TRACING WINTER-CLIMATE CHANGE SCENARIO FOR THE KATHMANDU VALLEY

BY

SAMI KUNWAR

THESIS

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Letter of Recommendation

*This thesis entitled '**TRACING WINTER-CLIMATE CHANGE SCENARIO FOR THE KATHMANDU VALLEY**' has been completed by Mr. **SAMI KUNWAR** under my supervision. I certify that he had carried out all his work sincerely with keen interest. I hereby recommend this thesis for approval.*

………………………………

LOCHAN PRASAD DEVKOTA

D.Phil./Professor

HEAD

Central Department of Hydrology and Meteorology,
Tribhuvan University
Kirtipur

TRIBHUVAN UNIVERSITY

CENTRAL DEPARTMENT OF HYDROLOGY & METEOROLOGY
KIRTIPUR, KATHMANDU, NEPAL

WE HEREBY RECOMMEND THAT THE THESIS SUBMITTED

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Thesis Approval Committee:

Prof.Dr.Lochan Pd. Devkota
Supervisor
Head, Central Department of Hydrology and Meteorology
Tribhuvan University

Suresh Maharajan
Internal Examiner
Lecturer, Central Department of Hydrology and Meteorology
Tribhuvan University

Ngamindra Dahal
External Examiner
Energy and Climate Change Coordinator
National Trust for Nature Conservation

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Disclaimer

Except where otherwise stated and acknowledged, I certify that this thesis is my sole and unaided work,

Sami Kunwar
12th April 2009

Abstract

Change in local climate of Kathmandu has already been reported in national media. Scientific analysis of climatic indicators is important to confirm the public perceptions. This study attempts to fill the gap by analyzing the rainfall and temperature data of the Valley with a focus on winter season.

As a part of this study, temperature and rainfall data were analyzed. The key findings include increased number of hotter days and decreased number as well as volume of rainy days in winter months (December to February). Incidentally, this year's winter months (December 2008 through February 2009) remained total dry. Though there are rare incidents of this type of severe and longer drought in the history, this one is the second in three years. There is wide belief that such a frequent drought of this scale is the result of climate change. However, defining change in climatic pattern requires analysis of minimum of 30 years of data or more.

Annual temperature growth trend of Kathmandu is already established but the fact that the higher rate of temperature growth of winter season is rarely discussed. In this ground this study is significant in the ground that winter temperature growth in Kathmandu Airport station is statistically significant. Decreased amount of rains or absence of rains throughout winter has been noticed as a cause behind this sharp rise of winter temperature.

In Kathmandu Valley, the winter of 1998/99 was the hottest winter of 20th century with average of 12.26 °C. Normally, the central Valley receives about 33 mm of winter rainfall, while the southern slopes receive over 55 mm in winter. The high hill around the Valley received snowfall on 14th February 2007 first time after 62 years. This event has indicated that extreme events in weather are already experienced in Kathmandu as an effect of climate change.

With the increased frequency of extreme weather events, exposure of the Valley residents has increased significantly for two reasons. First, the alarming growth of Valley population is already coping with serious water shortage problem. The consecutive drought like conditions throughout winter has exacerbated the situation. Therefore the Valley is highly vulnerable to climate change. Unless there is an implementable plan of climate change adaptation, the future of the Valley will be very stressful through water management point of view. To this purpose, adoption of Integrated Water Resource Management (IWRM) is essential to address the challenge.

Abbreviations/Acronyms

BoB	Bay of Bengal
CCCM	Canadian Climate change Model
CLTU	Central Library of Tribhuvan University
cP	Continental Polar Air Mass
DHM	Department of Hydrology and Meteorology
DJF	December, January, February
GCM	Global Circulation Model
GFD3	Geophysical Fluid Dynamics Models
GHGs	Greenhouse Gases
HadRM2	Hadley Centre Regional Climate Model
ICIMOD	International Centre for Integrated Mountain Development
IES	Institute for Environmental Studies
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	The World Conservation Union
IWRM	Integrated Water Resource Management
Km	kilometer
LPS	Low Pressure System
LULUCF	Land Use, Land-Use Change and Forestry
MAM	March, April, May
mfd	Meteorological Forecast Division
mm	millimeter
MoPE	Ministry of Population and Environment
msl	mean sea level
TAR	third Assessment Report
UNFCCC	United Nations Framework Convention on Climate change
VDC	Village Development Committee
WD	Western Disturbances
WHO	World Health Organization
WMO	World Meteorological Organization
WWW	World Wide Web

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Chapter 1: INTRODUCTION

1.1 Background of the Study

Climate change is the biggest environmental challenge in human history to achieve and sustain prosperity. Growing scientific evidences including the highly acclaimed fourth climate change assessment report by Intergovernmental Panel on Climate Change (IPCC) has reconfirmed that the Earth's atmosphere has already been saturated with greenhouse gases (GHGs) and additional emissions would lead to a global scale disaster. Several basic indicators in our surroundings such as steady rise in temperatures, increasing concentration of greenhouse gases in the atmosphere, and growing weather or climatic uncertainties evidently show that collectively impacts of these changes would not be favorable at all to nature and humanity. Given the gravity of impacts of climate change on lives and livelihood sources of an economically poor and climatically sensitive country are immense; the issue is yet to be mainstreamed into contemporary dialogues of national priority (Davidson, 2005).

A change in climate is inevitable if the increasing trend in concentration of GHGs levels continues depending upon the land use, land use change and forestry (LULUCF). The expected changes will have adverse effects on the water resources, agriculture, natural ecosystems and human health with serious social and economic consequences. Therefore, regions and countries with relatively weak adaptive capacities and infrastructure are vulnerable to climate change.

1.2 Statement of the Problem

Although industrial and infrastructure development is still in its infancy in Nepal, changes in atmospheric condition have been noticed in some parts of the country due to gaseous emission from mobile and stationary sources, even due to trans-boundary causes. About 85 per cent of the total population who reside in rural areas meets their energy demand from biomass combustion, particularly firewood, while about 16 per cent of the total population living in urban areas is exposed to different levels of concentration of gases, including greenhouse gases.

The usual winter rains of Nepal have vanished and dry winter has been the main feature since last 12 years. When talking with farmers in the outskirts of Kathmandu, most of them mention changes like early flowering and ripening of their crops and fruits by an average of two weeks (Dahal, Answering Basic Questions on Climate

Change, 2008). Extension of southerly winter fogs to Himalayan foothills and stronger presence of haze over Nepal's mountain regions are also recent phenomena. These are few examples of people experiencing climate change in recent years. The people who have lived in Kathmandu for the past 25-30 years have experienced the temperature change. Twenty years ago, Kathmandu was much cooler during winter and much less hotter during summer .During the last 20 years; the temperature has gone beyond 35° C (MOPE, 2000).

Moreover, days and nights during winter seasons used to be very chilly a few decades back. But in recent years, they are experiencing less chilly winter days and nights. Similarly during summer season, the days are becoming hotter. In the surrounding hills and mountains, the frequency of snowfall in the winter, which used to high in the past, has decreased. At the same time, the frequency and intensity of frost days have also reduced. According to villagers of Phedigaon community of Palung Village Development Committee (VDC) in Makwanpur District, the most significantly observed changes are decrease in rainfall amount, delayed monsoon, and shorter period of rainy season. At the same time, usual and untimely rainfall at once, and decreased winter rainfall are other important changes experienced by the local community (Joshi, 2008).

1.3 Objective of the Study

Objective of this study is to analyze two key climate indicators - the temperatures and rainfall of winter months of Kathmandu Valley. This study will also contribute to enhance knowledge of local impacts of climate change.

1.4 Justification of the Study

Climate change has cross cutting impacts and encompasses all vital systems. Change in weather patterns means increase in level of uncertainties. As a consequences of variability of rainfall pattern and increasing trend of temperature during winter season in Kathmandu Valley subsequent negative impacts on agriculture, water resources and health.

This sort of study which bridges winter and climate change is probably the first of its kind in Nepal. Since, winter season becoming warm and there is change in basic weather patterns which is experiencing season by season and is the best indicator/example to understand climate change.

So, some assistance that can be extracted from this study is listed below:-

- This study provides a scientific knowledge on climate change regarding Kathmandu Valley, Nepal and the world in this single thesis.
- This research will provide ideas for researchers who are connecting climate change with social and economic issues.
- The broad aspects of the study can be helpful to the vulnerability and adaptation framework to mitigate climate induced disaster.

1.5 Limitation of the Study

- **Selection of Limited Stations**: Limited stations are selected for the data analysis for several reasons. Though this study tends to cover whole of the Kathmandu Valley, its approach is limited. Only 10 stations are included in order to cover Kathmandu Valley due to lack of time and resource constraints. Out of existed stations only 5 stations are considered for temperature and 10 for rainfall analysis. Consequently, it may have affected the result.

- **Unavailability of Data**: The data of rainfall and temperature are collected for about 30 years but it is not possible to obtain the rainfall and temperature data for 30 years for all the stations because the stations were not fixed in those periods and for some fixed stations the data are missing. Only Kathmandu Airport station data are available for 30 or more years. The missing data may lead to abnormal result.

2.1. Winter

Winter is one of the four seasons of temperate zones. Astronomically, this is the period between the winter solstice and vernal equinox. It is the season characterized as having the shortest days and the lowest average temperatures of the year. It has colder weather and, especially in the higher latitudes or altitudes, snow and ice. The coldest average temperatures of the season are typically experienced in January in the Northern Hemisphere and in July in the Southern Hemisphere (Wikipedia, p. 2008). Customarily, this refers to months of December, January and February in the Northern Hemisphere and the months of June, July and August in the Southern Hemisphere (The Weather Channel Interactive, 2009).

In part of the Asian Monsoonal region, near the surface, this is the season of the outblowing ‘winter monsoon’, but aloft westerly airflow dominates. This reflects the hemispheric pressure distribution. A shallow layer of cloud, high-pressure air is centered over the continental interior, but this has disappeared even at 700 mb where there is a trough over East Asia and zonal circulation over the continent. The upper westerlies split into two currents to the north and south of the high Tibetan (Quighai-Xizang) Plateau, to reunite again off the east coast of China. The plateau, which exceeds 4,000 m over a vast area, is a tropospheric cold source for winter, particularly over its western part; although the strength of this source depends on the extent and duration of snow cover (snow-free ground acts as the heat source in *all* months). Below 600 mb, the tropospheric heat sink gives rise to a shallow, cold plateau anticyclone, which is the best developed in December and January. The two jet-stream branches have been attributed to the disruptive effect of the topographical barrier on the air flow, but this is limited to altitudes below about 4 Km. In facts, the northern jet is highly mobile and may be located far from the Tibetan Plateau. Two currents are also found to occur farther west, where there is no obstacle to the flow. The branch over northern India corresponds to a strong latitudinal thermal gradient (from November to April) and it is probable that this factor, combined with the thermal effect of the barrier to the north, is responsible for the anchoring of the southerly jet. This southern branch for the stronger, either an average speed of more than 40 ms^{-1} at 200 mb, compared with about 20-25 ms^{-1} in the northern one. Where the two unite over north China and south Japan the average velocity exceeds 66 ms^{-1}.

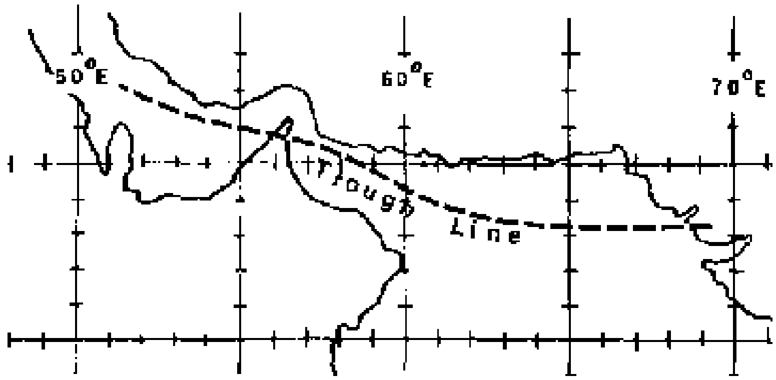


Figure2.1: Mean position of lee low pressure trough in northeast flow during the winter monsoon season (Adapted from Meteorological phenomena of the Arabian Sea)

Air subsiding beneath this upper westerly current gives dry outblowing northerly winds from the subtropical anticyclone over north-west India and Pakistan. The surface wind direction is north-westerly over most of northern India, becoming north-easterly over peninsular India. Equally important is the steering of winter depressions over northern India by the upper jet. The lows, which are not usually frontal, appear to penetrate across the Middle East from the Mediterranean and are important sources of rainfall for northern India, Nepal and Pakistan especially as it falls when evaporation is at a minimum. The equatorial trough of convergence and precipitation lies between the equator and about latitude 15°S.

Some of these westerly depressions continue eastwards, redeveloping in the zone of jet stream confluence about 30°N, 105°E over China, beyond the area of subsidence in the immediate lee of Tibet, and it is significant that the mean axis of the winter jet stream over China shows a close correlation with the distribution of winter rainfall. Other depression affecting central and north China travel within the westerlies north of Tibet or are initiated by outbreaks of fresh Continental Polar Air Mass (cP) air. In the rear of these depressions are invasions of very cold air (e.g. the burans blizzards of Mongolia and Manchuria). Winter mean temperatures in less-protected southern China are considerably below those at equivalent latitudes in India; for example, temperatures at Calcutta and Hong Kong (both are approximately 22 °N) are 19°C and 16°C in January and 22°C and 15°C in February, respectively.

In Nepal, temperature starts decreasing from October and reaches the minimum in December or January. Again, from February it starts increasing. Winter precipitation is caused by the westerly disturbances or western disturbances (WD) originating in the Mediterranean. The lows formed here are steered and swept eastwards by the westerly aloft. Westerly disturbances (WD) affect the northern and western parts of Nepal (Singh, 1985). Winter precipitation contributes significantly to the annual total precipitation in Nepal's northwest. It plays a major role in the mass balance of glaciers in western Nepal while playing a secondary role in the glaciers of eastern and central Nepal (Seko, 1998). Although winter precipitation is not as impressive in volume or intensity as the summer monsoon, it is of vital importance in generating lean flow for agriculture. Most of the winter precipitation falls as snow and nourishes snowfields and glaciers and generates melt water in dry seasons between February and April. Lower temperatures mean less evaporation and rain of lesser intensity can have a higher rate of percolation that nourishes the root zone of the soil.

2.2. Climate Change

Realization that climate change radically with time came only during the 1840s, when disputable evidences of former ice ages was obtained, yet in many part of the world the climate has altered sufficiently, even within the last few thousand years, to affect the possibilities for agriculture and settlements. Reliable weather records have been kept only during the last hundred years or so, but proxy indicators of past conditions from tree rings, pollen in bog and lake sediments, ice core records of physical and chemical parameters, ocean foraminifera in sediments provide a wealth of paleo-climatic data (Barry & Chorley, 2002).

Box 1: Definitions of Climate Change

According to Intergovernmental Panel on Climate Change (IPCC), "Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use" (IPCC, 2007).

Whereas, United Nations Framework Convention on Climate Change (UNFCCC) defines as, "Climate change means 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 period" (UNFCCC, 1997).

Climate change is caused by greenhouse gases (GHGs), which enhance the "greenhouse" properties of the earth's atmosphere. These gasses allow solar radiation from the sun to travel through the atmosphere but prevent the reflected heat from escaping back into space. This causes the earth's temperature to rise.

Eleven of the last twelve years (1995 -2006) rank among the 12 warmest years ever recorded since global surface temperatures are measured (1850). Over the last 100 years, (1906–2005) there has been an increase in surface temperature of 0.74°C, which is larger than the 0.6°C increase given in the Third Assessment Report (TAR) of Intergovernmental Panel on Climate Change(IPCC) for the 1901-2000 period. And the warming trend over the last 50 years (0.13°C per decade) is nearly twice that for the last 100 years. Temperatures in the higher atmosphere and in the oceans (to depths of at least 3000m) have also been rising, along with the water vapor content of the atmosphere. Mountain glaciers, snow cover and ice caps have declined on average in both hemispheres, contributing in part to the rise of global sea level. The Greenland and Antarctic ice sheets have also contributed to the observed rise of sea level, which amounted to 17cm in total over the course of the 20th century (IPCC, 2007).

Climate change has impacts mainly on the following areas;

Water: Rising global temperatures will lead to an intensification of the hydrological cycle, resulting in dryer dry seasons and wetter rainy seasons, and subsequently heightened risks of more extreme and frequent floods and drought. Changing climate will also have significant impacts on the availability of water, as well as the quality and quantity of water that is available and accessible. Melting glaciers will increase flood risk during the rainy season, and strongly reduce dry-season water supplies to one-sixth of the World's population (Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, June 2008).

Agriculture: The future impact of climate change on agriculture production as calculated in Cline's models suggests an initial increase of production until 2050 due to carbon fertilization but a decrease by 2080 by 4.8 % of agricultural production based on the assumption of positive carbon fertilization effect up to 2.5°C temperature increase, and decrease of 17.3 % or without that effect thereafter (Cline, 2007).However, agriculture also plays an appreciative role of making positive contribution to climate change (IISD & IES, 2007).The countries in temperate and polar locations may benefit as additional temperature may be good for their agricultural sectors.

Ecosystems: Changing temperatures will cause ecosystems to shift – forests, land types and plant species will dieback in some areas as temperatures rise, but increase in other areas. However, in many cases, the pace of change in temperature may be too fast for ecosystems to adjust, resulting in the loss of forests and species (IPCC, 2007).

Health: Climate change is a significant and emerging threat to public health, and changes the way we must look at protecting vulnerable populations. The most recent report of the Intergovernmental Panel on Climate Change confirmed that there is overwhelming evidence that humans are affecting the global climate, and highlighted a wide range of implications for human health. Climate variability and change cause death and disease through natural disasters, such as heat-waves, floods and droughts. In addition, many important diseases are highly sensitive to changing temperatures and precipitation. These include common vector- borne diseases such as malaria and dengue; as well as other major killers such as malnutrition and diarrhea. Climate change already contributes to the global burden of disease, and this contribution is expected to grow in the future. The impacts of climate on human health will not be evenly distributed around the world. Developing country populations, particularly in Small Island States, arid and high mountain zones, and in densely populated coastal areas, are considered to be particularly vulnerable (WHO, 2009).

Coastlines: Melting ice and thermal expansion of oceans are the key factors driving sea level rise. In addition to exposing coastlines, where the majority of the human population lives, to greater erosion and flooding pressures, rising sea levels will also lead to salt water contamination of groundwater supplies, threatening the quality and quantity of freshwater access to large percentages of the population.

2.2.1Nepalese Context

Nepal experiences a wide variety of climate from the tropics to the alpine regions. The country witnesses hot and rainy season or monsoon, from June to September, warm and moist to cold or post-monsoon, from October through January, and dry and hot or pre-monsoon, from March to May. The eastern part of Nepal receives more rainfall which decreases as one proceeds to the west. However, the Lumle area, which is located in the western part of the country, south to the Annapurna Himalayan range. In general, the southern part receives more rainfall and the Himalayas act as a barrier for monsoon, and the rain-shadow effect is obvious in the trans-Himalayan regions. In the other words, all areas across the Himalayas in the western part of the country are dry and receive low rainfall. Similarly, the southern parts of the country are hot and experience high temperature, which decline as one moves to the north. In the different ecological belts, there is a slight variation in temperature. The average maximum temperature is slightly increasing, particularly in January, February and April. The cases is different in the Kathmandu Valley, where there is a significant fluctuation between the average maximum and minimum temperatures, which may be attributed to the increasing amount of dust and other air pollutants. However, there is no clear departure from the average wind speed and amount of rainfall due to atmospheric changes (MOPE, 2000).

Nepal's physical characteristics, geographic position, topography and weak socio-economic vis-à-vis political condition make it one of the highly vulnerable country to climate change, though its share in polluting the atmosphere is negligible. Nepal has already witnessed a number of changes in its mean temperature and climate patterns. Rates of temperature change ranges between 0.4 °C to 0.8 °C per decade which is much higher than the world average (Dahal, 2008).

2.2.1.1. Temperature Change

In the study carried out with different models like Canadian Climate Change Model(CCCM), Geophysical Fluid Dynamic Laboratory R-30 Model(GFD3) & Hadley Center, Regional Climate Model (Had RM2) and their projections, there is rise in average annual temperature in the range of 2 to 4ºC over Nepal, when CO_2 is doubled (MOPE, 2004). Magnitude of temperature rise is greater in western Nepal than other regions. The average warming in annual temperature between 1977 and 1994 was 0.06 ºC/yr (Shrestha, 1999). The warming is found to be more pronounced in the high altitude regions of Nepal such as the Middle Mountain and the High Himalaya, while the warming is significantly lower or even lacking in the Terai and Siwalik regions. Further, warming in the winter is more pronounced compared to other seasons. In this sense the trends in observed data are in agreement with projections made by climate models.

Season wise, winter shows greater increase (2.4°C to 5.4ºC) in far-western region than any other seasons according to CCCM model, and for all seasons in general, the rising gradient is from east to west, whereas in GFD3 model it is from west to east during pre-monsoon and winter (HMG/MoPE, 2004).

The range of variation in temperature rise, projected by models for different seasons, is presented in Table 2.2.1.1.

Table 2.2.1.1.: Range of Variation in Temperature Rise (°C) in Nepal

Model	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
CCCM	+2.0 to +4.0	+1.4 to +4.4	+3.7 to +4.7	+2.4to +5.4	+2.3 to +4.3
GFD3	+2.8 to +3.5	+1.8 to +3.3	+2.7 to +3.7	+3.2 to +3.8	+2.9 to +3.3
RCM	+ 1.0 to +15	+0.5 to +13.3	+1.0 to +12.5	+2.0 to +10.5	+1.0 to +12.4

Source: (MOPE, 2004)

The temperature trend analysis (Fig. 2.2.1.1) shows that, except for small pockets in the eastern region and far western Terai, most of Nepal are depicted with a positive trend of 0 to 0.5° C per decade based upon the data of 80 stations for the period 1981-1998 (HMG/MoPE, 2004).Recently, according to GCM projection of future climate, the mean temperature is projected to increase by 1.3 to 3.8°C by 2060s, and 1.8 to 5.8°C by the 2090s.The range of projections by the 2090s under any one emissions scenario is 1.5 - 2°C, with the rate of warming is most rapid in winter(DJF) and pre-monsoon(MAM) (McSweeney, New, & Lizcana, 2008).

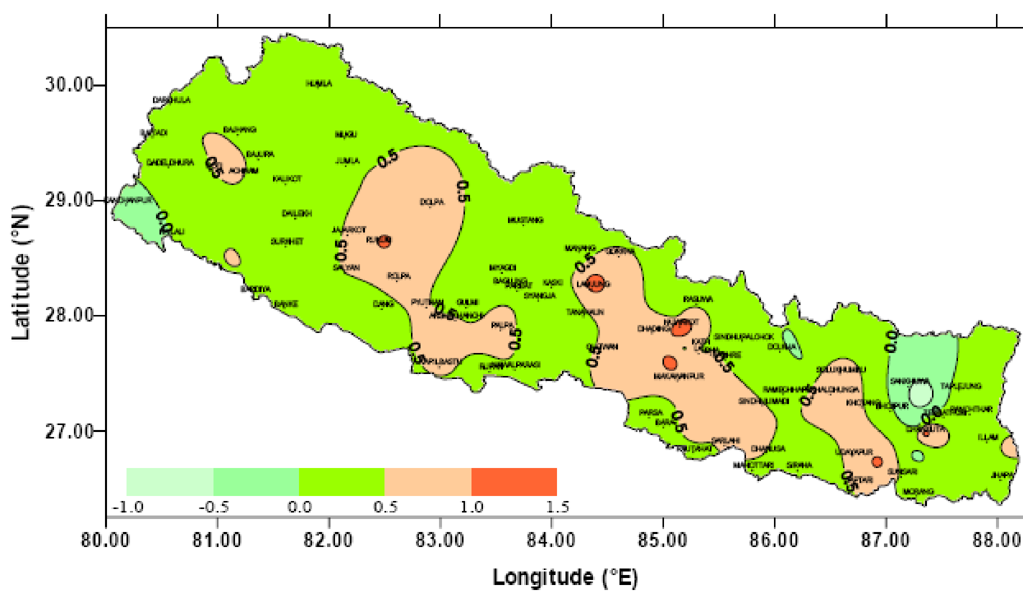
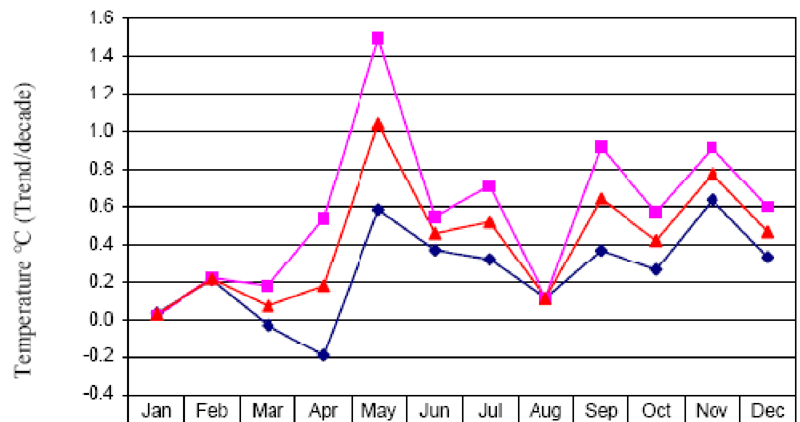


Figure 2.2.1.1: Observed Mean Annual Temperature Trend (°C) per Decade for the Period {1981-1998) Source: (MOPE, 2004)

But the overall temperature in the country is found to be rising at the rate of 0.41º C per decade and this is shown in figure 2.2.1.1(a) together with monthly details of the average trend of maximum, minimum and their mean per decade.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmin. TREND	0.034	0.208	-0.03	-0.19	0.583	0.369	0.319	0.109	0.367	0.265	0.636	0.332
Tmax. TREND	0.021	0.221	0.178	0.537	1.496	0.546	0.711	0.114	0.918	0.569	0.916	0.598
Tmean TREND	0.028	0.215	0.072	0.177	1.04	0.458	0.518	0.109	0.641	0.418	0.775	0.465

	Annual	Monsoon	Pre-monsoon	Winter
T min. Trend /decade	0.25	0.29	0.12	0.30
T max. Trend /decade	0.57	0.57	0.74	0.44
T mean Trend /decade	0.41	0.43	0.43	0.37

Figure 2.2.1.1(a): Trend of Maximum, Minimum and Average Temperature for Nepal (1981-1998) Source: (MOPE, 2004)

2.2.1.2. Precipitation Change

The GFD3 model projects general increase in precipitation for whole of Nepal with gradient from south west to north east in the magnitude of 150 to 1050 mm at 2 x CO2 level. CCCM model projects a decrease in precipitation from 0 to 400 mm in the eastern region, but increase in precipitation in other regions up to 1600 mm. On the other hand, the RCM indicates a change in precipitation by -1000 to +3000 mm. Range of precipitation change during various seasons projected by the models is given in Table 2.2.1.2.

Table 2.2.1.2: Range of Precipitation Change (mm) in Nepal

Model	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
CCCM	-70 to +20	-100 to +1600	+25 to +72	-200 to -18	-400 to +1600
GFD3	0 to +60	+100 to +900	+2 to +14	+24 to +59	+150 to +1050
RCM	0 to +900	-1500 to +2000	-100 to 100	-25 to +200	-1000 to +3000

Note: CCCM and GDF3 projections apply to the time period when CO_2 is doubled

:RCM projections apply to the year 1950 (mean between 1940 and 1960)

Source: (MOPE, 2004)

The GCM projection of precipitation scenario against observed precipitation values shows that rainy season in Nepal including pre and post monsoon seasons will be more intense. Highly noticeable increase is found especially during June and July; while slightly lower than observed precipitation amounts are estimated for August. Precipitation scenario also indicates that winter and spring will be drier than what it is now.

Overall average trend for Nepal (Figure 2.2.1.2) indicates that the precipitation over Nepal is decreasing at the rate of 9.8 mm per decade on annual basis.

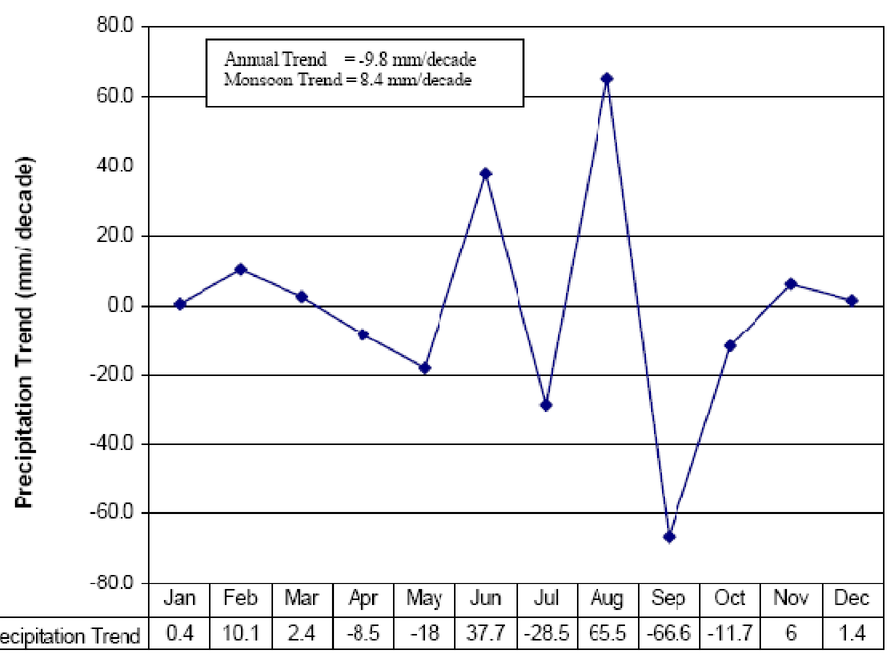


Figure 2.2.1.2: Precipitation Trend for Nepal (1981-1998) Source: (MOPE, 2004)

Average precipitation trend shows that increase in rainfall during monsoon season in Nepal is both by increase in number of rainy days and by increase in rainfall magnitudes.

Trend of monsoon onset and monsoon withdrawal (Figure 2.2.1.2 a and b) from 21 years of data show that monsoon season is elongating in both the ends, and onset has occurred earlier by 71 % of a day per annum and withdrawal is delaying by about 15%. Although this trend appears to elongate monsoon for long, it will not be possible to continue for ever due to changes in seasons. In the case of trend of withdrawal of monsoon it is not so distinct whereas the trend of monsoon onset is quite distinct. Hence before the trend terminates, monsoon may overtake some parts of pre-monsoon season.

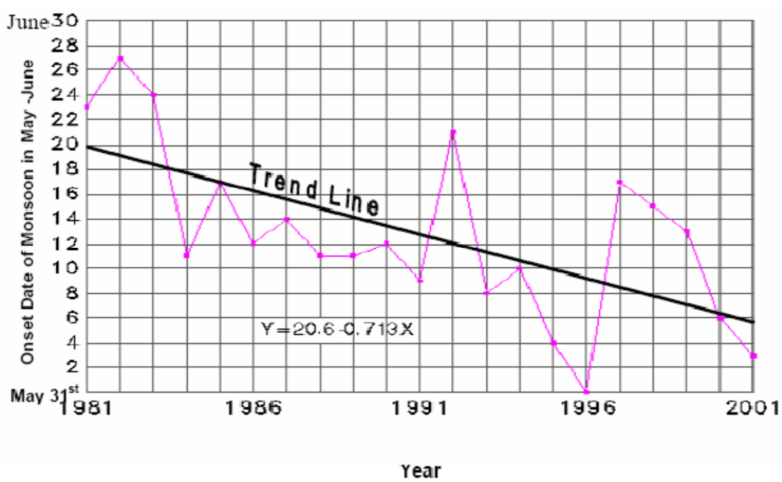


Figure 2.2.1.2 a: Variation of Monsoon Onset dates (1981-2001) Source: (MOPE, 2004)

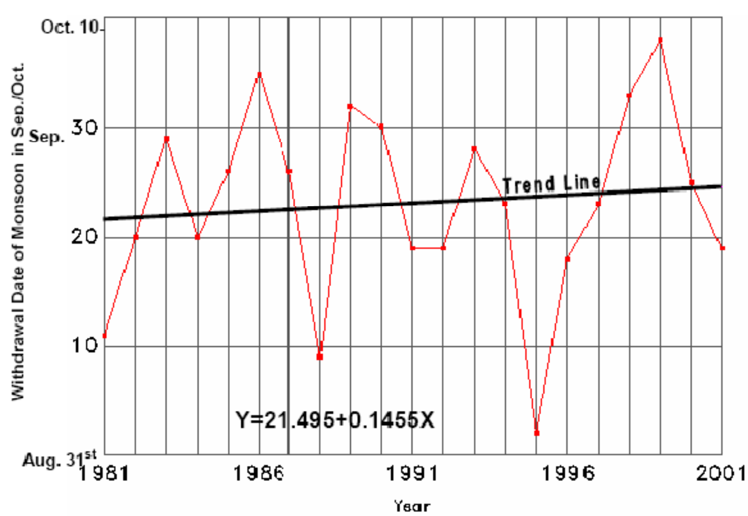


Figure 2.2.1.2 b: Variation of Monsoon Withdrawal dates (1981-2001) Source: (MOPE, 2004)

2.3 Vulnerability and Adaptation Framework for Climate Change

Vulnerability and Adaptation (V&A) frameworks provide a structure for examining the potential impacts of climate change and adaptation. There are two general types of V&A frameworks: impacts and adaptation. Impacts frameworks are sometimes referred to as "first generation" frameworks. They were mainly designed to help understand the potential long term impacts of climate change. The adaptation frameworks, sometimes referred to as "second generation" frameworks, have been designed to focus on adaptation and involve stakeholders.

Figure 3.4.2a gives the main elements of the impacts framework. First, baseline socioeconomic and environment scenarios as well as climate change scenarios are developed. These should be internally consistent. In other words, assumptions about related variables should be consistent. For example, a higher population may be associated with a higher total gross national product (GNP), but not necessarily with a higher personal income (GNP/capita). Then, biophysical impacts (sensitivity) are assessed. Impacts are integrated across related sectors and autonomous adaptations are examined. From this vulnerability can be estimated. Following that, adaptations can be examined. Many adaptations are changes to baseline conditions.

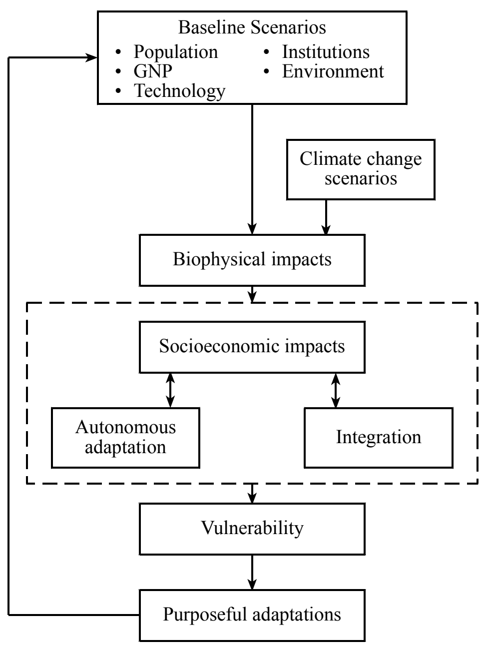


Figure 3.4.2: Main elements of impacts framework

Adaptation frameworks focus on involving stakeholders and addressing adaptation. These frameworks also put relatively more emphasis on current concerns such as vulnerability to climate variability.

Adaptation Policy Framework (Lim, B.; E. Spanger-Siegfried; I. Burton; E. Malone; S. Huq;, 2005)emphasizes stakeholder involvement and analysis of vulnerability to current climate. Figure 3.4.2b displays the framework. The process works from the bottom of the figure to the top with stakeholder involvement at each stage. The framework contains technical papers on scoping an adaptation project, engaging stakeholders, assessing vulnerability, assessing current and future climate risks, assessing changing socioeconomic conditions, assessing adaptive capacity, formulating an adaptation strategy, and continuing the adaptation process.

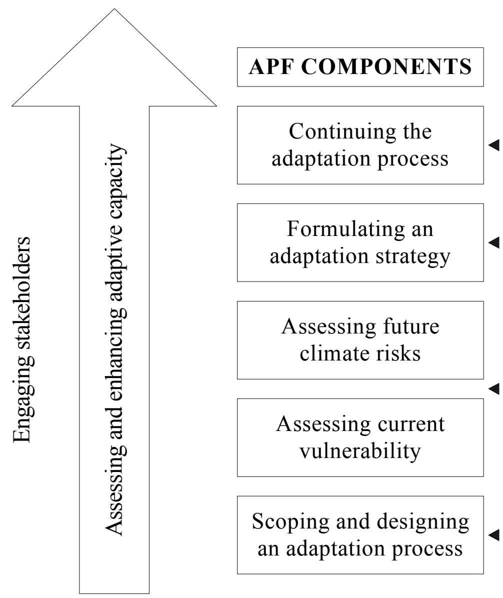


Figure 3.4.2b: Adaptation policy framework Adapted from Lim et al., 2005)

2.3.1 Water Resources

Climate change is likely to alter the hydrologic cycle in ways that may cause substantial impacts on water resource availability and changes in water quality. For example, the amount, intensity, and temporal distribution of precipitation are likely to change. Less dramatic but equally important changes in runoff could arise from the fact that amount of water transpired by plants will change with changes in soil moisture availability and plant responses to elevated CO_2 concentrations. This overview briefly summarizes potential impacts on the most important water resource elements.

Evaporation will increase with warming because a warmer atmosphere can hold more moisture. Exactly how much global average precipitation will increase is less certain. On average, current climate models suggest an increase of about 1%-2% per degree Celsius from warming forced by CO_2 (Allen & Ingram, 2002). An increase in global average precipitation does not mean that it will get wetter everywhere and in all seasons. In fact, all climate model simulations show complex patterns of precipitation change, with some regions receiving less and others receiving more precipitation than they do now.

Where stream flows and lake levels decline, water quality deterioration is likely as nutrients and contaminants become more concentrated in reduced volumes. Warmer water temperatures may have further direct impacts on water quality, such as reducing dissolved oxygen concentrations. Prolonged droughts also tend to allow accumulation of contaminants on land surfaces, which then pose greater risks when precipitation returns.

Adaptation Method: Integrated Water Resources Management (IWRM)

IWRM is a systematic approach to planning and management that considers a range of supply-side and demand-side processes and actions, and incorporates stakeholder participation in decision processes. It also facilitates adaptive management by continually monitoring and reviewing water resource situations.

To capture the supply and demand side processes and actions, IWRM must simultaneously address the two distinct systems that shape the water management landscape. Factors related to the biophysical system shape the availability of water and its movement through a watershed; factors related to the socioeconomic management system shape how available water is stored, allocated, and delivered within or across watershed boundaries. Increasingly, operational objectives of the management system seek to balance water for human use and water for environmental needs. Thus, integrated analysis of the natural and managed systems is arguably the most useful approach.

This type of analysis relies on the use of hydrologic modeling tools that simulate physical processes, including precipitation; evapotranspiration, runoff, and infiltration (Figure 5.2.1a). In managed systems, analysts must also account for the operation of hydraulic structures such as dams and diversions (Figure 5.2.1b) as well as institutional factors that govern the allocation of water between competing demands, including consumptive demand for agricultural or urban water supply or non-consumptive demands for hydropower generation or ecosystem protection. Changes in each of these elements can influence the ultimate impacts of climate change on water resources.

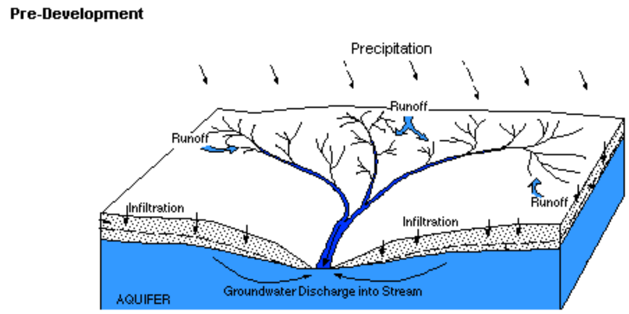


Figure 5.1.2a: Hydrologic fluxes in a "natural" watershed

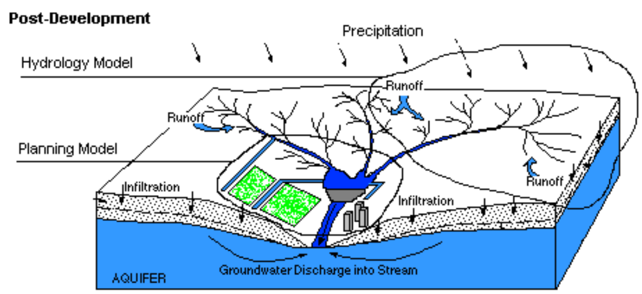


Figure 5.1.2b Hydrologic fluxes in a managed watershed
Source: Adapted from Handbook on Vulnerability and Adaptation Assessment Draft Report, UNFCCC 2005

2.3.2 Agriculture

Agriculture is strongly tributary to water resources and climatic conditions. Crop production is consequently extremely sensitive to large year-to-year weather fluctuations. Crop diseases or pest infestations are also weather-dependent, and tend to cause more damages in Nepal with lower technological levels.

The main drivers of agricultural responses to climate change are biophysical effects and socioeconomic factors. Crop production is affected biophysically by changing meteorological variables, including rising temperatures, changing precipitation regimes, and increasing levels of atmospheric carbon dioxide. Biophysical effects of climate change on agricultural production depend on the region and the agricultural system, and the effects vary through time.

Agriculture is a complex sector involving different driving parameters (environmental, economic, and social). It is now well recognized that crop production is very sensitive to climate change (McCarthy, 2001)with different effects according to region. The IPCC analysis on climate change impacts (Third Assessment Report) estimates a general reduction of potential crop yields and a decrease in water availability for agriculture and population in many parts of the developing world (Table 5.2.2.).

Table 5.2.2. Climate change and related factors relevant to agricultural production and food security

Climate factor	Direction of change	Consequences and factors that interact with agricultural production and food security
Sea level rise	***Increase***	*Sea level intrusion in coastal (agricultural) areas and salinization of water supply.*
Precipitation intensity/runoff	***Intensified hydrological cycle, so generally increases, but with regional variations***	*Changed patterns of erosion and accretion; changed storm impacts.* *Changed occurrence of storm flooding and storm damage, water logging, increase in pests.*
Heat stress	***Increases in heat waves***	*Damage to grain formation, increase in some pests.*
Drought	***Poorly known, but significant temporal and spatial variability expected***	*Crop failure, yield decrease.* *Competition for water.*
Atmospheric CO_2	***Increase***	*Increased crop productivity but also increased weed productivity and therefore competition with crops.*

Source: Adapted from Handbook on Vulnerability and Adaptation Assessment Draft Report, UNFCCC 2005

Adaptation Options: Technology and Policy

A few emergency management items such as construction of emergency shelters and provision of housing for disaster-affected families have been proposed in the tenth plan but given the enormity of climate change, policies that help slow down the climate change and those that aod to adapt are also required (Alan & Regmi, 2005).The actions need to be taken to reduce the rates and quantity of the GHGs released by agricultural related activities. Policies can be taken to impose environmental taxes on nitrogen fertilizers, promote better timing of fertilizer and manure applications, development of rice cultivars emitting less methane, better feed quality for livestock waste management and expansion of agro-forestry. On adaptive side, measures such as breeding of greater tolerance of crops, vegetables, livestock and fish to higher temperatures, development of low cost water conservation technologies, development of early warning and drought and food forecasting systems, preparedness plans for relief and rehabilitation, development and implementation of land use systems that stabilize slopes and reduce the risks of soil erosions and landslides, and construction of livestock shelters and food stores can be taken to alleviate the effects of extreme conditions affecting agriculture and livelihoods((IISD & IES, 2007).

2.3.3 Health

Climate Change will have both direct and indirect impacts on human health. Indirect impacts of Climate Change to health may come from crop damage or water shortage. More direct impacts are vector-borne diseases. Rising temperatures may make certain diseases more active. Because of the poor state of health services in Nepal, public health can indeed be at higher risks than before from unfavorable effects of Climate Change. Malaria and Japanese Encephalitis are the two most common vector-borne diseases in the country, mosquito being the vector of these diseases.

The general trend of Malaria positive cases was found increasing during the period 1963 to 1985, and then decreased due to mitigation measures taken (Figure 5.2.3a).

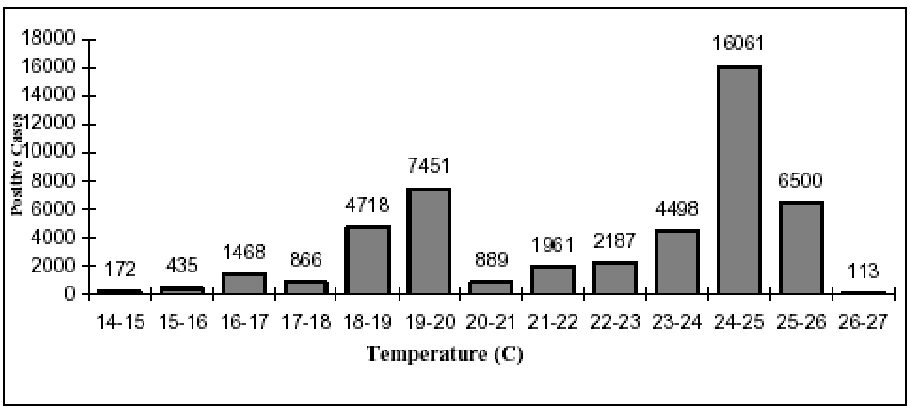


Figure5.2.3a: Average Temperature and Positive Cases of Malaria in Nepal

Source: MoPE/UNEP 2004

Malaria positive cases are reported, when the average annual temperature is between 14 and 27º C, with the highest number of cases at 24-25º C in the tropical zone. Malaria cases are also found in the subtropical (18-24º C) and warm temperate (14-18º C) regions of Nepal. Obviously rise in temperature due to Climate Change will increase the Malaria cases; particularly subtropical and warm temperate regions of Nepal will be more conducive to the diseases. Temperatures between 22 and 32º C are very favorable for Malaria diseases to develop and complete their cycle, while those above 32-34º C could reduce their survival rates substantially (MOPE, 2004). Thus the range of temperatures in Kathmandu Valley is becoming suitable for the Malaria parasites to exist & develop.

Similarly, the Japanese Encephalitis occurs mainly at the average annual temperature range of 23-26ºC, and increase in temperature will make the subtropical regions more vulnerable to this disease. Vulnerability is becoming serious in Nepal as the number of patients of this disease is increasing every year in the country most probably due to rising trend of temperatures (Figure 5.2.3b).

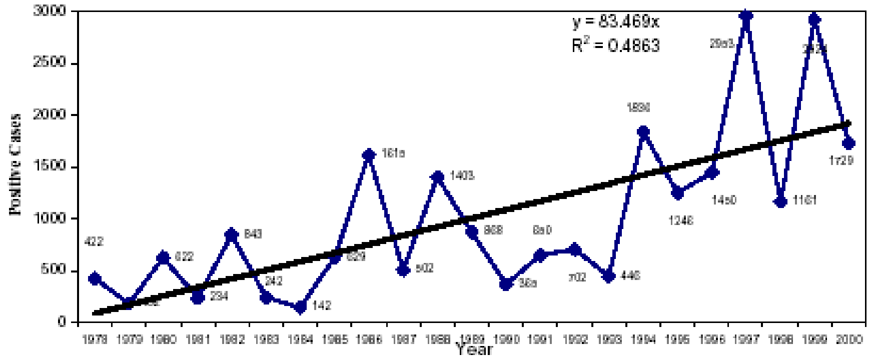


Figure 5.2.3b: Annual Total Positive Cases of Japanese Encephalitis in Nepal

Source: MoPE/UNEP 2004

<u>**Adaptation Options:**</u>

Since diseases like Malaria and Japanese Encephalitis are likely to occur mainly in the poor regions of Kathmandu Valley, they spread through mosquitoes that flourish well in hot (up to 40º C) and polluted stagnant wetlands. The cleanliness of the area is the most important requirement for adaptation. However, serious consideration must be taken of the potential side effects of such adaptation measures as the use of chemicals to control mosquitoes. But Kathmandu Valley has already experienced the emergence of chemical resistant mosquitoes. Hence, research and development of alternative approaches to cure and eliminate these diseases are needed. Quarantine program needs to be strengthened, and effective mechanism on eradication and disease control program should be given more emphasis. In this regard, ethno botanical information may be useful to prevent or control these diseases. Promotion of health education for creating community awareness to diseases may be an effective adaptive measure to prevent occurrences these diseases.

The Study was carried out in Kathmandu Valley on the basis of secondary data observed by Department of Hydrology and Meteorology (DHM), Ministry of Environment, Science and Technology, Kathmandu Nepal.

3.1 Study Area

3.1.1 Geography

Kathmandu Valley is located between latitude 27.34° N and 27.50° N and longitude 85.11° E and 85.32° E. The valley is almost a circular bowl-shaped and surrounded on all sides (although the narrow gap in the south) by the mountains which have a height of about 2,122m on average., its east-west axis being about 25 km in length with a maximum north-south width of nearly 19 km(Figure 3.1.1). Its area is approximately 339 sq. km. The valley lies at an average altitude of 1350 m above mean sea level (msl), with hills and mountain ranges rising rather steeply on all sides completely enclosing the valley. The lowest altitude in the valley floor is 1230 m at Katuwaldah gorge in the south-west and the highest peak is Phulchowki in the south-east at an altitude of 2762m (HMG/IUCN, 1995).

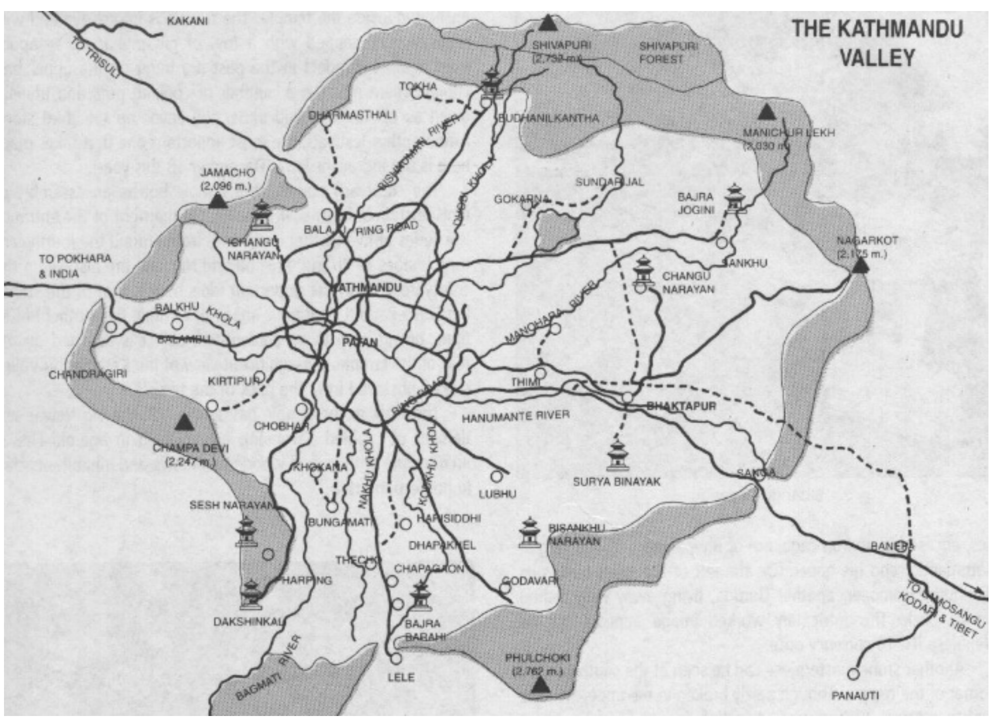


Figure 3.1.1: Map of Kathmandu Valley showing observed stations (Source: www.gpgrieve.org)

Specially the Valley floor has two distinct level a) the higher plateau-like flat surface composed of brown fragile sandy, horizontally bedded, deposits of the lacustrine origin, and b) the low lying alluvial flood plain which has the river flowing in meandering courses, and contains the recent alluvia, freshly deposited by rivers almost every year. The most striking feature of the higher plateau- like surfaces and the low-lying alluvial plain, popularly known as *Tar* and *Dol* respectively, is the remarkable flatness of their surfaces. The edge of the Tar slopes to the Dol with a fairly steep gradient.

Bagmati is the main river in the valley which originates at Bagdwar, in the northern part of the valley. It flows by creating meandering courses along the valley floor. The first one is at Kapan-Gokarna ridge, second at Pashupati, third at Chobhar where most of the water bodies of the valley find their way to the south through this gorge and the last one is at Katuwaldah.

3.1.2 Climate of Kathmandu

Kathmandu Valley is influenced by the Indian monsoon. The general pattern is characterized by a hot season in May and June, followed by a well-defined monsoon during July, August and September, and an almost rainless, cold winter in December, January and February. Kathmandu has an annual rainfall of 1,400 mm, with the 1997 annual rain fall recorded at 1528 mm (DHM, 1998). Average annual rainfall varies from 1221.6 mm at Khumaltar in Lalitpur to 2832.8 mm at Kakani, a station located northern hills of valley (Karki, 2008). The normal onset date for monsoonal rainfall is 12 June for Kathmandu (Yogacharya, 1998). Wind is ordinarily light throughout the year, but there is a strong wind in and around the hot season. The temperature in Kathmandu may drops below freezing in winter and in summer it may rise to 35 °C. The mean annual temperature in Kathmandu is 18 °C. The coldest month is January with a mean temperature of 10 °C. The warmest months are July and August, with an average temperature of 24 °C. Fog is common in the morning during the months of October to February (Pandey, 1987).

A high altitudinal variation with extreme diurnal radiation leads to a potentially strong cooling system in the night and a warming in the day. During the dry winter season, cooling in the morning and late afternoon cause the formation of deep inversion layers (Figure 3.1.2). When the inversion layer is deep enough, insulation may not break through the inversion (Pandey, 1987). This situation of temperature inversion may last for several days, especially during the winter period which entraps accumulated pollutants within the valley air basin resulting in high particulate concentrations (Sapkota & Dhaubhadel, 2000).

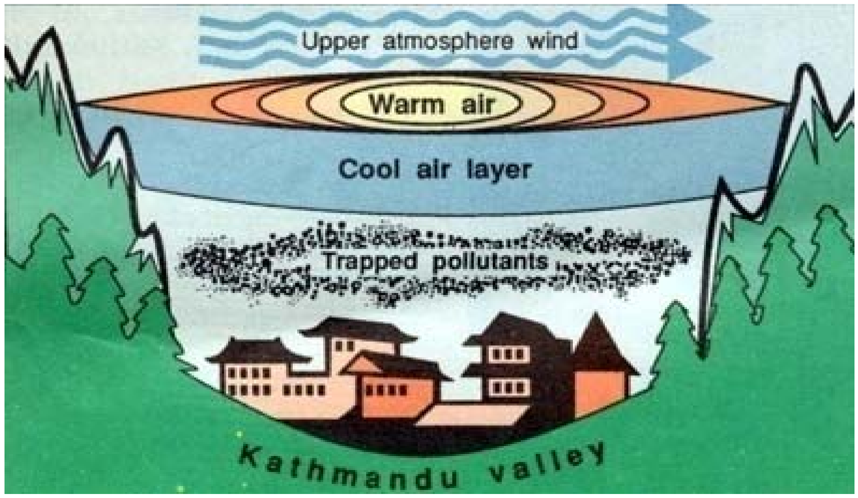


Figure 3.1.2: Atmospheric inversion over Kathmandu during winter

Source: (Tuladhar, 2004)

The average temperature has increased slightly by 1.5°C, this shifts can be said to be significant only in that it is indicative of a warming trend caused by escalated vehicular emissions, urbanization and loss of green areas in the valley. Frosts occur during January and early February, however, the number of frost days and the intensity of frost have declined in the last 15 years (HMG/IUCN, 1995).

In general, the climate of the valley is suitable for the cultivation of summer crops such as rice, maize, and soyabean during the monsoon season, and wheat, mustard and potato in winter. However, the variation in topographical gradients and elevation permits the cultivation of diverse plant species in the valley (HMG/IUCN, 1995).

3.2 Sampling Stations

5 different stations were selected namely Kathmandu Airport, Nagarkot, Khumaltar, Budhanilkantha and Panipokhari were taken for temperature data and respective data of the stations mentioned above along with Sankhu, Godavari, Thankot, Bhaktapur and Chapagaon on rainfall with were taken into account from the large number of meteorological stations operational under the Department of Hydrology and Meteorology (DHM) in and around the valley. However, time series data in all stations are not available, and the duration of observations varies from station to station. The key station equipped with automatic recording instruments is the one located at the Tribhuvan Airport in Kathmandu. A meteorological station for agricultural purposes has been established at Khumaltar. Some of these stations lie

at the outskirts of the Kathmandu Valley in case of Nagarkot. The sampled stations are depicted in Table 3.

Table 3: List of Sampled Stations

S.No.	Station Name	Index No.	Latitude (°/min.)	Longitude (°/min.)	Elevation (m.)
1	Bhaktapur	1052	2740	8525	1330
2	Budhanilkantha	1071	2747	8522	1350
3	Chapagaon	1060	2736	8520	1448
4	Godavari	1022	2735	8524	1400
5	KathmanduAirport	1030	2742	8522	1336
6	Khumaltar	1029	2740	8520	1350
7	Nagarkot	1043	2742	8531	2163
8	Panipokhari	1039	2744	8520	1335
9	Sankhu	1035	2745	8529	1449
10	Thankot	1015	2741	8512	1630

3.3 Sample Collection

The required data and information were collected from different agencies like Department of Hydrology and Meteorology (DHM), Central Library of Tribhuvan University (CLTU), different official annual reports bulletins, journals, different books and theses, all of these sources were mentioned in the reference of this thesis paper, of various researchers. So, their contributions were acknowledged by citation. Further, more information were obtained from the websites of different countries related to climate change and winter. Necessary maps, charts, diagrams were presented for the illustration of discussions and findings. Finally a thesis is prepared to fulfill the objectives.

All data are collected from Department of Hydrology and Meteorology (DHM) except in the case of data for rainfall and temperature of 2006-2009 for winter season are collected from “Weather Summary of Nepal” from the year 2006 to 2007 published by Department of Hydrology and Meteorology. The daily data for rainfall and temperature of Kathmandu Airport were obtained from different national daily like The Himalayan Times and Gorkhapatra and some data, from 20th February 2009 to 28th

February 2009, are collected from the website of Meteorological Forecast Division (***www.mfd.gov.np***) of Department of Hydrology and Meteorology.

3.4 Analysis Technique

The standard interval adopted by the World Meteorological Organization (WMO) for climatic statistics is thirty years: 1901-30, 1931-60, for example. However, for historical records and proxy indicators of climate, longer, arbitrary time intervals may be necessary to calculate average values. Tree rings and ice cores can give seasonal/annual records, while pear bog and ocean sediments may provide records with only 100- to 1,000-years time resolution. Hence, short-term changes and the true rates of change may, or may not, be identifiable (Barry & Chorley, 2002).

The climatic state is usually described in terms of an average value (arithmetic mean, or the median value in a frequency distribution), a measure of variation about the mean (the standard deviation, or inter-quartile range), the extreme values, and often the shape of the frequency distribution. A change in climate can occur in several different ways. For example there may be shift in the mean level, or gradual trend in the mean. First, it is important to determine whether they are an artifact of changes in instrumentation, observational practices, station location, or the surrounding of the instrumental site, or due to errors in the transcribed data. Even when changes are real, it may be difficult to ascribe them to unique causes because of the complexity of the climate system. Natural variability operates over a wide range of time scales, and superimposed on these natural variations in climate are the effects of human activities (Barry & Chorley, 2002).

3.4.1 Statistical Methods

Statistical methods are used widely in the field of hydrology and meteorology, as these methods specially adapted to the elucidation of quantitative data affected by a multiplicity of causes (Yule & Kendall, 1999).

Fundamentally, statistics is concerned with uncertainty. Evaluating and quantifying uncertainty, as well as making inferences and forecasts in the face of uncertainty, are all parts of statistics. It should not be surprising, then, that statistics has many roles to play in the atmospheric sciences, since it is the uncertainty in atmospheric behavior that makes the atmosphere interesting. For example, many people are fascinated by weather forecasting, which remains interesting precisely because of the uncertainty that is intrinsic to the problem. If it were possible to make perfect forecasts even one day into the future (i.e. if there were no certainty involved), the practice of meteorology would be very dull, similar in ways to calculation of tide tables (Wilks, 2006).

3.4.1.1 Arithmetic Average (Mean) Method

The average monthly data of certain years were missing. Mean rainfall and mean temperature is computed to find out the mean characteristics and the variability of the data. Such data are fulfilled by Arithmetic Average (Mean) Method. In this method the simple arithmetic mean of the monthly data is obtained and the mean value is used as the missing data. If x_1, x_2, x_3, ..., x_n represents the series of values then the arithmetic mean of the series is given by

$$\overline{X} = \frac{1}{N}\sum_{1}^{n} x_i$$

where N is the total number of values in the series. Mean rainfall and mean temperature is computed to find out the mean characteristics and the variability of the data.

3.4.1.2 Linear Regression Analysis

Literally, regression means,' *stepping back or returning to the average value*.' In the words of M.M. Blair, "Regression analysis is a mathematical measure of the average relationship between two or more variables in terms of the original unit of the data" and according to Morris Hamburg, "it is the methods by which estimates are made of the values of a variable from knowledge of the values of one or more other variables and to the measurement of the errors involved in this estimation process." Thus, in actual, regression is a fundamental relationship between a dependent random variable and one or more independent random variable(s). The general form of the regression function is

$$Y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_kX_k + C$$

Where (b_o, b_1, b_2,......, b_n) are the regression coefficients, X and Y are two variables and C is a constant.

Line of Regression: Line of regression is the line which gives the best estimate of one variable for any given value of the other variable. The line of regression (best fit) of *x* and *y* is given by

$$y = a + bx$$

In this study linear analysis is carried out to study the trend of climate i.e. climatic parameters (rainfall and temperature).

3.4.1.3 Bar Diagram: In a bar diagram, the rainfall is represented as a rectangular bar whose height denotes the magnitude of the rainfall to some scale.

Chapter 4: DATA PRESENTATION AND INTERPRETATION

4.1 Overview of Temperature Data

Nagarkot (1993/94-2003/04): The winter of 1998/99 was the hottest winter season for Nagarkot. The mean maximum and mean minimum temperature is the highest with temperature 15.61 °C and 5.20 °C respectively. The extreme maximum temperature is 26 °C in 14th February 2002 and extreme minimum temperature is -1.6 °C in 23 January 1997.The days with less than 1 °C temperature is decreasing.

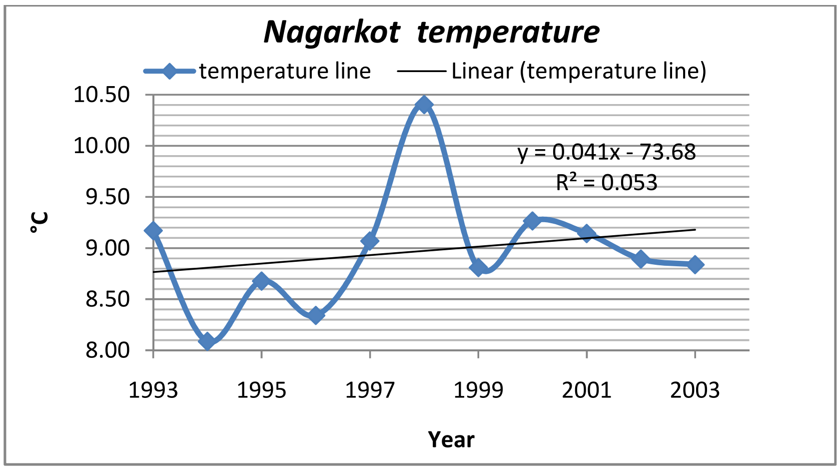


Figure 4.1a: Temperature trend of Nagarkot

Panipokhari (1995/96-2003/04): The mean maximum and mean minimum temperature are 18.86 °C and 4.38 °C respectively. The winter 1998/99 is the hottest winter season of the last decade of 20th century with mean of 26 °C and extreme maximum temperature of -2.4 °C observed in 12th January 1999.

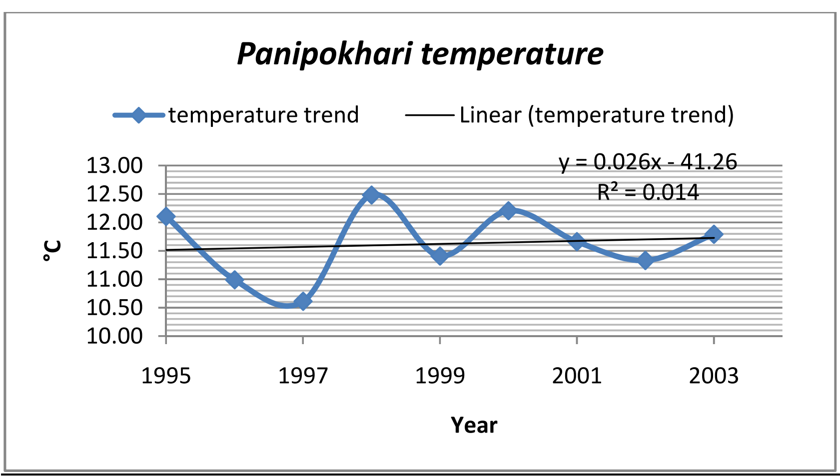


Figure 4.1b: Temperature trend of Panipokhari

Khumaltar (1987/88-2003/04): Unlike above two stations, Khumaltar experienced a hottest winter with mean of 27.8 °C in winter of 1999/00. In 21 January 1998, -3.8 °C was recorded as extreme minimum temperature and 27.8 °C as extreme maximum temperature on 18 December 1999.

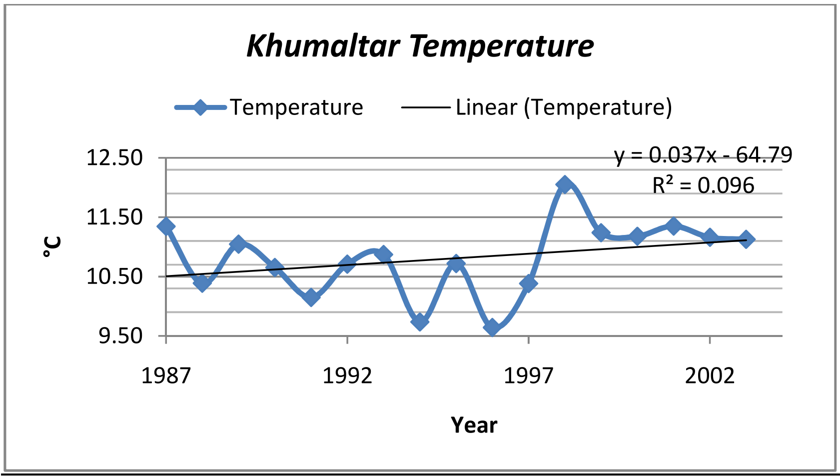


Figure 4.1c: Temperature trend of Khumaltar

Kathmandu Airport (1975/76-2008/09): 34-years data were analyzed for Kathmandu Airport Station from winter 1975/76 to 2008/09.The highest average maximum temperature is found during the winter year 2008/09 and is 23.5 °C. The temperature shows an increasing trend and is significant. From winter of 1998/99 the there is rapid increase in temperature.

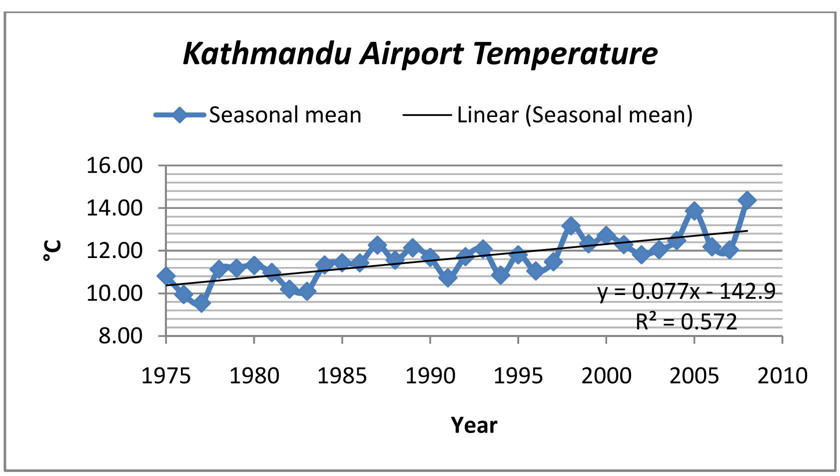


Figure 4.1d: Temperature trend of Kathmandu Airport

Budhanilkantha (1989/90-2003/04): The winter of 1998/99 became the hottest winter of the decade with 13.21 °C of average winter mean, and in the same winter maximum extreme of 25.7 °C was recorded in 20th February 1999. The minimum temperature has reached up to -1.3 °C in 21st January 1993.

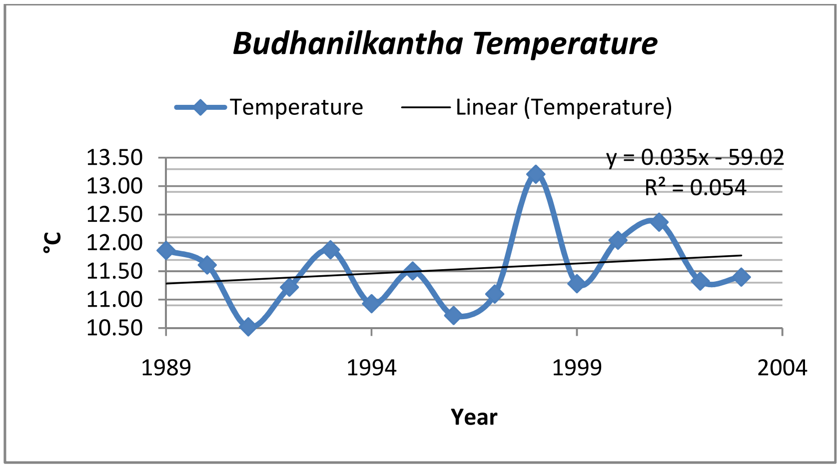


Figure 4.1e: Temperature trend of Budhanilkantha

4.2 Temperature Interpretation

The air temperature in Kathmandu Valley is greatly influenced by monsoon and altitude. The winter mean, winter mean maximum and minimum; and extreme maximum and minimum temperatures with respective dates recorded in selected winter year at Kathmandu Airport, Panipokhari, Nagarkot, Budhanilkantha and Khumaltar are presented in Appendix 1.

The data show that weather is cool from December to February with a mean temperature of about 11 °C. The January is the coldest month of winter season with mean temperature of about 10 °C and temperature falls below freezing point.

4.3 Main features of Rainfall Data

Panipokhari (1971/72-2004/05): From the data considered 100.9 mm rainfall is the highest amount received in winter 1986/87. No rainfall is measured in two successive winters, 1999/00 and 2000/01 whereas in 16 January, 1995 in 24 hours maximum amount is received as 62.5 mm.

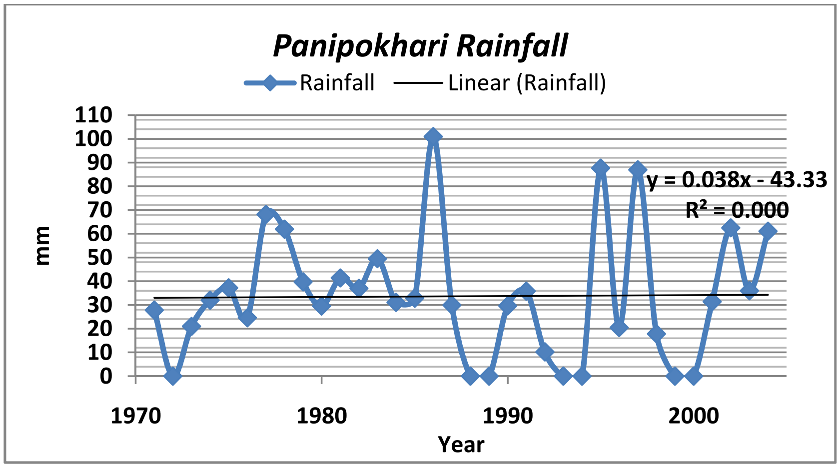


Figure 4.3a: Winter Rainfall trend at Panipokhari

Budhanilkantha (1987/88-2004/05): 110.2 mm is the highest amount of rainfall received for the considered year in 1997/98. In 1995/96, 24hrs maximum rainfall is received as 42.8 mm in 16 January, 1996 whereas no rainfall is observed in winter 2001/2002.

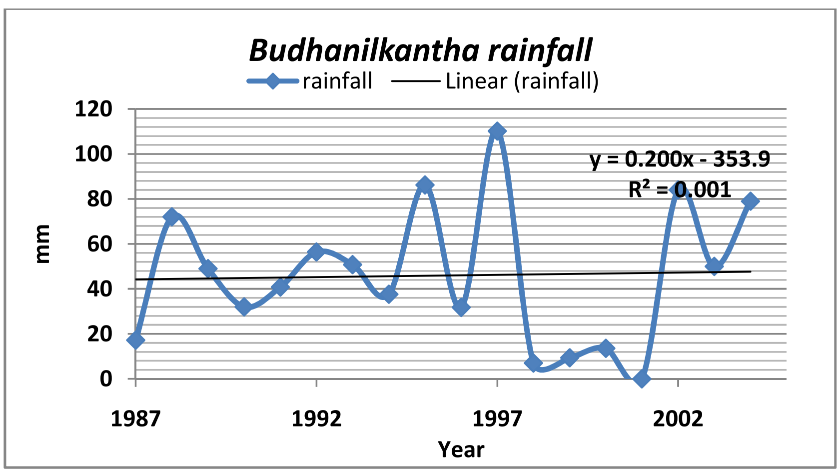


Figure 4.3b: Winter Rainfall at Budhanilkantha

Kathmandu Airport (1968/67-2008/09): 115.7 mm is the highest amount of rainfall received in winter 1997/98.The 24hrs maximum rainfall is highest in 1995/96 winter which is 62 mm in 16 January, 1996.And maximum rainy days was recorded in 1974/75 for 14 days with 24hrs maximum rainfall of only 11 mm in 2 Feb 1975.For the first time in recorded history, Kathmandu recorded 0 mm of winter rainfall for the year 2005/06.This time the valley did not experience a drop of rain since November

2005. This is the longest dry spell in Kathmandu ever recorded in winter. Whereas, the following winter 2006/07 received a snowfall in Kathmandu Valley after 62 years on 14 February 2007.Again there traces or no recordable amount of rainfall for two successive winter s i.e. winter 2007/08 and winter 2008/09.

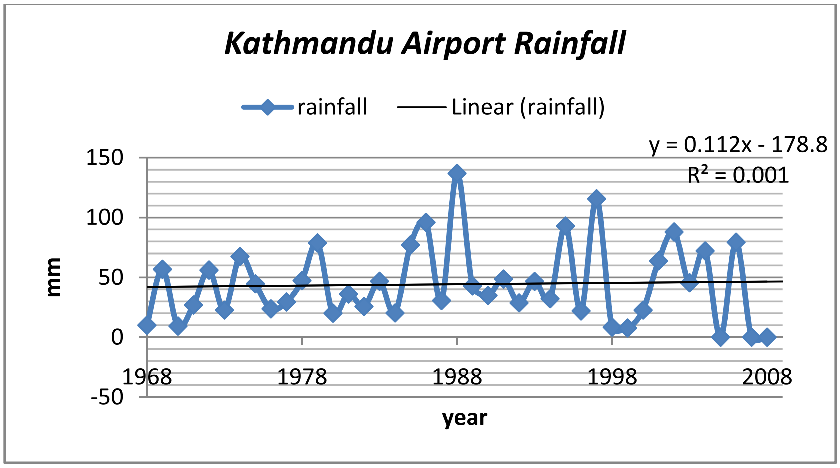


Figure 5.3c: Winter Rainfall at Kathmandu Airport

Nagarkot (1971/72-2004/05): The highest amount of winter rain was received is 157.3 mm in 2002/03 by 11 days rainfall and in that winter 24hrs maximum precipitation was recorded in 1 Feb 2003 is only 26.2 mm. Winter of 1999/00 is without rainfall.

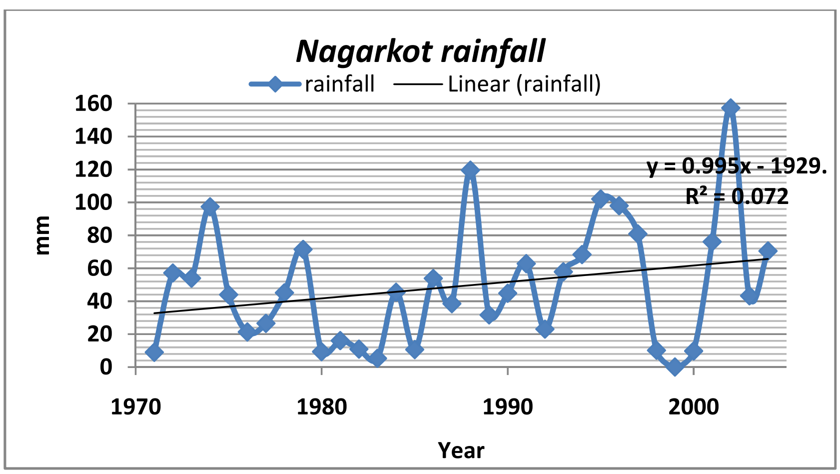


Figure 4.3d: Winter Rainfall at Nagarkot

Khumaltar (1967/68-2004/05): The highest amount of rainfall received in Khumaltar is 174.5 mm in 1988/89 with 78 mm as the maximum amount received for 24hrs. Very scanty amount of only 2.4 mm is received in 1998/992 with max 24hrs of 2 mm. Almost, every winter rainfall is observed in Khumaltar station.

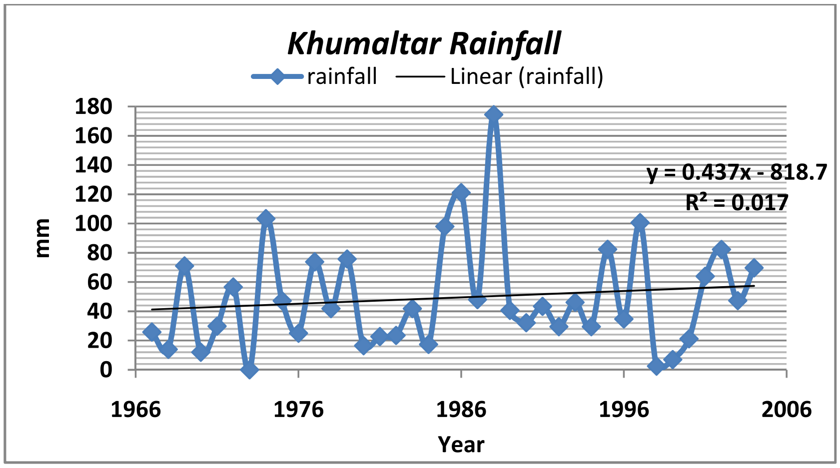


Figure 4.3e: Winter Rainfall at Khumaltar

<u>Sankhu (1971/72-2004/05):</u> In 1980/81 winter no rainfall is experienced whereas following winter of 1981/82 received 171.9 mm from 9 days storms. Also, winter of 2004/05 no rainfall storm occurred.24hrs maximum rainfall of 55 mm was received in 15th January, 1996, winter of that year 1995/96 has 11 days of rainfall.

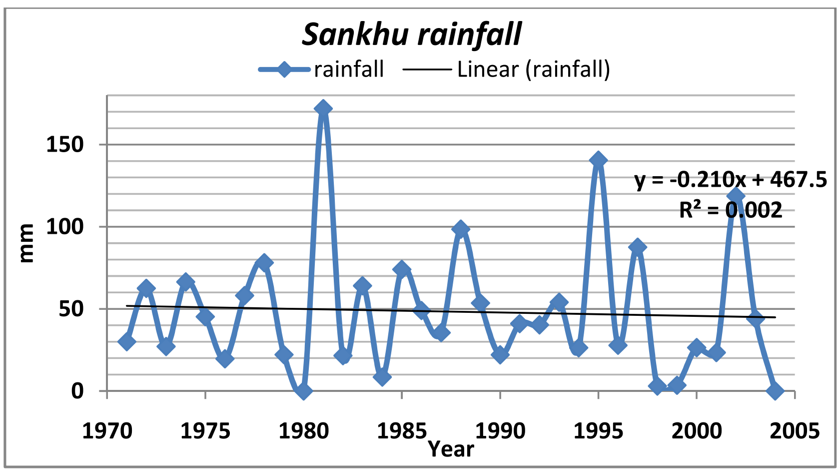


Figure 4.3f: Winter Rainfall at Sankhu

<u>Godavari (1971/72-2004/05):</u> The highest recorded 24 hour rainfall is 77.2 mm in 16 January 1996.And, 167.5 mm was the highest winter rain received in 1988/89 when 7 days of rainfall was experienced with 24 hour maximum rain of more than 50 mm on 26th December, 1988.

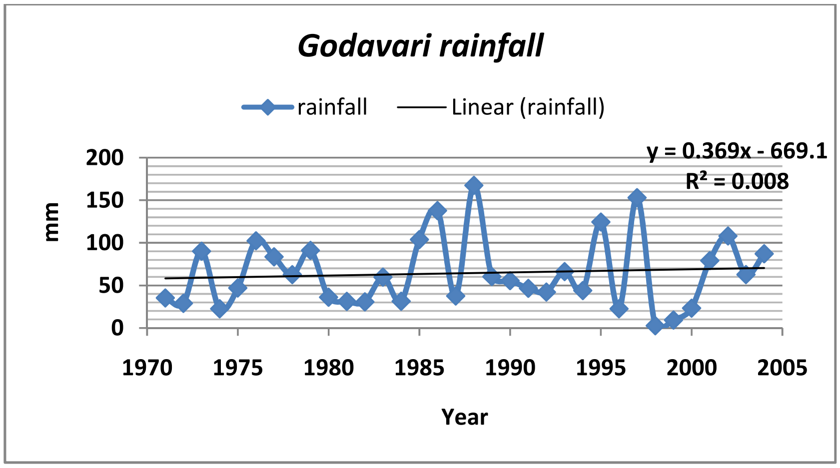


Figure 4.3g: Winter Rainfall at Godavari

Thankot (1970/71-2004/05): The highest amount of winter rainfall received is 212.8 mm in 1988/89 when 2 days with more than 50 mm of rainfall occurred. In this same winter, 24 hour maximum rainfall of 66.4 mm was experienced on 27th December, 1988. In these period 4.3 mm was the least amount of rain received in winter of 1998/99 with single day rain storm.

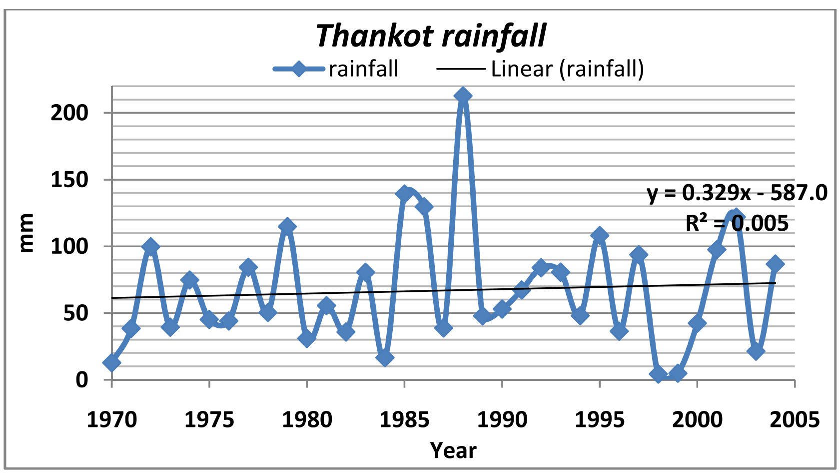


Figure 4.3h: Winter Rainfall at Thankot

Bhaktapur (1971/72-2004/05): 153.3 mm in winter of 1995/96 was the highest rainfall amount received in Bhaktapur station with 24 hour maximum rainfall of 51.3 mm in 16th January, 1996, whereas no rainfall recorded in 1988/89 winter.

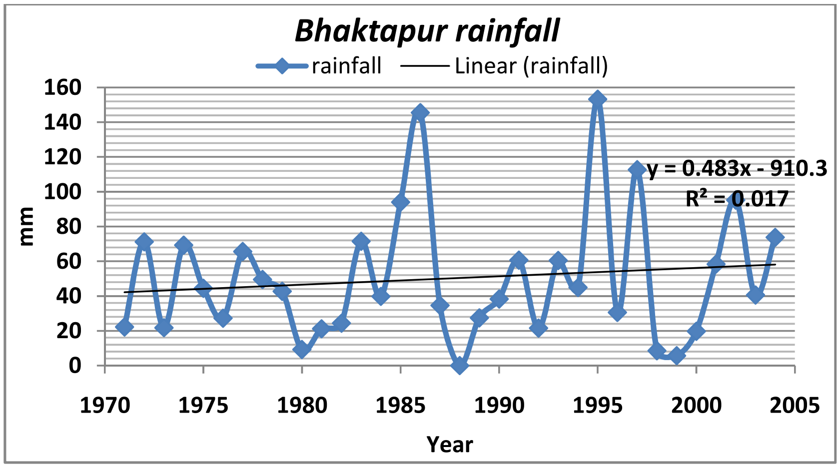


Figure 4.3i: Winter Rainfall at Bhaktapur

Chapagaon (1976/77-2004/05): In 1988/89 highest amount of winter rainfall of 159.6 mm was received with 24 jour maximum rainfall of 61 mm in 26th December, 1988 as the highest extreme for the considered period. In 1999/00, only 1.5 mm of rainfall received in 11th February, 2000.

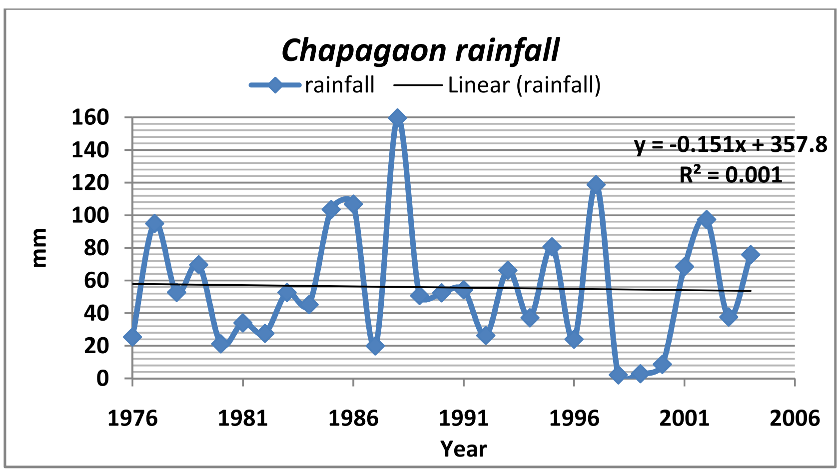


Figure 4.3j: Winter Rainfall at Chapagaon

4.4 Precipitation (Rainfall) Interpretation

Winter seasonal mean annual precipitation (rainfall) does not totally vary with altitude (Table 4.4); though mean annual precipitation varies according to altitude (HMG/IUCN, 1995).Average winter seasonal rainfall varies from 68.48 mm at Godavari (1400 m) in south-western side, to 33.46 mm at Panipokhari in central part of the city area. Rainfall is generally higher in the valley hills than in the valley floor. The northward facing slopes in the southern part of the valley received more rain than the south facing the northern part which is just reversible in summer monsoon.

There is marked spatial and temporal rainfall variation in the valley due to topography and other effects. The central valley received about 33 mm of winter rainfall, while the southern slopes have more than 55 mm of winter rainfall. The high hill around the valley receives snowfall during winter though it has been suspended after snowfall event observed after 62 years in the valley floor in 14 February 2007.

Table 4.4a: Mean Winter Seasonal rainfall in Kathmandu Valley

Station	Elevation(m)	Duration	Rainfall(mm)
Panipokhari	1335	1973-2005	33.64
Budhanilkantha	1350	1989-2005	45.94
Kathmandu airport	1336	1960-2005	46.88
Sanku	1449	1971-2005	48.33
Nagarkot	2163	1971-2005	49.19
Khumaltar	1350	1967-2005	49.27
Bhakatapur	1330	1971-2005	50.16
Chapagaon	1448	1976-2005	55.74
Thankot	1630	1970-2005	66.89
Godhavari	1400	1971-2005	68.48

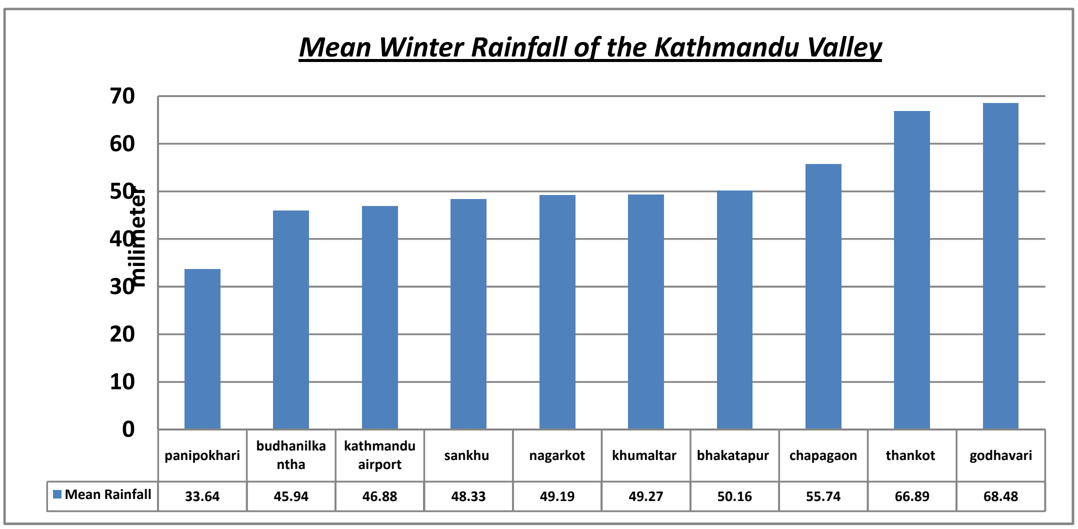


Figure 4.4: Mean Winter Seasonal rainfall in Kathmandu Valley

The 24 hour maximum rainfall distribution varies within the valley(Table 4.4b).The extreme rainfall is at the same day of the year in the stations, Bhaktapur, Budhanilkantha, Kathmandu Airport, Panipokhari and Sankhu but the amount are different. And, Chapagaon, Godavari, Khumaltar and Thankot gets the extreme amount of rainfall in the same day of the year. But the rainfall amount is different in case of Nagarkot in this regard.

Table 4.4b:24 Hour Maximum Rainfall

Station	24hrs max	year	date
Bhaktapur	51.3	1996	16-Jan
Budhanilkantha	42.8	1996	16-Jan
Chapagaon	61	1988	26-Dec
Godavari	50	1988	26-Dec
Kathmandu Airport	62	1996	16-Jan
Khumaltar	78	1988	27-Dec
Nagarkot	26.1	2003	1-Feb
Panipokhari	62.5	1996	16-Jan
Sankhu	55	1996	15-Jan
Thankot	66.4	1988	27-Dec

5.1 Climate Change Scenario

5.1.1 Temperature

Temperature, undoubtedly, is the most important climatic variables used in every impact analysis. It has been found that temperature generally decreases with rise in elevation i.e. valley floor has high temperature than surrounding hills and towards country side.

In all the stations analyzed, the temperature shows an increasing trend. The Kathmandu Airport Station shows a significant increasing trend and is important stations for the valley. Up to winter 2004/05 mean temperature is highest in winter 1998/99 with average of 12.26 °C. But the mean temperature recorded in Kathmandu Airport station shows that winter 2005/06 break the early record and again winter 2008/09 break the previous records.

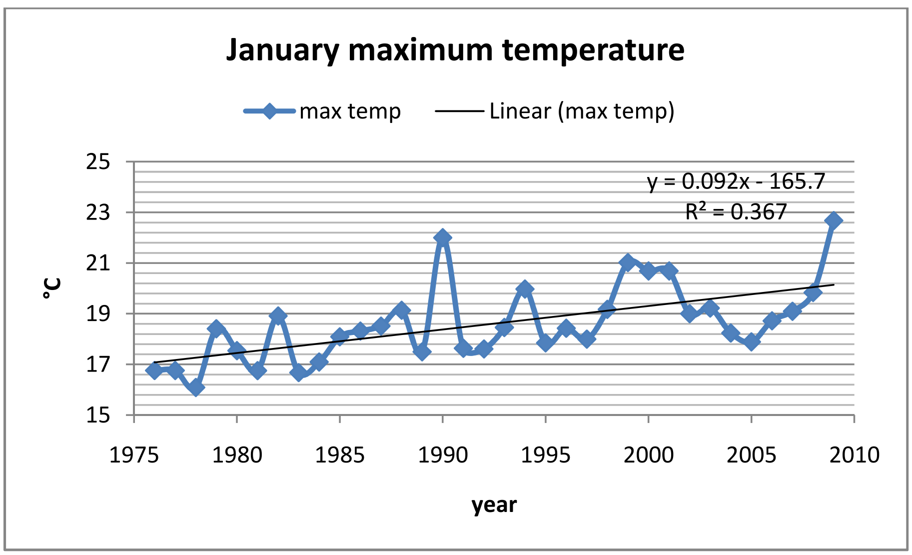


Fig 5.1.1 January maximum temperature trend (Kathmandu Airport Station)

January is mid winter month and the figure 5.1.1 shows the maximum temperatures are rising during this month which provide evidence to warming of the valley. This rising trend line of maximum temperature means diurnal temperature are raising during January.

The annex 1 provides information on Winter Temperature of Kathmandu Valley.

5.1.2 Precipitation

Mean precipitation describes an average seasonal or annual precipitation observed in the station. The Table 4.4 and Figure 4.4 illustrate the mean precipitation in the valley for different stations. Almost in all the stations (see Figure 4.3(a-j) rainfall is increasing but has no significant trend.

The winter precipitation in the Kathmandu Valley is due to western disturbances which is the main rain bearing weather system in winter which is brought by the upper air westerly troughs (low pressure system). Sometimes low pressure systems (LPS)/depressions formed over southern parts of Bay of Bengal (BoB) and Arabian Sea intensifying the western disturbances, enhancing rainfall activity in Nepal. But, when LPS formed over BoB were feeble and the western disturbances moved northeastward towards Tibet just touching northwestern part of Nepal. Then, there is no rain condition in winter in Nepal so in Kathmandu Valley (DHM, Weather Summary of Nepal Year-2006, 2007).

Normally, Kathmandu used to have one rainfall spell in December and two spells each in January and February. But, for the first time in recorded history in winter 2005/06, the Kathmandu Valley experienced the longest dry spell. After 62 years, Kathmandu received a little snowfall in the city floor and heavy snowfall around the hills of the valley on 14th February, 2007. Again, winter 2007/08 and 2008/09 remained dry, only traces or no recordable amount is received in the valley.

The annex 2 provides information on precipitation (rainfall) data.

5.1.3 Sources of Greenhouse gases Emission in the valley

Greenhouse gases are defined as, ‘Gases in the atmosphere that absorb and re-emit infrared radiation. These gases occur through both natural and human-influenced processes. The major GHG is water vapor. Other GHGs include CO_2, N_2O, CH_4, Ozone, and CFCs’ (IPCC, EMISSION SCENARIOS, 2000).

Due to urbanization, the Kathmandu Valley has different sources of GHGs mainly, Energy Sector, Land Use Change (see Section 5.1.4) and Solid Waste.

Carbon dioxide emissions depend on the type and amount of energy consumed, energy consumption is closely linked to the socio-economic development of a country. Hence, projection of CO_2 emissions from the energy sector is based mainly on projections of the population and economic growth of a country over a specific period in the future. Besides, other Greenhouse Gases are also emitted from a number of activities that uses energy such as residential and commercial cooking, space heating, industrial processes, transportation and so on (IPCC, EMISSION SCENARIOS, 2000). So, in the similar way, the Kathmandu Valley's energy consumption rate is high.

Since solid waste disposal is specifically an urban problem as it is poorly managed, present study was concentrated only on the principal municipalities of Nepal. According to the analysis, the emission of Methane in Kathmandu Valley was estimated at 2.56 Gg in 1994/95, and the combined Methane emission from all other 58 municipalities of Nepal was estimated at 9.69 Gg/year for the same year (Restuc, 1999).

5.1.4 State of Land Use, Land Use Change and Forestry

The transformation of agriculture area and forest area has increased over the past ten years period in the valley with the significant depletion of stock biomass. Area under natural forest with more than 50 % crown cover has decreased from 7562 ha in 1984 to 2070 ha in 1994, an annual decrease of 7.3 % (Table 5.1.4).

The urban areas including residential area have increased significantly from 3096 ha in 1984 to 8378 ha and this increase has been mainly at the expense of the agricultural land, mostly in valley floors, flood plain areas, *Tars* and level terraces.
A study carried out by Kathmandu Valley Town Development Committee in 2001 revealed that between 1984 and 2000, land covered by urban settlements had increased from 3,096 to 9,193 ha. Similarly, agricultural land had decreased from 40,950 to 27,570 ha (ICIMOD, 2007). Loss of agricultural land in Kathmandu Valley is posing a serious problem in the context of recharging groundwater; and it is also contributing to air pollution and loss of greenery. Kathmandu residents are becoming more reliant on outside supplies of cereals and vegetables.

Land use dynamics within the Kathmandu Valley are identified as critical, as land is currently being utilized at levels beyond its optimal use. The prime agricultural land is being converted into urban uses. The increasing demand for fuel woods, fodder and timber in the hills of the valley has resulted in massive conversion of forest land into scattered forests, shrub lands and grasslands. All these suggest that there is a serious interaction between various land use types in the valley. So there occurs alteration of energy fluxes due to land use change.

Table 5.1.4: Trend of Urban and Agricultural Use in the Valley

YEAR	1984	1991**	1994	2000*	2010*	2020*
Urban Area(% of total valley floor)	4.8	11.0	13.1	18.0	26.0	34.3
Agricultural Area((% of total valley floor)	64.0	56.0	49.6	42.2	28.3	14.5

Note:**Area projection based on Linear Regression Analysis*

***Areas coded by Halcrow Fox and Associates, 1991*

Source: Adapted from Regulating Growth: Kathmandu Valley (HMG/IUCN, 1995)

The effect of a new management or land use on atmospheric CO_2 cannot be judged solely on the basis of net carbon storage within the ecosystem. In many managed ecosystem, there significant removal of carbon in harvested product. Some of these harvested carbon may accumulate in long term repositories (e.g., wood products), and some is quickly returned to the atmosphere via respiration (e.g., agricultural products). Thus the full impact of a new management practice on atmospheric CO_2 can be assessed only by including net changes in off-site carbon stocks.

Figure 5.1.4 shows the change in Land use in the Kathmandu valley from 1976 to 2001. The different extensions of the city are well visible in brief time period. The strong reflection of chlorophyll by vegetation (reddish color) has been found in decreasing order towards 2001 so that, the urban areas (blue color) are extending. With rise in urban areas and less in vegetative areas, it will bring more complexities towards the availability and utilization of water resources.

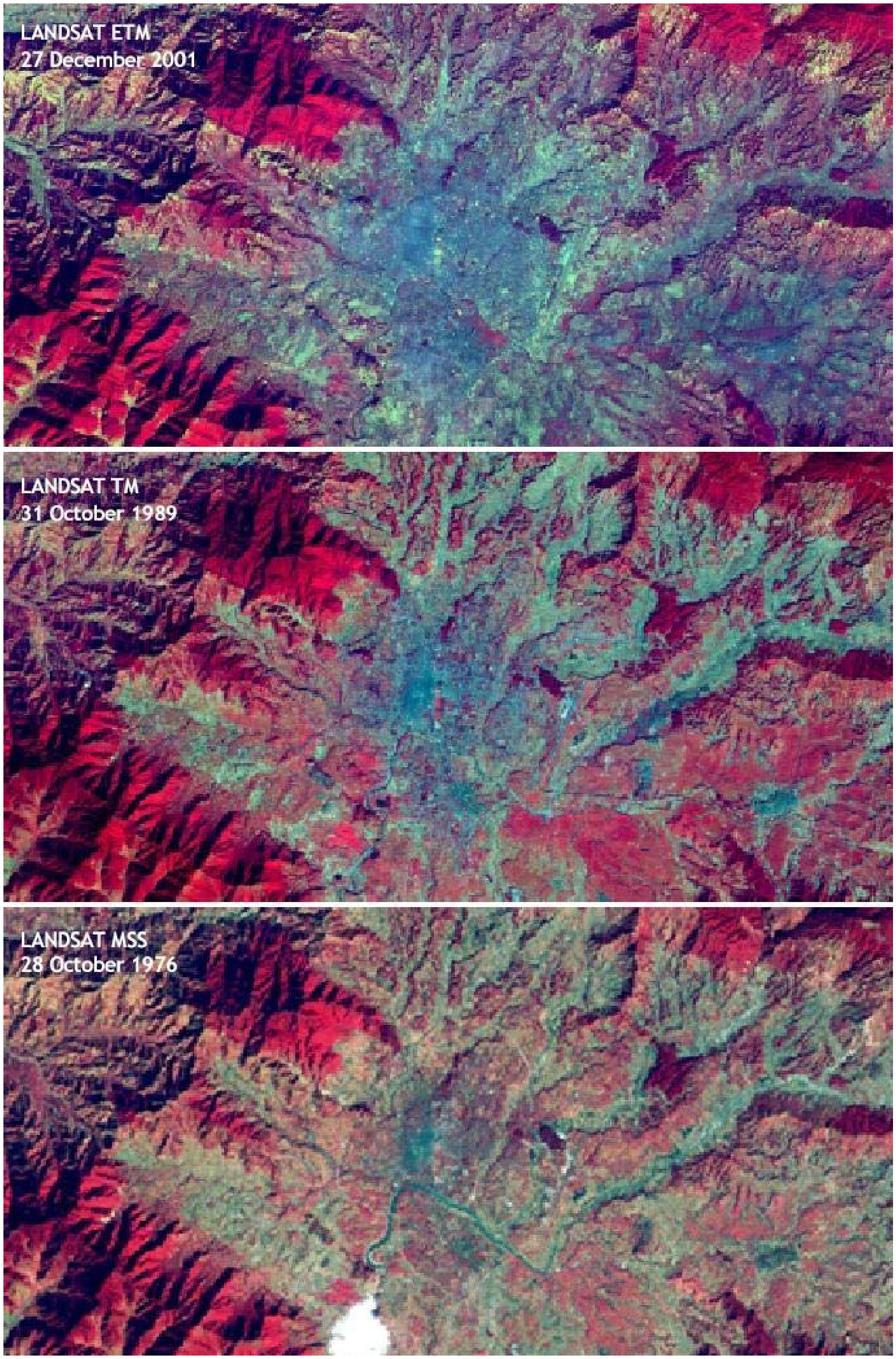


Fig 5.1.4 Land use change from 1976 to 2001

(Blue color means Urban(settlement) area and Red color means vegetative reflection of infrared)

Source: http://www.esa.int/education/eduspace

5.2 Climate Change Vulnerability in Kathmandu Valley

From the newspapers, interviews with local people, field observations and different seminar attended, the following vulnerability framework and adaptation methods, which were directly or indirectly related to climate change and variability, were identified in Kathmandu Valley. It has been found that urbanization features together with rising population and unique valley-landscape leaves it quite vulnerable to climate change and variability. As a result, some of the major vulnerable areas identified in Kathmandu Valley are Water Resources, Agriculture and Health.

People of Kathmandu Valley have experienced and aware that weather patterns are changing over time. They identified changes in the nature of rainfall, temperature increment, winter fog, and frost condition. Days and nights during winter seasons used to be very chilly a few decades back. But in recent years, they are experiencing less chilly winters days and nights. In the surrounding hills of the Kathmandu valley, the frequency of snowfall in the winter, which used to be high in the past, has decreased or suspended in recent years. At the same, the frequency and intensity of frost days have also reduced.

Kathmandu is facing high demand for water due to rapidly increasing population and change in weather pattern. The drinking water supply each year is inadequate to meet the growing demand which is becoming severe during dry season. Due to lack of rainfall at proper period and prolonged dry condition together with higher normal temperature has resulted in drying up wells, springs and other water resources in the valley.

Water sources have dried up including the critical depletion of ground water reserve. There is not only a huge gap between demand and supply of water, the quality of water has also degraded, putting public health at risk. Ponds and community taps of the capital valley have gone dry or witnessed depleted water level due to pressure on the water sources feeding them. Ground water has been the major alternative water source. But the haphazard urban growth has affected its re-charging process.

Kathmandu Valley is abating its ground water level due to its excessive use for drinking purpose.It has been found an alarming situation of the lowering down of the groundwater level from 9 meters to as much as 68 meters in the valley during dry season. Unfortunately the recharge areas of the surrounding hills, which were once densely forested, have been turned into agricultural purposes extensively. So there is little support from the surrounding watershed areas to replenish the groundwater source in the valley.

Changes in temperature and precipitation are also disturbing the natural water system. This has resulted in drying up wells, springs and other water sources. Due to dry spell conditions together with lack of recharge areas, the historical Stone Taps (Dhunge Dhara) were the major source of water before the advent of the city water supply are getting valueless due to no or very low amount of water flowing state. People have to wait for long time to collect small amount of water. Drinking water supplier for the valley, Kathmandu Upatyaka Khanepani Limited (KUKL), could not fulfill the demand of Kathmanduties due to lack of rainfall causing drought like condition and depleted groundwater sources during winter seasons.

Figure 5.1: Waiting for the turn to collect water

River pollutions are also very pronounced during winter and dry season due to shortage of water in the river. The Bagmati, Bishnumati and River, which drains the Kathmandu Valley, is highly polluted at different stretches and its water is unfit for human consumption. This level rose to its extreme level during winter and dry season due to flowless condition of the river. The climate change condition will make this more pronounced, due to change in rainfall pattern and rise in temperature, and helps in spreading diseases through these polluted rivers.

Different winter crops are likely to hit hard due to drought-like condition. The yield of winter crops like wheat, maize, millet and barley has been affected. The dry weather condition has posed a big threat to crops which has led to growing food security. Besides crops vegetables are also in the risk.

Box 2: Experience on Climate Change

Impact in his livelihood

Tirbikram Tuladhar, 52 years, is a farmer at land nearby Manohara River in Bhaktapur. He has faced ups and downs in his life. He has one wife, three daughters and two sons. He has been cultivating from this agricultural land with indigenous methods for 22 years. Nevertheless, he was satisfactory able to grow wheat, paddy and maize without using any chemical fertilizers and pesticides. In a gesture of time, he came across many challenges to grow the agricultural crops. He added those 10 to 15 years ago, sources of water were sufficient with the green forest near by land. Now sources of water have reduced and going to be the drought. As a result of, they are facing many difficulties and challenges due to lack of productivity. So he believes such phenomenon has directly impacted in his livelihood. Being local to the valley, he has lot of experiences in this village. He realized that temperature has risen up as compare to earlier winters. He thinks it is due to higher deforestation rate and urbanization, in order to solve the problems for rapidly growing human population. He recalls farmers are facing droughts like condition since 2060 B.S. during winter. Manohara River is flowing in its lowest level and becoming the drought. Production of agricultural crops has lowered due to climate change.

The climate change scenario is also affecting different species of life. *"Bhaiya Khanal of Natural History Museum has stated that out of 20 endangered species of butterflies, 12 are threatened due to habitat losses. He also said that some of it hasn't been sighted in the past 15 years and Chinese Windmill is seldom found in the valley these days"*. Moreover, this year birds from Siberia were not seen in Kathmandu. About 160 species of birds used to migrate to Nepal.

In Kathmandu valley different extreme cases of weather are being felt. Unpredicted snowfall event in valley was observed in 14th February 2007. The intensified rainfall has been measured.*"According to meteorologist Shiva Nepal, Forecasting Division of Department of Hydrology and Meteorology, in March 12, 1978, 39 mm rainfall was recorded in 24 hours in Kathmandu while recently, after 31 years, in March 31, 2009, 19 mm rainfall was measured in single hour"*.

Recently (March 2009) huge forest fires were observed in most part of the country. The country has witnessed a series of devastating wildfires on an unprecedented scale spreading across the highly fire-prone pine forests in high altitudes. The wildfires that started last January have turned vast tracts of forests into barren lands. Due, partly to the long dry spell, to the practice of 'slash and burn' agriculture method got out of control caused disastrous crown wildfires in the mid-hills and high altitude regions. Active fires were recorded in renowned conservation success stories like the Annapurna, Kanchanjunga, Langtang and Makalu Barun national parks. National

Aeronautic and Space Administration (NASA) has listed Nepal as a most vulnerable country because of wildfires this year. These cases have increased uncertainty of climate change.

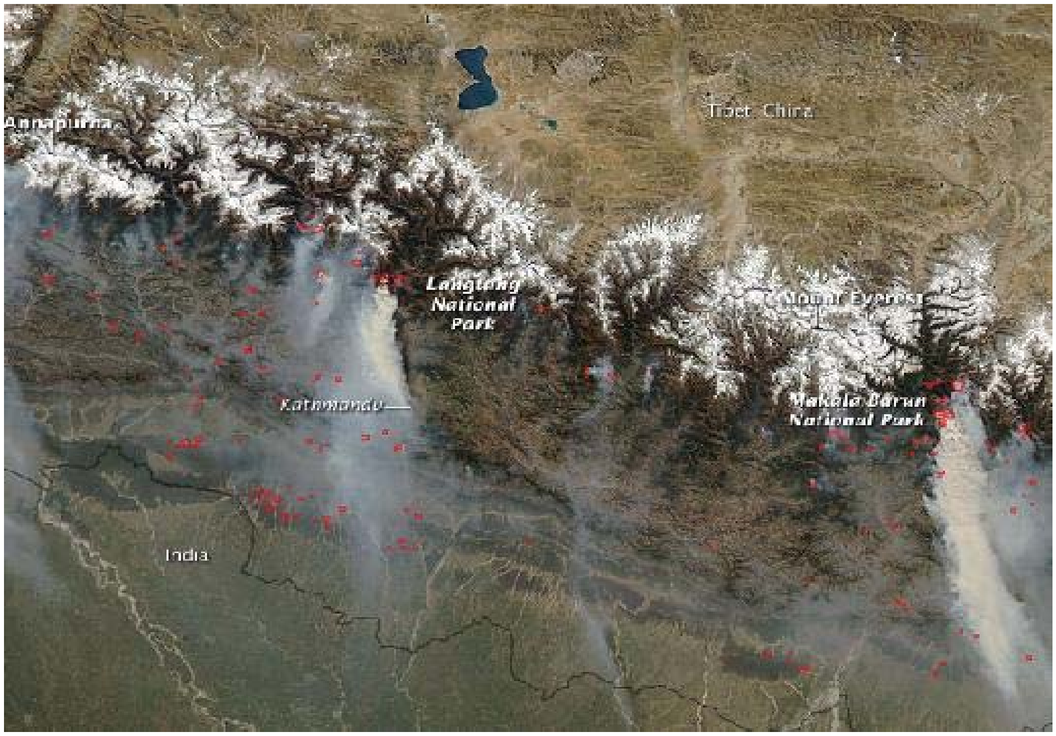


Figure 5.2: Forest fires in Nepal (Red mark shows fire places)

Therefore, changing temperature and rainfall patterns have impose a variety of pressures upon the human and also to plant and animal life.

Chapter 6 : CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

For the study purpose, at least 5 years and maximum of 32 years of temperature and rainfall data were analyzed for 10 different stations located in the Kathmandu Valley. The analyzed trend pattern for 30 years for Kathmandu Airport station showed an increasing statistical significant temperature and also found increment in frequency of maximum temperatures. The winter 1998/99 was the warmest winter season of 20th century with average temperature of 13.17°C.In this winter, maximum winter temperature was recorded as 29°C in 17th February, 1999 which is the highest temperature recorded in winter in the Kathmandu Valley. Similarly, in 20th century, December 1999 with average temperature 13.35°C, January 1990 with 12.69°C and February 1999 with 15.82°C were the warmest months. In the beginning of 21st century, winter 2005/06 was the hotter than previous hottest winter of 20th century with average temperature 13.82°C.Whereas, the recent winter 2008/09 is the hottest of all the winter with average temperature 14.36°C.

It was also concluded that the winter is getting drier (than previous ones) due to low rainy days or no rainfall conditions. The highest amount of 115.7mm of rain was recorded in winter 1997/98.Then the successive two winters 1998/99 and 1999/00 were with below normal rainfall. The winter rainfall from 2000/01 to 2004/05 was normal but there was no rainfall in winter 2005/06.In winter 2006/07 snowfall observed after 62 years in 14th February 2007.But again following two winter (2007/08 and 2008/09) are with traces or no rainfall condition in Kathmandu Valley.

From the vulnerability analysis, it has been found that water resources are much vulnerable to climate change in Kathmandu Valley during winter and dry season. The extinctions of species are also likely due to habitat loss and human encroachment of land use. Moreover, unpredictable climatic variability and weather extremities events like snowfall and forest fires during winter, adding up uncertainties to future climate change scenarios.

Consequently, uncertainties about the rate and magnitude of climate change and potential impacts prevails in the Kathmandu Valley i.e. variability and change in hydro-meteorological parameters as well as ecological and socio-economical landscape during winter, particularly in relation to water resources.

6.2 Recommendation

1. Quality Assurance and Quality Control of the data: The fundamental problem in research is due to lack of adequate data. There is problem of data availability When available data are poor in quality, do not match between years or places, or are not reliable. A well-defined database management like in case of Kathmandu Airport Station is a must. Metadata containing the description of the data set of every component by source, area, time(year and month), type, and amount should be recorded. Data should be shared among departments and within Department of Hydrology and Meteorology and with the general publics. This would help to control data duplication among organizations of a similar type.
2. Need for Research: Research and scientific assessment could play a vital role in improving the understanding of the potential impacts of climate change in Water Resources, Agriculture and Health sectors ,hence provide adaptation strategies. For example, Kathmandu seems vulnerable to drought during winter so drought tolerant seed varieties should be developed. The problem of drinking water shortage can be mitigated by Integrated Water Resources Management (IWRM) so IWRM must be taken into consideration. Health sector is vulnerable to diseases like Malaria and Japanese Encephalitis even during winter due to rise in temperature so disease resistant medicines must be developed. Moreover, there is need to undertake prospective and retrospective studies on identified diseases patterns such as eye and skin disorders relevant to climatic change. Besides, these social, economical and ecological aspects of climate change research are strongly recommended.

3. Climate/Disaster Risk Management (CRM/DRM): If development is to be guarded and advanced in areas affected by climate risks, an integrated approach to climate risk management needs to be promoted, building on successful approaches piloted by the disaster risk management community but mainstreamed in to national strategies and programs. Addressing and managing climate risk as it is manifested in extreme events and impacts in the here and now is the most appropriate way of strengthening capacities to deal with changing climate in the future.

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ANNEXES

Annex 1. Winter Temperature Summary of Kathmandu Valley

Nagarkot Temperature(°C)

year	Average maximum	Average minimum	mean	max extreme	date	min extreme	date	<=0	<=1	dec	jan	feb
1993	14.46	3.88	9.17	18.5	21-Feb	-2	17-Jan	3	8	9.92	9.06	8.67
1994	13.33	2.85	8.09	17.2	3-Dec	-1.3	2-Jan	3	15	9.06	6.97	8.33
1995	14.16	3.20	8.68	19	29-Jan	0	16-Jan	1	10	8.88	7.43	9.65
1996	14.11	2.57	8.34	20.5	9-Dec	-1.6	23-Jan	6	16	9.56	7.34	7.79
1997	14.85	3.29	9.07	19.4	26-Feb	0	21&22jan	3	8	8.29	8.03	10.14
1998	15.61	5.20	10.40	21	14-Feb	-1.3	10-Jan	1	4	9.79	8.13	13.05
1999	14.42	3.20	8.81	18.6	19-Dec	0.5	26-Feb	0	7	9.77	8.25	8.37
2000	15.07	3.46	9.27	19.5	1-Feb	0.1	25-Jan	0	7	9.34	7.66	11.51
2001	14.59	3.69	9.14	26	14-Feb	0	25-Jan	1	6	9.02	7.82	10.75
2002	14.20	3.59	8.89	19.8	7-Dec	0.4	30-Dec	0	2	9.34	8.45	8.89
2003	13.36	4.32	8.84	18.5	28-Feb	0	28-Dec	1	8	9.50	8.41	9.88
Mean	**14.38**	**3.57**	**8.97**	**19.82**		**-0.47**				**9.32**	**7.96**	**9.73**

Panipokhari Temperature (°C)

year	Average maximum	Average minimum	Seasonal mean	extreme max	date	extreme min	date	<=0	<=1	dec	jan	feb
1995	18.27	5.95	12.11	22.5	26-Feb	1	16-Jan	0	1	12.16	10.81	13.91
1996	18.90	3.08	10.99	22.5	2&3Jan	0.4	18-Jan	0	7	11.72	9.30	10.91
1997	17.51	3.71	10.61	23	18&19Feb	1.2	4-Jan	0	0	10.35	9.11	12.56
1998	21.06	3.91	12.48	26	23-Feb	-2.4	12-Jan	3	6	12.12	10.57	15.00
1999	18.27	4.55	11.41	23.5	3-Dec	0	16-Jan	1	6	12.85	10.38	10.95
2000	19.48	4.93	12.21	24	18-Feb	2	6-Feb	0	0	12.40	15.20	12.87
2001	19.14	4.18	11.66	23.2	28-Feb	0.1	6-Jan	0	5	11.80	10.39	12.92
2002	18.56	4.11	11.33	22	25&28 Feb	0.1	10,12,13,15jan	0	13	12.05	9.63	12.42
2003	18.60	4.99	11.79	22.7	26-Feb	1	6-Jan	0	1	12.11	10.47	12.90
Mean	**18.86**	**4.38**	**11.62**	**23.27**		**0.38**				**11.95**	**10.65**	**12.72**

Khumaltar Temperature(°C)

year	Average maximum	Average minimum	Seasonal mean	extreme max	date	extreme min	date	<=0	<=1	dec	jan	feb
1987	19.66	3.03	11.35	23	28-Feb	-3	28-Jan	14	27	11.46	9.83	12.90
1988	18.42	2.36	10.39	25	1-Dec	-3	16-Jan	15	28	12.07	8.76	10.32
1989	19.09	3.00	11.05	26.8	23-Feb	-2.5	31-Dec	10	17	10.35	11.12	11.74
1990	19.25	2.24	10.65	25	7-Feb	-1	12-Jan	8	31	11.17	8.92	11.99
1991	17.67	2.48	10.15	23	16-Dec	-2	16-Jan	3	14	10.33	10.21	9.89
1992	18.42	2.80	10.71	24.6	17-Dec	-2.2	13-Jan	10	23	10.35	9.54	12.40
1993	19.22	2.52	10.87	23.4	27-Feb	-2	20-Jan	7	23	11.50	10.34	10.76
1994	18.27	1.90	9.74	22.4	4-Dec	-2.4	17-Jan	11	36	10.51	8.06	10.73
1995	18.60	3.30	10.72	22.8	17-Feb	-1.4	18-Jan	4	9	11.41	9.48	11.33
1996	18.36	2.02	9.64	22.6	13-Feb	-1.8	2 & 4 jan	9	19	11.23	8.05	9.64
1997	18.89	2.74	10.38	22.6	21-Feb	-3.2	21-Jan	6	19	10.15	9.10	12.06
1998	21.60	3.20	12.05	26.6	17-Feb	-2	14-Jan	6	25	12.12	9.65	14.63
1999	19.97	2.72	11.24	27.8	18-Dec	-2.6	16-Jan	5	23	12.69	9.94	11.08
2000	20.22	2.33	11.18	24	22-Feb	-1.2	3-Feb	13	28	11.05	9.92	12.72
2001	19.82	2.88	11.35	23.2	4-Feb	-1	2&7 Jan	7	22	11.15	10.24	12.81
2002	19.66	2.66	11.16	24.2	28-Feb	-2.4	13-Jan	7	21	11.72	9.85	12.00
2003	19.05	3.21	11.13	23.2	4-Feb	-1.2	28-Jan	4	15	11.37	10.07	12.05
Mean	**19.19**	**2.67**	**10.81**	**24.13**		**-2.05**				**11.21**	**9.59**	**11.71**

Kathmandu Airport Temperature(°C)												
year	**Average maximum**	**Average minimum**	**Seasonal mean**	**extreme max**	**date**	**extreme min**	**date**	**<=0**	**<=1**	**dec**	**jan**	**feb**
1975	18.06	3.36	10.82	24	21-F	0	29-Dec	1	8	10.40	9.69	12.51
1976	18.58	1.31	9.95	24.3	21-F	-2.4	1-Jan	34	49	9.71	8.64	11.65
1977	17.40	1.34	9.54	23.7	28-F	-3.5	11-Jan	34	48	9.90	8.17	10.65
1978	18.99	3.27	11.13	23.7	14-D	-0.8	7-Jan	3	10	11.51	10.47	11.43
1979	18.28	3.85	11.19	22.8	26-F	-1	14-Jan	6	18	11.48	9.97	12.09
1980	18.71	3.92	11.31	24.5	26-F	-1.4	11-Jan	5	12	11.69	9.81	12.55
1981	18.95	2.75	10.98	22.7	26-F	-0.4	12-13 J	5	23	11.24	10.66	11.03
1982	18.12	2.08	10.20	24.4	16-F	-2.2	4-Feb	24	34	11.47	8.83	10.30
1983	18.86	1.33	10.10	24.8	28-F	-2.6	27-Jan	28	49	10.18	8.61	11.53
1984	19.25	3.24	11.34	27.8	28-F	-1.9	26-Dec	7	14	11.65	10.35	12.08
1985	19.21	3.67	11.44	23.4	24-F	0	1-Feb	1	9	12.04	10.51	11.81
1986	19.22	3.45	11.43	25.2	25-F	-0.6	1-Jan	3	13	11.03	10.48	12.94
1987	20.40	4.13	12.27	24.2	4-F	-1	26-Jan	4	12	12.36	11.07	13.39
1988	19.79	3.32	11.56	27	28-F	-1.7	20-Feb	13	20	12.69	10.11	11.89
1989	20.91	3.36	12.14	25.5	30-J	-1.5	1-Jan	9	21	11.24	12.69	12.53
1990	20.17	3.19	11.68	27.9	22-F	-1.2	12-Jan	1	12	11.98	9.89	13.35
1991	18.59	2.67	10.72	24.2	18-D	-2.2	1-Jan	9	23	11.06	10.03	11.03
1992	19.93	3.52	11.72	25.9	17-F	-1.4	14-Jan	6	17	11.12	10.64	13.59
1993	20.58	3.34	12.08	24.9	19-F	-1.7	4-Jan	4	11	12.52	11.35	12.40
1994	19.27	2.42	10.85	24.9	13-F	-2.4	4-Jan	12	26	11.29	9.47	11.88
1995	19.64	3.96	11.80	25.1	17-F	-0.6	18-Jan	3	8	12.09	10.41	12.87
1996	19.48	2.61	11.05	23.8	14-F	-1	11-Jan	6	16	12.07	9.86	11.22
1997	19.71	3.25	11.48	24.6	17-F	-3	20-Jan	5	14	11.15	10.39	13.06
1998	22.89	3.44	13.17	29	17-F	-2	11-Jan	5	18	12.78	11.16	15.82
1999	21.06	3.60	12.33	24.6	12-J	-3	16-Jan	2	13	13.35	11.55	12.06
2000	22.04	3.40	12.72	27.4	31-J	-1	13-14 J	8	19	12.26	11.41	14.68
2001	20.70	3.87	12.28	28.2	24-F	-0.5	24-Jan	5	10	12.15	10.84	14.03
2002	19.89	3.74	11.82	23.8	19-J	-1.3	16-Jan	5	12	11.90	10.59	13.08
2003	19.89	4.20	12.05	25.8	28-F	0.6	4-Feb	0	8	11.98	10.66	13.46
2004	20.11	4.84	12.48	24.9	27-F	-0.3	27-Dec	2	4	12.56	11.08	13.93
2005			**13.82**							**12.25**	**12.15**	**17.05**
2006			**12.20**	23.6	24-F	-0.5	14-16 J			12.65	10.94	13.01
2007			**12.04**	25.2	24 f	-0.2	5J/4F			12.41	11.43	12.30
2008			**14.36**	28.6	20F	1	8J			14.06	13.25	15.79

Budhanilkantha Temperature(°C)												
year	**Average maximum**	**Average minimum**	**Winter mean**	**max**	**date**	**min**	**date**	**<=0**	**<=1**	dec	jan	feb
1989	18.25	5.49	11.87	21.5	24-J	1.5	30-Dec	0	0	11.02	12.44	12.16
1990	18.78	4.44	11.61	23.5	22-F	0.7	10-Jan	0	4	12.11	9.84	13.02
1991	16.59	4.44	10.52	21.7	17-D	-0.3	2-Jan	1	5	11.16	10.15	10.14
1992	17.39	5.04	11.22	22	17-F	-1.3	21-Jan	1	4	10.58	9.94	13.34
1993	18.55	5.21	11.88	22.3	5/6D	-0.5	16-Jan	1	1	12.79	11.16	11.67
1994	17.61	4.25	10.93	21.7	13-F	0.3	2-Jan	0	3	11.39	9.77	11.70
1995	18.18	4.84	11.51	22	7-J	0.5	27-Dec	0	2	11.81	10.14	12.58
1996	17.34	4.10	10.72	21	27-F	1.3	20-Feb	0	0	11.90	9.60	10.66
1997	17.65	4.54	11.10	23	2-D	0.5	15-Dec	0	3	10.84	10.12	12.47
1998	20.64	5.78	13.21	25.7	20-F	1.3	12-Jan	0	0	12.90	11.41	15.54
1999	18.30	4.26	11.28	21.5	8-D	1.5	16-18 D	0	0	12.80	10.43	10.54
2000	19.15	4.94	12.05	23.5	4/5 F	1	4-Jan	0	1	11.42	10.77	14.16
2001	20.31	4.42	12.36	23	16-D	3	1,2, 4-11J	0	0	12.89	11.65	12.58
2002	17.97	4.68	11.33	22	7-F	0	26-Jan	1	3	11.60	10.39	12.07
2003	17.97	4.82	11.40	23.5	28-F	0.5	25-Jan	0	4	11.49	9.94	12.73

Annex 2. Precipitation (rainfall) of Kathmandu Valley

PANIPOKHARI RAINFALL(mm)								Budhanilkantha Rainfall(mm)							
year	**total**	**>=1**	**>=10**	**>=25**	**>=50**	**24 hrs max**	**Day**	**year**	**total**	**>=1**	**>=10**	**>=25**	**>=50**	**24hrs max**	**Day**
2004	61.1	8	2	0	0	20.3	19-Jan	**2004**	79	6	3	1	0	31	22-J
2003	36	4	2	0	0	16	29-Dec	**2003**	50	6	1	0	0	17	24-J
2002	62.5	5	3	1	0	26.4	1-Feb	**2002**	84	8	4	0	0	21	1-F
2001	31.4	3	1	0	0	16	12-Feb	**2001**	0	0	0	0	0	0	No- rain
2000	0	0	0	0	0	0	no rain	**2000**	13.6	1	1	0	0	13	26-F
1999	0	0	0	0	0	0	no rain	**1999**	9.4	3	0	0	0	6.4	6-F
1998	17.8	3	0	0	0	6.4	29-Jan	**1998**	7	3	0	0	0	3.2	29-J
1997	86.9	5	4	1	0	42.4	10-Dec	**1997**	110.2	10	3	1	0	36	10-D
1996	20.5	4	1	0	0	14.4	20-Jan	**1996**	31.8	5	1	0	0	15	20-J
1995	87.6	6	1	1	1	62.5	16-Jan	**1995**	86.2	6	2	1	0	43	16-J
1994	0	0	0	0	0	0	DNA of J/F	**1994**	37.6	6	0	0	0	9.6	16-F
1993	0	0	0	0	0	0	DNA of J/F	**1993**	50.8	6	3	0	0	14	17-J
1992	10.2	1	1	0	0	10.2	3dec DNA of J/F	**1992**	56.4	10	2	0	0	14	19-F
1991	35.8	6	1	0	0	18.6	26-Dec	**1991**	40.8	6	1	0	0	14	26-D
1990	29.6	5	2	0	0	12.2	27-Feb	**1990**	32	2	2	0	0	20	31-D
1989	0	0	0	0	0	0	DNA for J/F	**1989**	49	6	1	1	0	28	15-F
1988	0	0	0	0	0	0	DNA for D	**1988**	72	4	4	1	0	26	19-J
1987	29.9	3	1	0	0	19.5	13-Dec	**1987**	17.2	2	1	0	0	15	24-F
1986	100.9	8	3	2	0	39.4	19-Dec								
1985	32.8	3	1	0	0	23.5	11-Feb								
1984	31.1	5	0	0	0	9	3-Jan								
1983	49.5	5	2	0	0	18.1	20-Feb								
1982	37	6	2	0	0	14.5	29-Jan								
1981	41.4	7	1	0	0	10.1	26-Jan								
1980	29.5	7	1	0	0	13.4	26 Dec; DNA of J/F								
1979	39.7	7	1	0	0	10.6	30-Dec								
1978	61.9	7	2	0	0	23.7	8-Feb								
1977	68.2	8	2	1	0	35.7	27-Dec								
1976	24.6	3	2	0	0	11.6	21-Jan								
1975	37.2	5	1	0	0	22	18-Jan								
1974	32	6	0	0	0	7.6	22-Jan								
1973	21	3	1	0	0	14.4	15-Jan								
1972	0	0	0	0	0	0	DNA								
1971	27.8	5	1	0	0	12.4	5-Feb								

Kathmandu Airport Rainfall (mm)							
Year	**rainfall**	**>=1**	**>=10**	**>=25**	**>=50**	**24hrs max rainfall**	**day**
1968	10	3	0	0	0	7	14J
1969	56.7	6	2	0	0	17.4	20F
1970	9.3	2	0	0	0	6.3	28F
1971	26.9	4	1	0	0	11.2	4F
1972	56.1	8	1	0	0	23.2	28F
1973	22.7	3	1	0	0	14.8	15J
1974	67.4	14	1	0	0	11	2F
1975	44.7	5	1	0	0	21	18J
1976	23.6	3	1	0	0	12.1	5F
1977	29.4	6	0	0	0	9.8	28D
1978	47.1	8	2	0	0	22	8F
1979	78.7	9	0	1	1	51	1D
1980	20.1	3	1	0	0	11.2	25J
1981	36.1	7	0	0	0	9.5	2F
1982	25.6	6	1	0	0	15.5	29J
1983	46.6	5	3	0	0	15	26D
1984	20.3	5	0	0	0	7.4	14D
1985	77.1	4	3	2	0	27.6	27D
1986	95.9	10	3	2	0	32	19D
1987	30.7	3	1	0	0	18.3	13D
1988	137	7	4	3	0	48.8	27D
1989	42.9	6	2	0	0	11.6	15F
1990	34.9	6	2	0	0	14.6	2J
1991	48.5	6	1	0	0	21.5	26D
1992	28.7	5	1	0	0	14.6	19F
1993	46.7	4	3	0	0	16.2	16J
1994	32.1	6	0	0	0	9.1	16F
1995	93	9	1	1	1	62	16J
1996	21.9	5	1	0	0	11	20J
1997	115.7	9	4	1	0	37.1	10D
1998	8.4	2	0	0	0	4.2	27F
1999	7.7	4	0	0	0	2.9	12F
2000	22.7	3	1	0	0	14.2	26f
2001	63.7	7	4	0	0	15	12F
2002	87.9	8	4	0	0	20.7	1F
2003	45.5	6	1	0	0	10.8	29D
2004	72.1	8	3	0	0	21.7	18J
2005	0						
2006	79.3	14	2	1	0	45	14F
2007	0						
2008	0						

Nagarkot Rainfall (mm)							
year	**Total**	**>=1**	**>=10**	**>=25**	**>=50**	**24hrs max rainfall**	**day**
2004	70.5	10	2	0	0	20.8	20-Jan
2003	43.3	5	1	0	0	16.6	25-Jan
2002	157.3	11	7	2	0	26.1	31 Jan & 1 Feb
2001	76.1	7	3	0	0	22.5	12-Feb
2000	9.8	1	0	0	0	9.8	1-Jan
1999	0	0	0	0	0	0	xx
1998	10.2	2	0	0	0	5.7	29-Jan
1997	80.9	7	3	1	0	34.5	25-Feb
1996	98	3	1	1	1	93	21-Jan
1995	102	9	3	1	0	41.1	16-Jan
1994	68.3	14	2	0	0	14.5	20-Dec
1993	57.9	5	2	0	0	19.6	16-Jan
1992	23.1	5	0	0	0	9	19 feb DNA of Jan
1991	62.8	8	3	0	0	12.2	7-Feb
1990	44.8	4	2	1	0	30	1-Jan
1989	31.7	3	2	0	0	17.2	14-Feb
1988	119.6	7	4	1	0	49.2	26-Dec
1987	38.5	5	2	0	0	19.4	12-Dec
1986	53.9	4	2	1	0	33	19-Dec
1985	10.6	4	0	0	0	4	15-Feb
1984	45.5	5	1	0	0	20	6-Feb
1983	5.3	2	0	0	0	3	12-Feb
1982	10.9	4	0	0	0	4.5	29-Jan
1981	16.1	3	0	0	0	7.5	1-Feb
1980	9.4	3	0	0	0	5.2	24-Dec
1979	71.4	6	1	1	1	52	1-Dec
1978	45.1	6	2	0	0	18.5	8-Feb
1977	26.5	4	1	0	0	15	27-Dec
1976	21.3	4	1	0	0	13.9	5-Feb
1975	44	5	2	0	0	20	18-Jan
1974	97.4	10	4	1	0	29	14-Feb
1973	54	3	3	1	0	30	13-Feb
1972	57.2	7	1	0	0	22	27-Feb
1971	9	2	0	0	0	6	6-Feb

Khumaltar Rainfall(mm)							
year	Total	>=1	>=10	>=25	>=50	24hrs max	day
2004	69.7	8	2	1	0	26.6	19-Jan
2003	47.3	7	1	0	0	16.8	29-Dec
2002	82.2	7	4	0	0	21	1&19 Feb
2001	63.9	8	2	0	0	14.2	12-Feb
2000	21.2	3	1	0	0	15.8	27-Feb
1999	7	2	0	0	0	2.8	12-Feb
1998	2.4	1	0	0	0	2	29-Jan
1997	100.6	9	3	1	0	34.8	10-Dec
1996	34.7	6	0	0	0	8.2	23-Feb
1995	82.3	9	1	1	1	52.7	16-Jan
1994	29.5	5	0	0	0	8.8	16-Feb
1993	46.2	6	3	0	0	16.2	16-Jan
1992	29.5	6	1	0	0	12.2	19-Feb
1991	43.4	7	1	0	0	20.3	26-Dec
1990	32.2	6	0	0	0	7.9	2-Jan
1989	40.6	8	1	0	0	16.8	14-Feb
1988	174.5	6	4	3	1	78	27-Dec
1987	48	4	3	0	0	17	13-Dec
1986	121.1	11	5	2	0	34	4-Feb
1985	98	6	3	2	0	37	27-Dec
1984	17.4	5	0	0	0	6.5	6-Jan
1983	41.8	4	3	0	0	14	26-Dec
1982	23.5	4	1	0	0	13.5	29-Jan
1981	22.7	6	0	0	0	7.5	28-Jan
1980	16.4	4	0	0	0	9.5	24-Dec
1979	75.8	6	2	1	0	42	1-Dec
1978	41.8	4	2	0	0	23.5	8-Feb
1977	73.8	6	3	1	0	35	27-Dec
1976	25	3	2	0	0	12	5-Feb
1975	47.2	4	2	0	0	21	19-Jan
1974	103.3	11	7	0	0	22.1	22-Jan
1973	0	0	0	0	0	0	DNA
1972	56.6	9	2	0	0	22.6	28-Feb
1971	29.8	3	2	0	0	14.2	6-Feb
1970	12	2	0	0	0	7	28-Feb
1969	71	6	4	0	0	18	19-Feb
1968	14	3	1	0	0	12	14-Jan
1967	25.8	6	0	0	0	7	15-Jan

SANKHU rainfall(mm)							
year	total rain	>=1	>=10	>=25	>=50	24 hrs max	day
1971	30	5	1	0	0	14	4-Feb
1972	62.4	9	1	0	0	24	28-F
1973	27	4	2	0	0	13.2	13-F
1974	66.4	10	2	0	0	20	1-Feb
1975	45.2	3	2	0	0	24	17-J
1976	19.6	3	1	0	0	10.4	5-F
1977	58	5	2	0	0	20.4	28-D
1978	78	7	3	1	0	25.5	9-Feb
1979	22.1	7	0	0	0	7	30-D
1980	0	0	0	0	0	0	no rain
1981	171.9	9	8	2	0	27.8	2-F
1982	21.5	5	0	0	0	9	29-J
1983	64	6	4	0	0	22	17-J
1984	8.4	3	0	0	0	3.2	5-Feb
1985	74	3	3	2	0	28	28-D
1986	49	4	2	0	0	23	19-D
1987	35.5	4	2	0	0	20.5	13-D
1988	98.5	6	3	1	0	47	27-D
1989	53.5	9	3	0	0	18	14-F
1990	22	6	0	0	0	6	27-F
1991	41	5	1	0	0	21.5	26-D
1992	40.2	6	2	0	0	11.5	19-F
1993	54	5	3	0	0	22	16-J
1994	26.3	4	2	0	0	11.5	6-Feb
1995	140.5	11	3	3	1	55	15-J
1996	27.8	5	2	0	0	10.5	20-J
1997	87.5	6	5	1	0	26	26-F
1998	3	1	0	0	0	3	27-F
1999	3.5	2	0	0	0	2	12-F
2000	26.4	3	2	0	0	12	26-F
2001	23.4	3	0	0	0	8.4	28-J
2002	118.7	7	6	1	0	30.6	2-F
2003	43.9	6	1	0	0	10.4	25-J
2004	0	0	0	0	0	0	no rain

Godavari Rainfall								Thankot Rainfall							
year	total	>=1	>=10	>=25	>=50	24 hrs max	day	year	Total	>=1	>=10	>=25	>=50	24 hrs max	day
2004	87	6	3	1	0	39	19-J	**1970**	12.8	2	0	0	0	6.4	27-F
2003	63	7	2	0	0	18.4	29-D	**1971**	38.4	3	2	0	0	16	4-F
2002	108	7	5	2	0	30.5	1-F	**1972**	99.6	8	3	1	0	39.2	28-F
2001	79	7	4	1	0	29.4	25-F	**1973**	39.4	3	1	1	0	30.6	15-J
2000	23	4	1	0	0	14.6	25-F	**1974**	74.8	11	2	0	0	10.4	14-F
1999	9.3	4	0	0	0	3	6-Feb	**1975**	45.2	3	2	1	0	28.6	18-J
1998	2.5	1	0	0	0	2.5	29-J	**1976**	44	4	2	0	0	17.6	21-J
1997	153	7	6	3	0	44.2	9-D	**1977**	84.2	4	2	1	1	55.6	28-D
1996	23	3	1	0	0	11.5	20-J	**1978**	50.4	5	2	0	0	18.9	19-F
1995	125	5	3	1	1	77.2	16-J	**1979**	114.7	8	4	2	0	44.8	1-Dec
1994	44	8	1	0	0	16	16-F	**1980**	30.9	4	1	0	0	15	24-J
1993	66	4	3	1	0	25.1	16-J	**1981**	55.6	6	3	0	0	15	1-F
1992	42	6	1	0	0	13.5	19-F	**1982**	35.8	4	2	0	0	19.7	29-J
1991	47	6	1	0	0	24.5	25-D	**1983**	80.4	4	3	1	0	39.7	26-D
1990	56	6	3	0	0	23.2	3-Jan	**1984**	16.6	3	0	0	0	8.1	6-J
1989	60	10	2	0	0	23.5	14-F	**1985**	139.3	5	3	3	0	43.5	11-F
1988	168	7	4	3	1	63.5	26-D	**1986**	129.5	12	4	2	0	36	4-F
1987	38	6	2	0	0	16	24-F	**1987**	38.8	3	1	0	0	23.4	13-D
1986	138	12	5	2	0	35.7	19-D	**1988**	212.8	6	5	3	2	66.4	27-D
1985	104	4	3	2	0	47	28-D	**1989**	47.9	7	1	0	0	22.2	14-F
1984	31	4	1	0	0	10.4	14-D	**1990**	53	7	2	0	0	22.1	2-J
1983	60	4	3	1	0	25.7	17-J	**1991**	67.3	8	2	1	0	29.3	26-D
1982	31	6	1	0	0	18	29-J	**1992**	83.9	7	3	1	0	31.2	19-F
1981	31	7	1	0	0	10	28-J	**1993**	80.6	4	4	1	0	29.1	16-J
1980	36	8	1	0	0	10.2	25-J	**1994**	48	7	2	0	0	19.2	16-F
1979	91	5	1	1	1	63.4	1-D	**1995**	108.1	10	3	1	1	51.2	16-J
1978	63	5	2	1	0	29.9	8-Feb	**1996**	36.4	3	1	1	0	29.2	20-J
1977	83	5	2	1	1	55.6	28-D	**1997**	93.6	5	5	0	0	24.4	15-D
1976	102	5	2	2	1	55.6	28-D	**1998**	4.3	1	0	0	0	4.3	29-J
1975	47	8	1	0	0	11.1	22-J	**1999**	4.9	3	0	0	0	2.1	12-F
1974	23	2	1	0	0	12.8	15-J	**2000**	42.4	3	1	1	0	33.4	26-F
1973	90	12	3	1	0	31.8	28-F	**2001**	97.5	7	5	0	0	23.4	12-F
1972	29	3	2	0	0	15.8	13-F	**2002**	122	8	5	2	0	37.4	19-F
1971	35	4	2	0	0	12.9	28-F	**2003**	21.4	4	1	0	0	11.4	28-D
								2004	86.7	9	3	2	0	28	19-J

Note: D=Dec, J=Jan, F=Feb; DNA-Data Not Available

Bhaktapur Rainfall

year	total	>=1	>=10	>=25	>=50	24 hrs max	day
2004	73.8	7	3	1	0	32.1	19-Jan
2003	40.5	5	2	0	0	12.3	29-D
2002	95.2	10	4	0	0	22.2	1-Feb
2001	58.4	7	2	0	0	14	17-Jan
2000	19.7	2	1	0	0	13	26-F
1999	5.7	3	0	0	0	3.1	12-F
1998	8.5	2	0	0	0	6.1	27-F
1997	113	8	6	1	0	33.2	10-D
1996	30.6	4	1	0	0	12.2	20-J
1995	153	8	3	3	1	51.3	16-J
1994	44.9	7	2	0	0	10.2	17-F
1993	60.4	6	2	1	0	25.3	17-J
1992	21.5	6	0	0	0	6.4	7-J
1991	60.6	7	2	1	0	25.2	26-D
1990	38.3	6	1	0	0	10	31-D
1989	27.4	4	1	0	0	11.4	15-F
1988	0	0	0	0	0	0	no rain
1987	34.6	3	2	0	0	17.3	13-D
1986	146	9	5	2	0	41.6	4-F
1985	94	4	3	2	0	43.1	27-D
1984	39.8	7	0	0	0	8.3	17-F
1983	71.5	5	3	1	0	30	17-Jan
1982	24.4	6	1	0	0	11.2	29-Jan
1981	21.2	5	0	0	0	8.1	28-Jan
1980	9.2	2	0	0	0	4.2	25-D
1979	42.7	5	1	1	0	31.9	1-Dec
1978	49.5	8	2	0	0	18.9	8-Feb
1977	65.6	8	2	1	0	32.3	27-D
1976	27.2	3	2	0	0	12.8	5-Feb
1975	44.4	5	1	0	0	16	18-Jan
1974	69.3	14	1	0	0	12	22-Jan
1973	21.8	2	2	0	0	10.4	15-Jan
1972	71.2	5	2	1	0	34	27-F
1971	22.2	4	0	0	0	8	4-Feb

Chapagaon Rainfall

Year	total	>=1	>=10	>=25	>=50	24 hrs max	day
2004	75.8	7	2	1	0	39	19-J
2003	37.6	6	2	0	0	11	29-D
2002	97.3	7	4	1	0	28	1-Feb
2001	68.5	8	3	0	0	15	12-F
2000	8.6	3	0	0	0	3.5	1-Jan
1999	2.9	2	0	0	0	1.5	11-F
1998	2.1	1	0	0	0	2.1	29-J
1997	119	6	5	1	1	58	10-D
1996	24	3	0	0	0	9.6	20-D
1995	80.6	6	1	1	1	60	16-J
1994	37.1	6	0	0	0	8.5	16-F
1993	66.3	4	4	0	0	24	16-J
1992	26.3	5	1	0	0	10	8-J
1991	54.3	8	1	1	0	27	26-D
1990	52.4	7	1	0	0	21	3-J
1989	50.8	9	2	0	0	21	14-F
1988	160	6	4	3	1	61	26-D
1987	19.9	4	1	0	0	15	24-F
1986	107	9	3	2	0	31	19-D
1985	104	4	3	2	0	38	28-D
1984	45.2	4	2	0	0	18	2-J
1983	52.7	4	3	0	0	18	26-D
1982	27.6	6	1	0	0	15	29-J
1981	34	7	0	0	0	9.8	28-J
1980	21.2	4	1	0	0	10	25-J
1979	69.7	4	1	1	1	50	1-Dec
1978	52.7	6	2	0	0	24	8-Feb
1977	94.9	6	3	2	0	36	24-F
1976	25.3	4	1	0	0	15	5-Feb

Note: D=Dec, J=Jan, F=Feb; DNA-Data Not Available