agglomeration. Generally, they are found poor or worse in the remote districts like Dolpa, Mugu, etc, whereas better in urban agglomeration districts like Kathmandu, Kaski, Sunsari, etc. In densely settled districts like central Terai, there is poor sanitation coverage, despite better drinking water coverage. Considering effects of socioeconomic and other changes like in development indicators that occurred during the study period on diarrheal cases, these effects are accounted in aggregate by annual trend effects to diarrheal cases which is included as one of the predictor variables in the models built. However, the separate effects of these variables are not studied. This is one of the major of the present study. Results show that there is increase in annual diarrheal cases during the study period with wide variations (6-20%) between regions suggesting that the effects are quite different due to these factors between regions of Nepal. Another reason may be multiple reporting of same case due to improved diagnosis and referral system of severe cases to higher level health facilities.

Beside water supply and sanitation coverage, population growth and climatic factors, the incidence of diarrhoea is affected by improved case detection, recording and reporting of cases. Hence, increasing incidence of diarrhea cases in Nepal may be also attributed by scale up of community based integrated management of childhood illness (CB-IMCI) program in Nepal. However, comparison of malaria and diarrhea which are managed under the same CB-IMCI programs shows significantly declining trend of malaria incidence but significantly increasing trend of diarrhea incidence in the last decade in Nepal [32]. Hence, role of climatic factors and WASH cannot be ruled out as there is continuous increase in incidence of diarrhea in overall and frequent outbreaks of diarrhea and cholera in different parts of Nepal including in urban areas such as Kathmandu, Lalitpur, Biratnagar etc.

5. CONCLUSION AND RECOMMNEDATION

The analysis of last 40 years air temperature data shows warming trend with more pronounced trend in highlands and greater trend rate in the last decade. Seasonal warming trend is found highest in winter season. The general trend of annual precipitation is declining. Despite increasing coverage of water supply and sanitation, socio-economic development and community based integrated management of childhood illness and new born care, annual incidence of diarrheal diseases is significantly increasing in Nepal. Our analysis shows significant effect of air temperature and rainfall on incidence of diarrhea with wide variation across eco-development regions. The effects of climatic parameters on incidence of diarrhea are more pronounced in Mountain and Hill regions compared to Terai region.

Climate change is likely to increase diarrheal incidences in Nepal unless preventive measures, health infrastructure, economic development of Nepalese people, etc. are improved substantially to counter the effects of climate change. The water supply and sanitation coverage should be 100% to eliminate epidemics of diarrheal diseases and to meet related sustainable development goals by 2030. As far as regional differences in effects are concerned, this could be due to many reasons such as differences in socio-economic status, development level, population density, etc.

This calls for exploration of these reasons with improved surveillance and minimization of known risk factors of diarrheal diseases such as lack of access of health facilities and promote awareness level on safe water, sanitation, hygiene practices.

These strategies are applicable at present context. Existing diarrhea control program should be updated from climate change adaptation perspective to reduce burden of diarrheal diseases in Nepal. Mountainous regions should be given high priority regarding the implementation of such strategies as these regions are more sensitive to climate variability and the occurrence of diarrheal diseases. Moreover, further research and studies should be carried out to accurately assess the health problems caused by climate change and develop evidence-based adaptation strategies.

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ANNEXES

Table 6 Station wise annual maximum temperature trends

Longitude	Latitude	Elevation	Station Index	Station Name	Trend (1971-2014)	Trend (2004-2014)	Year	Physiographic
83.75	27.53	154	**728**	Simari	-0.039	-0.113	32	TAR
80.63	28.87	288	**215**	Godavari(West)	0.036	0.089	38	TAR
85.08	27.60	2314	**905**	Daman	0.103	-0.066	40	MM
87.32	27.29	1262	**1303**	Chainpur (East)	***	***	27	H
87.29	27.05	1720	**1304**	Pakhribas	0.039	0.045	27	MM
87.28	26.70	116	**1320**	Tarahara	-0.011	0.077	28	SW
87.86	26.65	107	**1421**	Gaida (Kankai)	0.036	-0.134	31	TAR
83.82	27.88	460	**810**	Chapkot	0.002	-0.065	35	SW
87.35	26.98	1187	**1307**	Dhankuta	0.198	0.123	28	MM
83.80	27.87	500	**725**	Tamghas	0.046	0.039	29	MM
80.53	29.47	1266	**103**	Patan (West)	0.057	0.011	32	SW
81.12	28.53	140	**207**	Tikapur	0.021	0.141	38	TAR
85.52	27.70	2163	**1043**	Nagarkot	0.011	0.076	38	MM
85.33	27.73	1335	**1039**	Panipokhari(Kathmandu)	0.081	0.262	38	MM
83.87	28.10	868	**805**	Syangja	0.044	0.183	39	MM
83.72	28.78	2744	**601**	Jomsom	-0.002	-0.001	34	H
83.15	27.93	1760	**715**	Khanchikot	0.058	-0.005	35	MM
81.25	28.88	950	**401**	Pusma Camp	0.008	-0.191	38	MM
84.59	27.97	720	**809**	Gorkha	0.094	0.064	43	MM
81.34	28.33	155	**417**	Rani Jaruwa Nursery	0.011	0.259	34	TAR
82.20	28.63	910	**513**	ChaurJhari Tar	-0.033	-0.015	36	MM
83.97	28.22	856	**811**	Malepatan (Pokhara)	0.025	-0.038	43	MM
86.23	27.63	1930	**1103**	Jiri	0.045	0.008	45	MM
87.92	26.91	1208	**1407**	Ilam Tea Estate	0.048	-0.046	43	SW
84.37	28.28	823	**802**	Khudi Bazar	0.067	0.132	44	MM
80.93	29.23	720	**218**	Dipayal (Doti)	0.015	0.267	33	MM
80.55	28.80	187	**209**	Dhangadhi(Atariya)	-0.004	-0.067	40	TAR
81.22	29.55	1304	**202**	Chainpur(West)	0.057	0.036	34	MM
80.98	29.27	1360	**203**	SilgadhiDoti	0.029	0.199	38	MM
81.29	28.65	225	**405**	Chisapani(Karnali)	-0.019	-0.108	43	SW
81.97	28.03	162	**419**	Sikta	0.017	0.217	35	TAR
83.46	27.53	120	**707**	Bhairahawa (Agric)	0.017	-0.070	44	TAR
81.52	28.05	144	**416**	Nepalgunj(Reg.Off.)	-0.015	-0.047	40	TAR
83.68	28.74	2655	**604**	Thakmarpha	0.051	0.255	43	HH
82.17	28.38	1457	**511**	Salyan Bazar	0.086	0.060	37	MM
80.58	29.30	1848	**104**	Dadeldhura	0.106	-0.037	37	MM
84.35	27.65	173	**902**	Rampur	0.018	-0.082	40	SW
87.67	27.36	1744	**1405**	Taplejung	0.055	0.071	41	H
82.48	28.13	725	**508**	Tulsipur	0.041	-0.138	42	SW

84.93	27.08	115	**911**	Parwanipur	-0.004	-0.096	44	TAR
84.22	27.68	154	**706**	Dumkauli	-0.016	-0.057	39	SW
85.92	26.71	78	**1111**	Janakpur Airport	0.008	0.000	44	TAR
85.38	27.59	1400	**1022**	Godavari	0.066	0.024	44	MM
81.72	28.85	1402	**402**	Dailekh	0.140	0.046	42	MM
82.18	29.27	2366	**303**	Jumla	0.053	0.013	42	H
85.27	27.83	2034	**1007**	Kakani	0.009	-0.222	43	MM
84.09	28.03	526	**815**	Khairini Tar	0.037	-0.091	44	MM
85.16	27.72	988	**1038**	Dhunibesi	0.023	0.050	41	SW
88.08	26.87	1570	**1416**	Kanyam Tea Estate	0.052	0.102	43	SW
81.63	28.59	720	**406**	Surkhet(Birendra Nagar)	0.047	0.202	42	MM
84.98	27.16	137	**909**	Simara Airport	0.008	0.039	43	TAR
85.33	27.67	1350	**1029**	Khumaltar	0.049	-0.044	43	MM
87.26	26.48	72	**1319**	Biratnagar Airport	0.021	0.012	44	TAR
85.03	27.42	474	**906**	Hetaunda N.F.I.	0.032	0.007	44	SW
86.50	27.31	1720	**1206**	Okhaldhunga	0.077	0.017	43	MM
83.42	27.51	109	**705**	Bhairahawa Airport	0.007	-0.085	44	TAR
83.82	28.30	1740	**814**	Lumle	0.057	0.011	44	MM
83.98	28.20	827	**804**	Pokhara Airport	0.045	0.011	45	MM
85.37	27.70	1337	**1030**	Kathmandu Airport	0.066	0.006	45	MM
28.11	81.59	129	409	Khajura (Nepalganj)	0.000	-0.019	42	TAR
29.18	83.97	3705	612	Mustang	0.120	***	22	HH
27.69	83.47	180	703	Butwal	0.009	-0.033	38	SW
27.52	86.62	2770	1220	Chaialsa	0.065	***	28	HH
85.62	28.22	3920	HH2	Langtang	0.036	0.071	21	HH
83.95	28.52	3470	HH1	Khumbu	-0.006	0.226	22	HH
85.94	27.89	4355	HH3	Annapurna	0.034	0.090	19	HH
87.18	27.73	2100	HH4	Makulu	-0.152	-5.560	16	HH

*** Stations not considered for this study

Table 7 Station wise annual minimum temperature trends

Longitude	**Latitude**	**Elevation**	**Station Index**	**Station Name**	**Trend (1971-2014)**	**Trend (2004-2014)**	**Year**	**Physiographic**
83.75	27.53	154	**728**	Simari	-0.03	-0.275	33	TAR
80.63	28.87	288	**215**	Godavari(West)	0.00	0.059	38	TAR
85.08	27.60	2314	**905**	Daman	0.08	0.039	40	MM
87.32	27.29	1262	**1303**	Chainpur (East)	***	***	27	H
87.29	27.05	1720	**1304**	Pakhribas	0.03	-0.034	27	MM
87.28	26.70	116	**1320**	Tarahara	0.02	-0.082	28	SW
87.86	26.65	107	**1421**	Gaida (Kankai)	0.04	-0.002	31	TAR
83.82	27.88	460	**810**	Chapkot	-0.03	0.178	35	SW
87.35	26.98	1187	**1307**	Dhankuta	0.03	0.018	28	MM
83.80	27.87	500	**725**	Tamghas	0.01	-0.013	29	MM
80.53	29.47	1266	**103**	Patan (West)	0.02	-0.003	32	SW

81.12	28.53	140	**207**	Tikapur	-0.04	-0.038	38	TAR
85.52	27.70	2163	**1043**	Nagarkot	0.00	0.037	38	MM
85.33	27.73	1335	**1039**	Panipokhari(Kathmandu)	0.06	0.162	38	MM
83.87	28.10	868	**805**	Syangja	0.05	0.039	39	MM
83.72	28.78	2744	**601**	Jomsom	0.06	0.169	34	H
83.15	27.93	1760	**715**	Khanchikot	0.02	-0.079	35	MM
81.25	28.88	950	**401**	Pusma Camp	0.08	-0.474	38	MM
84.59	27.97	720	**809**	Gorkha	-0.01	-0.106	44	MM
81.34	28.33	155	**417**	Rani Jaruwa Nursery	0.03	0.348	34	TAR
82.20	28.63	910	**513**	ChaurJhari Tar	0.03	0.027	36	MM
83.97	28.22	856	**811**	Malepatan (Pokhara)	0.04	-0.067	43	MM
86.23	27.63	1930	**1103**	Jiri	-0.02	0.041	45	MM
87.92	26.91	1208	**1407**	Ilam Tea Estate	0.00	-0.455	43	SW
84.37	28.28	823	**802**	Khudi Bazar	0.07	0.007	44	MM
80.93	29.23	720	**218**	Dipayal (Doti)	0.05	0.014	33	MM
80.55	28.80	187	**209**	Dhangadhi(Atariya)	-0.01	0.008	40	TAR
81.22	29.55	1304	**202**	Chainpur(West)	0.00	-0.367	34	MM
80.98	29.27	1360	**203**	SilgadhiDoti	-0.10	-0.220	38	MM
81.29	28.65	225	**405**	Chisapani(Karnali)	0.03	-0.208	43	SW
81.97	28.03	162	**419**	Sikta	-0.04	0.196	35	TAR
83.46	27.53	120	**707**	Bhairahawa (Agric)	0.01	-0.055	44	TAR
81.52	28.05	144	**416**	Nepalgunj(Reg.Off.)	-0.02	-0.018	40	TAR
83.68	28.74	2655	**604**	Thakmarpha	0.00	0.246	43	HH
82.17	28.38	1457	**511**	Salyan Bazar	0.03	0.045	38	MM
80.58	29.30	1848	**104**	Dadeldhura	-0.01	-0.009	37	MM
84.35	27.65	173	**902**	Rampur	0.01	-0.270	40	SW
87.67	27.36	1744	**1405**	Taplejung	0.01	0.016	41	H
82.48	28.13	725	**508**	Tulsipur	0.09	-0.012	42	SW
84.93	27.08	115	**911**	Parwanipur	0.03	-0.057	44	TAR
84.22	27.68	154	**706**	Dumkauli	0.02	-0.004	39	SW
85.92	26.71	78	**1111**	Janakpur Airport	0.03	-0.029	44	TAR
85.38	27.59	1400	**1022**	Godavari	-0.01	-0.264	44	MM
81.72	28.85	1402	**402**	Dailekh	-0.04	0.332	42	MM
82.18	29.27	2366	**303**	Jumla	0.03	-0.039	42	H
85.27	27.83	2034	**1007**	Kakani	0.07	-0.007	43	MM
84.09	28.03	526	**815**	Khairini Tar	0.03	-0.065	44	MM
85.16	27.72	988	**1038**	Dhunibesi	0.03	-0.094	41	SW
88.08	26.87	1570	**1416**	Kanyam Tea Estate	-0.04	-0.252	43	SW
81.63	28.59	720	**406**	Surkhet(Birendra Nagar)	0.02	-0.062	42	MM
84.98	27.16	137	**909**	Simara Airport	0.01	-0.143	43	TAR
85.33	27.67	1350	**1029**	Khumaltar	0.04	0.009	43	MM
87.26	26.48	72	**1319**	Biratnagar Airport	0.02	-0.037	44	TAR
85.03	27.42	474	**906**	Hetaunda N.F.I.	0.03	-0.038	44	SW
86.50	27.31	1720	**1206**	Okhaldhunga	-0.01	-0.249	43	MM
83.42	27.51	109	**705**	Bhairahawa Airport	0.01	-0.146	44	TAR

83.82	28.30	1740	**814**	Lumle	0.00	-0.040	44	MM
83.98	28.20	827	**804**	Pokhara Airport	0.02	-0.107	45	MM
85.37	27.70	1337	**1030**	Kathmandu Airport	0.03	-0.004	45	MM
28.11	81.59	129	409	Khajura (Nepalganj)	0.00	0.003	42	TAR
29.18	83.97	3705	612	Mustang	0.09	***	22	HH
27.69	83.47	180	703	Butwal	-0.05	-0.822	37	SW
27.52	86.62	2770	1220	Chaialsa	0.08	***	27	HH
85.62	28.22	3920	HH2	Langtang	0.14	-0.157	21	HH
83.95	28.52	3470	HH1	Khumbu	0.01	0.338	23	HH
85.94	27.89	4355	HH3	Annapurna	-0.09	-0.368	22	HH
87.18	27.73	2100	HH4	Makulu	-0.06	-4.519	17	HH

*** Stations not considered for this study

Table 8 Station wise train analysis of precipitation

Longitude	**Latitude**	**Elevation (m)**	**Station Index**	**Station Name**	**Trend 2005-2014**	**Trend 1971-2014**	**Number of year**	**Physiographic**
82.1667	28.3833	1457	511	Salyan Bazar	2.16	-2.39	44	MM
83.9797	28.2000	827	804	Pokhara Airport	63.02	-2.19	43	MM
85.3729	27.7039	1337	1030	Kathmandu Airport	53.41	3.71	44	MM
85.9211	27.0131	251	1110	Tulsi	-15.19	-0.71	44	SW
85.9242	26.7105	50	1111	Janakpur Airport	-40.85	7.78	44	TAR
87.2639	26.4814	72	1319	Biratnagar Airport	-22.36	-3.34	44	TAR
80.3500	28.6833	159	106	BelauriSantipur	-21.39	-0.89	44	TAR
81.6347	28.5871	720	406	Surkhet(Birendra Nagar)	10.36	2.48	44	MM
84.9794	27.1594	137	909	Simara Airport	-96.41	2.21	44	TAR
85.1500	27.6167	1530	915	MarkhuGaun	-32.71	-8.13	43	MM
87.2444	27.0500	1464	1306	Munga	-23.71	-7.21	44	MM
87.3167	27.2922	1262	1303	Chainpur (East)	-10.70	1.13	44	MM
88.0272	26.8866	1654	1410	HimaliGaun	-31.66	-1.95	44	H
80.5333	29.4667	1266	103	Patan (West)	-11.58	-2.39	43	SW
83.87	28.10	868	805	Syangja	-96.11	-10.68	42	MM
80.5667	29.8500	1097	107	Darchula	-70.41	6.54	41	MM
81.5228	28.0519	144	416	Nepalgunj(Reg.Off.)	-24.85	5.54	42	TAR
84.2167	27.6833	154	706	Dumkauli	-12.96	5.46	41	SW
85.3333	27.6000	1448	1060	Chapa Gaun	13.85	-5.98	39	MM
87.6700	27.3588	1744	1405	Taplejung	-13.30	1.53	42	H
80.9167	28.7500	195	208	Sandepani	30.12	7.06	44	TAR
82.1796	29.2747	2366	303	Jumla	16.16	-1.57	43	H
82.5333	27.7000	320	510	Koilabas	-11.64	1.55	44	SW
87.2847	26.7919	310	1311	Dharan Bazar	-15.82	-10.71	44	SW
80.5500	28.8000	187	209	Dhangadhi(Atariya)	-41.20	8.44	44	TAR
80.5000	29.6500	842	101	Kakerpakha	-25.20	-4.62	44	SW
80.8667	29.6167	1456	201	Pipalkot	43.82	7.03	44	SW
81.4417	28.9528	650	206	AsaraGhat	-14.75	-2.34	44	SW
81.9000	29.2000	1905	308	Nagma	18.44	2.56	44	H
84.0500	27.6833	150	704	Beluwa (Girwari)	-36.51	2.74	44	TAR
83.4205	27.5069	109	705	Bhairahawa Airport	-23.02	0.16	44	TAR
84.3500	28.1333	855	807	Kunchha	77.25	-3.12	43	MM

83.8178	28.2967	1740	814	Lumle	12.39	9.07	43	MM
85.1386	27.5597	1729	904	ChisapaniGadhi	-88.32	-8.77	44	MM
85.0000	27.2833	396	907	Amlekhganj	-61.18	-15.93	44	SW
84.9328	27.0789	68	911	Parwanipur	-46.69	0.93	44	TAR
85.7050	27.6388	659	1023	DolalGhat	-25.78	-7.93	44	MM
86.1667	26.9167	165	1112	Chisapani Bazar	8.54	-2.29	44	TAR
85.8486	27.4197	690	1115	Nepalthok	-12.07	-4.89	44	SW
86.7500	27.3500	2143	1204	Aisealukhark	-61.56	-7.72	44	H
86.5042	27.3081	1720	1206	Okhaldhunga	-35.87	-0.12	44	MM
87.2892	27.1533	452	1305	LeguwaGhat	29.64	-6.09	44	MM
80.5833	29.3000	1848	104	Dadeldhura	29.76	0.79	44	MM
82.6333	28.3000	1270	504	LibangGaun	-31.95	-8.56	44	MM
83.8167	27.8833	460	810	Chapkot	98.14	1.94	44	SW
87.7939	27.5472	1807	1403	Lungthung	18.65	1.65	44	H
87.9887	26.6898	153	1415	Sanischare	14.45	-0.97	43	TAR
87.3458	26.9833	1187	1307	Dhankuta	-32.61	-3.74	44	MM
81.5833	28.7833	610	410	Bale Budha	40.77	8.13	44	SW
85.1642	27.7231	991	1038	Dhunibesi	28.72	9.69	44	SW
85.4268	27.7161	1502	1059	ChanguHarayan	-6.51	0.61	41	MM
84.0866	28.0270	526	815	Khairini Tar	-80.60	-3.24	43	MM
86.5167	26.9333	1175	1213	UdayapurGadhi	-83.31	-20.25	42	MM
85.5209	27.6933	2143	1043	Nagarkot	-2.86	-1.85	44	MM
82.2000	28.7000	1231	404	Jajarkot	-18.35	-6.92	43	MM
82.4842	28.1317	725	508	Tulsipur	-13.42	-5.99	44	SW
83.4333	27.9500	442	701	Ridi Bazar	34.20	-7.01	44	MM
84.3667	28.2833	823	802	Khudi Bazar	-160.71	-12.29	44	MM
84.3506	27.6541	148	902	Rampur	-87.79	-3.54	44	SW
84.5333	27.5833	270	903	Jhawani	-46.06	1.92	44	SW
85.3833	27.0167	152	912	RamoliBairiya	-49.53	-7.94	43	TAR
85.2213	27.6882	1457	1015	Thankot	2.49	-22.88	44	MM
85.5727	27.7925	774	1018	Baunepati	-3.46	-7.35	44	MM
85.3788	27.5929	1527	1022	Godavari	0.52	-12.78	44	MM
85.4770	27.7443	1465	1035	Sankhu	-41.99	-9.75	43	MM
86.7167	27.7000	2619	1202	Chaurikhark	73.80	-0.37	44	H
87.2786	26.6986	116	1320	Tarahara	8.88	4.08	44	SW
82.1167	28.2167	698	507	Nayabasti (Dang)	50.07	5.70	44	SW
82.2833	28.3000	885	512	Luwamjula Bazar	71.95	-14.25	43	SW
83.7100	28.2250	912	614	Kushma	10.30	6.77	43	MM
85.8667	27.8667	2000	1006	Gumthang	-164.09	-5.20	44	H
85.3258	27.6518	1334	1029	Khumaltar	46.17	2.06	44	MM
87.9886	26.6251	122	1409	AnarmaniBirta	7.03	3.19	44	TAR
81.3500	28.4333	200	415	Bargadaha	21.22	30.34	43	TAR
85.0279	27.4227	452	906	Hetaunda N.F.I.	-25.70	6.94	44	SW
85.4240	27.6768	1315	1052	Bhaktapur	-50.19	-7.90	44	MM
87.7033	26.7706	121	1408	Damak	5.09	-10.79	44	TAR
80.4167	29.5500	1635	102	Baitadi	-40.08	-8.41	42	MM
85.5286	27.5723	1442	1049	Khopasi(Panauti)	-69.01	-7.03	44	MM
85.2699	27.8144	2034	1007	Kakani	15.86	4.01	43	MM
81.2167	29.5500	1304	202	Chainpur(West)	-125.62	-2.96	43	MM
80.9833	29.2667	1360	203	SilgadhiDoti	30.74	-4.16	44	MM
81.7167	28.8500	1402	402	Dailekh	-83.68	-8.85	44	MM

83.1500	27.9333	1760	715	Khanchikot	7.67	-1.90	43	MM
83.2667	28.1667	1280	722	Musikot	-19.58	10.23	44	MM
86.0500	27.6667	1940	1102	Charikot	42.09	-1.40	44	MM
86.2117	26.6561	102	1216	Siraha	-33.44	-2.51	43	TAR
86.5667	27.4333	1982	1203	Pakarnas	-23.96	-5.98	44	H
87.1667	26.9667	158	1322	Machuwaghat	40.47	-5.67	44	SW
87.1500	27.3667	1190	1325	Dingla	52.39	-3.89	44	MM
80.8167	28.5667	152	212	Sitapur	31.29	-5.24	42	TAR
81.7167	28.2667	135	412	Naubasta	18.13	0.05	43	TAR
83.6811	28.7389	2655	604	Thakmarpha	-1.39	1.51	43	HH
86.6986	26.8008	91	1223	Rajbiraj	39.56	2.21	43	TAR
88.0783	26.8682	1560	1416	Kanyam Tea Estate	-64.01	-21.57	43	SW
81.2869	28.6531	225	405	Chisapani(Karnali)	-15.48	-4.27	43	SW
83.6094	28.6328	2490	607	Lete	11.29	10.55	44	H
82.8517	28.1031	823	505	Bijuwar Tar	-49.47	-8.23	44	MM
82.5000	28.0500	725	509	Ghorahi (Masina)	-19.10	-12.35	38	SW
84.4064	27.9417	995	808	Bandipur	11.32	-5.01	44	MM
85.6245	27.8129	1457	1008	Nawalpur	-9.44	-2.88	44	MM
85.5664	27.8582	1506	1017	Dubachaur	-96.93	-14.76	43	MM
85.9000	27.7886	850	1027	Bahrabise	-12.06	-11.79	44	MM
85.6596	27.0999	162	1109	Pattharkot(East)	-99.73	-25.50	44	TAR
87.3194	26.9317	283	1308	MulGhat	-42.00	-2.12	44	SW
87.1667	26.8167	183	1316	Chatara	8.76	-6.01	44	SW
87.1500	26.9333	143	1309	Tribeni	-29.85	-4.87	44	TAR
81.3333	28.7833	260	403	Jamu (Tikuwa Kuna)	68.62	-28.03	42	SW
85.1667	27.1833	244	910	Nijgadh	-122.54	-26.25	44	TAR
86.8333	27.0333	1295	1211	Khotang Bazar	-71.28	4.24	44	MM
84.1000	28.3667	1820	824	Siklesh	54.71	6.68	38	H
85.5000	27.3333	250	1117	HariharpurGadhi Valley	-20.88	2.42	37	SW
83.2500	28.0667	1530	725	Tamghas	23.60	3.15	34	MM
80.9333	29.2333	720	218	Dipayal (Doti)	0.78	-5.39	33	MM
85.4167	26.8833	100	1118	Manusmara	-91.05	-1.21	34	TAR
87.8607	26.6569	112	1421	Gaida (Kankai)	33.46	-26.49	31	TAR
81.3378	28.3336	155	417	Rani Jaruwa Nursery	27.15	-0.16	36	TAR
80.6833	29.1167	1304	214	Kola Gaun	-4.77	0.22	40	MM
80.4667	29.5333	2370	108	Satbanjh	-73.19	-2.97	39	H
82.8000	27.6833	80	723	Bhagwanpur	17.79	-5.09	40	TAR
82.2000	28.6333	910	513	ChaurJhari Tar	-1.56	-4.07	39	MM
86.9000	26.5953	85	1226	Barmajhiya	-35.24	-5.96	39	TAR
83.7500	27.5333	154	728	Simari	-33.31	3.84	33	TAR
81.9749	28.0299	162	419	Sikta	8.19	-7.25	37	TAR
82.4833	28.6333	2100	514	Musikot(Rukumkot)	-74.13	6.01	42	H
83.8167	28.2667	1600	813	BhadaureDeurali	61.11	-18.40	30	MM
84.8781	27.0233	41	918	Birganj	-77.29	5.07	39	TAR
81.2831	29.1500	1345	217	Mangalsen	-88.60	-3.54	38	MM
81.1000	28.4333	129	411	Rajapur	19.35	7.99	39	TAR
83.7500	28.1833	1720	613	KarkiNeta	53.24	4.76	38	MM
87.1969	27.3186	477	1321	Tumlingtar	-13.55	0.80	38	MM
87.7656	27.1437	1157	1419	Phidim (Panchther)	-37.60	-0.90	37	MM
87.2925	27.0464	1720	1304	Pakhribas	14.04	-1.02	38	MM
81.1167	28.9667	340	210	Bangga Camp	96.04	8.77	42	MM

83.4581	27.5292	120	707	Bhairahawa (Agric)	-16.18	7.73	44	TAR
81.3167	29.3833	1400	204	Bajura	188.01	-12.93	39	H
84.8092	27.5347	272	920	Beluwa(Manahari)	-81.16	-8.41	40	SW
86.8000	27.2167	1623	1222	Diktel	28.41	-3.14	42	H
83.0500	27.7667	200	721	Pattharkot (West)	1.79	-1.43	42	SW
80.6333	28.8667	288	215	Godavari(West)	77.50	17.47	40	TAR
83.2761	27.4703	95	727	LumbiniMandir	-91.79	-23.22	34	TAR
86.1667	27.1833	1417	1108	BahunTilpung	-131.80	-6.81	43	SW
86.4295	27.1363	497	1210	KuruleGhat	-38.71	-1.17	44	SW
85.1562	27.4162	1050	919	MakwanpurGadhi	-97.28	10.84	40	SW
84.2650	27.9736	330	817	Damauli	-6.74	2.00	41	MM
82.3167	29.2833	3080	304	GuthiChaur	7.59	-1.66	39	H
81.1167	28.5333	140	207	Tikapur	29.21	0.61	39	TAR
83.8000	27.8667	500	726	Garakot	0.53	-2.22	33	MM
81.5903	28.1138	135	409	Khajura (Nepalganj)	-20.84	-2.85	41	TAR
83.9742	28.2183	856	811	Malepatan (Pokhara)	64.56	7.35	44	MM
87.6199	27.3637	700	1420	Dovan	-19.04	0.11	42	MM
88.0616	26.5639	95	1412	Chandra Gadhi	27.28	1.05	44	TAR
83.6647	27.5347	125	708	Parasi	-91.60	-9.21	41	TAR
83.7200	28.7800	2744	601	Jomsom	1.71	1.63	42	H
86.5833	27.5000	2378	1219	Salleri	-20.43	1.42	42	H
85.0012	27.0354	70	921	Kalaiya	-78.55	-7.56	39	TAR
81.9000	28.0500	226	414	Baijapur	77.35	-1.31	43	TAR
85.3833	28.2833	1900	1001	Timure	10.46	6.04	43	H
86.4167	27.4833	1576	1207	Mane Bhanjyang	-37.20	-2.80	44	H
87.3833	26.6167	152	1312	Haraincha	25.06	-4.76	43	TAR
87.9298	27.1855	1590	1406	MemengJagat	68.14	11.98	41	MM
85.6325	27.9014	1347	1078	Dhap	-48.03	-33.60	17	MM
82.2833	28.9833	2000	418	MainaGaun (D.Bas)	-18.61	5.76	40	H
85.2833	27.5833	1590	1075	Lele	-25.51	-17.82	21	MM
82.4842	28.0369	634	515	Ghorai (Dang)	30.23	9.02	26	SW
83.4000	28.3833	1160	621	Darbang	82.35	31.26	26	SW
83.5667	28.1500	1740	622	Rangkhani	-93.31	-56.34	25	H
85.2833	27.6333	1212	1073	Khokana	0.81	4.93	24	MM
83.7550	27.9772	750	826	Walling	93.78	-9.16	25	SW
84.1333	27.8667	660	827	Rumjakot	0.88	0.89	24	SW
83.9667	28.2667	1070	818	Lamachaur	20.31	-15.21	43	MM
84.6167	28.6667	3650	806	LarkeSamdo	-3.97	-19.89	33	HH
84.9000	28.3667	1334	801	Jagat (Setibas)	-53.47	7.96	43	MM
83.8747	27.5908	164	710	Dumkibas	-58.43	18.99	43	SW
86.9314	26.7367	100	1212	Phatepur	-3.50	30.18	35	TAR
86.2314	27.6342	1930	1103	Jiri	49.64	9.29	44	MM
85.1167	28.0167	1240	1057	Pansayakhola	44.19	-3.92	42	MM
82.6333	28.6000	1560	501	Rukumkot	-49.20	-44.28	37	MM
85.5667	26.8667	150	1120	Malangwa	-47.54	-7.95	32	TAR
85.3242	27.7286	1314	1039	Panipokhari(Kathmandu)	-20.36	2.28	42	MM
80.2167	29.0333	176	105	Mahendra Nagar	65.49	2.89	42	TAR
81.1333	29.0000	1388	205	Katai	-154.84	-6.51	41	MM
83.4663	27.6944	205	703	Butwal	-41.60	-14.75	44	SW
83.2167	28.6000	2530	616	GurjaKhani	8.10	0.65	36	H
85.7833	26.8833	200	1119	Gausala	68.19	18.58	36	TAR

82.9167	28.9333	2058	312	Dunai	9.68	-6.66	41	H
85.7786	27.6877	1565	1063	Thokarpa	#DIV/0!	-39.30	30	MM
85.5655	27.6161	1543	1024	Dhulikhel	-26.99	-10.92	40	MM
85.3583	27.7767	1350	1071	Buddhanilakantha	-119.22	-18.13	28	MM
81.7667	29.3167	1006	302	Thirpu	2.46	-6.13	44	MM
82.1500	29.5500	2133	306	Gam Shree Nagar	-120.57	-12.57	38	MM
81.2500	28.8833	950	401	Pusma Camp	14.35	-4.35	44	MM
83.6000	28.2636	960	605	Baglung	-58.89	4.44	41	MM
84.8962	27.9126	630	1005	Dhading	-97.26	-28.36	44	MM
86.0500	27.5167	1536	1104	Melung	26.39	-45.11	43	MM
81.3506	28.2031	215	408	Gulariya	-130.23	-11.44	43	TAR
84.5894	27.9714	720	809	Gorkha	-18.13	-12.85	44	MM
85.7167	27.7833	1660	1009	Chautara	-162.97	-11.45	42	MM
86.3833	27.5500	1662	1224	Sirwa	-129.29	-17.47	42	H
84.0167	28.6667	3420	820	ManangBhot	-20.79	-4.28	39	HH
84.6167	28.2000	1120	823	Gharedhunga	17.01	14.25	37	MM
82.0939	28.0075	200	407	Kusum	-203.16	-7.12	39	MM
87.9231	26.9096	1208	1407	Ilam Tea Estate	23.60	-15.42	42	SW
83.6500	28.4833	1243	606	Tatopani	29.18	9.42	44	MM
83.0667	27.5500	94	716	Taulihawa	43.89	-10.67	43	TAR
86.1000	27.6833	850	1101	Nagdaha	17.82	-13.53	38	MM
87.5361	27.1228	1633	1314	Terhathum	-30.57	1.62	43	MM
83.8833	29.0500	3465	610	Ghami (Mustang)	1.78	-3.11	38	HH
83.8622	28.8156	3671	608	Ranipauwa (M.Nath)	22.78	-3.37	43	HH
85.4838	27.1318	116	1121	Karmaiya	-54.09	8.88	31	TAR
81.6333	29.2333	1814	309	Bijayapur (Raskot)	43.45	8.32	38	H
81.6000	29.1333	1210	305	Sheri Ghat	-53.85	-7.20	43	MM
85.5544	27.9993	2596	1058	TarkeGhyang	-92.38	20.15	41	H
87.2833	27.5500	1497	1301	Num	-86.78	7.08	43	H
87.4123	27.7533	2039	1317	Chepuwa	31.85	-17.62	41	H
85.5573	26.8528	66	1020	Mandan	145.59	-6.64	39	TAR
82.2167	29.2667	2310	310	DipalGaun	72.77	-3.40	38	H
85.7489	27.5536	633	1028	PachuwarGhat	377.20	-2.22	36	MM
87.7731	27.4892	1389	1404	Taplethok	118.42	-0.07	39	MM
85.9167	27.2142	534	1107	SindhuliMadhi	29.15	-25.63	41	SW
85.3000	28.1000	1982	1055	Dhunche	14.96	5.19	41	H
83.5386	27.8639	1187	702	Tansen	73.17	13.70	41	MM
81.8189	29.9711	2818	311	Simikot	-147.32	-20.86	41	H
85.5951	27.9446	2574	1016	Sarmathang	133.20	-18.40	39	H
85.0833	27.6000	2314	905	Daman	-147.32	-20.86	41	MM
84.8167	28.0500	518	1002	AruGhatD.Bazar	57.22	-28.48	38	MM
82.1000	29.7333	1950	313	Darma	-52.57	-10.57	32	H
85.1667	27.9167	1003	1004	Nuwakot	18.14	-10.43	43	MM
85.6210	27.6452	857	1036	Panchkhal	-60.38	-10.15	41	MM
83.8000	28.3833	1960	821	Ghandruk	172.73	22.56	38	MM
83.1000	28.4000	2273	615	Bobang	-13.27	-13.65	37	H
82.0833	29.5397	2975	307	Rara	-12.40	-0.70	35	H
81.6667	28.1000	165	420	Nepalgunj Airport	-46.71	-0.34	19	TAR
85.62	28.22	3920	HH2	Langtang	-10.32	10.37	24	HH
85.94	27.89	4355	HH3	Khumbu	50.64	-2.06	17	HH
83.95	28.52	3470	HH1	Annapurna	-	-	-	HH

87.18	27.73	2100	HH4	Makulu	-	-	-	HH

Table 9 Details of Statistical Modelling

Domain	Model	Parameter	B	Standard Error	95% Wald Confidence Interval		Hypothesis Test			RR	95% Wald Confidence Interval for RR	
					Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
	1.1	Intercept	4.842	.2431	4.365	5.318	396.544	1	0.000	126.673	78.655	204.003
	1.1	TEMP	.019	.0130	-.006	.044	2.130	1	.144	1.019	.994	1.045
EM	1.3	MIN TEMP	.021	.0104	.001	.041	4.077	1	.043	1.021	1.001	1.042
	1.1	Rainfall	.007	.0035	.000	.014	4.091	1	.043	1.007	1.000	1.014
	1.1	Year	.145	.0152	.115	.175	90.915	1	0.000	1.156	1.122	1.191
	2.1	Intercept	4.681	.1710	4.345	5.016	749.254	1	0.000	107.825	77.121	150.754
	2.1	TEMP	.031	.0075	.016	.046	16.837	1	.000	1.031	1.016	1.047
	2.2	MAX TEMP	.028	.0074	.013	.042	13.954	1	.000	1.028	1.013	1.043
EH	2.3	MIN TEMP	.029	.0071	.016	.043	17.275	1	.000	1.030	1.016	1.044
	2.1	Rainfall	.006	.0027	.000	.011	4.332	1	.037	1.006	1.000	1.011
	2.1	Population	.012	.0032	.006	.018	13.903	1	.000	1.012	1.006	1.018
	2.1	Year	.114	.0092	.096	.132	154.800	1	0.000	1.121	1.101	1.141
	2.1	Summer	.222	.1011	.024	.421	4.842	1	.028	1.249	1.025	1.523
	3.1	Intercept	5.795	.4733	4.867	6.722	149.868	1	0.000	328.558	129.927	830.852
	3.1	TEMP	.015	.0078	3.181E-05	.031	3.857	1	.050	1.015	1.000	1.031
ET	3.2	MAX TEMP	.017	.0090	-.001	.034	3.422	1	.064	1.017	.999	1.035
	3.3	MIN TEMP	.013	.0065	.000	.026	3.992	1	.046	1.013	1.000	1.026
	3.1	RH	.005	.0032	-.001	.011	2.303	1	.129	1.005	.999	1.011
	3.1	Population	.009	.0030	.004	.015	10.206	1	.001	1.010	1.004	1.015
	3.1	Year	.085	.0127	.060	.110	45.005	1	.000	1.089	1.062	1.116
	4.1	Intercept	4.598	.2370	4.133	5.062	376.233	1	0.000	99.264	62.377	157.964
	4.1	TEMP	.035	.0129	.009	.060	7.240	1	.007	1.035	1.009	1.062
	4.2	MAX TEMP	.033	.0141	.005	.061	5.516	1	.019	1.034	1.006	1.063
CM	4.3	MIN TEMP	.034	.0099	.015	.053	11.867	1	.001	1.035	1.015	1.055
	4.1	Rainfall	.004	.0029	-.002	.010	1.951	1	.162	1.004	.998	1.010
	4.1	Population	.022	.0038	.014	.029	32.841	1	.000	1.022	1.014	1.030
	4.1	Year	.088	.0146	.059	.117	36.247	1	.000	1.092	1.061	1.124
	4.1	Summer	.272	.1604	-.043	.586	2.870	1	.090	1.312	.958	1.797
	5.1	Intercept	4.634	.1345	4.371	4.898	1187.902	1	0.000	102.933	79.087	133.968
	5.1	TEMP	.045	.0060	.033	.056	55.659	1	.000	1.046	1.034	1.058
	5.2	MAX	.042	.0055	.031	.053	56.487	1	.000	1.043	1.031	1.054

CH		TEMP										
	5.3	MIN TEMP	.038	.0057	.027	.049	43.971	1	.000	1.039	1.027	1.050
	5.1	Rainfall	.006	.0015	.002	.009	12.742	1	.000	1.006	1.002	1.009
	5.1	Population	.006	.0009	.005	.008	52.613	1	.000	1.006	1.005	1.008
	5.1	Year	.137	.0084	.120	.153	265.984	1	0.000	1.147	1.128	1.166
	5.1	Spring	-.162	.0689	-.297	-.027	5.529	1	.019	.850	.743	.973
	6.1	Intercept	5.929	.2734	5.393	6.465	470.267	1	0.000	375.794	219.899	642.207
	6.1	TEMP	.008	.0066	-.005	.021	1.628	1	.202	1.008	.995	1.022
	6.2	MAX TEMP	.012	.0058	.001	.024	4.390	1	.036	1.012	1.001	1.024
CT	6.3	MIN TEMP	.019	.0061	.007	.031	9.864	1	.002	1.019	1.007	1.031
	6.1	Population	.008	.0023	.003	.012	10.974	1	.001	1.008	1.003	1.012
	6.1	Year	.100	.0097	.081	.119	108.158	1	0.000	1.106	1.085	1.127
	6.1	Summer	.293	.0925	.112	.475	10.051	1	.002	1.341	1.118	1.607
	6.1	Autumn	.197	.0811	.038	.356	5.877	1	.015	1.217	1.038	1.427
	7.1	Intercept	2.240	.2278	1.793	2.686	96.683	1	0.000	9.393	6.010	14.680
	7.1	TEMP	.049	.0192	.012	.087	6.578	1	.010	1.051	1.012	1.091
	7.2	MAX TEMP	.036	.0199	-.003	.075	3.270	1	.071	1.037	.997	1.078
WM	7.3	MIN TEMP	.076	.0177	.041	.110	18.295	1	.000	1.079	1.042	1.117
	7.1	Year	.078	.0191	.040	.115	16.587	1	.000	1.081	1.041	1.122
	7.1	Summer	.309	.2198	-.121	.740	1.983	1	.159	1.363	.886	2.096
	7.1	Autumn	.420	.1628	.101	.740	6.671	1	.010	1.523	1.107	2.095
	8.1	Intercept	4.697	.1637	4.376	5.017	823.254	1	0.000	109.580	79.506	151.030
	8.1	TEMP	.016	.0063	.003	.028	6.234	1	.013	1.016	1.003	1.029
	8.2	MAX TEMP	.007	.0053	-.003	.018	1.928	1	.165	1.007	.997	1.018
	8.3	MIN TEMP	.024	.0068	.011	.038	12.782	1	.000	1.025	1.011	1.038
WH	8.1	Rainfall	.005	.0015	.002	.008	11.015	1	.001	1.005	1.002	1.008
	8.1	Population	.014	.0022	.010	.018	41.361	1	.000	1.014	1.010	1.018
	8.1	Year	.134	.0080	.119	.150	280.764	1	0.000	1.144	1.126	1.162
	8.1	Summer	.264	.0984	.071	.457	7.214	1	.007	1.302	1.074	1.580
	8.1	Autumn	.164	.0649	.037	.291	6.398	1	.011	1.178	1.038	1.338
	9.1	Intercept	5.922	.2604	5.412	6.433	517.220	1	0.000	373.295	224.074	621.891
	9.1	TEMP	.015	.0097	-.004	.034	2.406	1	.121	1.015	.996	1.035
WT	9.2	MAX TEMP	.010	.0090	-.007	.028	1.319	1	.251	1.010	.993	1.028
	9.3	MIN TEMP	.017	.0096	-.002	.036	2.976	1	.085	1.017	.998	1.036

	9.1	Year	.167	.0146	.139	.196	130.706	1	0.000	1.182	1.149	1.216
	9.1	Spring										
	9.1	Summer	.207	.1330	-.054	.467	2.411	1	.121	1.229	.947	1.596
MWM	10.1	Intercept	4.083	.1442	3.800	4.366	801.718	1	0.000	59.325	44.719	78.702
	10.1	TEMP	.027	.0086	.010	.044	9.978	1	.002	1.027	1.010	1.045
	10.2	MAX TEMP	.033	.0087	.016	.050	14.179	1	.000	1.033	1.016	1.051
	10.3	MIN TEMP	.019	.0069	.005	.032	7.321	1	.007	1.019	1.005	1.033
	10.1	Population	.025	.0073	.011	.039	11.987	1	.001	1.025	1.011	1.040
	10.1	Year	.172	.0114	.149	.194	226.976	1	0.000	1.187	1.161	1.214
	10.1	Summer	.466	.1313	.208	.723	12.570	1	.000	1.593	1.231	2.061
MWH	11.1	Intercept	3.610	.2209	3.177	4.043	267.131	1	0.000	36.974	23.982	57.006
	11.1	TEMP	.029	.0076	.014	.044	14.358	1	.000	1.029	1.014	1.045
	11.2	MAX TEMP	.026	.0071	.012	.040	13.684	1	.000	1.027	1.012	1.041
	11.3	MIN TEMP	.027	.0075	.012	.042	12.911	1	.000	1.027	1.012	1.043
	11.1	Rainfall	.008	.0036	.001	.015	4.970	1	.026	1.008	1.001	1.015
	11.1	Population	.034	.0041	.026	.043	69.645	1	.000	1.035	1.027	1.043
	11.1	Year	.188	.0096	.170	.207	388.734	1	0.000	1.207	1.185	1.230
	11.1	Summer	.292	.1288	.040	.545	5.150	1	.023	1.340	1.041	1.725
	11.1	Autumn	.208	.0816	.048	.368	6.481	1	.011	1.231	1.049	1.444
MWT	12.1	Intercept	5.760	.4367	4.904	6.616	174.000	1	0.000	317.445	134.884	747.099
	12.1	TEMP	.048	.0091	.030	.066	27.740	1	.000	1.049	1.030	1.068
	12.2	MAX TEMP	.051	.0107	.030	.072	22.588	1	.000	1.052	1.030	1.074
	12.3	MIN TEMP	.041	.0076	.026	.056	29.541	1	.000	1.042	1.027	1.058
	12.1	RH	-.007	.0041	-.015	.001	3.028	1	.082	.993	.985	1.001
	12.1	Year	.130	.0162	.098	.162	64.491	1	.000	1.139	1.103	1.175
	12.1	Spring	-.449	.1414	-.726	-.172	10.094	1	.001	.638	.484	.842
FWM	13.1	Intercept	5.092	.5115	4.090	6.095	99.108	1	0.000	162.765	59.725	443.576
	13.1	TEMP	.016	.0114	-.006	.038	1.970	1	.160	1.016	.994	1.039
	13.2	MAX TEMP	.016	.0122	-.008	.040	1.765	1	.184	1.016	.992	1.041
	13.3	MIN TEMP	.017	.0091	-.001	.035	3.523	1	.061	1.017	.999	1.036
	13.1	RH	-.007	.0039	-.014	.001	3.008	1	.083	.993	.986	1.001
	13.1	Population	.026	.0095	.007	.045	7.409	1	.006	1.026	1.007	1.046
	13.1	Year	.108	.0164	.076	.141	43.512	1	.000	1.115	1.079	1.151
	13.1	Summer	.500	.1397	.227	.774	12.829	1	.000	1.649	1.254	2.169

FWH	14.1	Intercept	5.844	.2012	5.450	6.239	844.141	1	0.000	345.307	232.799	512.189
	14.1	TEMP	.025	.0088	.008	.042	7.956	1	.005	1.025	1.008	1.043
	14.2	MAX TEMP	.014	.0079	-.001	.030	3.150	1	.076	1.014	.999	1.030
	14.3	MIN TEMP	.029	.0087	.012	.046	11.277	1	.001	1.030	1.012	1.047
	14.1	Year	.058	.0129	.033	.083	20.374	1	.000	1.060	1.033	1.087
	14.1	Summer	.282	.1184	.050	.514	5.664	1	.017	1.325	1.051	1.672
	14.1	Autumn	-.144	.1042	-.349	.060	1.917	1	.166	.866	.706	1.062
FWT	15.1	Intercept	5.354	.2891	4.787	5.920	343.040	1	0.000	211.416	119.974	372.554
	15.1	TEMP	.035	.0103	.015	.055	11.390	1	.001	1.035	1.015	1.056
	15.2	MAX TEMP	.046	.0120	.023	.070	14.810	1	.000	1.047	1.023	1.072
	15.3	MIN TEMP	.025	.0086	.008	.042	8.580	1	.003	1.026	1.008	1.043
	15.1	Year	.189	.0194	.151	.227	95.450	1	0.000	1.208	1.163	1.255
	15.1	Spring	-.243	.1407	-.519	.033	2.984	1	.084	.784	.595	1.033
NEPAL	16.1	Intercept	4.382	.0424	4.299	4.465	10703.927	1	0.000	80.015	73.641	86.941
	16.1	TEMP	.043	.0022	.039	.047	378.835	1	0.000	1.044	1.039	1.048
	16.2	MAX TEMP	.038	.0021	.034	.042	315.020	1	0.000	1.039	1.034	1.043
	16.3	MIN TEMP	.037	.0020	.033	.041	355.334	1	0.000	1.038	1.034	1.042
	16.1	Rainfall	.003	.0007	.001	.004	17.651	1	.000	1.003	1.001	1.004
	16.1	Population	.015	.0004	.014	.016	1450.586	1	0.000	1.015	1.015	1.016
	16.1	Year	.130	.0029	.124	.135	2017.141	1	0.000	1.139	1.132	1.145
	16.1	Spring	-.157	.0262	-.208	-.106	35.876	1	.000	.855	.812	.900
	16.1	Summer	.110	.0353	.041	.179	9.728	1	.002	1.116	1.042	1.196

List of participants

S.N.	Name	Organization
1	Suman Karmacharya	DWSS
2	Raja Ram Pote Shrestha	WHO
3	Shiva Prasad Nepal	DHM
4	Dilli Raman Adhikari	RHD
5	Dr Madhab Prasad Lamsal	DoHs
6	Baburam Acharya	NHRC
7	Bihungom Bista	NHRC
8	Ashok Pandey	NHRC
9	Achyut Raj pandey	NHRC
10	Anil Poudel	NHRC
11	Namuna Shrestha	NHRC
12	Shambhu Gyawali	DHO, Mustang
13	KM Neupane	NHCS
14	Jiwan Malla	DPHO, Ilam
15	Dr Bishnu Prasad Sharma	Patan Hospital
16	Tirtha Raj Adhikari	CDHM,TU
17	Asha Chaudhary	NHRC
18	Sunita Dhungana	NHRC
19	Prabina Makai	NHRC
20	Mukti Nath Khanal	HMIS
21	Prof. Dr Srijan Lal Shrestha	TU
22	Deepak Jha	CHD
23	Dr Sher Bahadur Pun	STIDH
24	Jhalak Sharma	DPHO Lalitpur

25	Rajeev Pokharel	MoH
26	Sajana Maharjan	NHRC
27	Dr. Khem Bahadur Karki	NHRC
28	Sabina Khanal	thahakhabar.com
29	Ram Prasad Neupane	nepalihealth.com
30	Namita Ghimire	NHRC
31	Mohammad Daud	PHCRD/DoHS
32	Dr Dipendra Raman Singh	MoH
33	Purna Chandra Poudel	NHRC
34	Prof. Dr. Subodh Sharma	KU
35	Prof. Dr Bandana Pradhan	IoM
36	Ram Krishna Lamichhane	MoH
37	Kalpana Poudel	RSS
38	Junu Bhattarai	Karobar Daily
39	Yesshoda Aryal	MoH
40	Mona Giri	NHRC
41	Dr Bhupendra Basnet	Bir Hospital
42	Dr Bhola Ram Shrestha	MoH
43	Nirbhay Kumar Sharma	NHRC
44	Dr. Krishna Kumar Aryal	NHRC
45	Mr. Bijay Kumar Jha	NHRC
46	Mr. Subdh Kumar Karna	NHRC
47	Dr. Meghnath Dhimal	NHRC